United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-348
May 1995

Biology and Management of the Western Gray Squirrel and Oregon White Oak Woodlands: With Emphasis on the Puget Trough

Loreen A. Ryan and Andrew B. Carey

Authors

LOREEN A. RYAN is a biological technician and ANDREW B. CAREY is a principal research biologist, Ecological Foundations of Biodiversity Team, Forestry Sciences Laboratory, 3625 93d Avenue SW, Olympia, Washington 98512-9193.

Abstract

Ryan, Loreen A.; Carey, Andrew B. 1995. Biology and management of the western gray squirrel and Oregon white oak woodlands: with emphasis on the Puget Trough. Gen. Tech. Rep. PNW-GTR-348. Portland, OR: U.S. Department of Agriculture. Forest Service, Pacific Northwest Research Station. 36 p.

The western gray squirrel *(Sciurus griseus* Ord, 1818) has been accorded "threatened species" status by the state of Washington. Populations are small, scattered, and declining primarily due to the loss and fragmentation of suitable habitat. Western gray squirrels are closely associated with Oregon white oak *(Quercus garryana* Dougl. ex Hook.) conifer communities on forest-prairie-wetland interfaces. Several other wildlife species also are closely tied to Oregon white oak woodlands. Oak woodland wildlife habitat is being reduced and fragmented by human development. Management of oak woodlands is necessary to protect ecological biodiversity, wildlife habitat, and habitat quality of existing oak woodlands. Specific management goals include maintaining large, open-form oak stands with adjacent intergrading conifers, prairies, and wetlands; preventing habitat fragmentation; maintaining open to patchy understory devoid of invasive species such as Scot's broom; and minimizing human disturbances that could accelerate root damage to oaks. Management recommendations include removing overtopping Douglas-fir trees *(Pseudotsuga menziesii* (Mirb.) Franco) except old-growth trees; thinning dense understory oak and Douglas-fir to release remaining oaks; maintaining or developing habitat corridors to link scattered oak patches; using prescribed burning to prevent dense shrub competition; and promoting oak woodland conservation and enhancement on public and private lands through information, education, and legislation.

Keywords: Western gray squirrel, *Sciurus griseus,* Oregon white oak, *Quercus garryana,* management, Pacific Northwest.

Contents

Introduction

The western gray squirrel[1] once was common in the Pacific Northwest (Bowles 1921). Recently, the state of Washington accorded the western gray squirrel "threatened species" status (RCW 77.12.020 and WAC 232-12-011) because of a decline in squirrel numbers due to loss of oak habitat, fluctuating food supplies, disease, and illegal hunting (Washington Department of Wildlife 1993). Oak woodlands are considered "priority habitats" for conservation by the Washington Department of Wildlife. In 1991, State Resolution 1991-8654 authorized the state of Washington to officially declare 1991 as the "Year of the Oak." California declared 1990 as the "Year of the Oak" (Standiford 1991). To avoid further decline of the western gray squirrel and Oregon white oak woodlands, management must include the preservation and enhancement of oak woodland habitat. In this report, we summarize information from the scientific literature on the western gray squirrel and oak woodlands, integrate that information with results from our surveys of western gray squirrels and oak stands on Fort Lewis, Military Reservation, Washington, and make management recommendations for ensuring the survival of western gray squirrels and oak woodlands in the Puget Trough.

Biology of the Western Gray Squirrel

Species Description

The western gray squirrel is the largest native tree squirrel in Washington. It is silver gray with dark flanks and creamy white underparts. Adults may weigh 17.6 to 33.4 ounces (Asserson 1974, Bamum 1975, Oilman 1986) with total body lengths (including tail) ranging from 19.7 to 23.6 inches (Barnum 1975). Foster (1992) reported body lengths (nose to base of tail) of 10.6 to 15.4 inches, and tail lengths of 9.5 to 15 inches for western gray squirrels in Oregon. She found that male body lengths (13.0 ± 0.7) were significantly greater than female body lengths (12.1 ± 0.07), but that tail lengths were similar for both sexes. There was no apparent sexual dimorphism in the small sample of Fort Lewis squirrels (table 1).

The western gray squirrel resembles the eastern gray squirrel, a common squirrel of the Eastern United States that has been introduced into the range of the western gray squirrel (including the Puget Trough). The two squirrels are similar in appearance, but eastern gray squirrels are smaller, have less prominent tails, and have rufous coloration on the head, back, flanks, and underparts. The eastern and western gray squirrel differ markedly in their evolutionary relations. The eastern gray squirrel is in the subgenus *Neosciurus* (Hall 1981) and is related to the fox squirrel of the Eastern United States and the red squirrel of Europe. The western gray squirrel is in the subgenus *Hesperosciurus* and is related to Abert's squirrel of the Rocky Mountain west and southwest (Wade and Gilbert 1940).

Life History

Breeding—Breeding occurs from January to September in western Washington and western Oregon (Brown 1985) and from December to July in California (Oilman 1986). In Oregon, Foster (1992) found females in estrus from January through March and again in June. Cross (1969) witnessed mating chases involving one female and two to four males. We witnessed similar behavior on Fort Lewis involving one female and six males. One male was larger and appeared more dominant than the other five males. We observed the large male mounting the female on the trunk of a large Douglas-fir tree. The female ran from the area shortly after the mounting. We then

[1] Scientific names of all species are given at end of text.

Table 1—Size and reproductive condition of western gray squirrels collected on Fort Lewis, Washington, 1992-93

Squirrel no.	Date[a]	Weight	Measurements[b]	Sex	Reproductive condition
		Ounces	*Inches*		
1	04/14/92	24.8	21.6-10.7-3.0-1.6	F	3 fetuses, C-R = 0.7 [c]
2	04/24/92	29.3	22.4-10.8-3.1-1.5	F	3 scars, lactating
3	05/06/92	28.2	23.0-10.7[d]	F	3 fetuses (2M, 1 F)
4	06/01/92	29.4	23.2-11.3-3.1-1.7	M	T-L=1.4x0.7[d]
5	07/01/92	12.2	19.5-9.4-2.9-1.5	M	T-L = 0.4 x 0.6
6	07/22/92	23.3	22.3-11.2-3.1-1.5	M	R = 0.6 x 0.3, inguinal
7	07/23/92	16.9	19.1-8.4-3.1-1.4	M	Nonreprod.
8	08/04/92	20.3	21.9-9.9-2.9-1.6	M	T-R[e] = 0.7 x 0.4
9	08/12/92	25.5	22.3-10.9-3.1-1.5	M	R = 0.8 x 0.3, inguinal
10	08/21/92	17.3	22.2-11.1-2.9-1.4	M	Nonreprod.
11	01/03/93	23.1	22.3-10.9-3.0-1.5	M	L= 1.2x0.6
12	04/27/93	26.6	21.3-8.9-3.1-1.7	M	Slightly scrotal
13	08/11/93	18.1	21.1-9.6-2.8-1.5	F	Nonreprod.

[a] Date squirrel was found.

[b] Four measurements are total length-body length-hindfoot length-pinna (ear) length.

[c] C-R is the average crown to rump measurement of fetuses.

[d] Hindfoot and pinna length measurements were not taken.

[e] T-R is the right testis, T-L is left testis.

saw the five other males running and chasing each other up and down trees, showing frenzied, agonistic behavior which continued for several hours. In Oregon, pregnancies occur from January to March and again in August; lactation occurs in March, April, and July through October (Foster 1992).

Most researchers believe that a female may produce only one litter per year. Cross (1969) followed adults for three summers and observed no late breeding and no pregnant or lactating females. Fletcher (1963) believed there were two litters per year because he found (1) mature follicles in squirrels that had previously produced litters that year and (2) a pregnant female in September with two generations of ovarian scars (corpora lutea), thereby indicating two separate ovulations. From this evidence, it seems biologically possible, but uncommon, for squirrels to produce two litters in a year. A litter of two to five young is born after 44 days gestation (Ingles 1965). The period of lactation is unknown. Adult squirrels are quiet and unobtrusive while raising young (Maser and others 1981). Young can be seen outside the nest starting in mid-March (Ingles 1947).

Male sexual development—Males reach sexual maturity by 1 year of age (Asserson 1974) and may breed the winter after their birth (Fletcher 1963). The testes enlarge from December through mid-January (Maser and others 1981), reach maximum size in February, and remain constant or become slightly smaller through May (Cross 1969). Testes regress in June and enlarge again in late winter (Cross 1969). Swift (1977) found squirrels in California with enlarged testes from February to July, and

one in September. Males with enlarged testes were found January 3, June 1, and August 4 on Fort Lewis. One male with slightly developed testes was found at the end of April. Testes are abdominal before sexual maturity and regressed during the nonbreeding season (Swift 1977).

Female sexual development—Females reach sexual maturity at 10 to 11 months of age (Fletcher 1963). Teats are gray as pregnancy progresses, and become gray pink just before parturition. Most researchers (Asserson 1974, Cross 1969, Foster 1992, Oilman 1986, Ingles 1947, Swift 1977) report one long breeding season with two peaks of estrus, one in winter and one in spring. Late breeding may be favored in times of food shortage because females without an adequate winter food supply will have few reserves to sustain themselves and their litters if they become pregnant early in the breeding season (Foster 1992).

Activity

Western gray squirrels are active throughout the day. They are most active in the morning, alternate periods of resting and activity throughout the day, and decrease or cease activity late in the day (Cross 1969, Gilman 1987, Rodrick 1986). Activity begins with the first movement in the nest just after dawn and may be influenced by light intensity (Cross 1969). Emergence time differs with the weather and averages 18 to 22 minutes after the first movement in the nest (Cross 1969, Oilman 1987). Only one emergence time was monitored on Fort Lewis, and it occurred 20 minutes after the onset of activity in the nest. Cross (1969) reports that the peak of activity is between 30 and 90 minutes after dawn. Barnum (1975) observed squirrels from August through October in the Puget Trough area and found the most activity 30 to 180 minutes after dawn. We observed active squirrels from dawn until dusk and year-round on Fort Lewis. Squirrel activity seemed greater from dawn to 1100 hours than later in the day. Squirrels return to their nests late in the afternoon, and by two hours before dusk, most squirrels are in nests (Oilman 1987). No nocturnal activity has been observed. Activity periods are influenced by food availability, competition, disturbance, and weather conditions (Cross 1969). Oilman (1987) noticed a decrease in activity during hot spells. Packard (1956) reported an increase in activity associated with low-incident light, high relative humidity, low wind velocity, and moderate temperatures. We observed active squirrels on several occasions during rainy and cool weather, especially in the winter.

Western gray squirrels are active all year long but are most visible in August and September when they are collecting acorns. During June and July, squirrels were seen less often than the rest of the year. Qauike (1984) reported that squirrels are not as visible from May to July possibly due to migrations to cooler, predominately conifer habitat in the summer. Foster (1992) also reported fewer sightings during the summer.

Distribution

There are three subspecies of western gray squirrel: *Sciurus g. anthonyi* in southern California; S. *g. nigripes* in the San Francisco Bay area; and S. *g. griseus* in central California, the interior valley margins of northern California and Oregon, along the Columbia River Qorge of Oregon and Washington, in southern Puget Sound, and on the eastern slopes of the Cascade Range in Oregon north to Okanogan County, Washington (Hall 1981; fig. 1).

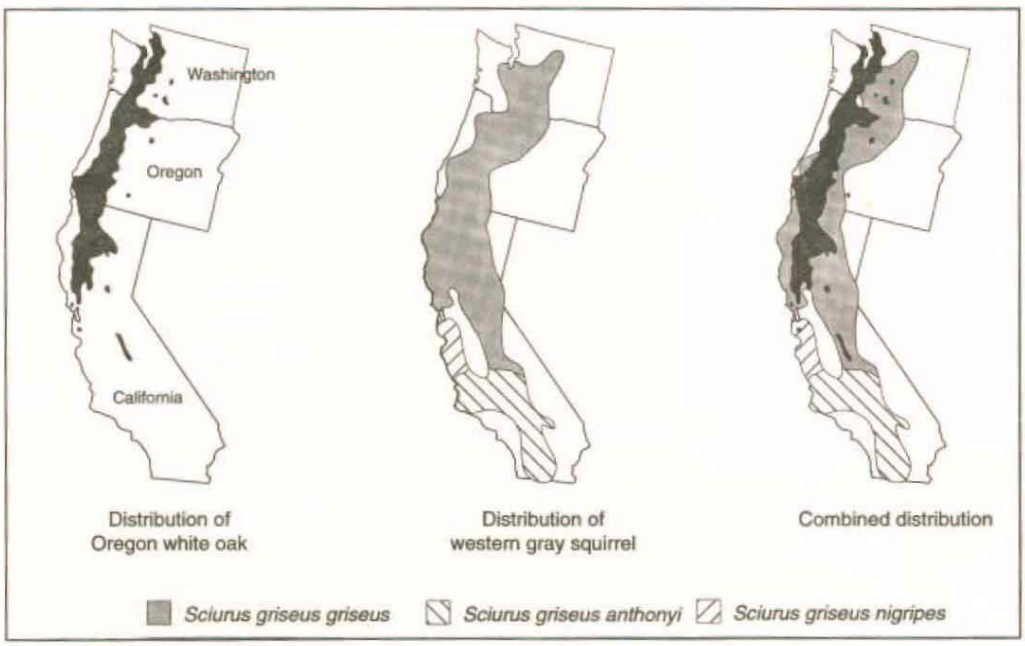

Figure 1—Distribution of Oregon white oak (Stein 1990) and three subspecies of western gray squirrel (Hall 1981).

The western gray squirrel was one of the most commonly encountered mammals in the Northwest (Bowles 1921) because of its propensity for woodland habitats near open grasslands in river valleys. Their range in Washington now consists of small, scattered populations that follow the range of Oregon white oak (fig. 1). There are three major subpopulations in Washington (Rodrick 1986): one in Klickitat County, along the southern Columbia River, another in Okanogan and Chelan Counties along the northern Columbia River basin, and a third in Thurston and Pierce Counties in the Puget Trough (fig. 2). The latter population seems to be centered on Fort Lewis, an 86,000-acre military reservation (fig. 3).

Habitat

General—The specific vegetational components of western gray squirrel habitat change with climate and latitude. In northern California, western gray squirrels occupy conifer-hardwood forests with various species of conifers and oaks: Oregon white oak, Douglas-fir, and redwoods along the northern California coast; mixed evergreen forests of Oregon white oak, California black oak, tanoak, Pacific madrone, California-laurel, and Douglas-fir; and coast live oak, blue oak, black oak, Oregon white oak, pines, firs, and junipers along the Coast Range.

In most of its range in Washington and Oregon, western gray squirrels inhabit conifer-hardwood forests with Oregon, white oak (Cross 1969). In Oregon, western gray squirrels are found in three main Oregon white oak community types: evergreen hardwood forests in southwest Oregon; deciduous hardwood forests in the Rogue, Umpqua, and Willamette Valleys; and conifer-hardwood forests on the eastern slope of Mount Hood consisting mainly of ponderosa pine, Douglas-fir at higher elevations, and various species, of oak including black oak, valley oak, and Oregon white oak (Asserson 1974, Foster 1992). Understory dominants include poison oak, California hazel, swordfern, serviceberry, snowberry, and bitter cherry.

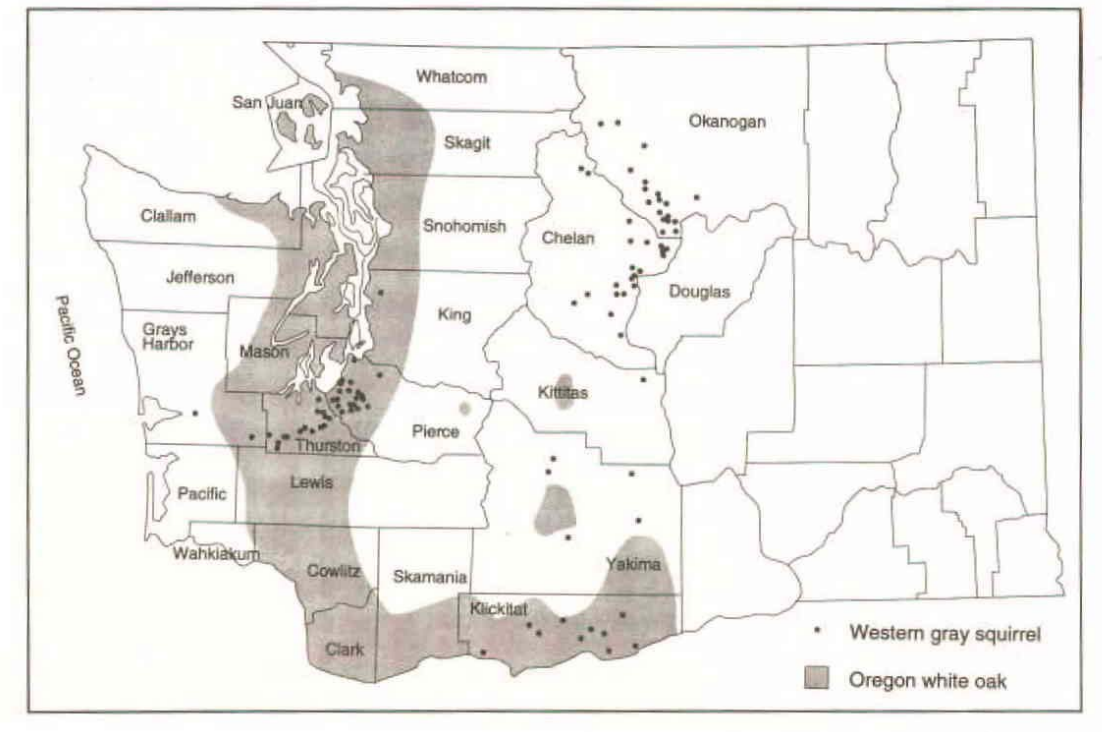

Figure 2—Distribution of the western gray squirrel (Rodrick 1986) and Oregon white oak (Stein 1990) in Washington.

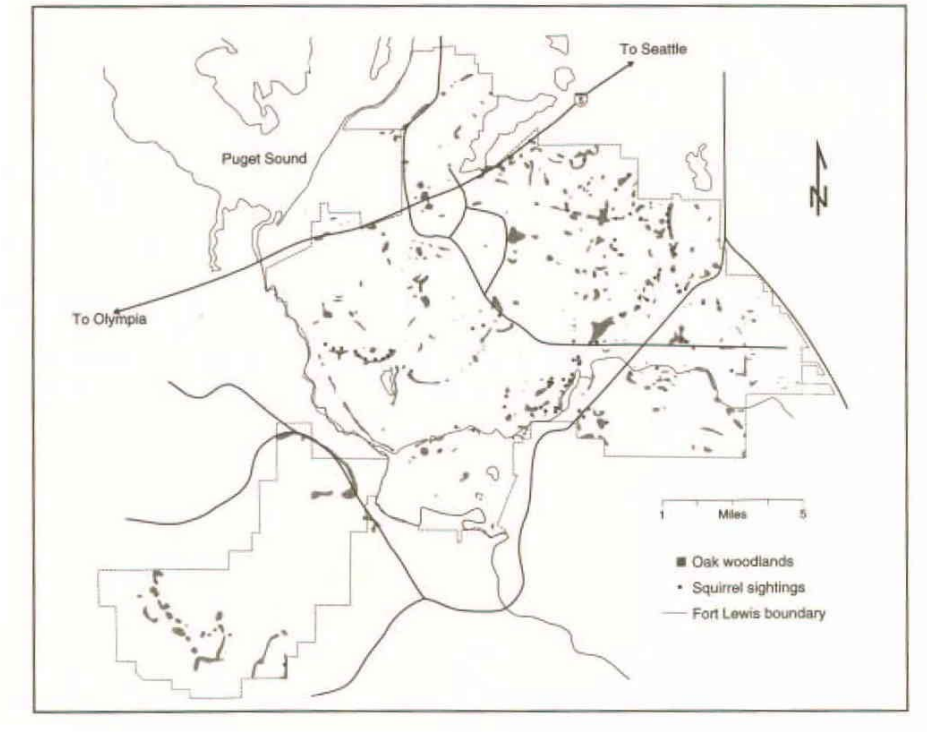

Figure 3—Locations of western gray squirrels and Oregon white oak woodlands, Fort Lewis, Washington, 1993.

Western gray squirrels inhabit two distinct vegetation types in Washington: ponderosa pine-Oregon white oak forests in south-central Washington along the Columbia River Gorge, and Douglas-fir-Oregon white oak woodlands in the Puget Trough (Washington Department of Wildlife 1993). Dominant understory vegetation includes Scot's broom, snowberry, California hazel, Indian plum, and swordfern. Oak stands most commonly are located on the edges of Douglas-fir stands, prairies, ponds, and wetlands. The origin and maintenance of open prairies are thought to be due to gravelly, well-drained soils from glacial outwash, frequent wildfires, and controlled burning by early inhabitants (Franklin and Dyrness 1988). Douglas-fir and Oregon white oak stands recently established on former prairie sites usually have sparse understory layers of snowberry, Indian plum, serviceberry, rattlesnake plantain, and Pacific senicle.

Although western gray squirrels are associated with Oregon white oak in most of their range in Washington, they also are found in Chelan and Okanogan Counties (in central Washington) in groves of English walnut and black walnut planted by early settlers (Bamum 1975). Western gray squirrels are particularly attracted to nut groves in Washington and Oregon (Bailey 1936). The Chelan-Okanogan population, however, is small and may have been introduced into the area (Washington Department of Wildlife 1993).

Characteristics of oak woodlands important to western gray squirrels—Western gray squirrels usually are found in forests and woodlands that have some species of oak (Asserson 1974, Cross 1969, Foster 1992, Oilman 1986). They use oaks for food, seasonal cover, travel, and escape routes; conifer-fir trees provide cone seed, truffles (Luoma 1991), nests sites, and year-round escape cover. In the Puget Trough, including Fort Lewis, squirrels were seen most often in the ecotonal (transitional) areas between Oregon white oak and Douglas-fir stands (figs. 4-6) and in stands where oak and Douglas-fir are interspersed with several other species of hardwoods and conifers. Because these stands were ecotonal, Douglas-fir was abundant, comprising 53 percent of the stand on average; oaks comprised 34 percent on average; other tree species averaged 13 percent. Squirrels on Fort Lewis preferred stands with a patchy understory (covering 42 percent of the stand on average) to stands with a continuous dense understory.[2] Stands with western gray squirrels had a greater diversity of food-producing trees and shrubs, on average, than oak stands where no squirrels were seen (see footnote 2). Tree and shrub species common in oak stands with western gray squirrels included bigleaf maple, vine maple, Oregon ash, Indian plum, and California hazel (table 2). These stands had connected tree canopies that allow arboreal travel. Foster (1992) found that an important feature of western gray squirrel habitat is a contiguous tree canopy that allows for arboreal travel for at least 66 yards around nest sites. Squirrels generally do not cross prairies to use isolated trees (Barnum 1975).

[2] Ryan, Loreen Anne; Carey, Andrew Brian. 1993. The ecology of the western gray squirrel on Fort Lewis, Washington. Unpublished report. On file with: Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93d Ave. SW, Olympia, WA 98512.

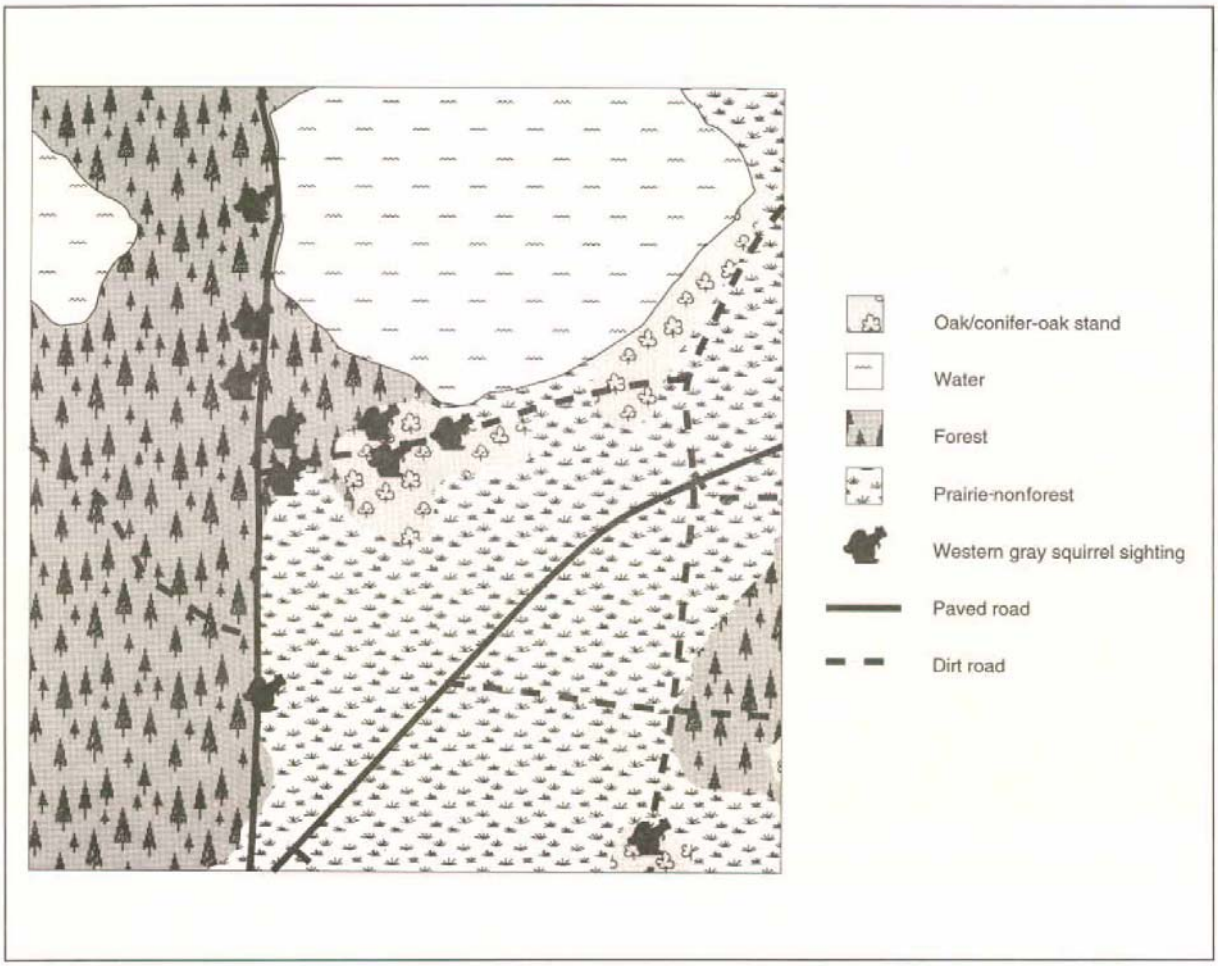

Figure 4—Ecotonal nature of western gray squirrel habitat in a 0.25-square mile area (prairie interface).

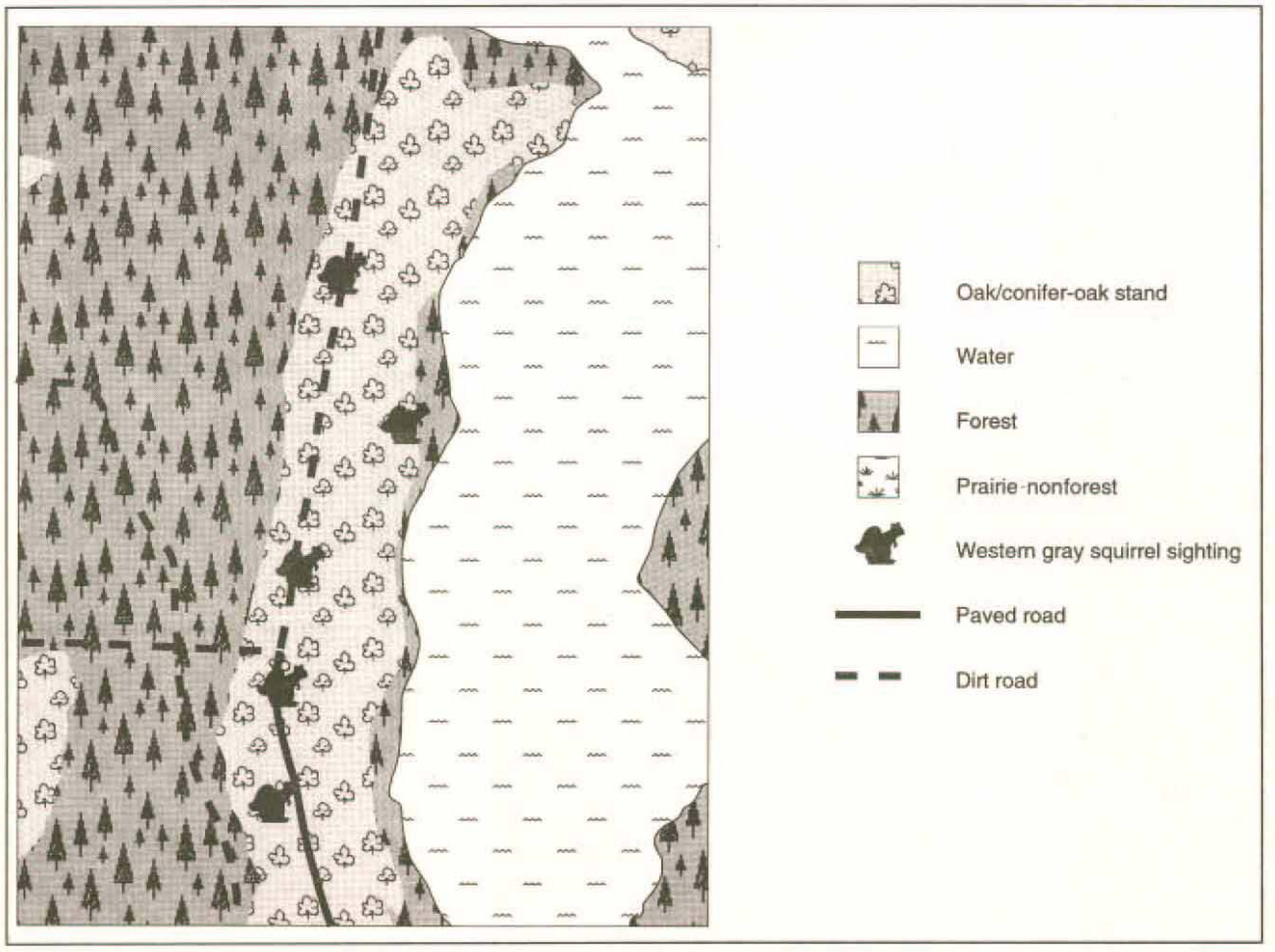

Figure 5—Ecotonal nature of western gray squirrel habitat in a 0.25-square mile area (riparian-Douglas-fir forest interface).

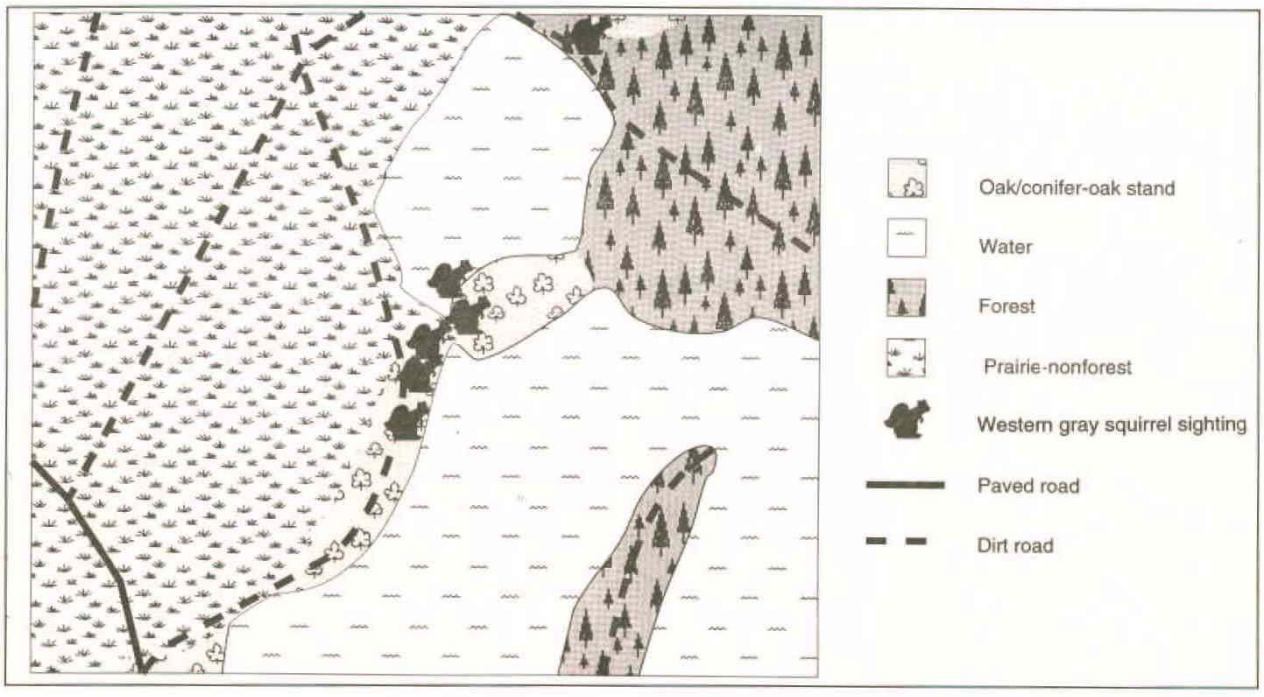

Figure 6—Ecotonal nature of western gray squirrel habitat in a 0.25-square mile area (prairie-riparian interface).

Table 2—Seasonal availability of food items for western gray squirrels in oak woodlands on Fort Lewis military installation

Food item[a]	Winter	Spring	Summer	Fall
ACMA				Samaras
AMAL			Fruit	Fruit
CONU				Fruit
FRLA2	Samaras			Samaras
PIPO		Catkins		Cone seed
POTR2		Catkins		
PRUN			Fruit	Fruit
PSME	Cone seed	Catkins		Cone seed
QUGA		Catkins		Acorns
RHPU			Berry	Berry
TABR		Catkins		Fruit seeds
ACCI				Samara
ABGR				Cone seed
OECE			Fruit	
COCOC				Nuts
GASH			Fruit	Fruit
RULA			Fruit	
CRDO			Fruit	
ROSA			Rosehips	Rosehips
SYAL	Berry	Berry	Berry	Berry
RIBE			Berry	
RUPR			Fruit	
VAPA			Berry	Berry
APPL				Fruit, bark
Fungi and truffles		X	X	

[a] Mnemonics listed with scientific and common names.

Home Range

Home ranges of western gray squirrels vary from 0.3 to 42.0 acres (table 3). A main source of variability in home range size may be due to methods used to determine locations and to calculate home range areas of the squirrels. Ingles (1947) used visual observations of park squirrels; Asserson (1974) and Barnum (1975) used trapping locations; Cross (1969) and Foster (1992) used trapping and telemetry locations; and Oilman (1986) used telemetry locations alone to determine home range. Various methods were used to calculate home range area including planimeters and computer programs. Cross (1969) found that home range size differs with sex, age, season, location, and population density and from year to year, and that home range size increases with social rank and the number of nests used by an individual.

Most research showed that female western gray squirrels generally have a smaller home range than males (Barnum 1975, Cross 1969, Foster 1992, Ingles 1947). Oilman (1986) reported, however, that females have larger home ranges than males in her study areas in Oregon. She reported that home ranges overlap extensively (0 to 85 percent, average 24 percent) and that female ranges overlap less than male

Table 3—Home range sizes of western gray squirrels

Location	Sex	Sample size	Home range size	Reference
			Acres	
California[a]	M	3	1.2-1.5	Ingles (1947)
California	F	5	.3-0.8	Ingles (1947)
Oregon (winter)	M	4	2.0-8.6	Cross (1969)
Oregon (winter)	F	4	2.2-6.8	Cross (1969)
Oregon (summer)	M	3	5.1-22.0	Cross (1969)
Oregon (summer)	F	3	3.3-42.0	Cross (1969)
California	M	unknown	3.8 (avg.)	Asserson (1974)
California	F	unknown	3.4 (avg.)	Asserson (1974)
Washington	M	4	.6-1.2 fall	Barnum (1975)
Washington	F	2	.5-1.0 fall	Bamum(1975)
California	M	5	4.8-7.8	Oilman (1986)
California	F	3	4.7-9.2	Oilman (1986)
Northern Oregon	M	4	7.4-12.6	Foster (1992)
Northern Oregon	F	3	4.2-16.0	Foster (1992)

[a] Home ranges measured within a city park.

ranges. Ingles (1947) also found that the home ranges of females overlap less than those of males. Barnum (1975) concluded that both habitat quality and population density are important factors controlling home ranges of individuals. In a small ponderosa pine woodland with high seed production, squirrels concentrated in the area and had small home ranges that overlapped significantly. Cross (1969) reported that summer home ranges are larger than winter home ranges. He attributed this to a change in food sources and changes in the population structure. He also reported that squirrels in less dense populations have larger ranges than those in denser populations. We did not measure home ranges of Fort Lewis squirrels but observed squirrels using the same portion of an oak stand, 2 to 3 acres in size, for 9 months in one stand and for 2 months in another stand. It seems that 2 to 3 acres is a minimum area for supporting squirrels in the short term (table 3). Long-term occupancy probably requires $\geq$5 acres.

Food Habits

The diet of the western gray squirrel is similar throughout its range. Foods include hypogeous fungi (truffles and false truffles, hereafter referred to as truffles), epigeous fungi (mushrooms), -acorns, seeds and nuts of trees and shrubs, fleshy fruits, and green vegetation. Maser and others (1978) and Foster (1992) report heavy use of truffles and mushrooms by western gray squirrels in Oregon. In northern California, truffles are the principal food, by volume, of western gray squirrels, often comprising more than one-half the diet (Byrne 1979). Byrne (1979) considered the reliance of western gray squirrels on truffles to be the main factor accounting for the different patterns of abundance of introduced eastern gray squirrels and western gray squirrels in northern California. Mushrooms occur in lesser proportions in the diet than truffles—about 4 percent annually (Stienecker 1977). Truffles have a lower water content and a higher food value (salts, phosphorus, and protein) than mushrooms (Steinecker and

Browning 1970). The most common fungi eaten are from the class Basidiomycetes, which is associated with conifers and includes both mushrooms and truffles of the genera *Rhizopogon, Octavianina, Gaultheria, Histerangium, Melanogaster, Leucogaster, Russela,* and *Boletes.* Fungi of the class Ascomycetes, including *Elaphomyces, Tuber, Genea,* and *Cortinarius* also are eaten (Foster 1992). Most of these species occur within Fort Lewis and are most abundant in spring and fall.[3] Many of these species are consumed at Fort Lewis by northern flying squirrels, and although we could not confirm that western gray squirrels were using truffles, we believe they could be an important component of their diet. Western gray squirrels at Fort Lewis were observed eating mushrooms.

Acorns and conifer seed are important in summer, fall, and winter in California, Oregon, and Washington (Asserson 1974, Barnum 1975, Cross 1969, Foster 1992, Stienecker and Browning 1970). Western gray squirrels, like many tree squirrels, cache foods for use over the winter, but instead of collecting acorns and cones in a central location like red squirrels and Douglas' squirrels, they bury them individually in holes 1.5 to 2.0 inches underground (scatter hoards) and relocate them by smell (Gurnell 1983). Stienecker and Browning (1970) concluded that acorn and pine seed may be more critical in the diet than fungi because acorns and seeds are high-energy foods that prepare squirrels for overwintering. Fungi cannot be stored for winter use as can acorns and cones, but fungi can provide seasonally available food, especially when the mast (seed and nut) crop is low. Mast crops differ from year to year for most tree species for several reasons: (1) depletion of food reserves during a heavy seed year; (2) weather, especially temperature, rainfall, and frosts; (3) weather in previous years; (4) diseases and parasites of the tree; and (5) maturation differences among tree groups (Gurnell 1987, Nixon and others 1975). Smith (1970) proposed an "anti-squirrel strategy," developed by mast-producing trees to ensure survival and maturation of some seeds. This strategy includes unpredictable seed crops, simultaneous failures to produce seed by different conifer species (Carey 1991), and impediments to seed and cone harvesting. The use of fungi and several different types of seeds, including those of bigleaf maple, vine maple, and Oregon ash. may be an adaptation of squirrels to these unpredictable seed crops. Squirrels, being food opportunists, also will eat buds, forb leafage, stems, and shoots all year, especially when mast is in short supply (Gurnell 1983, Stienecker 1977, Stienecker and Browning 1970). Western gray squirrels have been seen stripping bark from the upper sections of redwoods (Ingles 1947) and ponderosa pine (Cross 1969) to eat the cambium layer inside the bark. We observed one incident on Fort Lewis of several young squirrels stripping bark off of young Douglas-fir trees in summer. Cross (1969) observed squirrels eating deer antlers.

In general, the diet of western gray squirrels on Fort Lewis consists of acorns from late summer through early spring; fungi, both mushrooms and truffles, mostly in spring and fall; Douglas-fir seed from late summer through fall; and succulent vegetation from late spring through early summer (table 4). Most foraging occurs on the ground except in fall when squirrels are gathering cones or acorns for winter storage (Foster 1992). Squirrels drink freely from permanent and intermittent sources of water such as lakes, marshes, rivers, streams, or puddles.

[3] Colgan, Wes, III; Trappe, James; Carey, Andrew B. 1993. The forest ecosystem study. On file with: Pacific Northwest Research Station, Forestry .Sciences Laboratory, 3625 93d Ave S.W, Olympia, WA 98512.

Table 4—Food items eaten by western gray squirrels on Fort Lewis military installation, Washington, 1992-93

Spring	Summer	Fall	Winter
Douglas-fir staminate cones	Maple samaras (green)	Acorns	Acorns
Indian plum fruit	Mushrooms	Hazelnuts	Hazelnuts
Mushrooms		Mushrooms	Maple samaras (brown)
Truffles[a]		Truffles	Douglas-fir seed
Douglas-fir cambium			

[a] Many "unknown" items eaten in spring and fall; western gray squirrels are known to eat truffles (Asserson 1974, Foster'1992); truffles most prevalent in spring and fall.

Den Sites

Western gray squirrels use both tree cavities and stick nests. Squirrels may use cavities and tree holes in the winter and for rearing young (Cross 1969, Maser and others 1981). They use cavities created by other species and "natural" cavities formed by decay (Brown 1985). Ingles (1965) stated that females usually enlarge old woodpecker holes for brood dens.

Stick nests are of two general types: large, round, twig-and-leaf nests, constructed with a thick roof for winter use and rearing of young; loosely constructed platforms of leaves used as temporary nests, summer nests, or alternative nests (Foster 1992). Platform nests are used for resting during the day, especially in the summer (Cross 1969). Foster (1992) observed that, in her study areas in northeastern Oregon, squirrels most commonly build their nests in ponderosa pine, which was the most abundant conifer in these stands. She found one nest in Douglas-fir. Winter and rearing nests are usually built in conifers, whereas platform nests are often built in various species of deciduous trees (Foster 1992). Foster saw an adult squirrel build a twig nest in 45 minutes. Most stick nests in conifers are in the upper one-third of the tree, next to the trunk (Foster 1992). Nests are made of sticks, twigs with leaves, mosses, and lichens, and are lined with mosses, lichens, and shredded bark (Maser and others 1981). Squirrels may travel long distances for nesting material (Cross 1969).

Stick nests usually are occupied by only one squirrel at a time (Oilman 1986). Cross (1969), however, notes several incidents of two young squirrels staying in the same nest. Squirrels commonly use many stick nests (Cross 1969, Foster 1992). Cross (1969) reports that squirrels use an average of 3.5 nests in Oregon. Oilman (1986) found that a squirrel may often use one nest during the day and another at night.

On Fort Lewis, western gray squirrels, Douglas' squirrels, and northern flying squirrels use similar nests. All squirrel nests were found in Douglas-fir trees primarily in the forks of branches. Nests generally were constructed of sticks and twigs, and some were covered with moss. Some platform nests were built farther away from the trunk on large branches.

Mortality Factors

Predators—Potential predators of western gray squirrels include the red-tailed hawk, great horned owl, coyote, bobcat, gray fox, fisher, dogs, and cats. At higher elevations, marten prey on western gray squirrels (Ingles 1965). Red-tailed hawks, great-.horned owls, dogs, and cats are common at Fort Lewis in areas occupied by squir-

rels. Cross (1969) noted a case of a western gray squirrel being carried off by a red-tailed hawk. Oilman (1986) found the remains of two young gray squirrels in a red-tailed hawk nest in California. Cross (1969) found remains of western gray squirrels in stomach contents of coyotes and bobcats, and Murie (1936) saw a house cat take a sickly gray squirrel. In Oregon, two squirrels were killed and eaten by a bobcat and one by a coyote (Foster 1992).

Automobiles—Automobiles are a serious threat to western gray squirrels in parts of their range, particularly Fort Lewis. From April 1992 through August 1993, we saw about 81 individual western gray squirrels. Thirteen of these were found dead on roads, 12 on the same primary road (East Gate Road). Automobiles could affect squirrel numbers, especially during peaks of gestation and juvenile dispersal. Eleven of the thirteen dead squirrels were found from April through August: two were pregnant females, a third was lactating, and four were juveniles. Because the western gray squirrel population at Fort Lewis seems very low, a significant percentage of squirrels may be killed by automobiles.

Disease—Notoedric mange (scabies) is still present in Washington western gray squirrels, having reached epidemic proportions in 1917 and in the 1930s (Rodrick 1986). Western gray squirrels in Yosemite were virtually exterminated in 1926 because of mange (Byrne 1979). Foster (1992) reports that mange was common in her study areas in Oregon in 1984. Mange is caused by a mite, *Notoedres douglasi,* which burrows under the skin, causing red spots, followed by scaly or mangy appearance, and finally sores and hair loss (Cross 1969). Hair loss usually begins on the head and neck and spreads to the rest of the body (Oilman 1986). The loss of insulating hair often leads to hypothermia and death. Dead squirrels often are found at the base of trees (Ingles 1947). Other diseases and parasites of western gray squirrels include coccidiosis, western equine encephalitis virus, fleas, ticks, mites, intestinal roundworms, and ringworm (Cross 1969, Ingles 1947). We saw no signs of disease with Fort Lewis squirrels. Fleas were present in low numbers, but squirrels generally looked healthy.

Hunting and trapping—Although western gray squirrels in Washington are protected from hunting, some may be killed illegally or when mistaken for the California ground squirrel or the eastern gray squirrel. In California, the western gray squirrel is hunted throughout most of its range (Foster 1992). In Oregon, the western gray squirrel is a game species and is regarded as a pest in the nut orchards of northwestern Oregon. The hunting season in north-central Oregon extends from late August to early November. Foster (1992) reported that lactating females were taken during six consecutive hunting seasons, sometimes as late as mid-October.

Competition

Many mammals and birds compete with the western gray squirrel for habitat, food, and nest sites (Barnum 1973), including California ground squirrels, fox squirrels, eastern gray squirrels, Townsend's chipmunks, Douglas' squirrels, northern flying squirrels, black-tailed deer, Stellar's jays and scrub jays, common crows, northern flickers, Lewis' woodpeckers, and acorn woodpeckers (Foster 1992). Cross (1969) and Ingles (1947) both observed incidents of harassment of squirrels by acorn woodpeckers.

Cross (1969) reports that during a period of food shortage in California, the western gray squirrel population decreased while the ground squirrel population increased, possibly due to the ground squirrels' outcompeting the western gray squirrels. Foster (1992) observed both species eating acorns, pine seeds, and truffles and noted that

the ground squirrel is more aggressive than the western gray squirrel. In Klickitat County, Washington, the western gray squirrel population has decreased, whereas ground squirrel population has increased (Washington Department of Wildlife 1993).

Introduced fox squirrels and eastern gray squirrels are potential competitors in parts of the western gray squirrel's range (Rodrick 1986). They have been introduced into the Western United States since the 19th century for sentimental and aesthetic purposes. Eastern gray squirrels evolved in the extensive deciduous forests of the Eastern United States but have been able to proliferate in areas of the West. Fox squirrels and eastern gray squirrels survive in natural wildland communities but are most common in human-dominated areas such as orchards, parks, and suburbs. Because the eastern gray squirrel is ecologically more flexible than the western gray squirrel, it has moved into areas occupied by western gray squirrels before human disturbance (Rodrick 1986). They are able to take advantage of good nut crops by producing two litters of young per year, whereas western grays generally are unable to respond to plentiful food with two litters (Cross 1969). Eastern gray squirrels are common within Fort Lewis, particularly in the housing areas, and we saw and trapped them in several areas occupied by western gray squirrels. They may compete for acorns, conifer seeds, and fungi (Martin and others 1951). Fox squirrels have not been seen in the Fort Lewis area. They do occur in nearby King County, however, and could compete in other parts of the western gray squirrel's range such as Okanogan County. In California, western gray squirrels have been displaced in areas favorable to the introduced squirrels, but nonnative squirrels do not seem to be able to invade the drier woodlands (Byrne 1979). Eastern gray squirrels are more successful in moist conditions, but western gray squirrels preferred drier upland areas. Introduced eastern gray squirrels and fox squirrels in California normally do not include hypogeous fungi in their diet, rather they concentrate on orchards and cultivated foods (Foster 1992).

Douglas' squirrels, northern flying squirrels, Stellar's jays, and Townsend's chipmunks are common throughout western Oregon and Washington, including Fort Lewis. Douglas' squirrels use similar nest sites and eat many of the same foods as western gray squirrels, including acorns, maple samaras, and Douglas-fir seed. They are aggressive towards western gray squirrels and could interfere with western gray squirrel use of limited food and nest sites. Douglas' squirrels have been seen to chase western gray squirrels (Ingles 1947). Northern flying squirrels use similar nests sites and fungi but probably provide little direct competition (Cross 1986). Flying squirrels, however, are strict mycophagists (fungi eaters) and heavily exploit fungi (Carey 1991). Stellar's jays compete for acorns and aggressively dive and strike at western gray squirrels (Cross 1969, see footnote 2). We observed the squirrels chasing jays that were antagonizing them. Townsend's chipmunks compete for acorns, fungi, and conifer seed but were not seen in any aggressive competition with western gray squirrels.

Limiting Factors

Factors that limit the abundance of western gray squirrels include (1) availability of oak-conifer habitat, (2) year-round food availability. (3) dispersal and mortality, and (4) competition from introduced species.

Habitat availability—Squirrels commonly were seen only in stands with $\geq$5 acres of mature oak (oaks $\geq$5 inches in diameter) and $\leq$ 430 yards from water (see footnote 2). Isolated small islands of oak (<5 acres) are not adequate habitat to support western gray squirrels because squirrels generally do not inhabit isolated

trees or pure oak stands far from conifers (Bamum 1975). Less than one-third of :the oak stands at Fort Lewis are >5 acres (129/413); only 63 stands are S5 acres and ≤430 yards from water.

Food availability—Asset-son (1974) concluded that one principal limiting factor for western gray squirrels in California is food availability. Stienecker and Browning (1970) believe that mast crops are a key factor governing California .gray squirrel populations because the interval between good and bad mast crop years is unpredictable and differs among species. Bailey (1936) reports that western gray squirrels can become pests when food abundance is great, as in nut orchards. Gurnell (1983) found that density and diversity of trees of mast-bearing age influences the long-term densities of western gray squirrels and that dispersal is the main factor regulating population size.

Dispersal and mortality–Dispersal is the process by which vacant habitats are colonized. Dispersal of squirrels during spring and summer may force them into marginal or inadequate habitat or increase their chances of getting killed by automobiles or predators. Mortality factors are various. Local extirpations by mange have seriously affected populations of western gray squirrels in many parts of its range in the past (Washington Department of Wildlife 1993). Recovery from disease outbreaks may be difficult when populations are small and widely dispersed. Small and widely dispersed populations often are extirpated by random increases in natural mortality or random failures to reproduce or recruit juveniles into tree population.

Competition from introduced species—In the future, competition from introduced tree squirrels also may limit western gray squirrel numbers. Eastern gray squirrels are very .invasive and ecologically flexible. They are able to survive in a wide range of habitat types, whereas the western gray squirrel seems more limited in its choice of habitat. When food is abundant, eastern gray squirrels have additional competitive advantages because they can respond by having two or even three litters of young per year, whereas western gray squirrels normally have only one litter regardless of food abundance. Although -the number of eastern gray squirrels within the western gray squirrel's habitat seem low, the possibility of eastern gray squirrels outcompeting the western gray squirrels exists. Fox squirrels also have been introduced into parts of the range of the western gray squirrel, and many also compete with the western gray squirrel, for resources.

Management of Western Gray Squirrel Populations

In 1980, the Washington Department of Wildlife (WDW) Nongame Program brought attention to the western gray squirrel by placing it on the first "Species of Concern List." Since then, the WDW has listed the western gray squirrel and oak woodlands under the WDW Priority Habitats and Species Program and are in the process of evaluating and (protecting critical habitat. Aspects of western gray squirrel management discussed here include (1) monitoring and protecting existing populations, (2) managing and conserving habitat, (3) monitoring introduced squirrel species, and other competitors, and (4) increasing public awareness and education.

Monitoring and Protecting of Existing Populations

Monitoring—Surveys of oak woodlands are necessary to determine locations of squirrels and to monitor the effects of management activities.

Hunting regulations—The western gray squirrel has been listed as a nongame protected species in Washington since 1943, although a special hunting season was opened in 1949 near Yelm, Thurston County, to control squirrel damage to Douglas-fir trees. Hunters and fur trappers in Washington should be made aware of the presence

of western gray squirrels and their status as a State threatened species. Where hunting can be justified, Foster (1992) recommended delaying the hunting season (for example, in north-central Oregon) until early October to decrease the chance of taking lactating females in the hunt.

Public awareness and education—Few people know the western gray squirrel as a separate species of tree squirrel. Many people are surprised to hear that the western gray squirrel is a "threatened" species when they commonly see squirrels in their yard. The eastern gray squirrel is so similar in appearance to the western gray squirrel that many might wonder what the difference is and why there is concern about western gray squirrels. Informational brochures that describe the squirrel and explain its status in the area may help to increase public awareness and concern. Signs posted along major roads through western gray squirrel habitat will alert drivers to important squirrel crossing areas and may reduce squirrel deaths, especially from late spring through fall when squirrels are reproducing and young are dispersing.

Monitoring and controlling introduced squirrel species—Western gray squirrels are less tolerant of human development than are eastern gray squirrels. This was evident at Fort Lewis where eastern gray squirrels were abundant in housing and business areas, whereas western gray squirrels were never seen in the housing areas but were found within forested areas generally away from ongoing disturbances. Several eastern gray squirrels were trapped in forested areas that contained western gray squirrels. Because eastern gray squirrels seem to be more tolerant and adaptable to changing habitats than western gray squirrels, eastern gray squirrel populations within western gray squirrel habitats should be monitored. If eastern gray squirrels continue to spread into habitat occupied by western gray squirrels, trapping and killing the introduced eastern gray squirrel could become necessary to ensure viable populations of the native, threatened western gray squirrel. Eastern gray squirrels were easily trapped at Fort Lewis.

Habitat Management

the Washington Department of Wildlife is currently working on a plan to protect critical western gray squirrel habitat. This plan emphasizes identification and protection of known squirrel habitat and protection of ecotonal oak communities near water sources. Specific recommendations for managing oak communities are given below (see "Management of Oregon White Oak" in this paper).

Biology of Oregon White Oak

Species Description

Oregon white oak is commonly known as Garry oak in British Columbia but is also called white oak, post oak, Oregon oak, Brewer's oak, or shin oak (Bleier and others). Oregon white oak is a deciduous hardwood tree with broad, lobed, shiny leaves, 4 to 6 inches long. The lobes are rounded and the underside of the leaf appears whitish due to a thick coat of downy hairs (Bleier and others 1993). The bark is light gray or whitish, thin, and scaly or furrowed into broad ridges. The acorns are large, round, and bulge out from small, scaly acorn cups.

Oregon white oak has evolved specific survival strategies to adapt to its environment. Oak grows on dry or moist sites on shallow, dry, rocky, or heavy clay soils (Stein 1990). Oaks are not tolerant of shade but are very tolerant of moisture stress. Reserves of, moisture, minerals, and food are stored in the roots, thereby allowing oaks to go dormant during drought conditions. Mature oaks are fire-resistant. Indeed, the survival of oak communities depends on low-intensity fires that eradicate invasive competing species. Large isolated Oregon white oak trees were proved to be fire resistant during fall field burnings, strengthening the hypothesis that open Oregon white oak stands were maintained by fire (Franklin and Dyrness 1988). Oak trees grow at

different rates depending on site conditions, competition, fire, and disturbances by humans or wildlife but are relatively slow growing compared to conifers, especially on dry rangelands. A 40-year-old oak is generally 12 to 15 feet tall with a 6-inch diameter at breast height (d.b.h.). Mature trees are 20 to 60 inches in d.b.h. (Stein 1990).

Oak Life History

Oaks reproduce through acorns or vegetative sprouting. Acorns are produced when oaks are 20 to 30 years old and mature enough to flower (Bleier and others 1993). Flowering occurs in spring. Oaks are monoecious with staminate flowers (catkins) that emerge from buds on twigs and pistillate flowers that appear in the axils of developing leaves. Once flowers are pollinated and fertilized, acoms develop. Acorns are typically about 1.2 inches long and 0.6 inches wide and remain green until late summer or early fall. From late August to November, they turn brown as they ripen and drop to the ground. Acorns must be kept moist until they germinate (Stein 1990). Acorns can remain moist by being under a layer of fallen leaves, or by being inserted shallowly into the soil by rodent activity or other soil disturbance. Acorns begin to germinate and sprout in the spring after the rain has washed away growth-inhibiting chemicals from the outer shell. Normally, seeds remain viable only until the next growing season (Stein 1990). Sprouting acorns produce long tap roots that can penetrate up to 12 inches of leaf litter and reach down to the moist mineral soil. They have little success in dense stands of grass or compacted soils. Acorn crops can differ greatly over short distances (Bleier and others 1993). The factors that control acorn production are not well known, but it seems that crops are cyclical with good production every 3 to 6 years. Fort Lewis biologists reported poor acorn production in fall 1991. We found high acorn production in 1992. Oak trees usually produce more acorns as they get older and larger, up to about 200 years of age. Acorn crops range from 108 to 308 pounds per acre (dry weight, Stein 1990). Oregon white oak can sprout from stumps, roots, and along exposed trunks. Larger stumps produce more and faster growing sprouts. Stump sprouting is the most prolific method of natural regeneration of oaks (Stein 1990). Oregon white oaks can live up to 500 years (Stein 1990).

Oregon White Oak Distribution

Oregon white oak has the longest distribution of western oaks. It occurs from Vancouver Island in Canada south to San Francisco. Oregon white oak is the only native oak in British Columbia and Washington and the principal oak in Oregon. This makes Oregon white oak the dominant oak species in most of the western gray squirrel's range.

Currently there are about 851,000 acres of Oregon white oak woodlands in the United States, 458,000 acres in California, 298,000 acres in Oregon, and 95,000 acres in Washington.[4] An additional 739,000 acres of woodlands comprised of other oak species occur in California (Bolsinger 1988). Oregon white oak is the only native oak in Washington and occurs in Klickitat and Yakima Counties and in scattered groves in the Puget and Chehalis basins, and dark, Lewis, and Skamania Counties. Oak is at its prime in Clarke and Lewis Counties in Washington, and in the Willamette Valley

[4] Personal communication. 1993. Charles Bolsinger, principal resource analyst. Pacific Northwest Research Station, Forestry Sciences Laboratory, P.O. Box 3890, Portland, OR 97208-3890

of Oregon. In western Washington and Oregon, it is often mixed with Douglas-fir, Oregon ash, and bigleaf maple. Oaks also are found along stream drainages in association with ponderosa pine forests from Yakima County to the Columbia Gorge and south along the foothills of Mount Hood.

Oak Habitats and Communities

Diverse communities are referred to as "oak woodlands." They range from very open savannas with grass understories to dense forest stands, and from pure oak to mixed stands with an abundance of conifer species, particularly Douglas-fir and ponderosa pine (Franklin and Dyrness 1988). Oregon white oaks grow on dry sites such as edges of open prairies as well as moderately moist sites such as well-drained foothills. flood plains, and river terraces. Oaks tend to be dominant where soils are well drained and droughty in summer or where soils are saturated in spring and fall. The deep tap root allows exploitation of deep water tables under gravelly soils; dormancy during leafless periods reduces any impact of flooding (Stein 1990). Open oak savanna communities occur in valleys and low foothills of former natural prairies or grasslands that were perpetuated by repeated burning. Many of these communities depend on fires for their maintenance. Fire helps maintain natural prairies and can prevent bigleaf maple and Douglas-fir from invading oak woodlands. Rigg (1918) found oaks on the borders of Douglas-fir forests on the hills in Puget Trough in the early 1900s. Oaks were mixed with Douglas-fir when the Douglas-fir trees were young. The oaks were especially abundant on the steep slopes extending down to the prairies with only a few oaks and Douglas-firs on the level prairie itself. Today most of the oaks are on former prairies. With control of fires, prairies have been invaded by oaks followed by bigleaf maple and Douglas-fir; similar succession took place in the Willamette Valley after settlement (Stein 1990). Fire control is thought to have fostered development of closed-form oak forests (Gumtow-Farrior and Gumtow-Farrior 1992). In transition zones east of the crest of the Cascade Range, grazing may help maintain open oak woodlands. On dry west-side hillsides on coniferous forest borders, oaks are often intermixed with bigleaf maple and Douglas-fir. Such oak woodlands are found on dry sites and in areas disturbed by fire and intensive grazing. They may be small isolated stands with little or no understory except for grasses and a few forbs (Columbia Gorge Audubon 1990). Riparian areas include the vegetation bordering a stream, lake, or seep. Riparian oak stands can be found in dry interior locations along intermittent streams; the valleys of the Rogue, Umpqua, and Willamette Rivers in Oregon; the flood plain of the Columbia River near Vancouver, Washington; the Yakima and Klickitat Rivers of south-central Washington; the Lewis, Cowlitz, and Chehalis Rivers of southwest Washington; and the Puget Sound area. In moist west-side riparian areas, oaks are normally associated with Oregon ash, bigleaf maple, vine maple, and Douglas-fir, with an understory of snowberry, Indian plum, serviceberry, oceanspray, and Oregongrape.

Oregon white oak stands provide a favorable environment for establishing Douglas-fir seedlings. Oaks provide ectomycorrhizal (belowground) fungi that facilitate the establishment and growth of Douglas-fir trees (Molina 1992). Large Oregon white oak often shelter abundant conifer reproduction (Franklin and Dyrness 1988). The oaks often become overtopped by the conifer seedlings they sheltered. Undisturbed, Oregon white oak stands may be replaced by Douglas-fir and then by climax stands of grand fir or grand fir and Douglas-fir (Franklin and Dyrness 1988). Oaks protect the watershed because their root structures bind and hold soils, and the extensive leaf litter protects the soil from rain droplet impact. Oaks provide shade on the forest floor, thereby increasing soil moisture availability.

Wildlife Use of Oregon White Oak Woodlands

In California, oak woodlands are some of the richest wildlife habitats. More than one half of the native terrestrial vertebrates (331 species) use oak woodlands for food, cover, and reproduction (120 mammals, 147 birds, and 60 amphibians and reptiles). Other vertebrates use oaks during winter or during seasonal migrations or movements. In Oregon, oak woodlands provide nesting and foraging habitat for 214 vertebrate species (Gumtow-Farrior and Gumtow-Farrior 1992). In Washington, over 321 species of wildlife may use Oregon white oak communities (Columbia Gorge Audubon 1990).

At least 25 wildlife species are closely tied to the oak-prairie-conifer-wetland mosaic but are not common in strictly coniferous forests (table 5). Several components of oak woodlands are especially valuable to wildlife, including mast-producing trees, cavity trees, perches, riparian areas, and habitat corridors.

Martin and others (1951) called *Quercus* the single most important genus of North American wildlife food plants. Douglas' squirrels, western gray squirrels, California ground squirrels, Townsend's chipmunks, deer, scrub jays, band-tailed pigeons, wood ducks, Stellar's jays, and many other vertebrates eat acorns. Acorns are only one of many important oak woodland foods; oak woodlands often have many other food-producing trees and shrubs (table 2) that provide food at different times throughout the year.

Compared to many kinds of trees, oaks have a greater proportion of biomass in branches which provide many feeding and hiding sites for wildlife (Bleier and others 1993). Upland Oregon white oak, especially large, open-form oak, tend to be significant cavity producers, which can support large numbers of cavity-nesting fauna and almost every species of cavity-using vertebrate in the Pacific Northwest (Gumtow-Farrior and Gumtow-Farrior 1992). Northern flying squirrels, western gray squirrels, Douglas' squirrels, raccoons, bats, some owls, American kestrels, many other birds, and certain reptiles and amphibians use cavities in oaks. Raptors such as red-tailed hawks and bald eagles, as well as crows and ravens, often construct nests in oaks.

Riparian areas typically have many hardwood trees and berry-producing shrubs that provide a diverse and abundant supply of food, cover, and nest sites for wildlife. Moist riparian sites may support more wildlife species than do open oak woodlands, because of increased food and cover resources and may provide travel corridors for safe daily and seasonal movements. Riparian areas do not have the temperature extremes of more upland areas; they are warmer in winter and cooler in summer than surrounding uplands. Oaks and other hardwoods persist in these areas because they can tolerate seasonal flooding during their dormant period (Bolsinger 1988).

Factors Influencing the Quality of Oak Woodlands

Oak communities are valuable for their function in providing landscape biodiversity. They often occur as ecotones—interfaces between coniferous forests and prairies, prairies and wetlands, and low-lying streams and adjacent uplands. Thus, conservation of oak communities cannot be separated from conservation of native prairies and grasslands, wetlands, and riparian forests. Their provision of abundant high-quality food (truffles, fruits, seeds, and nuts of associated species), perches (particularly for raptors), and cavities at the juncture of conifer forest, prairie, wetlands, and streams makes these communities uniquely valuable. Thus, the high number of species closely associated with them—species of diverse life forms such as the western gray squirrel, wood duck, and western pond turtle.

Table 5—Animals especially benefitting by oak woodlands in western Washington and Oregon

Species	Status[a]	Reference[b]
Western pond turtle	FC, WT	1,2
Racer	May be extirpated in WA	2,3
Ring-necked snake	WM, disjunct populations	2,3
Sharptail snake	WM, OS-critical	2,3
Northern alligator lizard	Common in WA	2,3
Southern alligator lizard	WM	2,3
Pacific gopher snake	WM, may be extirpated	2.3
California-mountain kingsnake	WC, limited distribution	2
Western bluebird	WC, OS-vylnerable	1,3,4
Violet-green swallow	0-NG	3
Tree swallow	0-NG-protected	3
Purple martin	WC, OS-critical	1,3
White-breasted nuthatch	0-NG-protected	3
Cavity nesting ducks[c]	W-game, 0-game	1,3
Band-tailed pigeon	W-game, 0-game	1,3
House wren	0-NG-protected	4
Lazuli bunting	0-NG-protected	3
Downy woodpecker	0-NG-protected	1,3
Lewis' woodpecker	WC, OS-critical	1,3,4
Acorn woodpecker	OS	3
Black-capped chickadee	0-NG-protected	3
Bewick's wren	0-NG-protected	3
Blue-gray gnatcatcher	0-NG-protected	3
Ash-throated flycatcher	WM, 0-NG-protected	3,4
Western gray squirrel	WT, 0-game	1,3

[a] F = Federal, W = Washington, 0 = Oregon; C = candidate, M = monitor, S = sensitive, T = threatened, and NG =,nongame.

[b] 1 = Rodrick and Milner 1991, 2 = Larry Jones 1993 personal communication, 3 = Gumtow-Famor and Gumtow-Farrior 1992, and 4 = Andelman and Stock 1993.

[c] Especially woodducks, but including Barrow's goldeneye, common goldeneye, bufflehead, and hooded merganser.

Oak woodlands are often small and scattered. All discrete oak woodlands are more valuable to biodiversity when linked to other communities (Douglas-fir stands, prairies, and wetlands) and when connected by corridors. Corridors are strips of vegetation that allow safe and unobstructed movement between patches of habitat. A corridor may be a hedgerow, the vegetation along a stream or river, or vegetation along a roadway through a developed area. Wildlife with requirements that cannot be found within one oak stand or small set of oak stands may be very dependent on corridors in the landscape (Bleier and others 1993). These corridors become increasingly important for species such as the western gray squirrel that rely on oak woodlands, which are often small and scattered. Because small habitat patches can only support a certain number of western gray squirrels, young must disperse to other patches and establish themselves there. To survive, squirrels must have travel lanes of habitat for food and protection from predation during dispersal. The importance of maintaining corridors and connectiveness increases as the size of the habitat block decreases.

Urban development and other human activities often have negative impacts on oak woodlands and on wildlife. Fragmentation due to urbanization may not destroy oak communities completely but may alter them so that their value for wildlife is greatly reduced (Bleier and others 1993). Most affected wildlife cannot simply move to another area because other habitat patches may be too isolated, may already be occupied by other animals, or may be too small to meet the requirements of the animal for food, water, and nest sites. Fragmentation may cause the decline of some native wildlife species as oak woodlands are broken up into smaller and smaller stands. Diversity of native wildlife is often greater where habitat is concentrated in a single large block rather than into many smaller pieces. Large patches of oak woodland provide various habitat elements and several individuals of a particular species. Large populations are less likely to be extirpated than small populations.

Threats to Oak Woodlands

Real and potential impacts to oak woodlands include (1) the immediate removal or damage to oaks by logging, construction, and landscaping; (2) death of mature oaks caused by activities that restrict oxygen and water from getting to the roots (such as soil compaction by human activities and overwatering); (3) diseases and parasites; (4) reduced regeneration of oaks caused by replacement of native understory with more competitive plants, grazing by livestock or wildlife, and increased wildfires resulting from fuel build-up on unmanaged land; (5) invasion of upland oak communities by bigleaf maple and Douglas-fir with the eventual creation of a coniferous forest community; and (6) long-term reduction of wildlife habitat quality because of fragmentation, modification of water courses and riparian vegetation, and alteration of intermittent pools, springs, and other water sources.

The most serious threats to oak woodlands in Washington are land conversion and logging (Columbia Gorge Audubon 1990). Since 1945, over 1,300,000 acres of oak woodland in California have been converted to other land uses (Bolsinger 1988). Since 1973. 16,000 acres of oak woodland a year have been lost. Oak woodlands have decreased from well over a million acres (Thilenius 1964) to 221,000 acres in Oregon (Gumtow-Farrior and Gumtow-Farrior 1992). Washington also has suffered severe oak woodland loss due to land conversions, unsound management practices, insects and disease, fires, overgrazing, and lack of public policy (Andelman and Stock 1993, Columbia Gorge Audubon 1990).

Oaks are especially sensitive to activities associated with construction and ground disturbance. Because most roots are near the soil surface (usually within the top 2 feet), grading and trenching around trees may cause extensive root damage. Compaction of soil around the root zone also can kill roots by decreasing the amount of oxygen available to the roots (Bleier and others 1993). Water-saturated soils during summer may cause death from oxygen starvation in the root system or promote root rot.

The greatest damage to mature trees may be caused by wood decay fungi that gain entrance through wounds in the bark caused by fire, strong winds, nearby construction. careless operation of machinery, or vandalism (Arora 1986, Bleier and others 1993). Shoestring root rot or oak root fungus, as it is called in California, and white pocket root and butt rot are probably the most damaging rot fungi to Oregon white oak (Stein 1990). Shoestring root rot has black mycelial strands that may spread up the trunk of the host or infect neighboring trees by traveling long distances through the soil. It can be seen as whitish fanlike growths between the bark and wood. It feeds on the roots and lower trunk making them soft and pulpy (Arora 1986). White pocket rot digests cellulose and lignins in the tree, making the wood soft and spongy, and may completely hollow out the trunk and produce small, hollow pockets (Arora 1986). Butt rots are confined to the roots and base of the tree and can cause holes in the lower trunks of oaks. Leaf-spot, mildew, and anthracnose fungi may attack oak leaves (Stein 1990). In 1968, anthracnose fungi caused damage to leaves and possibly death of some trees in southern Pierce County, Washington. Hairy mistletoe grows commonly in the crowns of Oregon white oaks in California and Oregon, but its effect on the oaks is unknown. The most damaging insect is the western oak looper which can cause widespread defoliation of oaks (Stein 1990). Defoliation may slow the growth of oaks but will not permanently damage the trees. Larvae of the filbertworm and the filbert weevil damage acorns before they ripen (Stein 1990).

When oak savannas created by fire remain undisturbed, oaks regenerate quickly, eventually forming two-storied stands. If stands become dense, side branches on trees may be sparse and crowns small because of lack of sunlight. The presence of large oak trees does not guarantee the long-term viability of oak woodlands; regeneration must also be occurring in the area. Bleier and others (1993) report that in many areas throughout California, natural regeneration of oaks is inadequate. Lack of regeneration may involve (1) changes in understory plant composition, (2) changes in ambient soil moisture, (3) livestock and wildlife grazing, (4) fire suppression, (5) increases in seedling and acorn-eating animals from historic times, and (6) residential development and off-road vehicles. Planting oak acorns or oak seedlings is often proposed as a method of reestablishing oaks, but establishing seedlings is often difficult because of the same factors that prevent or limit natural regeneration.

Much of the understory of oak woodlands, particularly those adjacent to prairies, has been invaded by Scot's broom. Scot's broom probably was introduced to the Pacific Northwest between 1906 and 1914 and has since become a pest species, replacing native vegetation on prairies.[5] Scot's broom can grow to over 10 feet tall and may create shade conditions unsuitable for the establishment of oak seedlings and other native prairie vegetation. It also may compete with native vegetation for water and nutrients in the soil.

[5] Personal communication. 1993. Mary Fries, botanist, Native Plant Society, 620 N. C, Tacoma, WA 98403.

Many oak woodlands, particularly those in the Puget Trough, are being invaded by faster growing Douglas-fir trees. Oak canopies provide an excellent growing environment for Douglas-fir seedings that eventually overtop the shade-intolerant oaks and cause them to lose vigor and die.

The actual abundance of oak woodlands in the southern Puget Trough is unknown. Most oak woodlands are on private land although Fort Lewis has 3,600 acres of oak woodlands, primarily in Pierce County, managed by the Department of Defense. Directly north of Fort Lewis, McChord Air Force Base contains about 130 acres of oak woodlands.[6] There are 10,300 acres of oak in neighboring Thurston County (Kessler 1990). Of this, 2,200 acres are administered by the Washington Department of Natural Resources in the Bald Hills Lake area, Mima Mounds Natural Area, and the Capitol Forest. The Washington Department of Wildlife manages 300 acres in the Scatter Creek Wildlife Area[7] and an unmeasured amount of oak along the Black River. Because Fort Lewis has the greatest block of publicly managed oak woodlands, it is an important reserve for oak woodland communities. The acreage of oak on public lands is low and deserving of special attention. Because the greatest amount of oak woodland in the southern Puget Trough occurs on private lands, the State, counties, and municipalities need to become involved in promoting conservation of oak woodlands and their associated prairies and wetlands. Guidelines for an oak management program of this type have been developed in California (Bleier and others 1993).

Management of Oregon White Oak Woodlands

Long-term oak woodland management is necessary to limit and mitigate damage and to sustain Oregon white oak woodlands. Propagation, growth, and survival of young oak trees are necessary for the survival of the species and persistence of local populations. Size, species diversity of the woodland, and nearness to Douglas-fir stands, prairies, and wetlands will determine the value of the stand for wildlife. Our management recommendations will emphasize the management of oak woodlands as western gray squirrel habitat, not as pristine oak communities. Additional benefits of managing oak woodlands for the western gray squirrel will be the preservation and enhancement of Oregon white oak communities and the preservation of other wildlife species that rely on Oregon white oak communities.

To sustain oak communities and encourage oak regeneration, careful selective cutting or thinning of oak and long-term planning are critical. It is important that enough trees be retained to provide an adequate acorn supply.

Specific Objectives for Oak Management

Conserving our natural heritage, promoting biodiversity, and ensuring viable populations of native species necessitate maintaining sustainable oak woodland communities throughout their natural range. Because so many oak communities have been destroyed by human activities and because most of the oak woodlands are on private lands, a strong conservation program will be necessary.

---

[6] Personal communication. 1993. Bob MacDonald, base forester, McChord Air Force Base, 62 CES-CEVN, Tacoma, WA 98438.

[7] Personal communication. 1993. Robin Sherry, wildlife area manager, Scatter Creek Wildlife Area, Washington Department of Wildlife, 600 Capital Way, Olympia, WA 98506.

Specific objectives for such a program could include (Bleier and others 1993):

- Achieving no net loss of oak woodlands.
- Promoting restoration and restocking of degradated oak stands.
- Increasing oak woodland habitat extent and quality.
- Restricting fragmentation of oak woodland habitat.
- Directing development away from sensitive and significant oak woodlands.
- Centralizing and coordinating management activities by county.
- Promoting oak woodland conservation and enhancement on private lands.

In western Washington, particularly the Puget Trough, conservation of oak communities will require (1) a current inventory, an assessment of condition, and initiation of a monitoring system and (2) interagency coordination and planning (Washington Department of Wildlife, Washington Department of Natural Resources, U.S. Department of Defense, The Nature Conservancy, U.S. Fish and Wildlife Service, counties, and municipalities) such as was done in California (Bleier and others 1993).

Desired Future Condition

The desired future condition of oak stands in the Puget Trough includes (1) large, live, open-form oaks, the more the better; (2) water in or near a lake, pond, stream, marsh, or waterhole; (3) adjacent intergrading stands of Douglas-fir or ponderosa pine; (4) associated deciduous trees and shrubs; (5) a second age class of closed-form oaks to replace aging oaks; (6) natural prairie plant associations, devoid of Scot's broom, to provide an open to patchy understory, increased light penetration, and areas provided for oak regeneration to increase the size of the stand; and (7) corridors linking habitat fragments (fig. 7).

Recommendations for Oak Management

Recommendations for management of oak woodlands are available for California (Bleier and others 1993), Oregon (Gumtow-Farrior 1991, Gumtow-Farrior and Gumtow-Farrior 1992), and south-central Washington (Columbia Gorge Audubon 1990). Here we add recommendations for the Puget Trough, although these may be appropriate elsewhere:

- The minimum management unit should be 5 acres (see footnote 2) of existing oak woodland, with a goal of 10 acres as the minimum size (Bleier and others 1993).
- To maximize wildlife use, maintain or develop corridors to link habitat fragments and minimize the adverse impacts of fragmenting the landscape.
- Retain adjacent stands of conifers and hardwoods.
- Maintain canopy cover at 40 to 60 percent (Bleier and others 1993, Columbia Gorge Audubon 1990). Canopy cover may differ substantially depending on community type, from scattered trees in an oak savannah in the Willamette Valley, to a relatively dense canopy of oaks, other deciduous trees, and Douglas-fir along a water course.
- Maintain tree species composition at 25- to 75-percent oak, 25- to 75-percent Douglas-fir, and 10- to 20-percent other hardwoods, at least in the Puget Trough, to maximize wildlife benefits (see footnote 2).
- Maintain at least 18 square feet per acre of Oregon white oak for western gray squirrels (see footnote 2).

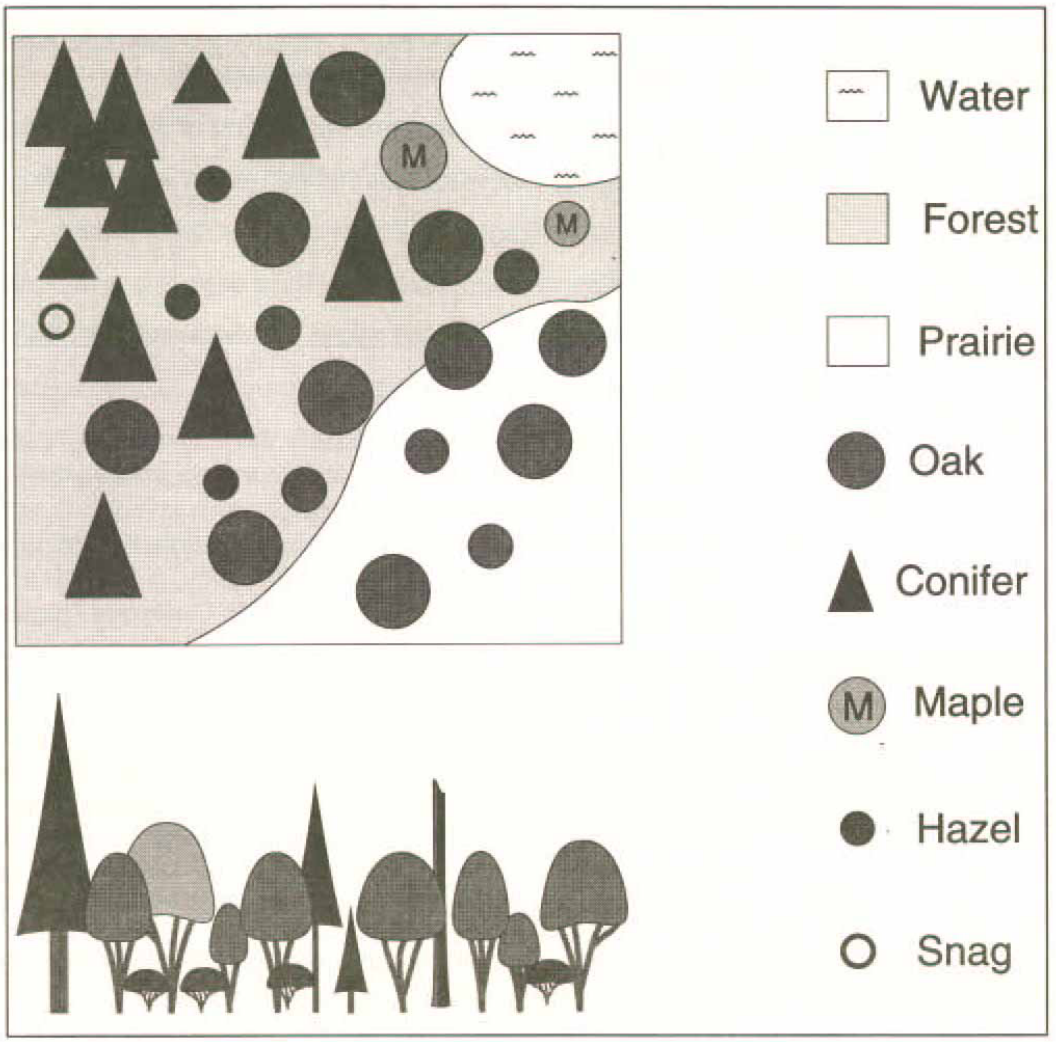

Figure 7—Idealized oak stand showing a prairie-forest interface with oaks, Douglas-fir, other hardwood trees, a snag, and understory shrubs.

- Preserve a near natural mix of snags, dead and downed trees, seed trees, and den trees.
- Kill overtopping Douglas-fir to allow oaks to grow to an open form (fig. 8). Overtopping Douglas-fir may be girdled to provide snags, felled to provide timber (avoid damage to oak roots), or felled and left on the ground to provide coarse woody debris (for nest sites of mountain quail, wild turkey, and ruffed grouse).
- Thin dense pure oak and Douglas-fir-oak stands to reduce crowding and water stress and allow remaining oaks to become larger, more vigorous, more productive, and more fire-resistant—eventually a second age class will develop to replace aging trees and sustain mast production (fig. 9).
- Remove smaller Douglas-fir trees under the oak canopy that are competing with oaks for water and that will eventually overtop the oaks.
- Retain old-growth Douglas-fir within oaks stands. Old-growth trees tend to be widely spaced and have a coarser crown that intercepts less sunlight than other trees while providing good year-round shelter for wildlife and their nests.

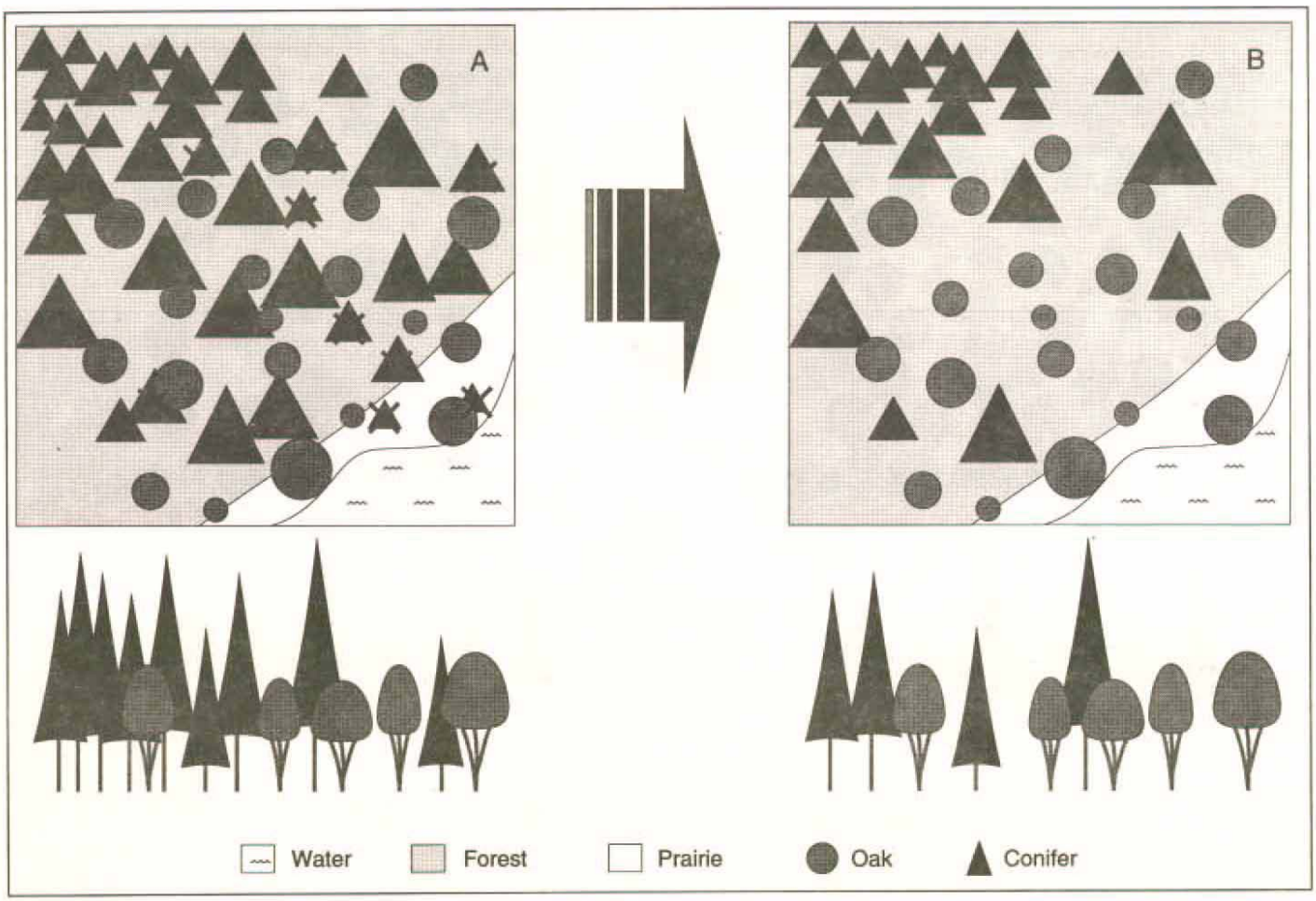

Figure 8—Overhead and cross-section view of a degraded Oregon white oak stand with Douglas-fir over overtopping oaks (A) and same stand with selective Douglas-fir removal (B).

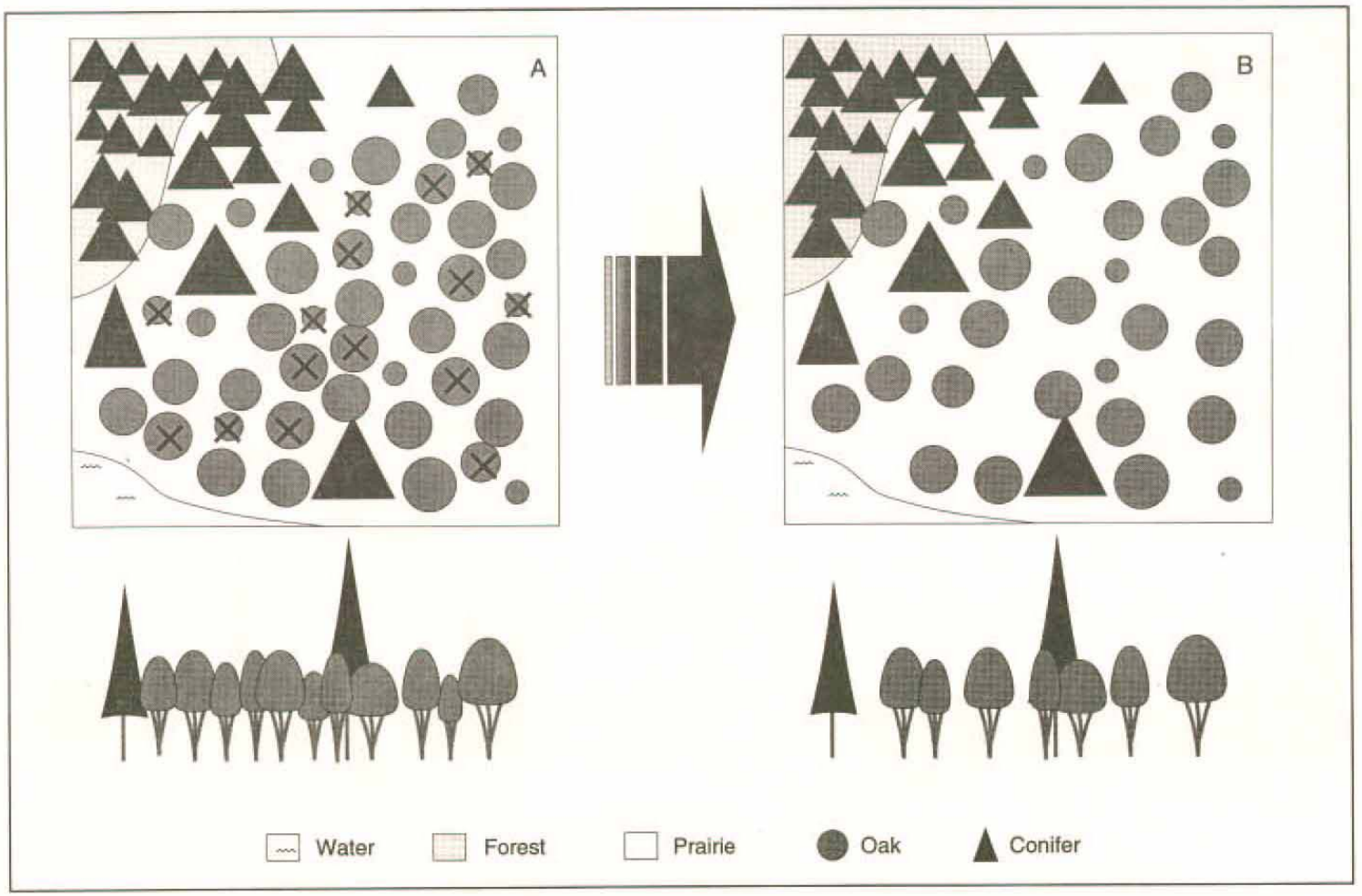

Figure 9—Overdense pure Oregon white oak stand (A) and same stand with selective oak removal to allow remaining oaks to grow larger and more productive (B).

- Maintain a mixture of age and size classes of hardwood trees to provide sustained mast production, vertical diversity, and recruitment (Bleier and others 1993).
- Plan periodic controlled burns of the grass and shrub layer to stimulate young shoot growth, prevent dense shrub competition (particularly Scot's broom), and maintain tree spacing (Columbia Gorge Audubon 1990).
- Maintain an open to patchy understory with a high level of vegetation diversity.
- Minimize human disturbance. Excessive trails and roads through open space accelerate root damage to oaks and invasion of weedy species. Particularly damaging are heavy construction equipment and other heavy trucks and tracked vehicles.
- Include oak preservation in zoning criteria.
- Increase public awareness of Oregon white oak and western gray squirrels.

Properly stewarding oak provides many long-term benefits including biological diversity, enhanced wildlife habitat, aesthetics, production of wood and other forest products, and soil retention.

Scientific and Common Names, and Alpha Codes of Plants[8]

Scientific name	Alpha code	Common name
Plants:		
Abies Mill.	ABSP	True firs
Acer circinatum Pursh	ACCI	Vine maple
Acer macrophyllum Pursh	ACMA	Big-leaf maple
AInus rubra Bong.	ALRU	Red alder
Amelanchier ainifolia Nutt.	AMAL	Western serviceberry
Arbutus menziesii Pursh	ARME	Pacific madrone
Berberis aquifolium Pursh	BEAQ	Tall Oregongrape
Berberis nervosa Pursh	BENE	Cascade Oregongrape
Corylus cornuta Marsh, var. *califomica* (DC.) Sharp	COCO	California hazel
Cornus nuttallii Aud. ex T. & G.	CONU	Pacific dogwood
Crataegus douglasii Lindl.	CRDO	Black hawthome
Cytisus scoparius (L.) Link	CYSC	Scot's broom
Fraxinus latifolia Benth.	FRLA	Oregon ash
Gaultheria shallon Pursh	GASH	Salal
Goodyera oblongifolia Raf.	GOOB	Rattlesnake-plantain
Holodiscus discolor Pursh Maxim.	HODI	Oceanspray
Juglans nigra L.	JUNI	Black walnut
Juglans regia L.	JURE	English walnut
Juniperus L.	JUSP	Juniper
Syringa sp. L.	LILA	Lilac
Lithocarpus densifloris (Hook. & Am.) Rend.	LIDE	Tanoak
Pyrus malus sp.	PYMA	Apple
Oemleria cerasiformes (H. & A.) Landon	OECE	Indian plum
Pinus contorta Dougl. ex Loud.	PICO	Lodgepole pine
Pinus ponderosa Dougt. ex Laws.	PIPO	Ponderosa pine
Polystichum munitum (Kaulf.) Presi	POMU	Sword-fern
Populus trichocarpa T. & G.	POTR	Black cottonwood
Prunus emarginata L.	PREM	Bittercherry

[8] Tree names and authorities from Little (1978); shrub and fort) names and authorities from Hitchcock and Cronquist (1991); fungi names from Boyce (1938).

Pseudotsuga menziesii (Mirb.) Franco	PSME	Douglas-fir
Quercus agrifolia Nee	QUAG	Coast live oak
Quercus douglasii Hook. & Am.	QUDO	Blue oak
Quercus garryana Dougl. ex. Hook.	QUGA	Oregon white oak
Quercus kelloggii Newb.	QUKE	California black oak
Quercus lobata Nee	QULO	Valley oak
Rhus diversiloba T. & G.	RHDI	Poison oak
Rhamnus purshiana DC.	RHPU	Cascara
Salix scouleriana Barr.	SASC	Scouler willow
Sanicula crassicaulis Poepp.	SACR	Pacific senicle
Sequoia sempervirens (D. Don) Endl.	SESE	Coast redwood
Symphoricarpos albus (L.) Blake	SYAL	Common snowberry
Taxus brevifolia Mutt.	TABR	Pacific yew
Thuja plicata Donn ex D. Don	THPL	Western redcedar
Tsuga heterophylla (Raf.) Sarg.	TSHE	Western hemlock
Umbellularia californica (Hook. & Am.)	UMCA	California bay
Fungi:		
Armillaria mellea (Fr.) Karst.		Honey mushroom (shoestring root rot)
Gnomonia veneta (Sacc. & Speg.) Kleb.		Anthractose fungi
Phorodendron villosum Nutt.		Hairy mistletoe
Polyporus dryophilus Berk.		White pocket root and butt rot

Scientific and Common Names of Animals[9]

Scientific name	Common name
Amphibians and reptiles:	
Aneides lagubris (Hallowell 1849)	Arboreal salamander
Clemmys marmorata (Baird & Girard 1852)	Western pond turtle
Coluber constrictor (Linnaeus 1758)	Racer
Diadophis punctatus (Linnaeus 1766)	Ring-necked snake
Contia tenuis (Baird & Girard 1852)	Sharptail snake
Gerrhonotus coeruleus (Wiegmann 1828)	Northern alligator lizard
Gerrhonotus multicarinatus (Blainville 1835)	Southern alligator lizard
Lampropeltis zonata (Blainville 1835)	California mountain kingsnake
Pituophis catenifer catenifer (Blainville 1835)	Pacific gopher snake
Mammals:	
Canis familiaris (Linnaeus 1758)	Dog
Canis latrans (Say 1823)	Coyote
Lynx rufus (Schreber 1776)	Bobcat
Felis silvestris (Schreber 1777)	House cat
Glaucomys sabrinus (Shaw 1801)	Northern flying squirrel
Martes americana (Turton 1806)	Marten
Martes pennant! (Erxleben 1777)	Fisher
Odocoileus hemionus (Rafinesque 1817)	Black-tailed deer
Didelphis virginiana (Kerr 1792)	Virginia opossum
Sciurus aberti (Woodhouse 1853)	Abert's squirrel
Sciurus carolinensis (Gmelin 1788)	Gray squirrel
Sciurus griseus (Ord 1818)	Western gray squirrel
Sciurus niger (Linnaeus 1758)	Fox squirrel
Spermophilus beecheyi (Richardson 1829)	California ground squirrel
Tamiasciurus douglasii (Bachman 1839)	Douglas' squirrel
Tamias townsendii (Bachman 1839)	Townsend's chipmunk
Urocyon cinereoargenteus (Schreber 1775)	Gray fox

[9] Names of mammals and birds are from Banks, McDiarmid, and Gardner (1987); names of amphibians and reptiles are from Collins (1990); invertebrate names are from Furniss and Carolin (1977).

Birds:

Myiarchus cinerascens (Lawrence 1851)	Ash-throated flycatcher
Columba fasciata (Say 1823)	Band-tailed pigeon
Thryomanes bewickii (Audubon 1827)	Bewick's wren
Troglodytes aedon (Vieillot 1808)	House wren
Parus atricapillus (Linnaeus 1766)	Black-capped chickadee
Polioptila caerulea (Linnaeus 1766)	Blue-gray gnatcatcher
Corvus brachyrhynchos (Brehm 1822)	American crow
Bubo virginianus (Gmelim 1788)	Great homed owl
Passerina amoena (Say 1823)	Lazuli bunting
Picoides pubescens (Linnaeus 1766)	Downy woodpecker
Melanerpes lewis (Gray 1849)	Lewis's woodpecker
Melanerpes formicivorus(Swainson 1827)	Acorn woodpecker
Meleagris gallapavo (Linnaeus 1758)	Merriam's wild turkey
Colaptes auratus (Linnaeus 1758)	Northern flicker
Parus inornatus (Gambel 1845)	Plain titmouse
Progne subis (Linnaeus 1758)	Purple martin
Buteo jamaicensis (Gmelim 1788)	Red-tailed hawk
Aphelocoma coerulescens (Bosc 1795)	Scrub jay
Cyanocitta stellteri (Gmelin 1788)	Steller's jay
Tachycineta bicolor (Vieillot 1808)	Tree swallow
Tachycineta thalassina (Swainson 1827)	Violet-green swallow
Sialia mexicana (Swainson 1832)	Western bluebird
Sitta carolinensis (Latham 1790)	White-breasted nuthatch
Aix sponsa (Linnaeus 1758)	Woodduck
Bucephala albeola (Linnaeus 1758)	Bufflehead
Bucephala clangula (Linnaeus 1758)	Common goldeneye
Bucephala islandica (Gmelin 1789)	Barrow's goldeneye
Lophodytes cucullatus (Linnaeus 1758)	Hooded merganser
Chamaea fasciata (Gambel 1845)	Wrentit

Invertebrates:

Milissopus latiferreanus (Walsingham)	Filbertworm
Curculio occidentalis (Casey)	Filbert weevil
Lambdina fiscelleria somniaria (Hulst)	Western oak looper

Acknowledgments

The authors acknowledge all those who assisted in producing this paper. We thank Curt Soper, Charles Bolsinger, Susan Foster, Betty Rodrick, and Fort Lewis ENRD biologists for their helpful review comments; Jim Stephenson for obtaining funding and providing the scope of work; Gary McCausland for graphics; Brandy Riche for Geographic Information Systems information; Karma Gerth for the cover drawing of the western gray squirrel; Andrew Craig, Ammy Gillesberg, and Michelle Minstrell for field assistance; Janet Jones for editorial assistance; and Ted Thomas and Jan Kershner for additional support. This report was funded by the Ecosystem Processes Research Program, USDA Forest Service, PNW Station, and by the U.S. Department of Defense, U.S. Army, Fort Lewis Environment and Natural Resources Division.

Literature Cited

Andelman, Sandy; Stock, Amy. 1993. Management, research and monitoring priorities for the conservation of neotropical migratory birds that breed in Washington State. Olympia, WA: Washington Natural Heritage Program, Washington Department of Natural Resources. 42 p.

Arora, David. 1986. Mushrooms demystified: a comprehensive guide to the fleshy fungi. Berkeley, CA: Ten Speed Press. 959 p.

Asserson, W.C., III. 1974. Western gray squirrel studies in Kern County, California. Sacramento, CA: California Department of Fish and Game; Admin. rep. 74.1. 32 p.

Bailey, Vernon. 1936. The mammals and life zones of Oregon. North American Fauna. 55:1-416.

Banks, Richard C.; McDiarmid, Roy W.; Gardner, Alfred L,eds. 1987. Checklist of vertebrates of the United States, the U.S. Territories, and Canada. Resour. Publ. 166 Washington, DC: United States Department of the Interior, Fish and Wildlife Service. 79 p.

Barnum, Douglas A. 1975. Aspects of western gray squirrel ecology. Pullman, WA: Washington State University. 55 p. M.S. thesis.

Bleier, Cathy; Bolsinger, Charles; Huntsinger, Lynn [and others]. 1993. A planner's guide for oak woodlands. In: Guisti, Gregory A.; Tinnin, Pamela J., eds. Berkeley, CA: University of California, Integrated Hardwood Range Management Program. 94 p.

Bolsinger, Charles R. 1988. The hardwoods of California's timberlands, woodlands, and savannas. Resour. Bull. PNW-RB-148. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 148 p.

Bowles, J. Hooper. 1921. Notes on the California gray squirrel *{Sciurus griseus griseus}* in Pierce County, Washington. Murrelet. 2:12-13.

Boyce, John Shaw. 1938. Forest pathology. New York: McGraw-Hill Book Company, Inc. 600 p.

Brown, E. Reade. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 2: Appendices. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 302 p.

Byrne, Sheila. 1979. The distribution and ecology of the non-native tree squirrels *Sciurus carolinensis* and *Sciurus niger* in northern California. Berkeley, CA: University of California. 196 p. Ph.D. dissertation.

Carey, Andrew B. 1991. The biology of arboreal rodents in Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 46 p.

Collins, Joseph T., ed. 1990. Standard common and current scientific names for North American amphibians and reptiles, 3d edition. Oxford, OH: Society for the Study of Amphibians and Reptiles, Miami University. 41 p.

Columbia Gorge Audubon. 1990. A plan for managing oak forests of Washington State. Hood River, OR: Columbia Gorge Audubon Society. 36 p.

Cross, Stephen Paul. 1969. Behavioral aspects of western gray squirrel ecology. Tucson, AZ: University of Arizona. 168 p. Ph.D. dissertation.

Fletcher, Richard A. 1963. The ovarian cycle of the gray squirrel, *Sciurus griseus nigripes.* Berkeley, CA: University of California. 30 p. M.S. thesis.

Foster, Susan Ann. 1992. Studies of ecological factors that affect the population and distribution of the western gray squirrel in northcentral Oregon. Portland, OR: Portland State University. 154 p. Ph.D. dissertation.

Franklin, Jerry F.; Dyrness, C.T. 1988. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-GTR-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 417 p.

Furniss, R.C.; Carolin, V.M. 1977. Western forest insects. Misc. Publ. 1339. Washington, DC: U.S. Department of Agriculture, Forest Service. 654 p.

Gauike, Jerry A.; Gauike, Patricia A. 1984. Status of the western gray squirrel population in the Oak Creek Wildlife Recreation Area. Yakima, WA: Washington Department of Game. 15 p.

Gilman, Kathleen N. 1986. The western gray squirrel *(Sciurus griseus),* its summer home range, activity times, and habitat usage in Northern California. Sacramento, CA: California State University. 71 p. M.S. thesis.

Gumtow-Farrior, Daniel L. 1991. Cavity resources in Oregon white oak and Douglas-fir stands in the mid-Willamette Valley, Oregon. Corvallis, OR: Oregon State University. 89 p. M.S. thesis.

Gumtow-Farrior, Daniel L; Gumtow-Farrior, Catherine M. 1992. Managing Oregon white oak communities for wildlife in Oregon's Willamette Valley: a problem analysis. Corvallis, OR: Oregon Department of Fish and Wildlife, Non-Game Program. 75 p.

Gurnell, John. 1983. Squirrel numbers and the abundance of tree seeds. Mammal Review. 13: 133-148.

Gurnell, John. 1987. The natural history of squirrels. New York: Facts on file publications. 201 p.

Hall, E. Raymond. 1981. The mammals of North America, 2d ed. New York: John Wiley and Sons, Inc. 1181 p.

Hitchcock, Leo C.; Cronquist, Arthur. 1991. Flora of the Pacific Northwest. Seattle: University of Washington Press. 730 p.

Ingles, Lloyd G. 1947. Ecology and life history of the California gray squirrel. California Fish and Game Bulletin. 33:139-157.

Ingles, Lloyd G. 1965. Mammals of the Pacific States. Stanford, CA: Stanford University Press. 506 p.

Kessler, Richard. 1990. The oak woodlands of Thurston County, Washington: mapping and descriptions of stands. A report to the Washington Department of Wildlife and the Capital Land Trust. Olympia, WA: Washington Department of Wildlife. 25 p.

Luoma, D.L. 1991. Annual changes in seasonal production of hypogeous sporocarps in Oregon Douglas-fir forests. In: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service. Pacific Northwest Research Station: 83-90.

Martin, Alexander C.; Zim, Herbert S.; Nelson, Arnold L. 1951. American wildlife and plants: a guide to wildlife food habits. New York: Dover Publications, Inc. 500 p.

Maser, Chris; Mate, Bruce R.; Franklin, Jerry F.; Dyrness, C.T. 1981. Natural history of Oregon coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 496 p.

Maser, Chris; Trappe, James M.; Nussbaum, Ronald A. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology. 59: 799-809.

Molina, Randy; Massicotte, Hugues; Trappe, James M. 1992. Specificity phenomena in mycorrhizal symbioses: community-ecological consequences and practical implications. In: Mycorrhizal functioning: an integrative plant-fungal process. New York: Chapman and Hall. 423 p.

Murie, Adolph. 1936. A predator eliminates a sick animal. Journal of Mammalogy. 17:418.

Nixon, Charles M.; McClain, Milford W.; Donahoe, R.W. 1975. Effects of hunting and mast crops on a squirrel population. Journal of Wildlife Management. 39: 125.

Packard, R.L. 1956. The tree squirrels of Kansas: ecology and economic importance. Misc. Publ. 11. Kansas: University of Kansas Museum of Natural History. 67 p.

Rigg, George B. 1918. Notes on plants found in the vicinity of Camp Lewis. In: Leighton, Morris M., ed. The country about Camp Lewis. Olympia, WA: Washington Geological Survey Bulletin. No. 18: 74-90.

Rodrick, Elizabeth Anna. 1986. Survey of historic habitats of the western gray squirrel *{Sciurus griseus)* in the southern Puget Trough and Klickitat County, Washington. Seattle, WA: University of Washington. 41 p. M.S. thesis.

Smith, Christopher C. 1970. The coevolution of pine squirrels *{Tamiasciurus)* and conifers. Ecological Monographs. 40: 349-371.

Standiford, R.B., tech. coord. 1991. Proceedings of the symposium on oak woodlands and hardwood rangeland management, October 31-November 2,1990. Gen. Tech. Rep. PSW-126. Davis, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 371 p.

Stein, William 1.1990. *Quercus garryana* Dougl. ex Hook (Oregon white oak). In: Burns, Russell M.; Honkala, Barbara H., tech. coords. Silvics of North America: vol. 2, hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 650-660.

Stienecker, Walter E. 1977. Supplemental data on the food habits of the western gray squirrel. California Department of Fish and Game Bulletin. 63(1): 11-21.

Stienecker, Walter E.; Browning, B.M. 1970. Food habits of the western gray squirrel. California Department of Fish and Game. 56: 36-48.

Swift, R.J. 1977. The reproductive cycle of the western gray squirrel in Butte County, California. Chico, CA: California State University. 78 p. M.S. thesis.

Thilenius, J.F. 1964. Synecology of the white-oak *(Quercus garryana* Douglas) woodlands of the Willamette Valley, Oregon. Corvallis, OR: Oregon State University. 151 p. Ph.D. dissertation.

Wade, 0.; Gilbert, P.O. 1940. The baculum of some sciuridae and its significance in determining relationships. Journal of Mammalogy. 21: 52-63.

Washington Department of Wildlife. 1993. Status of the western gray squirrel *(Sciurus griseus)* in Washington. Olympia, WA: Washington Department of Wildlife. Final status report. 36 p.

Ryan, Loreen A.; Carey, Andrew B. 1995. Biology and management of the western gray squirrel and Oregon white oak woodlands: with emphasis on the Puget Trough. Gen. Tech. Rep. PNW-GTR-348. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 36 p.

The western gray squirrel *(Sciurus griseus* Ord, 1818) has been accorded "threatened" status by the state of Washington. Populations are small, scattered, and declining primarily due to the loss and fragmentation of suitable habitat. Western gray squirrels plus several other wildlife species are closely associated with Oregon white oak conifer communities on forest-prairie-wetland interfaces. Management of oak woodlands is necessary to protect ecological biodiversity, wildlife habitat, and habitat quality of existing oak woodlands. Recommendations include removing overtopping Douglas-fir trees thinning of dense understory oak and Douglas-fir; maintaining or developing habitat corridors; prescribed burning; and promoting oak woodland conservation and enhancement on public and private lands through information, education, and legislation.

Keywords: Western gray squirrel, *Sciurus griseus,* Oregon white oak, *Ouercus garryana,* management. Pacific Northwest.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

***U.S. GOVERNMENT PRINTING OFFICE: 1995-689-313/02018**

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890