Polepatch Huckleberry Enhancement

Fuels and Fire Ecology Report

Prepared by:

Jessica Hudec

Natural Resource Specialist- Fire

and

Jennifer Harris

Zone Fire Management Officer

for:

Cowlitz Valley Ranger District

Gifford Pinchot National Forest

November 30, 2012



## Introduction

The following fuels and fire ecology report discusses the current and desired future conditions for the Polepatch planning area with respect to fuels and fire ecology. We analyze the conditions necessary to re-introduce the traditional cultural practice of prescribed fire as a management tool and the effects of the proposed action on fuel characteristics, air quality, and fire ecology.

## *Project Description*

The Polepatch Huckleberry Restoration project proposes treatment of 774? acres of forest land to maintain and enhance the production of native huckleberries (*Vaccinium spp.*) on the Cowlitz Valley Ranger District. Such action would benefit local Native Americans, recreational berry pickers, local communities, and wildlife, plant communities, and other natural resources associated with these berry fields. The action would commercially thin overstory conifers to permit more light to reach the existing huckleberry shrubs, thus increasing berry production, and remove competing understory vegetation, which would allow an increase in shrub cover.

The project area is located in the Mosquito Meadows and Polepatch areas of the Cowlitz Valley Ranger District. The project planning area is approximately 14 air miles south of Randle, Washington, within the Lower Cispus watershed, specifically the upper reaches of the Yellowjacket, Greenhorn, and Iron Creek drainages of the Cispus River.

Action is needed to reverse the current decline in huckleberry cover and fruit production. These declines are attributed to increased shading from tree ingrowth and competition with other understory species.

Treatment of the proposed 574? acres would utilize a combination of ground based and/or skyline logging systems, followed by prescribed fire, where feasible. Approximately 140 additional acres are not accessible to commercial logging equipment and would be pre-treated by hand-falling small trees to add slash to the unit before treating with prescribed fire.

Proposed units are natural, fire-regenerated stands ranging from 80 to 90 years old. Stands are between 3,750 and 4,850 feet in elevation and are predominantly comprised of Pacific silver fir (*Abies amabilis*), western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata)* with minor amounts of western white pine (*Pinus monticola*), Alaska yellow cedar (*Callitropsis nootkatensis*), noble fir (*Abies procera)*, and mountain hemlock (*Tsuga mertensiana*).

Project implementation would begin in the summer of 2013. The project area is currently accessible and no permanent or temporary road construction is proposed. Specific actions associated with this project include construction of landings, commercial thinning of conifers using ground based and skyline equipment, thinning and pruning to enhance undergrowth, prescribed burning of surface and canopy fuels, and prescribed burning of slash.

The project is expected to meet Forest-wide standards and guidelines and the Management Area direction for land allocations within the planning area.

### Overview of Issues Addressed

This report addresses the historic, current, and desired future conditions of Polepatch planning area with respect to fire ecology, fuel characteristics, and air quality. Fire ecology analyses discuss average fire return intervals and anthropogenic use of fire as a traditional cultural practice by the Cowlitz Tribe. Quantitative fuels analyses include potential fire behavior and canopy characteristics pre-harvest, post-harvest, and post-prescribed fire, where applicable. Potential fire behavior characteristics analyzed include rate of spread, flame length, and fireline intensity. These fire behavior characteristics are derived from quantitative and qualitative measurements of ground, surface, and canopy fuels. Canopy cover and percent mortality are analyzed in stands where the use of prescribed fire is proposed. We discuss the effects of timing on prescribed fire feasibility and public and firefighter safety. Air quality analyses address concentrations of greenhouse gases emitted by burning of activity fuels and potential effects on global climate change.

## Affected Environment

### Applicable Regulations and Guidance

The Polepatch Huckleberry Enhancement EA is tiered to the 1990 Final Environmental Impact Statement for the Gifford Pinchot National Forest Land and Resource Management Plan.

Management direction on the Gifford Pinchot National Forest comes from the *Gifford Pinchot National Forest Land and Resource Management Plan* (LRMP, 1990), as amended by the *Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl* (NWFP, 1994). These two documents guide planning on the forest by land allocation, have stated desired future conditions and contain standards and guidelines that must be adhered to. Land allocations that occur in the project area are explained in detail below. Where land allocations overlap between the LRMP and the NWFP, the more restrictive standards and guidelines apply, unless otherwise noted.

Stands proposed for treatment are located within lands allocated as either Roaded Recreation (approximately 90% of the project area) or Timber Production (approximately 10% of the project area) according to the LRMP and as Administratively Withdrawn Areas (AWAs) and Matrix according to the NWFP. A description of the objectives and restrictions for these allocations are described below.

The project is expected to meet Forest-wide standards and guidelines and Management Area direction for LRMP allocations and to meet the objectives and intent of the NWFP. All applicable standards and guidelines have been evaluated for consistency.

**Gifford Pinchot Forest Plan Land Allocations:**

**Roaded Recreation:** The goal of the Roaded Recreation management area category is to provide a variety of dispersed recreational opportunities in areas conveniently reached by auto. The desired future condition in areas where timber harvest is permitted includes some evidence of management activities; however, such evidence should not be conspicuous and vegetation should remain largely natural in appearance along major travel ways. Natural appearance of vegetation may range from natural openings through stands of mature and old-growth timber. Much of the area provides for interaction with a near-natural environment.

Fire suppression guidelines indicate that a containment strategy should be used during periods of low fire hazard, and a control strategy should be used during periods of high fire hazard.

**Timber Production:** The goal of the Timber Production management area category is to optimize timber production, the utilization of wood fiber, and other commodities in a manner which assures the future productivity of the land. The desired condition for this allocation is that evidence of land managed intensively for timber production is apparent and all tree sizes and mixtures of native species from seedlings to mature sawtimber are well distributed.

Fire suppression guidelines in the LRMP dictate that all wildfires in stands less than sawlog size be controlled. Fires in sawlog size stands should be contained or controlled. These guidelines indicate that initial attack efforts have intended to contain or control all fires in Timber Production lands, at least since the LRMP was written (1990), and fire has not been allowed to place its natural role in the disturbance regime. Over time this lack of fire could lead to fuel accumulations, but current fuel loadings are not likely to be outside of the natural range of variability.

**Northwest Forest Plan Land Allocations:**

**Administratively Withdrawn Areas:** Administratively Withdrawn Areas include recreation and visual areas, backcountry, and other areas where management emphasis precludes scheduled timber harvest and which are not included in calculations of allowable sale quantity (ASQ). Standards and guidelines common to all land allocations apply to Administratively Withdrawn Areas. The most restrictive standards and guidelines apply when multiple management guidelines exist for a common area. Standards and guidelines for key watersheds apply where the watershed overlays the Administratively Withdrawn Area.

No fire and fuels management guidelines exist specific to Administratively Withdrawn Areas.

**Matrix:**  Matrix consists of those federal lands outside the six categories of designated areas from the NWFP (Congressionally Reserved Areas, Late-Successional Reserves, Adaptive Management Areas, Managed Late-Successional Areas, Administratively Withdrawn Areas, and Riparian Reserves). Most timber harvest and other silvicultural activities would be conducted in the portion of the matrix with suitable forest lands, according to standards and guidelines (NWFP, C-39).

Fire suppression guidelines are determined by LRMP land management allocations (NWFP, C-48). Fire and fuels management activities on matrix lands in the wildland-urban interface (WUI) should be coordinated with state and local governments and landowners. Hazard reduction may take management priority on WUI lands and near values at risk. No WUI-designated lands exist in the planning area.

**Other Management Direction and Landscape Analyses:**

**Watershed Analyses**: Recommendations from the Lower Cispus watershed analysis will be incorporated into the project design.

**Minimum Roads Analysis:** The Gifford Pinchot National Forest is currently undergoing a forest-wide analysis of current forest roads and associated use. The goal of the analysis is to identify the most important roads for accessibility and roads that are not cost effective to maintain. The result would be a road system that the forest can maintain to designated standards with the funds allocated.

Considerations for the minimum roads analysis are not incorporated into this project. Thus, although the proposed action for the Polepatch restoration does not identify any roads for closing, the minimum roads analysis might make different determinations.

**Clean Air Act and National Ambient Air Quality Standards (NAAQS):** Ambient air quality is defined by the Clean Air Act of 1963 as the air quality anywhere people have access, outside of industrial site boundaries. Ambient air quality standards are designed to protect human health, welfare, and environmental quality. Air resource management includes any activity to anticipate, regulate, or monitor air pollution, air pollutant emissions, ambient air quality, or the effects of air pollution resulting from fires or fire management. The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) and thresholds for criteria pollutants to control pollution and protect public health, safety, and welfare (Table 1). Furthermore, the Clean Air Act establishes state-level responsibilities for preventing and controlling air pollution. Emissions from forest burning in Washington are regulated by the Washington Clean Air Act (RCW 70.94, 1991) and the Department of Natural Resources Smoke Management Plan (1998).

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 1. NAAQS for PM10, PM2.5, and CO** | | | |
| **Pollutant** | **Averaging Time** | **NAAQS Violation Determination** | **Washington State Exceedance Level\*** |
| PM2.5 | Annual | 3-year average of the annual arithmetic mean. | 12 µg m-3 |
| PM2.5 | 24-hour | 98th percentile of the 24-hour values determined for each year. 3-year average of the 98th percentile values. | 35 µg m-3 |
| PM10 | 24-hour | Expected number of days per calendar year with a 24-hour average concentration above 150 µg m-3 is ≤1 over a 3-year period. | 150 µg m-3 |
| CO | 1-hour | Not to be exceeded more than once in a year. | 35 ppm |

\*Washington state standards reflect national EPA standards.

*Sensitive Airsheds:*  The Clean Air Act identifies three classes of airsheds (I-III). Increases in sulfur dioxide and particulate matter concentrations are highly restricted in Class I airsheds (FSM 5280). Wilderness areas that were designated prior to 1977 and exceed 5,000 acres in size are classified as Class I airsheds. Wilderness areas designated after 1977, research areas, and reserves are typically Class II airsheds. Sensitive airsheds that may be affected by prescribed burning in Polepatch Huckleberry Enhancement are listed in Table 2. No non-attainment areas exist in the vicinity of the Polepatch Huckleberry Enhancement planning area.

|  |  |  |
| --- | --- | --- |
| **Table 2. Sensitive Airsheds** | | |
| **Sensitive Area** | **Sensitivity Classification** | **Distance and Direction from Project Area\*** |
| Mount St. Helens National Volcanic Monument | Class II | 4 miles West |

\*Approximate distance from nearest stand in project area; direction from entire project area.

### Existing Condition

**Vegetation Condition**

Proposed units are natural, fire-regenerated stands ranging from 80 to 90 years old. Stands are classified into Pacific silver fir plant groups (Brockway et al., 1983), which are found in high elevation (3000-4300 ft.), moist forests west of the Cascade Crest with cold winter conditions and deep snow packs. Pacific silver fir/big huckleberry/queencup beadlily (ABAM/VAME/CLUN) plant association is most abundant in the planning area and is characterized by stands of Pacific silver fir, western hemlock, Douglas-fir, and noble fir with an understory of big huckleberry (*Vaccinium membranaceum)*, queencup beadlily (*lintonia uniflora*), and other herbs. ABAM/VAME/CLUN is found in cool environments on sites tending to north aspects, positioned on benches to upper slopes. Pacific silver fir/fool’s huckleberry (*Menziesia ferruginea*) (ABAM/MEFE) and Pacific silver fir/Alaska huckleberry (*Vaccinium alaskense)* (ABAM/VAAL) plant associations are also present. ABAM/MEFE occupies similar sites to ABAM/VAME/CLUN and is characterized by a tall, dense, diverse shrub layer of fool’s huckleberry, various huckleberry species and other shrub species and a diverse herb layer dominated by dogwood bunchberry (*Cornus canadensis)* and queencup beadlily. Pacific silver fir and western hemlock dominate both the overstory and understory with Douglas-fir present in the overstory to a lesser degree. ABAM/VAAL occupies mesic sites with relatively moderate environmental conditions. Pacific silver fir and western hemlock dominate the canopy with lesser amounts of Douglas-fir. Pacific silver fir dominates the understory. The prominent shrub layer is made up of several huckleberryspecies and lacks salal (*Gaultheria shallon*). The herbaceous layer is highly variable is species composition and cover.

Polepatch planning area includes open stands with poor soil quality and shallow soil depths, and with large trees and advanced regeneration occurring in clumps. Other stands are in the stem exclusion phase of forest succession with little to no regeneration or shrub and herb understory. Finally, some stands or portions of stands exhibit late-seral characteristics with a predominantly closed canopy, scattered large trees, and regeneration and shrub concentrations occurring in canopy gaps. Scattered evidence of white pine blister rust exists and contributed to the snag component by affecting Western white pine. Sign from elk, deer, and other wildlife is present throughout the planning area and particularly abundant in some of the more open stands. Refer to the silviculture report for a full stand by stand description of current vegetation conditions.

**Fuel Conditions**

Current fuel loads vary among the units, but are sparse overall. Stands typically lack dead, down fine fuels, have minimal coarse woody debris, and vary with respect to duff depth and coverage. Stands affected by white pine blister rust and/or pockets of root rot might have high fuel loadings, including larger numbers of standing snags and more coarse woody debris.

Deep, heavy snowpacks rapidly compact surface fuels, while warm summer conditions allow for rapid decay of fine, woody fuels. Rapid compaction and rate of decay effectively limit the receptiveness of the fuelbed to ignition except under rare conditions. Abundant shrubs provide a heat sink under average conditions, reducing the rate of fire spread in the event of an ignition. Climatic conditions further limit the receptiveness of fuelbeds to fire throughout most of the year. Most fires that occur are either very small (<10 acres) or very large (>1000 acres) (Evers et al., 1996; Agee, 1993), and the highest levels of fire danger generally occur mid-September through October (Evers et al., 1996). Wildfire hazard in this area is low to moderate depending on the weather in any given year, the amount and extent of canopy gaps, and localized fuel conditions. Dry east wind events and prolonged drought (3+ years) can increase fire hazard. These dry conditions result in an increased probability of large fire spread and occur approximately every 30 years (Evers et al., 1996).

Exclusion of lightning-caused fires has probably not affected current fuel conditions and expected fire behavior at broad scales, nor do natural fuel accumulations present much wildfire hazard under average conditions. Exclusion of Native American burning practices might have caused a relative increase in fuel loads and a decrease in coarse woody debris.

**Fire Ecology**

Stands classified into Pacific silver fir plant groups typically experience little wildfire risk and long fire return intervals. Dominant tree species in this plant group are thin-barked and not well-adapted to fire, with the exception of Douglas-fir.

Evers et al. (1996) describe the plant association groups present as belonging in fire groups 6—cool, moist lower subalpine, and 8—warm, moist western hemlock and Pacific silver fir. Fire group 6 occurs at a mix of high and mid-elevations west of the Cascade crest. Fire group 6 is common to several locations on the Gifford Pinchot National Forest including the Dark Divide roadless area and along Juniper Ridge and McCoy Peak, which extend north from the Dark Divide, near Polepatch. Sites generally occur on gentle slopes and appear at lower elevations in frost pockets or cold air drainages. Soils are generally rocky compared to other soils in the Pacific silver fir and western hemlock zones. Although fire history data is generally scarce, ecology plot data suggests a fire return interval of 170-430 years.

Fire group 8 occurs across a wide range of topographic positions and experiences a variety of moisture and temperature regimes. Like fire group 6, fine fuels tend to be lacking and decay rapidly. However, fuel loadings can build quickly when the overstory is affected by insects and disease. Conditions are drier in canopy gaps and are more likely to support fire. Deeper duff and heavier large fuel loadings than fire group 6 may occur, but moisture levels are typically high and wildfire hazard is similar—low to moderate depending on weather conditions and the number of canopy gaps. Ecology plot data suggests a fire return interval of 170-300 years. Yamaguchi (1986) found extremely variable fire return intervals (90-730 years) in an area sampled north of Mount St. Helens with no discernible mode.

Stand-replacing fires are the most common type of disturbance in fire groups 6 and 8. These stand replacing fires occur during droughts, when conditions are favorable to large fire spread and/or strong winds carry fire from adjacent stands.

Large areas of huckleberries serve as a food source for black bears (*Ursus americana)* and big game summer range. Moist conditions and north-facing aspects make fire an unlikely tool for wildlife management and slash burning can be difficult except under a narrow range of environmental conditions.

**Fire History**

Natural (lightning-caused) and anthropogenic fire have been a part of the fire ecology of the Polepatch planning area at varying frequencies throughout history. Plant community analysis and written and oral records indicate natural fires tend to be low in frequency but can be high in severity and extent. Native people used fire in various ways to improve game habitat, facilitate travel, reduce insect pests, remove cover for potential enemies, enhance conditions for berries, and drive game, among other purposes (Zyback, 1993). American Indian bands of the Columbia Plateau maintained huckleberry fields near the Cascade crest with periodic, repeated burning (French, 1999; Mack, 2001). Fires were likely caused by both escaped campfires as well as intentional burning. Several ethnographic studies offer more evidence regarding Native American burning as a traditional cultural practice, specifically with regards to the creation and maintenance of huckleberry fields (e.g. Burke, 1979; Zyback, 1993; French, 1999; Mack, 2001).

The ceding of Indian lands and National Forest Service policy prohibited traditional burning practices beginning in the early 1900s (Fisher, 1997). Lack of fire and other disturbances have led to the encroachment by conifers into open huckleberry fields. Increased canopy cover shades huckleberries and reduces productivity (Minore et al., 1979). See “*Vaccinium* ecology” below for more information on the relationship between huckleberries and fire. During early project planning members of the Cowlitz tribe, with families who have returned to the Polepatch area for generations, noted the encroachment of timber in the huckleberry fields and decline of berry quality and quantity (personal communications).

Notable historic fires in the area include:

* Big Fire (early 1800’s)- approximately 1,500 square miles in a triangular area between Chehalis, Mount St. Helens, and Mt. Rainier
* Strawberry Mountain Fire (September 1886)- 2,000 acres
* Tumwater Mountain Fire (September 1886)- 3,000 acres
* Cispus Fire (September 2, 1902)- approximately 72,000 acres in the Upper and Lower Cispus watersheds including Camp Creek, Yellowjacket, McCoy, and Ferrous Creek drainages in the Lower Cispus watershed.
* Unnamed Pinto Rock fire (1916 or 1917)- approximately 2,000 acres
* Greenhorn Fire (June 12, 1918)- re-burn of much of the 1902 Cispus Fire.

***Vaccinium* *membranacuem* Ecology**

*Vaccinium membranaceum,* big huckleberry, is the most important commercial huckleberry species in the Pacific Northwest. Big huckleberry is a native, rhizomatous, frost-tolerant shrub (Brockway et al., 1983) that is well-represented in mesic subalpine communities of the Pacific Northwest as an understory associate of Pacific silver fir and mountain hemlock. Big huckleberry is often codominant in the understory with common competitor, beargrass (*Xerophyllum tenax)* (Simonin, 2000). Lodgepole pine regeneration and mountain ash (*Sorbus sitchensis*) also commonly compete with big huckleberry (Minore, 1972).

Big huckleberry plants are present throughout stand succession, but plants are generally most productive in recently disturbed sites (Martin, 1979). Soil pH seems to be a significant factor affecting shrub cover (Minore and Dubrasich, 1978). Large fields dominated by huckleberry shrubs are seral communities that, in the absence of disturbance, likely see a gradual decrease in huckleberry dominance as trees encroach and shading increases (Minore, 1972).

Presence of huckleberry shrubs does not indicate the presence of fruit. Martin (1979) found that fruit production was not related to the percent cover or height of globe huckleberry (*Vaccinium globulare)* plants in Montana. Lack of correlation between height and fruit production suggests that vegetative growth and fruit production respond to different environment influences. Similar relationships are likely found in big huckleberry, but the morphology and growth behaviors of big huckleberry can differ from globe huckleberry and other Montana species so comparisons should be made with caution (Minore et al., 1979). Martin (1983) found that huckleberry shrub height is positively correlated with canopy density. Shaded environments that limited fruit production and reduced cover in old forest stands did not eliminate huckleberry shrubs, and shrubs continued to grow taller as crowns closed.

Time since disturbance, environmental site factors, and meteorological influences determine fruiting productivity in huckleberry shrubs. A few years after establishment they produce a maximum amount of berries; then, production gradually declines as other shrubs and trees dominate the site (Hall, 1964). Stands on mesic, northern or eastern aspects with light tree canopies that were burned by wildfire 25-60 years ago or clearcut and broadcast-burned 8-15 years ago were the most productive sites; whereas, timber stands not disturbed in the previous 60 years were among the least-productive sites samples (Martin, 1979). Exceptions occurred and huckleberry production was low when wildfires burned on very steep slopes at high elevation, on xeric aspects, and with high intensity (Martin, 1979). Hunn and Norton (1984) found fruit yields were correlated with elevation, slope, and distance east or west of the Cascade crest.

Annual fruit production is influenced more by weather than by environmental site factors (Minore and Dubrasich, 1978). Factors that affect fruit production include snow pack duration (Minore, 1972; Minore and Bubrasich, 1978), snow depth (Minore and Dubrasich, 1978; Martin, 1979), drought (Stark and Baker, 1992), and cold or wet weather during critical phases of pollination and fruit development (Shaffer, 1971). Sites protected from frost have more consistent fruit production (Minore and Smart, 1978). Huckleberry flowers develop in early spring when adequate moisture is provided by snow melt and precipitation. Lingering snow packs on mesic aspects could delay flower formation and protect bushes from fatal frosts that occur in open areas on xeric aspects (Minore and Smart, 1975). The strong influence of weather on fruit production suggests that no conclusions about specific site productivity can be drawn based on samples from one or two years. Repeated measurements over longer time scales are necessary to determine site productivity and trends.

Fire is the most common disturbance that creates the seral conditions in which big huckleberry dominates. Some small huckleberry fields have developed following timber harvest, but timber harvest impacts forest succession differently than fire. Without fire or other large-scale disturbance, invading trees and brush gradually crowd out huckleberries. Old shrubs (75 years or older) may produce less fruit and fruit of lower quality than younger shrubs; therefore, disturbance may benefit huckleberry fruit production by destroying old stems and rejuvenating shrubs (Martin, 1979). Seedlings and clonal shoots begin flowering and fruiting three (Minore et al., 1979) to five (Barney, 1999) years after establishment. Fire intensity affects huckleberry shrub recovery time, because heat penetration into soil layers where rhizomes occur affects the shrub’s ability to produce post-fire, vegetative sprouts (Miller, 1977). Moderate to severe fires on coarse textured soil or in areas with a thin organic layer can kill underground rhizomes and result in heavy mortality (Coates and Haeussler, 1986).

**Desired Future Condition**

The desired future condition of the Gifford Pinchot National Forest is a healthy, diverse, and resilient landscape that can adapt to future disturbances with minimal negative effects to ecosystems. This desired future condition prioritizes the restoration and maintenance of ecosystem resilience throughout the Lower Cispus Watershed. The proposed action for Polepatch specifically intends to restore huckleberry-dominated ecosystems for wildlife and traditional cultural uses through thinning and prescribed fire and to set up the landscape for long-term management of these huckleberry-dominated ecosystems.

Selective tree removal via thinning can foster stand development, which allows optimal individual tree growth and management of the understory for huckleberries, secondary tree layers, or special habitats. Thinning with the treatment of logging slash can reduce potential wildfire behavior along major travel corridors.

For more discussion on desired future condition, see the Management Direction section which summarizes the desired condition of the Gifford Pinchot according to the LRMP and the Lower Cispus Watershed Analysis.

**Summary of Existing Conditions**

Proposed units in the Polepatch Huckleberry Restoration project area are natural, fire-regenerated stands ranging from 80 to 90 years old. Stands are classified into Pacific silver fir plant groups, which are found in high elevation (3000-4300 ft.), moist forests west of the Cascade crest with cold winter conditions and deep snow packs. Proposed units include open stands with poor soil quality and shallow soil depths, and with large trees and advanced regeneration occurring in clumps. Other stands are in the stem exclusion phase of forest succession with little to no regeneration or shrub and herb understory. Finally, some stands or portions of stands exhibit late-seral characteristics with a predominantly closed canopy, scattered large trees, and regeneration and shrub concentrations occurring in canopy gaps. Sign from elk, deer, and other wildlife is present throughout the planning area and particularly abundant in some of the more open stands.

Current fuel loads vary *among* units, but are sparse overall. Stands typically lack dead, down fine fuels, have minimal coarse woody debris, and vary with respect to duff depth and coverage. *P*lant groups present typically experience little wildfire risk and long fire return intervals.

### Ceding of Indian lands and changes in forest policy halted Native American practices of burning in huckleberry fields to maintain open, early-seral characteristics and huckleberry productivity. This loss of fire use as a maintenance tool has led to conifer encroachment and a reduction in the extent and productivity of traditional berry-picking grounds, including Polepatch.

**Fuel Loadings and Fire Behavior**

The Fuel Characteristic Classification System (FCCS) (Ottmar et al., 2007) was used to model current fuel and fire behavior characteristics and the effects of the proposed action on those characteristics. FCCS provides a set of 216 predefined fuelbeds covering a variety of forests and compiled from published and unpublished literature, fuels photo series, fuels datasets, and expert opinion (Ottmar et al., 2007). Field data and observations were used along with the *Photo series for quantifying natural forest residues in common vegetation types of the Pacific Northwest* (Maxwell and Ward, 1980) to modify FCCS fuelbeds to represent pre- and post- mechanical treatment and post- prescribed fire stand conditions in the planning area.

FCCS captures the structural complexity of fuelbeds by compiling and analyzing the data from six fuel strata: canopy, shrub, nonwoody, litter, dead and down woody, and ground fuel (e.g., humus or duff). FCCS converts the quantitative descriptions of fuel characteristics to estimates of potential surface fire behavior. Surface fire behavior predictions are based on a modification of the Rothermel (1972) fire spread model, which calculates the potential spread rate of a quasi-steady state head fire (a fire moving upslope with the wind) through homogeneous surface fuels under uniform conditions with respect to fuel loading and arrangement, fuel moisture, wind, and slope. The spread rate calculations describe fire behavior in the flaming front of the fire, which is influenced primarily by fine fuels. Sandberg et al. (2007b) reformulated the Rothermel model to allow input of multiple fuelbed strata into the surface fire behavior model. Potential fire behavior outputs were generated based on the default fuel moisture scenario D2L2C3 and midflame wind speed of 4 mph. Based on local knowledge, the D2L2C3 fuel moisture scenario (1 hr=6%, 10 hr=7%, 100 hr=8%, 1000 hr=12%, nonwoody=60%, shrub=90%, crown=90%, duff=60%) corresponds to dry conditions under which fuels ignite readily and prescribed fire would be successful at meeting project objectives. Slope was assumed constant at 0%.

FCCS calculates reaction intensity (RI), rate of spread (ROS), and flame length (FL) based on Sandberg et al.’s (2007b) reformulation of the Rothermel fire spread model. The RI (BTU ft-2) is derived from the reactive volume of fuels per unit of ground surface, surface fuel depth, heat of combustion (Sandberg et al. 2007a). The ROS (ft min-1) is a function of the RI, propagating energy flux, and radiant heat sink (Sandberg et al. 2007a). The FL (ft) is derived from the product of RI, ROS, and flame residence time (Byram, 1959; Albini, 1976; Sandberg et al., 2007a).

Potential fire behavior and emissions may be misrepresented where fuel cover is not continuous, because FCCS assumes continuity of the fuelbed components used to calculate fire behavior characteristics (Riccardi et al., 2007). Site specific field observations are needed periodically throughout the mechanical treatment phase to verify whether sufficient continuous fuels exist to propagate fire spread. Fuel conditions are expected to change over time as new vegetation develops and activity fuels compress and decompose. Further analyses are required to predict future fire behavior characteristics as fuel loads change over time.

Modeled constant wind speeds and fuel moisture scenarios do not account for differences in surface wind speeds, fuel moistures, and potential fire behavior related to canopy density. Dense forest canopies shade fuels more than open canopies, which results in higher relative humidities, lower temperatures, and higher surface fuel moistures under dense canopies (Andrews, 1986). Dense forest canopies may retard surface winds that dry fuels more than open canopies (Agee, 2002), which contributes to higher fuel moistures under dense canopies (Weatherspoon, 1996). Higher surface fuel moistures under dense canopies may reduce the probability of ignition in these forest stands (Graham et al., 2004). Additional factors, such as slope (Chandler et al., 1991), influence potential fire behavior; however, the FCCS default setting assumes no slope (0%) for surface fire behavior predictions.

*Current Conditions*

Current conditions are represented by FCCS default fuelbed 238, which is modeled from Pacific silver fir and mountain hemlock forests occurring on cool, moist sites at high elevations in montane and subalpine forests along the western slopes of the Cascade crest. These forests often have dense understories of false azalea, huckleberry, beargrass, and sedge species. Changes to the default fuelbed were made to reflect specific local conditions based on field data, observations, and photo series(Maxwell and Ward, 1980). Average tree heights and height to crown were reduced for all stories. Midstory density was increased to 60 trees per acre and understory decreased to 200 trees per acre with an average DBH of 3 inches. Changes to species composition reflect the presence of Douglas-fir, western hemlock, and western white pine in addition to Pacific silver fir. Woody fuel loading was increased slightly but remains light and rotten wood and duff loadings were decreased.

Stand characteristics vary throughout the Polepatch planning area. Pockets of dense sapling and pole-sized trees are contrasted by large meadow openings with stringers of trees. The fuelbed that represents current conditions, described above, is intended to be a best average representation of the stands proposed for prescribed burning. General conclusions can be drawn about other stands in the analysis area by adapting modeled treatment effects.

*Post-Harvest Conditions*

Expected near-term post-treatment conditions (1-5 years following treatment) are represented by changes made to the current condition FCCS fuelbed (see above) based on the treatment prescription. The thinned version of this fuelbed reduces total canopy cover to 15-30% with the majority of the removal in the mid-story. Shrub cover is expected to increase by 3-5 years after harvest as more light is able to penetrate the canopy. Increases in fuel loading are attributed to harvest residue. Forest residue photo series by Maxwell and Ward (1976) and Ottmar et al. (1990) were used to estimate fuel loadings.Post-treatment fuels remaining on site will vary, but fuel accumulations are expected to compress and decompose quickly, aided by moist conditions and heavy winter snowpacks. Treatment specifications will minimize fuel accumulations along any major travel routes.

*Prescribed Fire Pre-treatment Conditions*

Studies by Minore et al. (1979) on the Gifford Pinchot and Mt. Hood National Forests found that huckleberry fields were unreceptive to burning by drip torch without cured slash added to the site. Preliminary evidence from a 2011 prescribed burn corroborates Minore et. al’s findings. The 2011 prescribed burn took place in the Sawtooth Berry Fields on the Gifford Pinchot National Forest. Fire effects monitoring noted the mosaic burn pattern of the 70 acre unit. Consumption occurred where red slash was present on the site, but fire did not travel into adjacent huckleberry and beargrass plants. Therefore, prescribed fire site preparation for Polepatch will specify at least 8 tons/acre of downed fuels less than 3 inches in diameter be on site in areas that will be burned. Desired fuel loadings will be achieved by cutting understory trees, limbing overstory trees, and allowing slash to cure on site. Changes to the current conditions fuelbed include a reduction in understory canopy cover and an increase in dead, down woody fuels. Some overstory and midstory trees may be harvested and removed from the site where access allows.

*Post-Prescribed Fire Conditions*

Expected post-prescribed fire conditions are represented by changes made to the fuelbed created for prescribed fire pre-treatment conditions (see above). The fire-treated version of this fuelbed reduces total canopy cover to 28% as indicated by the results of FOFEM analyses (see below for information on FOFEM analyses). Shrub and herb covers are expected to decrease by 25-100%, with the greatest consumption where slash is present. Fuel loading is expected to decrease in all size classes with 75-100% consumption of fuels under 3 inches diameter. Post-treatment fuels remaining on site will vary depending on fuel continuity and environmental conditions at the time of burning, but residual fuel accumulations are expected to compress and decompose quickly, aided by heavy winter snowpacks and generally moist conditions.

**Fire Effects**

FOFEM (First Order Fire Effects Model) version 6.0 (Keane et al., 2012) is a computer program for predicting tree mortality, fuel consumption, smoke production, and soil heating caused by prescribed fire or wildfire. First order fire effects are the immediate consequences of fire and form an important basis for the prediction of secondary effects such as tree regeneration, plant succession, and changes in site productivity. FOFEM is intended to directly assess fire impacts and severity and to plan prescribed fires that accomplish resource needs.

Analyses in this report highlight the effects of fire on tree mortality. Tree mortality outputs in FOFEM include tree mortality by species and size class, and pre- and post-fire canopy cover. Predicted changes in canopy cover and percent mortality from prescribed burning in Polepatch are found in Table 3. Species present, except Douglas-fir, are relatively fire intolerant; therefore, even low flame lengths and scorch heights result in a moderate-high amount of mortality, particularly in small diameter trees.

FOFEM is a point model which means that it predicts fuel consumption and smoke emissions for a point on the landscape/stand (about 1-5 m2). The extrapolation of that point measurement upwards in scale is at the discretion of the user. Fuel and moisture conditions across a stand and landscape are notoriously variable so one point estimate for large areas can introduce bias into the predictions.

**Fuel Consumption and Emissions**

Fuel consumption and emissions were calculated using Consume 3.0 (Ottmar et al., 2005) and results will be incorporated into an approved burn plan before any slash treatment occurs.

Consume imports data from the FCCS fuelbeds created and outputs fuel consumption, pollutant emissions, and heat release. Consume makes calculations based on fuel loadings, fuel moisture and other environmental factors. Consume includes separate equations to calculate consumption of activity, natural, and piled fuels. Emissions outputs from a fire that burns through each of the treatment condition scenarios are found in Table 3. Emissions associated with the burning of “Rx pre-treat” are those expected from prescribed burning operations in the proposed action.

Emissions will be regulated through compliance with the Washington Department of Natural Resources Smoke Management Plan, which meets the requirements of the Washington Clean Air Act (RCW 70.94), Forest Protection Laws (RCW 76.04), and the United States Clear Air Act (42 USC §7401 et seq.). Activities that include prescribed fire will follow guidelines in the Best Smoke Management Practices publication issued by the USDA Forest Service and USDA Natural Resources Conservation Service (O’Neill et al., 2011) to minimize the impacts of prescribed fire smoke. Guidelines include evaluating smoke dispersion, monitoring the effects of smoke on air quality, communicating with the public, considering emissions reduction techniques, and sharing the airshed by coordinating prescribed fire activities with adjacent landowners. Alternative methods of activity slash disposal that will be considered include biomass utilization. Desired burning conditions will be specified in the prescribed fire burn plan. All piles to be burned will be covered to minimize fuel moisture content in the piles, which facilitates quick ignition and a shorter burnout phase.

## Environmental (and/or Social) Consequences

### Alternative 1 – No Action

#### Direct Effects/ Indirect Effects

There are no direct effects of choosing the no action alternative. Immediate stand conditions are unchanged. (See Current Conditions in Table 3.)

In the no action alternative, conifer species continue to grow and shade huckleberry plants, which reduces huckleberry cover and productivity (Minore et al., 1979). Increased canopy continuity supports crown fire potential, but only under extreme fire weather conditions.

#### Cumulative Effects

Future restoration efforts will prove more difficult if no action is taken to enhance huckleberries while the plants are still a major component of the understory vegetation.

#### Summary of Effects

### In the no action alternative, conifer ingrowth continues as a result of forest policy, fire suppression activities, and natural succession processes. Over time, restoration opportunities for huckleberry enhancement and the re-introduction of traditional cultural practices will become increasingly complex.

### Alternative 2 – Proposed Action

Action is proposed to reverse the current decline in huckleberry cover and fruit production. These declines are attributed to increased shading from tree ingrowth and competition with other shrub species. Proposed treatments include commercial thinning, pre-commercial thinning, pruning, and prescribed burning.

#### Direct Effects/ Indirect Effects

Effects of the proposed action include an increase in surface fuel loading immediately post- mechanical treatment, where slash is allowed to remain on site. Increased surface fuel loading results in increased potential surface fire behavior immediately following treatment (Table 3). Fire hazard associated with increased fire behavior potentials is expected to be of short duration due to heavy winter snowpacks and associated compaction and fuel decomposition. Potential surface fire behavior generally decreases in stands and portions of stands that are piled and burned or broadcast burned compared to both existing conditions and post treatment conditions with no slash disposal. Table 3 lists the potential fire behavior for stands if wildfire were to burn through under the following conditions: current, immediately after harvest, after pre-treatment for prescribed fire, and after prescribed fire. Stand conditions best reflect the area proposed for prescribed burning, but general conclusions can be drawn for the larger Polepatch area. See the methodology section above for specific stand conditions and analysis procedures.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3. Expected fire behavior and fire effects under current conditions and conditions following the proposed action alternative.** | | | | | | | | |
|  | **Flame Length**  **(ft)** | **Rate of Spread**  **(ft/min)** | **Reaction Intensity**  **(BTU/ft2/min)** | **Pre-fire Canopy Cover %** | **Residual**  **Canopy Cover %** | **% Mortality** | **PM2.5**  **(tons/acre)** | **PM10**  **(tons/acre)** |
| Current condition | 1.9 | 3.3 | 1445 | 50 | 29 | 49 | 0.18 | 0.18 |
| Post-harvest, no Rx | 4.3 | 10.0 | 2171 | 30 | 18 | 58 | 0.45 | 0.49 |
| Rx pre-treat | 3.3 | 8.6 | 1556 | 40 | 28 | 50 | 0.27 | 0.29 |
| Post-Rx | 1.2 | 2.1 | 937 | 28 | 23 | 44 | 0.17 | 0.18 |

#### The table summarizes the results of FCCS, FOFEM, and Consume analyses for variables of concern by different stand conditions. Expected fire behavior and fire effects refer to a theoretical wildfire that occurs in the treatment area under dry (late summer) environmental conditions. Fire behavior potentials increase following harvest without slash disposal and as a result of pretreatment site preparation for prescribed burning. The lowest fire behavior potentials exist after prescribed burning. Post-treatment canopy covers range from 10-40%. Potential emissions are highest following harvest without slash disposal but will decrease over time.

#### Metrics of crown fire behavior are difficult to quantify, but the proposed action is expected to reduce the potential for crown fire initiation and spread. Crown fire cannot be considered independently of surface fire (Van Wagner, 1977; Alexander, 1988), but predictions can be made about the likelihood of crown fire based on canopy fuel characteristics. A decrease in the quantity and horizontal continuity of canopy fuels can prevent crown fire spread (Raymond and Peterson, 2005). Mixed severity and high severity fire effects are the ecological norm in the vegetation types represented; therefore, a reduction in potential crown fire behavior is not an ecological objective. However, reduced crown fire potential is desirable to increase public safety and protect values at risk in this high use area, particularly during berry harvest season.

Tree mortality from prescribed burning is expected and desirable to meet project objectives in the stands designated for restoration by prescribed fire. Predicted fire behavior and fire effects from prescribed fire treatment are represented in the “Rx pre-treat” row of Table 3. Additional effects of prescribed burning include minor threats to wildlife, temporary limitation to public access, and an output of greenhouse gases including carbon monoxide, nitrous oxides, volatile organic matter, and particulate matter with aerodynamic diameter less than 2.5 and less than ten microns (PM2.5 and PM10). Level of emissions is related to the intensity and duration of the fire, which is determined by fuel and weather conditions at the time of burning. Emissions from prescribed burning can be detrimental to firefighter and public health and contribute to greenhouse gas concentrations in the atmosphere. Indirect effects of individual or multiple projects on global climate change are difficult to quantify; therefore, the significance of project effects on global climate change cannot be determined at any scale. Mortality of huckleberry rhizomes and site sterilization can result from intense and prolonged soil heating; however, long heat residence times from prescribed fire are not expected based on prescription parameters. Desirable environmental burning conditions will be identified in an approved prescribed fire burn plan.

Reduction in canopy cover to less than 30 percent has been shown to increase huckleberry productivity (Minore et al., 1979; Martin, 1983). Application of prescribed fire prunes plants, which may increase fruiting by stimulating the grown of more productive young shoots (Hall, 1984; Martin, 1979). Use of prescribed fire also recognizes and reintroduces a traditional cultural practice for huckleberry field maintenance.

Increases in huckleberry production are not expected to be immediate. Thinning without prescribed fire may increase berry production on existing plants as soon as the following growing season if plants were not injured during harvest. Fire intensity and duration will influence the time associated with huckleberry response where prescribed burning is used in restoration efforts. New shoots may emerge the following growing season but are not expected to bear fruit for at least three years (Minore et. al, 1979). Furthermore, huckleberry cover will likely take at least seven years to reach pre-treatment levels (Minore, 1984; Coates and Haeussler, 1986; Bradley et al., 1992).

#### Cumulative Effects

#### Large-scale disturbance by wildfire or insects and disease in conjunction with this project is not expected but could result in large amounts of early seral stand structure. This change in seral stage distribution could affect ecosystem function in the Lower Cispus watershed. Prescribed burning that occurs may coincide with burning on other federal, private, and state lands. The Washington Department of Ecology regulates all silvicultural burning through a permitting and daily approval process. Therefore, emissions from this project will be limited by state and federal policy for the entire geographic area.

#### Summary of Effects

Effects of the proposed action include an increase in surface fuel loading immediately post- mechanical treatment, where slash is allowed to remain on site. Increased surface fuel loading results in increased potential surface fire behavior immediately following treatment. Fire hazard associated with increased fire behavior potentials is expected to be of short duration due to heavy winter snowpacks and associated compaction and fuel decomposition. Potential surface fire behavior is expected to decrease in stands and portions of stands that are piled and burned or broadcast burned compared to both existing conditions and post treatment conditions with no slash disposal. The proposed action is expected to reduce the potential for crown fire initiation and spread, which may be desirable to increase public safety and protect values at risk in this high use area, particularly during berry harvest season.

Tree mortality from prescribed burning is expected and desirable to meet project objectives. Additional effects of prescribed burning include minor threats to wildlife, temporary limitation to public access, and an output of greenhouse gases including carbon monoxide, nitrous oxides, volatile organic matter, and particulate matter with aerodynamic diameter less than 2.5 and less than ten microns (PM2.5 and PM10).

The proposed action is expected to increase huckleberry cover over time where canopy cover is reduced to less than 30 percent. Increases in huckleberry production are not expected to be immediate. Thinning without prescribed fire may increase berry production on existing plants as soon as the following growing season if plants were not injured during harvest. Fire intensity and duration will influence the time associated with huckleberry response where prescribed burning is used in restoration efforts. New shoots may emerge the following growing season but are not expected to bear fruit for at least three years (Minore et. al, 1979). Huckleberry cover will likely take at least seven years to reach pre-treatment levels (Minore, 1984; Coates and Haeussler, 1986; Bradley et al., 1992). Use of prescribe fire recognizes and reintroduces a traditional cultural practice for huckleberry field maintenance.

#### *Mitigation*

* Activity fuel concentrations will be limited along major travel routes.
* An approved burn plan that addresses smoke emissions and other hazards to firefighter and public safety will accompany any prescribed fire activities.

#### *Monitoring Recommendations*

* Fire effects monitoring during prescribed fire activities is recommended. Requirements will be specified in the prescribed fire burn plan.
* Pre- and post- prescribed fire fuel loadings and canopy cover data collection is recommended.
* Huckleberry cover and productivity monitoring with and without mechanical and prescribed fire treatments is recommended.
* Future monitoring opportunities with respect to social and environmental consequences will be determined based on project effects.

## Compliance with Forest Plan and Other Relevant Laws, Regulations, Policies and Plans

The proposed action complies with standards and guidelines listed in the Gifford Pinchot National Forest LRMP, NWFP Record of Decision, United States Clean Air Act, Washington Clean Air Act, and Washington Department of Natural Resources Smoke Management Plan.

Final Signature/ Date

*/s/ Jessica Hudec\_\_\_\_\_\_\_\_\_\_\_\_\_*

Jessica Hudec

Natural Resource Specialist- Fire

Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Jennifer Harris

Zone Fire Management Officer

Date

## References

Albini, F. A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. INT-GTR-30.

Alexander, M. E. 1988. Help with making crown fire hazard assessments. *In*: Fischer, W. C., Arno, S. F., comps. Protecting people and homes from wildfire in the Interior West: proceedings of the symposium and workshop. 1988. Missoula, MT. USDA For. Serv. INT-GTR-251.

Agee, J. K. 1993. Fire Ecology of Pacific Northwest Forests. Covelo, CA: Island Press.

Agee, J. K. 2002. Fire behavior and fire-resilient forests. *In* Fitzgerald, S., ed. Fire in Oregon’s Forests: Risks, Effects, and Treatment Options. Portland, OR: Oregon Forest Resources Institute.

Andrews, P. L. 1986. BEHAVE: fire behavior prediction and fuel modeling system – BURN subsystem, Part 1. USDA For. Serv. INT-GTR-194.

Anzinger, D. L. Big huckleberry (*Vaccinium membranaceum* Dougl.) ecology and forest succession, Mt. Hood National Forest and Warm Springs Indian Reservation, Oregon. 2002. M.S. Thesis. Corvallis, OR: Oregon State University.

Barney, D. L. 1999. Growing western Huckleberries. University of Idaho. http://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0821.pdf. 24 Jan. 2013.

Bradley, A. F., Noste, N. V., Fischer, W. C. 1992. Fire ecology of forests and woodlands of Utah. USDA For. Serv. INT-GTR-287.

Brockway, D. G., Topik, C., Hemstrom, M. A., Emmingham, W.H. 1983. Plant association and management guide for the Pacific silver fir zone Gifford Pinchot National Forest. USDA For. Serv. R6-Ecol-130a-1983.

Burke, C. J. 1979. Historic fires in the central western Cascades, Oregon. M.S. thesis. Corvallis, OR: OSU.

Byram, G. M. 1959. Combustion of forest fuels. *In* Davis, K. P., ed. Forest Fire Control and Use. New York: McGraw Hill.

Chandler, C., Cheney, P., Thomas, P., Trabaud, L., Williams, D. 1991. Fire in Forestry Volume 1: Forest Fire Behavior and Effects. Malabar, FL: Krieger Publishing Company.

Climate Change Considerations in Project Level NEPA Analysis. 2009. USDA For. Ser. Unpublished document. http://www.fs.fed.us/climatechange/documents/nepa-guidance.pdf. 12 Dec. 2012.

Coates, D., Haeussler, S. 1986. A preliminary guide to the response of major species of competing vegetation to silvicultural treatments. Land Management Handbook Number 9. Victoria, BC: Ministry of Forests, Information Services Branch.

Evers, L., Hubbs, H., Crump, R., Colby, J., Dobson, R. 1996. Fire ecology of the mid-Columbia region. USDA For. Serv. Unpublished.

Fisher, A. H. 1997. The 1932 Handshake Agreement: Yakima Indian treaty rights and Forest Service policy in the Pacific Northwest. Western Historical Quarterly (summer 1997): 187-217.

Fischer, W. C., Bradley, A. F. 1987. Fire ecology of western Montana forest habitat types. USDA For. Serv. INT-GTR-223.

French, D. [1957] 1999. Aboriginal control of huckleberry yield in the Northwest. In Boyd, R. ed. Indians, Fire, and the Land in the Pacific Northwest. Corvallis, OR: OSU Press.

Gifford Pinchot National Forest Land and Resource Management Plan. 1990. (Amendment 11). 1995. http://www.fs.usda.gov/main/giffordpinchot/landmanagement/planning. 12 Dec. 2012.

Graham, R. T., McCaffrey, S., Jain, T. B. 2004. Science basis for changing forest structure to modify wildfire behavior and severity. USDA For. Serv. RMRS-GTR-120.

Hall, F. C. 1964. Literature review of huckleberry (*Vaccinium membranaceum*) in the Cascade Range of Oregon. Unpublished, on file at USDA Forest Service, Region 6, Portland, OR.

Hardy, C. 1996. Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash. USDA For. Serv. Gen. Tech. Rep. PNW-364.

Hunn E. S., Norton H. H. 1984. Impact of Mt. St. Helens ashfall on fruit yield of mountain huckleberry, *Vaccinium membranaceum*, important Native American food. Economic Botany 38(1):121-127.

Keane, R., Lutes, D., and Reinhardt, E. 2012. FOFEM 6.0. http://www.firelab.org/science-applications/fire-fuel/111-fofem. 8 Jan. 2013.

Mack, C. A. 2003. A burning issue: American Indian fure use on the Mt. Rainier Forest Reserve. Fire Management Today (63):2.

Martin, P. A. E. 1979. Productivity and taxonomy of the *Vaccinium globulare,* *Vaccinium membranaceum* complex in western Montana. M.S. Thesis. Missoula, MT: University of Montana.

Martin, P. 1983. Factors affecting globe huckleberry fruit production in northwestern Montana.Int. Conf. Bear Research and Manage. 5:159-165.

Maxwell, W. G., Ward, F. R. 1976. Photo series for quantifying forest residues in the coastal Douglas-fir-hemlock type and coastal Douglas-fir-hardwood type. USDA For. Serv. PNW-GTR-51.

Maxwell, W. G., Ward, F. R. 1980. Photo series for quantifying natural forest residues in common vegetation types of the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-105.

Miller, M. 1977. Response of blue huckleberry to prescribed fires in a western Montana larch-fir forest. USDA For. Serv. INT-RP-188.

Minore, D. 1972. The wild huckleberries of Oregon and Washington: a dwindling resource. USDA For. Serv. PNW-RP-143.

Minore, D. 1984. *Vaccinium membranaceum* berry production seven years after treatment to reduce overstory tree canopies. Northwest Science 58(3): 208-212.

Minore, D., Dubrasich, M. E. 1978. Big huckleberry abundance as related to environment and associated vegetation near Mount Adams, Washington. USDA For. Serv. PNW-RN-322.

Minore, D., Smart, A. W. 1975. Sweetness of huckleberries near Mount Adams, Washington. USDA For. Serv. PNW-RN-248.

Minore D., Smart A. W., Dubrasich M. E. 1979. Huckleberry ecology and management research in the Pacific Northwest. USDA For. Serv. PNW-GTR-93.

Northwest Forest Plan Record of Decision. 1994. http://www.fs.usda.gov/main/giffordpinchot/

landmanagement/planning. 12 Dec. 2012.

O’Neill, S., Lahm, P., Matthews, A. 2011. Best Smoke Management Practices. USDA For. Serv. USDA Natural Resources Conservation Service. http://www.nrcs.usda.gov/Internet/

FSE\_DOCUMENTS/stelprdb1046311.pdf. 12 Dec. 2012.

Ottmar, R. D., Hall, J. N., Vihnanek, R. E. 1990. Improved prediction of fuel consumption during spring-like prescribed burns. Unpublished final report; ODIN Corporation contract PNW-89-617.

Ottmar, R. D., Hardy, C. C., Vihnanek, R. E. 1990. Stereo photo series for quantifying forest residues in the Douglas-fir-hemlock type of the Willamette National Forest. USDA For. Serv. PNW-GTR-258.

Ottmar, R. D., Prichard, S. J., Anderson, G. A. 2005. Consume 3.0. http://www.fs.fed.us/pnw/

fera/research/smoke/consume/index.shtml. 12 Dec. 2012.

Ottmar, R. D., Sandberg, D. V., Riccardi, C. L., Prichard, S. J. 2007. An overview of the fuel characteristic classification system-quantifying, classifying, and creating fuelbeds for resource planning. Canadian Journal of Forest Research 37(12): 2383-93.

Raymond, C. L., Peterson, D. L. 2005. Fuel treatments alter the effects of wildfire in a mixed-evergreen forest, Oregon, USA. Canadian Journal of Forest Research 35(12): 2981-95.

# Riccardi, C. L., Prichard, S. J., Sandberg, D. V., Ottmar, R. D., 2007. Quantifying physical characteristics of wildland fuels using the Fuel Characteristic Classification System. Canadian Journal of Forest Research 37(12): 2413-20.

Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. INT-RP-115.

Sandberg, D. V., Riccardi, C. L., Schaaf, M. D. 2007a. Fire potential rating for wildland fuelbeds using the fuel characteristic classification system. Canadian Journal of Forest Research 37(12): 2456-63.

Sandberg, D. V., Riccardi, C. L., Schaaf, M. D. 2007b. Reformulation of Rothermel’s wildland fire behaviour model for heterogeneous fuelbeds. Canadian Journal of Forest Research 37(12): 2438-55.

Shaffer, S. C. 1971. Some ecological relationships of grizzly bears and black bears of the Apgar Mountains in Glacier National Park, Montana. M.S. thesis. Missoula, MT: University of Montana.

Simonin, K. A. 2000. *Vaccinium membranaceum*. In: Fire Effects Information System. USDA For. Serv. RMRS, Fire Sciences Laboratory (Producer). http://www.fs.fed.us/database/feis. 24 Jan. 2013.

Stark, N., Baker, S. 1992. The ecology and culture of Montana Huckleberries: a guide for growers and researches. Misc. Publication 52. Missoula, MT: University of Montana.

United States Environmental Protection Agency. 1970. The Clean Air Act. Title 42 Ch. 85 U.S.C. §7401 et seq. http://www.gpo.gov/fdsys/pkg/USCODE-2008-title42/pdf/USCODE-2008-title42-chap85.pdf. 10 Dec. 2012.

Van Wager, C. E. 1977. Conditions for the start and spread of crown fire. Can. J. For. Res. 7: 23-34.

Washington Clean Air Act. RCW 70.94. http://apps.leg.wa.gov/rcw/default.aspx?cite=70.94. 12 Dec. 2012.

Washington Department of Natural Resources Smoke Management Plan. http://www.dnr.wa.gov/

Publications/rp\_burn\_smptoc.pdf. 12 Dec. 2012

Weatherspoon, C. P., 1996. Fire-silviculture relationships in Sierra forests. *In* Centers for Water and Wildland Resources, ed. Sierra Nevada Ecosystem Project, Final Report to Congress, Vol. II: Assessments and scientific basis for management options. University of California, Davis. Water Resources Center Report No. 37.

Yamaguchi, D.K. 1986. The development of old-growth Douglas-fir forests northeast of Mt. St. Helens, Washington, following an ad 1480 eruption. Ph.D. dissertation. Seattle, WA: University of Washington.

Zyback, B. 1993. Native forests of the Northwest, 1788-1856: American Indians, cultural fire, and wildlife habitat. Northwest Woodlands (Spring 1993):10-11, 31.