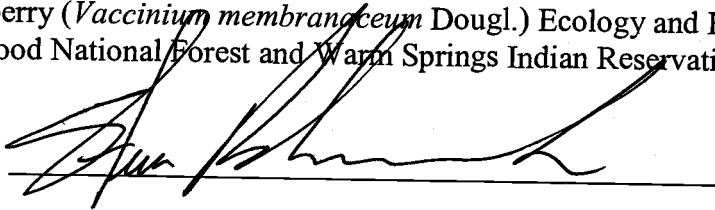


AN ABSTRACT OF THE THESIS OF

Dawn L. Anzinger for the degree of Master of Science in Forest Science presented on August 26, 2002.

Title: Big huckleberry (*Vaccinium membranaceum* Dougl.) Ecology and Forest Succession, Mt. Hood National Forest and Warm Springs Indian Reservation, Oregon.

Abstract approved



Steven R. Radosevich

This thesis is an observational study that examines relationships between disturbance, forest stand development, and big huckleberry (*Vaccinium membranaceum*) fruit productivity and growth by combining ecological methods with the traditional ecological knowledge of Warm Springs ceremonial huckleberry pickers. Shrub fields of fruiting big huckleberry develop in early seral subalpine environments such as forest burns. With fire suppression, the abundance of big huckleberry fields on the Mt. Hood National Forest and Warm Springs Indian Reservation has declined, though mechanical disturbances, such as timber harvests, have occasionally created productive fields. During summer and fall 2000, characteristics of forest overstories (canopy cover, basal area, stand density) and huckleberry understories (fruit productivity, stem height, leaf cover) were measured in 25 huckleberry fields representing a range of initial disturbance types and stand ages. Data were analyzed with univariate and linear regression techniques. Forest

stands on huckleberry fields created by historic fires were older and had greater stand development than fields created by mechanical disturbances. Though once extremely productive, at the time of this study huckleberry fields created by historic fires produced less fruit than fields created by mechanical disturbances.

Huckleberry field fruit production was negatively associated with overstory canopy cover and basal area, suggesting that sexual reproduction in forest understories is resource-limited. Regressions on stand age indicated that huckleberry shrubs take over a decade to recover from disturbance and begin abundant fruit production in open environments. Huckleberry stem height and leaf cover were not associated with forest stand characteristics that change with successional time; therefore, big huckleberry appears tolerant of extended periods in closed canopy forests.

Huckleberry fruit production and stem height were correlated, and both variables were greater on ridges than on slopes, perhaps due to slowed stand development on ridges. Future yields of big huckleberry will require management practices that mimic past disturbance regimes and slow stand development.

©Copyright by Dawn L. Anzinger

August 26, 2002

All Rights Reserved

Big Huckleberry (*Vaccinium membranaceum* Dougl.) Ecology and Forest
Succession, Mt. Hood National Forest and Warm Springs Indian Reservation,
Oregon.

by

Dawn L. Anzinger

A THESIS

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Master of Science

Presented August 26, 2002

Commencement June 2003

Master of Science thesis of Dawn L. Anzinger presented on August 26, 2002.

APPROVED:

Major Professor, representing Forest Science

Head of the Department of Forest Science

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of the Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Dawn L. Anzinger, Author

ACKNOWLEDGMENTS

The author expresses gratitude to the ceremonial huckleberry pickers of the Warm Springs Indian Reservation, without whose thoughtful observations this study would not have been possible. I thank Eveline Platt for interviewing ceremonial huckleberry pickers, transcribing taped interviews, and providing relevant excerpts for use during this study. I am grateful to Dr. Steve Radosevich for his guidance in designing this study and in organizing and writing this manuscript as well as for giving me the freedom to work through the process independently.

I appreciate Dr. Judith Vergun for making the collection of invaluable interviews with Warm Springs elders and this study possible through her hard work on the Warm Springs Sustainability Project. This study is part of the Warm Springs Sustainability Project which is supported by a grant from The Ford Foundation.

TABLE OF CONTENTS

	<u>Page</u>
CHAPTER 1. INTRODUCTION.....	1
STUDY BACKGROUND AND JUSTIFICATION.....	4
APPROACH.....	7
STUDY OBJECTIVES.....	9
THESIS ORGANIZATION.....	9
CHAPTER 2. LITERATURE REVIEW.....	11
BIG HUCKLEBERRY ECOLOGY.....	11
Habitat.....	13
Big huckleberry and forest succession.....	14
Environmental factors influencing fruit production.....	17
Big huckleberry disturbance ecology.....	19
Conclusion.....	22
DISTURBANCE ECOLOGY OF THE HIGH CASCADES.....	23
Forest stand dynamics.....	25
Fire regimes of the High Cascades.....	30
Human influences on Cascade Range fire regimes.....	35
Pre-settlement period.....	35
Settlement period.....	39
Fire suppression.....	41
Timber harvesting and development.....	43
Conclusion.....	44
CHAPTER 3. BIG HUCKLEBERRY (<i>Vaccinium membranaceum</i> Dougl.) FRUIT PRODUCTION AND SUCCESSIONAL ECOLOGY, MT. HOOD NATIONAL FOREST AND WARM SPRINGS INDIAN RESERVATION, OREGON.....	47

TABLE OF CONTENTS (Continued)

	<u>Page</u>
INTRODUCTION.....	47
METHODS.....	53
Study sites.....	53
Data collection.....	54
Data analysis.....	57
STAND DESCRIPTIONS.....	58
RESULTS.....	66
Fruit production and forest encroachment.....	66
Fruit production and stand age.....	68
Stem height and leaf cover.....	70
Initial disturbance type.....	73
DISCUSSION.....	73
Fruit production and forest encroachment.....	73
Response to disturbance.....	78
Reproductive strategy.....	80
MANAGEMENT CONSIDERATIONS.....	82
CONCLUSION.....	84
LITERATURE CITED.....	85
CHAPTER 4. ADDITIONAL CONSIDERATIONS.....	90
METHODS.....	90
Study sites.....	90
Data collection.....	91
Data analysis.....	92

TABLE OF CONTENTS (Continued)

	<u>Page</u>
RESULTS AND DISCUSSION.....	92
Fruit production and forest encroachment.....	92
Edge effect.....	95
Topographical influences.....	96
Huckleberry height and fruit production.....	103
Huckleberry growth and elevation.....	104
Associated vegetation.....	106
CHAPTER 5. CONCLUSION.....	109
LITERATURE CITED.....	114

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
3.1 Proportions (with standard error bars) of total basal area occupied by conifer genera in forest stands located on sampled huckleberry fields.....	63
3.2 Sapling densities (with standard error bars) by species in sampled harvest units.....	65
3.3 Regression (with 90% confidence limits) of fruit production class on overstory canopy cover (%).....	69
3.4 Regression (with 90% confidence limits) of fruit production class on stand age in huckleberry fields greater than 24 years old.....	71
3.5 Regression (with 90% confidence limits) of fruit production class on stand age in huckleberry fields less than 26 years old.....	72
3.6 Huckleberry field fruit production classes by stand age and initial disturbance type.....	75
4.1 Regression of fruit production class on overstory canopy cover, including site x.....	94
4.2 Multiple linear regression of overstory canopy cover on stand age and topographical position.....	97
4.3 Multiple linear regression of fruit production class on stand age and topographical position.....	100
4.4 Regression of huckleberry stem height on the constancy of dwarf bramble (<i>Rubus lasiococcus</i>).....	108

LIST OF TABLES

<u>Table</u>	<u>Page</u>
3.1 Definitions of big huckleberry fruit production classes.....	56
3.2 Forest stand characteristics of huckleberry fields located in mechanical disturbance gaps (MDHF) and on old burns (OBHF)....	62
3.3 Big huckleberry characteristics in huckleberry fields located in mechanical disturbance gaps (MDHF) and old burns (OBHF).....	67
3.4 Mean huckleberry fruit production class, stem height, and leaf cover in huckleberry fields created by different initial disturbances..	74
4.1 Percent overstory canopy cover of ridge and slope huckleberry fields established by different initial disturbance types.....	98
4.2 Mean huckleberry stem height in fields located on ridges and slopes.....	102
4.3 Mean increase in elevation associated with unit increase in huckleberry variables.....	105

Big Huckleberry (*Vaccinium membranaceum* Dougl.) Ecology and
Forest Succession, Mt. Hood National Forest and Warm Springs Indian
Reservation, Oregon.

CHAPTER 1. INTRODUCTION

Big huckleberry (*Vaccinium membranaceum* Dougl.), also known as thin-leaved or black mountain huckleberry, is a common understory shrub of Pacific silver fir and mountain hemlock zone forests in the Oregon and Washington Cascade Range. The delicious purple-black fruits of big huckleberry are highly valued by commercial, recreational, and subsistence harvesters. Huckleberry fields—locations with a high density of fruiting shrubs—are typically in open, fire-disturbed environments (Minore 1972). Big huckleberry survives fire by sprouting from an underground network of rhizomes. Though the shrubs take seven or more years to fully recover from fire disturbance (Minore 1984), they will only fruit abundantly during early seral stages of forest succession, the temporary stages of plant community development which follow immediately after disturbance to the forest canopy (Minore 1972). During the first half of the twentieth century, the crest and volcanic peaks of the Cascade Range were dotted with large and small huckleberry fields that developed after wildfires burned during the latter half of the 19th and early 20th centuries (Minore 1972). Until prohibited in the first decade of

the 20th century (Fisher 1997), American Indian bands of the Columbia Plateau maintained open, seral conditions in the huckleberry fields through periodic, repeated burning (French 1999).

Since about 1910, fire suppression policies enacted by the United States Forest Service (Burke 1979) have greatly reduced the amount of open, disturbed habitat available within the ecological range of big huckleberry. Over time, conifers have established on early seral huckleberry fields, and dense stands of lodgepole pine and other conifers have developed (Minore et al. 1979). Under a closed canopy, big huckleberry fruit productivity wanes (Minore et al. 1979). Big huckleberry shrubs compete with trees for light, water, and nutrients and may have inadequate resources to initiate or complete sexual reproduction in forest understory environments. Berry harvesters and forest managers have observed huckleberry fruit production declining due to forest encroachment for over 60 years (Minore et al. 1979, Fisher 1997). Forest succession is the key ecological process causing the decline in fruit yields.

Patterns of landscape disturbance have changed over the last century with development and timber harvesting replacing fire as dominant disturbance agents in Cascade Range forests. In the 1930s, several high ridges and buttes were cleared for fire lookouts, and numerous roads, firebreaks, campgrounds, and ski areas were constructed on or near big huckleberry fields. Productive huckleberry—shrubs producing flowers and fruits—can be fairly common along roadsides and in campgrounds where sunlight reaches the forest floor.

True fir, hemlock, and Douglas-fir have been harvested from the High Cascades since the 1950s and 1960s (Halverson and Emmingham 1982). In some locations, small huckleberry fields have developed subsequent to timber harvesting (Davis, pers. com. 2000). Big huckleberry shrubs increase fruit production when overstory canopies are thinned (Minore et al. 1979), but they do not necessarily respond favorably to the complete canopy removal associated with large clearcuts (Minore, pers. com. 2001). Timber harvesting may impact forest succession differently than fire disturbance, and successional processes, in turn, affect big huckleberry ecology.

Forest clearing practices can maintain or restore productive big huckleberry fields. Repeated human disturbance is common in the strips of subalpine forest located under utility lines and ski lifts. Manual forest clearing can maintain early seral conditions and may prolong big huckleberry fruit production in some areas, but herbicides often damage or kill huckleberry stems (Minore et al. 1979). In addition, girdling of overstory trees can restore productive big huckleberry fields by reducing overstory canopy cover and has been used for this purpose on both Mt. Hood National Forest and the Warm Springs Indian Reservation.

Forest succession and disturbance regimes have a strong influence on big huckleberry field creation, maintenance, and decline. Successional processes determine the longevity of early seral huckleberry fields and the quantity and quality of light and other resources available to huckleberry shrubs. Observations of declining fruit productivity over time synthesized with contemporary forest

stand data from huckleberry fields in varying stages of succession may reveal successional patterns in reproductive allocation and growth in big huckleberry.

STUDY BACKGROUND AND JUSTIFICATION

Members of the Confederated Tribes of the Warm Springs value big huckleberry for cultural, spiritual, and subsistence reasons. The Tribes retained treaty rights to harvest huckleberries on “unclaimed” ceded and usual and accustomed lands when they signed the Treaty of 1855 with the federal government.¹ Ceded lands were formally relinquished to the federal government in the Treaty of 1855. Usual and accustomed lands are those that were used for subsistence or spiritual practice by the tribes at the time the treaty was signed. Big huckleberry fields are located within Mt. Hood National Forest and the boundaries of the ceded lands and usual and accustomed lands of the Confederated Tribes of the Warm Springs as well as on mountain slopes of the Warm Springs Indian Reservation. Federal land agencies are instructed to work on a “government-to-government” basis regarding the management of treaty resources on “unclaimed” federal lands, including lands under the jurisdiction of the US Forest Service.² Tribal members are extremely interested in forest management practices affecting big huckleberry on Mt. Hood National Forest, and steps have been taken to

¹ Mt. Hood National Forest, Warm Springs Indian Reservation. 1997. Memorandum of Understanding MOU-606-97045. Available from Sandy (OR): Mt. Hood National Forest Headquarters.

² Executive Order 13084.

coordinate huckleberry management between the Confederated Tribes of the Warm Springs and Mt. Hood National Forest.¹

My thesis research is part of the Warm Springs Sustainability Project (WSSP). The WSSP was developed, in part, to improve huckleberry management on ceded lands and usual and accustomed lands of the Confederated Tribes of the Warm Springs. WSSP goals are to collect and integrate ecological, social, and socioeconomic information on big huckleberry and to develop ecologically sound management practices that maintain or improve huckleberry fruit yields.³ My thesis synthesizes ecological information on big huckleberry and forest stand development with ethnographic information on historic huckleberry field productivity and describes successional processes affecting big huckleberry growth and fruit production on Mt. Hood National Forest and the Warm Springs Indian Reservation. Advancing understanding of the disturbance and successional ecology of big huckleberry will improve prediction of ecological response to proposed management actions concerning big huckleberry.

Declines in big huckleberry fruit productivity have developed gradually over generations due to the often slow, incremental progress of forest succession. Past studies examining the relationship between reproductive allocation of big huckleberry and plant community composition and structure have been focused on relatively short time periods (Minore and Dubrasich 1978, Dahlgreen 1984) and have been unable to capture the larger picture of gradually fluctuating

³ Vergun J. Warm Springs Sustainability Project. 1998 grant proposal.

environmental conditions that appear to influence huckleberry fruit productivity. In addition, annual huckleberry fruit yield is highly variable and strongly influenced by climatic conditions during flowering and fruiting (Minore and Dubrasich 1978). Studies that rely solely on quantitative fruit yield data collected over short time periods are unable to separate weather influences from more subtle environmental factors that impact huckleberry fruit productivity.

Disturbance ecology studies of big huckleberry (Minore et al. 1979, Minore 1984) have also been conducted over relatively short time periods and small geographical areas. Big huckleberry takes seven or more years to recover from disturbance and attain abundant fruit production (Minore 1984). Therefore, studies that examine huckleberry response to different disturbance types during seven or fewer years after disturbance are likely to underestimate the fruit production response. Furthermore, due to complex associations between disturbance, stand development, and big huckleberry ecology, disturbance studies conducted in one forest type do not necessarily address the range of ecological relationships that might influence big huckleberry field creation and decline.

In order to add temporal and spatial depth to my thesis research, I synthesized ecological methods of studying forest stand development with ethnographic information collected from elder huckleberry pickers of the Confederated Tribes of the Warm Springs. Warm Springs elders have collected berries from numerous historic and contemporary huckleberry fields and have witnessed landscape-level declines in fruit productivity over the last 50-70 years.

Twentieth century huckleberry fields on Mt. Hood National Forest and the Warm Springs Indian Reservation have been created by several disturbance types and are currently at many different stages of forest succession and fruit productivity. My research combined qualitative descriptions and limited quantitative measures of fruit productivity in order to develop a picture of changing huckleberry productivity over large temporal and spatial scales. My thesis research is a retrospective, observational study that examines the relationships between disturbance type, forest stand development, and big huckleberry fruit productivity and growth.

APPROACH

As part of the Warm Springs Sustainability Project, interviews with Warm Springs ceremonial huckleberry pickers—women who are or were responsible for collecting berries for the annual first fruits ceremony in honor of big huckleberry and for monitoring the huckleberry resource—were recorded and transcribed.⁴ Excerpts from these interviews were made available for my research. Many the 47 women interviewed are elders; some have harvested huckleberries on Mt. Hood National Forest and the Warm Springs Indian Reservation for as long as 70 years. In these interviews, ceremonial huckleberry pickers identified and described many huckleberry fields that developed after 19th and 20th century wildfires. These fields are now almost exclusively closed canopy forests with unproductive huckleberry

⁴ Warm Springs ceremonial huckleberry pickers, interviews. 1998, 1999, 2000. Warm Springs Museum archives. Audio cassette recordings.

understories. The ceremonial huckleberry pickers described harvesting environments when the fields were productive between the 1930s and 50s, provided qualitative estimates of fruit yield, and described the process of forest encroachment that eventually led to declines in fruit productivity. In addition, younger ceremonial huckleberry pickers identified contemporary harvesting sites located in clearcut and shelterwood harvest units and other areas where trees have been cleared.

During summer and fall 2000, I measured forest stand characteristics, such as overstory canopy cover, basal area, stand density, and species composition, in fourteen huckleberry fields created by old fires and nine huckleberry fields created by mechanical disturbances that were identified by Warm Springs ceremonial huckleberry pickers and Mt. Hood Forest Service personnel. I measured big huckleberry fruit productivity, leaf cover, and height as well as other attributes of the understory plant community at each site. In addition, stand age and disturbance information was collected from US Forest Service fire and timber harvesting records and from communications with Bureau of Indian Affairs (BIA) foresters.

Data were analyzed with regression and univariate techniques in order to describe huckleberry fields created by different initial disturbances and to explore relationships between forest stand development and big huckleberry fruit production and growth.

STUDY OBJECTIVES

The goal of this study was to develop an understanding of big huckleberry fruit productivity and stand development. To accomplish this goal, ecological methods of data collection and analysis were synthesized with ethnographic information provided from interviews with Warm Springs ceremonial huckleberry pickers⁴ in order to meet the following objectives:

- To describe the forest stands that have developed on Mt. Hood National Forest and Warm Springs Indian Reservation huckleberry fields that were created by old fires and by more recent mechanical disturbances,
- To quantify the relationships between forest stand development, time since disturbance, and big huckleberry fruit productivity and growth,
- To examine the influences of initial disturbance type and topography on big huckleberry ecology and forest stand development,
- To identify associated plant species indicative of big huckleberry fruit production or growth, and
- To make management recommendations for big huckleberry field restoration and maintenance based on my results.

THESIS ORGANIZATION

My thesis is organized into five chapters. The introduction, chapter one, provides justification and objectives for the research. The literature review, chapter

two, is in two sections; section one covers big huckleberry ecology, while section two covers the disturbance history and successional ecology of the research area. Chapter three, "Big huckleberry fruit production and successional ecology, Mt. Hood National Forest and Warm Springs Indian Reservation," provides methods, results, and discussion of central research questions as well as management recommendations. Chapter four, "Additional considerations," provides methods, results, and discussion of peripheral research questions. The conclusion, chapter five, provides direction for future research.

CHAPTER 2. LITERATURE REVIEW

BIG HUCKLEBERRY ECOLOGY

Big huckleberry (*Vaccinium membranaceum* Dougl.) is a common understory shrub occurring in moderate to high elevation conifer forests of the Oregon and Washington Cascades (Franklin and Dyrness 1973). Eleven other species of *Vaccinium* are found in the Pacific Northwest (Minore 1972), six of which grow within the ecological range of big huckleberry. Though all members of the genus *Vaccinium* have edible berries, big huckleberry has long been the most popularly harvested species due to its abundant fruit production, large fruit size, and great flavor (Minore 1972; Hunn with Selan 1990; French 1999).

Big huckleberry has a complex heredity and variable morphology. Unique ecotypes are not uncommon (Camp 1942). In general, leaves are thin, thus the name “membranaceum,” and egg-shaped to oblong with tapered leaf tips and finely serrated margins (USDA Forest Service 1937). Stems are 0.3 to 1.5 meters in height (USDA Forest Service 1937).

Big huckleberry is a clonal shrub with a spreading “complex, multilayered maze” of woody rhizomes located 8 to 30 centimeters below ground (Minore 1975). Big huckleberry rhizome biomass may be greater than above-ground shoot biomass (Minore 1975). Rhizomes have numerous vegetative buds that develop leafy shoots in response to disturbance (Minore et al. 1979, Minore 1984) and possibly in response to vigorous above-ground stem growth or increased light

levels (Miller 1977). Sparse sinker roots extend from big huckleberry rhizomes to a depth of 70-100 centimeters (Minore 1975).

Big huckleberry flowers in late spring, from mid-May through early July, in response to warming temperatures (USDA Forest Service 1937). Big huckleberry flowers are greenish-white to pink bells that persist at the distal end of ripe fruit (Hitchcock and Cronquist 1976) and are pollinated by bees (Hunn and Norton 1984). Big huckleberry produces more and larger fruit when cross-pollinated (Barney 1999). Fruits ripen from mid-July to mid-September with the greatest sugar content found in late September berries (Minore and Smart 1975). The berries are born singly from leaf axils and, when ripe, are typically purple-black and without bloom (USDA Forest Service 1937). Big huckleberry fruit size is highly variable; berries may be as large as a small "grape" (Cooper 1860) or as small as an elderberry (~3 millimeter diameter). Though western huckleberries, such as big huckleberry, are not as productive as eastern blueberries (Martin 1979), big huckleberry has long been famous for its commercially valuable berry yields (Filloon 1952, Minore 1972, Fisher 1997). However, big huckleberry fruit production is only abundant in open, early seral environments (Minore 1972).

Despite its high fruit production, reproduction of big huckleberry is predominantly asexual; huckleberry seedlings are rare in the wild (Barney 1999). Big huckleberry seedlings are fragile and grow slowly (Barney 1999). Seedling establishment requires continuously moist soils (Barney 1999) and, therefore, may be limited to rare years with adequate summer rainfall (Stark and Baker 1992).

Seedlings and clonal shoots begin flowering and fruiting three (Minore et al. 1979) to five (Barney 1999) years after establishment.

Habitat

Big huckleberry grows in mountainous environments from 900 to 1,800 meters above sea level (Dahlgreen 1984) with the most productive huckleberry fields (areas with an abundance of fruiting shrubs) located between 1,200-1,800 meters (Minore et al. 1979.) Big huckleberry prefers a relatively moderate climate with abundant moisture (Haeussler and Coates 1986) and thrives along the Cascade Crest just south and north of the Columbia River (Franklin and Dyrness 1973). Big huckleberry is adapted to medium to coarse textured soils (USDA Forest Service 2002) and, in Oregon and Washington, grows well on cinder and ash soils and soils with high organic matter content (Stark and Baker 1992).

Big huckleberry dominates the shrub layer of the Pacific silver fir/big huckleberry/beargrass, Pacific silver fir/big huckleberry/queencup bead lily and mountain hemlock/big huckleberry plant associations (Hemstrom and Emmingham 1982) and the big huckleberry/beargrass early seral plant association (White et al. 1996). Because shrubs sprout from rhizomes after fire, big huckleberry is particularly abundant on burned sites within its ecological range (Minore 1972).

Big huckleberry and forest succession

Big huckleberry is a dominant understory species in all stages of forest succession (Franklin and Dyrness 1973, Hemstrom and Emmingham 1982, White et al. 1996). However, Minore and Dubrasich (1978) state that big huckleberry only has abundant cover and fruit production during "optimal seral stages" of forest succession, namely, early seral stages. Big huckleberry frequently dominates early seral shrub communities in subalpine burns (Franklin and Dyrness 1973), and these shrub communities or fields have long been famous for producing abundant crops of fruit (Minore 1972). However, fruit production declines when huckleberry shrubs are crowded and shaded by young trees or other vegetation (Minore 1972, Minore et al. 1979). Shrubs under a partial canopy may grow vigorously and occasionally produce a crop of berries but not as consistently as shrubs located in more open environments (Minore 1972). These observations suggest that the sexual reproduction of big huckleberry is strongly influenced by forest succession.

As forest stands develop and the overstory canopy expands, the understory resource environment changes with light levels decreasing and below-ground competition for moisture and nutrients increasing. Therefore, resource limitation may be responsible for declining big huckleberry fruit set in forest understories. Although pollinator availability may also be a limiting factor for fruit production in closed forest stands, previous studies indicate that fruit set of understory shrubs is rarely limited by inadequate pollination (Stephenson 1981, Niesenbaum 1993).

Dahlgreen (1984) found that big huckleberry fruit production in southern Washington is positively associated with “adjusted solar radiation.” Adjusted solar radiation is computed by multiplying canopy cover estimates by the annual potential solar radiation. He suggested that both light and warm temperatures during the growing season may be critical for big huckleberry fruit production. Since warm understory temperatures are associated with open canopies, the relationship between canopy cover and fruit production may reflect both the effects of light availability on photosynthesis and warm temperatures on fruit maturation.

In contrast, in a study conducted by Minore and Dubrasich (1978) in huckleberry fields near Mt. Adams, Washington, neither big huckleberry fruit production nor leaf cover was correlated with overstory canopy cover. Nevertheless, the authors do mention the detrimental effect of encroaching trees on big huckleberry fruit productivity.

Big huckleberry may share ecological characteristics with globe huckleberry (*V. globulare*). Like big huckleberry, globe huckleberry is a subalpine understory shrub within the subgenus *Euvaccinium*. In Montana, high globe huckleberry fruit productivity is associated with sparse canopy cover (Martin 1979). Martin (1979), measuring overstory canopy cover with a spherical densiometer, found that huckleberry fruit productivity was positively associated with canopy cover when canopy cover was less than 30%. However, fruit productivity was negatively associated with canopy cover at canopy cover values greater than 30%. A partial canopy may protect globe huckleberry shrubs from

extreme temperatures, explaining the positive association between fruit production and low levels of overstory canopy cover.

In environments with extremely low overstory canopy cover such as burns and clearcuts, big huckleberry leaves often turn red in response to strong sunlight (Stark and Baker 1992). Red, sunburned leaves do not photosynthesize as well as green leaves (Stark and Baker 1992). However, globe huckleberry shrubs with sunburned leaves tend to have more fruit than green shrubs (Martin 1979). The increased fruit productivity associated with red leaves may be due to physiological stress and does not necessarily indicate optimal environmental conditions for vegetative growth (Martin 1979).

Increasing overstory canopy cover and decreasing light availability to the forest floor may be the primary causes of declining fruit productivity in big huckleberry shrub fields. However, shrub age may also be a factor. Really old shrubs (75 years or older) may produce less fruit and fruit of lower quality than younger shrubs. Martin (1979) noted that old globe huckleberry shrubs did not produce much fruit in areas with low canopy cover such as canopy gaps and high-graded harvest units. Disturbance may benefit huckleberry fruit production by destroying old stems and rejuvenating the shrubs.

Even though big huckleberry fruit production and cover may be greater during early seral stages of forest succession (Minore and Dubrasich 1978), big huckleberry continues to dominate the shrub layer in late successional forests (Franklin and Dyrness 1973, Hemstrom and Emmingham 1982, Brockway et al.

1983). Similarly, globe huckleberry cover, though positively associated with the abundance of early seral tree species and negatively associated with stand age, is never completely eliminated in late-successional forest stands (Martin 1979). Martin (1979) states "the rhizome network maintained under mature canopies allows the shrub cover to increase when conditions again become favorable."

Environmental factors influencing fruit production

Forest succession may be the most important factor influencing big huckleberry fruit production across the landscape, but several other environmental factors affect fruit production during particular years and in particular environments. Meteorological conditions, in particular, exert a strong influence on annual big huckleberry fruit production (Minore and Dubrasich 1978.) Even in optimal environments, huckleberry fruit production is affected by snow pack duration (Minore 1972, Minore and Dubrasich 1978), snow pack depth (Minore and Dubrasich 1978, Martin 1979), drought (Stark and Baker 1992), cold or wet weather during critical phases of pollination and fruit development (Shaffer 1971, Minore and Dubrasich 1978, Minore and Smart 1978, Martin 1979), and even volcanic ash fall (Hunn and Norton 1984). Sites protected from frost have more consistent fruit production (Minore and Smart 1978.)

Big huckleberry fruit productivity is also influenced by soil chemistry. In southern Washington, big huckleberry fruit productivity is associated with soil pH, with optimal soils having a pH of 5.5 (Minore and Dubrasich 1978). Furthermore,

Stark and Baker (1992) found that high concentrations of soil nutrients, particularly organic matter and manganese, were associated with globe huckleberry fruit production and growth in Montana.

Physical environments influence big huckleberry fruit production as well. In a study conducted to assess the impact of volcanic ash fall on big huckleberry fruit productivity, yields were correlated with elevation, slope, and distance east or west of the Cascade Crest (Hunn and Norton 1984). In addition, Minore and Dubrasich (1978) found that aspect and elevation explain some of the variation in big huckleberry fruit yields in southern Washington.

In Montana, Martin (1979) found that aspect was the most important physical site variable influencing globe huckleberry fruit productivity. Fruit production was greatest on northwest exposures and declined clock-wise around the compass with west-facing slopes having the lowest fruit production. A lack of canopy cover accentuated the effect of aspect. Mesic aspects produced more fruit than xeric aspects; therefore, Martin concluded that moisture stress was limiting production on south and west-facing slopes.

Martin (1979) also found that sites with high globe huckleberry fruit productivity tended to be located at higher elevations than sites with moderate or low fruit productivity. She attributed this relationship to the greater availability of radiant energy at higher elevations.

Martin (1979) found that shrubs located on ridges and steep upper slopes, though shorter than shrubs growing on lower slopes, tended to produce more fruit

and have higher leaf cover than shrubs growing on lower slope positions (Martin 1979).

Big huckleberry disturbance ecology

Plants that sprout vigorously from rhizomes after disturbance, like big huckleberry, are among the first species to re-colonize after fire (Morgan 1984). Huckleberry regeneration after fire is typically composed of clonal shoots (Minore et al. 1979). In a study of globe huckleberry, the depth of heat penetration into the soil strongly influenced the number of sprouts that emerged subsequent to fire (Miller 1977). Heat penetration is determined by fuel load, fuel moisture, and soil moisture (Miller 1977). High soil temperatures apparently damage or destroy rhizomes, and hot fires may remove huckleberry completely. However, big huckleberry rhizomes are mostly located deep enough in the soil profile to avoid being damaged by light surface fires (Minore 1975).

The clonal shoots of big huckleberry (Minore et al. 1979) and globe huckleberry (Miller 1977) begin to emerge one year after fire disturbance. Globe huckleberry sprouts may take two or more years to emerge if initiated from rhizomes located deeper in the soil profile (Miller 1977). Furthermore, if above-ground globe huckleberry stems are destroyed by fire, significantly more clonal shoots are initiated from rhizomes than if stems are simply damaged (Miller 1977). Charred stumps of globe huckleberry may sprout new shoots, rather than rhizomes,

if not completely consumed (Miller 1977). Big huckleberry shrubs may exhibit similar responses to fire disturbance as globe huckleberry.

After fire destroys or damages above-ground stems, big huckleberry takes several years to recover (Minore 1984). In fact, western huckleberries may grow too slowly to take advantage of the flush of nutrients released by fire (Martin 1979). Big huckleberry shoots begin to flower and fruit during the third growing season after fire (Minore et al. 1979), but abundant fruit production may be delayed more than seven years (Minore 1984). Globe huckleberry takes 8 to 15 years before fruiting abundantly after broadcast burns (Martin 1979).

In a study conducted on the Gifford Pinchot National Forest, Washington, disturbance treatments, including cutting and burning and burning without prior timber removal, were applied to plots established in a reforested portion of the Sawtooth huckleberry field (Minore et al. 1979). The plots were extremely difficult to ignite, so the authors applied large amounts of diesel fuel which may have confounded results. After five years, big huckleberry shrubs in burned plots were still fruiting poorly in comparison with shrubs in control plots though leaf cover had recovered to pre-burn levels.

In subsequent studies on Mt. Hood National Forest, Oregon, Minore et al. (1979) examined the effect of bulldoze-and-burn and cut-and-burn treatments on big huckleberry growth and fruit production in a reforested huckleberry field. Three years after application of bulldoze-and-burn treatments, big huckleberry shrubs had sprouted vigorously but still had significantly lower leaf cover and fruit production

than shrubs in control plots. Similarly, big huckleberry shrubs in cut-and burn plots sprouted vigorously but had significantly lower leaf cover than shrubs in control plots three years after treatment application (Minore et al. 1979) and lower fruit production than shrubs in control plots both three years (Minore et al. 1979) and seven years after treatment application (Minore 1984).

Timber harvesting disturbances occasionally stimulate the development of productive patches of big huckleberry, but patch development is unpredictable (Minore 1972). Excessive transpiration (Atlegrim and Sjoberg 1996), droughty soils (Minore 1972), over-exposure (Moola and Mallik 1998), vegetative competition (Minore 1972, Moola and Mallik 1998), mechanical damage (Moola and Mallik 1998), and scarification (Martin 1979) have all been cited as possible causes for poor growth and low fruit production of huckleberry shrubs on timber harvest units.

In a study of globe huckleberry, Martin (1979) found that post-logging treatments significantly affected fruit productivity. Harvest units on north- or east – facing slopes that had been broadcast burned tended to have higher fruit production than harvest units where debris was piled and burned. Scarification by piling machinery probably destroyed or damaged huckleberry rhizomes, preventing recovery. Huckleberry shrubs in scarified harvest units were clustered around the bases of trees and boulders where heavy machinery was unable to damage them.

In addition, Martin (1979) found that globe huckleberry populations that had been disturbed by either timber harvesting or fire within the last 50 years

tended to have clumped distributions while older populations had more even distributions. Martin inferred that disturbance destroys some huckleberry rhizomes, creating isolated clumps of huckleberry shrubs that, with time, grow back together.

Big huckleberry shrubs occasionally respond with vigorous growth and fruit production when overstory trees are killed. For example, when overstory trees were killed with a 2,4-D frill, the fruit production of big huckleberry shrubs located on a reforested huckleberry field increased significantly within two years (Minore et al. 1979). However, in plots where trees and shrubs were sprayed with the herbicide 2,4-D, big huckleberry shrubs recovered leaf cover after five years but produced less fruit than shrubs in frill treatment plots (Minore et al. 1979).

Because no huckleberry study to date has been conducted for the length of time required by big huckleberry to fully recover from disturbance, it is uncertain whether, once recovered, rejuvenated shrubs (shrubs with young shoots) produce more or less fruit than old undisturbed shrubs.

Conclusion

Although big huckleberry is a dominant species in forests of all successional stages, it only initiates sexual reproduction in early seral environments. Fruit production in big huckleberry may represent an opportunistic response to high resource conditions by a species otherwise adapted to extended periods in dark forest understories and reliant on vegetative reproduction. However, since big huckleberry shrubs can take several years to recover from the

disturbances that create open, early seral environments, disturbance gaps must remain open long enough for shrubs to recover and initiate fruit production. Historically, fires created gaps large enough to allow big huckleberry to fully recover before forest encroachment impinged on fruit production. It is not yet clear whether the forest gaps created by timber harvesting can substitute for fire. That big huckleberry response to timber harvesting is unpredictable suggests there may be key differences between fire and logging that affect big huckleberry vigor. And, though removing forest overstories without damaging huckleberry shrubs results in increased fruit productivity, it is uncertain how long big huckleberry shrubs may remain productive without asexual rejuvenation.

DISTURBANCE ECOLOGY OF THE HIGH CASCADES

The fruit production and growth of big huckleberry is strongly influenced by local disturbance regimes and forest succession. Fire has been the most important disturbance agent contributing to forest heterogeneity in the Cascade Range over the last millennia (Hemstrom and Franklin 1982, Dickman and Cook 1989). At higher elevations, where big huckleberry grows, fire is typically less frequent and more severe than in middle elevation forests (Agee et al. 1990). As a result, subalpine forests are predominantly composed of fire-sensitive, late successional species such as Pacific silver fir (*Abies amabilis*) and mountain hemlock (*Tsuga mertensiana*). However, scattered stands of fire-adapted species such as lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), and

noble fir (*Abies procera*) occur along the Cascade Crest in northern Oregon.

Interestingly, big huckleberry is found in both the fire-sensitive and fire-adapted forest types of the High Cascades (Franklin and Dyrness 1973, Hemstrom and Emmingham 1982, White et al. 1996).

There are many important differences relevant to fire ecology between lower elevation forests and the subalpine forests that big huckleberry inhabits. Subalpine forests tend to be cooler and wetter than lower elevation forests, and winter snow packs are usually deep and persistent (Franklin and Dyrness 1973). Potential fuels have high moisture content and are less likely to ignite or burn with high severity, so fires tend to be small and patchy (Agee et al. 1990). Cold temperatures slow decomposition rates, so large amounts of duff and woody debris accumulate on the forest floor. With increasing elevation, a greater proportion of site nitrogen is stored in the forest floor (Brockway et al. 1983). Fires may consume forest floors and thereby volatilize significant amounts of site nutrients (Hemstrom and Emmingham 1982). High elevations tend to have more lightning ignitions than lower elevation forests (Burke 1979). Dominant tree species in subalpine forests have thin bark and dense canopies. These factors combine to cause higher tree mortality after comparable fire events in subalpine forests than in adjacent Douglas-fir or ponderosa pine forests. Finally, regeneration after fire can be very slow (75-100+ years) in harsh subalpine environments, particularly on reburns and southern aspects (Burke 1979, Agee et al. 1990, Weisberg 1998).

Forest stand dynamics

In northern Oregon and southern Washington, big huckleberry grows in the Pacific silver fir zone and mountain hemlock zone forests that occupy the high-elevation slopes and the rolling plateaus and ridges of the Cascade Crest (Hemstrom and Emmingham 1982). Big huckleberry fruit production and growth is strongly influenced by forest succession; therefore understanding forest stand dynamics in these forest types may be key to understanding big huckleberry ecology.

The Pacific silver fir zone is located on the west slope of the Cascade Range between the western hemlock and mountain hemlock zones. In Oregon, Pacific silver fir zone forests have an elevational range of 1,000 to 1,500 meters (Franklin and Dyrness 1973). Winter snow packs may be as deep as 1-3 meters and persist into May, June, or July, but little precipitation falls during the summer months (Franklin and Dyrness 1973). Topography greatly influences annual precipitation values (Hemstrom and Emmingham 1982).

Forest composition within the Pacific silver fir zone is diverse and varies considerably with location and disturbance history. Pacific silver fir (*Abies amabilis*) is the climax species, but common associates include shade-tolerant western redcedar (*Thuja plicata*), subalpine fir (*Abies lasiocarpa*), Alaska cedar (*Chamaecyparis nootkatensis*), western hemlock (*Tsuga heterophylla*), and mountain hemlock (*T. mertensiana*) as well as early seral, shade-intolerant noble fir (*A. procera*), western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga*

menziesii), western larch (*Larix occidentalis*), lodgepole pine (*P. contorta*), and Engelmann spruce (*Picea engelmannii*) (Franklin and Dyrness 1973). Ericaceous shrubs and herbs (*Vaccinium*, *Gaultheria*, *Rhododendron*, *Chimaphila*, *Menziesia*, and *Pyrola*) are important components of forest understory vegetation in the Pacific silver fir zone (Franklin and Dyrness 1973). Beargrass (*Xeropyllum tenax*) is a widespread understory species in drier forests (Hemstrom and Franklin 1982).

After canopy-replacing disturbance in Pacific silver fir zone forests, conifer regeneration typically peaks within 20 years, but in unfavorable growing environments it may take as long as 150 years (Franklin and Dyrness 1973, Hemstrom and Franklin 1982). Noble fir and Douglas-fir are first to occupy recently disturbed sites (Franklin and Dyrness 1973). Western hemlock or mountain hemlock may invade mesic, recently disturbed sites and mature slowly under Douglas-fir or noble fir canopies (Franklin and Dyrness 1973). Pacific silver fir is occasionally a pioneer species when seed source is available, but more often it is a late-comer to the understory of mature forests (Franklin and Dyrness 1973). Pacific silver fir is fire-sensitive, extremely shade-tolerant, and slow-growing (Oliver and Larson 1996). Pacific silver fir stands have dense canopies under which few species can regenerate, and in 400-500+ years they gradually replace early seral stands (Franklin and Dyrness 1973).

Dominant understory vegetation in the Pacific silver fir zone remains roughly the same throughout the stages of forest succession (Franklin and Dyrness

1973). In particular, big huckleberry, *Sorbus* species, and beargrass persist in all successional environments (Franklin and Dyrness 1973).

The mountain hemlock zone is the highest elevation forest zone of the Oregon Cascade Range and the coldest and wettest forest zone in the Pacific Northwest (Franklin and Dyrness 1973). Winter snow pack in the mountain hemlock zone may be as deep as 7.5 meters and last 6 to 8 months (Franklin and Dyrness 1973). The mountain hemlock zone begins on the west slope where the Pacific silver fir zone leaves off (1,300-1,500 meters), extends over the Cascade Crest, and continues down the east slope a variable distance (Franklin and Dyrness 1973). On the eastern slope, in the rain shadow of the Cascade Crest, mountain hemlock zone forests are gradually replaced by subalpine fir zone forests or by dry, interior grand fir-white fir forest associations (Brockway et al. 1983, Franklin and Dyrness 1973).

Forest composition in mountain hemlock zone forests is highly variable depending on location and disturbance history. Mountain hemlock tends to dominate old-growth stands (> 200 years), but both mature and old-growth stands often include Pacific silver fir (minor/major climax species), white fir (*A. concolor*), and Alaska cedar (Franklin and Dyrness 1973). Lodgepole pine, subalpine fir, noble fir, western white pine, and western larch are common in dry, early seral forests, while mesic, recently disturbed sites may initially support Pacific silver fir or mountain hemlock (Franklin and Dyrness 1973). Large burns may be quickly invaded by lodgepole pine (Franklin and Dyrness 1973).

Understory vegetation in mountain hemlock zone forests is largely composed of members of the *Ericaceae*, *Rosaceae*, and *Compositae* (Franklin and Dyrness 1973). In particular, big huckleberry and beargrass, both fire-resistant species, are widespread under mountain hemlock zone forests in the northern Oregon and southern Washington Cascades (Franklin and Dyrness 1973, Hemstrom and Emmingham 1982, Brockway et al. 1983).

Stand-replacing fires raged during the late 1800s and early 1900s, burning considerable acreage along the Cascade Crest (Burke 1979, Hemstrom and Franklin 1982, Morrison and Swanson 1990, Weisberg 1998) in both mountain hemlock and Pacific silver fir zone forests (Franklin and Dyrness 1973). Many of these burns supported persistent shrub fields dominated by big huckleberry, beargrass, *Sorbus* species, and *Spirea* species (White et al. 1996). Conifer regeneration after fire in the cold subalpine climates can be very slow (Franklin and Dyrness 1973). Gradually, burns were colonized by lodgepole pine or subalpine fir. The resulting early seral forests are extensive and retain understories of big huckleberry and beargrass (Franklin and Dyrness 1973).

Lodgepole pine stands are an interesting ecological phenomenon in the largely fire-sensitive forests of the Cascade Crest. In the Rocky Mountains, lodgepole pine stands develop as a direct result of repeated fire (Lotan et al 1984). Repeated surface fires increase the proportion of lodgepole pine in relation to fire-sensitive, late-successional conifers (Lotan et al. 1984). After stand-replacing fires, lodgepole pine may form pure stands when adequate seed source is available

(Lotan et al. 1984). Some lodgepole pine ecotypes have serotinous cones that are stored in the live canopy until fire triggers a mass release of seeds. Cascade lodgepole pines do not have serotinous cones but do have long-lived, widely dispersed seed (Dickman and Cook 1989). Lodgepole seedling establishment is best on fire-exposed mineral soils and in full sun (Lotan et al. 1984).

Lodgepole pine is adapted to both frequent crown fires (every 50-200 years) and frequent low-severity surface fires (every 25-50 years) (Bork 1984). Longer fire return intervals are associated with more severe (canopy replacing) fire behavior. Frequent surface fires may thin the stand without doing serious damage, because surface fuels are generally not very flammable and trees have fire-resistant bark (Lotan et al. 1984). Fire-opened stands may have low fuel loads but typically have increased flammability due to exposure to drying winds and solar radiation (Lotan et al. 1984). Young lodgepole pine stands are self-pruning, open, and not as prone to crown fires as dense-canopied late-successional species (Lotan et al. 1984). However, as stands mature and senesce (80+ years) they become increasingly susceptible to crown fires due to the development of ladder fuels and accumulations of standing dead trees (Lotan et al. 1984). Fuel loads tend to be higher after stand replacing fires, and lodgepole pine regeneration may be very dense and susceptible to suppression mortality (Lotan et al. 1984). In the absence of fire, shade-tolerant conifers usually replace lodgepole pine after 80-200 years (Lotan et al. 1984).

Fire regimes of the High Cascades

Creation and maintenance of historic huckleberry fields were linked with past fire regimes. Fire regimes describe fire frequency, severity, and size in particular forest environments or locations. Fire frequency is the average fire free interval between the last recorded fire at a site and the present (or the beginning of fire suppression) (Morrison and Swanson 1990). The mean fire return interval estimates the frequency of site fire during a particular time interval. Fires do not move evenly across the landscape; fires are more likely to reburn particular areas and avoid others due to topographic differences. Fire frequency estimates are conservative and biased toward longer fire rotations (Morrison and Swanson 1990).

Fire regimes are broken into three categories: low-severity, moderate-severity, and high-severity. Low-severity fire regimes have frequent, low-severity surface fires of small extent and may result in forests with multiple age and size classes (Agee et al. 1990). High-severity fire regimes have infrequent, high-severity fires that burn extensive area and kill most canopy trees. Subalpine forests have, in general, high-severity fire regimes (Agee et al. 1990). Forests with moderate-severity fire regimes have a mixture of both frequent low- to moderate-severity fires and infrequent canopy-replacing fires. Dry subalpine forests and subalpine forests adjacent to drier montane forests may have moderate severity regimes (Agee et al. 1990).

Fire severity, the magnitude of fire-caused tree mortality, has a strong influence on subsequent forest regeneration (Weisberg 1998). Fire creates mineral

seedbeds and canopy gaps that allow the regeneration of shade-intolerant conifers (or shade-tolerant conifers if fire severity is low) (Krusemark et al. 1996). Conifers that survive fire disturbance (residuals) are important seed sources and influence recolonization and regeneration of disturbance gaps. Fire severity is determined by relative canopy mortality. High-severity fires consume over 70% of the mature canopy. Moderate-severity fires consume between 30-70% of the mature canopy and most understory trees. Low-severity fires primarily consume regenerating conifers and cause less than 30% mature canopy mortality (Agee et al. 1990, Morrison and Swanson 1990).

Fire regimes of Cascade Range forests have been and continue to be influenced by regional climate, topography, forest development, and human activities. Infrequent, large-scale wildfires have swept through subalpine forests when climatic conditions have allowed fuel accumulations to dry (Hemstrom and Franklin 1982, Cwynar 1987, Agee et al. 1990, Morrison and Swanson 1990). Fire climate for the Cascade Range has three separate components. First, an extended period of summer drought primes fuels for combustion. Second, easterly winds dry fuels and fan flames. Easterly wind events occur periodically in the Pacific Northwest when a low-pressure cell develops over the Pacific Ocean and a high-pressure ridge settles over eastern Oregon and Washington. Easterly wind events tend to occur in late summer/early fall when fuel moisture content is low. Third, an ignition source is required (Weisberg 1998). Lightning storms in the Cascade Range occur with sufficient frequency to ignite most wildfires (Weisberg 1998).

citing Teensma 1987). In general, cold, wet climatic periods and mesic environments and aspects are associated with infrequent, high-severity fires; warm and droughty climatic periods and xeric environments and aspects are associated with frequent, low-severity fires (Hemstrom and Franklin 1982, Agee et al. 1990, Weisberg 1998).

Topography influences the spatial variability of fire regimes. In general, steep slopes and high elevations tend to be associated with long fire return intervals (Weisberg 1998). However, fires typically burn upslope, therefore ridgelines and upper slopes (high elevations) in some locations may burn more frequently than lower slopes and basins (Hemstrom and Franklin 1982, Agee et al. 1990, Krusemark et al. 1996). In addition, ridges and high elevations are more vulnerable to lightning strike than lower slopes (Burke 1979, Morrison and Swanson 1990). Steep slopes may burn with high-severity due to preheating of fuels and exposure to solar radiation and convective winds (Weisberg 1998). Slopes exposed to dry easterly winds may have shorter fire return intervals than protected areas (Morrison and Swanson 1990, Weisberg 1998). The extremely variable nature of mountain terrain creates fires events with high spatial variability (Burke 1979). Nevertheless, topography may have less influence on fire frequency and severity than weather and little effect on catastrophic fires (Weisberg 1998).

Forest structure and composition influence fire behavior and post-fire stand composition (Weisberg 1998). Moderate and high severity fires allow the establishment of cohorts of seral conifers such as lodgepole pine, Douglas-fir, and

noble fir (Hemstrom and Franklin 1987, Krusemark et al. 1996). Recruitment generally continues for 30-50 years after fire disturbance (Agee et al. 1990). Fuel loads and proportions of seral (fire-adapted) and climax (fire-sensitive) species change significantly with repeated fire events and during post-fire forest succession (Lotan et al. 1984, Weisberg 1998). Frequent fire favors the dominance of early seral, fire-adapted species such as lodgepole pine. However, time since the last high-severity fire (stand age) is a better indicator of post-fire stand composition and structure than fire frequency, except in sites dominated by shade-tolerant conifers (Weisberg 1998). Successional processes, in the absence of high- and moderate-severity fires, lead to the canopy replacement of early-seral, shade-intolerant species by shade-tolerant climax species.

Particular fire regimes may be associated with forest community associations or canopy compositions. For example, canopy dominance by seral species such as lodgepole pine is associated with shorter fire return intervals (<100 years), whereas canopy dominance by late successional species such as Pacific silver fir is indicative of longer fire return intervals (100-200+ years) (Cwynar 1987, Agee et al. 1990). Fires, ignited in lower elevation forest associations, may be extinguished upon reaching adjacent subalpine forest types (Krusemark et al. 1996). However, Weisberg (1998) found that forest zones did not explain the spatial patterning of fires very well. Weather and topography had more influence on fire regimes than forest zone. In addition, extensive catastrophic fires have

periodically swept through Cascade Range forests without reference to forest type (Agee et al. 1990).

Subalpine forests have burnt with either lesser or greater frequency and severity than middle elevation forests, depending on topographical location and weather (Morrison and Swanson 1990, Krusemark et al. 1996, Weisberg 1998). In theory, subalpine forests all have high-severity fire regimes. Climates keep fuels moist; therefore, fire frequencies are low. When fuel accumulations dry during extreme fire weather, subalpine forests are vulnerable to high severity fires. In the Cascade Range, however, subalpine fire regimes include severe-, moderate-, and low-severity regimes (Weisberg 1998). Subalpine fire regimes have considerable spatial variability (Krusemark et al. 1996). Moderate- and low-severity fire regimes may be associated with site vulnerability to fire spread from lower elevations or drier forest associations (Krusemark et al. 1996), or they may be associated with high ignition rates, either from lightning strikes (ridges) or human activities. Alternatively, less severe regimes may be associated with early seral forest associations or exposure to easterly winds (Agee et al. 1990, Krusemark et al. 1996).

Human influences on Cascade Range fire regimes

Pre-settlement period

Humans have modified natural fire regimes in the Pacific Northwest for thousands of years. Humans have been an important ignition source in many forest community types. American Indians used fire to maintain certain forested areas in early seral conditions for hunting, harvesting, safety, and ease of transportation (Zybach 1993). On either side of the Cascade Range intentionally set fires and/or abandoned campfires may have spread out of control, burning up slope from low elevation to high elevation forests (Burke 1979, Zybach 1993, Bork 1984). Upon reaching cold, moist subalpine forests, fires probably slowed, cooled, and burnt out (Agee et al. 1990, Krusemark et al. 1996). Alternatively, during periods of extreme fire weather, subalpine forests may have burnt with greater severity than adjacent middle elevation forests (Agee et al. 1990).

In particular, ethnographic sources document fire maintenance of subalpine big huckleberry shrub fields by Columbia Basin Indian bands (Burke 1979, French 1999). Numerous big huckleberry shrub fields, created by large stand replacing fires, were once located in subalpine forests around Mt. Hood and Mt. Jefferson in Oregon (Murdock 1938, French 1961, Minor and Pecor 1977) and Mt. Adams and Mt. St. Helens in southern Washington (Murdock 1938, French 1961, Hunn 1982, Hunn with Selan 1990). Huckleberries have been a highly valued food source for Columbia Basin Indian bands for countless centuries. Sahaptin bands from south of

the Columbia, except the John Day, (French 1961), the Wasco from the southern shore of the Columbia River (French 1961), and the Molala of the northern Cascades (Minor and Pecor 1977) all harvested from the huckleberry fields of the northern Oregon Cascades, while Sahaptin bands from north and east of the Columbia along with the John Day, the Klickitat, and the Wishram of the northern shore of the Columbia harvested huckleberry fields in southern Washington (French 1961).

As detailed previously, big huckleberry shrubs fruit most abundantly in early seral environments, and productivity declines with canopy closure (Minore and Dubrasich 1978). Prior to about 1904 (Fisher 1997), Columbia Basin Indian bands maintained huckleberry fields in early seral conditions by the periodic ignition of low intensity burns (French 1999, Mack 2001). Although assigning responsibility for the maintenance of Cascade huckleberry fields is difficult today, ethnographic sources indicate that bands now associated with the Warm Springs Indian Reservation (Warm Springs Sahaptins and Wasco upper Chinookan speakers) maintained huckleberry fields in northern Oregon¹ and bands now associated with the Yakima Indian Reservation (Yakima and Klickitat Sahaptins and Wishram upper Chinookan speakers) maintained fields in southern Washington (Fisher 1997). Maintenance fires burned relatively small areas, only occasionally spreading into adjacent older forest stands (French 1999) and were lit in late

¹ Warm Springs ceremonial huckleberry pickers, interviews. 1998, 1999, 2000. Warm Springs Museum archives. Audio cassette recordings.

summer and early fall (Mack 2001). Although individual huckleberry patches probably took several years to recover from fire disturbance, a cyclic pattern of burning over a large area may have insured an abundance of productive huckleberry fields across the landscape.

Mack (2001) uncovered valuable information about American Indian burning practices in early fire records from the Mt. Rainier Forest Reserve (now Gifford Pinchot National Forest in southern Washington), providing evidence that Indians were burning huckleberry fields into the first decade of the twentieth century. The records indicate that American Indians were setting fires in areas with little or no tree cover (between 0 and 15 million board feet/acre) within or adjacent to pre-existing larger burns. These fires burned anywhere from 0.1 to 2,300 hectares, though most were smaller than four hectares, and were most often set in mid-September when rain or snow could be expected within a few weeks time.

In another study, fuel load reconstructions based on early photographs and historical data suggested a fire-return interval of 20 years within huckleberry fields on the Gifford Pinchot National Forest.² Together, these studies from southern Washington suggest a culturally maintained low-severity fire regime within big huckleberry fields originally established by stand-replacing fires. Frequent low-intensity fires may also have marked the disturbance regime of big huckleberry fields in northern Oregon. The Gifford Pinchot National Forest is just north of the

² Martinez J. No date. Huckleberries: a renewable resource. An historical perspective with management implications. Report prepared by the Washington Institute for the Gifford Pinchot National Forest. Available from Trout Lake (WA): Mt. Adams Ranger District, Gifford Pinchot National Forest.

Mt. Hood National Forest, and American Indian bands that harvest huckleberries from the Gifford Pinchot have close cultural ties with bands of the Warm Springs Indian Reservation (French 1961, Hunn 1982, Boyd 1996). Patterns of indigenous burning inferred from early fire records from the Gifford Pinchot may be similar to those practiced on what is now the Mt. Hood National Forest and Warm Springs Indian Reservation.

Huckleberry field burning may have been accomplished by simply leaving huckleberry drying logs burning after the families packed up and left (French 1999). According to contemporary Warm Springs ceremonial huckleberry pickers,

“[T]hey used to leave their campfires going, pile more wood on it, at least that’s what my Ulla used to say, just pile more wood on it then leave. And if it burns, she used to say it’ll burn itself out, it can’t burn far. She was usually right, the smoke brings clouds and the clouds bring rain, that’s the way she used to put it.”¹

Alternatively, men may have set huckleberry fields on fire with burning logs or brush.¹

Men and/or women responsible for burning huckleberry fields were knowledgeable about weather and fuels and burned when rains were expected (French 1999). If fires got away, American Indian people would call rain to extinguish the blaze.¹ Elder Warm Springs ceremonial huckleberry pickers say rain-calling no longer works because there are too many outsiders around.

Contact with European and American explorers and fur trappers in the late 18th and early 19th centuries lead to catastrophic disease epidemics in Columbia Basin Indian populations. Therefore, American Indian influences on Pacific

Northwest fire regimes are assumed to have declined precipitously during the early part of the 19th century (Burke 1979, Morrison and Swanson 1990).

Based on interpretation of natural fire rotation data from different time periods, fire ecologists have concluded that American Indian populations had little impact on subalpine fire regimes even before the disease epidemics (Morrison and Swanson 1990, Weisberg 1998). However, dendrochronological methods are unable to differentiate between anthropogenic and lightning ignition (Hemstrom and Franklin 1982, Agee et al. 1990). In addition, fire history studies are more likely to find evidence of large, stand-replacing fires than of repeated, low-severity fires such as maintenance burns (Hemstrom and Franklin 1982, Krusemark et al. 1996), especially if those fires occurred in areas with little or no tree cover. Catastrophic fires tend to be associated with large-scale climatic fluctuations regardless of ignition source (Cwynar 1987, Agee et al. 1990, Weisberg 1998). American Indians may have significantly increased the frequency of low severity fires, particularly during cold, wet climatic periods, without greatly impacting the frequency of high-severity events or the dendrochronological record.

Settlement period

Burke (1979) studied Euro-American settlement effects on recent Cascade Range fire regimes through the analysis of archival data. European and American fur trappers began arriving in the Pacific Northwest during the first half of the 19th century. Settlers began to flood into the Willamette Valley and Puget Lowlands

around 1840, but an overland route through the Cascade Range (the Barlow Road just south of Mt. Hood, Oregon) was not constructed until the early 1850s. During the 1860s, several more roads were cut through the Cascades. Forest clearing for early wagon road construction was achieved mainly through ignition of forest fires. In addition, forests of the Cascade foothills were burned throughout the settlement period (1840-1910) to make way for agricultural development. Some of these fires may have escaped to middle and high elevation forests as well.

By the 1880s, sheep and cattle were grazing in Cascade Range forests, hundreds of miners were combing the mountains for gold, settlers and Indians alike were hunting and berry picking in high elevation forests, and loggers were leaving hazardous slash in lower elevation harvest units. Increased use of Cascade Range environments led to many accidental and intentional ignitions and a very high fire frequency during the latter half of the 19th century. Additionally, sheepherders intentionally and repeatedly burned subalpine meadows and forests to increase cover of browse species and facilitate flock movement. Many of these burns had extremely poor conifer regeneration and supported extensive populations of snowbrush (*Ceanothus velutinus*). President Grover Cleveland set aside the Cascade Forest Reserve under the Forest Reserve System in 1893, but sheep herding continued. Eventually, conflicts between sheepherders and conservationists led to grazing regulations and cessation of intentional burning in the High Cascades in the first decade of the 20th century (Burke 1979). After 1900, ranger presence

increased on the forest reserve (Mack 2001), and American Indian fires were no longer permitted.

Fires raged in the Cascades and throughout the Pacific Northwest between 1830-1910, and fire frequency was very high (Hemstrom and Franklin 1982, Morrison and Swanson 1990, Weisberg 1998). Fire size was variable; numerous small fires burned, as did several huge wildfires (Burke 1979, Hemstrom and Franklin 1982, Morrison and Swanson 1990). Increased fire frequency and size during this period was related to both climatic and human influences. The 19th century differed from previous centuries in having a high occurrence of repeat burns (Hemstrom and Franklin 1982, Weisberg 1998).

Fire suppression

Raging fires and stifling smoke eventually raised public concern about the waste and risks of wildfire. The era of modern fire suppression dawned in 1911 with the organization of cooperative state and federal forest protection agencies. Private timberland owners also joined in fire prevention efforts. Early management activities of the Forest Service (1905-1945) were directed at fire prevention and suppression. Management activities included building fire lookouts, blazing trails and firebreaks, and planting trees on burned over slopes. Areas burned repeatedly by sheepherders in the late 1800s were targeted for replanting efforts in particular. In the 1930s, the Civilian Conservation Corp built numerous roads, trails, fire

breaks, and lookouts; lay miles of telephone line; fell countless snags; and fought fires throughout the Cascade Range (Burke 1979).

Fire suppression techniques became increasingly sophisticated and effective during the 20th century (Burke 1979). As a result, fire has not been a significant disturbance in Cascade Range forests for the last 90 years. Though numerous fires have been accidentally ignited along roadways, in campgrounds, and in timber harvest units, few have been allowed to burn out of control (Burke 1979). Fire return intervals in the Cascade Range are lower for the 20th century than for any other within the last 500 years (Morrison and Swanson 1990, Weisberg 1998, Agee et al. 1990). The 20th century fire regime has been characterized by a low frequency of small, low-severity events (Weisberg 1998).

Because the abundance and productivity of big huckleberry fields in the Cascade Range is directly influenced by the occurrence and frequency of stand replacing and low-severity fires, fire suppression has led to significant declines in big huckleberry fruit production across the landscape. In 1970, there was an estimated 65 hectares of productive huckleberry fields in Oregon and Washington (Nelson 1970 as cited by Minore 1972). These huckleberry fields were initiated by stand-replacing fires which created open, early seral conditions above 900 meters elevation (Minore 1972, USDA Forest Service 1995). With time and fire suppression, the natural processes of forest succession have led to the encroachment of trees into once productive huckleberry fields, and fruit yields have declined steadily as a result (Minore 1972). Huckleberry fields that once produced

abundant crops of delicious fruit now produce no fruit at all, though big huckleberry shrubs are usually still present. For example, the Twin Buttes field on the Gifford Pinchot shrank from 3,200 hectares (1938) to 1,000 hectares (1978) in forty years due to forest succession. American Indians have harvested this area since before 1853, and its ongoing health and productivity was due to the periodic ignition of maintenance fires (Minore et al. 1979). In 1972, Don Minore, Forest Service ecologist, warned that big huckleberry fields would continue to disappear if encroaching vegetation was not controlled, and today there are very few open, productive huckleberry patches remaining of the once abundant huckleberry fields of the early 20th century.

Timber harvesting and development

Prosperity and economic growth in the 1950s spurred development of a large-scale timber industry in the Cascade Range on both private and public lands (Burke 1979), and, though not as extensively harvested as lower elevation forests, subalpine conifer stands have been harvested since the 1950s and 1960s (Halverson and Emmingham 1982). Initially, subalpine forest stands were clearcut and broadcast burned, but problems with poor conifer regeneration led to the adoption of selective harvesting practices, particularly shelterwood systems, in the 1980s (Halverson and Emmingham 1982). Shelterwood harvests leave stands lightly stocked with seed trees, and slash is piled and burned rather than broadcast burned (Halverson and Emmingham 1982). In addition, subalpine forests of the Cascades

are occasionally cleared for winter recreation and utility right-of-ways (Davis 2000 pers. comm.). The frequency of severe (i.e. stand replacing) disturbance may have actually been higher during the last 50 years than during past fire regimes (Cwynar 1987). Though huckleberry fields are periodically created by timber harvesting, the development of these fields is unpredictable (Minore 1972).

Conclusion

Subalpine fire regimes in the Cascades have considerable spatial and temporal variability. Some of this variability is explained by long-term fluctuations in regional climate. Other aspects are explained by the extreme topographical and environmental heterogeneity of the High Cascades. Still other features of subalpine fire regimes are explained by shifting patterns of human activity in the region.

In general, Cascade Range subalpine forests have a high-severity fire regime: infrequent high-severity fires of great extent occurring during periods of extreme fire weather. Drier, warmer, more exposed environments may have less severe fire regimes, i.e. more frequent fire of low- to moderate-severity. Proximity to drier forest associations and to centers of human activity may also shift fire regimes toward lesser severities. However, large catastrophic fires are a dominant feature of all montane and subalpine fire regimes in the Cascade Range; therefore, low-severity disturbance regimes (frequent low-severity disturbances with only rare occurrence of high-severity disturbance) are uncommon except in areas managed by humans (huckleberry fields, pasture meadows) or heavily utilized by humans

(transportation routes, utility throughways, recreation areas). Huckleberry fields, prior to fire suppression, may be conceptualized as islands of low-severity fire regimes within a matrix of forest characterized by high-severity fire-regimes.

Modern fire suppression has, in general, shifted Cascade Range fire regimes toward higher severities. Stand developmental processes, when left unchecked by disturbance, lead to increases in fire-sensitive species abundance. As forests are increasingly dominated by shade-tolerant species, they burn with lesser frequency and become more vulnerable to high-severity crown fires under extreme weather conditions. Even the fairly young forest stands occupying historic huckleberry fields would probably burn with high severity if ignited today.

Timber harvesting has maintained a patchy distribution of early seral conditions within a matrix of later successional forests. However, fire and logging disturbance processes are extremely different. Timber harvesting generally involves mass removal of site biomass, significant scarification of the forest floor, extremely hot slash fires, and intentional manipulation of post-logging plant communities. In the short-term, logging disturbance appears to favor weedy annuals and biennials, certain fire-adapted shrubs, and early seral and commercially valuable tree species. Long-term ecological impacts of logging disturbance regimes are unknown.

It is also difficult to anticipate potential interactions between fire and logging disturbance regimes. Logging may reduce or increase fuel loads. Harvest units and logging roads may act as firebreaks. Dispersed logging activity may expose mature and old-growth stands to solar radiation and desiccating winds,

increasing their flammability. It is, however, likely that fire will again be a key disturbance agent in Cascade Range subalpine forests in the future.

CHAPTER 3. BIG HUCKLEBERRY (*Vaccinium membranaceum* Dougl.) FRUIT PRODUCTION AND SUCCESSIONAL ECOLOGY, MT. HOOD NATIONAL FOREST AND WARM SPRINGS INDIAN RESERVATION, OREGON.

INTRODUCTION

*“When it was open, before the forest grew back, there was a lot of huckleberries on those slopes. Now, there is trees and not huckleberries. The old time Indians recognized huckleberries as a viable crop of the mountains. They did things to preserve that crop. Basically it was burning and keeping those trees out.”*¹

Big huckleberry (*Vaccinium membranaceum*) is a common understory shrub in subalpine forests of the Cascade Range in Oregon. The delicious purple-black fruits of big huckleberry are an important cultural food and have long been harvested for winter storage by members of the Confederated Tribes of the Warm Springs. Huckleberry fields—open areas with an abundance of fruiting shrubs—have historically been associated with fire-disturbed environments (Minore 1972). Prior to the second half of the twentieth century, members of the Confederated Tribes of the Warm Springs harvested huckleberries from forest burns located on

¹ Warm Springs ceremonial huckleberry pickers, interviews. 1998, 1999, 2000. Warm Springs Museum archives. Audio cassette recordings. *Excerpts from recent interviews with Warm Springs ceremonial huckleberry pickers were graciously shared with us during the course of this study. Quotes from excerpted interviews are included in the text. Interviewees preferred to remain anonymous.*

their ceded and accustomed-use lands in the Oregon Cascade Range (managed by the Mt. Hood National Forest) and the Warm Springs Indian Reservation.

Subalpine forests of the Cascade Range are characterized by high-severity fire regimes with fire-return intervals of centuries and the occurrence of huge, stand-replacing fires during periods of particularly favorable climatic conditions (Agee et al. 1990). High-severity fire regimes generally result in the dominance of late-successional, fire-sensitive forest taxa susceptible to stand-replacing events (Agee et al. 1990). Although infrequent, wildfires burned unchecked in the High Cascades prior to the implementation of fire suppression policies after 1910 (Burke 1979). Historical and dendrochronological evidence indicates that climatic conditions and ignition sources converged in the 1800s, resulting in a century of intense fires throughout the Cascade Range (Burke 1979, Hemstrom and Franklin 1982, Morrison and Swanson 1990, Weisberg 1998). Several huge, stand-replacing fires burned in the northern Oregon Cascade Range during the second half of the 19th century (Burke 1979, USDA Forest Service 1995). By the turn of the 20th century, as much as 60% of some townships within the Cascade Forest Reserve (now the Mt. Hood National Forest) consisted of burnt-over land (USDA Forest Service 1995). Large wildfires continued to be common along the crest of the Cascade Range into the early twentieth century (USDA Forest Service 1995).

Shrub communities dominated by big huckleberry (*Vaccinium membranaceum*) frequently developed on the high elevation burns and were a

common component of the High Cascades landscape until the middle of the 20th century (USDA Forest Service 1995). Big huckleberry shrubs survive fire disturbance by developing clonal shoots from underground rhizomes. Fire-initiated huckleberry fields of the Cascade Range were famous for producing abundant crops of berries in late summer and early fall, and the huckleberry harvest was once an anticipated event in the seasonal round of fishing and gathering of Warm Springs Indians (Hunn with Selan 1990, Boyd 1996).

In the 1930 and 1940s, huckleberry fields associated with burns were numerous and extensive. *“No matter where you went you found berries.”*¹ These fields covered tens to thousands of hectares with huckleberry patches of variable size and productivity located within them. Families were able to harvest tens of liters of huckleberries in a single day, and individual huckleberry fields could be productively harvested for several days or weeks.

*“[In a day, we would pick] easily ten gallons... I would say those big baskets were at least five gallons. If there were two of us, we could very easily fill the two.”*¹

*“I used to pick about four baskets, two in the morning and two in the afternoon... They were the gallon baskets.”*¹

*“I had a five gallon basket and a small one, must have been almost eight gallons I picked in one day.”*¹

*“We picked about fifty gallons in about four days time.”*¹

“...[G]randma would take us up there for nearly three or four weeks. One time we were up there almost until the end of November... and grandma still didn't want to come home because there was a lot of berries.”¹

Prior to federal management of Cascade Range forests, Columbia Basin Indians periodically set low-intensity fires in order to prevent forest development on huckleberry fields (French 1999). Recent interviews with Warm Springs ceremonial huckleberry pickers¹ indicate that maintenance fires were set in late summer or early fall when rains were expected, that campfires may have been stoked and left to burn or, alternatively, fires may have been set with burning brush or logs in specific locations, and that fires generally did not burn far.

Early fire records from the Mt. Rainier Forest Reserve (now the Gifford Pinchot National Forest) provide further insights into the traditional fire management of Cascade Range huckleberry fields (Mack 2001). These records indicate that Yakima Indians, who have close cultural ties with bands of the Warm Springs Indian Reservation (French 1961, Hunn 1982, Boyd 1996), repeatedly set fires in lightly timbered areas within or next to existing burns that supported productive huckleberry fields. In another study², fuel load reconstructions based on early photographs and historical data suggested a fire-return interval of about 20 years within huckleberry fields on the Gifford Pinchot. Together, these studies

² Martinez J. No date. Huckleberries: a renewable resource. An historical perspective with management implications. Report prepared by the Washington Institute for the Gifford Pinchot National Forest. Available from Trout Lake (WA): Mt. Adams Ranger District, Gifford Pinchot National Forest.

suggest a culturally maintained regime of frequent low-severity fires within huckleberry fields originally established by stand-replacing wildfires.

Fire suppression policies enacted by the US Forest Service have influenced big huckleberry disturbance regimes since about 1910 (Burke 1979). American Indian maintenance fires were prohibited, and forest wildfires were fought aggressively (Fisher 1997). Over the last 90 years, conifers have established in traditional huckleberry fields, and dense stands of lodgepole pine (*Pinus contorta*) and other tree taxa have developed (Minore et al. 1979). As forests encroach onto huckleberry fields, fruit productivity wanes (Minore et al. 1979). In the words of one ceremonial huckleberry picker, "*as the trees came in, the huckleberries go out.*"¹ The old fire-initiated huckleberry fields of the Oregon Cascade Range are now largely reforested and unproductive.

Disturbance regimes of the Cascade Range have changed over the last century with machinery replacing fire as the principal disturbance agent in subalpine forests. Road building and forest clearing for fire lookouts began in earnest in the 1930s (Burke 1979), but harvesting of subalpine conifer stands did not start until the 1950s and 1960s (Halverson and Emmingham 1982). Initially, subalpine forests were clearcut and broadcast burned, but poor conifer regeneration led to adoption of selective harvesting practices, particularly shelterwood systems, in the 1980s (Halverson and Emmingham 1982). Shelterwood harvests leave stands lightly stocked with seed trees, and slash is piled and burned rather than broadcast

burned. In addition, subalpine forests of the Cascade Range are occasionally cleared for winter recreation and utility rights-of-way. Contemporary huckleberry pickers now must go to disturbance gaps created by timber harvesting, forest clearing, and road building to find fruiting huckleberry shrubs.

Warm Springs huckleberry pickers are concerned about the loss of productive huckleberry fields to forest encroachment and the relative lack of new huckleberry field establishment occurring across the Cascade Range landscape. In this study, we sought to address these concerns by:

- 1) comparing the characteristics of huckleberry fields located on old burns and in forest gaps created by mechanical disturbances,
- 2) examining possible limitations to sexual reproduction of big huckleberry in forested environments, and
- 3) describing relationships between big huckleberry fruit production, time, and disturbance.

Traditional Ecological Knowledge (TEK) about big huckleberry provided by Warm Springs ceremonial huckleberry pickers contributed significantly to the development and completion of this study. Ceremonial huckleberry pickers are women who were or are responsible for collecting berries for the annual first fruits ceremony in honor of big huckleberry and for monitoring the huckleberry resource. Many the 47 women interviewed are tribal elders; some have harvested huckleberries on the Mt. Hood National Forest and Warm Springs Indian Reservation for as long as 70 years. The traditional knowledge of ceremonial

huckleberry pickers guided problem identification and site selection, suggested hypotheses for declines in fruit productivity in reforested huckleberry fields, and provided descriptive information about past environments and traditional management practices.

METHODS

Study sites

The study was conducted in the Cascade Range, northwestern Oregon, south of Mt. Hood and north of Mt. Jefferson (T 3-6 S, R 7-10 E). Study sites were in Pacific silver fir (*Abies amabilis*) and mountain hemlock (*Tsuga mertensiana*) forest zones (Franklin and Dyrness 1973) and ranged in elevation between 1,200 and 1,600 meters. Summers in the study area are short and cool; winters are long and cold. Snow packs linger late into the spring (Franklin and Dyrness 1973). Soils consist of medium-textured glacial till of variable depth overlaying hard andesites and basalts of volcanic origin (Howes 1979).

Study sites were huckleberry fields selected from lists compiled from interviews with Warm Springs ceremonial huckleberry pickers¹ and from communications with Mt. Hood Forest Service personnel (Davis, pers.com. 2000). Huckleberry fields are defined as areas that have supported abundant populations of productive big huckleberry shrubs within the last 100 years and are distinct forest

stands. Sites were selected to represent a range of initial disturbance types (fire, clearcut timber harvest, shelterwood timber harvest, forest clearing) and stand ages (3-150+ years old). Twenty-one sites were located on the Mt. Hood National Forest and two on the Warm Springs Indian Reservation.

Data collection

In summer and fall 2000, twenty-three sites were sampled. Within each site, data were collected from four randomly placed, one-dimensional 50-m long sampling transects. In two sites, data were collected from two and three sampling transects respectively. Eighty-nine total transects were sampled.

To estimate overstory canopy cover, hemispherical canopy photographs were taken at the mid-point of each sampling transect from a leveled position one meter above the ground. Photos were later analyzed using CANOPY© software, as described by Rich (1989), and the uncorrected, indirect site factor (ISF) was used as an estimate of percent canopy cover $[(1-\text{ISF}) \times 100 = \text{canopy cover.}]$ Transect values were averaged for estimates of site-level overstory canopy cover.

Stand density and density of saplings taller than 10 cm were estimated by species within 2 x 10-m belt transects. Belt transects were centered lengthwise between the 25-m and 35-m points of each one-dimensional sampling transect and extended one meter to either side. Belt transect values were averaged for site-level

estimates of stand density and sapling density, expressed as stems/ha. The proportion of total stand density occupied by individual species was calculated.

Total basal area and basal area by genus were estimated by taking basal area counts by genus every ten meters along sampling transects (six counts/transect) with a JIM-GEM® Cruz-all set at Basal Area Factor (BAF) 5. At each reading, counts of individual genera and total counts of all genera were multiplied by five. Values were averaged to estimate transect basal area by genus and total transect basal area. Transect values were averaged to estimate huckleberry field basal area and expressed as m^2/ha . The proportions of total basal area occupied by individual conifer genera were calculated.

To estimate huckleberry fruit production, huckleberry shrubs within 1-m^2 quadrats were assigned to one of six fruit production classes (Table 3.1). Two quadrats were nested within each 20-m^2 belt transect; eight total quadrats were sampled in each site. Assigned fruit production class values from the two quadrats in each belt transect were averaged for estimates of transect fruit production class. Transect estimates were then averaged for site-level estimates of huckleberry fruit production class.

Table 3.1 Definitions of big huckleberry fruit production classes.

Fruit Production Class	Class Definition
0	No huckleberry plants in plot.
1	Huckleberry plants in plot, no fruit.
2	Low (< 5 fruits/stem on all stems in plot.)
3	Medium (< 5 fruits/stem on most stems in plot, between 5-10 fruits on others.)
4	Medium-high (< 10 fruits on most stems in plot, between 10-15 fruits on others.)
5	High (< 15 fruits on most stems in plot, between 15-20 fruits on others.)
6	Extra high (> 20 fruits on most stems in plot.)

Huckleberry stem height was estimated by measuring stem height (cm) within the 1-m² quadrats. Plot measurements were averaged for site-level estimates of huckleberry stem height.

Percent huckleberry leaf cover was estimated using the line-intercept method, as described by Canfield (1941), along each 50-m long sampling transect.

Transect values were averaged to estimate percent huckleberry leaf cover in each site.

Disturbance history information (initial disturbance type and stand age) for each site was collected from Mt. Hood National Forest Total Resource Inventory (TRI) cards, Mt. Hood National Forest watershed analyses, and personal communications with Mt. Hood National Forest and Bureau of Indian Affairs (BIA) foresters.

Data analysis

Data were analyzed with simple linear regression and univariate analyses using SAS Version 8 software (©1999 SAS Institute Inc.). Regression analyses were used to relate big huckleberry fruit production and growth to forest succession and stand development. In regression, huckleberry fruit production class, huckleberry stem height, and huckleberry cover were dependent variables, while overstory canopy cover, stand density, total basal area, and stand age were independent variables. Univariate analysis was used to compare huckleberry fields located in old burns with those located in forest gaps created by mechanical disturbances and to relate big huckleberry fruit production and growth to initial disturbance type. Sample sizes for initial disturbance types (fire, clearcut timber harvesting, shelterwood timber harvesting, forest clearing) were small. Significance was determined at $P \leq 0.10$.

STAND DESCRIPTIONS

Fourteen huckleberry fields were sampled on old, reforested burns (OBHF), ranging in age from 67 to 150+ years. Nine huckleberry fields were sampled in mechanical disturbance gaps (MDHF), ranging from 3 to 46 years old. All of the OBHF were created by fire disturbance. In contrast, MDHF were created by a variety of disturbances. The youngest MDHF (3 years old) was established after a dense fir/hemlock stand was girdled in order to improve understory huckleberry fruit production. Because this site was sampled after fruit fall, fruit production class was not estimated. Another MDHF (5 years old) is located on a site used for winter recreation but was previously occupied by lodgepole pine. This field has been maintained without tree cover for over 30 years using cut and pile methods with repeat entry every 5-7 years. Four other MDHF, ranging from 15 to 25 years old, were created by shelterwood timber harvests in mature fir/hemlock stands. The remaining three MDHF, ranging from 20 to 46 years old, were caused by clearcut timber harvests and followed by broadcast burns. Two of the clearcut harvest units were in mature fir/hemlock stands, while the third was a small clearcut in mature lodgepole pine (Minore et al. 1979).

There are several similarities between the currently productive MDHF sampled in this study and the descriptions of OBHF as they appeared in the 1930s and 1940s. Several of the OBHF examined were, within living memory, sparsely timbered burns. The following quotes from Warm Springs ceremonial huckleberry

pickers describe these OBHF as they appeared when productive and actively harvested for huckleberries.

*"You were able to look down the hill, see clearings because the trees were shorter."*¹

*"At that time, the trees were a little taller than us and scattered."*¹

*"The trees weren't very tall. There were some young trees, I know because I used to ride the trees. I was rodeo-ing out there all the time."*¹

*"[The logs on the ground] were huge and must have been old, because they were already red and spread out."*¹

*"You had to search, when I was a child, to find a log on the ground...If you found one, it was a bigger log that had not burned."*¹

*"Oh, there were always some logs lying around, but not that many. They were big logs, because I used to run on them, that was my trail."*¹

These descriptions raise several points about the successional ecology of productive fire-created huckleberry fields. First, while being harvested, OBHF were open and in the stand initiation stage of forest development (Oliver and Larson 1996). Second, OBHF were harvested for huckleberries several years after fire disturbance, inferred from the saplings and young trees commonly observed. Third, sites occupied by OBHF previously supported mature forest, as evidenced by the large logs on the ground, though several low-intensity fires may have run through the area subsequent to stand destruction and considerable time may have passed since the original stand-replacing disturbance.

Similarly, huckleberry fields created by mechanical disturbance (MDHF) had fairly open canopies, were in the stand initiation stage of forest stand development (Oliver and Larson 1996), and were generally over five years old. In addition, the MDHF supported mature forests prior to canopy-replacing disturbance, though numerous minor disturbances occurred at one field since canopy replacement.

However, ecological differences existed between OBHF and MDHF due to the type of initial disturbance. Interviews with Warm Springs ceremonial huckleberry pickers indicate that OBHF were more numerous and extensive than the MDHF found today. OBHF covered tens to thousands of hectares when they were productive and had huckleberry patches of variable size and productivity located within them. In contrast, sampled huckleberry fields located in mechanical disturbance gaps were uniform blocks typically less than 20 hectares in size with thin patches of productive shrubs along their edges.

Furthermore, due to differences in both stand age and initial disturbance type, forest stands located on reforested OBHF and currently productive MDHF exhibited differences in structure and species composition. Overstory canopy cover (Table 3.2) was significantly greater in OBHF (80%) as compared with MDHF (52%). Basal area (Table 3.2) was also significantly greater in OBHF (27 m²/ha) than in MDHF (14 m²/ha). Stand density (Table 3.2) was 1,100 trees/ha in OBHF and 900 trees/ha in MDHF.

Forest stands located on sampled OBHF and MDHF had unique compositions due, in part, to initial disturbance type. Figure 3.1 shows proportional differences in mean basal area in OBHF and MDHF. Forest stands growing on OBHF contained more pine, particularly lodgepole pine (*Pinus contorta*), than stands growing on MDHF (Figure 3.1). Pine basal area accounted for 45% of the basal area of the forest stands located on OBHF but only 21% of the basal area of forest stands located in mechanical disturbance gaps (MDHF). Eight of the youngest OBHF (aged 67-100 years) examined in this study supported dense stands of pure lodgepole pine. Lodgepole pine is an aggressive pioneer tree species that establishes quickly after stand-replacing fires when adequate seed-sources are available (Fowells 1965). Lodgepole pine stands are adapted to both frequent (every 50-200 years) crown fires and frequent (every 25-50 years) low-severity ground fires (Bork 1984). The proportion of lodgepole pine in mixed conifer stands tends to increase with each recurring fire (Lotan et al. 1984). In the Rocky Mountains, pure lodgepole pine stands develop mainly as a result of repeated fire disturbance (Lotan et al. 1984). Warm Springs Indians used maintenance fires to prevent forest encroachment into huckleberry fields prior to the implementation of fire suppression.

Table 3.2 Forest stand characteristics of huckleberry fields located in mechanical disturbance gaps (MDHF) and on old burns (OBHF). Forest stand age, overstory canopy cover, and conifer basal area were greater in MDHF than in OBHF.*

<i>Forest stand characteristics</i>	<i>Mechanical disturbance gaps (N = 9)</i>		<i>Old burns (N = 14)</i>	
	Mean	90% Confidence Interval	Mean	90% Confidence Interval
Stand age (years)	18 a	6-30	99 b	90-109
Canopy cover (%)	52 a	47-57	80 b	76-84
Stand density (stems/ha)	900	500-1,300	1,000	700-1,300
Basal area (m ² /ha)	14 a	10-18	27 b	24-30
Sapling density (stems/ha)	6,900	4,000-9,800	4,500	2,200-6,800

*Means followed by different letters are significantly different, P = 10%.

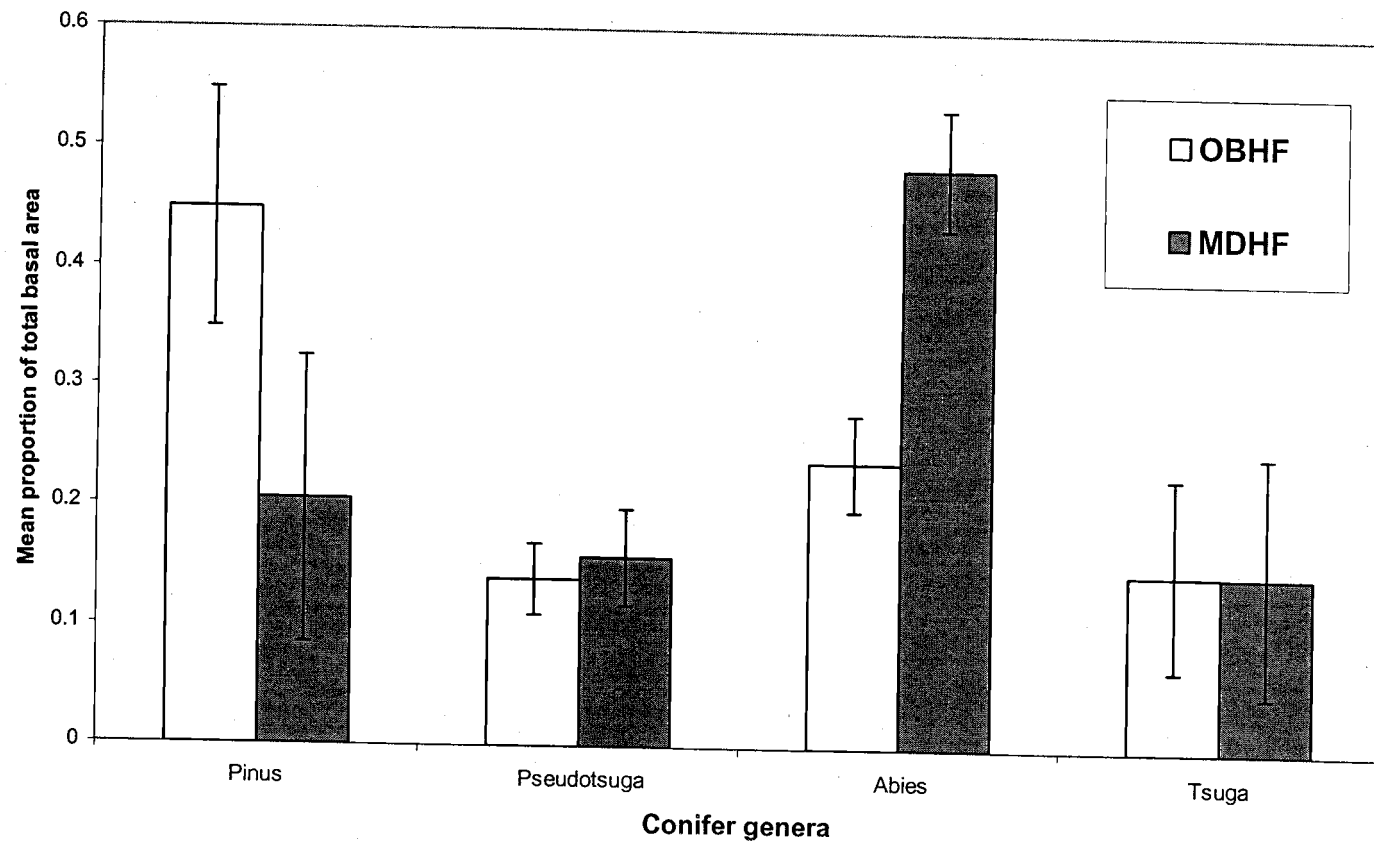


Figure 3.1 Proportions (with standard error bars) of total basal area occupied by conifer genera in forest stands located on sampled huckleberry fields. Forest stands on OBHF contained more pine (*Pinus*) than stands on MDHF, while forest stands located on MDHF contained more true fir (*Abies*) than stands on OBHF.

“Long ago they used to burn. They knew when it was time to burn, especially if it looked like it was going to rain. Burning didn’t really kill the berry bushes. They would start burning in one area, then move to another area.”¹

Recurring fire disturbance may have encouraged the development of pure lodgepole pine stands on the OBHF in this study.

In contrast, forest stands growing on MDHF contained more true fir than stands growing on OBHF (Figure 3.1). True fir accounted for 48% of the basal area of MDHF but only 24% of the basal area of OBHF. Furthermore, Pacific silver fir accounted for 41% of total stand density in MDHF compared with 20% in OBHF. As can be seen in Figure 3.2, Pacific silver fir was the most abundant conifer regenerating in huckleberry fields located on timber harvest units. Subalpine forest stands selected for timber harvest are typically old-growth fir/hemlock stands³ (ie. stands that have not experienced fire for several centuries). Pacific silver firs, though fire-sensitive, are extremely shade-tolerant and may live as long as 100 years as slow-growing saplings in mature forest understories (Oliver and Larson 1996). While fire selectively favors shade-intolerant species such as lodgepole pine, small-scale timber harvests without subsequent broadcast burns may favor extremely shade-tolerant species such as Pacific silver fir (Oliver and Larson 1996). When gaps in the forest canopy are created, Pacific silver fir saplings are released and often grow faster than newly established seedlings (Oliver and Larson 1996).

³ USDA Forest Service, Mt. Hood National Forest, Total Resource Inventory (TRI) cards. Available from Mt. Hood National Forest Ranger District offices.

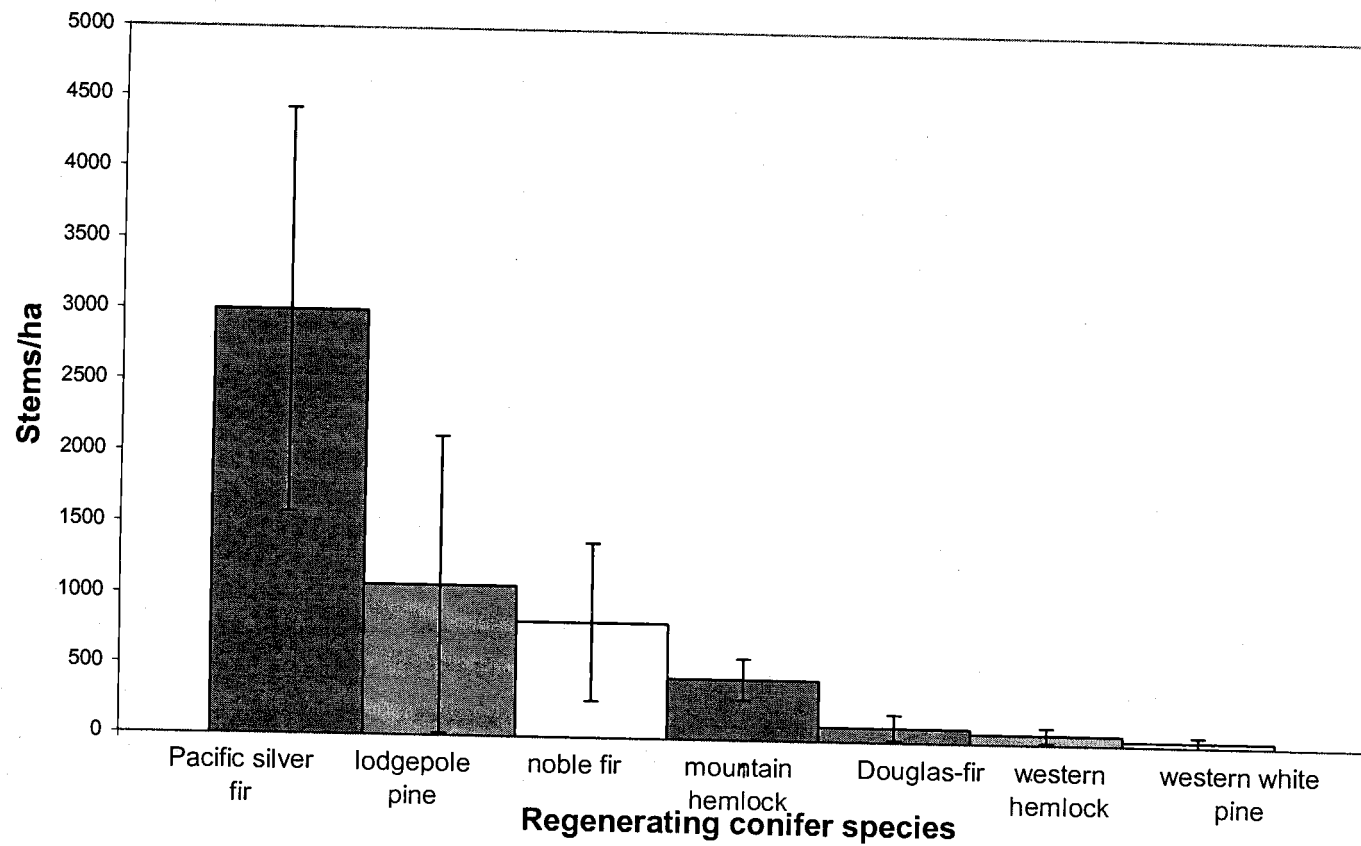


Figure 3.2 Sapling densities (with standard error bars) by species in sampled harvest units. Pacific silver fir (*Abies amabilis*) was the most abundant tree species regenerating in timber harvest units.

Pacific silver fir saplings undisturbed by timber harvesting may have a competitive advantage over seedlings of other conifer species; therefore, young stands initially dominated by Pacific silver fir saplings may quickly develop dense canopies of Pacific silver fir (Oliver and Larson 1996).

RESULTS

Fruit production and forest encroachment

Open huckleberry fields located in mechanical disturbed gaps (MDHF) had significantly higher fruit production (Table 3.3) than reforested huckleberry fields located on old burns (OBHF) ($F = 15.95$, $p = 0.0007$). However, fruit production classes for both MDHF and OBHF were low, 2.3 and 1.5 respectively. Despite significant differences between OBHF and MDHF, field-level fruit production class estimates were variable. Patches of abundantly fruiting shrubs were often observed along sparsely timbered ridgelines within OBHF. Further, many of the MDHF had only low fruit production. Nevertheless, these results confirm the concerns of Warm Springs ceremonial huckleberry pickers about the loss of productive OBHF to forest encroachment, since big huckleberry fruit production was absent or low in most of the OBHF sampled. *“When it was open, before the*

Table 3.3 Big huckleberry characteristics in huckleberry fields located in mechanical disturbance gaps (MDHF) and old burns (OBHF). Fruit production was significantly greater in MDHF than in OBHF.*

<i>Huckleberry characteristics</i>	<i>Mechanical disturbance gaps (N = 9)</i>		<i>Old burns (N = 14)</i>	
	Mean	90% Confidence Interval	Mean	90% Confidence Interval
Fruit production (class)	2.3 a	2.1-2.6	1.5 b	1.3-1.7
Stem height (cm)	50	40-58	48	41-55
Cover (%)	42	35-49	46	40-51

*Means followed by different letters are significantly different, P = 10%.

forest grew back, there was a lot of huckleberries on those slopes. Now, there is trees and not huckleberries.”¹

Stand density and basal area, indicators of competition (Biging and Dobbertin 1992) in huckleberry fields in varying stages of forest stand development from stand initiation to understory reinitiation, were not strongly associated with huckleberry fruit production class. Stand density was not related to huckleberry fruit production class, and, basal area, though having a negative relationship with huckleberry fruit production class ($F = 21.1$, $p = 0.0002$), explained considerably less of the variation in fruit production class than overstory canopy cover ($R^2 = 0.51$ and 0.75 respectively). In Figure 3.3, a 24% increase in canopy cover (90% confidence interval = 20-32%) was associated with a one-unit decrease in fruit production class when canopy cover values were between 34 and 86%.

Fruit production and stand age

Observed declines in traditional huckleberry field productivity over time and the negative association between fruit productivity and canopy cover (Figure 3.3) found in this study suggest a negative relationship between huckleberry field productivity and stand age.

“The last time I went [to pick huckleberries] was about ten years ago. I’ve been away for about that long. I thought I’d go pick huckleberries. When I got to where I used to pick, it was just a forest! I couldn’t find one berry.”¹

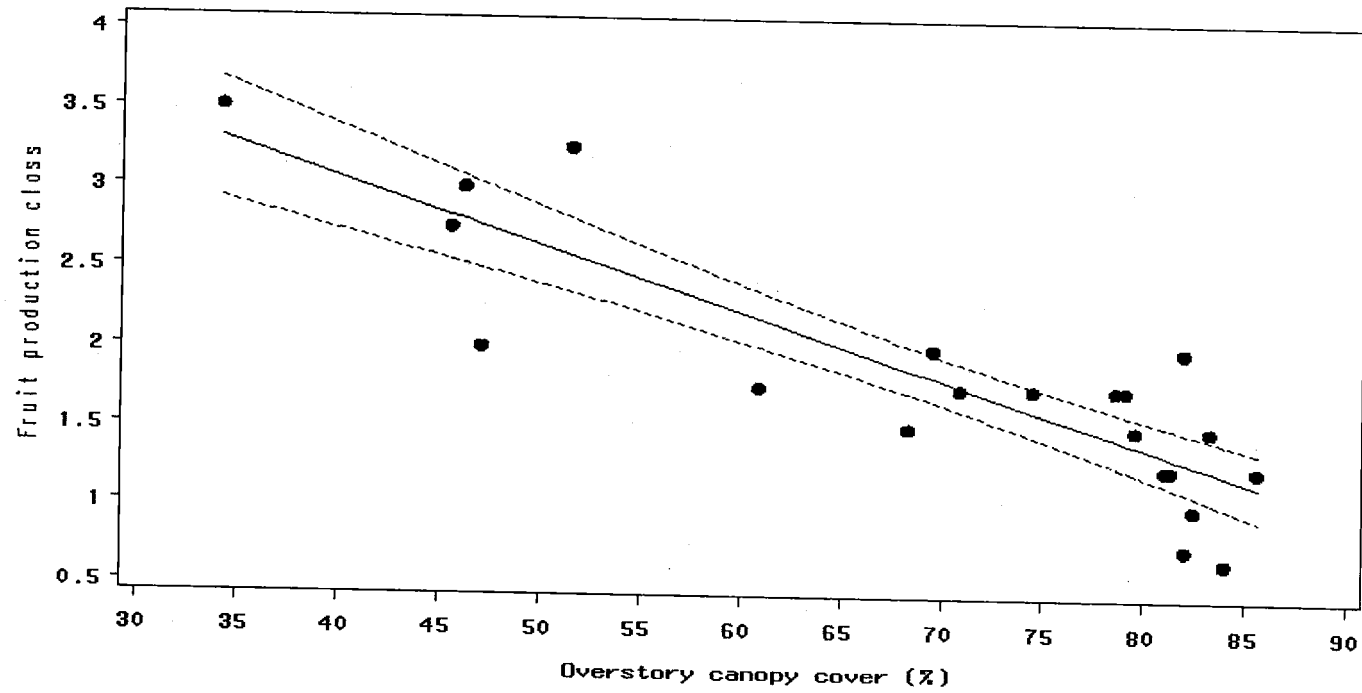


Figure 3.3 Regression of fruit production class on overstory canopy cover (%) with 90% confidence limits. Fruit production class was negatively associated with overstory canopy cover.

Huckleberry fields sampled in this study were between 3 and 150+ years of age, and regression analysis (Figure 3.4) revealed a negative relationship between fruit production class and increasing stand age in fields greater than 24 years old ($R^2 = 0.45$, $F = 12.06$, $p = 0.0034$).

However, fruit production class (Figure 3.5) was positively associated with stand age in sampled huckleberry fields less than 26 years old ($R^2 = 0.70$, $F = 11.63$, $p = 0.019$). Previous research indicates that big huckleberry may require seven or more years to recover pre-disturbance levels of fruit production after fire disturbance (Minore 1984). Results from this study suggest that big huckleberry may take more than a decade to attain high levels of fruit productivity after timber harvesting disturbances, with or without broadcast burning, as well.

Stem height and leaf cover

Neither huckleberry leaf area nor huckleberry stem height were significantly associated with overstory canopy cover, stand density, basal area, or stand age.

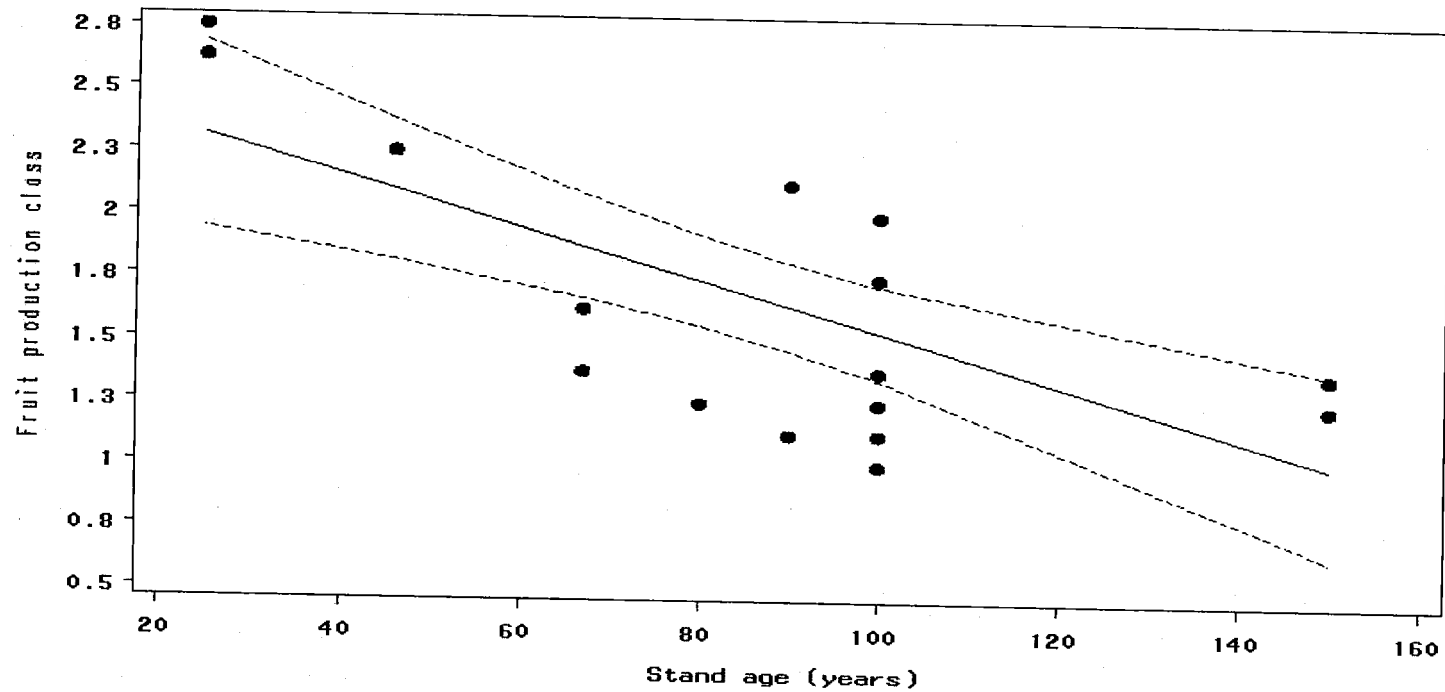


Figure 3.4 Regression (with 90% confidence limits) of fruit production class on stand age in huckleberry fields greater than 24 years old. Fruit production is negatively associated with stand age in huckleberry fields greater than 24 years old.

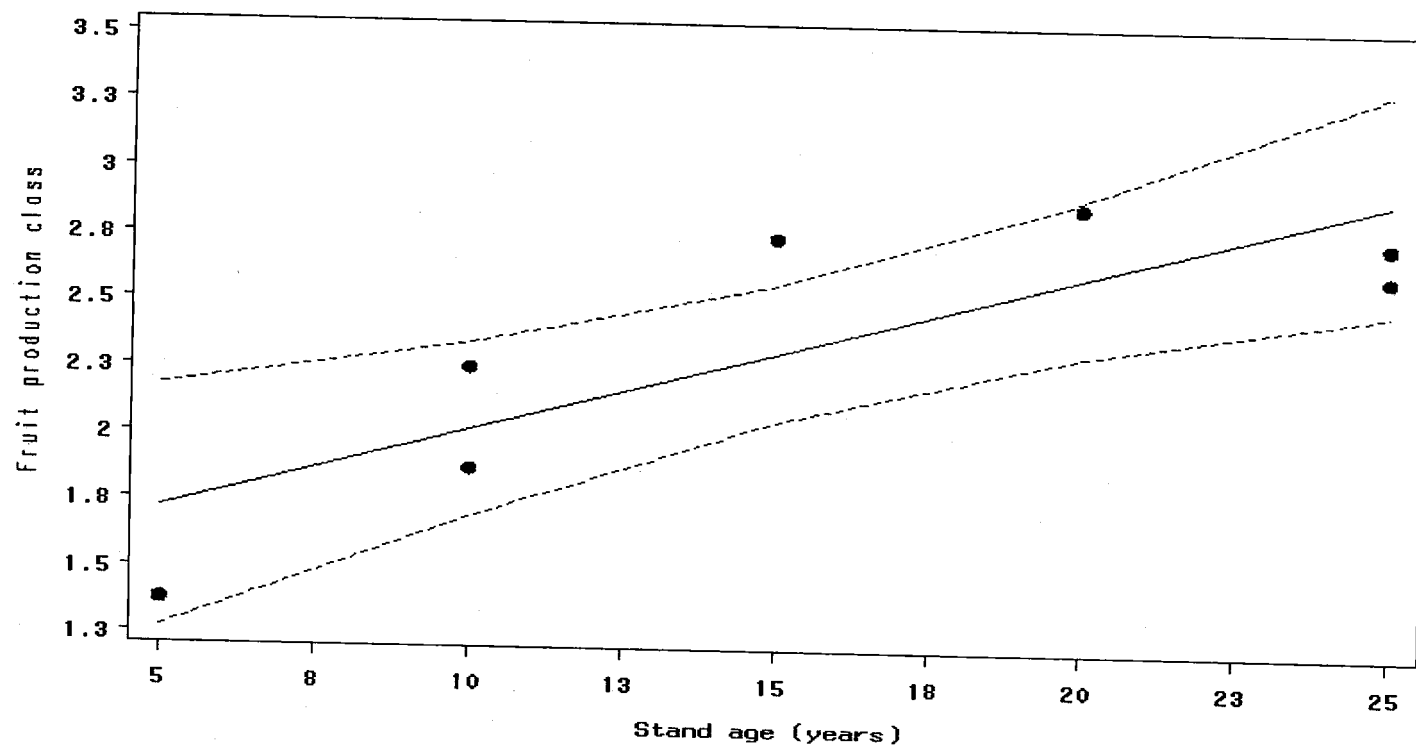


Figure 3.5 Regression (with 90% confidence limits) of fruit production class on stand age in huckleberry fields less than 26 years old. Fruit production is positively associated with stand age in huckleberry fields less than 26 years old.

Initial disturbance type

Using univariate analysis (SAS Version 8, ©1999 SAS Institute Inc.), initial disturbance type (Table 3.4) explained 69% of the variation in fruit production class in sampled huckleberry fields ($F = 12.13$, $p = 0.0001$) but did not explain any of the variation in huckleberry stem height or cover. However, initial disturbance type was confounded with stand age (Figure 3.6), so the relationship between fruit production class and disturbance type could not be disentangled from the relationship between fruit production and stand age. Table 3.4 lists huckleberry fruit production class, stem height, and cover by initial disturbance type. Both young forest clearings and old fire-created huckleberry fields fell into the very low fruit production class, while middle-aged shelterwood and clearcut harvest units were most often observed in medium-low fruit production class (Table 3.4).

DISCUSSION

Fruit production and forest encroachment

Warm Springs Indians have long been aware of the negative impact of forest encroachment on the productivity of huckleberry fields, and ceremonial huckleberry pickers stated that fire was traditionally used to keep trees from

Table 3.4 Mean huckleberry fruit production class, stem height, and leaf cover in huckleberry fields created by different initial disturbances. 90% confidence limits for means and stand age ranges provided. Fruit production class was greater in huckleberry fields created by timber harvests than in fields created by old fires or forest clearing.*

<i>Initial disturbance type</i>	<i>Stand age (years)</i>	<i>N</i>	<i>Big huckleberry variables</i>					
			<i>Fruit production class</i>		<i>Stem height (cm)</i>		<i>Cover (%)</i>	
			<i>Mean</i>	<i>90% Confidence Interval</i>	<i>Mean</i>	<i>90% Confidence Interval</i>	<i>Mean</i>	<i>90% Confidence Interval</i>
Forest clearing	3	1-2	1.4 a	0.7-2.0	31	14-49	34	19-49
Shelterwood harvest	15-25	4	2.4 b	2.1-2.7	50	37-62	46	36-57
Clearcut harvest	20-46	3	2.6 b	2.2-2.9	60	46-75	42	30-54
Fire	67-150+	14	1.5 a	1.3-1.6	48	41-55	46	40-51

*Means followed by different letters are significantly different, P = 10%.

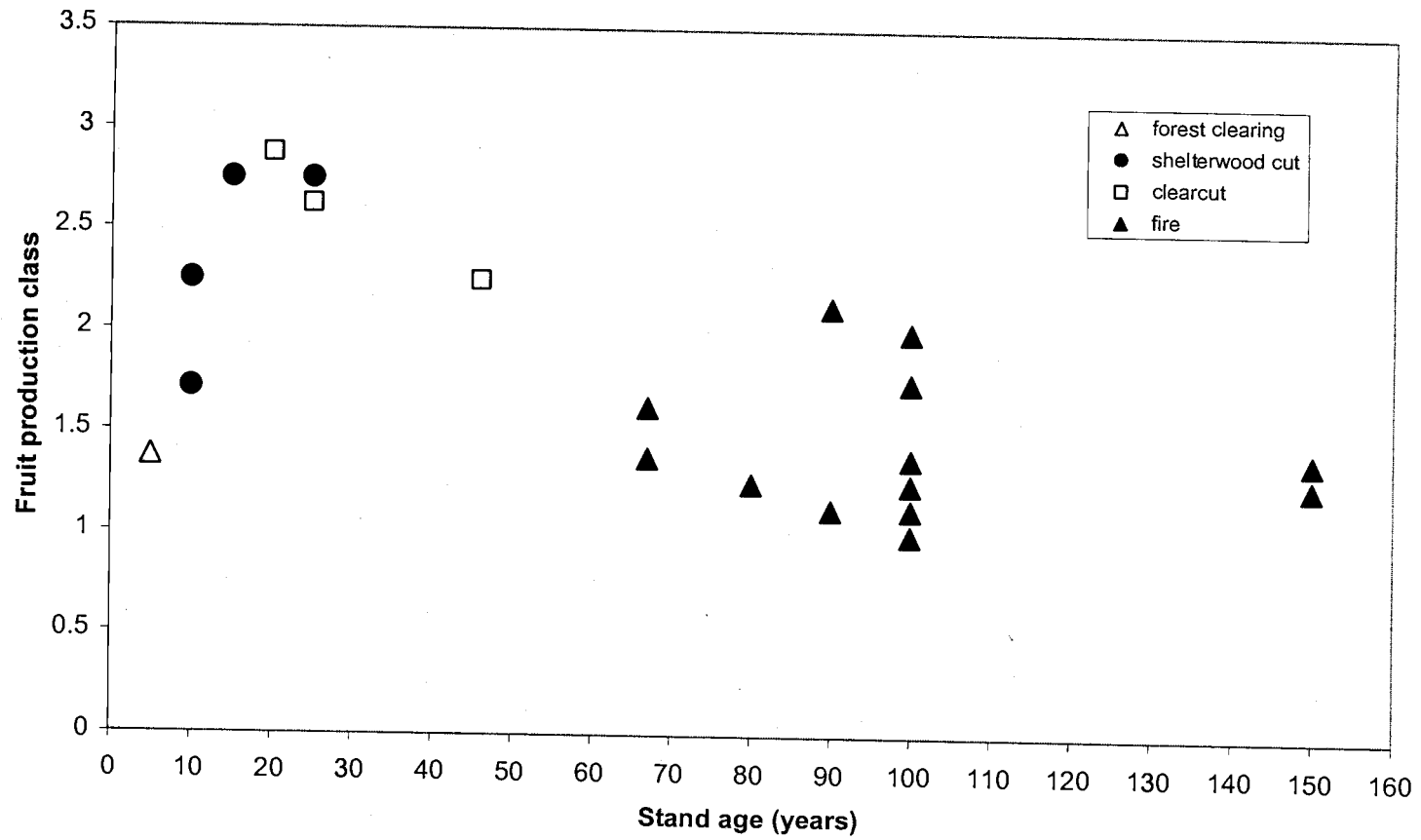


Figure 3.6 Huckleberry field fruit production classes by stand age and initial disturbance type. Stand age and initial disturbance type were confounded.

invading huckleberry fields prior to fire suppression. *"They would set the trees on fire when they were through picking, but they can't do that anymore."*¹ Ecologists also have noted the negative relationship between forest encroachment and big huckleberry fruit productivity (Minore 1972, Dahlgreen 1984), suggesting that local environmental changes associated with forest succession may be responsible for observed reductions in big huckleberry fruit set. As forest stands develop, the understory resource environment changes, e.g. light levels decrease as below-ground competition for moisture and nutrients increases. Warm Springs ceremonial huckleberry pickers suggest that low understory light levels may be limiting big huckleberry fruit set in reforested huckleberry fields. *"They [the huckleberry shrubs] always had to have a little bit of light or sunshine that came in and hit the berries, but it all turns into growth, evidently chokes out the berries."*¹ Resource limitation could be responsible for declining fruit production in developing forest understories. Alternatively, pollinator availability could also be a limiting factor for fruit production in closed forest stands, but previous studies indicate that fruit set of understory shrubs is rarely limited by inadequate pollination (Stephenson 1981, Niesenbaum 1993). The negative relationship between overstory canopy cover and fruit production observed in this study (Figure 3.3) supports the suggestion put forward by Warm Springs ceremonial huckleberry pickers that light availability is limiting big huckleberry fruit production in forest understories.

Ecological studies in boreal and Interior Northwest forest environments indicate that fruit production of understory shrubs in the genus *Vaccinium* may benefit from a partial canopy (Martin 1979, Hoefs and Shay 1981, Stark and Baker 1992, Atlegrim and Sjoberg 1996). Partial canopies may protect buds from freezing temperatures early in the growing season (Hoefs and Shay 1981) and/or prevent excessive transpiration during warm summer weather (Stark and Baker 1992, Atlegrim and Sjoberg 1996). It is uncertain whether big huckleberry shrubs growing in mild, mesic climates of the Oregon Cascade Range require such protection. Although fruit production class was negatively correlated with overstory canopy cover in this study (Figure 3.3), the lowest estimate of canopy cover was only 34%. Therefore, all the huckleberry fields sampled had partial canopies.

Fruit production of other shrubs in the genus *Vaccinium* requires a large proportion of the plant's carbon reserves (Karlsson 1985). Both flower production and fruit size are limited by carbohydrate reserves in rhizomes, stems, and roots (Darnell and Birkhold 1996), while fruit set is limited by the availability of current-year photosynthate (Roper and Klueh 1994, 1996). Flower bud formation (Hall and Ludwig 1961, Hoefs and Shay 1981, Moola and Mallik 1998), fruit maturation (Aalders et al. 1969, Dahlgreen 1984), and fruit set (Janke 1968, Martin 1979, Dahlgreen 1984, Stark and Baker 1992, Moola and Mallik 1998) have all been negatively correlated with overstory shading in *Vaccinium* species. Presumably,

shrubs growing under sparse canopies or in the open have more rapid photosynthetic rates, allowing carbohydrate storage in rhizomes and stems for future fruit production (Stark and Baker 1992), as well as providing photosynthate for current-year fruit development. Shrubs growing under dense canopies have lower photosynthetic rates and, therefore, lack the carbohydrate reserves necessary to initiate flowering and/or the photosynthate to complete fruit maturation.

Response to disturbance

Since carbohydrate reserves are needed to initiate flower bud formation, several year delays in huckleberry fruit production could be expected following overstory canopy disturbances, especially disturbances that destroy above-ground stems and leaves. Required periods of resource accumulation prior to sexual reproduction may partially explain the positive relationship between huckleberry fruit production and stand age observed in fields less than 26 years old (Figure 3.5). Delays in fruit production after canopy-replacing disturbance may also be related to strategies of reproductive allocation in changing resource environments (Alaback and Tappeiner 1991) or the positive effect of partial canopies on fruit production (Stark and Baker 1992).

Warm Springs ceremonial huckleberry pickers have indicated that the most productive huckleberry fields found today are located on clearcut harvest units.

“Basically that’s where you find huckleberries today is in the clearcuts, because

there aren't any burns."¹ Results of this study generally concur with this assessment. Mean fruit production class (Table 3.4) was higher in huckleberry fields created by clearcut timber harvests than in huckleberry fields created by other disturbances but was not significantly greater than fruit production class in fields created by shelterwood timber harvests. This result does not suggest that clearcut timber harvests are the best disturbance for initiating huckleberry fields. In fact, Minore (1972) noted that clearcut harvest units do not predictably support communities of productive big huckleberry shrubs. Excessive transpiration (Atlegrim and Sjoberg 1996), droughty soils (Minore 1972), over-exposure (Moola and Mallik 1998), vegetative competition (Minore 1972, Moola and Mallik 1998), mechanical damage (Moola and Mallik 1998), and scarification (Martin 1979) have all been cited as possible causes for poor growth and low fruit production of *Vaccinium* species on clearcut harvest units. However, only clearcut harvest units known for their high fruit productivity were sampled in this study; therefore, the detrimental effects of clearcut timber harvests on huckleberry growth and fruit production suggested by other studies could not be confirmed.

Big huckleberry fruit production may have been relatively greater in the fields created by clearcut timber harvests than those created by other disturbances because they were the oldest huckleberry fields in this study (Table 3.4) that still retained fairly open canopies. If huckleberry shrubs develop the carbohydrate reserves necessary for sexual reproduction over time, longer periods in open

environments could result in greater levels of fruit production. Further, fruit production may have been higher in clearcut harvest units because they were broadcast burned. Fire may have destroyed seedlings and saplings of competing conifers, effectively extending the length of time huckleberry shrubs were able to grow in the open and accumulate resources for sexual reproduction. Alternatively, fire may have had beneficial effects on fruit productivity by rejuvenating decadent shrubs, stimulating rhizome sprouting (Miller 1977), or by creating more favorable soil environments (Kautz 1987).

Three timber harvest units sampled were noted by Forest Service silviculturists for their poor conifer regeneration (Shannon 2001, pers.com.). Poor regeneration of subalpine harvest units in the Cascade Range, particularly those with understories dominated by big huckleberry, has been a common silvicultural problem (Halverson and Emmingham 1982). However, an extended stand initiation stage of forest development caused by poor conifer regeneration may be favorable for big huckleberry fruit production.

Reproductive strategy

In this study, neither huckleberry stem height nor leaf area was associated with any forest stand development variables measured, such as stand age, stand density, basal area, or overstory canopy cover. In sampled harvest units where old-growth fir/hemlock forests were cut, clonal shoots of big huckleberry dominated

the understory plant community, suggesting that the shrubs had survived centuries in those closed canopy forest environments. Big huckleberry appears to be a “stress-tolerater” (Alaback and Tappeiner 1991) capable of vegetative growth, though lacking sufficient resources to initiate and complete sexual reproduction, in closed canopy forests. Forest understory *Vaccinium* species are, in general, shade-tolerant (Hall and Ludwig 1961, Hoefs and Shay 1981, Holloway et al. 1982, Alaback and Tappeiner 1991, Stark and Baker 1992). Big huckleberry apparently tolerates long periods in low light environments and responds opportunistically, though slowly, to canopy disturbances. Big huckleberry, like *V. ovalifolium* (Alaback and Tappeiner 1991) and *V. myrtilloides* (Moola and Mallik 1998), may also have a strategy of colonizing disturbance gaps and young forest stands via advanced regeneration from previous old forests.

The life history traits of big huckleberry represent adaptations to a high-severity fire regime. High-severity fire regimes are noted by centuries-long fire-return intervals punctuated by huge canopy-replacing fires. Big huckleberry appears to be tolerant of extended periods in closed-canopy, late-successional forests, and the historic creation of huckleberry fields after wildfires suggests that big huckleberry is resistant to high intensity, stand-replacing fires as well. Furthermore, the slow recovery of big huckleberry after fire and other disturbance indicates that extremely large disturbance gaps, such as those associated with high-intensity fires, are required for big huckleberry to reach its sexual reproductive

potential. Forest canopies would close on smaller burns or other disturbance gaps before big huckleberry shrubs ever attained full sexual reproduction. If big huckleberry has, indeed, a unique life history strategy consisting of extreme longevity and shade tolerance coupled with fire-resistance and clonal rejuvenation, it suggests that individual big huckleberry clones may easily be several centuries old and that effective sexual reproduction need only take place every few hundred years, providing adequate openings are present.

MANAGEMENT CONSIDERATIONS

If productive huckleberry fields are to be part of the landscape of the northern Oregon Cascade Range in the future, forest managers of the Mt. Hood National Forest and Warm Springs Indian Reservation must determine how disturbance gaps are to be created and maintained in stands supporting big huckleberry. If a culturally maintained fire-return interval of roughly 20 years characterized huckleberry field disturbance regimes at the turn of the century, up to five fire cycles have been missed since fire suppression was implemented. The opportunity for maintaining huckleberry fields located on old stand-replacement burns with frequent, low-severity fire has probably passed. Future huckleberry fields need to be created with stand-replacing disturbances. Since stand-replacing fires, wild or otherwise, continue to be socially unacceptable phenomena, future huckleberry fields will most likely be created by alternative disturbances.

Fire is an extremely difficult disturbance to replace, especially in the highly restricted forest management environment of the US Forest Service. Historic wildfires were often huge and stand-replacing. Therefore, large-scale timber harvests followed by broadcast burning may mimic stand-replacing wildfires closer than other mechanical disturbance types. Ideally, harvest units be big, forest canopies would be destroyed or removed, and seedlings and saplings of competing conifers would be killed. Historic fires probably destroyed big huckleberry leaves. In order to prevent solar radiation or heat stress to shade-grown huckleberry leaves, timber harvests should either be immediately followed by broadcast burns or conducted when shrubs are not leafed out. Big huckleberry, like other *Vaccinium* species, may require the protection of a sparse canopy, such as that provided by dead snags after a wildfire (Minore pers. Com. 2000), for vigorous growth and fruit production. In this study, the highest fruit production class values were observed in huckleberry fields with 35-50% canopy cover and 4-7m²/ha of conifer basal area. Therefore, selected individual trees and/or groups of trees should be left within the harvest unit even though they may be killed by subsequent broadcast burns. Forest managers should be prepared to wait as long as a decade for big huckleberry fruit production after canopy disturbance.

Once huckleberry fields are created or re-created in areas that once supported them, frequent low-severity disturbance will be needed to prevent forest encroachment and maintain field productivity. Prescribed burns conducted about

every 20 years in late summer and early fall would most closely mirror the traditional disturbance regime. Girdling and cut-and-pile methods of forest clearing may be suited to the maintenance of existing huckleberry fields as an alternative to prescribed burning.

CONCLUSION

The reforestation of fire-created huckleberry fields in the northern Oregon Cascade Range has been a significant cultural loss for members of the Confederated Tribes of the Warm Springs. Similarly, it has been a great loss for the many animals—bears, foxes, rodents, birds—that feasted on the abundant crops of late-summer huckleberries. However, the ecological event of abundant big huckleberry fruit production may be, without human involvement, as rare in subalpine forests as catastrophic high-intensity fire. Without the fire management of Warm Springs Indians, huckleberry fields have succeeded back into the matrix of fire-sensitive forests that surrounded them. Big huckleberry seems prepared to wait for centuries for the next inevitable round of stand-replacing fires in the High Cascades. If huckleberries are again to be a “viable crop of the mountains,” forest managers must supplement the natural disturbance regime of the High Cascades in ways that favor the development of early seral huckleberry fields.

LITERATURE CITED

- Aalders LE., Hall IV., Forsyth FR. 1969. Effects of partial defoliation and light intensity on fruit-set and berry development in the lowbush blueberry. Horticultural Research 9: 124-129.
- Agee JK, Finney M., de Gouvenain R. 1990. Forest history of Desolation Peak, Washington. Canadian Journal of Forest Research 20: 350-356.
- Alaback PB., Tappeiner JC. 1991. Response of western hemlock (*Tsuga heterophylla*) and early huckleberry (*Vaccinium ovalifolium*) seedlings to forest windthrow. Canadian Journal of Forest Research 21: 534-539.
- Atlegrim O., Sjoberg K. 1996. Response of bilberry (*Vaccinium myrtillus*) to clear-cutting and single-tree selection harvests in uneven-ages boreal *Picea abies* forests. Forest Ecology and Management 86: 39-50.
- Biging GS., Dobbertin M. 1992. A comparison of distance-dependent competition measures for height and basal area growth of individual conifer trees. Forest Science 38(3): 695-720.
- Bork JL. 1984. Fire history in three vegetation types on the east side of the Oregon Cascades. PhD. Dissertation. Corvallis (OR): Oregon State University. 94 p.
- Boyd R. 1996. People of the Dalles: the Indians of the Wascopom Mission. Lincoln (NE): University of Nebraska Press. 396 p.
- Burke CJ. 1979. Historic fires in the central western Cascades, Oregon. M.S. thesis. Corvallis (OR): Oregon State University. 130 p.
- Canfield RH. 1941. Application of the line intercept method in sampling range vegetation. Journal of Forestry 39: 388-394.
- Dahlgreen MC. 1984. Observations on the ecology of *Vaccinium membranaceum* Dougl. on the southeast slope of the Washington Cascades. M.S. thesis. Seattle (WA): University of Washington. 120 p.
- Darnell RL, Birkhold KB. 1996. Carbohydrate contribution to fruit development in two phenologically distinct rabbiteye blueberry cultivars. HortScience 121(6): 1132-1136.

- Davis J., silviculturist and Warm Springs Indian Reservation liaison, Mt. Hood National Forest [former]. June 2000. Personal communication.
- Dickman A., Cook S. 1989. Fire and fungus in a mountain hemlock forest. *Canadian Journal of Botany* 67: 2005-2016.
- Fisher AH. 1997. The 1932 Handshake Agreement: Yakima Indian treaty rights and forest service policy in the Pacific Northwest. *Western Historical Quarterly* (summer 1997): 187-217.
- Fowells HA. (ed.) 1965. *Silvics of Forest Trees of the United States*. USDA Agricultural Handbook No. 271. Washington D.C. 762 p.
- Franklin JF., Dyrness CT. 1973. *Natural vegetation of Oregon and Washington*. USDA Forest Service General Technical Report PNW-8. Portland (OR): Pacific Forest and Range Experiment Station. 417 p.
- French D. 1961. Studies in the acculturation of the Wasco-Wishram. In Spicer EH. (ed.) *Perspectives in American Indian Culture Change*. Chicago (IL): University of Chicago Press. 549 p.
- 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): Oregon State University Press. 313 p.
- Hall IV., Ludwig RA. 1961. The effects of photoperiod, temperature, and light intensity on the growth of the lowbush blueberry (*Vaccinium angustifolium* Ait.) *Canadian Journal of Botany* 39: 1733-1739.
- Halverson NM., Emmingham WH. 1982. Reforestation in the Cascades Pacific silver fir zone: a survey of sites and management experiences on the Gifford Pinchot, Mt. Hood, and Willamette National Forests. USDA Forest Service R6-ECOL-091-1982. Portland (OR): Pacific Northwest Region, Mt. Hood National Forest. 34 p.
- Hemstrom MA., Franklin JF. 1982. Fire and other disturbances of the forests in Mt. Rainier National Park. *Quaternary Research* 18: 32-51.

- Hoefs MEG., Shay JM. 1981. The effects of shade on shoot growth of *Vaccinium angustifolium* Ait. After fire pruning in southeastern Manitoba. Canadian Journal of Botany 59: 166-174.
- Holloway PS., Van Veldhuizen RM., Stuchoff C., Wildung DK. 1982. Effects of light intensity on vegetative growth of lingonberries. Canadian Journal of Plant Science 62: 965-968.
- Howes S. 1979. Soil resource inventory. USDA Forest Service, Pacific Northwest Region, Mt. Hood National Forest. Sandy (OR): Mt. Hood National Forest Headquarters. 312 p.
- Hunn ES. 1982. Mobility and resource use: Columbia Plateau. In Williams NM., Hunn ES. (eds.) Resource Managers: North American and Australian hunter-gathers. American Association for the Advancement of Science Selected symposia Series # 67. 267 p.
- Hunn ES. with Selan J. and family. 1990. Nch'i-Wána "The Big River" Mid-Columbia Indians and their land. Seattle (WA): University of Washington Press. 378 p.
- Janke RA. 1968. The ecology of *Vaccinium myrtillus* using concepts of productivity, energy exchange, and transpiration. PhD. Dissertation. Boulder (CO): University of Colorado. 109 p.
- Karlsson PS. 1985. Patterns of carbon allocation above ground in a deciduous (*Vaccinium uliginosum*) and an evergreen (*Vaccinium vitis-idaea*) dwarf shrub. Physiological Plant Pathology 63: 1-7.
- Kautz EW. 1987. Prescribed fire in blueberry management. Fire Management Notes 48(3): 9-12.
- Lotan JE., Brown JK., Neuenschwander LF. 1984. The role of fire in lodgepole pine forests. In Baumgartner DM., Krebill RG., Arnott JT., Weetman GF. (eds.) Lodgepole Pine: the species and its management. Spokane (WA): Symposium Proceedings: 133-152.
- Mack, CA. 2001. A burning issue: native use of fire in the Mount Rainier Forest Reserve. Paper presentation. Durango (CO): Society of Ethnobiology Meeting, March 7-9, 2001. 5 p. Available from Mt. Adams Ranger District, Gifford Pinchot National Forest.

- Martin PAE. 1979. Productivity and taxonomy of the *Vaccinium globulare*, *Vaccinium membranaceum* complex in western Montana. Master's thesis. Missoula (MT): University of Montana. 136 p.
- Miller M. 1977. Response of blue huckleberry to prescribed fires in a western Montana larch-fir forest. USDA Forest Service Research Paper INT-188. Ogden (UT): Intermountain Forest and Range Experiment Station. 33p.
- Minore D. 1972. The wild huckleberries of Oregon and Washington: a dwindling resource. USDA Forest Service Research Paper PNW-143. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 20 p.
- Minore D. 1984. *Vaccinium membranaceum* berry production seven years after treatment to reduce overstory tree canopies. Northwest Science 58(3): 208-212.
- Minore D., USDA Forest Service research ecologist, Pacific Northwest Forest and Range Experiment Station [former]. January 2001. Personal communication.
- Minore D., Smart AW., Dubrasich ME. 1979. Huckleberry ecology and management research in the Pacific Northwest. USDA Forest Service General Technical Report PNW-93. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 50 p.
- Moola FM., Mallik AU. 1998. Morphological plasticity and regeneration strategies of velvet leaf blueberry (*Vaccinium myrtilloides* Michx.) following canopy disturbance in boreal mixedwood forests. Forest Ecology and Management 111: 35-50.
- Morrison PH., Swanson FJ. 1990. Fire history and pattern in a Cascade Range landscape. USDA Forest Service General Technical Report PNW-GTR-254. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 77 p.
- Niesenbaum RA. 1993. Light or pollen—seasonal limitations on female reproductive success in the understory shrub *Lindera benzoin*. Journal of Ecology 81: 315-323.
- Oliver CD., Larson BC. 1996. Forest Stand Dynamics. Update edition. New York (NY): John Wiley & Sons, Inc. 520 p.

- Rich PM. 1989. A manual for analysis of hemispherical canopy photography. Los Alamos National Laboratory Report LA-11733-M. Los Alamos (NM): Los Alamos National Laboratory. Available from: <http://www.hemisoft.com> [accessed 7/2001]
- Roper TR., Klueh JS. 1994. Removing new growth reduces fruiting in cranberry. *HortScience* 29(3): 199-201.
- Roper TR., Klueh JS. 1996. Movement of carbon from source to sink in cranberry. *HortScience* 121(5): 846-847.
- Shannon T., Forest Service silviculturist, Mt. Hood National Forest. March, 2001. Personal communication.
- Stark N., Baker S. 1992. The ecology and culture of Montana huckleberries: a guide for growers and researchers. Misc. Publication 52. Missoula (MT): Montana Forest and Conservation Experiment Station and School of Forestry, University of Montana. 87 p.
- Stephenson AG. 1981. Flower and fruit abortion: proximate causes and ultimate functions. *Annual Review of Ecology and Systematics* 12: 253-279.
- USDA Forest Service. 1995. Salmon River Watershed Analysis, Mt. Hood National Forest. First Iteration. Portland (OR): Pacific Northwest Region, USDA Forest Service.
- Weisberg PJ. 1998. Fire history, fire regimes, and development of forest structure in the central western Oregon Cascades. PhD. Dissertation. Corvallis (OR): Oregon State University. 256 p.

CHAPTER 4. ADDITIONAL CONSIDERATIONS

In this chapter, I present methods, results, and discussion of additional research questions. Further examination of the effect of canopy cover on huckleberry fruit production will be presented, as well as exploration into the influence of topography on stand development and huckleberry growth and fruit production. I will also examine relationships between big huckleberry growth and fruit production and the abundance of associated vegetation.

METHODS

Study sites

Two additional sites, one OBHF and one MDHF, were sampled but were not included in the analyses presented in chapter 3 because transect selection was not random. Site selection was as described in chapter 3. The additional OBHF, site x, was a small field located in a natural meadow. Because the field was small, only two transects were placed within observable field boundaries (based on big huckleberry cover). Though measured statistics may be representative of the huckleberry field as a whole, transects were not randomly selected. The additional MDHF, site y, was located in a clearcut harvest unit. In this site, patches of big huckleberry shrubs were scattered and widely spaced; therefore, transect locations

and bearings were selected to run through one or more patches of big huckleberry. Three transects were measured in site y. Estimates of big huckleberry leaf cover and fruit production class were biased toward higher values than representative of the site as a whole.

Data collection

Measurements additional to those described in chapter 3 were taken in all sites ($n = 25$). Site elevation was determined from topographical maps and expressed in meters. In order to estimate percent slope, clinometer readings were taken at either end of each sampling transect and values averaged. Transect slopes were averaged to estimate site slope and expressed as percents. Slope aspect was estimated with compass readings at either end of each sampling transect; values were averaged to estimate transect aspect. Transect values were then averaged to estimate site aspect and expressed as degrees.

Furthermore, in each 1-m² quadrat, the presence of associated plant species was recorded. As described by Daubenmire (1968), species constancy was estimated by combining species lists from the two 1-m² quadrats (per sampling transect) into a single species list for each sampling transect, counting the number of sampling transects that a species was observed in, and dividing by the total number of transects sampled in a particular site. Constancy was expressed as percent.

Data analysis

Statistical analyses were conducted with SAS Version 8 software (©1999 SAS Institute Inc.). Simple linear regression analysis was used to relate huckleberry fruit production and growth with characteristics of the physical environment and the constancy of associated vegetation. Dependent variables were huckleberry fruit production class, huckleberry leaf cover, and huckleberry stem height. Independent variables were elevation, slope, aspect, and associated plant species constancy. Multiple linear regression analyses were used to relate overstory canopy cover and huckleberry fruit production to stand age and topography. Dependent variables were overstory canopy cover and huckleberry fruit production class. Independent variables were stand age and topographical position. Univariate analysis was used to compare overstory canopy cover in huckleberry fields created by different initial disturbances and located in different topographical positions.

RESULTS AND DISCUSSION

Fruit production and forest encroachment

Regression analyses were run including the two sites, sites x and y, that were excluded from previous analyses. Statistics measured at site y supported relationships discussed in chapter 3. An estimated 22% (previously 24%) increase in canopy cover was associated with a one-unit decrease in fruit production class (t

= -8.37, $p < 0.0001$), and the variation in fruit production class explained by canopy cover increased from 75% to 78%. Similar to the results discussed in the chapter 3, basal area explained less of the variation in fruit production class than canopy cover ($R^2 = 0.59$) with the inclusion of site y. Further, with the inclusion of site y, the estimate of mean fruit production class in clearcut harvest units produced by univariate analysis increased from 2.6 to 2.9, but the variability in fruit production class explained by initial disturbance type declined from 67% to 32%.

In contrast, the inclusion of site x in the data set reduced the significance of relationships discussed in chapter 3. As can be seen in Figure 4.1, site x was an outlier of the otherwise linear association between fruit production class and canopy cover. The inclusion of site x reduced the amount of variability in fruit production class explained by canopy cover from 75% to 47% ($F = 18.74$, $p = 0.0003$), because site x had both extremely high fruit production class (4.5) and high overstory canopy cover (77%). Similarly, site x was an outlier of the linear association between fruit production class and basal area and reduced the amount of variability in fruit production class explained by basal area from 51% to 47% ($F = 19.65$, $p = 0.0002$).

Despite fairly closed canopy conditions, estimated fruit production class in site x was high. The fruit production in site x may be explained by exceptionally fertile soils with high nutrient or moisture levels which may have enabled the

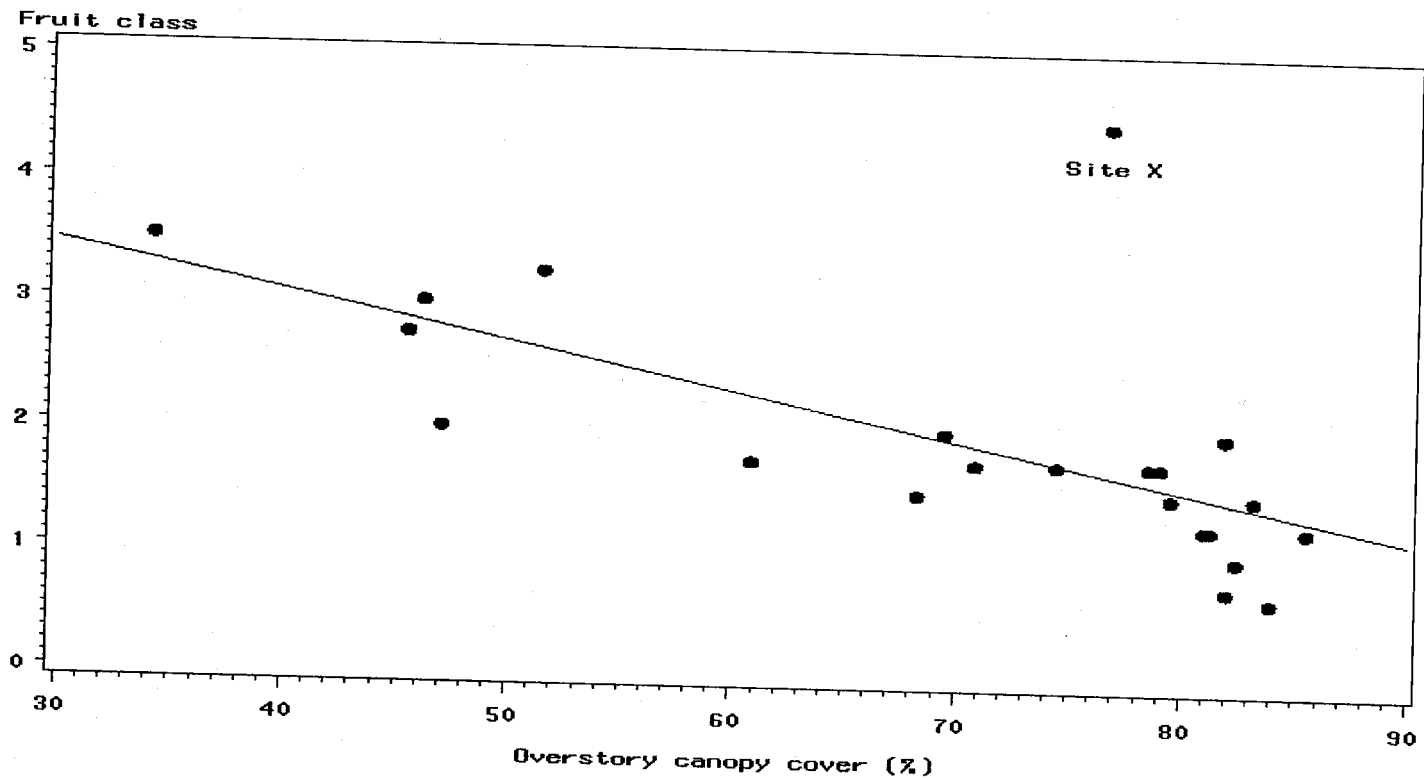


Figure 4.1 Regression of fruit production class on overstory canopy cover, including site x. Site x, a small OBHF, was an outlier of the otherwise linear negative relationship between fruit production class and canopy cover.

huckleberry shrubs to overcome the negative influence of reduced light availability. Site x was the only huckleberry field sampled that was not in the big huckleberry/beargrass plant association (Hemstrom and Emmingham 1982), possibly indicting a different soil environment than found in the other sampled huckleberry fields. Alternatively, similar to the other huckleberry fields sampled, fruit production in site x may be decreasing linearly with canopy closure but may have begun its descent from an exceptionally high initial level of fruit production.

Edge effect

A pattern observed in this study, and previously noted by Warm Springs ceremonial huckleberry pickers, seems to support the contention that timber harvesting may over-expose and stress huckleberry shrubs.

*"The only berries I picked that were even close to a forest, it was just like that. Here was a clearcut and right along the edge of the clear cut, where you had forest here and in the open, I picked some berries."*¹

In this study, patches of productive huckleberry shrubs were, almost invariably, located along the edge of clearcut and shelterwood harvest units within one or two tree height's distance from the uncut forest. This pattern suggests that big huckleberry may benefit from the protection from extreme temperatures and/or excessive solar radiation provided by a partial canopy.

¹ Warm Springs ceremonial huckleberry pickers, interviews. 1998, 1999, 2000. Warm Springs Museum archives. Audio cassette recordings.

Topographical influences

Using multiple linear regression analysis, overstory canopy cover and huckleberry fruit production were regressed on stand age and topographical position. Using univariate analysis, overstory canopy cover was compared in huckleberry fields created by different initial disturbances and located in different topographical positions. In addition, huckleberry stem heights in fields with different topographical positions were compared. Sites x and y were not included in these analyses.

As can be seen in Figure 4.2, ridgeline huckleberry fields younger than 100 years old had lower overstory canopy cover than huckleberry fields located on slopes ($t = -2.98, p = 0.008$). Huckleberry fields over 100 years old had fairly equivalent canopy cover regardless of topographical position. Furthermore, in every initial disturbance type category (Table 4.1), ridgeline huckleberry fields had lower mean overstory canopy cover than huckleberry fields located on slopes, with disturbance type and topographical position explaining 82% of the variation in overstory canopy cover ($F = 9.28, p < 0.0001$). Huckleberry fields disturbed by forest clearing disturbances had the lowest overstory canopy cover of all sampled huckleberry fields, while huckleberry fields established on old burns had the highest overstory canopy cover. See Table 4.1 for overstory canopy cover by initial disturbance type and topographical position.

Using multiple linear regression analysis, huckleberry fruit production class was regressed on stand age and topographical position. The regression of fruit

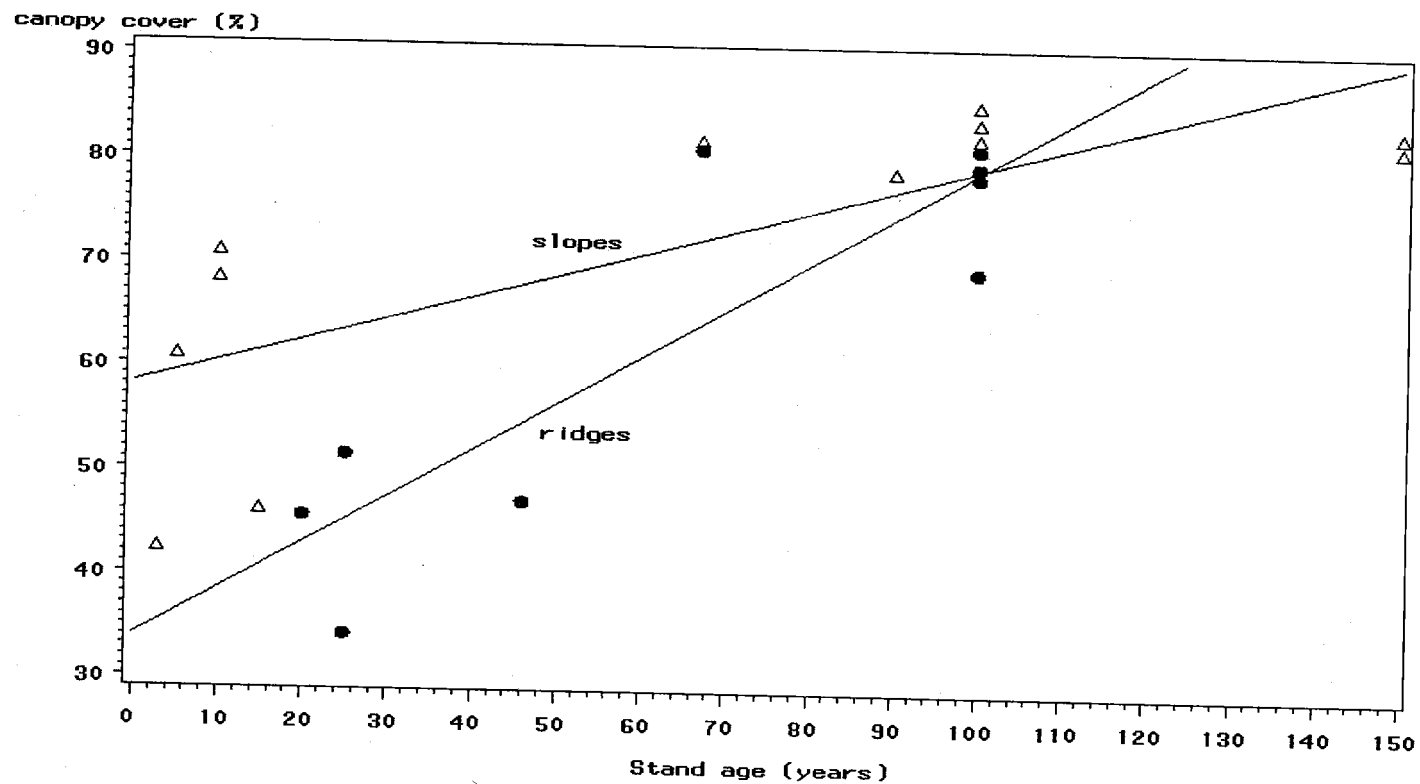


Figure 4.2 Multiple linear regression of overstory canopy cover on stand age and topographical position. In huckleberry fields younger than 100 years, overstory canopy cover is lower on ridges than on slopes.

Table 4.1 Percent overstory canopy cover of ridge and slope huckleberry fields established by different initial disturbance types. In every disturbance type, mean canopy cover is greater on slopes than on ridges.

Topographical position	Initial Disturbance Type							
	forest clearing		shelterwood		clearcut		old fire	
	Overstory canopy cover (%)							
	Mean	90% Confidence Interval	Mean	90% Confidence Interval	Mean	90% Confidence Interval	Mean	90% Confidence Interval
ridge	42	24-59	48	39-57	48	40-56	75	70-81
slope	52	46-58	57	50-64	57	47-68	85	80-90

production class on stand age and topographical position presented an inverse image of observed trends in overstory canopy cover. As can be seen in Figure 4.3, in huckleberry fields younger than 100 years, fruit production was higher in ridgeline fields than slope fields ($t = 2.31$, $p = 0.034$).

There are several possible explanations for observed relationships between overstory canopy cover, fruit production, and topography. First, ridgeline fields had slower overstory canopy development than slope fields. Huckleberry fruit production class showed a negative relationship with canopy cover; therefore, ridgeline huckleberry fields, with their lower canopy cover, may have been associated with extended periods of high fruit production. Furthermore, canopy cover may have been low on ridges simply because there were no higher slopes to block low-angle light. Second, ridges generally have thin soils, so conifer establishment can be slow. Seed rain may be lesser on ridges than on lower slope positions for logistical reasons. Again, the result may be lower overstory canopy cover and higher huckleberry fruit production. Third, thin ridge soils may slow the establishment of plants from seed thereby minimizing competition with asexually reproducing huckleberry shrubs and allowing greater fruit production. Fourth, ridges tend to burn more frequently (Hemstrom and Franklin 1982, Agee et al. 1990, Krusemark et al. 1996) and with greater severity (Weisberg 1998) than slopes. Fire damage to saplings or fire effects on soils may slow conifer regeneration on ridges. Alternatively, fires may favor big huckleberry over

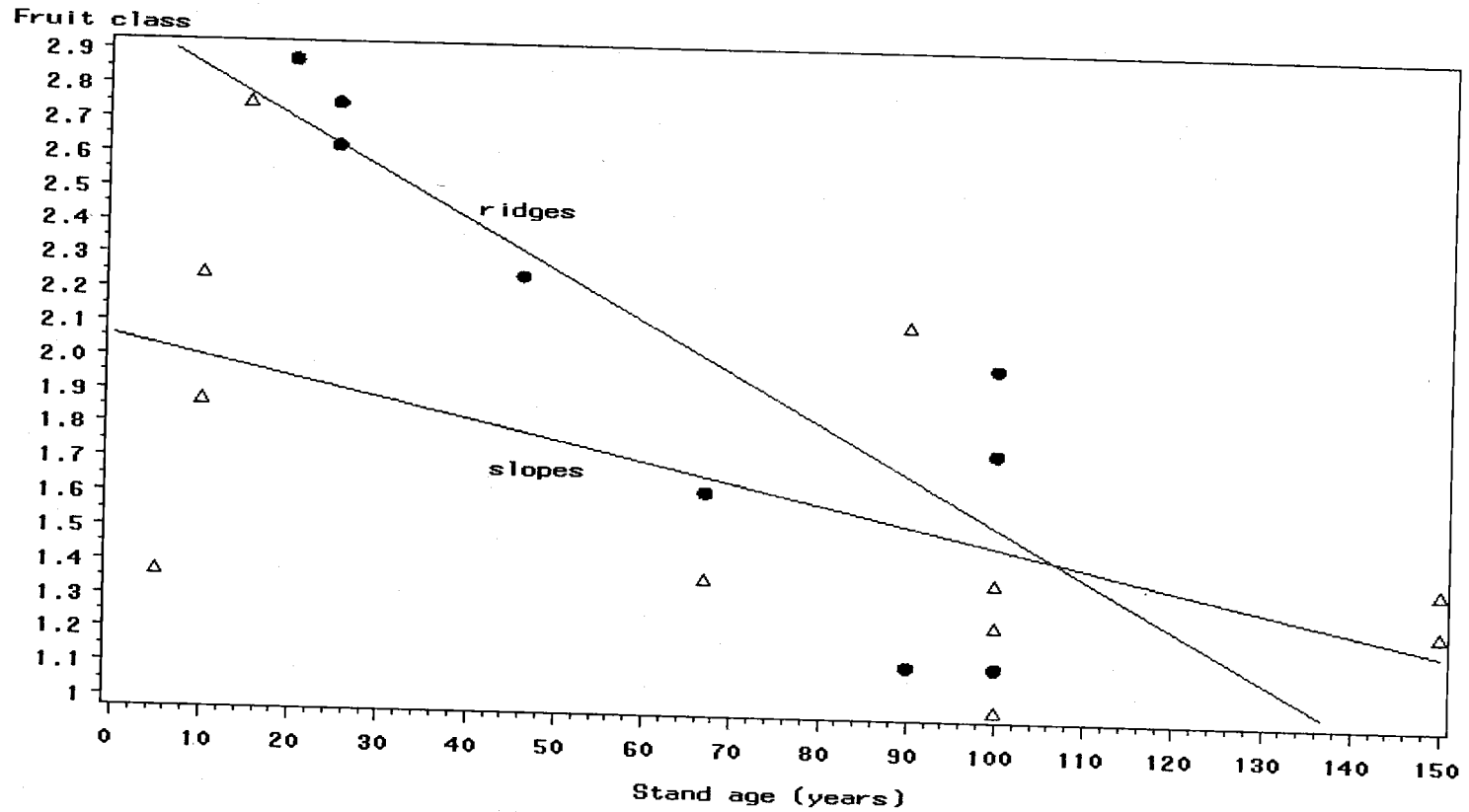


Figure 4.3 Multiple linear regression of fruit production class on stand age and topographical position. In huckleberry fields younger than 100 years old, fruit production is greater on ridges than on slopes.

competing understory species. Though fire history probably does not explain the higher fruit production and lower canopy cover found in ridgeline mechanical disturbance gaps, fire history may explain the high levels of fruit production frequently observed in very old ridgeline OBHF.

Using univariate analysis, huckleberry stem height was compared in fields having different topographical positions. Topographical position explained 47% of the variation in big huckleberry stem height ($F = 8.89$, $p = 0.002$). Big huckleberry shrubs were significantly taller on ridges than on slopes. Table 4.2 lists estimated huckleberry height by topographical position.

Martin (1979) found the opposite to be true for globe huckleberry (*V. globulare*) in Montana; ridgeline shrubs were generally shorter than shrubs located in other topographical positions. She suggested that stem buds were more subject to freeze kill on exposed ridges than on slopes, thereby reducing stem height. Furthermore, because soils are thinner on ridges than on lower slopes, Martin assumed that ridgeline soils did not support abundant huckleberry stem growth. Stark and Baker (1992) supported this view with observed associations between globe huckleberry stem height (and fruit production) and moist, fertile organic soils.

However, in this study, the thin soils and exposed environments of ridgeline huckleberry fields did not appear to limit the stem growth or fruit production of big huckleberry. In fact, big huckleberry shrubs were taller and produced more fruit on

Table 4.2 Mean huckleberry stem height in fields located on ridges and slopes.
Huckleberry stem height was significantly greater in ridgeline fields than in slope fields.*

<i>Topographical position</i>	<i>N</i>	<i>Huckleberry stem height (cm)</i>	
		<i>Mean</i>	<i>90% Confidence Interval</i>
Ridge	10	60 a	53-65
Slope	13	42 b	37-48

*Means followed by different letters are significantly different, $P = 10\%$.

ridges than on slopes. Unlike fruit production class, stem height was not associated with canopy cover in this study; therefore, the relationship between stem height and topography may not be related to canopy openness. Competition with associated vegetation may be less severe on ridges than on slopes, resulting in better vegetative growth despite thin soils. Thin soils may favor growth of big huckleberry by excluding the establishment of other plant species.

Huckleberry height and fruit production

In this study, huckleberry stem height was correlated with fruit production class (Pearson correlation coefficient = 0.45). The addition of sites y and x only strengthened the correlation between fruit production class and stem height (Pearson correlation coefficient = 0.65). This relationship is supported by the observations of Warm Springs ceremonial huckleberry pickers who have indicated that OBHF had a high proportion of tall huckleberry shrubs when they were harvested for berries. “... [M]y mother is five foot seven. I can remember her reaching up to pick huckleberries. You find me a huckleberry bush that high today.”¹

Studies of globe huckleberry in Montana have reported mixed results regarding the relationship between huckleberry fruit production and stem height. Martin (1979) did not find globe huckleberry fruit production to be correlated with stem height, but Stark and Baker (1992) did find a linear association between the two variables. Stark and Baker (1992) also found that high concentrations of soil

nutrients, particularly organic matter and manganese, were associated with globe huckleberry fruit production and stem height. A similar association between soil fertility, fruit production, and stem height may exist in the Cascades, explaining the correlation between fruit production class and stem height. However, the vigorous stem growth and fruit production observed on ridgeline huckleberry fields seems at odds with this hypothesis. Nevertheless, tall huckleberry stems may indicate sites with the potential for high fruit production during optimal stages of forest succession.

Huckleberry growth and elevation

Using simple linear regression, huckleberry fruit production class, leaf cover, and stem height were each regressed on elevation. Elevation was the only variable positively associated with huckleberry fruit production class ($R^2 = 0.15$, $F = 3.45$, $p = 0.078$), huckleberry stem height ($R^2 = 0.21$, $F = 5.59$, $p = 0.028$), and huckleberry leaf cover ($R^2 = 0.25$, $F = 7.11$, $p = 0.014$). In contrast, neither huckleberry fruit production, stem height, nor leaf cover was associated with percent slope or slope aspect. An estimated 450-m increase in elevation was associated with a one-unit increase in fruit production class ($t = 1.86$, $p = 0.078$). An estimated 15-m increase in elevation was associated with a one-cm increase in huckleberry stem height ($t = 2.36$, $p = 0.028$). And, an estimated 150-m increase in elevation was associated with a 10% increase in huckleberry leaf cover ($t = 7.11$, $p = 0.014$).

Table 4.3 Mean increase in elevation associated with unit increase in huckleberry variables. Elevation was the only environmental variable positively associated with huckleberry fruit production class, huckleberry stem height, and huckleberry leaf cover.

<i>Huckleberry Variables</i>	<i>Increase in Elevation (m)</i> <i>Associated with Unit Increase in Huckleberry Variables</i>	
	Mean	90% Confidence Interval
Fruit production class (one-unit increase)	450	230-3,720
Stem height (one-cm increase)	15	10-50
Leaf cover (10% increase)	150	100-500

There are several possible explanations for the observed relationships between elevation and huckleberry fruit production class, stem height, and leaf cover. First, greater levels of radiant energy available at higher elevations may result in higher rates of photosynthesis and sugar storage and, in turn, greater fruit production and vegetative growth. Second, big huckleberry stems are vulnerable to frost damage (Minore and Smart 1978); therefore, deep winter snow packs that develop at higher elevations may protect huckleberry stems from freezing temperatures. Shallow snow accumulations associated with lower elevations may expose stem tissue to freezing temperatures, causing stem dieback and resulting in shorter stems and lowered fruit production. Third, greater snow accumulations at higher elevations may equate to greater annual precipitation than associated with lower elevations. Martin (1979) noted that globe huckleberry stem height was positively associated with soil moisture (identified by plant associations). Similarly, big huckleberry stem height may be positively associated with precipitation and, therefore, elevation. Finally, the greater vigor of big huckleberry shrubs at higher elevations may be related to warming regional temperatures associated with global warming. The ecological range of big huckleberry may be gradually shifting to higher elevations with changing climatic conditions.

Associated vegetation

Using simple linear regression, huckleberry fruit production, stem height, and leaf cover were regressed on associated species constancy. Big huckleberry

fruit production class was positively associated with the constancy of fireweed ($R^2 = 0.37$, $F = 3.43$, $p = 0.006$), a shade-intolerant herb that colonizes recently disturbed soils (USDA Forest Service 2002). An estimated 50% (90% confidence interval = 34-100%) increase in fireweed constancy was associated with a one-unit increase in fruit production class ($t = 3.45$, $p = 0.003$). The association between big huckleberry fruit production class and fireweed constancy probably reflects the association between big huckleberry fruit production and open, disturbed environments as described in previous chapters.

In addition, huckleberry stem height was associated with dwarf bramble (*Rubus lasiococcus*) constancy ($R^2 = 0.29$, $F = 9.09$, $p = 0.008$). An estimated 5% (90% confidence interval = 3-11%) increase in dwarf bramble constancy was associated with a one-centimeter increase in huckleberry stem height ($t = 2.95$, $p = 0.008$). Linear regression of huckleberry stem height on dwarf bramble constancy is illustrated in Figure 4.4.

Dwarf bramble leaf cover was associated with big huckleberry biomass and fruit production in southern Washington (Dahlgreen 1984). Dwarf bramble may be a useful indicator species of potentially productive huckleberry fields in both the Oregon and Washington Cascade Range.

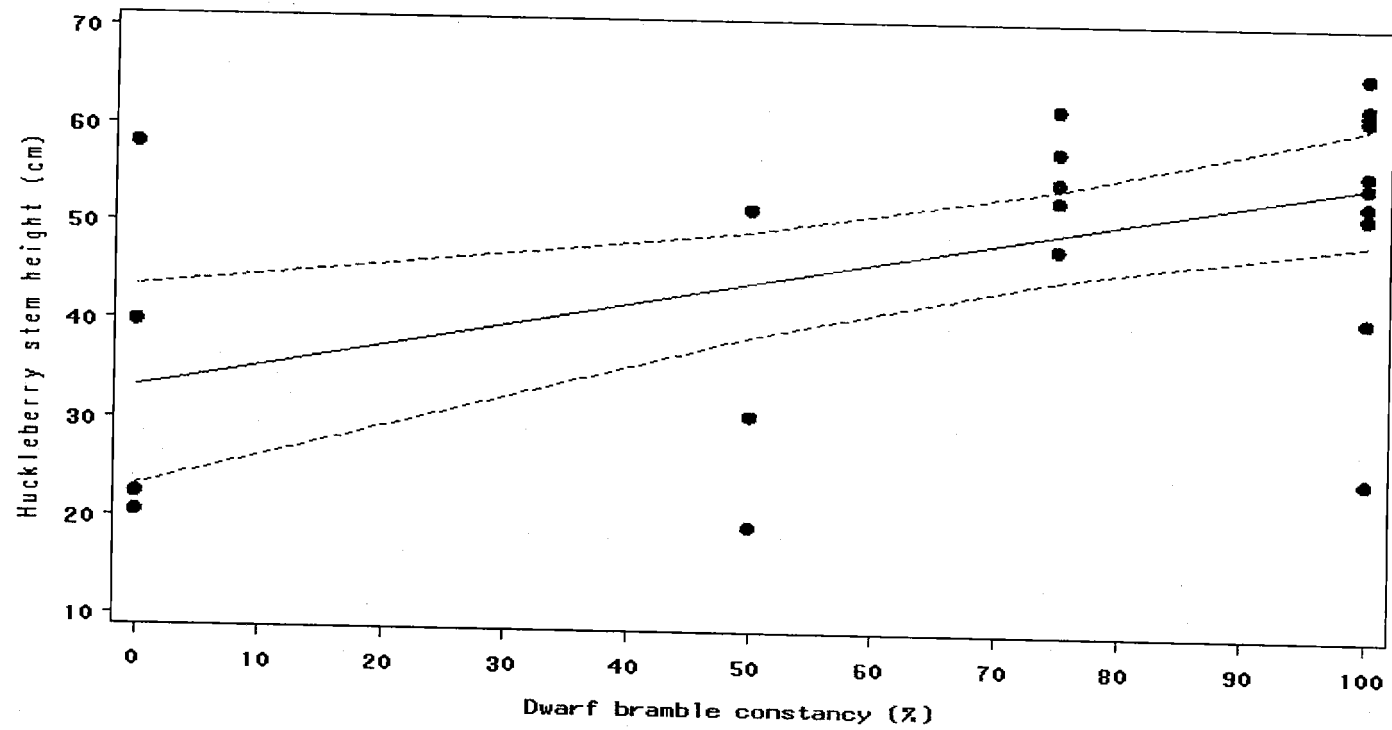


Figure 4.4 Regression of huckleberry stem height on the constancy of dwarf bramble (*Rubus lasiococcus*). Stem height is positively associated with the constancy of dwarf bramble.

CHAPTER 5. CONCLUSION

Big huckleberry, though remarkably tolerant of dark forest understories, apparently requires canopy-replacing disturbance in order to accumulate sufficient resources to initiate and complete sexual reproduction. The extensive range of big huckleberry attests to the periodicity of past disturbances across the landscape of the Cascade Range. Given that big huckleberry seedling establishment is rare, at least in the current climate, past disturbances must have occurred with a frequency that allowed both vigorous clonal expansion and occasional survival of seedling cohorts. Big huckleberry's considerable allocation to sexual reproduction despite the infrequency of seedling survival is curious. However, once an individual is established, it may live for several centuries and expand over a large area. Big huckleberry seeds are widely dispersed by animals and must occasionally be dropped in environments favorable to seedling survival. Perhaps the considerable effort of sexual reproduction is worth the establishment of seedlings every few centuries. Genetic studies may be able to elucidate the relative contributions of sexual versus asexual reproduction to big huckleberry regeneration.

Until the twentieth century, fires created and maintained the open environments in which big huckleberry initiated sexual reproduction. Huckleberry field fire regimes were an overlay of natural high-severity and culturally-maintained low-severity fire regimes. Infrequent stand-replacing wildfires destroyed all or most of the fire-sensitive trees as well as the above-ground parts of

understory plants such as big huckleberry. Fires may have been more likely to burn in areas supporting fire-adapted forest types like lodgepole pine stands. After fire, standing dead trees and islands of surviving trees were probably common in burned forest gaps. Wildfires regularly burned large areas. In these larger burns, rejuvenated huckleberry shrubs had time to recover and begin abundant fruit production well before pioneer trees shaded them out. As trees gradually invaded the more productive huckleberry fields, American Indians would ignite low-severity fires in late summer and early fall in order to destroy saplings and competing vegetation. American Indian involvement in huckleberry field disturbance regimes favored the sexual reproduction of big huckleberry. However, it is uncertain for how many hundreds or thousands of years human involvement was part of huckleberry field disturbance regimes and how large an ecological impact Indian involvement had on the evolutionary success of big huckleberry.

In the present era of fire suppression, subalpine forests are not yet outside their natural range of variability, and big huckleberry appears to be tolerant of extended periods in mature forest understories. However, the continuance of big huckleberry as a dominant understory species in Cascade Range forests requires periodic canopy-replacing disturbance. Modern mechanical disturbances may not be an effective ecological substitute for past fire regimes.

Clearcut timber harvests, though perhaps most closely resembling historic high-severity fires, are still quite different from past wildfires. Clearcut timber harvests are conducted over relatively limited geographical area and typically in

forest types not adapted to fire disturbance. Disturbance severity is fairly uniform throughout harvest units, and all standing live and dead trees are removed.

Scarification of surface soils by harvesting machinery may favor the establishment of weedy forbs over the expansion of fire-adapted clonal species such as big huckleberry. Perhaps most importantly, clearcut timber harvests are not followed with frequent low-severity fires, rather they are followed with reseeding or planting efforts aimed at rapid canopy closure.

Shelterwood timber harvests, unlike past stand-replacing fires and low-severity maintenance fires, are moderate-severity disturbances. There are other ways in which shelterwood harvests are dissimilar to past fires. The understory is not burned, and unharvested trees are left fairly evenly spaced throughout harvest units. Scarification from piling machinery may favor the establishment of weedy forbs over clonal shrubs. Though shelterwood timber harvesting may provide big huckleberry with an opportunity for sexual reproduction, overstory canopies of harvest units probably reclose quickly due to the release of understory saplings and the establishment of conifers from seeds released by unharvested trees. Finally, shelterwood harvest units, like clearcut harvest units, are not maintained with low-severity disturbances subsequent to harvest.

Repeated manual forest clearing for recreational areas and utility rights-of-way is, like past Indian burning practices, a low-severity disturbance regime. However, forest clearing disturbances are also different than past fires. Understory

plant communities are not burned, and the disturbance gaps created are small and uniformly shaped.

Research is needed to compare the ecological effects of fire and mechanical disturbances. Fire suppression is still the norm, but concerns about the risk of wildfire due to fire suppression are on the rise. Determining efficient mechanical disturbances that can fill the ecological void left by fire is critically important for big huckleberry and for subalpine forests in general. Many questions must be answered. For example, can mechanical disturbances be made to mimic the effects of wildfire? Is prescribed burning an ecological substitute for high-severity fires? For low-severity fires? What are the ecological functions of forest edges for understory plant species such as big huckleberry? How important are partial canopies to big huckleberry fruit production and growth?

In addition, understanding the ecological factors that slow conifer regeneration and allow the establishment of semi-stable shrub fields may aid forest managers in the future creation of productive huckleberry fields. For example, do established shrub fields resist conifer invasion or do shrub fields develop in areas where conifer regeneration is low or absent for other reasons?

In this study, ridges supported greater huckleberry fruit production and stem growth despite their presumably thin soils. This observation raises the question of the relative importance of canopy cover, soil fertility and moisture, and competition with associated vegetation to huckleberry growth and fruit production.

Furthermore, one small huckleberry field located on an old burn had high fruit production and high overstory canopy cover. Does this indicate that soil fertility may overcome the negative influence of canopy cover? Or, are there areas on the landscape that will support exceptionally high levels of fruit production during optimal seral stages? Research that addresses these questions may help guide the selection of sites for the establishment of huckleberry fields.

Finally, what does the improved growth and fruit production of big huckleberry with increasing elevation tell us? Are other montane plants species more successful at higher elevations and, if so, why? If global warming is causing species range shifts, what aspects of plant growth are useful indicators of these shifts?

It has been suggested by Warm Springs elders that big huckleberry is an indicator species, that declines in huckleberry fruit production may indicate a decline in forest health. While the results of this study do not suggest that big huckleberry fruit production is associated with “healthy” forests, I do believe the loss of productive huckleberry fields across the landscape is indicative of revolutionary changes in the dominant human culture. For countless centuries humans have played a part in shaping the disturbance-regimes and, thereby, the forests of the Cascade Range, and they will continue to do so in the future. Interactions between humans and Cascade Range forests have altered radically over the last 100+ years. The fruit production of big huckleberry reflects these changes.

LITERATURE CITED

- Aalders LE., Hall IV., Forsyth FR. 1969. Effects of partial defoliation and light intensity on fruit-set and berry development in the lowbush blueberry. *Horticultural Research* 9: 124-129.
- Agee JK, Finney M., de Gouvenain R. 1990. Forest history of Desolation Peak, Washington. *Canadian journal of Forest Research* 20: 350-356.
- Alaback PB., Tappeiner JC. 1991. Response of western hemlock (*Tsuga heterophylla*) and early huckleberry (*Vaccinium ovalifolium*) seedlings to forest windthrow. *Canadian Journal of Forest Research* 21: 534-539.
- Atlegrim O., Sjoberg K. 1996. Response of bilberry (*Vaccinium myrtillus*) to clear-cutting and single-tree selection harvests in uneven-ages boreal *Picea abies* forests. *Forest Ecology and Management* 86: 39-50.
- Barney DL. 1999. How to grow and use western huckleberries. Sandpoint Research and Extension Center, University of Idaho. Available: <http://www.uidaho.edu/~sandpoint/hucklebe.htm> [Accessed 6/2000]
- Biging GS., Dobbertin M. 1992. A comparison of distance-dependent competition measures for height and basal area growth of individual conifer trees. *Forest Science* 38(3): 695-720.
- Bork JL. 1984. Fire history in three vegetation types on the east side of the Oregon Cascades. PhD. Dissertation. Corvallis (OR): Oregon State University. 94 p.
- Boyd R. 1996. People of the Dalles: the Indians of the Wascopom Mission. Lincoln (NE): University of Nebraska Press. 396 p.
- Brockway DG., Topik C., Hemstrom MA., Emmingham WH. 1983. Plant association management guide for the Pacific silver fir zone: Gifford Pinchot National Forest. R6-Ecol-130a-1983. Portland (OR): Pacific Northwest Region, USDA Forest Service. 122 p.

- Burke CJ. 1979. Historic fires in the central western Cascades, Oregon. M.S. thesis. Corvallis (OR): Oregon State University. 130 p.
- Camp W.H. 1942. A survey of the American species of *Vaccinium* subgenus *Euvaccinium*. *Brittonia* 4: 205-247.
- Canfield RH. 1941. Application of the line intercept method in sampling range vegetation. *Journal of Forestry* 39: 388-394.
- Cooper JG. 1860. Reports of explorations and surveys to ascertain the most practicable route for a railroad from the Mississippi River to the Pacific Ocean. Executive Document, Senate, 36th Congress, 1st Session. Washington D.C.: Thomas H. Ford, Printer.
- Cwynar L. 1987. fire and forest history of the North Cascade Range. *Ecology* 68(4): 791-802.
- Dahlgreen MC. 1984. Observations on the ecology of *Vaccinium membranaceum* Dougl. on the southeast slope of the Washington Cascades. M.S. thesis. Seattle (WA): University of Washington. 120 p.
- Darnell RL, Birkhold KB. 1996. Carbohydrate contribution to fruit development in two phenologically distinct rabbiteye blueberry cultivars. *HortScience*. 121(6): 1132-1136.
- Daubenmire R. 1968. Plant communities: a textbook of synecology. New York (NY): Harper & Row, Publishers. 300 p.
- Davis J., silviculturist and Warm Springs Indian Reservation liaison, Mt. Hood National Forest [former]. June 2000. Personal communication.
- Dickman A., Cook S. 1989. fire and fungus in a mountain hemlock forest. *Canadian Journal of Botany* 67: 2005-2016.
- Filloon RM. 1952. Huckleberry pilgrimage. *Pacific Discovery* (May-June 1952): 4-13.
- Fisher AH. 1997. The 1932 Handshake Agreement: Yakima Indian treaty rights and forest service policy in the Pacific Northwest. *Western Historical Quarterly* (summer 1997): 187-217.

- Fowells HA. (ed.) 1965. *Silvics of Forest Trees of the United States*. USDA Agricultural Handbook No. 271. Washington D.C. 762 p.
- Franklin JF., Dryness CT. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8. Portland (OR): Pacific Forest and Range Experiment Station. 417 p.
- French D. 1961. Studies in the acculturation of the Wasco-Wishram. In Spicer H. (ed.) *Perspectives in American Indian Culture Change*. Chicago (IL): University of Chicago Press. 549 p.
- 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): Oregon State University Press. 313 p.
- Haeussler S., Coates D. 1986. Autecological characteristics of select species that compete with conifers in British Columbia: a literature review and Management Report 33. Victoria, (BC): Canadian Forestry Service and BC Ministry of forests and Lands. 180 p.
- Hall IV., Ludwig RA. 1961. The effects of photoperiod, temperature, and light intensity on the growth of the lowbush blueberry (*Vaccinium angustifolium* Ait.) *Canadian Journal of Botany* 39: 1733-1739.
- Halverson NM., Emmingham WH. 1982. Reforestation in the Cascades Pacific silver fir zone: a survey of sites and management experiences on the Gifford Pinchot, Mt. Hood, and Willamette National Forests. USDA Forest Service R6-ECOL-091-1982. Portland (OR): Pacific Northwest Region, Mt. Hood National Forest. 34 p.
- Hemstrom MA., Emmingham WH. 1982. Plant association and management guide for the Pacific silver fir zone, Mt. Hood and Willamette National Forests. USDA Forest Service R6-Ecol-100-1982a. Portland (OR): USDA Forest Service, Pacific Northwest Region. 37 p.
- Hemstrom MA., Franklin JF. 1982. Fire and other disturbances of the forests in Mt. Rainier National Park. *Quaternary Research* 18: 32-51.

- Hitchcock CL., Cronquist A. 1976. Flora of the Pacific Northwest: an illustrated manual. Seattle (WA): University of Washington Press. 730 p.
- Hoefs MEG., Shay JM. 1981. The effects of shade on shoot growth of *Vaccinium angustifolium* Ait. After fire pruning in southeastern Manitoba. Canadian Journal of Botany 59: 166-174.
- Holloway PS., Van Veldhuizen RM., Stuchoff C., Wildung DK. 1982. Effects of light intensity on vegetative growth of lingonberries. Canadian Journal of Plant Science 62: 965-968.
- Howes S. 1979. Soil resource inventory. USDA Forest Service, Pacific Northwest Region, Mt. Hood National Forest. Sandy (OR): Mt. Hood National Forest Headquarters. 312 p.
- Hunn ES. 1982. Mobility and resource use: Columbia Plateau. In Williams NM., Hunn ES. (eds.) Resource Managers: North American and Australian hunter-gathers. American Association for the Advancement of Science Selected symposia Series # 67. 267 p.
- Hunn ES., Norton HH. 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.
- Hunn ES. with Selan J. and family. 1990. Nch'i-Wána "The Big River" Mid-Columbia Indians and their land. Seattle (WA): University of Washington Press. 378 p.
- Janke RA. 1968. The ecology of *Vaccinium myrtillus* using concepts of productivity, energy exchange, and transpiration. PhD. Dissertation. Boulder (CO): University of Colorado. 109 p.
- Karlsson PS. 1985. Patterns of carbon allocation above ground in a deciduous (*Vaccinium uliginosum*) and an evergreen (*Vaccinium vitis-idaea*) dwarf shrub. Physiological Plant Pathology 63: 1-7.
- Kautz EW. 1987. Prescribed fire in blueberry management. Fire Management Notes 48(3): 9-12.
- Krusemark F., Agee JK., Berry D. 1996. The history of fire in the Bull Run watershed, Oregon. Final Report on the supplemental Agreement PNW-92-0225 between USDA Forest Service and University of Washington.

- Lotan JE., Brown JK., Neuenschwander LF. 1984. The role of fire in lodgepole pine forests. In Baumgartner DM., Krebill RG., Arnott JT., Weetman GF. (eds.) Lodgepole Pine: the species and its management. Spokane (WA): Symposium Proceedings: 133-152.
- Mack, CA. 2001. A burning issue: native use of fire in the Mount Rainier Forest Reserve. Paper presentation. Durango (CO): Society of Ethnobiology Meeting, March 7-9, 2001. 5 p. Available from Mt. Adams Ranger District, Gifford Pinchot National Forest.
- Martin PAE. 1979. Productivity and taxonomy of the *Vaccinium globulare*, *Vaccinium membranaceum* complex in western Montana. Master's thesis. Missoula (MT): University of Montana. 136 p.
- Martinez J. Unpublished. Huckleberries--a renewable resource: an historical perspective with management implications. Duvall (WA): Washington Institute Inc. Available from Mt. Adams Ranger District, Gifford Pinchot National Forest.
- Miller M. 1977. Response of blue huckleberry to prescribed fires in a western Montana larch-fir forest. USDA Forest Service Research Paper INT-188. Ogden (UT): Intermountain Forest and Range Experiment Station. 33p.
- Minor R., Pecor AF. 1977. Cultural overview of the Willamette National Forest, western Oregon. University of Oregon anthropological Papers #12.
- Minore D. 1972. The wild huckleberries of Oregon and Washington: a dwindling resource. USDA Forest Service Research Paper PNW-143. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 20 p.
- Minore D. 1975. Observations on the rhizomes and roots of *Vaccinium membranaceum*. USDA Forest Service Research Note PNW-261. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 5 p.
- Minore D. 1979. Comparative autecological characteristics of northwestern tree species: a literature review. USDA Forest Service General Technical Report PNW-87. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 72 p.

- Minore D. 1984. *Vaccinium membranaceum* berry production seven years after treatment to reduce overstory tree canopies. Northwest Science 58(3): 208-212.
- Minore D., USDA Forest Service research scientist, Pacific Northwest Forest and Range Experiment Station [former]. January 2001. Personal communication.
- Minore D., Dubrasich ME. 1978. Big huckleberry abundance as related to environment and associated vegetation near Mt. Adams, Washington. USDA Forest Service Research Note PNW-322. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 8 p.
- Minore D., Smart AW. 1975. Sweetness of huckleberries near Mt. Adams, Washington. USDA Forest Service Research Note PNW-248. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 4 p.
- Minore D., Smart AW. 1978. Frost tolerance in seedlings of *Vaccinium membranaceum*, *V. globulare*, and *V. deliciosum*. Northwest Science 52(3):179-185.
- Minore D., Smart AW., Dubrasich ME. 1979. Huckleberry ecology and management research in the Pacific Northwest. USDA Forest Service General Technical Report PNW-93. Portland (OR): Pacific Northwest Forest and Range Experiment Station. Portland, Oregon. 50 p.
- Moola FM., Mallik AU. 1998. Morphological plasticity and regeneration strategies of velvet leaf blueberry (*Vaccinium myrtilloides* Michx.) following canopy disturbance in boreal mixedwood forests. Forest Ecology and Management 111: 35-50.
- Morgan P. 1984. Modeling shrub succession following clearcutting and burning. PhD. Dissertation. Moscow (ID): University of Idaho. 146 p.
- Morrison PH., Swanson FJ. 1990. Fire history and pattern in a Cascade Range landscape. USDA Forest Service General Technical Report PNW-GTR-254. Portland (OR): Pacific Northwest Forest and Range Experiment Station. 77 p.
- Murdock GP. 1938. Notes on the Tenino, Molala, and Piute of Oregon. American Anthropologist 40: 395-402.

- Niesenbaum RA. 1993. Light or pollen—seasonal limitations on female reproductive success in the understory shrub *Lindera benzoin*. *Journal of Ecology* 81: 315-323.
- Oliver CD., Larson BC. 1996. *Forest Stand Dynamics*. Update edition. New York (NY): John Wiley & Sons, Inc. 520 p.
- Rich PM. 1989. A manual for analysis of hemispherical canopy photography. Los Alamos National Laboratory Report LA-11733-M. Los Alamos (NM): Los Alamos National Laboratory. Available: <http://www.hemisoft.com> [accessed 7/2001]
- Roper TR., Klueh JS. 1994. Removing new growth reduces fruiting in cranberry. *HortScience* 29(3): 199-201.
- Roper TR., Klueh JS. 1996. Movement of carbon from source to sink in cranberry. *HortScience* 121(5): 846-847.
- Shaffer SC. 1971. Some ecological relationships of grizzly bears and black bears of the Apgar Mountains in Glacier National Park, Montana. Master's thesis. Missoula (MT): University of Montana. 133 p.
- Shannon T., silviculturist, Mt. Hood National Forest. March 2001. Personal communication.
- Stark N., Baker S. 1992. The ecology and culture of Montana huckleberries: a guide for growers and researchers. Misc. Publication 52. Missoula (MT): Montana Forest and Conservation Experiment Station and School of Forestry, University of Montana. 87 p.
- Stephenson AG. 1981. Flower and fruit abortion: proximate causes and ultimate functions. *Annual Review of Ecology and Systematics* 12: 253-279.
- USDA Forest Service. 1937. *Range Plant Handbook*. Washington D.C. 532 p.
- USDA Forest Service. 1995. *Salmon River Watershed Analysis*, Mt. Hood National Forest. First Iteration. Portland (OR): Pacific Northwest Region, USDA Forest Service.

- USDA Forest Service, 2002. Fire Effects Information [online]. Rocky Mountain Research Station, Fire Sciences Laboratory. Available: <http://www.fs.fed.us/database/feis> [Accessed 5/2002.]
- Weisberg PJ. 1998. Fire history, fire regimes, and development of forest structure in the central western Oregon Cascades. PhD. Dissertation. Corvallis (OR): Oregon State University. 256 p.
- White JD., Haglund JC., Mellen TK. 1996. Early seral plant communities: Pacific silver fir zone, Mt. Hood National Forest. USDA Forest Service R6-NR-TP-16-96. Portland (OR): Pacific Northwest Region, USDA Forest Service.
- Zyback B. 1993. Native forests of the Northwest, 1788-1856: American Indians, cultural fire, and wildlife habitat. Northwest Woodlands (Spring 1993): 10-11, 31.