
**Effects of the Biscuit Fire on
Frasera umpquaensis
on the Medford District BLM**

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Final Report

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PREFACE

This report is the result of a cooperative Challenge Cost Share project between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization dedicated to natural resource conservation, research, and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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INTRODUCTION

Umpqua gentian (*Frasera umpquaensis*) is a rare plant of gaps and forested habitats ranging from the central western Cascade Mountains of Oregon south to the Klamath Mountains in northwestern California (Meinke 1982). It is a candidate for endangered species listing by the Oregon Department of Agriculture (ODA) and is listed as a Species of Concern with the US Fish and Wildlife Service and as endangered throughout its range by the Oregon Natural Heritage Program (ORNHC 2004). It is managed as a Special Status Species by the Bureau of Land Management (BLM) and occurs on five National Forests and two BLM Districts. A joint U.S. Forest Service and BLM Conservation Strategy for the species was developed in 1993, with a primary objective of maintaining viable, genetically stable populations of the species over time throughout its range (Cripps 1993).

The Biscuit Fire of 2002 burned several *F. umpquaensis* populations on federal lands, including three populations on the Medford District BLM that have been monitored annually since 1995. Prior to this event, no information was available on the effect of fire on this species. The presence of long-term pre-fire data on *F. umpquaensis* and associated forest canopy at these monitoring sites provided an opportunity to detect changes in populations of this species associated with the 2002 Biscuit Fire. The Conservation Strategy for the species recommends studies of this type to determine its response to disturbance. Initial assessments following the fire showed that the



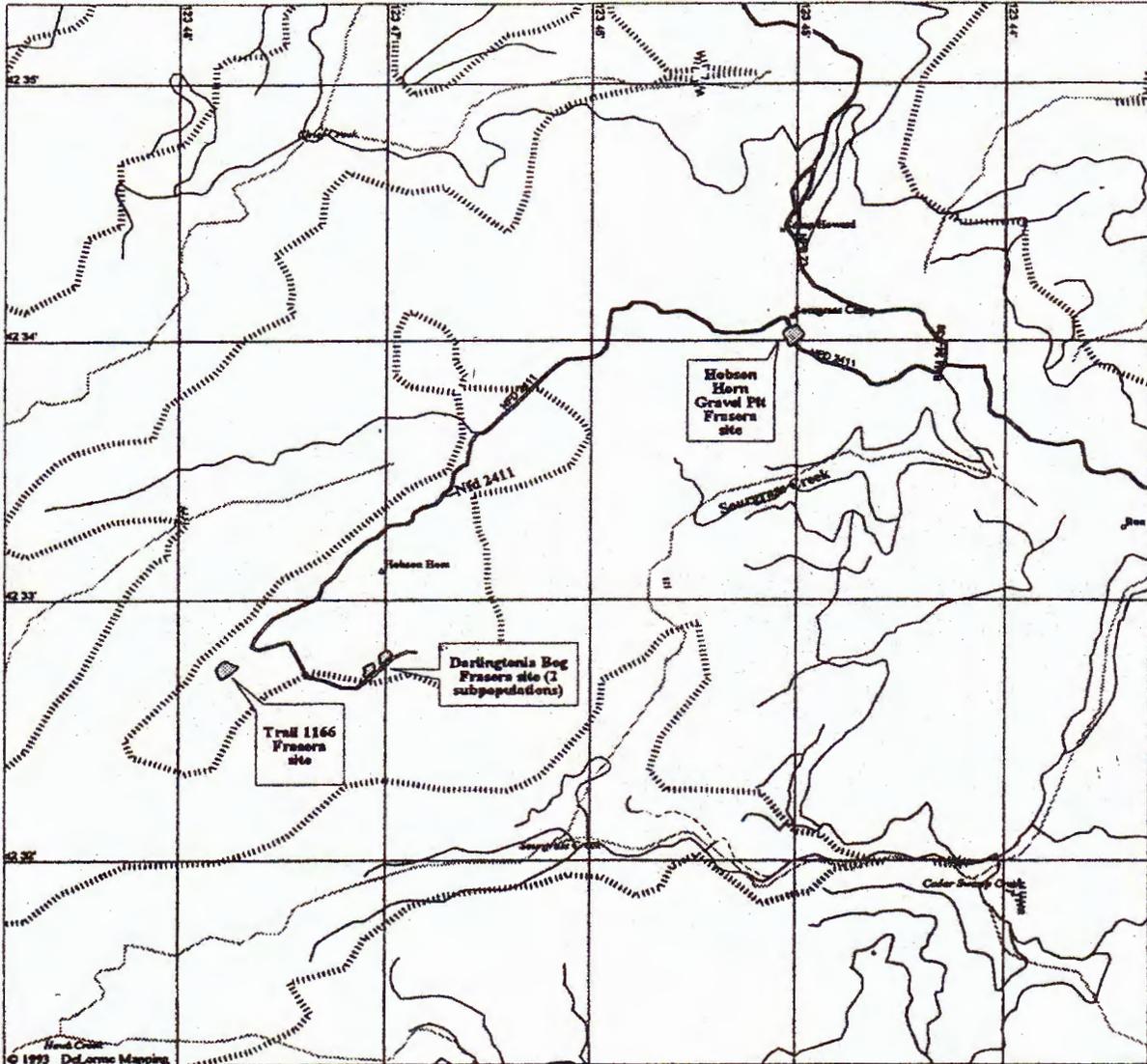
Figure 1. Burning during the 2002 Biscuit Fire was patchy, as seen in this habitat in the northern Siskiyou Mountains (June, 2003).

population areas experienced a broad range of burn severity, from overall low severity at one site to moderate at a second and high severity at a third. This severity not only varied between sites but also within each site (Figure 1). Char and scorch heights as well as combustion of the duff layer varied from none to complete combustion of the duff layer and tree mortality. First order fire effects to individual *F. umpquaensis* plants varied from no scorch to light/moderate scorch to complete combustion of above ground vegetative material and rhizomes.

Fire has the potential to negatively affect *F. umpquaensis* by damaging above-ground

parts and/or killing its shallow rhizomes. Alternatively, habitat burning could improve conditions for the species by creating openings in its habitat that increase light availability and seed bed abundance, and by stimulating plant growth through a short-term pulse of nutrients. Considering the species persists in a fire regime that historically was subject to frequent, low intensity burns, it most likely evolved to tolerate natural fire. However, recent fire frequencies have been low resulting in excess fuel build up, so that local fire conditions may be more intense than might have been expected under historic conditions and could negatively affect the species. Without knowledge of the effects of fire on *F. umpquaensis*, land managers are left without clear information with which to manage fire in landscapes where this species is present. Specifically, information is needed to determine if controlling fire in the species' habitat is necessary for its survival or, alternatively, if wildfire can be allowed to burn through the species habitat. In addition, prescribed burning may be a tool for improving conditions for the species and information on the response of wild populations to fire will help inform managers about this practice. Information on the effects of fire gained from the monitoring sites on the Medford District BLM is applicable to other populations on federal lands and may be used to update the existing Conservation Strategy.

This report documents *F. umpquaensis* monitoring methods and ten-year trends (1995-2004) at multiple sites (Figure 1) on the Medford District BLM. Monitoring plots were established by ODA staff in 1995 (Kaye 1995) and have been monitored by ODA, BLM, and the Institute for Applied Ecology. We examine several effects of the 2002 Biscuit Fire at the monitoring sites, including general post-fire population trends, change in *F. umpquaensis* populations as a function of habitat area burned, post-fire differences in individual plant sizes, seedling recruitment patterns, and change in forest canopy cover.



- LEGEND**
- o Geo Feature
 - △ Hill
 - Street, Road
 - - - Trails
 - == Major Street/Road
 - ~~~~ River
 - ||||| Contour

Scale 1:37,500 (at center)

2000 Feet

1000 Meters

Fraseria umpquaensis monitoring sites
 Mag 14.00
 Thu Sep 14 10:18:43 1995

Figure 2. Map showing relative locations of the three *Fraseria umpquaensis* monitoring sites on the BLM Medford District. Sketch maps of each site, with monitoring plot details, are located in Appendix I.

METHODS

Monitoring Protocol

Population monitoring of *Frasera umpquaensis* was initiated at three sites on the Medford District in 1995 (Figure 2, Appendix I). Monitoring was conducted at the Darlingtonia Bog and Trail 1166 sites every year from 1995-2004 and at the Gravel Pit site every year except 1996. Monitoring consisted of counting the number of *Frasera* plants present within each established plot and recording the number and phenological condition of basal rosettes of each plant. A basal rosette was defined as an individual cluster of leaves arising from a single rhizome (which may be connected to a larger root system). Phenological stages were defined as: seedling (very small plant with four or fewer leaves, Figure 3), vegetative (no flowering stalk present), and reproductive (flowering stalk present). Plants other than seedlings were labeled as vegetative if they possessed no flowering stalks and reproductive if they possessed at least one. These definitions are consistent with monitoring elsewhere in the range of the species (Cripps, 1993).



Figure 3. *Frasera umpquaensis* seedlings and small vegetative plants at the Gravel Pit site.

Distinguishing individual *Frasera* plants can be difficult, especially in areas of high plant density. To minimize investigator errors in population estimates from year to year, the following standard of distinguishing individual plants was recommended on the Medford District: rosettes are considered belonging to one plant if 1) aboveground they clearly appear to join one root system, 2) gentle probing in the upper 2-4 cm of soil detects a rhizome connection between them, or 3) they are located within 20 cm of each other.

Monitoring Sites

Darlingtonia Bog site

This site contained two subpopulations, 1 and 2. Subpopulation 1 was distributed as two patches, each circumscribed by a rectangular plot, 1A (Figure 4) and 1B. Plot 1A was approximately 9 x 12 m and plot 1B 8 x 16 m. All plot corners were marked with 5-ft lengths of galvanized conduit that were flagged and labeled with black felt-tip pen (indelible ink). A complete census of *Frasera* plants was taken in each plot in each year. A single 20 x 30 m plot (plot 2) encompassed subpopulation 2 and was marked with conduit posts in each corner and at 10-m intervals. To simplify monitoring, the plot was broken into twelve 5 x 10 m subplots in which a complete census was taken in each year, with all subplot data being combined for analysis. Subplot data was also useful in detecting large-scale shifts in the distribution of plants within the habitat area.



Figure 4. Plot 1A at the Darlingtonia Bog site (6/03) one year after the Biscuit Fire.

Trail 1166 site

This site (Figure 5) contained two plots: plot 1 was a 45 x 60 m rectangular plot encompassing most of the plants in the immediate vicinity and plot 2 was a circular plot with a 6 m radius containing a satellite patch of *Frasera* plants. The corners of plot 1 were marked with 5-ft lengths of galvanized conduit that were flagged and labeled with black felt-tip pen (indelible ink). To simplify monitoring, plot 1 was divided into twelve 5 x 45 m subplots delineated by rebar posts placed at 5-m intervals along the 60 m sides of the plot. A complete census was taken in each subplot in each year, with all subplot data combined for analysis. Subplot data was also useful in detecting large-scale shifts in the distribution of the plants in the habitat area. Data was also taken on two small groups of *Frasera*



Figure 5. Trail 1166 site (6/03).

plants located near plot 1 that were discovered in 1995—one on the ridge-top north of subplot 1 (three plants) and one west of plot 1 about 30 paces (four plants). These plants are included in the plot 1 census. Plot 2 was marked in the center with a flagged conduit post and a complete census of plants within 6 m of the conduit was taken in each year.

Gravel Pit site

This site contained four types of plots to encompass all of the scattered plants located there: the Large Plot (Figure 6), Patches 1-9, Roadside Patch, and Meadow Patches 1 (Figure 7) and 2. The Large Plot was 30 x 37 m, encompassing most of the plants in the high density patch and marked at the corners with 5-ft lengths of galvanized conduit that were flagged and labeled with black felt-tip pen (indelible ink). The plants in this area appeared to be concentrated in an area subjected to some disturbance in the past from logging followed by gravel pit activity—a skid road passes through the area and



Figure 6. Gravel Pit site, Large Plot (6/03), one year after the Biscuit Fire. Note patchy mortality of vegetation.

most plants occurred along it. The Large Plot was broken into 76-1 x 15 m subplots, 20 of which were randomly chosen for sampling and marked with a rebar post at each end. The subplots originate from the plot's central north-south axis and extend east or west for 15 m. Subplots are identified by the meter from which they originate along the central axis (0 to 37, from north to south) and the direction in which they extend (east or west perpendicular to the central axis). For example, subplot "17E" originates 17 m south along the central axis and extends 15 m to the east of it. A complete census was taken in each subplot and a mean density of plants per subplot was calculated in each year. The mean density was then used to estimate the total number of plants (with 95% confidence intervals) within the plot by multiplying by the total number of subplots.

A total of nine scattered patches of *Frasera* plants were located in the vicinity of the Large Plot, two of which were within it. The patches were numbered and flagged, with the patch number marked on the flagging with indelible ink. Four of these patches (#5, 6, 7, and 8) were randomly chosen and censused in 1995. All patches outside of the Large Plot (#1-2 and 5-9) were

censused in 1997-2004.

The Roadside Patch was immediately adjacent to the main road and marked by flagging at both ends and conduit posts at the northwest and southeast limits. One plant located southeast of the patch was flagged and included in the patch census. A complete census of the patch was taken in each year.



Figure 7. Meadow Patch 1 at Gravel Pit site (6/03).

Two *Frasera* patches were located across the road from the other plots in a meadow area and identified as Meadow Patches 1 and 2. Both were close to the road and flagged. Meadow Patch 1 was among three large (4-ft diam) stumps and Meadow Patch 2 was alongside and beneath shrubs of *Arctostaphylos* spp. on the south side of a patch of trees. A complete census of each patch was taken in each year.

Fire Effects on *Frasera umpquaensis* Populations



Figure 8. Charred duff on the soil surface was the predominant evidence of fire for determining area of habitat burned at each plot.

In 2003, general observations of the Biscuit Fire's effects at the monitoring sites were recorded and the percent area burned in each plot was estimated. Area burned was determined by observing the extent of charred duff (Figure 8) and burned plant material in each monitored population unit (plot or patch). At the Darlingtonia Bog site, percent area burned was estimated for plots 1A and 1B overall; percent area burned was estimated for each subplot of plot 2 and averaged for the overall plot estimate. At the Trail 1166 site, three 5 x 5 m plots were placed randomly within each subplot of plot 1 and percent area burned within these plots was estimated and averaged for the overall plot estimate. In the

Gravel Pit Large Plot, percent area burned was estimated for each of the sampled subplots and averaged for the overall Large Plot estimate. Five 1 x 1 m plots were placed randomly in Patches 1-9 and Meadow Patches 1 and 2 and percent area burned within these plots was estimated and averaged for the overall plot estimate. Five 5 x 7 m plots were placed randomly in the Roadside patch and percent area burned within these plots was estimated and averaged for the overall plot estimate. Linear regression was used to analyze the effects of plot area burned on four parameters: 1) percent population change of vegetative and reproductive *Frasera* plants combined from 2002 to 2003 and 2002 to 2004; 2) change in proportion of plants with one rosette ("V1" plants) from 2002 to 2003 and 2002 to 2004; 3) change in proportion of flowering plants from 2001 to 2003; and 4) seedling densities in 2003 and 2004.

Burned vs. Unburned Plants

To compare plant survival and growth of plants in burned habitat with undamaged plants, we marked twenty-seven *Frasera umpquaensis* plants (17 in the Large Plot, 2 in Patch 6, and 5 in Meadow Patch 2 at the Gravel Pit site, and 3 in plot 1 at the Trail 1166 site) with numbered wooden stakes in 2003, one year after the fire. Fourteen of these plants were damaged by the Biscuit Fire in 2002 and 13 were not. The number of vegetative and reproductive rosettes were

counted and the diameter of each rosette, length of the longest leaf of each rosette, and height (of flowering stalks in 2003, maximum vegetative or reproductive height in 2004) were measured for each marked plant in 2003 and 2004. One burned plant was removed from the study because it was considered dead in both years. Plant measurements were compared with two-way ANOVA with burned status and year as factors.



Figure 10. After the Biscuit Fire, burned (left) and unburned plants (right) were tagged and measured in 2003 and 2004.

Forest Canopy Coverage

A spherical densiometer (with convex mirror) was used to measure canopy coverage over monitoring plots at the Darlingtonia Bog and Trail 1166 sites in 1997, 2003, and 2004 and at the Gravel Pit Large Plot in 2003 and 2004. For each rectangular plot at the Darlingtonia Bog and Trail 1166 sites, densiometer readings were recorded in each of the plot corners and the plot center (located by crossing meter tapes from opposite corners). For plot 2 at the Trail 1166 site, densiometer readings were taken at the plot's center only. In the Gravel Pit Large Plot, densiometer readings were taken at each plot corner, the northern end of the plot's central axis, and the edges of several sampled subplots (11W end, 12E origin and end, 26E/26W origin, 26E end, 26W end, and 37E origin). For each measuring position, four densiometer readings were taken (facing north, south, east, and west), averaged, and multiplied by 1.04 to convert the readings to canopy coverage (as recommended by the densiometer manufacturer). The mean

canopy coverage for each plot was determined by averaging the canopy coverage of all the plot's measuring locations. The differences in canopy coverage before and after the Biscuit Fire at the Darlingtonia Bog and Trail 1166 sites were analyzed using one-tail paired t-tests.

RESULTS

Ten-Year Population Trends

Before the Biscuit Fire (1995-2002)

Population fluctuation was observed at all three monitoring sites before the Biscuit Fire, with only one serious decline documented (Figures 11-13). The population at the Darlingtonia Bog site declined more than 30% from 2000 to 2001, an amount considered substantial by the *Frasera* Conservation Strategy (Cripps 1993). The populations of vegetative and reproductive plants combined were at their highest in 1998 at the Trail 1166 site and 1999 at the Darlingtonia Bog and Gravel Pit sites; they were at their lowest in 1995 at the Darlingtonia Bog and Gravel Pit sites and 1995-1996 at the Trail 1166 site. Thus, each site had an overall increase in population of vegetative and reproductive plants from 1995 to 2002.

Flowering appeared periodic, on a 2-year cycle, at all sites, with 1997 and 2001 showing the greatest numbers of reproductive plants and 2000 the lowest (Figures 11-13). Greater seedling recruitment generally occurred in the year following a flowering event, particularly between 1997 and 2002 at the Darlingtonia Bog site and 1997 and 2001 at the Trail 1166 site. The highest seedling numbers were observed in 1996 at the Darlingtonia Bog site and 1998 at the Trail 1166 and Gravel Pit sites. Increases in seedling recruitment following a low flowering year, i.e. 1996 at the Darlingtonia Bog site, and decreases after a high flowering year, i.e. 2002 at the Trail 1166 site and 2000 at the Gravel Pit site, indicate that seedling recruitment is not solely determined by seed production. Only general observations on population change may be made without demographic data, but the *Frasera* populations at these sites appeared relatively stable before the Biscuit Fire.

Mean plant size of vegetative and reproductive plants fluctuated from year to year before the Biscuit Fire at all monitoring sites, averaging between 1.73 and 4.28 rosettes per plant (Table 1).

After the Biscuit Fire (2003-2004)

The *Frasera* populations at the three sites experienced a general decline from 2002 to 2003, but increased from 2003 to 2004, all to levels above the lowest numbers observed over the ten-year monitoring period (Figures 2-4), indicating significant recovery after the Biscuit Fire. At the Darlingtonia Bog site, the decline in non-seedling plants from 2002 to 2003 was very slight, despite the complete loss of plants in plot 1B in 2003. In 2004, the non-seedling population was

higher than it had been since 2000, with 10 individuals observed to re-sprout in plot 1B. The number of non-seedling plants at the Trail 1166 site experienced a greater decline following the Biscuit Fire, but made a similar rebound in 2004, with the largest numbers recorded since 2001. The Gravel Pit site was the only site at which the non-seedling population did not recover to its 2002 size, or greater, by 2004, though the 2003 and 2004 non-seedling populations were greater than those observed in some pre-burn years (1995, 1997, and 2001). Also, this general decline was not universal among the Gravel Pit plots, with the 2004 non-seedling populations in Meadow Patch 2 and Patch 2 populations greater than observed in 2002 and the Patch 8 population reaching a maximum for the ten-year monitoring period.

The greatest change in the populations at the three monitoring sites following the Biscuit Fire appeared to be in the number of reproductive plants. Because of the apparent periodicity of flowering events observed in monitoring before the Biscuit Fire, 2003 was expected to be a high flowering year. The number of reproductive plants in 2003 actually exceeded the 2002 census at all three sites, but the reproductive population was much lower than in any previous “good” flowering year (i.e., 1997, 1999, 2001). Unexpectedly, the number of reproductive plants increased from 2003 to 2004 at the Gravel Pit site, though the numbers observed were similar to those in other “poor” flowering years (i.e., 1998, 2000, 2002). The numbers of reproductive plants in 2004 at the Darlingtonia Bog and Trail 1166 sites were also similar to those observed in other “poor” flowering years.

The number of seedlings at the Darlingtonia Bog site declined from 2002 to 2003 and 2004, but they were not the lowest numbers observed during the ten-year monitoring period. Though no seedlings were observed at the Trail 1166 site in 2003, more seedlings were seen in 2004 than had been recorded since 2000. All of these seedlings were observed in plot 2, only the third time seedlings were observed in this plot. The number of seedlings at the Gravel Pit site declined from 2002 to 2004, though there were more in 2004 than observed than in 2001.

Mean plant size (number of rosettes) of non-seedling plants in 2003 and 2004 varied substantially from site to site, but showed not overall trend when compared to pre-burn sizes (Table 1). Mean plant size at the Darlingtonia Bog site increased from 2002 to 2003 and again in 2004. Plant size at the Trail 1166 site decreased from 2002 to 2003 but was greater in 2004 than the mean size observed in 2002. At the Gravel Pit site, plant size increased from 2002 to 2003, but decreased in 2004 to less than the mean size observed in 2002.

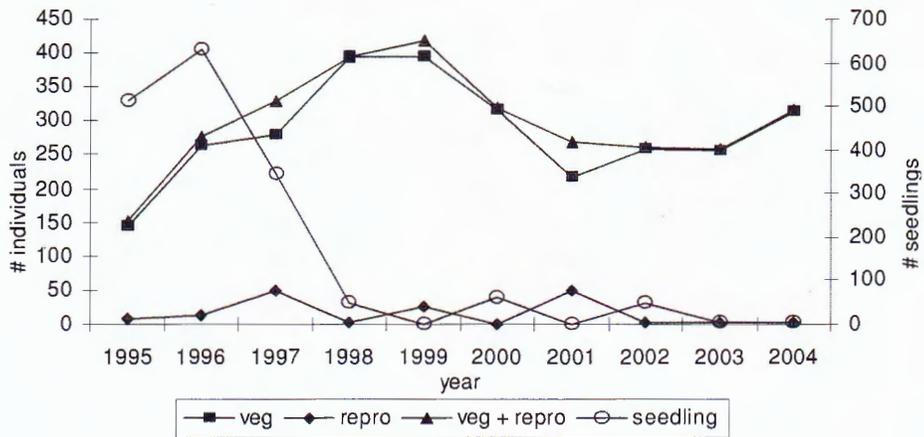


Figure 11. *Frasera umpquaensis* population trends at the Darlingtonia Bog site from 1995-2004. Total number of vegetative plants, reproductive plants, vegetative and reproductive plants together, and seedlings counted at the site are presented.

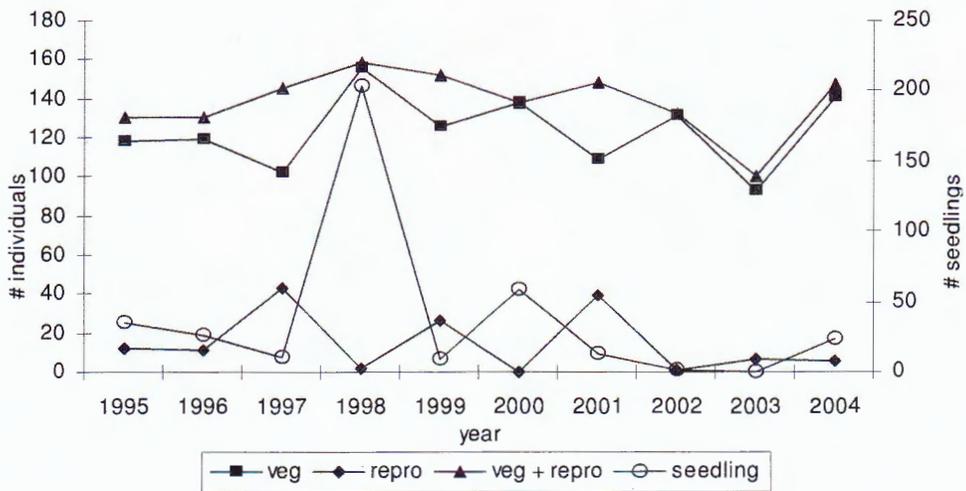


Figure 12. *Frasera umpquaensis* population trends at the Trail 1166 site from 1995-2004. Total number of vegetative plants, reproductive plants, vegetative and reproductive plants together, and seedlings counted at the site are presented.

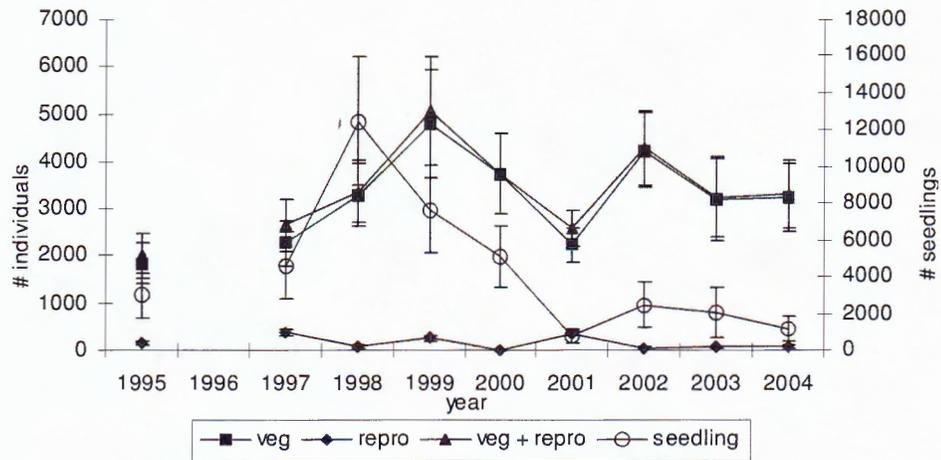


Figure 13. *Frasera umpquaensis* population trends at the Gravel Pit site in 1995 and 1997-2004. Total number of vegetative plants, reproductive plants, vegetative and reproductive plants together, and seedlings estimated at the site (with 95% confidence intervals) are presented.

Table 1. Mean number of rosettes (with 95% confidence intervals) per non-seedling *Frasera umpquaensis* plant in each plot at the Darlingtonia Bog, Trail 1166, and Gravel Pit monitoring sites from 1995-2004. Blank cells indicate no data available for that year.

Site	Plot	Year									
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Darlingtonia Bog	1A	2.23 (0.89-3.57)	2.56 (1.01-4.10)	2.00 (0.94-3.06)	1.91 (0.75-3.07)	1.88 (0.70-3.05)	1.62 (1.22-2.01)	2.22 (1.07-3.37)	2.45 (1.68-3.21)	5.86 (4.58-7.15)	3.96 (3.13-4.78)
	1B	4.64 (3.26-6.02)	6.10 (4.29-7.91)	3.36 (2.50-4.23)	4.48 (3.18-5.77)	4.03 (2.80-5.27)	2.91 (1.84-3.99)	3.25 (2.47-4.03)	2.70 (2.13-3.27)	0 [†]	3.00 (1.80-4.20)
	2	4.62 (3.29-5.96)	2.65 (2.14-3.15)	2.20 (1.83-2.56)	1.92 (1.62-2.22)	1.70 (1.43-1.97)	1.59 (1.39-1.79)	1.58 (1.38-1.77)	1.52 (1.36-1.69)	1.57 (1.40-1.75)	1.75 (1.56-1.94)
	weighted population average	4.28 (3.36-5.19)	3.01 (2.53-3.49)	2.33 (2.01-2.65)	2.13 (1.84-2.42)	1.88 (1.61-2.16)	1.74 (1.53-1.94)	1.80 (1.58-2.03)	1.73 (1.56-1.90)	1.94 (1.70-2.18)	2.11 (1.90-2.33)
Trail 1166	1	2.83 (2.41-3.25)	3.26 (2.78-3.74)	3.35 (2.84-3.85)	3.87 (2.77-4.97)	3.10 (2.61-3.58)	3.06 (2.61-3.50)	3.52 (3.03-4.01)	3.32 (2.83-3.81)	3.08 (2.43-3.72)	3.56 (3.13-3.99)
	2	3.67 (3.01-4.32)	3.17 (2.04-4.29)	3.90 (2.14-5.66)	2.92 (1.78-4.06)	4.60 (1.72-7.48)	3.27 (1.75-4.79)	3.30 (1.70-4.90)	3.85 (2.28-5.41)	4.13 (2.58-5.67)	3.62 (1.71-5.52)
	weighted population average	2.89 (2.49-3.28)	3.25 (2.81-3.70)	3.39 (2.90-3.87)	2.82 (2.45-3.39)	3.14 (2.67-3.62)	3.05 (2.62-3.48)	3.48 (3.01-3.95)	3.37 (2.90-3.85)	3.16 (2.55-3.77)	3.56 (3.13-4.00)

[†]No plants present. [‡]All plants had 1 rosette (SE=0); only one plant present in 2004.

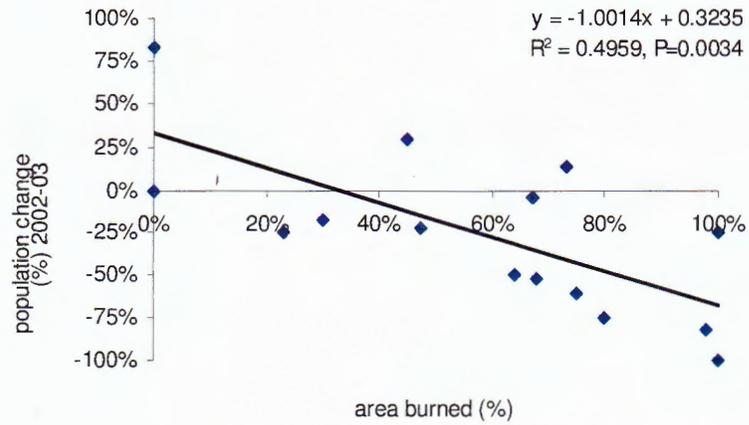
Table 1 (cont.)

Site	Plot	Year									
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gravel Pit	Large Plot	2.98 (2.50-3.45)		2.53 (2.13-2.93)	2.57 (2.18-2.96)	2.17 (1.86-2.48)	2.08 (1.70-2.46)	3.20 (2.44-4.02)	2.16 (1.79-2.53)	2.36 (2.00-2.73)	2.18 (1.85-2.51)
	Patch 1			1.44 (1.00-1.87)	2.50 (0.77-4.23)	1.00 [†]	1.00 [†]	1.00 [†]	1.00 [†]	1.20 (0.81-1.59)	1.00 [†]
	Patch 2			2.56 (0.85-4.26)	2.00 (0.61-3.39)	2.40 (0.88-3.92)	2.09 (1.24-2.95)	3.33 (0.92-5.74)	3.50 (0.98-6.02)	2.73 (0.89-4.56)	2.50 (0.44-4.56)
	Patch 5	2.90 (1.55-4.25)		4.70 (2.63-6.77)	3.45 (1.51-5.40)	3.43 (1.52-5.33)	4.00 (1.90-6.10)	3.09 (1.96-4.23)	3.33 (1.53-5.13)	3.67 (0.82-6.51)	2.00 (0.48-3.52)
	Patch 6	1.50 (0.71-2.29)		5.00 (1.55-8.45)	5.25 (2.67-7.83)	3.33 (1.33-5.34)	4.50 (1.31-7.69)	3.83 (1.72-5.95)	4.60 (2.23-6.97)	3.50 (0.56-6.44)	4.00 (0.08-7.92)
	Patch 7	3.52 (2.09-4.96)		4.67 (3.02-6.31)	5.73 (3.66-7.81)	5.44 (2.89-8.00)	7.30 (3.19-11.41)	4.33 (1.74-6.93)	7.18 (3.34-11.03)	4.50 (3.52-5.48)	4.80 (1.56-8.04)
	Patch 8	1.55 (1.09-2.01)		2.38 (1.40-3.35)	2.40 (1.34-3.46)	2.12 (1.45-2.79)	1.58 (0.96-2.19)	1.83 (1.40-2.25)	1.35 (1.09-1.62)	1.95 (1.38-2.52)	1.66 (1.28-2.03)
	Patch 9			1.90 (1.00-2.80)	2.08 (0.75-3.41)	1.73 (0.71-2.75)	2.18 (0.67-3.70)	2.10 (1.04-3.16)	1.95 (1.02-2.88)	1.53 (0.90-2.16)	1.94 (1.15-2.73)
	Roadside Patch	2.29 (2.01-2.57)		2.73 (2.29-3.18)	3.00 (2.58-3.41)	2.37 (2.08-2.67)	2.06 (1.74-2.38)	3.09 (2.60-3.58)	2.22 (1.91-2.54)	3.09 (2.54-3.65)	3.25 (2.72-3.78)
	Meadow Patch 1	1.88 (0.94-2.81)		2.40 (0.48-4.32)	1.74 (1.07-2.41)	1.36 (1.02-1.70)	1.50 (1.10-1.90)	2.00 (1.54-2.46)	1.79 (1.32-2.27)	1.57 (1.27-1.86)	4.48 (2.87-6.10)
	Meadow Patch 2	2.20 (1.55-2.80)		3.75 (2.21-5.29)	4.00 (2.75-5.25)	3.35 (2.44-4.26)	3.96 (2.95-4.97)	2.94 (2.15-3.72)	3.74 (2.75-4.73)	5.00 (0.36-9.64)	1.44 (1.12-1.77)
	weighted population average	2.68 (2.46-2.90)		2.81 (2.59-3.02)	2.80 (2.59-3.01)	2.24 (2.09-2.40)	2.05 (1.91-2.20)	2.98 (2.76-3.20)	2.31 (2.16-2.47)	2.39 (2.18-2.60)	2.20 (2.03-2.36)

Fire Effects on *Frasera umpquaensis* Populations

The percentage change in non-seedling population size from 2002 to 2003 was significantly ($P=0.003$) and negatively ($R^2=0.496$) correlated with area burned in each plot (Figure 14a). However, two years after the fire no significant correlation was detectable, suggesting substantial post-burn recovery of the *Frasera* populations. That is, no significant relationship ($P=0.977$) was observed between population change from 2002 to 2004 and overall percent area burned in each plot ($P=0.98$; Figure 14b). The change in proportion of V1 plants (those with 1 rosette) per monitoring plot from 2002 to 2003 showed a weakly negative relationship with area of plot burned ($P=0.07$), an effect that also disappeared in 2004 ($P=0.76$; Figure 15). The change in proportion of flowering plants per monitoring plot from 2001 to 2003 showed a weakly negative relationship with area of plot burned ($P=0.069$, $R^2=0.248$; Figure 16). No comparison of flowering plant abundance two years after the fire was made because 2004 was a non-flowering year for the species. The effects of burning on seedling density at the monitoring sites could not be evaluated with linear regression because seedlings were observed infrequently in this period (only in Darlingtonia Bog plot 2 and Gravel Pit Large Plot in 2003 and 2004 and Trail 1166 plot 2 in 2004).

(a)



(b)

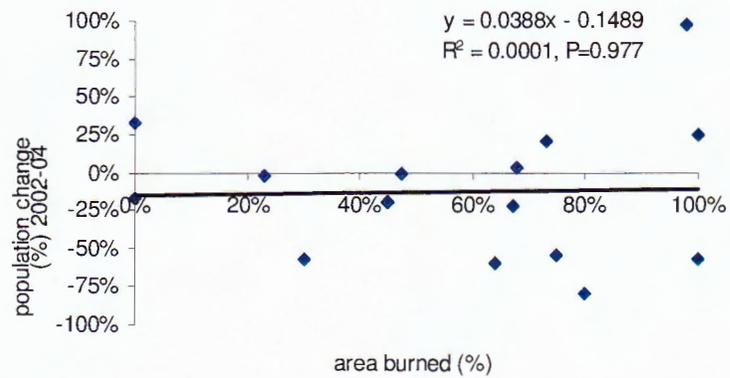
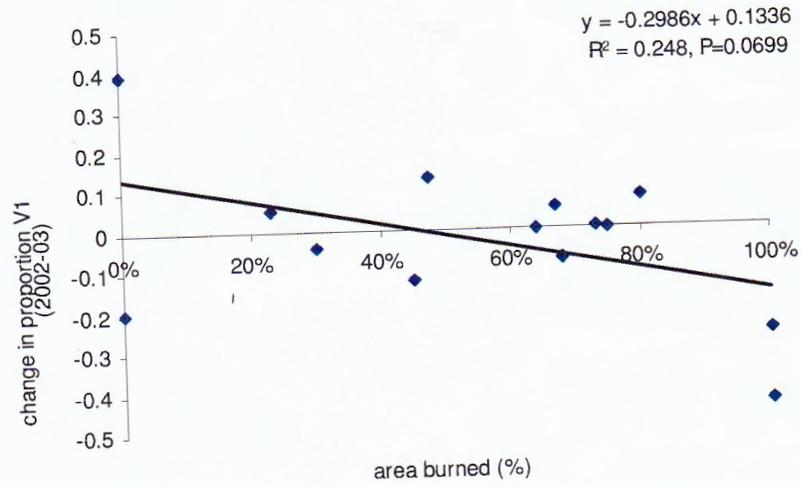


Figure 14. Percent population change from (a) 2002 to 2003 and (b) 2002 to 2004 per monitoring plot of vegetative and reproductive *Frasera umpquaensis* plants combined as a function of overall percent area of the plot burned.

(a)



(b)

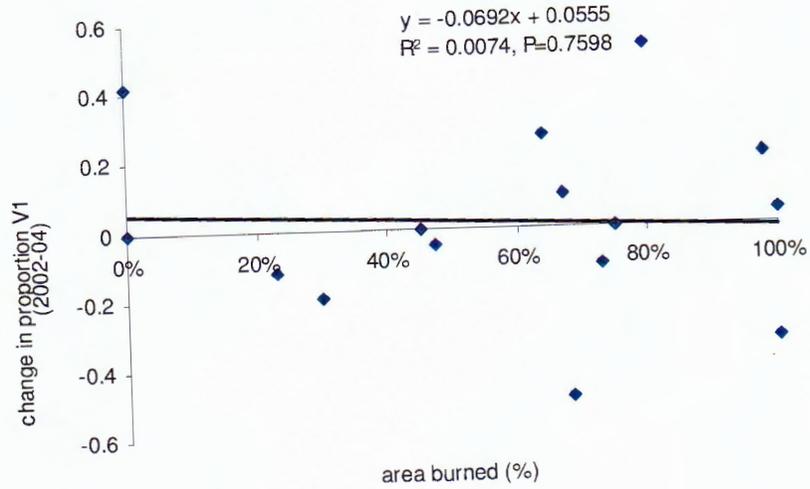


Figure 15. Change in the proportion of V1 *Frasera umpquaensis* plants per monitoring plot from (a) 2002 to 2003 and (b) 2002 to 2004 as a function of overall percent area of the plot burned.

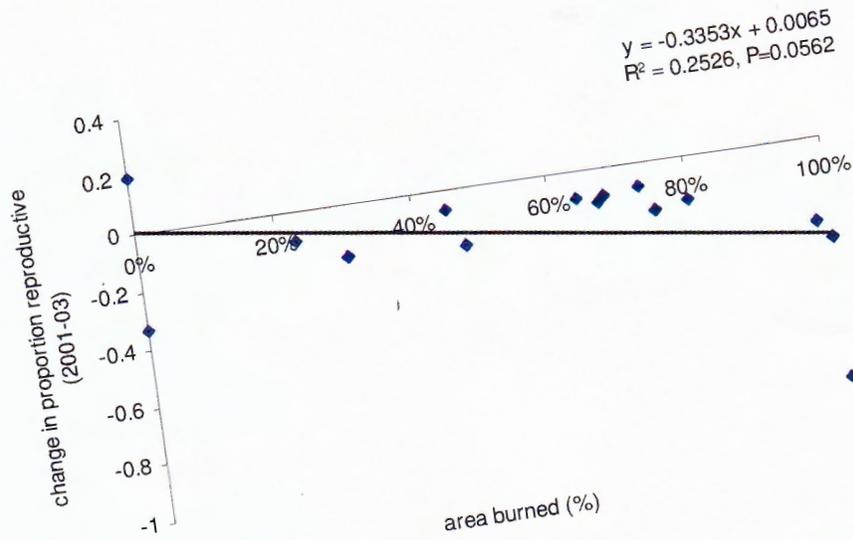


Figure 16. Change in the proportion of flowering *Frasera umpquaensis* plants per monitoring plot from 2001 to 2003 as a function of overall percent area of plot burned.

Burned vs. Unburned Plants

Unburned *Frasera umpquaensis* plants were significantly larger than burned plants in all analyzed characteristics, but the magnitude of this difference declined with time since the fire. For example, average leaf length of burned plants was 4.5 cm in 2003 (one year after the fire), while unburned plants had leaves 19.4 cm in length during the same period (Table 2). However, by 2004 (two years post-fire), average leaves were 17.3 cm on burned plants and 22.2 cm on undamaged individuals. Because the magnitude of size difference between burned and unburned plants was less two years post-fire, a significant ($P=0.0001$) interaction was detected between burn and year effects (Table 2). The same overall pattern was observed for other measures of plant size such as mean rosette diameter, largest rosette diameter, and maximum leaf length. Rosette number of burned and unburned plants also differed significantly, but the magnitude of this difference was similar between years, resulting in no statistical interaction between burn and year effects ($P=0.66$).

Table 2. Mean (95% confidence intervals) plant sizes for various measures of burned and unburned *Frasera umpquaensis* plants in 2003 and 2004. P -values are from two-way ANOVA. $n=13$ for each measurement except mean rosette diameter and mean leaf length in 2004, where $n=10$ for burned plants.

Plant measurements	2003		2004		P-values		
	Burned	Unburned	Burned	Unburned	Burned	Year	Interaction
Number of rosettes	3.4 (0.6-6.1)	7.1 (4.3-9.8)	5.0 (2.2-7.7)	7.5 (4.7-10.2)	0.03	0.48	0.66
Mean largest rosette diameter (cm)	7.4 (3.3-11.5)	30.0 (25.9-34.1)	21.8 (17.7-25.8)	32.4 (28.3-36.5)	<0.00001	0.0002	0.006
Mean rosette diameter (cm)	4.4 (1.7-7.2)	22.6 (19.9-25.3)	18.2 (15.1-21.4)	24.2 (21.4-26.9)	<0.00001	<0.00001	0.0001
Mean maximum leaf length (cm)	7.1 (4.4-9.7)	23.8 (21.1-26.4)	20.8 (18.1-23.4)	26.2 (23.6-28.9)	<0.00001	<0.00001	0.0001
Mean leaf length (cm)	4.5 (2.2-6.7)	19.4 (17.2-21.7)	17.3 (14.8-19.9)	22.2 (19.9-24.4)	<0.00001	<0.00001	0.0001

†only one reproductive plant; - no reproductive plants.

Change in Forest Canopy Cover

Mean forest canopy cover at the Darlingtonia Bog site was significantly lower in 2003 and 2004 than in 1997 (Table 3). Canopy cover at the Trail 1166 site in 2003 and 2004 did not significantly differ from that observed in 1997. Canopy cover was generally high (>80%) in the Gravel Pit Large Plot in 2003 and 2004, but no pre-burn data were available from that site for comparison.

Table 3. Mean forest canopy coverage (\pm SE) at the Darlingtonia Bog, Trail 1166, and Gravel Pit Large Plot monitoring sites in 1997, 2003, and 2004. No data were taken at the Gravel Pit Large Plot in 1997. P-values are from paired one-tail t-tests. (**denotes significance at the 0.01 level)

Year	Darlingtonia Bog	Trail 1166	Gravel Pit Large Plot
1997	63.01 (\pm 4.91)	23.01 (\pm 7.55)	-
2003	26.62 (\pm 2.29)	14.69 (\pm 5.79)	80.60 (\pm 5.81)
2004	17.09 (\pm 2.01)	23.83 (\pm 9.13)	81.47 (\pm 4.18)
p-values			
1997-2003 >0	<0.000001**	0.18	-
1997-2004 >0	<0.000001**	0.54	-

DISCUSSION

General Population Dynamics

Populations of *Frasera umpquaensis* at three sites on the Medford District, BLM, varied in size over time since monitoring began in 1995 through 2002, when sampling occurred in June, prior to the Biscuit Fire entering the sites in August. The most notable feature of the population dynamics under natural, undisturbed conditions was the periodicity of reproduction in all populations. In general, flowering occurred on a two year cycle (every other year), and seedling recruitment often followed suite, but in alternate years, as one might expect. This was especially pronounced and easy to visualize at the Trail 1166 site (Figure 12).

Effects of the Biscuit Fire of 2002

The Biscuit Fire of 2002 had significant negative effects on individual plants and subpopulations (patches and plots) as measured one year after the burn, but two years later much of this effect was either lessened or no longer detectable. Losses to subpopulations in 2003 increased as proportion of habitat burned increased (Figures 14a, 15a, and 16). In 2004, however, many subpopulations recovered substantially and this negative relationship was not longer detectable (Figure 14b and 15b). Burned area within the plots also negatively affected the proportion of small plants (those with one rosette), an effect which also disappeared in 2004. In addition, reproductive plant numbers were lower than expected in 2003, which should have been a substantial flowering year based on past patterns. The Biscuit Fire thus altered the structure of these *Frasera* populations in the first season after burning, but apparently not over the long-term.

Burned *Frasera* plants were smaller than unburned plants in 2003 and 2004. Burned plants grew significantly from 2003 to 2004, though they did not recover enough to be of comparable size to plants undamaged by the Biscuit Fire. A significant interaction between burning and year was observed for most variable measured because the regrowth of damaged plants was so substantial two years post-fire. The burned plants for this portion of the study were located in areas of light burning intensity and chosen because they were already resprouting in 2003 and could be located and identified. Thus, we believe that *Frasera* plants in areas of light burning recover to some extent after two years, but the recovery of plants in areas burned with moderate to high intensity could not be determined. We believe, based on field observations, that individuals in moderate to high intensity burns had higher mortality due to damage or consumption of the rhizome in the litter layer above the mineral soil surface.

Though the effect of burned area on seedling density could not be analyzed due to low recruitment, the absence of seedlings in most of the monitoring plots suggests that fire does not cause a flush of recruitment in this species. Prior to the Biscuit Fire, high levels of seedling recruitment appeared to alternate with good flowering years. As 2002 was a poor flowering year, seedling recruitment was expected to be low in 2003 due to low seed production. Seedling recruitment was again low in 2004, an expected good year for seedlings, but this was likely because flowering in 2003 was much lower than in other peak flowering years. If flowering in these populations resumes the cycle observed before the Biscuit Fire, 2005 is expected to be a good flowering year and 2006 should have high seedling recruitment.



Figure 18. Resprouting from a burned *Frasera umpquaensis* rhizome one year after the Biscuit Fire (June, 2003).

Forest Canopy

Forest canopy coverage was lower following the Biscuit Fire than had been observed in previous years at the Darlingtonia Bog site. The difference in canopy coverage at the Trail 1166 site was not significant, likely because the site had burned in the Silver Fire of 1987 and fuel loads were still low. Decreases in canopy coverage likely had some impact on the *Frasera umpquaensis* populations at these sites, though this impact may not have been as great as the impact of burned duff and soil around the plants or burning of the plants themselves.

General Conclusions

The *Frasera umpquaensis* populations studied here appeared to recover in terms of overall number and, to some extent, size of plants, by the second season after the Biscuit Fire. Based on the information gathered to date, wildfire appears to pose little threat to the species, especially in areas of low fuel loads. Burning during the Biscuit Fire was extremely patchy on every spatial scale, allowing some plants to remain untouched while the aboveground and shallow-rooted portions of others were completely gone. This is perhaps what has allowed these populations to

recover so quickly. On the individual level, light-intensity burning resulted in significantly smaller plants which regrew substantially but did not fully recover by the second season following the fire. We were not able to determine the recovery of plants burned with moderate to high intensity, but we predict it would be slower than that observed in this study, if recovery could occur at all. Higher intensity burning was observed in the plots with larger fuel loads and only low intensity burning in plots with less fuel, such as plot 1 at the Trail 1166 site which had burned only 15 years prior to the Biscuit Fire. Thus, maintaining lower fuel loads may lessen the negative impacts of burning on *Frasera umpquaensis*. The limited time-frame of this study did not permit us to observe two expected good flowering years after the fire, or three years total, which limits our ability to predict the potential for recovery of the reproductive populations at these sites. We thus recommend that monitoring continue in 2005 to provide another year of flowering plant data to compare to pre-fire numbers.

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APPENDIX I: SITE DOCUMENTATION

Darlingtonia Bog site

This site is reached via USFS road 2411 to BLM road 35-9-3. The *Frasera* population is divided into two subpopulations discovered at different times (see sighting report forms on file at the Medford BLM District office), both of which are located in T35S R9W Sec. 8 NE 1/4 NE 1/4. The subpopulations are located near a *Darlingtonia* bog—subpopulation 1 (plots 1A and 1B) directly to the east of the bog and subpopulation 2 (plot 2) 0.1 mile east along the road (Figure 8). The subpopulations are within 50 m to the north of the road, with flagging on the roadside indicating their general location (both pink and striped yellow and black flagging were used, often in combination, and contain written notes). All plot corners are marked with 5-ft lengths of galvanized conduit that are flagged and labeled with black felt-tip pen (indelible ink). Conduit also marks 10-m intervals of plot 2. A complete census of the subpopulations at both sites was taken from 1995-2004.

Note: A long-term demographic monitoring plot was established at this site in 1985 and is contained within the rectangular plot. The demographic plot is circular with a 7.7 ft radius and marked in the center with a piece of rebar. Most plants within the circle have been mapped and tagged. See a report by Knight (1991) and other reports on file at the Medford District BLM for details relating to the sampling and data from this plot.

Trail 1166 site

This site is reached via USFS road 2411 to the trailhead of USFS Trail 1166. The population is located west of the trailhead by walking through a log landing and along a game trail downslope to a saddle, about a 10-min. walk from the road (Figure 9). Do not take the hiking trail 1166. The *Frasera* population is divided into two patches, both located in T35S R9W Sec. 8 SW 1/4 NW1/4. Both patches are on a saddle and south-facing slope between two high-points of the ridge and marked conspicuously with pink flagging. Plot 1 is farthest west and is a large rectangle which encompasses most of the larger patch, with 5-ft lengths of galvanized conduit that were flagged and labeled with black felt-tip pen (indelible ink) marking the plot corners. Rebar posts mark 5-m intervals along the long sides of the rectangle to delineate subplots. Two small groups of plants lie outside of plot 1—one on the ridge-top north of subplot 1 (three plants) and one west of plot 1 about 30 paces (four plants). Plot 2 is a circular plot that includes all plants in the smaller patch and is marked with a flagged conduit post at its center. A complete population

census was taken at this site from 1995-2004. Note: At least one additional subpopulation is located west of this site in the next saddle and west-facing slope. This second subpopulation is on USFS land and was not monitored in July of 1995, though plans were in effect to establish plots there soon (for additional information, contact the Siskiyou National Forest botanist in Grants Pass).

Gravel Pit site

This site is reached via Hwy 23 (Galice-Gold Beach Road) to Road 34-9-35, then USFS road 2411 to the Hobson Horn gravel pit (about 1.0 road miles from Hwy 23). Parking is easiest at the gravel pit itself. The population is patchy and distributed mainly on the northeast side of the road and in a few patches on the southwest side of the road, all within T34S R9W Sec. 34 W ½ SE ¼ (Figure 10). Four components to the population have been identified: 1) a large, high-density patch ("Large Plot"); 2) adjacent scattered patches within the forest ("Patches 1-9"); 3) a roadside patch ("Roadside Patch"); and 4) two small patches on the southwest side of the road in the meadow ("Meadow Patch 1 and 2"). The Large Plot is marked at the corners with 5-ft lengths of galvanized conduit that are flagged and labeled with black felt-tip pen (indelible ink). Twenty randomly chosen subplots within the Large Plot are marked at each end with a rebar post and were sampled in 1995 and 1997-2004 to estimate the total number plants within the plot (Figure 11). Patches 1-9 are located within the vicinity of the Large Plot (two within it) and are marked with numbered flagging. A complete population census was taken on four of these patches in 1995 and the seven located outside of the Large Plot in 1997-2004. The Roadside Patch is adjacent to the main road and marked by flagging at both ends and conduit posts at the northwest and southeast limits. Meadow Patch 1 and 2 are located across the road from the other plots in a meadow area and are flagged. A complete population census of the Roadside Patch and Meadow Patch 1 and 2 was taken in 1995 and 1997-2004.

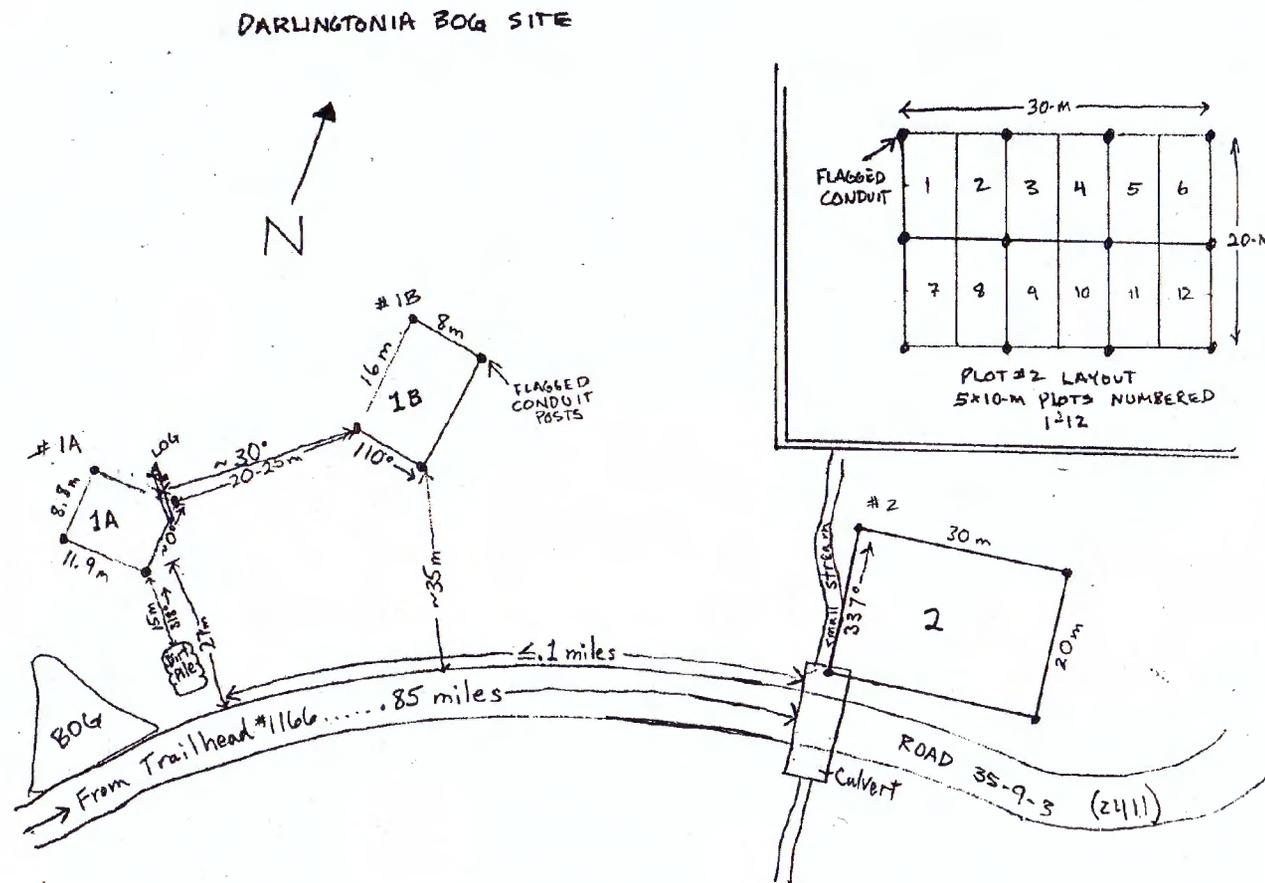


Figure 8. Sketch map of the Darlingtonia Bog site. Subpopulation 1 is monitored with two plots, 1A and 1B. The second subpopulation is monitored with plot 2. Insert shows the layout of plot #2 with plot dimensions, subplot numbering, and arrangement of permanent corner posts.

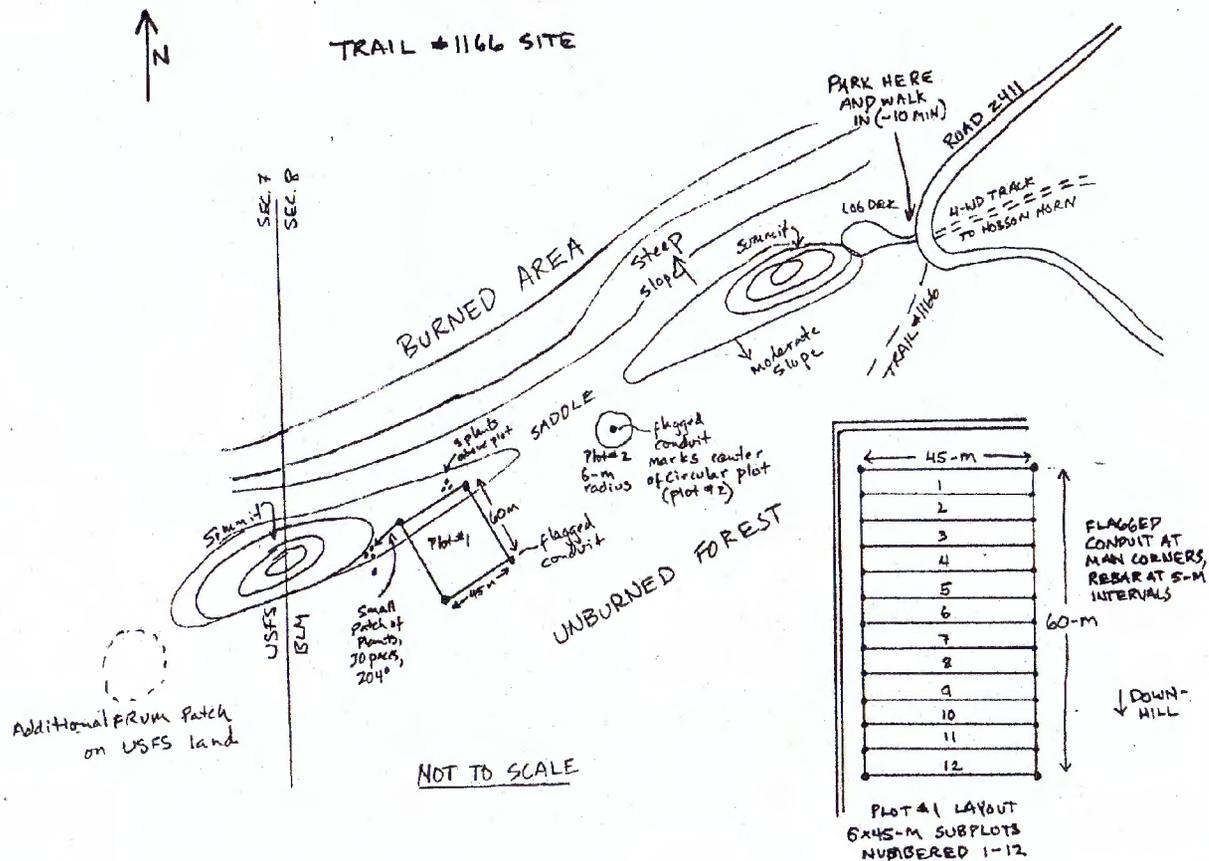


Figure 9. Sketch map of the Trail 1166 site. Two plots were used to census the population: plot 1 is a 45x60 m rectangle and plot 2 is a 6-m radius circular plot, marked only in the center. Insert shows the layout of plot 1 with plot dimensions, subplot numbering, and arrangement of permanent corner posts (conduit and rebar). Note the presence of a few stray plants outside of plot 1.

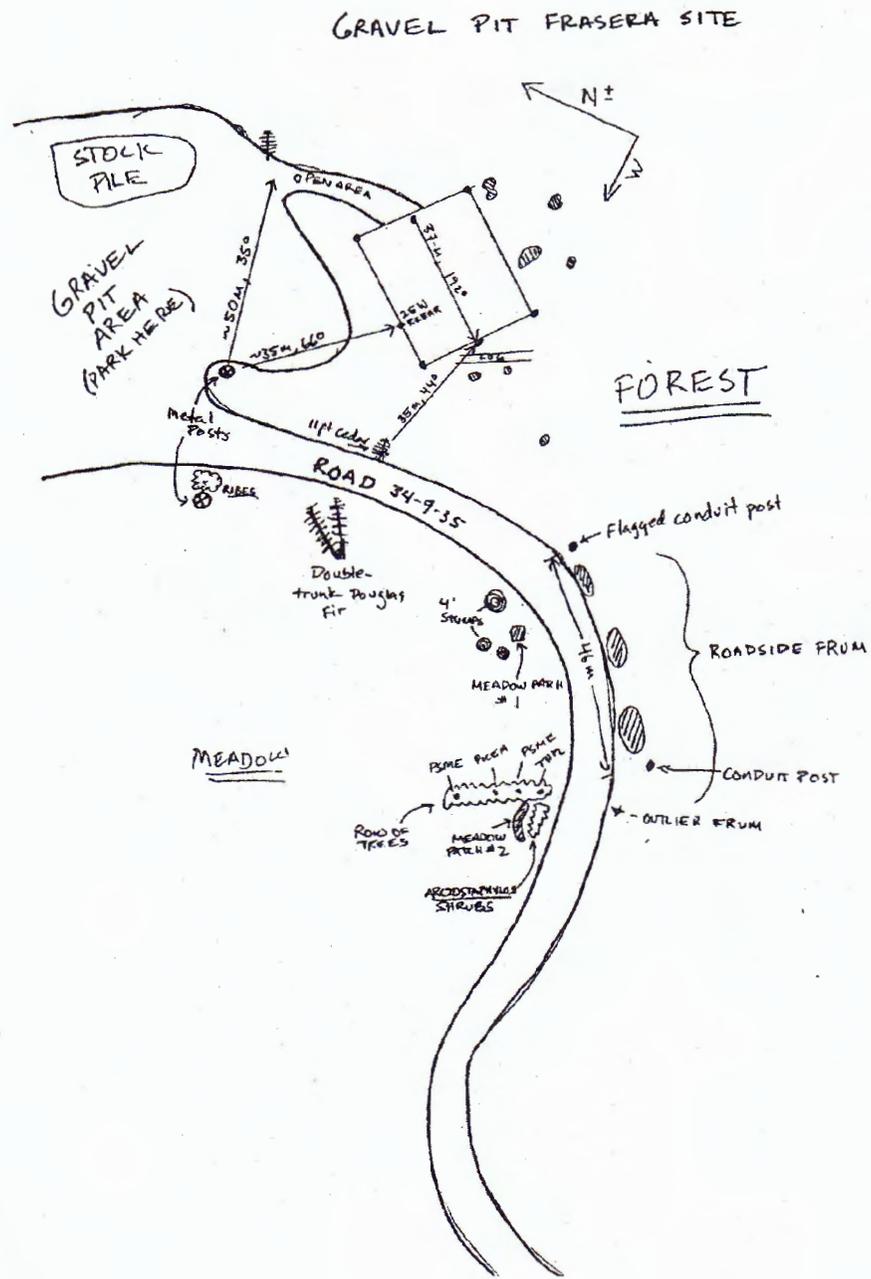


Figure 10. Sketch map of the Gravel Pit site. Plants are distributed in one dense area and several smaller patches on both sides of road 34-9-35.

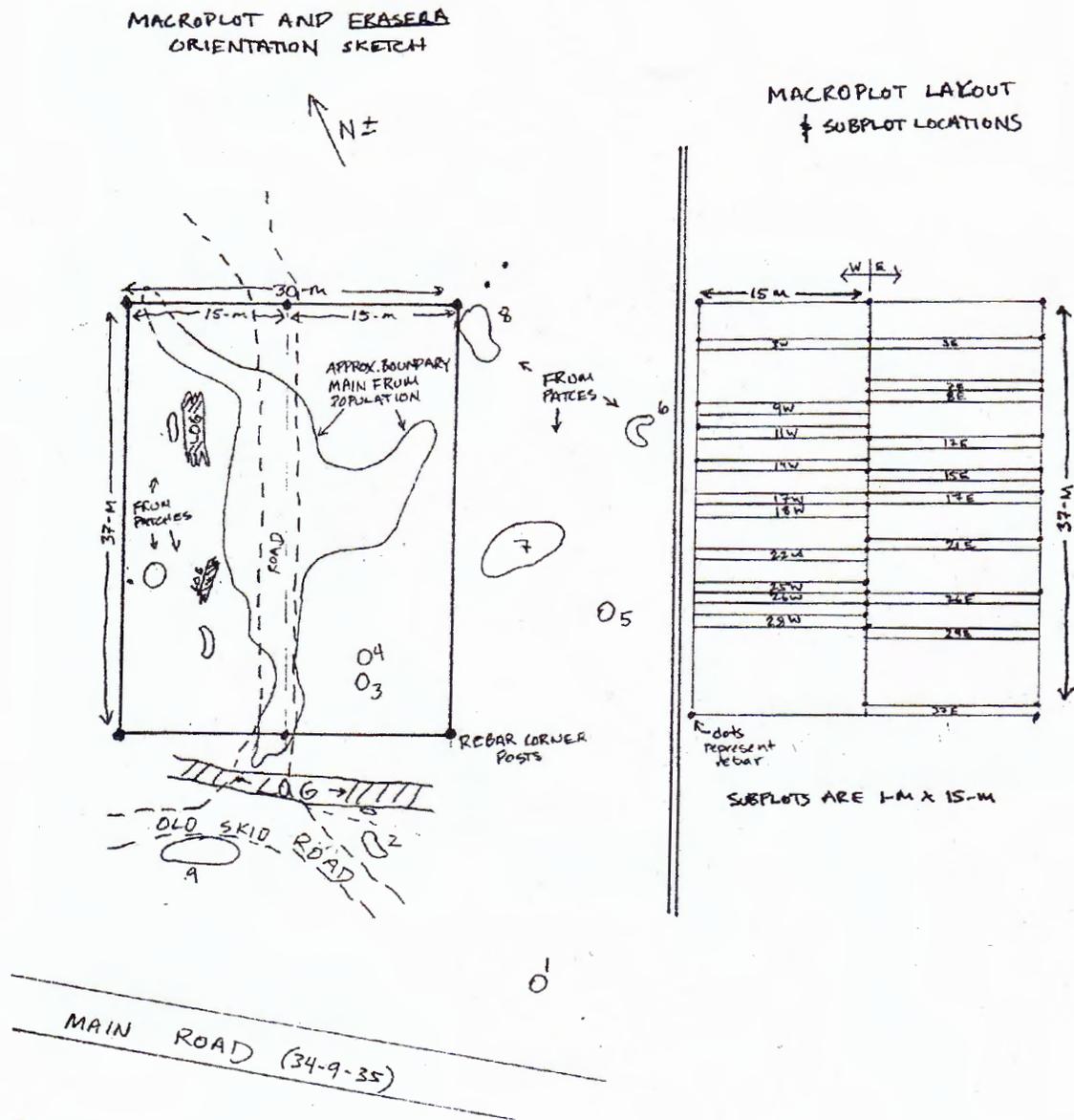


Figure 11. Detailed sketch of the Gravel Pit Large Plot and Patches 1-9. The Large Plot covers most of the large high-density group of plants associated with the old skid road. Insert shows the Large Plot layout and location of subplots.