Assessment of seedling failure in peripheral populations of Umpqua green gentian (*Frasera umpquaensis*)

2010 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 whose mission is conservation of native ecosystems through restoration, 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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Cover photograph: *Frasera umpquaensis* inflorescence (Tom Kaye, IAE), *Frasera umpquaensis* at Sourgrass Mountain (Andrea Thorpe, IAE).

REFERENCE

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EXECUTIVE SUMMARY:

Frasera umpquaensis is a long-lived perennial that may live up to 80 years (Kaye 2001). Most populations are found along the Rogue-Umpqua divide. This report describes activities at five sites in peripheral populations along the Calapooya divide; Sourgrass Mountain, Sourgrass Mountain Southeast, Elk Meadows, Elk Camp Shelter and Nevergo. Seedling recruitment at these sites had been reported to be absent and therefore the success of these populations was in question.

In order to test seed production and viability, seeds were collected at each site and tested for germination using both germination and tetrazolium tests. Germinated seeds were used to grow plants that were used in our experimental plots. In order to test the effects of litter, canopy type, propagule type (seeds vs. transplants), and exposure on seedling recruitment and survival, treatment plots were set up in the meadow and along the forest edge adjacent to existing populations. Plants were monitored in 2009 and 2010 to assess the survival of the plants within the treatment plots. We also surveyed the populations for natural recruitment. Briefly, we found that,

- Viability of seeds collected at the sites range from 5% - 92%.
- On the forest edge, plants had higher survival with northern exposure.
- Mortality of seedlings (both natural and seeded) is high from one year to the next.
- Survivorship of transplants is higher than seeds.
- We found no evidence for significant effects of canopy type (forest vs. meadow), litter depth or soil moisture.
- Natural seedlings were found at most sites.

Due to the low recruitment in these populations, one of the most important activities for their preservation is prevention of anthropogenic impacts. In 2010, we observed significant damage by ORVs in the boggy area adjacent to the *F. umpquaensis* population at Elk Camp Shelter. Given its location, this site is at the most risk for ORV damage; however the others could also be affected.

Given our observations of natural recruitment at some of the sites, apparently synchronous flowering of most plants every 3rd or 4th year, and variations in plants size between years, we recommend establishing two levels of annual monitoring. First, all sites should be surveyed each year for all individuals, including seedlings. Second, all individuals should be tagged and monitored for characteristics including height, number of leaves, and flowering status. Monitoring should include introduced plants. Annual data of this type would allow us to detect important population changes, rates of establishment in years after flowering events, and determine correlations between climate variables and population traits. Given the short duration of this study, continuous monitoring of the plants introduced through this project is necessary to provide insight into the population dynamics of this species.

Finally, our research suggests seed addition and planting seedlings may both be successful methods to augment declining populations of *F. umpquaensis*. Although these populations are not continuous with populations in the core of this species habitat, they may contain genetic diversity not represented elsewhere that may be important for the long term viability of the species.

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Introduction

Frasera umpquaensis M. Peck & Applegate (Umpqua green gentian; Gentianaceae) is endemic to Oregon and northern California. Most populations occur in Oregon on the Rogue-Umpqua Divide. Peripheral populations, such as the Elk Meadows/Saddleblanket Mountain and Sourgrass Mountain populations on the Calapooya Divide, are so isolated that little or no gene flow from other populations is possible (**Figure 1** Wilson, 2010).

Figure 1 *Frasera* populations in Oregon (black dots). Elk Meadows, Elk Camp Shelter, Nevergo Creek, and Sourgrass Mountain are circled in red.

These peripheral populations appear to have low seedling production and may be at risk of extinction due to low recruitment and adult mortality. Before this study, seedling recruitment had not been documented during monitoring of these isolated populations (C. Mayrsohn, *personal communication*; J. Lippert, *personal communication*).

Frasera umpquaensis, a G3/S3 species, is a candidate for listing as Threatened or Endangered by the state of Oregon; it is managed as a sensitive species by the USFS and a special status species by the BLM. The Conservation Strategy for *Frasera* identified examination of seed production, seedling recruitment, and factors that affect successful reproduction in the species as high priority issues for peripheral populations (Cripps 1993).

Frasera umpquaensis may potentially live more than 80 years (Kaye 2001). It is possible that the populations along the Calapooya Divide established under very different site conditions such as more frequent disturbance regimes or different temperature or moisture regimes. As an example, fewer disturbances to the forest canopy at these sites may have led to heavier shading or deeper litter (Figure 2). We have tested the effects of canopy openness and litter depth on seed establishment and seedling growth in our seedling recruitment trials.

The objective of this project is to understand and remedy the low seedling recruitment rates in the peripheral populations of *Frasera*. This will be addressed through observations and experiments with seeds and seedlings. Specifically, the goals are to:

1. Examine several aspects of the life-history of *Frasera* that could affect seedling recruitment, including seed production, seed viability, seed germination (field and greenhouse), and seedling survival.
2. Test habitat factors that may impact seed germination and seedling survival, including litter and canopy cover.

METHODS

This project is located in Lane and Douglas counties on land managed by the Eugene District BLM (Elk Meadows East, Lower Elk Meadows West and Upper Elk Meadows West) and Willamette National Forest (Elk Camp Shelter, Nevergo Creek, and Sourgrass Mountain; Figure 1).

Seed Production and Viability

In October 2007 and November 2008 we collected seeds for grow-out and to determine the percent of filled seeds (an estimate of viability). As many of the fruits had dehisced at the time of these collections, we were not able to determine seed production per inflorescence. At selected plants, fruits were gently shaken into a bag so that fewer than 10% of the seeds were sampled. Seeds were also collected in 2006 by agency

Figure 2. Senescing Frasera at Nevergo. Note the encroachment by native shrub and subshrub species including bracken fern.

personnel. All seeds were sorted as filled or unfilled using a light box to determine presence of an embryo. After counting, filled seeds were distributed on moistened blotting paper in germination boxes and stratified at 4°C in continuous dark. After 16 weeks, germination boxes were placed in a warm room (25°C/15°C, 8 hour day/16 hour night lighting cycle) for one week or until no additional plants were observed to germinate for three days.

In 2009, we altered our seed sampling methods to assess the number of seeds produced per inflorescence. In August at all sites, we haphazardly selected mature plants and covered them with mesh seed collection bags. Seed bags were collected in September and October 2009 after the seeds had matured.

As in 2008, all seeds were sorted as filled or unfilled using a light box to determine presence of an embryo. We also counted the number of aborted and viable capsules from inflorescences collected in 2009. Two hundred filled seeds from each site were sent to the Oregon State University Seed Lab to be tested for viability using a tetrazolium test. Seeds were not collected in 2010 due to the low number of flowering plants.

Natural recruitment

In 2010, in addition to monitoring the experimental plots, we surveyed for seedlings around mature plants. We looked within a one meter radius around the base of larger individuals, as well as around individuals with dried flowering stalks from the previous year. If a plant had a dried flowering stalk that fell outside of the one meter radius, we also looked for seedlings on the ground where the stalk had fallen.

Effects of cold stratification on seeds and seedlings

In the winter of 2009-2010 we took plants that remained from our outplanting efforts, wrapped them in black plastic and placed them in cold stratification. We took flats out of cold stratification every 30 days for 3 months. In addition to placing plants into cold stratification, ungerminated seeds from our growout efforts in 2009 were planted into 4” x 4” pots. These pots were left in the greenhouse throughout 2009 until December, when they were placed into cold stratification for 3 months.

Plot Establishment

In 2008 and 2009, after germination, seedlings were transplanted into rectangular pots (2” x 2” x 5”) filled with Gardener’s Gold potting soil. Plants were watered every 2-3 days and fertilized once a week with Miracle Grow. In October and November 2008, and October 2009 we established experimental plots at Elk Meadows, Elk Camp Shelter, Sourgrass Mountain, Sourgrass Mountain Southeast and Nevergo Creek. We placed plots among or adjacent to existing patches of *Frasera* in order to directly examine the low recruitment rates. Within each site, we established multiple 2m x 2m macroplots in the open meadow and forest/meadow edge (Figure 3, Table 1). Each macroplot was divided into 4-1m^2 plots. Macroplots were marked in the center with a piece of rebar and at the midpoint of each side using PVC conduit. Two plots in each macroplot were randomly selected for litter removal (Figure 3). Plots were then assigned to either be seeded, in which 10 seeds were scattered on the soil surface with toothpicks marking the location of each seed, or planted with two seedlings. Thus, this was a 2 (meadow or edge) x 2 (litter removal or not) x 2 (seeding or transplants) complete factorial design (Figure 4.).

Figure 3 Hypothetical assignment of treatments to experimental blocks.

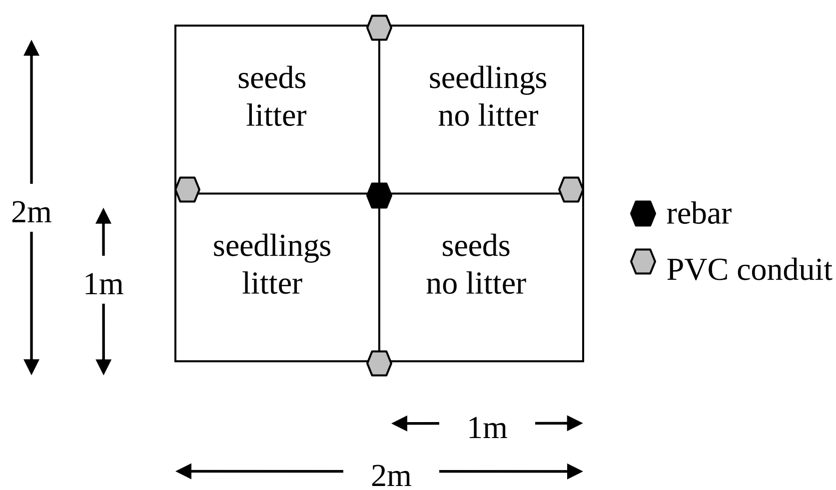


Table 1. The number of Frasera treatment plots in each study site.

Site	Year	Meadow	Forest edge south exposure	Forest edge north exposure	Forest edge west exposure	Forest edge east exposure
Elk Meadows/Saddleblanket Mountain (BLM)						
Upper Elk Meadows W.	2008	6	3	0	0	0
Lower Elk Meadows W.	2008	3	0	0	0	0
Elk Meadows E.	2008	5	6	4	0	0
	2009	7	5	0	0	0
	Total	***21***	***14***	***4***	***0***	***0***
Willamette National Forest populations						
Sourgrass	2008	3	2	3	0	0
	2009	3	0	3	0	0
Sourgrass, Southeast	2009	3	0	0	3	0
Nevergo	2008	3	2	3[1]	0	1
	2009	3	0	3	0	0
Elk Camp Shelter	2008	3	4	3	0	0
	2009	3	0	3	0	0
	Total	***21***	***8***	***18***	***3***	***1***

[1]After treatment in 2009, these plots are no longer on the forest edge

In the spring and summer of 2009, and in the summer of 2010, we revisited the plots set-up in 2008 and 2009 to determine the survival of transplants and seedlings within the plots. We also measured canopy cover using a spherical densitometer and solar pathfinder at each plot. Canopy cover was measured on the north end of each macroplot. The densiometer measurements were taken from the north end of each plot facing each cardinal direction; open squares were counted to determine the percent of open canopy while holding the densiometer level at waist height. Solar pathfinder measurements were taken at the center of each plot and recorded for the months of April-October. The solar pathfinder records the path of the sun at different times of year and determines the amount of sunlight a given location will receive at that time. Thinning activities at Nevergo significantly opened the canopy in 2009. Solar measurements were measured in 2010 at all Nevergo plots to assess the impact of the altered canopy cover.

To determine soil moisture we collected the top 10 cm of soil from just outside the north end of each macroplot. Gravimetric soil moisture was determined by weighing the soils before and after drying them for at least three days at 80^{o}C.

Plants that remained from our outplanting efforts in 2008 and 2009 were outplanted at Nevergo, Elk Camp Shelter, Elk Meadows East and Upper Elk Meadows West. At Upper Elk Meadows West, two 15 meter transects were put in place, and plants were planted every meter approximately one meter from the tape. Transects run roughly north-south with the origin on the north end. Transect 1 has a total of 30 plants from meter 1-15. Transect 2 has 28 plants. Plants were planted at the origin (meter 0) to meter 14. There are no plants at meter 13 due to the presence of dense vegetation. At Upper Elk Meadows West, a 30 meter transect that runs East-West was put in place with 60 plants. The origin is in the meadow and runs to the base of a Douglas fir. Plants begin at the origin and go to meter 29. Three areas were planted at each Nevergo and Elk Camp Shelter. At both Elk Camp Shelter and Nevergo, rebar was placed and plants were planted at the cardinal and intercardinal positions one meter from the center post in two areas. At the third location a plant was placed at the cardinal positions and in the center near the rebar. (See Appendix for map of approximate plot locations for all sites and GPS coordinates.)

Data Analysis

To determine the effects of our treatments on the survivorship of seedlings, a generalized linear model (Wald Chi-Square) with log-transformed survivorship data was run using SPSS statistical package. We tested the effect of soil moisture, litter, canopy type, propagule type, and exposure on survivorship using ANOVA. Significance between survivorship at all populations and by site was analyzed to determine if there were site specific variations in survivorship with treatment. A post-hoc analysis was performed on the survivorship of seeds and transplants with exposure.

RESULTS AND DISCUSSION

Seed production and viability

We observed great variation in the number and viability of seeds between years and populations. In 2008, there was significant variation in the percent of filled and viable seeds. The percent of filled seeds varied from a low of 21% (Forest Service 2007) to a high of 95% (BLM 2007) (Table 2). Of the seeds that were filled, germination rates varied from a low of 5% (Forest Service 2006) to a high of 68% (Forest Service 2008).

Plants were surveyed several times in late summer/early fall 2009 for floral and fruit development. In 2009, there were an average of 117-130 (63-78%) mature capsules and 34-69 (22-37%) aborted capsules per population (Table 3). The average number of seeds produced per plant ranged from 433-531 seeds per population, with an average of 344-440 (79-90%) filled seeds per plant. The viability of seeds collected in 2009, as determined by tetrazolium testing, ranged from 47%-92%.

Although it is unclear why there was such great variation in the percentages of filled seeds and germination, it is clear that there is sufficient seed production and high enough germination rates that seed viability should not be impacting these populations.

Table 2. Frasera seed viability. In 2009 TZ tests were performed by the OSU seed lab to test for viability. In previous years, germination was determined by counting germinated seeds after 16 weeks of cold stratification at 4 ^{o}C, and then placed in a warm room for at least one week.

Site	year collected	% filled seeds	Viability of filled seeds
Elk Meadows	2006	68%	31%
“	2007	95%	26%
“	2008	86%	59%
“	2009	81%	47%
Forest Service (all)	2006	92%	5%
“	2007	21%	31%
“	2008	83%	68%
Sourgrass Mtn.	2009	91%	75%
Nevergo	2009	79%	84%
Elk Camp Shelter	2009	87%	92%

Table 3. Number of seeds per plant and number of capsules per plant from plants collected in 2009.

	Elk Meadows	Sourgrass	Nevergo	Elk Camp Shelter
Avg. # of capsules per plant	173	194	186	155
mature capsules (avg.)	121 (70%)	130 (67%)	117 (63%)	121 (78%)
aborted capsules (avg.)	51 (29%)	64 (33%)	69 (37%)	34 (22%)
Avg. # of seeds per plant	531	486	433	475
filled	440 (83%)	437 (90%)	344 (79%)	411 (87%)
unfilled	92 (17%)	49 (10%)	89 (21%)	64 (13%)

Natural Recruitment

Natural seedlings were found around the base of mature plants, or near plants that had flowered the previous year in every population except Elk Camp Shelter. In 2010, five seedlings were found at Nevergo and four seedlings were found at Upper Elk Meadows (near plants marked with curlicues # 49 and #51). Natural recruits were noted in both years within and near our experimental plots at Sourgrass Mountain.

In 2009 and 2010, we observed naturally recruited seedlings at Sourgrass Mountain in our experimental plots. In 2009, in plot 285, 44 *Frasera* plants were present. Assuming a 100% success rate of both transplants and seedlings the maximum expected number of plants would be 24 (4 transplants and 20 seedlings). It can therefore be assumed that at least 20 of the plants in plot 285 were natural recruits. In the NE quadrant (treated with seeds and litter removed), 26 seedlings were noted. In the SE quadrant (planted with 2 transplants, and no litter removal), 6 seedlings were noted in addition to the 2 surviving transplants. There are natural *Frasera* plants on the eastern edge of the plot which likely provided the seed source for the natural seedlings. Natural seedlings were also noted sprouting in areas outside of our treatment plots at Sourgrass Mountain in 2009. In 2010 there were 3 natural seedlings in plot 285, (compared to the 26 in 2009). In the NE quadrant in 2010 there were only 7 seedlings in the same quadrant (compared to the 26 noted in 2009). The SE quadrant, which had 6 seedlings in 2009, had only 3 in 2010. This indicates that natural germination of seeds occurs, but interannual survival is low. It is unknown what factors influence the survival of seedlings from one year to the next; however, experiments with placing seedlings in a cold chamber (discussed below) suggest that a relatively long, cold winter may be necessary for survival and vigorous growth of young *Frasera*. .

During our survey for natural recruits, it was noted that plants that had flowered in the previous year (as evidenced by the presence of a dry inflorescence) were small compared to the size of the same plant in years of flowering. Work on a similar species, Frasera *speciosa,* has shown that the plant synchronously flowers every 3rd or 4th year, with only a small percentage of the population flowering in off years. Additionally *F. speciosa* that had flowered in the previous year was noted to be smaller in the subsequent year (Orley, 1985).

Figure 4. Natural plant at Nevergo surveyed for the presence of seedlings. Note the dry flowering stalk from the previous year.

Effects of Cold Treatment on Seeds and Seedlings

In 2009-2010 we placed one year old plants in cold treatment, and removed a subsample every 30 days. Plants that were in cold treatment for 90 days had the highest survival (23 out of 25 plants), were taller, and had more leaves than plants that received no or 30 days of cold stratification (7/25 and 11/25 survivors respectively). The implication is that established plants seem to do better with longer periods of cold, implying that longer (and colder) winters are best for established plants.

Approximately 20% of seeds that had not germinated the first year and were placed into a second round of cold stratification germinated. The germination of seeds after a second year of 'winter' implies that seeds may remain viable for at least two years, but require multiple periods of extended cold stratification to germinate.

Survival and establishment of introduced plants

Propagule Type

At all sites, transplants had higher survivorship than plants establishing from seed, however this is to be expected because although distributed seeds had been determined to be filled, tetrazolium tests indicated that actual viability of those seeds could have been anywhere between 47 and 95%. (Table 2,) Approximately 23% of the seeds sown at Sourgrass became established; less than half this number became established at the other sites. However, as noted above, we observed several naturally recruited seedlings at Sourgrass both in and outside of our plots. It is possible that the estimate of establishment by seed in our experimental plots includes some natural recruits and thus is an over-estimate. Survivorship of transplanted individuals was also highest at Sourgrass (~94% in 2009 and 75% in 2010). The lowest survivorship of transplants was approximately 43% at Upper Elk Meadows West in 2009 and only 11% in 2010 (Table 4). (This does not count Lower Elk Meadows, which had no seeds or transplants survive in 2010 due to extensive mountain beaver (*Aplodontia rufa*) activity and high cover of shrub and sub-shrub species in the area.)

Table 4. Survivorship of seeds and transplants in experimental plots in peripheral populations of Frasera. There was a significant difference in survivorship between seeds and transplants at all sites ($P < 0.0005$).

Site	Year	Survivorship	
		Seeds[1] (Mean ± 1 S.E.)	Transplants[2] (Mean ± 1 S.E.)
Elk Meadows East	2009	0.028 ± 0.008	0.111 ± 0.034
“	2008	0.112 ± 0.014	0.492 ± 0.052
Lower Elk Meadows West	2009	0	0
“	2008	0.067 ± 0.019	0.583 ± 0.104
Upper Elk Meadows West	2009	0	0.091 ± 0.061
“	2008	0.069 ± 0.016	0.091 ± 0.061
Elk Camp Shelter	2009	0.044 ± 0.016	0.344 ± 0.069
“	2008	0.015 ± 0.011	0.650 ± 0.090
Nevergo	2009	0.023 ± 0.009	0.400 ± 0.074
“	2008	0.022 ± 0.017	0.722 ± 0.073
Sourgrass Mtn SE	2009	0.108 ± 0.043	0.542 ± 0.096
Sourgrass Mtn	2009	0.236 ± 0.058	0.750 ± 0.066
“	2008	0.353 ± 0.063	0.938 ± 0.101

[1]10 seeds were sown per plot

[2]2 transplants were planted per plot

Year of Planting

In general, there was no difference between years of planting. Nor was there a difference between years of survival (one year vs. two years since planting). However, at Lower Elk Meadows, 58% of transplants survived and 6% of seeds established in 2009, but in 2010, there were no plants or seedlings. The poor survival and establishment in 2010 appeared to be due to extensive damage by mountain beavers. Additionally the first year survival compared between those planted in 2008 and 2009 differed in that more plants survived their first year in 2008 than in 2009 at Elk Meadows. This was especially true along the forest edge and is most likely because most of the optimal habitat had been utilized in 2008 so that those planted in 2009 were in sub-optimal habitat.

Canopy Cover

Frasera umpquaensis is a long-lived perennial species. The populations discussed in this report currently occur either just inside or just outside forest edges; therefore, we hypothesized that these populations had originally occurred in more open habitats and current levels of canopy cover inhibited seed establishment and seedling survival. However, we found no effect of canopy treatment (forest edge or open meadow) on establishment of seeds and transplants at any of the sites ($P>0.10$).

While there was no difference between closed and open canopy treatments, there was a significant effect ($P<0.0005$) of exposure on the survival of transplants and seeds planted along the forest edge (Figure 5). Transplants and seeds planted along the forest edge with a northern exposure had the highest survival, while plants with a southern exposure were the least likely to survive. At Elk Camp Shelter, 63% of transplants survived with a northern exposure and no transplants survived with a southern exposure. At Nevergo, plants with an eastern or western exposure had 50% survivorship whereas plants with a southern exposure only 8% survivorship. At Sourgrass Mountain north facing transplants had an 88% survival rate and south facing plants only 13%. Only at Elk Meadows was there no significant effect on survival between north and south facing plants; however this site generally had low survivorship.

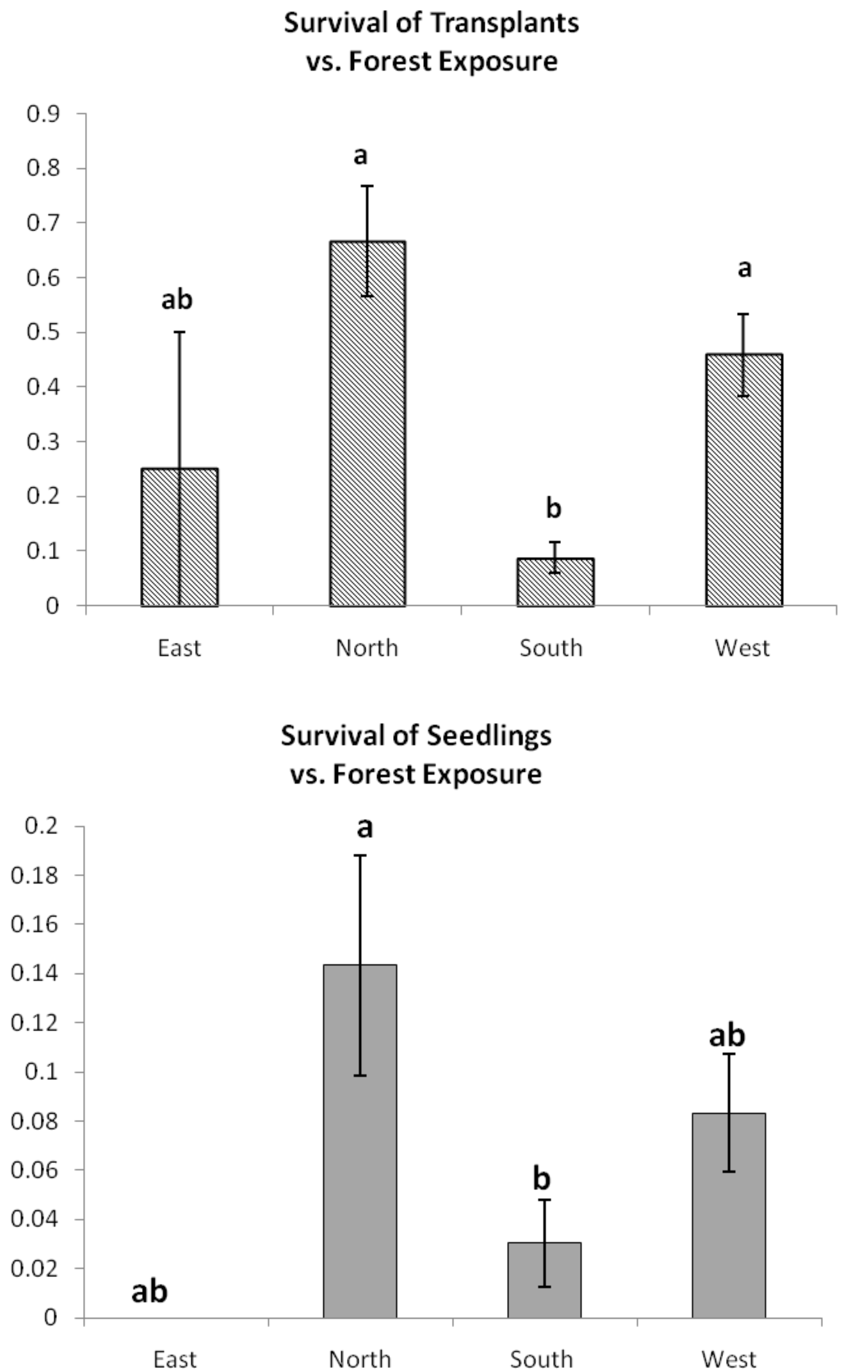


Figure 5.
Mean survivorship of forest transplants and seedlings by exposure type (average of all populations; error bars ± 1 SE). Both transplants and seedlings had the highest survival in north facing exposures, followed by west facing exposures. Bars with the same letter indicate exposure types that were not significantly different from each other when compared using a post-hoc Bonferroni test in SPSS.

Litter

As with canopy cover, we hypothesized that changes in the plant community since initial establishment of the existing *F. umpquaensis* at these sites may have resulted in increased litter cover, which inhibited establishment and seedling survival. However, there was no effect of litter removal on establishment of *F. umpquaensis* (P=0.626) (Figure 6 and Figure 7). The greatest impact of litter removal was at Sourgrass Mountain Southeast and Upper Elk Meadows, however these effects were not significant (P=0.112 and P=0.130 respectively).

Soil Moisture

Due to differences in solar exposure and landscape position, we hypothesized that there may be differences in soil moisture that affect establishment or seedling survival. However, we did not find a significant effect of soil moisture on survivorship of seeds or transplants (P>0.100; Table 5).

Solar Measurements

There was no significant effect of canopy cover as measured by either a densitometer for solar pathfinder on survivorship of seeds or transplants (P>0.100) (Table 6).

Table 5. Average percent water in soil collected at all sites.

	Meadow	**Forest**			
		North	**South**	**East**	**West**
Elk Camp Shelter	38%	39%	37%	-	-
Elk Meadows East	25%	26%	21%	-	-
Lower Elk Meadows West	23%	-	-	-	-
Upper Elk Meadows West	24%	-	25%		-
Nevergo	39%	-	37%	35%	40%
Sourgrass Mountain	28%	28%	28%		-
Sourgrass Mountain SE	26%	-	-	-	26%

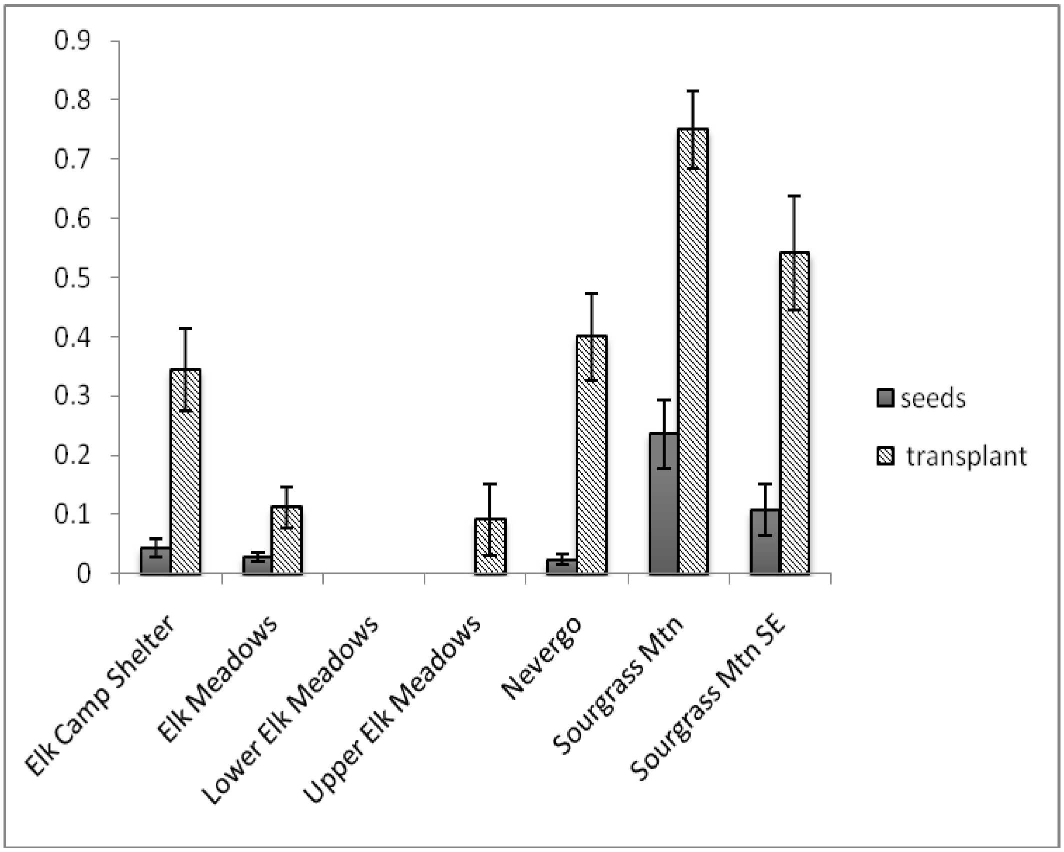
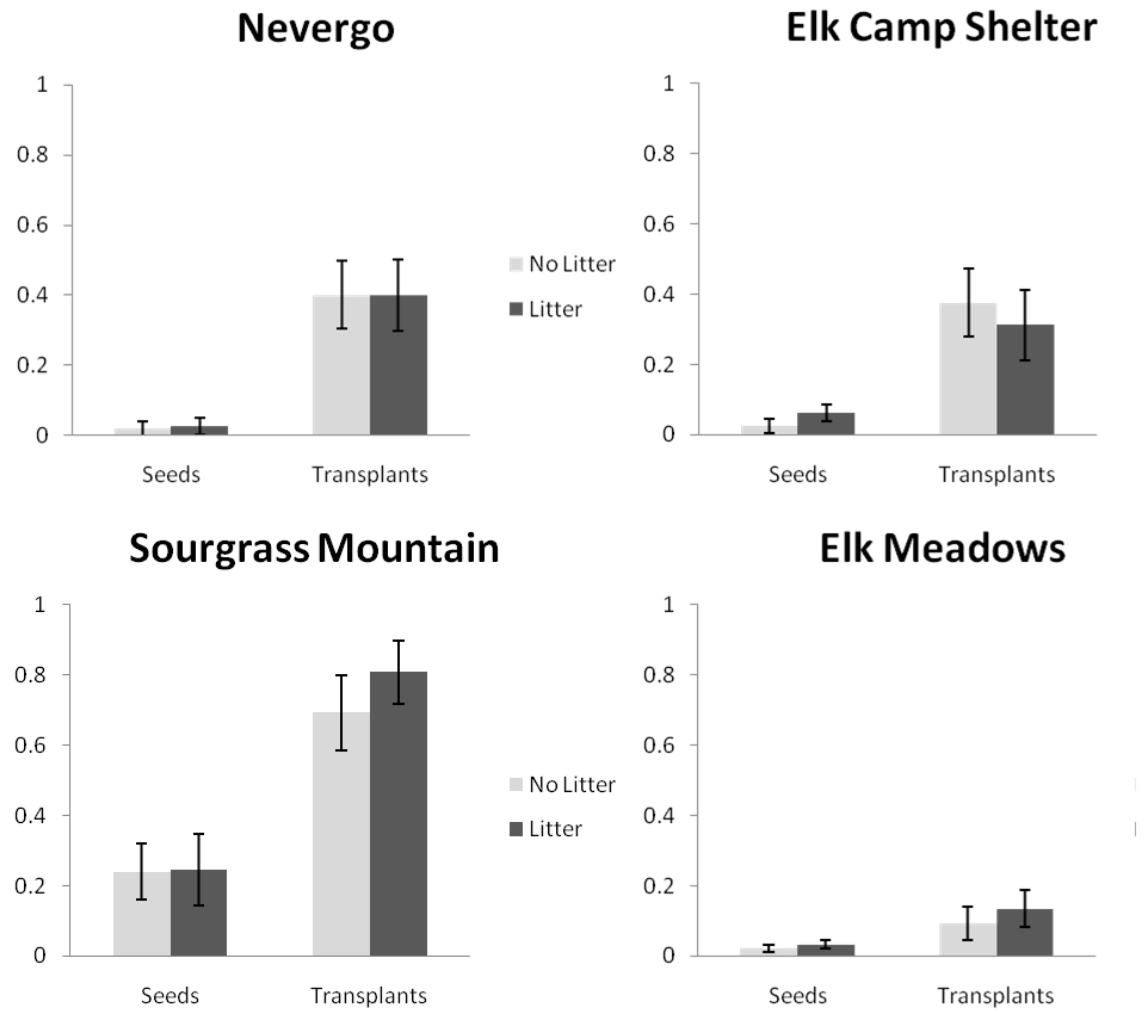


Figure 6. Mean survivorship (±1 S.E.) of Frasera seeds and transplants in experimental plots at Elk Camp Shelter (FS), Elk Meadows (BLM), Lower Elk Meadows (BLM), Upper Elk Meadows (BLM), Nevergo (FS), Sourgrass Mountain Southeast and Sourgrass Mountain (FS).



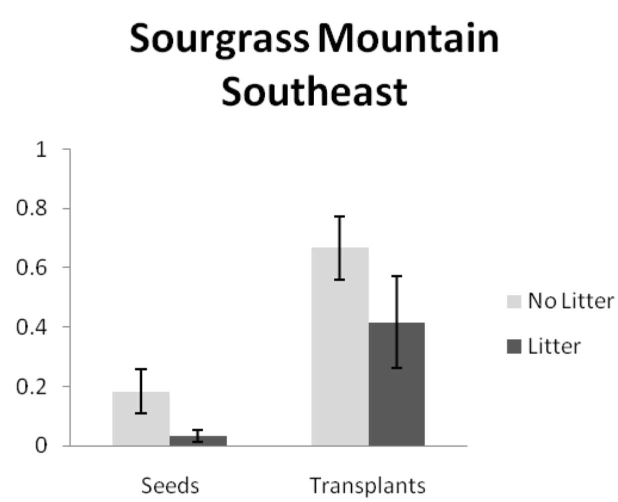


Figure 7. Mean survivorship (±1 S.E.) of *F. umpuaensis* seeds and transplants in experimental plots. There was not a significant difference between litter and litter removal treatments at Nevergo (FS) (P=0.933), Elk Camp Shelter (FS) (P=0.425), Sourgrass Mountain (FS) (P=0.666), Elk Meadows (BLM) (P=0.425) ,and Sourgrass Mountain Southeast (FS) (P=0.118).
Upper Elk Meadows is not included in this figure, however the 2 transplants that survived were in plots with litter removed (P=0.130).

Table 6. Summary of solar data at all sites. Light measurements indicate the percent of light reaching the plots as measured by the densiometer and Solar Pathfinder.

	Canopy cover, (%, Densiometer)					Solar Radiation (%, Solar Pathfinder)						
	North	**East**	**South**	**West**	**Average**	**April**	**May**	**June**	**July**	**August**	**September**	**October**
Elk Camp Shelter												
Average All Plots	56	58	55	66	59	46	58	54	53	49	33	20
Average Meadow Plots	87	88	85	96	89	73	89	93	90	75	40	13
Average Forest Plots	43	44	43	54	46	34	45	38	37	38	29	23
Average North Facing Forest Plots	71	34	28	77	53	12	36	34	30	18	3	1
Average South Facing Forest Plots	23	52	54	36	41	50	53	41	42	53	49	39
Elk Meadows												
Average All Plots	38	42	44	37	40	35	37	38	37	35	33	30
Average Meadow Plots	48	79	80	55	65	70	77	76	76	74	69	57
Average Forest Plots	33	23	27	27	27	18	17	19	17	15	16	16
Average North Facing Forest Plots	48	25	36	45	39	23	27	33	28	24	21	19
Average South Facing Forest Plots	23	22	21	16	20	16	11	9	10	10	12	14
Lower Elk Meadows												
Average Meadow Plots	77	63	32	39	52	35	42	31	38	34	32	28
Upper Elk Meadows												
Average All Plots	40	56	50	49	49	37	52	62	60	44	30	21
Average Meadow Plots	65	64	65	82	69	47	72	83	83	62	38	29
Average Forest Plots (all south facing)	15	48	36	16	29	27	33	41	37	25	23	12

Table 6 cont.

	Canopy cover, (%, Densiometer)					Solar Radiation (%, Solar Pathfinder)						
	North	**East**	**South**	**West**	**Average**	**April**	**May**	**June**	**July**	**August**	**September**	**October**
Nevergo												
Average All Plots	38	46	51	45	45	43	43	39	42	41	36	21
Average Meadow Plots	48	55	49	52	51	41	43	39	41	40	29	20
Average Forest Plots	26	34	53	37	37	46	44	40	42	42	45	23
Average South Facing Forest Plots	29	38	64	44	44	52	51	50	52	49	52	27
Average East Facing Forest Plots	17	21	18	15	18	28	23	9	14	18	22	12
Sourgrass Mountain												
Average All Plots	88	76	81	85	83	51	59	56	62	61	49	36
Average Meadow Plots	89	73	81	78	80	43	53	46	41	52	41	27
Average Forest Plots	88	78	81	89	84	55	63	63	74	65	54	41
Average North Facing Forest Plots	92	88	79	86	86	56	73	75	72	71	56	41
Average South Facing Forest Plots	81	62	85	95	81	54	49	45	77	57	52	43
Sourgrass Mountain Southeast												
Average All Plots	46	44	55	56	50	51	49	52	54	53	41	24
Average Meadow Plots	67	80	86	87	80	68	72	77	76	73	56	32
Average Forest Plots (all west facing)	25	7	24	25	20	33	26	26	31	34	26	16

CONCLUSIONS

After two years of greenhouse and field trials, we found that in northern peripheral populations of *F. umpquaensis*, seeds are viable and germinate under experimental conditions, seeds germinate in field plots, and transplants are able to survive in the field for at least two years (Figure 8). We also observed natural seedling recruitment at Nevergo, Upper Elk Meadows West and Sourgrass Mountain. Although establishment of seedlings occurred at all sites, we noted high interannual mortality of both seeded and natural seedlings. This could be caused by seasonal variability in moisture and winter length, interspecific competition, or natural population dynamics. It is currently unclear why these populations have declined, but it could be due to high mortality of young plants.

Figure 8. *Frasera* transplant at Sourgrass Mountain, August 2009 (approximately 10 months after planting).

Frasera umpquaensis is a long-lived perennial species. The existing peripheral populations tend to occur just within or outside of forest/meadow edges. Populations on the Rogue-Umpqua Divide occur in more open forests. Thus, it had been hypothesized that low recruitment in the peripheral populations was due to habitat changes associated with encroachment of shrubs and trees, including increased canopy cover, competition, and litter depth.

In contrast to our expectations, there was no effect of litter removal on survival of seedlings or transplants. Similarly, we did not find a difference in the survival of transplants and seedlings in the open meadow versus forest habitats. However, on the forest edge, we did find a significant effect of edge aspect.

The results of our studies suggest that broad climate factors, not habitat characteristics, may have the greatest impact on peripheral populations of *F. umpquaensis*. This species typically occurs in areas with relatively long, cold winters. Both transplants and seedlings along the forest edge survived best with north facing exposures. North facing areas represent a cooler microclimate as they receive less intense sun exposure and therefore remain covered with snow for longer periods compared to south facing exposures at the same site. In our greenhouse experiments we found that year-old plants that received an extended cold treatment were more robust than plants that received shorter periods of cold, and some seeds required multiple periods of extended cold stratification to germinate.

Poor recruitment and survival of young plants in these populations may be due to shorter, warmer winters either associated with short-term climate cycles or long-term global climate change. Climate models suggest that global climate change will result in generally warmer winter temperatures in this part of Oregon which may contribute to future population declines.

RECOMMENDATIONS FOR MANAGEMENT AND RESEARCH

Given the low recruitment in peripheral populations of *F. umpquaensis*, we suggest continued research and management activities are necessary. Although these populations are not continuous with populations in the core of this species' habitat, they may contain genetic diversity not represented elsewhere that may be important for the long term viability of the species.

Due to low recruitment in these populations, one of the most important activities for their preservation is prevention of anthropogenic impacts. In 2010, we observed significant damage by ORVs in the boggy area adjacent to the *F. umpquaensis* population at Elk Camp Shelter. Given its location, this site is at the most risk for ORV damage; however the other populations could also be affected.

Given our observations of natural recruitment at some of the sites, apparently synchronous flowering of most plants every 3rd or 4th year, and variations in plants size between years, we recommend establishing two levels of annual monitoring. First, all sites should be surveyed each year for all individuals, including seedlings. We found that July or August was the time to observe seedlings and adult flowering plants. Second, all individuals should be tagged and monitored for characteristics including height, number of leaves, and flowering status. Annual data of this type would allow us to detect important population changes, rates of establishment in years after flowering events, and determine correlations between climate variables and population traits. In order to complete these analyses, we recommend at least ten years of continuous monitoring data.

Our research suggests seed addition and planting seedlings may both be successful methods to augment declining populations of *F. umpquaensis*. However, given the short duration of this study, it is unclear how the individuals that survived through 2010 will ultimately contribute to this population. Continuous monitoring of the plants introduced through this project will provide important insight into the population dynamics of this species.

Finally, these results suggest factors to consider for successful population augmentation. Although there was no difference in the effect of canopy cover (forest vs. open), if planted on the forest edge, plants should be placed on a north-facing edge. Although sowing with seeds will be successful, greater success can be achieved by planting greenhouse-grown seedlings. Finally, as some sown seeds may not germinate until after two sequential years of cold stratification, success cannot truly be determined until several years after introduction due to the slow growth of the species. Additionally, the species' 3-4 year flowering cycles suggest that management of this species requires a long-term commitment.

Table 7. Schedule of activities for the study of recruitment failure in peripheral populations of *Frasera*. A final partner meeting to discuss results and recommendations in this report will be scheduled for late winter 2011.

	2007				2008				2009				2010				2011
Activity	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**
Partner meeting					■												
Seed sampling			■	■			■	■			■	■					
Seed testing				■	■			■	■			■	■				
Grow-out				■	■	■	■		■	■	■						
Plot establishment								■				■					
Seed placement								■				■					
Recruitment sampling											■	■			■		
Interim report								■				■					
Final report																	■
Summary meeting																	■

LITERATURE CITED

Barbara L. Wilson, Valerie Hipkins, Tom N. Kaye, 2010. One Taxon or Two: Are Frasera umpquaensis and F. fastigiata (Gentianaceae) Distinct Species?, Madroño Apr 2010 : Vol. 57, Issue 2, pg(s) 106-119.

Cripps, C. 1993. Conservation strategy for Frasera umpquaensis. Oregon: USDA Forest Service, Umpqua, Rogue River, Willamette and Siskiyou National Forests; USDI Bureau of Land Management Eugene and Medford Districts. 30 pp.

Kaye, T.N. 2001. *Frasera umpquaensis* population monitoring plan. Medford District, BLM. 2001 Progress Report. Prepared by Institute for Applied Ecology for Medford District BLM. 34 pp.

Orley R. T. Jr. and David W. Inouye, 1985. Sychrony and Periodicity of Flowering in Frasera Speciosa (Gentianaceae) Ecology, Vol. 66, No. 2 (Apr., 1985), pp. 521-527.

Appendix A. Contacts, directions, and gear list.

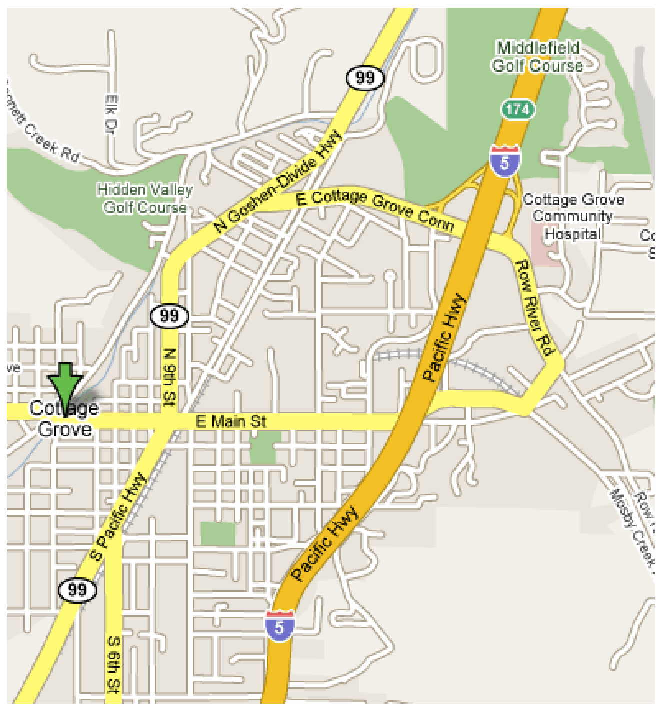
Contacts

<u>BLM</u>:
Cheshire Mayrsohn, Cheshire_Mayrsohn@or.blm.gov
Nancy Sawtelle, Nancy_Sawtelle@blm.gov

<u>Forest Service:</u>
Molly Juillerat: mjuillerat@fs.fed.us
Jenny Lippert: jlippert@fs.fed.us

Directions
Elk Meadows (Eugene District BLM)
***needs BLM Eugene District gate key**

- I-5 south to Cottage Grove
- Take 6'th street out south, out of town (sign in town will say to Cottage Grove/London Springs)
- 6'th St. becomes London Road.
- Go past Cottage Grove Lake.
- Continue through London.
- Left at sign for Big River/Steamboat – BLM road #25-3-5.4 – Big River Road (~4.1mi. after London school)
- Follow -5.4 (sign had been shot to pieces and unreadable 10/25/07) 8.6 mi. Turn right onto a road just before a white "1099" sign pinned onto a PSME. "JEN" was spray painted on the road at this intersection in 2008.
- Turn right, onto 33-2-35.1. Yellow gate shortly after turn (can see gate ~50' up road) - ***requires BLM gate key***. Signed: BLM stockpile site.



if you forget the key: it is not very far to site, can park before gate and walk in. A sedan would be fine to access this site.

Sourgrass Mountain, Elk Camp Shelter, and Nevergo Creek Populations.
Directions: take I-5 south to Highway 58 east. Turn left (go north) on Aufderheide Memorial Highway (Hwy 19 across from FS Ranger Station). Left onto Road 1912 (go over a one lane bridge). Go (roughly) about 6.5 miles. At big junction, continue up road 1912 (it will seem like you are taking a right-hand turn). At four-way intersection, take a left up Road 140.

<u>Sourgrass Mountain (FS):</u>

At fork, stay right on 140 (driving along alpine ridge)
Park at spur #266 (on right). Sign says “ROAD CLOSED”, and is shot up, has smiley face drawn on one of the O’s.
Walk up the road ~0.5 miles. The road has been washed out/sunken in a few spots and the view opens up to the left, at this point, walk up the ridge on your right through a timber cut and instersect the Alpine Trail. When you hit the Alpine Trail follow it (right) into the open beargrass meadow. The first plots are on your right just after the trail opens into the meadow.

You can also access the population by connecting with the Alpine Trail from 1912 and walking up the trail to Sourgrass Mountain.

There are some FRUM plants interspersed in the beargrass and along the Alpine trail. Largest patches are in mesic meadows located between beargrass and forest edge. Large beargrass meadow, 2 large patches on edge of beargrass. Also scattered in beargrass and along alpine trail. 3’rd patch along alpine trail, then up through beargrass.
Largest patches:

10T 0541061, 4856775
10T 0541107, 4856669
10T 0541481, 4856625

To Elk Camp Shelter: return to Road 140, keep going down road to 3-way intersection, turn right onto Road 142. Follow trail from road to Alpine Trail. UTM 10T 0541415, 4859377; 43°53’14”N, 122°29’10”W. At Alpine Trail, turn left and continue a short way until you reach the meadow to the right. Meadow off trail, pink flag visible through meadow, population on edge along timber. Cool wetland with bog orchids, elk wallow with *Scirpus* around edges. There is a tree with flagging marking where the FRUM are located.
Sign back 1824, Road 142
left at alpine trail

Nevergo Creek: from Elk Camp Shelter, continue along Road 142. There will be some plants scattered near the fork in the road. Turn right and go 10 – 20 meters. Plants are located downslope and are being over-grown by *Vaccinium* and bracken fern.

From Lowell
I-5 to highway 58. Turn left onto Jasper-Lowell Rd.
Big Fall Creek Rd.
Winberry Crk.
Rd. 1802, go east
north on 1824
at y-intersection, left up 142
right up 1824-182

Nevergo will be on the left.
from Nevergo to *Elk Camp Shelter*, bear right, stay on main road.

to *Sourgrass*, continue on main road. At intersection of 142 and 140, go left onto 140 ("to Sourgrass Prairie Rd."). Park at Rd. 266. (gate locked; road closed and washed out)

Gear list
copy of gear list and directions
last year’s report
plot maps
last year’s datasheets
new datasheets, some rite-in-the-rain
clipboards (4)/pencils
gazetteer, BLM transportation map, Forest Service roads map
GPS
5 tapes: 3-100m, 2 shorter
8 candy canes
rulers- one per person
3 plot frames
flagging
~20 pin flags
5 pieces rebar (for replacement)
5 pieces PVC-conduit (for replacement)
mallet
wire
tags
compass
densiometer
solar pathfinder
for soil collection: cooler, ziplocks, sharpies, soil corer

Health and Safety Kit (including Tecnu-although there is little to no poison oak in the area)

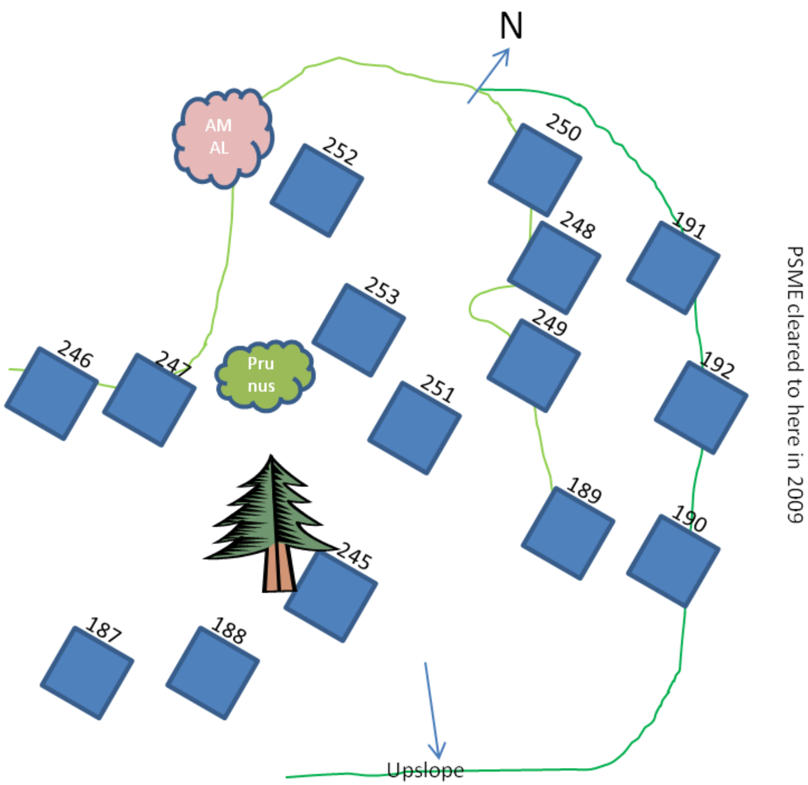
Extra water

Appendix B. Plot Maps of All Sites

Nevergo

NEVERGO Plot Map:

UTM (NAD 83):
541079 E
4860125 N



PSME Vine Maple

NEVERGO:
Park on spur road just off of 142. Walk down road ~30m, drop down through meadow and cut right along flagged path.

Map is not to scale

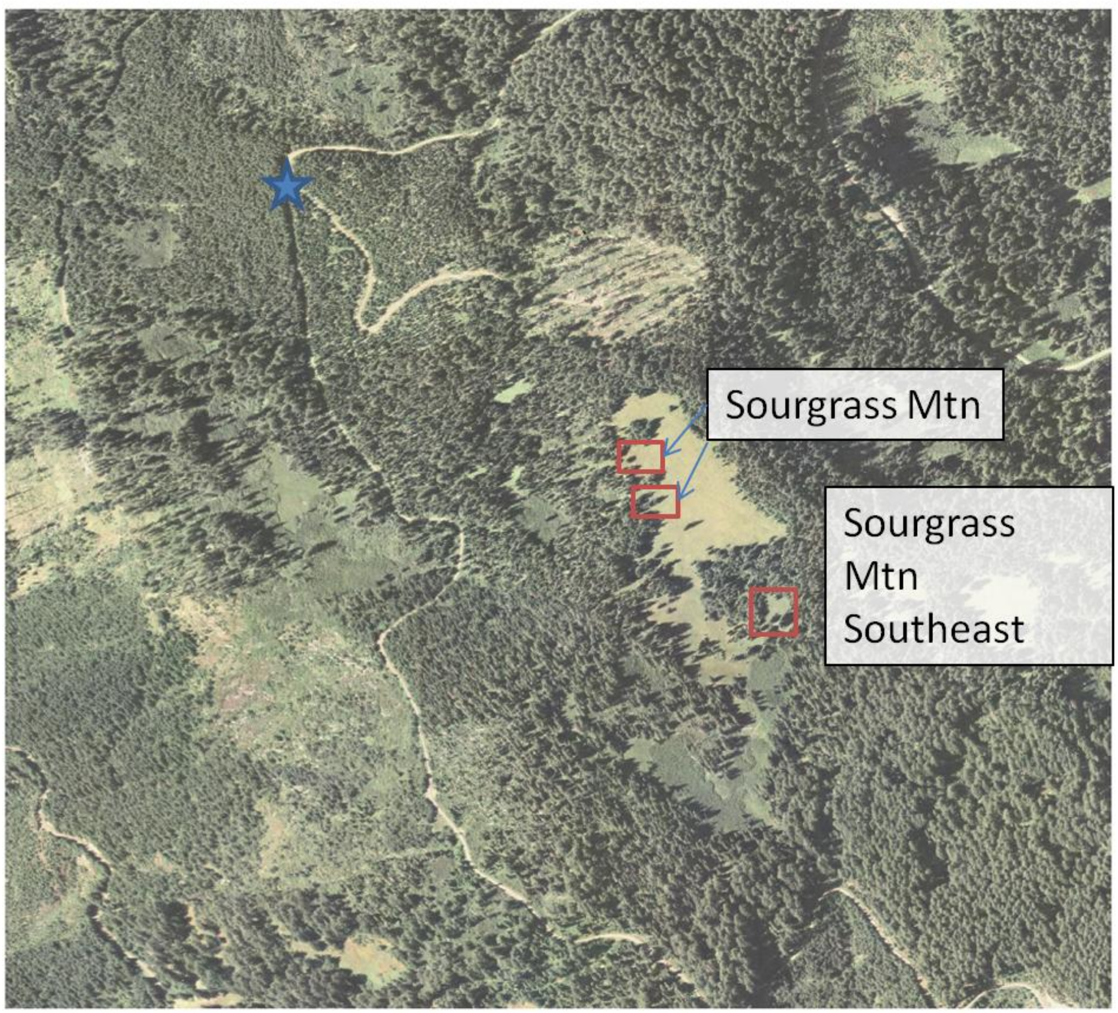
Location of 2010 outplantings with partners, Nevergo:

Sourgrass Mountain:

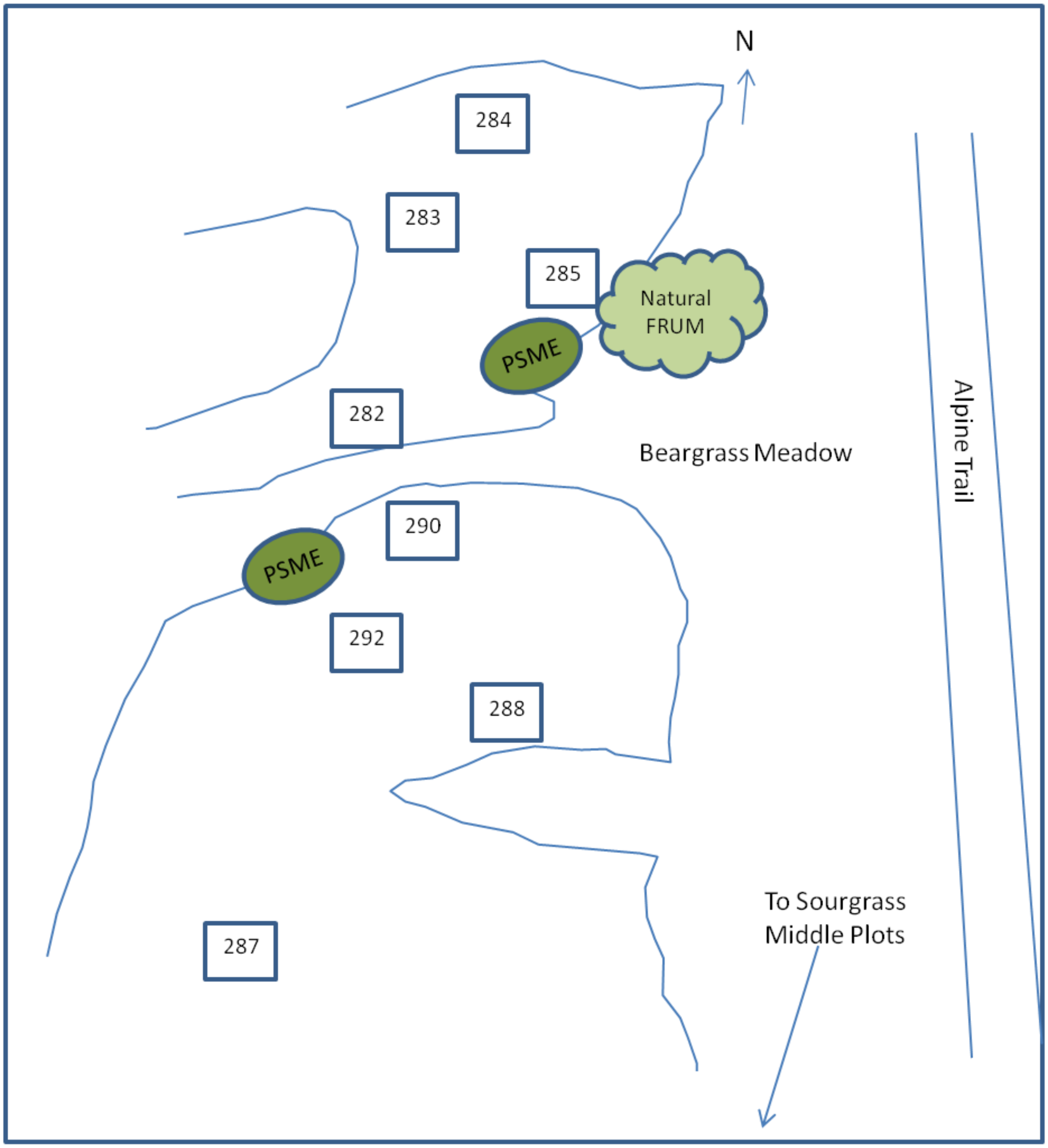
Sourgrass Mountain:

Park at star and walk up road ~0.4 miles. Cut right up logged section until you hit the Alpine Trail. Follow the Alpine Trail right (SW) until you come to the beargrass meadow. Plots will be on your right.

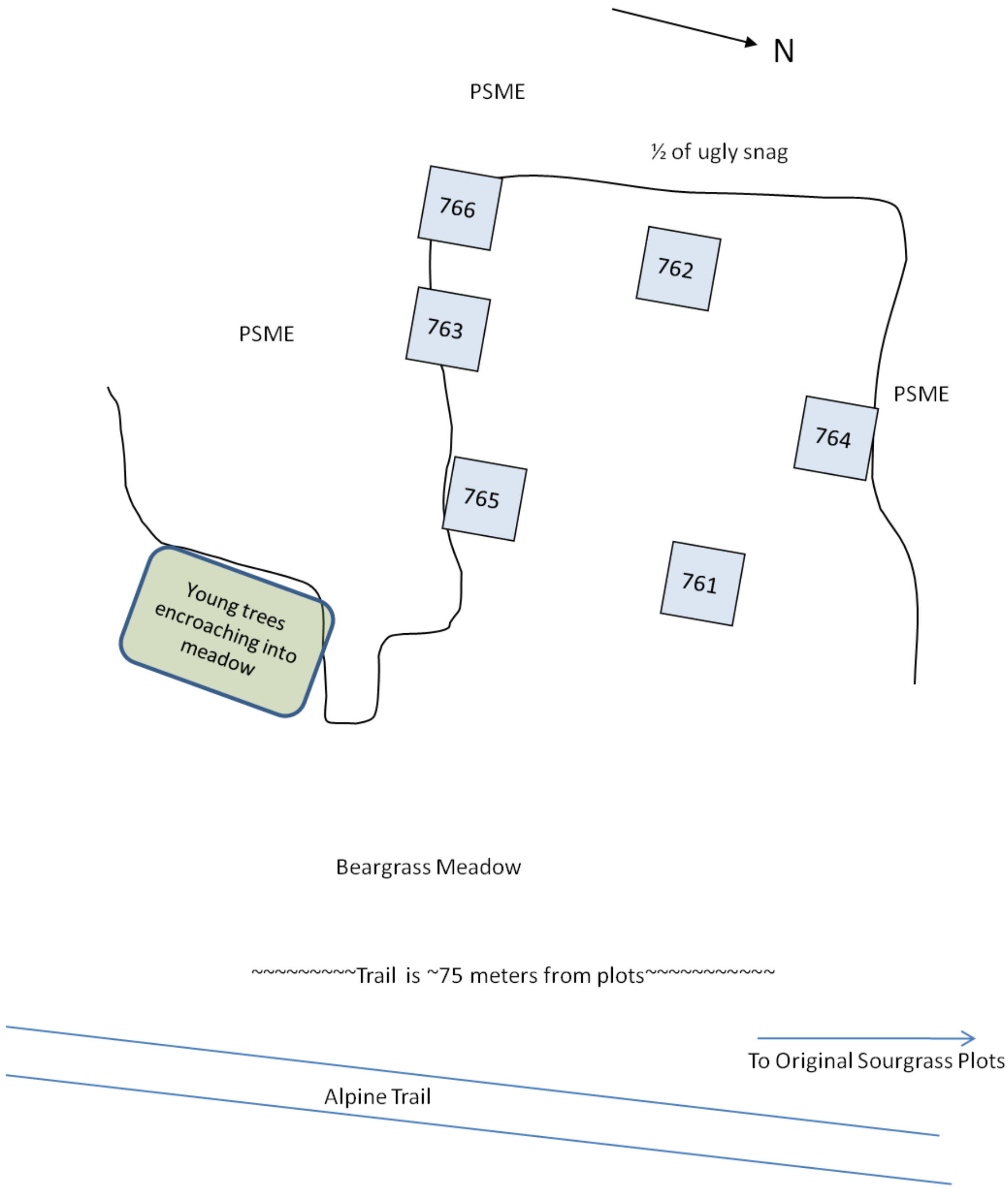
To reach Sourgrass Southeast, follow the Alpine Trail across meadow, when the trail begins to veer left, leave the trail and head south (downhill). The plots will be on your left in an isolated clearing surrounded by PSME.



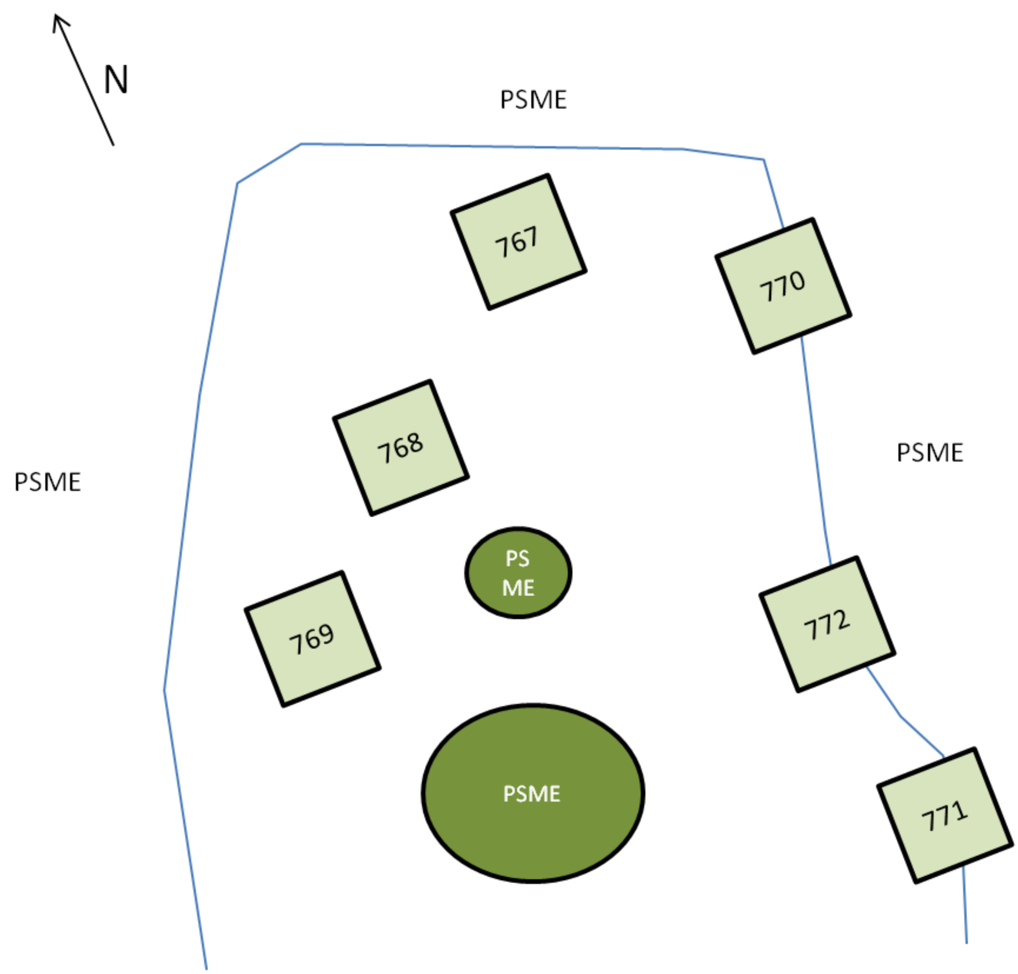
Sourgrass Mountain, Original 2008 Plots:



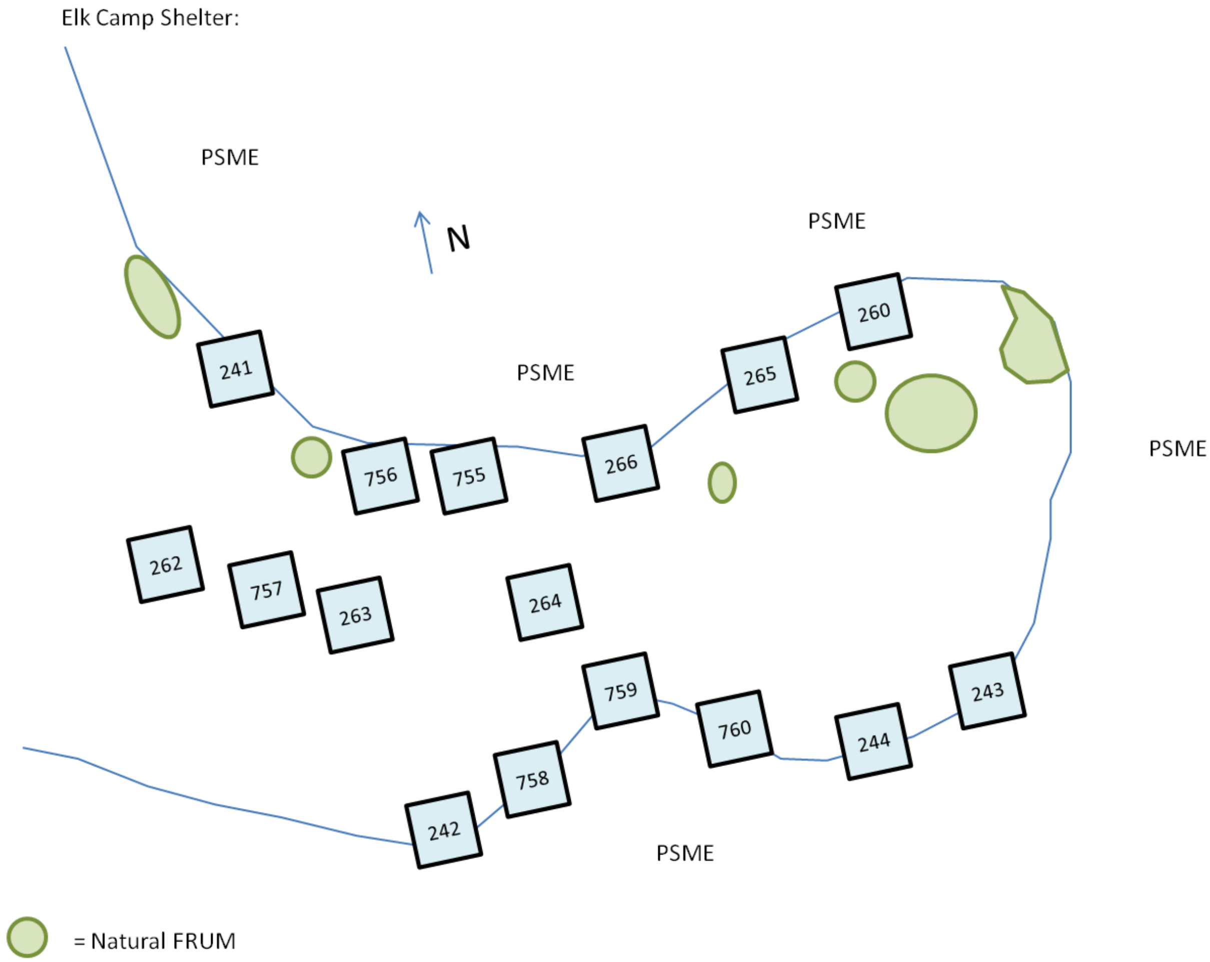
Sourgrass Mountain , 2009 Middle Plots



Sourgrass Mountain Southeast:

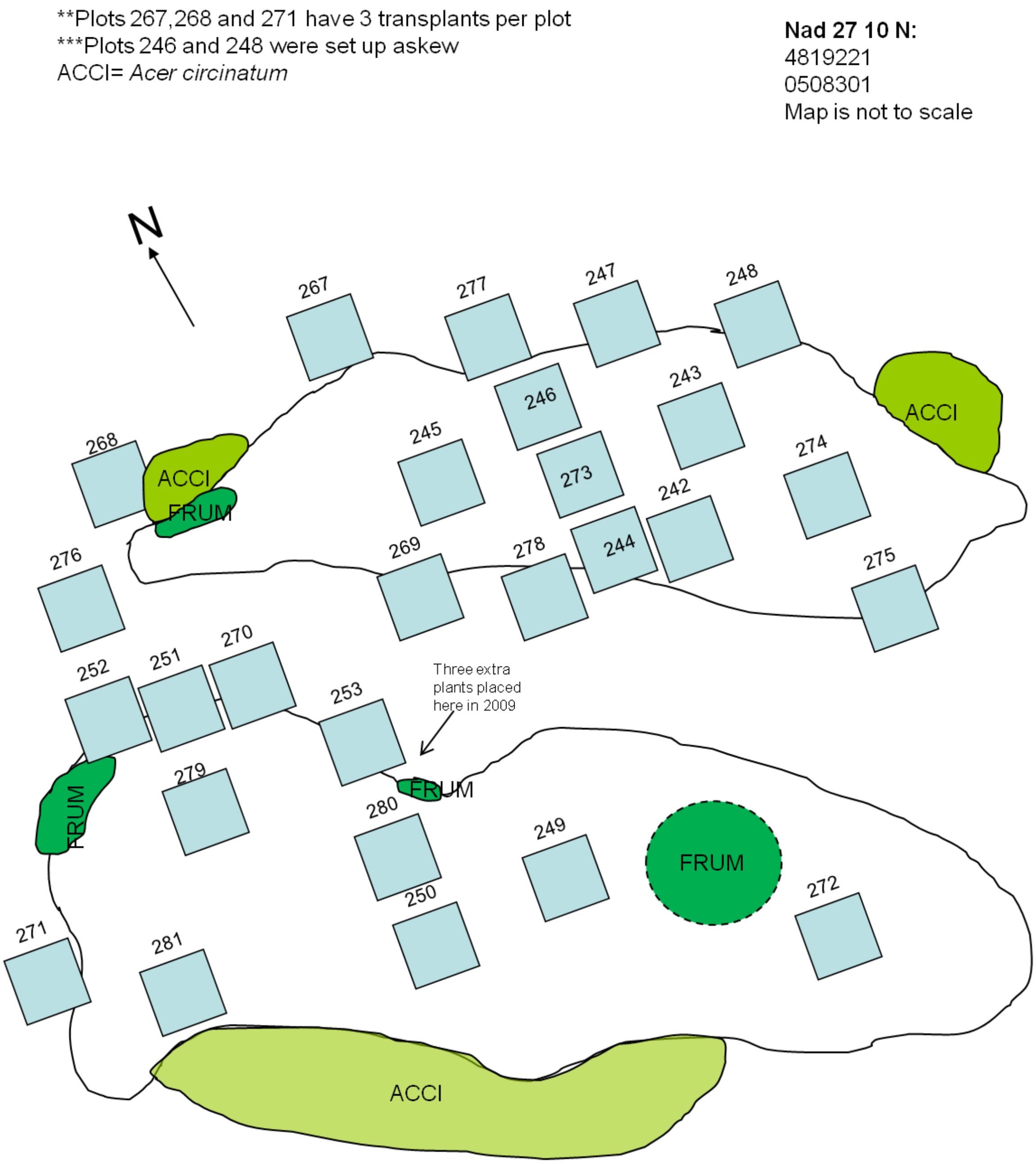


Elk Camp Shelter:

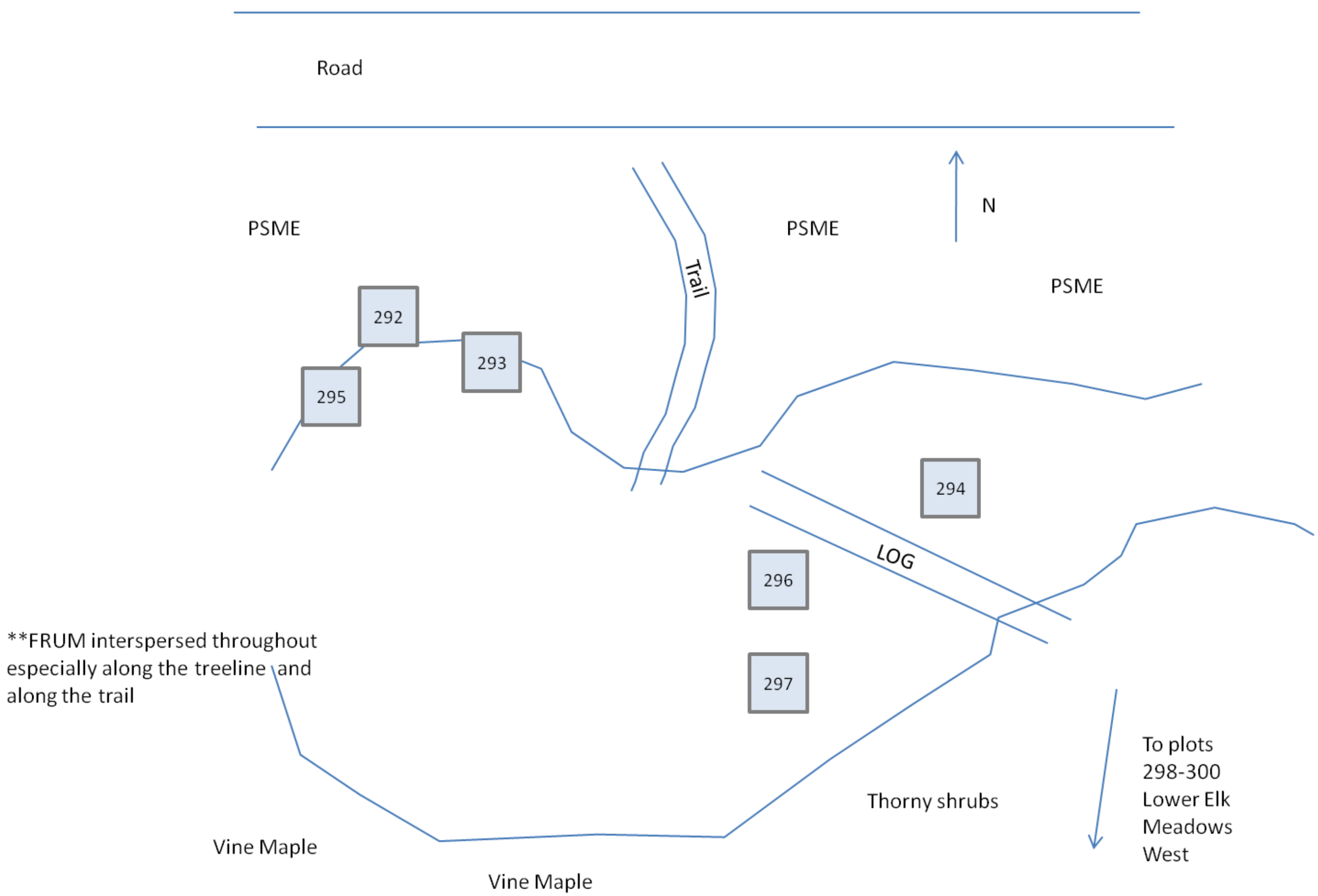


Location of 2010 outplantings with partners, Elk Camp Shelter:

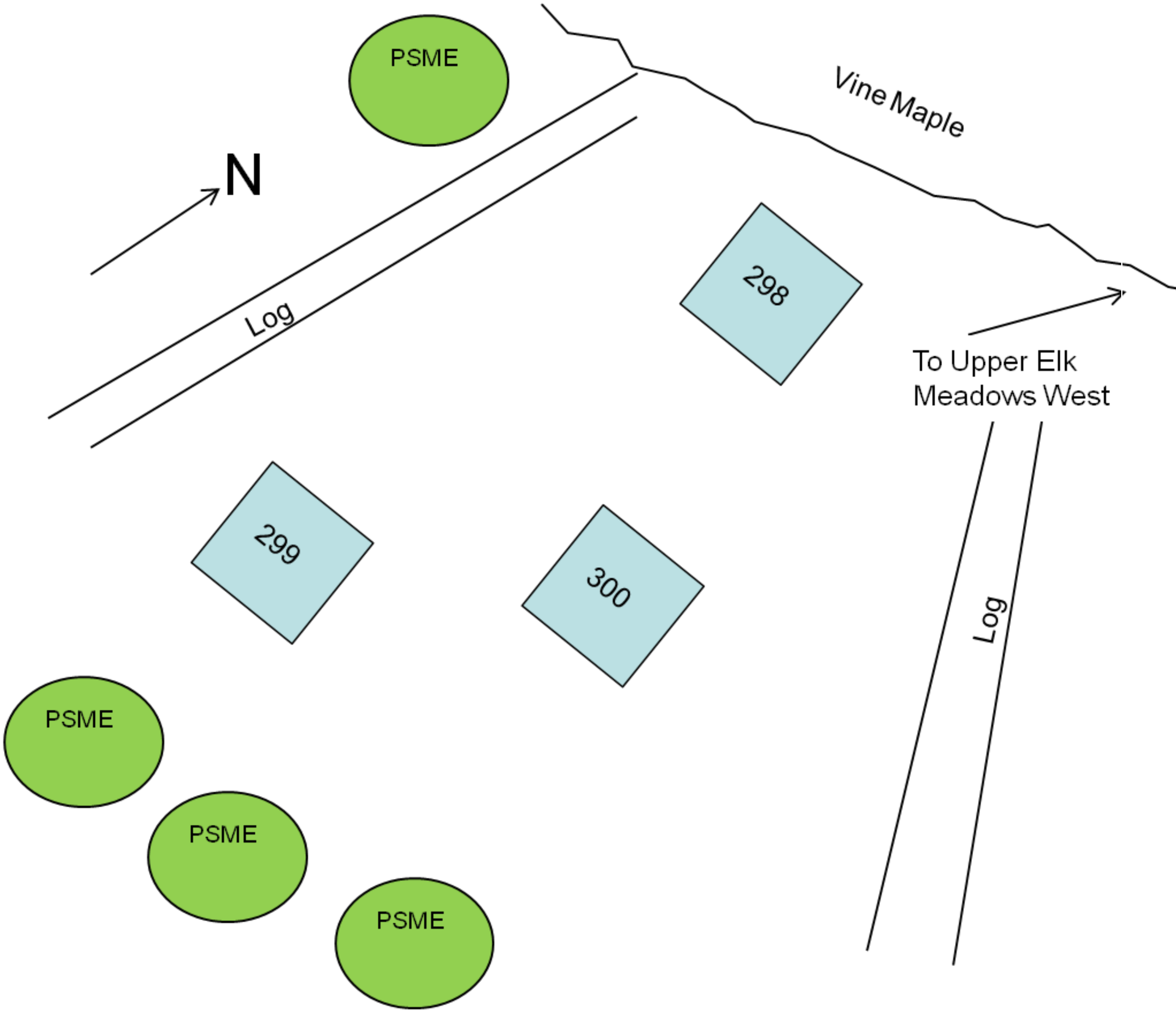
Elk Meadows East:



Upper Elk Meadows West:



Lower Elk Meadows West:



Location of 2010 outplanting transects with partners, Elk Meadows:

Transects 1 and 2 are located on the western edge of Elk Meadows East.
Transect 3 runs from the northeast end of Upper Elk Meadows West to the west end of the meadow at the base of a large tree.

APPENDIX C. GPS COORDINATES (NAD 83) OF ALL SITES

GPS Coordinates of all sites and outplantings of 'extra' plants in 2010:

Site Name	Latitude (N)	Longitude (W)	Type of outplanting
Elk Camp Shelter	43.88733	122.48504	8 plants (at cardinal and intercardinal directions)
Elk Camp Shelter	43.88739	122.78783	8 plants (at cardinal and intercardinal directions)
Elk Camp Shelter	43.88745	122.48487	5 plants at center rebar and at cardinal directions
Elk Camp Shelter	43.88723	122.48493	General location for all plots
Nevergo	43.96313	122.48888	8 plants (at cardinal and intercardinal directions)
Nevergo	43.89302	122.48870	8 plants (at cardinal and intercardinal directions)
Nevergo	43.89302	122.48890	5 plants at center rebar and at cardinal directions
Nevergo	43.89311	122.48842	General location for all plots
Elk Meadows East	43.52780	122.89845	Start of Transect 1
Elk Meadows East	43.52769	122.89845	End of Transect 1
Elk Meadows East	43.52793	122.89828	Start of Transect 2
Elk Meadows East	43.52801	122.89825	End of Transect 2
Elk Meadows East	43.52764	122.89809	General Plot locations
Lower Elk Meadows West	43.52793	122.90298	General plot location
Upper Elk Meadows West	43.52840	122.90273	Start of Transect 3
Upper Elk Meadows West	43.52838	122.90247	End of Transect 3
Upper Elk Meadows West	43.52837	122.90251	General plot location
Sourgrass Mountain	43.86524	122.49056	General plot location
Sourgrass Mountain Middle	43.86469	122.49047	General plot location
Sourgrass Mountain Southeast	43.86306	122.89808	General plot location

APPENDIX D. TREATMENTS FOR EACH QUADRANGLE IN ALL PLOTS FOR THIS STUDY:

Site	Year Planted	plot #	plot position	canopy type	sun exposure	litter?	propagule type
Elk Camp Shelter	2008	241	NE	forest	south	no	transplant
Elk Camp Shelter	2008	241	NW	forest	south	no	seeds
Elk Camp Shelter	2008	241	SE	forest	south	yes	seeds
Elk Camp Shelter	2008	241	SW	forest	south	yes	transplant
Elk Camp Shelter	2008	242	NE	Forest	north	yes	transplant
Elk Camp Shelter	2008	242	NW	Forest	north	no	transplant
Elk Camp Shelter	2008	242	SE	Forest	north	no	seeds
Elk Camp Shelter	2008	242	SW	Forest	north	yes	seeds
Elk Camp Shelter	2008	243	NE	Forest	north	no	transplant
Elk Camp Shelter	2008	243	NW	Forest	north	no	seeds
Elk Camp Shelter	2008	243	SE	Forest	north	yes	transplant
Elk Camp Shelter	2008	243	SW	Forest	north	yes	seeds
Elk Camp Shelter	2008	244	NE	Forest	north	yes	seeds
Elk Camp Shelter	2008	244	NW	Forest	north	no	seeds
Elk Camp Shelter	2008	244	SE	Forest	north	yes	transplant
Elk Camp Shelter	2008	244	SW	Forest	north	no	transplant
Elk Camp Shelter	2008	260	NE	forest	south	no	transplant
Elk Camp Shelter	2008	260	NW	forest	south	no	seeds
Elk Camp Shelter	2008	260	SE	forest	south	yes	seeds
Elk Camp Shelter	2008	260	SW	forest	south	yes	transplant
Elk Camp Shelter	2008	262	NE	meadow		no	seeds
Elk Camp Shelter	2008	262	NW	meadow		yes	transplant
Elk Camp Shelter	2008	262	SE	meadow		yes	seeds
Elk Camp Shelter	2008	262	SW	meadow		no	transplant
Elk Camp Shelter	2008	263	NE	meadow		yes	seeds
Elk Camp Shelter	2008	263	NW	meadow		yes	transplant
Elk Camp Shelter	2008	263	SE	meadow		no	seeds
Elk Camp Shelter	2008	263	SW	meadow		no	transplant
Elk Camp Shelter	2008	264	NE	meadow		no	transplant
Elk Camp Shelter	2008	264	NW	meadow		yes	transplant
Elk Camp Shelter	2008	264	SE	meadow		yes	seeds
Elk Camp Shelter	2008	264	SW	meadow		no	seeds
Elk Camp Shelter	2008	265	NE	forest	south	yes	transplant
Elk Camp Shelter	2008	265	NW	forest	south	no	seeds
Elk Camp Shelter	2008	265	SE	forest	south	no	transplant
Elk Camp Shelter	2008	265	SW	forest	south	yes	seeds

Elk Camp Shelter	2008	266	NE	forest	south	yes	transplant
Elk Camp Shelter	2008	266	NW	forest	south	no	transplant
Elk Camp Shelter	2008	266	SE	forest	south	yes	seeds
Elk Camp Shelter	2008	266	SW	forest	south	no	seeds
Elk Camp Shelter	2009	755	NE	meadow		no	transplant
Elk Camp Shelter	2009	755	NW	meadow		no	seeds
Elk Camp Shelter	2009	755	SE	meadow		yes	seeds
Elk Camp Shelter	2009	755	SW	meadow		yes	transplant
Elk Camp Shelter	2009	756	NE	meadow		no	transplant
Elk Camp Shelter	2009	756	NW	meadow		yes	seeds
Elk Camp Shelter	2009	756	SE	meadow		yes	transplant
Elk Camp Shelter	2009	756	SW	meadow		no	seeds
Elk Camp Shelter	2009	757	NE	meadow		yes	seeds
Elk Camp Shelter	2009	757	NW	meadow		no	transplant
Elk Camp Shelter	2009	757	SE	meadow		yes	transplant
Elk Camp Shelter	2009	757	SW	meadow		no	seeds
Elk Camp Shelter	2009	758	NE	forest	north	no	transplant
Elk Camp Shelter	2009	758	NW	forest	north	no	seeds
Elk Camp Shelter	2009	758	SE	forest	north	yes	seeds
Elk Camp Shelter	2009	758	SW	forest	north	yes	transplant
Elk Camp Shelter	2009	759	NE	forest	north	no	transplant
Elk Camp Shelter	2009	759	NW	forest	north	yes	transplant
Elk Camp Shelter	2009	759	SE	forest	north	yes	seeds
Elk Camp Shelter	2009	759	SW	forest	north	no	seeds
Elk Camp Shelter	2009	760	NE	forest	north	yes	seeds
Elk Camp Shelter	2009	760	NW	forest	north	yes	transplant
Elk Camp Shelter	2009	760	SE	forest	north	no	seeds
Elk Camp Shelter	2009	760	SW	forest	north	no	transplant
Nevergo	2008	245	NW	forest	east	yes	seeds
Nevergo	2008	245	NE	forest	east	no	transplant
Nevergo	2008	245	SW	forest	east	no	seeds
Nevergo	2008	245	SE	forest	east	yes	transplant
Nevergo	2008	246	NW	meadow		yes	seeds
Nevergo	2008	246	NE	meadow		no	seeds
Nevergo	2008	246	SW	meadow		no	transplant
Nevergo	2008	246	SE	meadow		yes	transplant
Nevergo	2008	247	NW	meadow		yes	transplant
Nevergo	2008	247	NE	meadow		yes	seeds
Nevergo	2008	247	SW	meadow		no	seeds
Nevergo	2008	247	SE	meadow		no	transplant
Nevergo	2008	248	NW	forest	south	no	seeds

Nevergo	2008	248	NE	forest	south	yes	seeds
Nevergo	2008	248	SW	forest	south	no	transplant
Nevergo	2008	248	SE	forest	south	yes	transplant
Nevergo	2008	249	NW	forest	south	no	transplant
Nevergo	2008	249	NE	forest	south	yes	seeds
Nevergo	2008	249	SW	forest	south	yes	transplant
Nevergo	2008	249	SE	forest	south	no	seeds
Nevergo	2008	250	NW	forest	south	yes	seeds
Nevergo	2008	250	NE	forest	south	no	transplant
Nevergo	2008	250	SW	forest	south	yes	transplant
Nevergo	2008	250	SE	forest	south	no	seeds
Nevergo	2008	251	NW	meadow		yes	seeds
Nevergo	2008	251	NE	meadow		yes	transplant
Nevergo	2008	251	SW	meadow		no	seeds
Nevergo	2008	251	SE	meadow		no	transplant
Nevergo	2008	252	NW	meadow		no	transplant
Nevergo	2008	252	NE	meadow		yes	transplant
Nevergo	2008	252	SW	meadow		yes	seeds
Nevergo	2008	252	SE	meadow		no	seeds
Nevergo	2008	253	NW	meadow		no	transplant
Nevergo	2008	253	NE	meadow		yes	transplant
Nevergo	2008	253	SW	meadow		no	seeds
Nevergo	2008	253	SE	meadow		yes	seeds
Nevergo	2009	187	NE	meadow		no	transplant
Nevergo	2009	187	NW	meadow		no	seeds
Nevergo	2009	187	SE	meadow		yes	seeds
Nevergo	2009	187	SW	meadow		yes	transplant
Nevergo	2009	188	NE	meadow		yes	transplant
Nevergo	2009	188	NW	meadow		no	transplant
Nevergo	2009	188	SE	meadow		no	seeds
Nevergo	2009	188	SW	meadow		yes	seeds
Nevergo	2009	189	NE	meadow		yes	seeds
Nevergo	2009	189	NW	meadow		yes	transplant
Nevergo	2009	189	SE	meadow		no	transplant
Nevergo	2009	189	SW	meadow		no	seeds
Nevergo	2009	190	NE	forest	west	no	seeds
Nevergo	2009	190	NW	forest	west	no	transplant
Nevergo	2009	190	SE	forest	west	yes	transplant
Nevergo	2009	190	SW	forest	west	yes	seeds
Nevergo	2009	191	NE	forest	west	no	seeds
Nevergo	2009	191	NW	forest	west	yes	transplant

Nevergo	2009	191	SE	forest	west	yes	seeds
Nevergo	2009	191	SW	forest	west	no	transplant
Nevergo	2009	192	NE	forest	west	yes	seeds
Nevergo	2009	192	NW	forest	west	yes	transplant
Nevergo	2009	192	SE	forest	west	no	seeds
Nevergo	2009	192	SW	forest	west	no	transplant
Elk Meadows East	2008	267	NE	forest	south	no	transplant
Elk Meadows East	2008	267	NW	forest	south	yes	transplant
Elk Meadows East	2008	267	SE	forest	south	no	seeds
Elk Meadows East	2008	267	SW	forest	south	yes	seeds
Elk Meadows East	2008	268	NE	forest	south	yes	seeds
Elk Meadows East	2008	268	NW	forest	south	no	transplant
Elk Meadows East	2008	268	SE	forest	south	no	seeds
Elk Meadows East	2008	268	SW	forest	south	yes	transplant
Elk Meadows East	2008	269	NE	forest	north	yes	transplant
Elk Meadows East	2008	269	NW	forest	north	no	seeds
Elk Meadows East	2008	269	SE	forest	north	yes	seeds
Elk Meadows East	2008	269	SW	forest	north	no	transplant
Elk Meadows East	2008	270	NE	forest	south	yes	transplant
Elk Meadows East	2008	270	NW	forest	south	no	transplant
Elk Meadows East	2008	270	SE	forest	south	no	seeds
Elk Meadows East	2008	270	SW	forest	south	yes	seeds
Elk Meadows East	2008	271	NE	forest	south	no	seeds
Elk Meadows East	2008	271	NW	forest	south	yes	seeds
Elk Meadows East	2008	271	SE	forest	south	no	transplant
Elk Meadows East	2008	271	SW	forest	south	yes	transplant
Elk Meadows East	2008	272	NE	meadow		no	seeds
Elk Meadows East	2008	272	NW	meadow		no	transplant
Elk Meadows East	2008	272	SE	meadow		yes	seeds
Elk Meadows East	2008	272	SW	meadow		yes	transplant
Elk Meadows East	2008	273	NE	meadow		no	transplant
Elk Meadows East	2008	273	NW	meadow		yes	seeds
Elk Meadows East	2008	273	SE	meadow		yes	transplant
Elk Meadows East	2008	273	SW	meadow		no	seeds
Elk Meadows East	2008	274	NE	meadow		yes	seeds
Elk Meadows East	2008	274	NW	meadow		no	transplant
Elk Meadows East	2008	274	SE	meadow		yes	transplant
Elk Meadows East	2008	274	SW	meadow		no	seeds
Elk Meadows East	2008	275	NE	forest	north	yes	seeds
Elk Meadows East	2008	275	NW	forest	north	no	seeds
Elk Meadows East	2008	275	SE	forest	north	no	transplant

Elk Meadows East	2008	275	SW	forest	north	yes	transplant
Elk Meadows East	2008	276	NE	forest	south	yes	transplant
Elk Meadows East	2008	276	NW	forest	south	yes	seeds
Elk Meadows East	2008	276	SE	forest	south	no	transplant
Elk Meadows East	2008	276	SW	forest	south	no	seeds
Elk Meadows East	2008	277	NE	forest	south	no	seeds
Elk Meadows East	2008	277	NW	forest	south	no	transplant
Elk Meadows East	2008	277	SE	forest	south	yes	transplant
Elk Meadows East	2008	277	SW	forest	south	yes	seeds
Elk Meadows East	2008	278	NE	Forest	north	no	seeds
Elk Meadows East	2008	278	NW	Forest	north	no	transplant
Elk Meadows East	2008	278	SE	Forest	north	yes	seeds
Elk Meadows East	2008	278	SW	Forest	north	yes	transplant
Elk Meadows East	2008	279	NE	meadow		no	seeds
Elk Meadows East	2008	279	NW	meadow		yes	seeds
Elk Meadows East	2008	279	SE	meadow		yes	transplant
Elk Meadows East	2008	279	SW	meadow		no	transplant
Elk Meadows East	2008	280	NE	meadow		yes	seeds
Elk Meadows East	2008	280	NW	meadow		no	transplant
Elk Meadows East	2008	280	SE	meadow		yes	transplant
Elk Meadows East	2008	280	SW	meadow		no	seeds
Elk Meadows East	2008	281	NE	Forest	north	no	transplant
Elk Meadows East	2008	281	NW	Forest	north	yes	seeds
Elk Meadows East	2008	281	SE	Forest	north	no	seeds
Elk Meadows East	2008	281	SW	Forest	north	yes	transplant
Elk Meadows East	2009	242	NE	meadow		no	transplant
Elk Meadows East	2009	242	NW	meadow		yes	transplant
Elk Meadows East	2009	242	SE	meadow		no	seeds
Elk Meadows East	2009	242	SW	meadow		yes	seeds
Elk Meadows East	2009	243	NE	meadow		no	transplant
Elk Meadows East	2009	243	NW	meadow		yes	seeds
Elk Meadows East	2009	243	SE	meadow		yes	transplant
Elk Meadows East	2009	243	SW	meadow		no	seeds
Elk Meadows East	2009	244	NE	meadow		yes	transplant
Elk Meadows East	2009	244	NW	meadow		yes	seeds
Elk Meadows East	2009	244	SE	meadow		no	transplant
Elk Meadows East	2009	244	SW	meadow		no	seeds
Elk Meadows East	2009	245	NE	meadow		no	transplant
Elk Meadows East	2009	245	NW	meadow		yes	seeds
Elk Meadows East	2009	245	SE	meadow		no	seeds
Elk Meadows East	2009	245	SW	meadow		yes	transplant

Elk Meadows East	2009	246	NE	meadow		no	transplant
Elk Meadows East	2009	246	NW	meadow		yes	seeds
Elk Meadows East	2009	246	SE	meadow		no	seeds
Elk Meadows East	2009	246	SW	meadow		yes	transplant
Elk Meadows East	2009	247	NE	forest	south	no	transplant
Elk Meadows East	2009	247	NW	forest	south	no	seeds
Elk Meadows East	2009	247	SE	forest	south	yes	seeds
Elk Meadows East	2009	247	SW	forest	south	yes	transplant
Elk Meadows East	2009	248	NE	forest	south	yes	seeds
Elk Meadows East	2009	248	NW	forest	south	no	seeds
Elk Meadows East	2009	248	SE	forest	south	yes	transplant
Elk Meadows East	2009	248	SW	forest	south	no	transplant
Elk Meadows East	2009	249	NE	meadow		yes	transplant
Elk Meadows East	2009	249	NW	meadow		no	seeds
Elk Meadows East	2009	249	SE	meadow		yes	seeds
Elk Meadows East	2009	249	SW	meadow		no	transplant
Elk Meadows East	2009	250	NE	meadow		yes	transplant
Elk Meadows East	2009	250	NW	meadow		no	seeds
Elk Meadows East	2009	250	SE	meadow		no	transplant
Elk Meadows East	2009	250	SW	meadow		yes	seeds
Elk Meadows East	2009	251	NE	Forest	south	no	transplant
Elk Meadows East	2009	251	NW	Forest	south	yes	seeds
Elk Meadows East	2009	251	SE	Forest	south	no	seeds
Elk Meadows East	2009	251	SW	Forest	south	yes	transplant
Elk Meadows East	2009	252	NE	Forest	south	no	seeds
Elk Meadows East	2009	252	NW	Forest	south	yes	seeds
Elk Meadows East	2009	252	SE	Forest	south	yes	transplant
Elk Meadows East	2009	252	SW	Forest	south	no	transplant
Elk Meadows East	2009	253	NE	Forest	south	yes	transplant
Elk Meadows East	2009	253	NW	Forest	south	no	transplant
Elk Meadows East	2009	253	SE	Forest	south	yes	seeds
Elk Meadows East	2009	253	SW	Forest	south	no	seeds
Sourgrass Mountain	2008	282	NE	Forest	north	no	seeds
Sourgrass Mountain	2008	282	NW	Forest	north	yes	transplant
Sourgrass Mountain	2008	282	SE	Forest	north	yes	seeds
Sourgrass Mountain	2008	282	SW	Forest	north	no	transplant
Sourgrass Mountain	2008	283	NE	meadow		yes	seeds
Sourgrass Mountain	2008	283	NW	meadow		yes	transplant
Sourgrass Mountain	2008	283	SE	meadow		no	seeds
Sourgrass Mountain	2008	283	SW	meadow		no	transplant
Sourgrass Mountain	2008	284	NE	Forest	south	no	seeds

Sourgrass Mountain	2008	284	NW	Forest	south	no	transplant
Sourgrass Mountain	2008	284	SE	Forest	south	yes	transplant
Sourgrass Mountain	2008	284	SW	Forest	south	yes	seeds
Sourgrass Mountain	2008	285	NE	forest	north	no	seeds
Sourgrass Mountain	2008	285	NW	forest	north	no	seeds
Sourgrass Mountain	2008	285	SE	forest	north	yes	transplant
Sourgrass Mountain	2008	285	SW	forest	north	yes	transplant
Sourgrass Mountain	2008	287	NE	meadow		no	seeds
Sourgrass Mountain	2008	287	NW	meadow		no	transplant
Sourgrass Mountain	2008	287	SE	meadow		yes	seeds
Sourgrass Mountain	2008	287	SW	meadow		yes	transplant
Sourgrass Mountain	2008	288	NE	forest	north	no	transplant
Sourgrass Mountain	2008	288	NW	forest	north	no	seeds
Sourgrass Mountain	2008	288	SE	forest	north	yes	transplant
Sourgrass Mountain	2008	288	SW	forest	north	yes	seeds
Sourgrass Mountain	2008	289	NE	meadow		no	seeds
Sourgrass Mountain	2008	289	NW	meadow		yes	seeds
Sourgrass Mountain	2008	289	SE	meadow		no	transplant
Sourgrass Mountain	2008	289	SW	meadow		yes	transplant
Sourgrass Mountain	2008	290	NE	forest	south	no	transplant
Sourgrass Mountain	2008	290	NW	forest	south	yes	seeds
Sourgrass Mountain	2008	290	SE	forest	south	no	seeds
Sourgrass Mountain	2008	290	SW	forest	south	yes	transplant
Sourgrass Mountain	2009	761	NE	Meadow		yes	transplant
Sourgrass Mountain	2009	761	NW	Meadow		yes	seeds
Sourgrass Mountain	2009	761	SE	Meadow		no	transplant
Sourgrass Mountain	2009	761	SW	Meadow		no	seeds
Sourgrass Mountain	2009	762	NE	Meadow		no	seeds
Sourgrass Mountain	2009	762	NW	Meadow		yes	seeds
Sourgrass Mountain	2009	762	SE	Meadow		yes	transplant
Sourgrass Mountain	2009	762	SW	Meadow		no	transplant
Sourgrass Mountain	2009	763	NE	Forest	north	no	transplant
Sourgrass Mountain	2009	763	NW	Forest	north	yes	seeds
Sourgrass Mountain	2009	763	SE	Forest	north	yes	transplant
Sourgrass Mountain	2009	763	SW	Forest	north	no	seeds
Sourgrass Mountain	2009	764	NE	meadow		no	seeds
Sourgrass Mountain	2009	764	NW	meadow		yes	transplant
Sourgrass Mountain	2009	764	SE	meadow		no	transplant
Sourgrass Mountain	2009	764	SW	meadow		yes	seeds
Sourgrass Mountain	2009	765	NE	Forest	north	yes	seeds
Sourgrass Mountain	2009	765	NW	Forest	north	yes	transplant

Sourgrass Mountain	2009	765	SE	Forest	north	no	transplant
Sourgrass Mountain	2009	765	SW	Forest	north	no	seeds
Sourgrass Mountain	2009	766	NE	Forest	north	yes	transplant
Sourgrass Mountain	2009	766	NW	Forest	north	no	transplant
Sourgrass Mountain	2009	766	SE	Forest	north	yes	seeds
Sourgrass Mountain	2009	766	SW	Forest	north	no	seeds
Sourgrass Mountain Southeast	2009	767	NE	meadow		no	seeds
Sourgrass Mountain Southeast	2009	767	NW	meadow		no	transplant
Sourgrass Mountain Southeast	2009	767	SE	meadow		yes	seeds
Sourgrass Mountain Southeast	2009	767	SW	meadow		yes	transplant
Sourgrass Mountain Southeast	2009	768	NE	meadow		no	seeds
Sourgrass Mountain Southeast	2009	768	NW	meadow		yes	seeds
Sourgrass Mountain Southeast	2009	768	SE	meadow		no	transplant
Sourgrass Mountain Southeast	2009	768	SW	meadow		yes	transplant
Sourgrass Mountain Southeast	2009	769	NE	meadow		no	transplant
Sourgrass Mountain Southeast	2009	769	NW	meadow		yes	transplant
Sourgrass Mountain Southeast	2009	769	SE	meadow		yes	seeds
Sourgrass Mountain Southeast	2009	769	SW	meadow		no	seeds
Sourgrass Mountain Southeast	2009	770	NE	forest	west	yes	transplant
Sourgrass Mountain Southeast	2009	770	NW	forest	west	no	seeds
Sourgrass Mountain Southeast	2009	770	SE	forest	west	yes	seeds
Sourgrass Mountain Southeast	2009	770	SW	forest	west	no	transplant
Sourgrass Mountain Southeast	2009	771	NE	forest	west	yes	transplant
Sourgrass Mountain Southeast	2009	771	NW	forest	west	no	seeds
Sourgrass Mountain Southeast	2009	771	SE	forest	west	yes	seeds
Sourgrass Mountain Southeast	2009	771	SW	forest	west	no	transplant
Sourgrass Mountain Southeast	2009	772	NE	forest	west	no	seeds
Sourgrass Mountain Southeast	2009	772	NW	forest	west	no	transplant
Sourgrass Mountain Southeast	2009	772	SE	forest	west	yes	seeds
Sourgrass Mountain Southeast	2009	772	SW	forest	west	yes	transplant
Upper Elk Meadows West	2008	292	NE	Forest	south	no	seeds
Upper Elk Meadows West	2008	292	NW	Forest	south	yes	transplant
Upper Elk Meadows West	2008	292	SE	Forest	south	no	transplant
Upper Elk Meadows West	2008	292	SW	Forest	south	yes	seeds
Upper Elk Meadows West	2008	293	NE	Forest	south	no	seeds
Upper Elk Meadows West	2008	293	NW	Forest	south	yes	transplant
Upper Elk Meadows West	2008	293	SE	Forest	south	yes	seeds
Upper Elk Meadows West	2008	293	SW	Forest	south	no	transplant
Upper Elk Meadows West	2008	294	NE	meadow		yes	transplant
Upper Elk Meadows West	2008	294	NW	meadow		yes	seeds
Upper Elk Meadows West	2008	294	SE	meadow		no	seeds

Upper Elk Meadows West	2008	294	SW	meadow		no	transplant
Upper Elk Meadows West	2008	295	NE	forest	south	yes	transplant
Upper Elk Meadows West	2008	295	NW	forest	south	no	seeds
Upper Elk Meadows West	2008	295	SE	forest	south	no	transplant
Upper Elk Meadows West	2008	295	SW	forest	south	yes	seeds
Upper Elk Meadows West	2008	296	NE	meadow		no	seeds
Upper Elk Meadows West	2008	296	NW	meadow		yes	seeds
Upper Elk Meadows West	2008	296	SE	meadow		no	seeds
Upper Elk Meadows West	2008	296	SW	meadow		yes	transplant
Upper Elk Meadows West	2008	297	NE	meadow		yes	transplant
Upper Elk Meadows West	2008	297	NW	meadow		no	transplant
Upper Elk Meadows West	2008	297	SE	meadow		yes	seeds
Upper Elk Meadows West	2008	297	SW	meadow		no	seeds
Lower Elk Meadows West	2008	298	NE	meadow		yes	seeds
Lower Elk Meadows West	2008	298	NW	meadow		yes	transplant
Lower Elk Meadows West	2008	298	SE	meadow		no	transplant
Lower Elk Meadows West	2008	298	SW	meadow		no	seeds
Lower Elk Meadows West	2008	299	NE	meadow		no	transplant
Lower Elk Meadows West	2008	299	NW	meadow		yes	transplant
Lower Elk Meadows West	2008	299	SE	meadow		no	seeds
Lower Elk Meadows West	2008	299	SW	meadow		yes	seeds
Lower Elk Meadows West	2008	300	NE	meadow		no	transplant
Lower Elk Meadows West	2008	300	NW	meadow		yes	seeds
Lower Elk Meadows West	2008	300	SE	meadow		no	seeds
Lower Elk Meadows West	2008	300	SW	meadow		yes	transplant