

Glacier National Park: Restoration Monitoring Report

2018

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October 2018



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I. INTRODUCTION

The Revegetation Monitoring Program, established in 1991, is designed to provide a systematic framework for describing a site prior to disturbance and for monitoring the success of seeded and planted species after revegetation. The goals of the monitoring program (Kurth and Potter, 1991) are to:

- (1) Develop revegetation techniques based on collected information;
- (2) Set feasible expected levels of success for revegetation and set reasonable time frames in which to expect those levels;
- (3) Establish appropriate site-specific goals for projects;
- (4) Determine the degree to which a project meets predetermined goals or expected levels of success;
- (5) Determine cause and effect relationships from revegetation treatments;
- (6) Determine spatial requirements for specific environments;
- (7) Identify sensitive areas where impacts must be avoided because revegetation is too costly or impossible;
- (8) Identify needs and methods for remedial work at a site; and
- (9) Reduce time and money spent on revegetation.

Based on these goals, four levels of monitoring have been established to document the success of revegetation projects. These levels range from a simple, quick assessment of a site (Level I) to complex experiments that test revegetation techniques (Level IV). Table 1 summarizes the main variables that are monitored within each level.

Table 1. Levels of Monitoring

Monitoring Level	Variables monitored
Level I	• soil erosion • estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs • ground cover description (% soil, rock, gravel, litter, moss/lichen, wood, and basal vegetation) • disturbance history • evidence of animal use
Level II	• data from Level I • species list of at least the dominant native and exotic species and their respective canopy covers • description of planted and seeded material (estimated density, mean height, phenology, vigor)
Level III	• data from Level II • permanent transects and microplots established to monitor the number of species, and their respective canopy covers, densities, and mean heights • permanent circular plots established to monitor height, width, vigor and damage of planted shrubs and trees
Level IV	• experiment using replicate and control plots to evaluate revegetation techniques

In addition, a site analysis procedure has been designed to collect information on revegetation sites prior to disturbance. Site analysis data includes information on:

- Parent material (weathered mineral or organic material from which the soil develops)
- Slope shape and aspect;
- Soil surface status and soil texture analysis
- Ground cover description (% soil, rock, gravel, litter, moss/lichen, down wood and basal vegetation)
- Estimated canopy cover of (1) mature, pole, sapling, and seedling trees; (2) tall, medium, and low shrubs; (3) native and exotic grasses; and (4) native and exotic forbs
- Species list of at least the dominant exotic and native species and their respective canopy covers
- Evidence of animal use

- Disturbance history
- List of species or cultural resources of special concern
- Recommendations for revegetation (target plant community, site preparation, use of plant or soil salvage, use restrictions and safety considerations)

Revegetation areas are listed in Table 2. The monitoring report for the appropriate year should be referenced for further information.

Table 2. Monitoring projects to date

LOCATION	Monitoring Level	Monitoring Dates
303-B: Lake McDonald segment of GTSR	Level III	1992, 1993, 1994, 1996, 2001, 2011
303-B Road shoulders	Level II	1993, 1994, 1995, 1998
303-C: St. Mary segment of GTSR	Level II	1993, 1994, 1995, 1998, 2003, 2013
303-C Road shoulders	Level II	1994, 1995, 1998, 2003
Two Dog Flats	Level IV	1993, 1995, 1997, 2002
303-D: Rising Sun segment of GTSR	Site Analysis, Level IV	1993-1997, 1999, 2004, 2005, 2015
303-D: Road shoulders	Level II	1996, 1997
303-E: Logan Pass and Oberlin Bend	Site Analysis, Level IV	1993, 1996, 1997, 1998, 1999, 2001, 2006, 2011, 2016
303-E: Logan Pass Seeding/ Planting Plots	Site Analysis, Level IV	1997, 1998, 1999, 2000, 2008
303-F: McDonald Creek segment of GTSR	Site Analysis, Level II	1994, 2000, 2001, 2002, 2009
303-F: Avalanche Campground & Picnic Area	Site Analysis	1995, 1996
Phase VI: West Tunnel to Haystack section of GTSR	Site Analysis, Level II	2007, 2010, 2011, 2012, 2013, 2015
Phase VII: Avalanche to West Tunnel section of GTSR	Site Analysis	2004, 2010, 2013, 2014, 2016
Phase VIII: Big Bend to Logan Pass section of GTSR	Site Analysis	2010
Phase IX: Haystack to Big Bend section of GTSR	Site Analysis	2010
Phase XI: Logan Pass to Siyeh Bend section of GTSR	Site Analysis, Level II	2010, 2013, 2014, 2016
Phase XII: Siyeh Bend to Rising Sun section of GTSR	Site Analysis	2010, 2015, 2016
Apgar Transit Center	Site Analysis, Levels II & IV	2006, 2007, 2008, 2009, 2010, 2012
Bowman Creek Campground	Level II	1993, 1998
Camas Road - Revegetation	Site Analysis, Level II	1995, 2000, 2002, 2003, 2008, 2018
Camas Road - Hydromulch	Level II	2004, 2005, 2007, 2009, 2014
Granite Park Chalet	Site Analysis	1994
Grinnell Point Picnic Area	Site Analysis	2010
Herbicide / Revegetation Experimental Plots	Level IV	2008, 2009, 2010, 2012
Hidden Lake Social Trails	Level II	2003, 2005, 2010, 2016
Lake McDonald Lodge dorm site	Site Analysis, Level II	2007, 2009, 2010, 2011, 2014
Logan Pass Comfort Station	Level II	1993
Polebridge Bridge	Level II	1993, 1998
Polebridge Ranger Station	Level II	1993, 1998
River Campground	Level II	1993, 1998
Sperry Chalet	Site Analysis	1996
St. Mary housing area	Level II	1993
St. Mary Visitor Center	Site Analysis, Level II	2006, 2010, 2011, 2013, 2015
Swiftcurrent Apartments	Level II	1993
Three Bears Lake	Level II	1993, 2000
Two Medicine housing area	Site Analysis	1994
West Glacier Bike Path	Level II	2005, 2007, 2009, 2014
West Glacier Entrance Station	Level II	2009, 2010, 2011, 2013, 2018

The objectives of this report are to document the results of the 2018 season. The report includes: (1) results from monitoring 11 eastside grassland plots nearly 20 years after their establishment; (2) data from two revegetation projects (West Entrance Station and Camas Road revegetation); (3) results from whitebark and limber pine restoration projects; (4) results from whitebark and limber pine plus tree monitoring; and (5) overall recommendations for the monitoring program, including a schedule for future monitoring. All road projects are based on and are evaluated against the following revegetation goals and objectives (Lange, 1988; Lapp, 1994):

Overall goal: Within 5 years following construction, a vegetative cover of native plants will be established that will potentially blend with the adjacent plant communities, is ecologically compatible with the surrounding community, and is consistent with maintenance and safety requirements. Within 20 years following construction, the color and structure of the vegetation will blend into the adjacent plant community and diversity of native species will resemble the plant community prior to disturbance.

Objectives:

- (1) Preserve genetic integrity of native floral populations.
- (2) Provide for optimum survival of plant material by using species collected at or near the disturbed site.
- (3) Quickly provide plant cover to stabilize soil and prevent erosion.
- (4) Keep coverage of exotic plants low in cut and fill slopes, and prevent invasion into undisturbed vegetation.
- (5) Restore aesthetic value of vegetation within disturbed area that blends in with adjacent undisturbed plant communities.
- (6) Use roadside vegetation that will not be a long-term food attraction to wildlife.
- (7) Select appropriate vegetation for cut slopes, ditches, and a turf shoulder that is low maintenance, durable, safe, and able to stand up under heavy visitor foot and automobile traffic.
- (8) Provide opportunity for research and technology transfer.

II. EASTSIDE GRASSLAND MONITORING: 2018

A. INTRODUCTION

1. Glacier National Park Eastside Grassland Ecology Project: 1999-2001

Glacier National Park's grasslands and closely associated communities are extremely important contributors to the character and ecology of the park. On the east side of the park, these meadows are typically characterized as fescue-dominated grasslands, transitional types between the mixed grass prairie and montane/subalpine grasslands occurring adjacent to or within forested habitats. Rough fescue (*Festuca campestris*) and Idaho fescue (*Festuca idahoensis*) are the dominant grasses in these meadows in northwestern Montana. Many wildlife species utilize these grasslands including elk, bighorn sheep, white-tailed and mule deer that regularly forage there. Federally listed grizzly bears and species of concern gray wolves and bald eagles feed on these ungulates or on carrion. Both grizzly and black bears utilize the meadows for vegetative components of their diets. Numerous smaller mammals such as coyotes, Columbian ground squirrels, deer mice, and voles are commonly observed there.

Nationwide, grasslands are the biomes that have been the most impacted by human activities. As a result, more of North America's grasslands have been lost through conversion to agriculture, urbanization, and desertification than any other biotic community (Hoekstra et al., 2005). While Glacier National Park's grassland communities have not faced as many human pressures, they have experienced continual impacts over the past century from bison grazing, domestic livestock grazing, including sheep, cattle, mules, and horses, development of historic chalets and concession horse barns in certain east side meadows, development of ranger stations, patrol cabins, and homestead areas in other grasslands, road development, the existence of small railroad and mining towns in certain meadows, haying operations, agronomic grass seeding and spread, noxious weed invasion, and change in fire regimes.

As there was no comprehensive report on the status and health of fescue grassland communities after decades of change to the park and ongoing disturbances to grassland communities, particularly on the east side of the park, GNP ecologists secured funding to inventory grassland communities east of the Continental Divide over a three year period. The Glacier National Park Eastside Grasslands Ecology Project was initiated in 1999 with the following goals:

1. To determine plant species composition in each of the numerous meadow systems and to classify the grassland communities on the east side of the park.
2. To monitor the presence and status of exotic plant species within east side grasslands.
3. To establish permanent vegetation plots, which may be used again in the future for comparative analysis.
4. To document wildlife utilization of grasslands to establish a baseline for determining relationships with vegetative conditions, comparison with historical records, and future monitoring. This assessment will focus on bighorn sheep, neotropical migratory birds, and small mammals.
5. To determine the initial extent of undisturbed grasslands, identify what changes (if any) have occurred over the last 100 years, and clarify the rate and direction of change to help forecast expected future conditions.
6. To create a management matrix that ranks the health of each grassland area based on current ecological values, severity of current stressors to ecological integrity, and potential threats to each of the sites.

In total, 155 permanent vegetation monitoring plots were established from 1999 to 2001 in 99 discreet meadows to describe and assess the health of fescue grasslands on the east side of the park. All results are written in a comprehensive report that describes the grassland communities, their threats, and possible management actions to consider (Asebrook and Shea, 2010).

2. Glacier National Park Eastside Grassland Ecology Monitoring: 2018

For over a decade, the Blackfeet Confederacy, Glacier's neighbors to the east, have been working to reintroduce bison to tribal lands. In 2014, tribes from the Blackfoot Confederacy signed a treaty between their own respective governments, pledging to reintroduce the buffalo onto Blackfeet land and to maintain conservation and educational efforts. Finally in 2016, 90 bison calves were shipped from Elk Island in Canada to a 9,000 acre reserve on the Blackfeet reservation. This first herd near the southeastern boundary of the park is the first successful herd that the Blackfeet Nation is managing.

With interest in introducing a second herd on Blackfeet tribal lands, several agencies with adjacent land decided to collaborate on introducing a genetically unique wild bison herd to the Chief Mountain area of the Blackfeet reservation and potentially Glacier National Park. Partners for the restoration of the second bison herd include the Blackfeet Tribe, Parks Canada, private landowners in US/Canada, and Glacier National Park. As this second herd has a higher potential to access Glacier National Park, park staff decided to collect new baseline data on the areas that could potentially see impacts from bison reintroduction. As grasslands are important areas for bison grazing, it was decided that initial data collection should focus on re-reading several grassland ecology plots that were established in 1999-2001, particularly those closer to the Chief Mountain area. Re-reading these plots would include collecting data on grassland vegetation and on bird populations. As these plots are nearly 20 years old, re-monitoring these areas will not only give park staff a new baseline of their status and health prior to potential bison reintroduction, but it will also give park staff insight on the natural changes of these grasslands over the past two decades. This information will be helpful to park managers when thinking of these sensitive communities in regards to climate change, weed invasion, and fire ecology.

In total, 11 permanent monitoring plots in 10 discreet meadows were re-read in 2018 to assess the health of these fescue grasslands almost 20 years after they were established (Figure 1, Table 4).

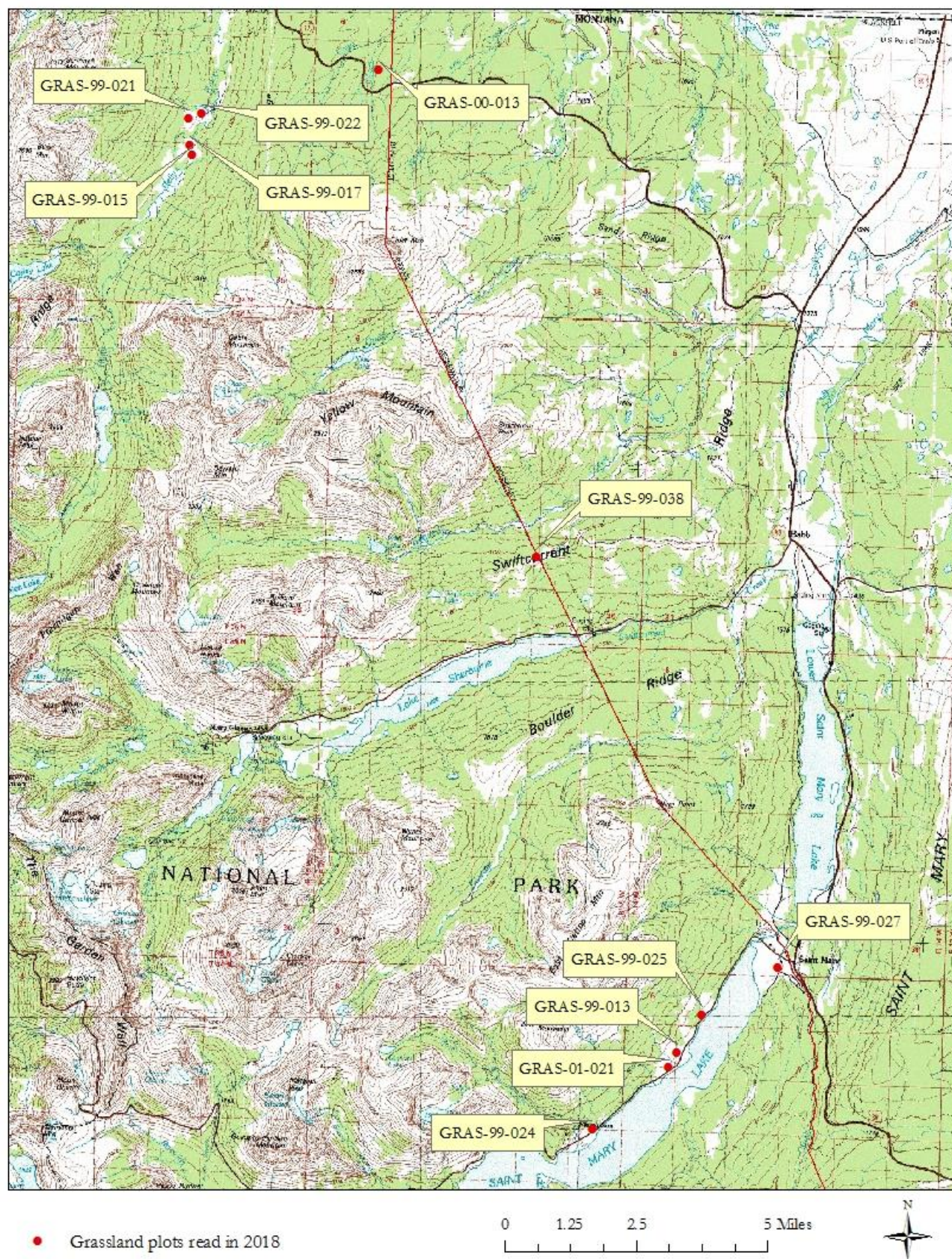
It is important to note that in the past, the western Great Plains were grazed by millions of bison for thousands of years, as well as by lesser numbers of deer, elk, pronghorns, and other ungulates. In 1815, Hugh Monroe saw mountain bison along upper St. Mary Lake (Schultz 1918). Biologist Vernon Bailey in 1885 described the remains of many old buffalo trails in the Belly River country leading from the higher river terraces down to the river bottoms that "showed where buffalo had at one time occupied this valley in great numbers." He also noted skeletal remains from all the eastside valleys (Bailey 1918). Apparently all park bison were gone by about 1850, as chronicles of hunting and surveying trips after this time make no mention of them (DeSanto 1971). Bison bones and Native American bison kill sites are still regularly unearthed, sometimes far up the drainages (Reeves 1995).

B. STUDY METHODS

1. Initial Methods from 1999-2001 Study

From 1999 to 2001, 155 sampling plots were established in 99 discreet meadows to assess the health and ecological features of fescue grasslands in those areas. In 1999, 57 vegetative sampling plots were established in thirty eastside grasslands. In 2000, 48 more plots were placed in 39 eastside grasslands. Finally, in 2001, 55 additional plots were established in 40 eastside grassland grasslands (See maps in Asebrook and Shea, 2010). Plots were located between 4,490 and 6,844 feet elevation with approximately half of all sites between 4,500 and 5,000 feet. Vegetation maps were made of several meadows by surveying and mapping according to vegetation types. Representative sites were then selected in these different types in each meadow, such as on drier ridges, lower moister swales, and disturbed areas.

Figure 1. Location of Eastside Grassland Plots Monitored in 2018



Permanent plots measuring 20m x 5m were randomly established in each grassland with one to many plots established depending on the number of different associations that were present. Often, if the grassland was large, multiple plots were established, even within the same association, to document the condition of the entire grassland area. Each plot was marked with eight-inch spikes placed in the lower right and upper left corners. Each spike has an aluminum tag with the plot number. Within this 100 square meters, fourteen 50cm x 50cm microplots were randomly located. Percent cover of all species located in each microplot was recorded, as was percent cover of bare soil, rock, gravel, lichen, moss, wood, animal droppings, and litter. Ocular cover estimates were made for other species in the 100 square-meter macroplot that were not captured in the microplots. In addition, a walk-through survey was made of each meadow in which the plots were located. This was preferably done more than once at different times of the season in an effort to record all plant species present in each of the various meadow systems. Plot and meadow photographs were also taken, and general site characteristics, such as aspect, slope, and soil texture, were documented.

Based on the evaluation of six plots at the beginning of the study, it was determined to read 14 microplots in each macroplot. Species curves were created for each plot, determining that 14 microplots captured 90% to 100% of all species in each plot. In addition, a comparison of 12, 14, 15, 16, and 18 microplots revealed that mean canopy cover estimates using 14 microplots were not significantly different from estimates using 16 or 18 microplots.

2. Study Methods for Repeat Monitoring: 2018

Monitoring methods remained the same for repeat surveys in 2018. A total of 11 plots in 10 discreet meadows were monitored during this year, chosen based on their nearby location to the Chief Mountain area in the northeastern portion of the park and their proximity to the park border (Figure 1, Table 4).

The two original nails/spikes in the lower right and upper left corners were found for all 11 plots. To assist with finding these plots in the future, two additional nails/spikes were installed in the upper right and lower left corners so that all four corners of each plot are now marked. New photographs of each plot were also taken from several directions to assist in finding the plot and documenting the overall condition of the meadow.

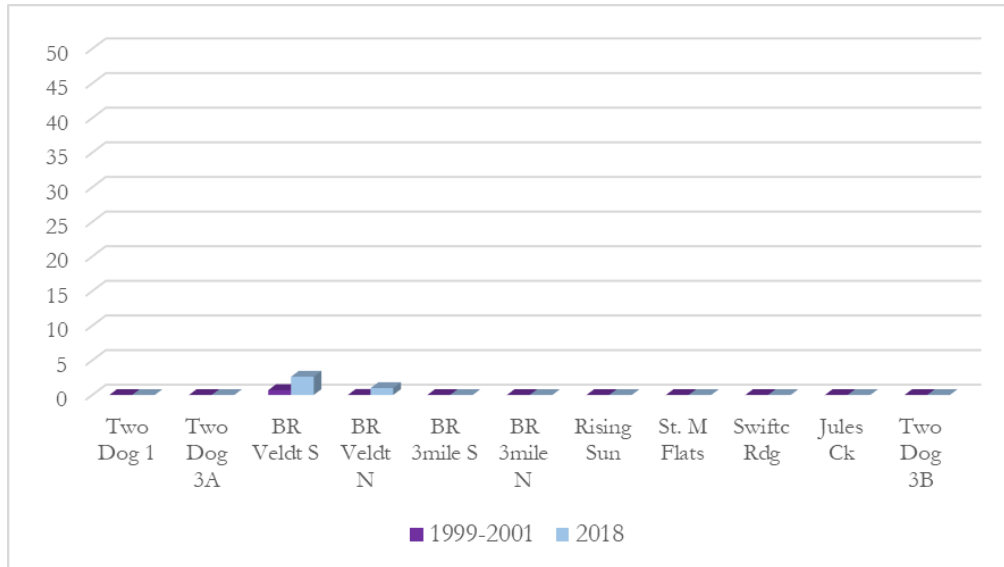
As we aim to define a new baseline of the grassland conditions on the east side of the park prior to the potential introduction of bison, the plan is to re-read 10-15 additional grassland plots on the east side each year over the next 5 years. The intent is not to re-read all 155 original plots but to find a subset of plots, estimated at 50-75 plots that could be read every 10-20 years, that can serve as longer-term monitoring plots for assessing the health of fescue grasslands.

C. RESULTS

1. Trees

Overall, trees are not present in 9 of the 11 plots that were monitored in 2018. In the two plots where trees do occur in the Belly River, *Populus tremuloides* is the only tree present and remains with relatively low cover. That said, cover of *P. tremuloides* has increased over the past two decades from 0.71% to 2.64% in plot 00-035 and from 0.1% to 1.0% in plot 99-017. Left unchecked, these areas could see increased spread of this tree through root sprouting and continued growth of existing stems.

Figure 2. Eastside Grasslands: Tree cover comparison over time: 1999-2001 vs 2018



2. Shrubs

Shrub cover underwent some of the most notable changes in the past two decades. All 11 eleven plots increased in shrub cover by a range of 3% to 19% and 5 of the 11 plots picked up a new shrub species that was not present 20 years ago. In 1999-2001, shrub cover ranged from 0.71% to 21.57% cover with 7 plots having less than 5% shrub cover and 4 plots having shrub cover ranging from 6-25%. In 2018, shrub cover ranged from 2.94% to 34.59% cover with only 3 plots having less than 5% shrub cover, 6 plots having 6-25% shrub cover, and 2 plots reaching shrub cover ranging from 25-35% (Table 3).

Table 3. Eastside Grasslands: Shrub cover changes from 1999-2001 to 2018.

Range of cover (%)	1999-2001 plots	2018 plots
>1	Two Dog 1, SM Flats, Belly River 3-mile S	
1 -5	Belly River Veldt N, Belly River 3-mile N, Jules Ck, Two Dog 3B	Two Dog 1, Belly River 3-mile S, Belly River 3-mile N
6 - 15	Two Dog 3A, Rising Sun, Swiftc Ridge	SM Flats, Swiftc Ridge, Jules Ck, Two Dog 3B
15 - 25	Belly River Veldt S	Two Dog 3A, Belly River Veldt N
25 - 35		Belly River Veldt S, Rising Sun

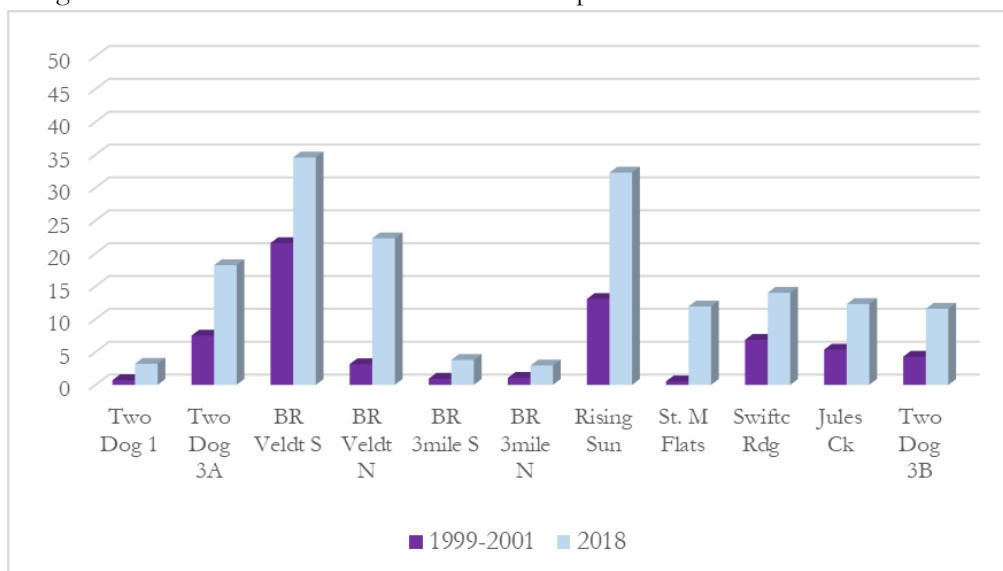
The shrub species that experienced the largest changes were *Rosa* spp. and *Amelanchier alnifolia*, *Arctostaphylos uva-ursi*, and *Mahonia repens* where they were present. On the 10 plots where *Rosa* spp. was present, this species increased on 8 plots by a range of 1-5% cover over the past two decades. On the 6 plots where *Amelanchier alnifolia* was present, this shrub became newly established on 2 plots and increased by a range of 0.5-6% cover on 4 plots. On the 5 plots where *Arctostaphylos uva-ursi* was present, this low-growing shrub newly established on 1 plot and increased by a range of 4-17% on 3 plots. Although *Mahonia repens* is only present on 1 plot, it increased in cover by 15% over the last 20 years.

Pentaptylloides floribunda remains a shrub with high frequency within these fescue grassland plots, present on 10 plots in 2018 compared to 9 plots in 1999-2001. While it remains a shrub with notable cover on several plots (4-14% cover on 5 plots), there was less consistency concerning its trend. This shrub became newly established on 1 plot and increased by 1-12% on 4 plots. At the same time, this shrub remained with the same low cover on 3 plots and actually decreased by 1-3% cover on 2 plots. It is uncertain whether increases of other lifeforms are causing some of these declines or

this shrub has another stressor. The last 2 shrubs documented within these plots remained with low cover: *Prunus virginiana* maintained generally low cover on the 4 plots where it is present and *Symphoricarpos albus* became newly established on 1 plot with low cover.

The grasslands that experienced the largest increase in shrub cover (11-19%) were in various areas in the park and due to different increases in shrub species. Shrub cover in Two Dog Flats meadow 3A increased by 11% due to 5-6% increases in cover of *Amelanchier alnifolia* and *Rosa* spp. Shrub cover in St. Mary Flats also increased by 11% due primarily to a 10% increase of *Arctostaphylos uva-ursi*. Shrub cover in south Veldt area of Belly River increased by 13% almost exclusively due to a 17% increase of *Arctostaphylos uva-ursi* (decrease of *P. floribunda* countered larger increase). Finally, shrub cover in the north Veldt area of the Belly River and Rising Sun each increased by 19% over the past 20 years, the largest increases in shrub cover. These increases were due to a 13% increase of *Pentaptylloides floribunda* and a 4% increase of *Rosa* spp. in the Belly River and 15% increase of *Mahonia repens* and a 4% increase of *Rosa* spp. at Rising Sun. The south Veldt area of the Belly River and Rising Sun currently have the highest shrub cover.

Figure 3. Eastside Grasslands: Shrub cover comparison over time: 1999-2001 vs 2018



3. Native Grasses

When looking at the overall ranges of native grass cover over time, it would appear that this lifeform has not changed dramatically. Native grass cover ranged from 7.21% to 33.07% in 1999-2001 and now ranges from 7.86% to 37.5%. However, six of the eleven plots had a notable increase in grass cover, increasing by 9-20%, while three of the remaining plots had small increases of 4-6% cover. All four plots in the Belly River had higher native grass cover in 2018 compared to two decades ago, currently ranging from 27% to 37.5% cover. This represents consistently high native grass cover in all monitored areas. Native grass cover increased by 4-20%, due primarily to increases of *Festuca scabrella* that increased on all 4 plots and increases of *Festuca idahoensis* and *Elymus lanceolatus* that each increased on 3 plots. *Carex* spp. had smaller increases on 3 plots, while *Koeleria macrantha* and *Stipa nelsonii* has small increases on 2 plots. Of note, *Danthonia intermedia* decreased on 2 plots, disappearing completely from the 3-mile south plot.

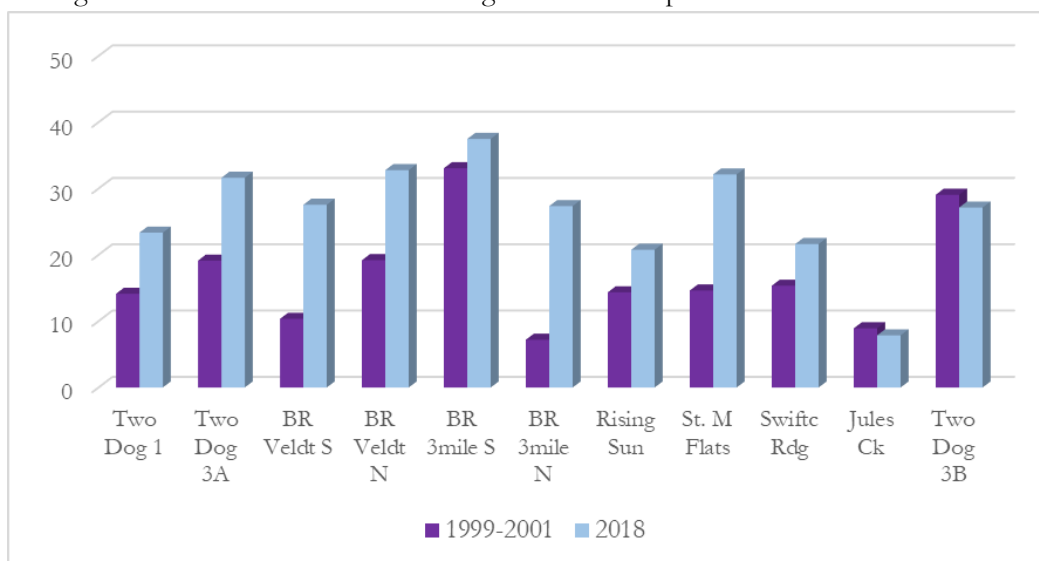
Native grass cover increased on four plots in the St. Mary Valley and remained the same on the fifth plot in that area. Overall, native grass cover ranged from 23% to 32%, also representing consistently high native grass cover in all monitored areas. Native grass increased by 6-18% at Rising Sun, at St. Mary Flats, and at 2 Two Dog Flats meadows. This was due to notable increases in cover of *Festuca scabrella* and *Festuca idahoensis* that each increased on 4 plots,

smaller increases of *Carex* spp. and *Koeleria macrantha* on 2 plots, and a notable increase of *Elymus lanceolatus* that newly established on the St. Mary Flats plot. While *Stipa nelsonii* increased slightly on 2 plots and *Danthonia intermedia* increased notably on 1 plot, both species generally decreased on other plots in St. Mary over the past two decades. In fact, larger decreases of *S. nelsonii* and *D. intermedia* on plot 01-021 in Two Dog Flats countered increases of *F. idahoensis*, *K. macrantha*, and *Carex* spp. that resulted in this plot having static cover.

In terms of the last 2 plots, native grass cover increased from 15.36% to 21.64% on Swiftcurrent Ridge and decreased slightly on Jule's Creek near the Chief Mountain Road. Increases on Swiftcurrent Ridge were due to increases of *Bromus carinatus*, *Carex* spp., and *Elymus smithii*. *F. scabrella* and *F. idahoensis* have notable cover on this ridge but did not increase in cover over the past two decades. Native grass on Jule's Creek is the lowest of any of the monitored plots at 7.86%. Despite having small increases of *Carex* spp. and *Elymus smithii* in this area, *F. idahoensis* decreased in cover over time and most native grasses remained with low cover. This plot experienced a large increase in exotic grass cover since 2000, likely causing these smaller native grasses to decline.

In terms of diversity, *Agrostis scabra* and *Bromus pumpeianus* were not observed in any plots in 2018 despite being present in 2 plots in 1999-2001. *Helictotrichon bookeri* also decreased in frequency from 4 plots to 1 plot over time. From a positive perspective, *Luzula macrantha* was newly established on 1 plot and the frequency of *Poa secunda* increased from 1 plot in 2001 to 7 plots in 2018.

Figure 4. Eastside Grasslands: Native grass cover comparison over time: 1999-2001 vs 2018



4. Native Forbs

Ten of the eleven plots that were monitored in 2018 had increases in native forb cover over the past two decades. Native forbs on eight of the plots increased by a dramatic 10-20% cover, while native forbs increased by 5% cover on one plot and 3.5% on another plot. Interestingly, native forb cover decreased by a notable 17% on the Jule's Creek plot near the Chief Mountain Road. This is the plot that had the highest cover of exotic grasses, as well as an area that had one of the largest increases in exotic grass over the past twenty years. This has resulted in a decrease in native grass cover, exotic forb cover, and native forb cover in this meadow.

There were very few native forbs that exhibited a consistent trend throughout all monitoring plots. Generally, the most dominant native forbs in these east side grasslands that have the highest frequency (present on 8 to 11 plots) and cover include *Achillea millefolium*, *Arnica sororia*, *Aster laevis*, *Cerastium arvense*, *Fragaria virginiana*, *Galium boreale*, *Lomatium*

triternatum, *Lupinus sericeus*, and *Penstemon confertus*. Over the past two decades, *G. boreale* has increased in cover on 8 of the plots, while *C. arvense* has increased in cover on 7 of the plots. Most of the remaining dominant species have increased in cover on 3 to 5 of the plots except for *A. laevis* which generally remained with the same cover.

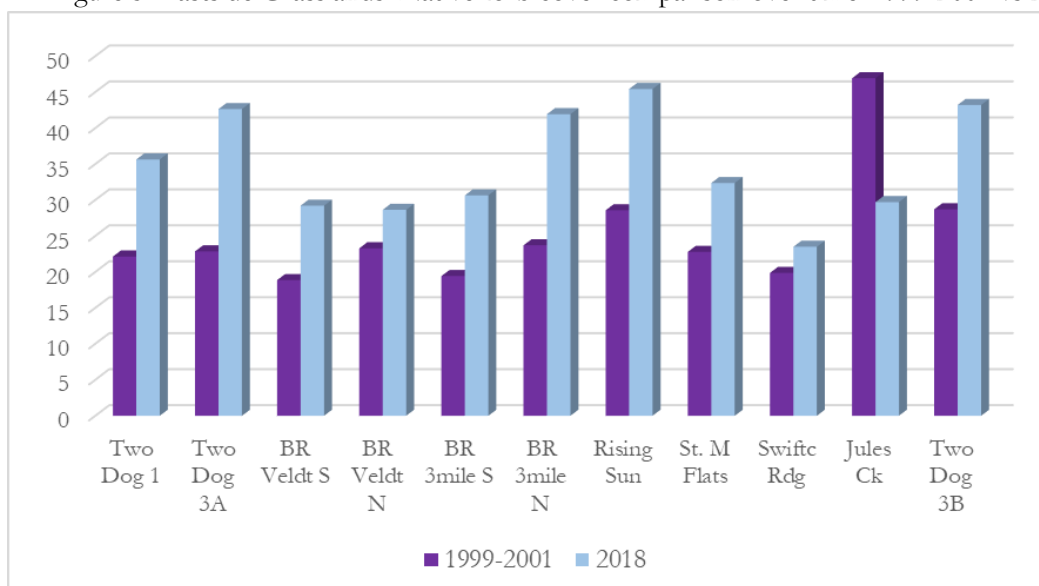
Other native forb species that had high frequency (present on 7 to 11 plots) but generally lower cover include *Agoseris glauca*, *Anemone multifida*, *Antennaria umbrinella*, *Campanula rotundifolia*, *Erigeron speciosus*, *Gaillardia aristata*, *Geranium viscosissimum*, *Heuchera cylindrica*, *Potentilla gracilis*, and *Solidago* spp. Most of these species increased in cover by only small amounts but many of them increased in frequency into additional plots. Finally, native forbs that only had moderate frequency (4 to 6 plots) but notable cover in certain areas include *Comandra umbellata*, *Hedysarum sulphurescens*, *Lithospermum ruderales*, *Perideridia gairdneri*, *Phlox hoodii*, and *Selaginella densa*. Many of these forb species increased in cover where they were present two decades ago.

Several new forb species were observed for the first time in these 11 meadows. New plants that were newly documented in these plots include *Antennaria racemosa*, *Arabis drummondii*, *Astragalus adsurgens*, *Astragalus alpinus*, *Astragalus robbinsii*, *Collomia linearis*, *Delphinium bicolor*, *Draba nemerosa*, *Epilobium brachycarpum*, *Heuchera parvifolia*, *Hieracium umbellatum*, *Microsteris gracilis*, *Orthocarpus luteus*, *Polygonum douglasii*, *Prenanthes sagittata*, *Saxifraga occidentalis*, and *Stellaria longipes*. Most of these species were only newly documented in one plot.

It is important to note that some species, even the dominant ones, did decrease in certain meadows. Despite each being a frequent native forb species, *Anemone multifida* and *Solidago* spp. decreased in both frequency and cover in certain areas. *Vicia americana*, *Selaginella densa*, *Polygonum bistortoides*, and *Eriogonum umbellatum*, while not dominant species, also exhibited large declines in certain meadows where they were once present with higher cover. Plot 00-013 in Jule's Creek that was the sole plot to have a decrease of native forb cover, correspondingly had decreases of several native forb species. These include *Achillea millefolium*, *Agoseris glauca*, *Castilleja sulphurea*, *Dodecatheon conjugens*, *Fragaria virginiana*, *Gaillardia aristata*, *Galium boreale*, *Lathyrus ochroleucus*, *Polygonum bistortoides*, and *Vicia americana*. As stated above, these declines were likely due to competition from notably increasing exotic grasses.

At the same time, several species were no longer found on these 11 plots. These include *Artemisia ludoviciana*, *Astragalus agrestis*, *Astragalus australis*, *Eriogonum flavum*, *Happlopappus carthamoides*, *Hedysarum alpinum*, *Linum lewisii*, *Minuartia rubella*, and *Senecio streptanthifolius*.

Figure 5. Eastside Grasslands: Native forb cover comparison over time: 1999-2001 vs 2018



5. Exotic Grasses

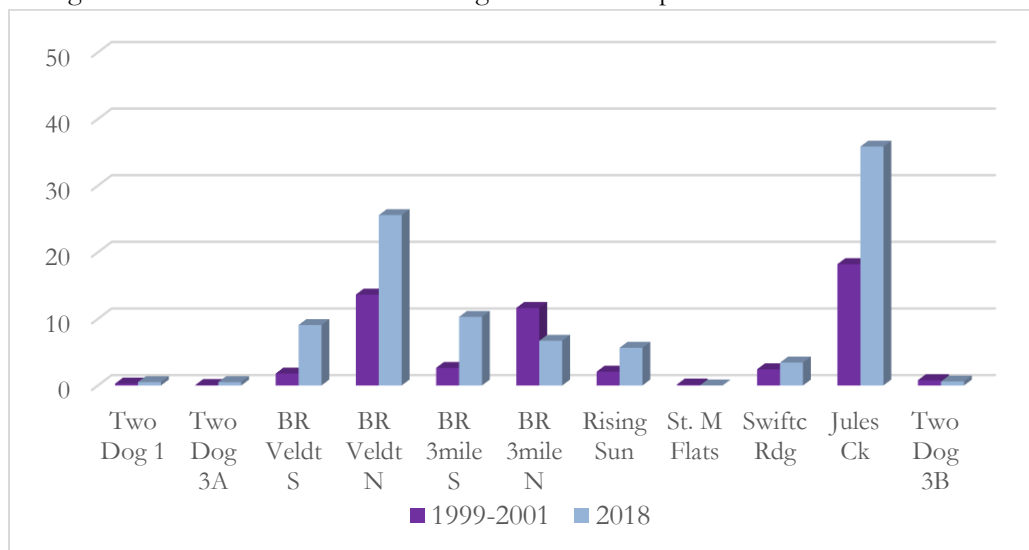
There was no overall trend for changes in exotic grass cover over the past two decades. Exotic grass cover did not change on five of the plots, remaining with the same relatively low cover that ranged from 0.01% to 3.44%.

Interestingly, the areas that have remained with low exotic grass cover include all the Two Dog Flats plots, the Swiftcurrent Ridge plot, and the St. Mary Flats plot.

Exotic grass cover notably increased, however, on five other plots, particularly in the Belly River area and in the Jule's Creek ridge off the Chief Mountain Road. While exotic grass cover only increased by 3% at Rising Sun, exotic grass cover increased by 7-12% at the Belly River Veldt north and south plots and the 3-mile south plot and increased by a dramatic 17% at the Jule's Creek plot. The Jule's Creek plot had the highest exotic grass cover compared to other monitored areas at 35.86%. These increases were due exclusively to increases in cover of *Phleum pratense*, which increased from 1-17% on these five plots, and *Poa pratensis*, which increased from 2-8% on four of these plots. Both of these species also increased in frequency with *Phleum pratense* found on all 11 plots in 2018 compared to 10 plots in 1999-2001 and *Poa pratensis* found on 10 plots compared to 7 plots in 1999-2001. *Poa compressa* was also a new exotic grass, found on one plot with low cover in 2018.

Only one plot at the Belly River 3-mile N area had a decrease in exotic grass cover from 11.64% to 6.71%. This was due to notable decrease of 6% of *Phleum pratense*. That same plot had small increases in cover of *Bromus inermis* and *Poa pratensis*. While the reasons for this decrease in exotic grass cover are uncertain, this plot did experience a 20% increase in native grass cover and an 18% increase in native forb cover which may be outcompeting certain exotic grasses.

Figure 6. Eastside Grasslands: Exotic grass cover comparison over time: 1999-2001 vs 2018



6. Exotic Forbs

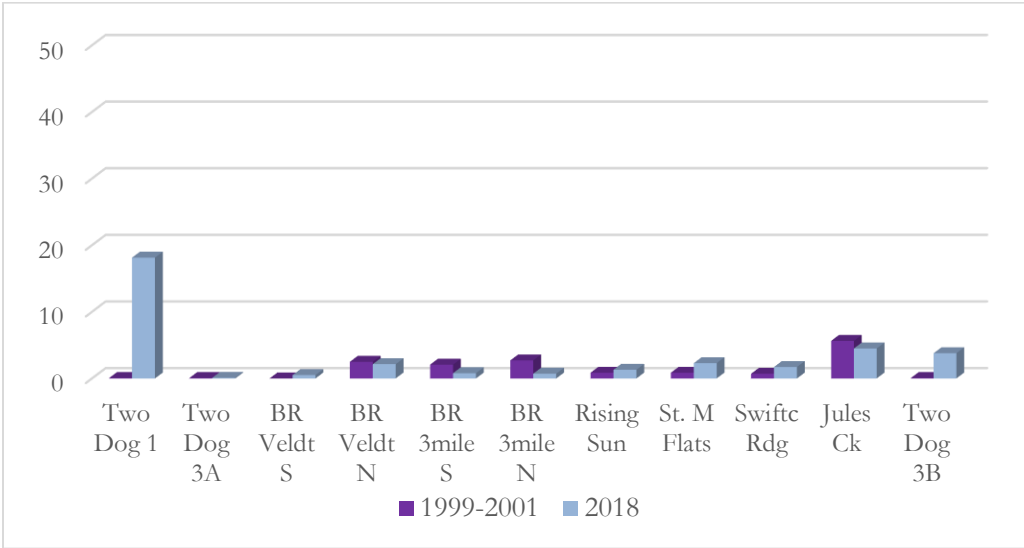
Overall, exotic forb cover has remained relatively low on the majority of the grassland plots monitored in 2018. Six plots in the Belly River Veldt north and south, Rising Sun, Swiftcurrent Ridge, Jule's Creek, and some areas of Two Dog Flats remained with trace to 5% exotic forb cover in 2018, similar to values in 1999-2001. Two additional plots in the Belly River 3-mile south and north areas actually decreased in exotic forb cover by 2% over time, due exclusively to a decrease in cover of *Taraxacum officinale* and no establishment of new exotic forb species.

Exotic forb cover did increase, however, on two plots in Two Dog Flats and on one plot in St. Mary Flats due exclusively to the increase of *Centaurea maculosa* in these areas. Exotic forb cover increased by 1.5-3.5% on plots in St. Mary Flats and in Two Dog Flats meadow 3, but increased by 18% in Two Dog Flats meadow 1 due to the increase

of noxious weed *C. maculosa*. *C. maculosa* also increased in frequency, now present on five plots compared to three plots in 1999-2001. This trend should be watched over time and documented if it is happening in other grassland areas.

Fortunately, there are very few exotic species that are establishing in grassland areas. Only five exotic forb species were noted in the plots monitored in 2018 with two of those species, *Alyssum alyssoides* and *Erysimum cheiranthoides*, having extremely low cover. Despite its low cover, there is some concern for the increase in frequency of *Tragopogon dubius* from presence in one plot in 1999-2001 to eight plots in 2018. Increases of this exotic forb have been documented in grasslands in other eastern Montana parks and, anecdotally, we have seen this weed increase across Glacier NP.

Figure 7. Eastside Grasslands: Exotic forb cover comparison over time: 1999-2001 vs 2018



D. CONCLUSIONS AND ACTION ITEMS

The 11 plots that were monitored in 2018 were hopefully the first of 50-75 plots that can serve as long-term monitoring plots for assessing the health of fescue grasslands. As stated above, the intent is not to re-read all 155 original plots from the initial study but find a subset of plots where management concerns are the highest to monitor every 10-20 years. This year is the first year of a 5 year effort (2018-2022) to determine that subset of plots and gather data that will serve not only as a new health baseline for these grassland areas, but allow change over time assessments to determine if these grasslands require different management tactics.

As changes to these plots are discussed, it is important to remember that several of these plots were re-read by different people. There is inherent observer error in estimating canopy cover, particularly for grasses, as visual estimation is often subjective, making it hard to maintain consistent measurements. We acknowledge that small changes in canopy cover may likely be due to this subjectivity and generally will not be addressing those in the overall conclusions. Big changes in lifeform or species cover, however, are less likely due to observer error and are presented below as noted changes occurring in these grassland communities.

1. Shrubs, and trees in certain areas, are increasing in every meadow monitored in 2018.

A major change over the past two decades is that all 11 eleven plots increased in shrub cover by a range of 3% to 19% and 5 of the 11 plots picked up a new shrub species that was not present 20 years ago. The shrub species that

experienced the largest changes were *Rosa* spp., *Amelanchier alnifolia*, *Arctostaphylos uva-ursi*, and *Mahonia repens*. Additionally, in the plots where it is present, tree species *Populus tremuloides* also notably increased.

As stated in the 2010 Eastside Grasslands Ecology Report, most North American grasslands have an inherent tendency to become dominated by woody plants; that is, they succeed from grassland to either shrubland or forest. Low-elevation grasslands historically experienced frequent, low-intensity fire that controlled the invasion of woody plants. These historic fire patterns generally ended almost a century ago, removing the primary means that shrubs and trees are kept in check in grassland communities.

While additional plots need to be monitored to support this overall trend, the preliminary data from these 11 plots indicate that shrub increase, and possibly tree increase, is a problem in several eastside grassland areas. It will likely remain an increasing trend and problem in these meadows as the Park does not have an active plan to return fire to these communities. It is recommended to follow the initial action items laid out in the 2010 report:

ACTION ITEMS: (1) Investigate returning prescribed fire to certain east side grasslands on a small-scale and monitor results. If fire is returned to certain problem areas, commitment for every-other-year fires should be considered for effective control of woody plants and weeds; (2) investigate manual methods of removing woody material, both trees and shrubs, in certain grassland areas.

2. The native grass component of these grasslands appears to be healthy and increasing.

Overall, nine of the eleven plots exhibited an increase in native grass cover over the past two decades, ranging from a 4% to 20% increase. Native grass cover on the remaining two plots was essentially the same as twenty years ago. Dominant native grasses remained the same and the overall diversity of native grasses did not dramatically change.

Currently, there are no action items to address the health of native grasses within these grassland communities. If fire is naturally or experimentally returned to some of these areas, caution should be taken to prevent high-intensity fires in areas that have high cover of *Festuca scabrella*. Studies have shown that this grass in particular can be seriously damaged when hot fires return to grasslands that have not burned in some time.

3. The native forb component of these grasslands appears to be healthy and increasing.

Overall, ten of the eleven plots that were monitored in 2018 had increases in native forb cover over the past two decades, ranging from a 3.5% to 20% increase. Generally, the dominant native forbs remained the same, and while there were species that disappeared from these 11 plots, there were more new species that were documented for the first time. The remaining plot at Jule's Creek off the Chief Mountain Road, on the other hand, had a 17% decrease in native forb cover. As explained above, this decrease in native forb cover was likely due to a dramatic increase in exotic grass cover in this meadow that is outcompeting many of the native species.

Currently, there are no action items to address the health of native forbs within these grassland communities. If herbicide is used in these meadows to control noxious weeds, care should be taken to spot-spray the weeds and avoid native forb species. Native forb species in the aster and pea families are particularly susceptible to herbicide contact.

4. Exotic grasses are increasing in certain areas of the park.

While there is no overall trend for exotic grasses, it does appear that they have notably increased in certain eastside grasslands. With increases ranging from 7% to 17%, four of the eleven plots monitored in 2018, specifically in meadows in the Belly River and off the Chief Mountain Road, experienced an increase in exotic grasses over the past two decades. These increases were primarily due to increases of *Phleum pratense* and *Poa pratensis*.

Fortunately, seven of the eleven plots remained with relatively low exotic grass cover similar to values documented in 1999-2001. This trend was noted in many of the plots in the St. Mary Valley.

As non-native perennial grasses are very hard to control once they become established, it remains a challenge to offer action items to control these exotic species. There is experimental research combining herbicide, fire, and restoration treatments that is showing promise in certain areas, but these methods tend to be time-consuming, expensive, and often work only in small areas. The issue of increasing exotic grasses should not be discredited, however, resulting in the following recommendations:

ACTION ITEMS: (1) Continue to investigate strategies to remove/control exotic perennial grasses within fescue grasslands and restore the areas with native species; (2) continue fencing key boundary areas to prevent livestock trespass that often results in exotic grass invasion and establishment; (3) as timothy stands become weak under close and continuous grazing, monitor these timothy-invaded areas if/when bison are re-introduced to see if some grazing negatively impacts these exotic grasses.

5. Exotic forbs remain low but control should continue on noxious weeds.

As stated above, overall exotic forb cover has remained relatively low on the majority of the grassland plots monitored in 2018. Six of the eleven plots remained with trace to 5% exotic forb cover in 2018, similar to values in 1999-2001. Two additional plots actually decreased in exotic forb cover by 2% over time, due exclusively to a decrease in cover of *Taraxacum officinale* and no establishment of new exotic forb species.

Two exotic forb species, however, remain of concern. Noxious weed *Centaurea maculosa* appears to be increasing in cover and frequency in certain areas, particularly in the St. Mary Valley. There is also some concern for the increase in frequency of *Tragopogon dubius* from presence in one plot in 1999-2001 to eight plots in 2018. Increases of this exotic forb have been documented in grasslands in other eastern Montana parks and, anecdotally, we have seen this weed increase across Glacier NP.

Due to the fact that overall exotic forb cover remains low and very few, if any, new exotic forb species are becoming established in these grasslands, it is recommended to follow the initial action items laid out in the 2010 report:

ACTION ITEMS: (1) Continue persistent and aggressive control of all noxious weeds within and near fescue grasslands; (2) consider seeding with native species in areas that have had weed control, including herbicide treatment and hand-pulling; and (3) continue fencing key boundary areas to prevent livestock trespass that often results in exotic forb invasion and establishment.

Ten to fifteen plots should be monitored in 2019 as part of this on-going study to determine a new baseline health for these eastside grasslands, especially prior to potential bison reintroduction. Potential plots to consider in 2019 include:

<u>Belly River</u>	<u>Many Glacier</u>	<u>Saint Mary</u>		
99-016	99-010 99-052	99-007	99-025	01-001
99-018	99-011 Slide Lake plots?	99-009	99-028	01-021
99-019	99-013	99-014	99-053	01-026
99-020	99-048			

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 11 plots: 1999-2001 vs 2018

	GRAS-99-005		GRAS-99-013		GRAS-99-015		GRAS-99-017		GRAS-99-021		GRAS-99-022		GRAS-99-024		GRAS-99-027		GRAS-99-038		GRAS-00-013		GRAS-01-021	
	Two Dog Flats		Two Dog Flats		Belly River		Belly River		Belly River		Belly River		Rising Sun		St. Mary Flats		Many Glacier		Many Glacier		Two Dog Flats	
	Meadow 1A		2 Dog - 3		Veldt South		Veldt North		3 Mile S		3 Mile N		Rising Sun W		High Ridge		Swiftc Ridge		Jule's Creek		#3, Lower W	
	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	2001	2018
Ground Cover																						
Bare soil		0.23	1.29	6.50	1.36	3.50		0.71		6.50	9.71	6.64		0.43	1.57	2.07	5.79	5.36	0.57	2.14	0.36	4.21
Basal vegetation	6.86	3.57	7.50	5.36	8.43	6.79	9.50	7.64	10.07	7.86	5.79	6.57	7.00	5.57	4.07	4.57	7.21	5.07	9.43	5.43	5.14	5.07
Gravel			0.07	0.29	0.29	0.71		0.14		0.93	0.71	2.07			0.07	0.07	0.71	1.14				0.22
Lichen	0.29		0.29	2.14											1.21	9.36					0.18	0.23
Litter	49.36	65.64	84.57	75.14	89.86	88.07	90.50	91.29	85.00	83.00	83.64	83.64	87.71	91.36	74.00	73.50	78.71	81.79	89.21	92.21	40.36	76.21
Moss	37.00	27.43	1.00	6.86		0.79			6.14	1.21		0.21		2.79	0.14	6.86		2.00			49.57	9.93
Rock	1.43	1.07	1.29	0.93		0.14		0.14		0.50	0.14	0.14	0.07		1.00	1.07	0.50	0.36	0.14		0.25	0.57
Wood																						
Other	3.36		0.86						0.21			0.07	0.07		6.57		6.21		0.64			
Other (domestic scat)																		4.43		0.21		
Other (elk scat)		1.73		1.93				0.07								3.94					2.32	2.16
Tree	0	0	0	0	0.71	2.64	0.01	1.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Populus tremuloides</i>					0.71	2.64	0.1	1														
Shrub	0.71	3.21	7.50	18.21	21.57	34.59	3.14	22.29	0.93	3.79	1.07	2.94	13.07	32.29	0.53	11.93	6.86	14.00	5.36	12.29	4.29	11.57
<i>Amelanchier alnifolia</i>	0.14	0.71	1.86	7.51		3.07	0.36	3.57										0.43			1.36	5.79
<i>Arctostaphylos uva-ursi</i>				0.1	6.71	24.01			0.21	0.80					0.43	10.71	1.14	4.29				
<i>Mahonia repens</i>													4.50	20.36								
<i>Pentaptylloides floribunda</i>	0.1	0.71	2.86	3.86	12.71	9.71	1.64	14.00	0.36	0.36	0.86	0.87				1.21	4.29	5.71	2.64	4.71	1.43	0.43
<i>Prunus virginiana</i>			0.07	0.51			0.21	1.29	0.1	0.1			0.1	0.1								
<i>Rosa acicularis</i>																			2.57	7.57		
<i>Rosa spp.</i>	0.57	1.79	2.71	7.36	1.57	1.86	0.93	4.86			0.21	2.07	8.57	13.43	0.1	0.14	1.36	3.57				
<i>Rosa woodsii</i>									0.36	2.64											1.86	5.43
<i>Symphoricarpos albus</i>												0.2										
# of shrub species	3	3	4	5	3	4	4	4	4	4	2	3	3	3	2	3	3	4	2	2	3	3
Native Grass	14.14	23.36	19.14	31.64	10.36	27.57	19.21	32.79	33.07	37.50	7.21	27.36	14.36	20.79	14.64	32.14	15.36	21.64	8.93	7.86	29.07	27.14
<i>Agrostis scabra</i>																	0.1					
<i>Bromus carinatus</i>	0.07																0.64	1.50	0.36	0.39		
<i>Bromus pumellianus</i>																			0.1			
<i>Carex aurea/obtusata</i>	3.36	5.50	5.14	3.72		2.29							0.57	1.10	0.93	0.81	2.07					
<i>Carex filifolia</i>		4.43	4.71	4.50											1.93	2.46					0.21	0.36
<i>Carex petasata</i>	0.14		0.07	0.14	0.1			3.07	2.36	3.57			0.1									
<i>Carex raynoldsii</i>																			0.1	0.1		
<i>Carex spp. (obtusata, petasata, rossii)</i>												0.57					0.1	5.64	0.21	1.79	6.54	9.43
<i>Danthonia intermedia</i>	2.64	1.57	1.21	3.86	1.79	0.50			1.00								0.21	0.37		0.09	5.39	2.57
<i>Elymus lanceolatus</i>					0.71	5.86	0.21	2.64	0.71	0.94	2.43	9.79				4.93						
<i>Elymus smithii</i>																	0.43	1.02	0.14	0.54	0.93	0.31
<i>Elymus spicatus</i>	0.07	0.86		0.51									0.57	0.14		0.43						

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 11 plots: 1999-2001 vs 2018

	GRAS-99-005		GRAS-99-013		GRAS-99-015		GRAS-99-017		GRAS-99-021		GRAS-99-022		GRAS-99-024		GRAS-99-027		GRAS-99-038		GRAS-00-013		GRAS-01-021	
	Two Dog Flats		Two Dog Flats		Belly River		Belly River		Belly River		Belly River		Rising Sun		St. Mary Flats		Many Glacier		Many Glacier		Two Dog Flats	
	Meadow 1A		2 Dog - 3		Veldt South		Veldt North		3 Mile S		3 Mile N		Rising Sun W		High Ridge		Swiftc Ridge		Jule's Creek		#3, Lower W	
	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	2001	2018
<i>Elymus trachycaulus</i> ssp. <i>subsecundus</i>	0.07		1.43	1.03	0.57	0.22	0.43	0.79	0.50	0.16	0.07	0.14					1.50	1.36				
<i>Elymus trachycaulus</i> ssp. <i>trachycaulus</i>																		1.00		0.29		
<i>Festuca idahoensis</i>	1.21	4.86	2.79	7.07	0.57	6.86		0.07	1.64	4.07	0.14	5.08	4.29	15.64	4.00	8.14	7.21	6.72	4.21	1.46	4.71	6.50
<i>Festuca scabrella</i>	1.00	4.71	1.86	5.43	6.36	11.86	18.79	27.58	23.57	28.43	4.07	9.07	2.50	3.94	4.43	10.29	2.00	3.29	3.57	3.66	3.96	3.29
<i>Helictotrichon bookeri</i>	0.07	0.14	0.1						0.21												0.64	
<i>Koeleria macrantha</i>	0.29	1.07	0.29	3.43	0.1	0.57	0.1	0.01	0.43	0.15	0.29	2.86	0.50	0.08	1.14	2.36	0.79	0.66		0.21	1.39	3.71
<i>Luzula multiflora</i>				0.1																		
<i>Poa secunda</i>				0.36						0.1		0.08		0.01		1.08		0.01			0.11	0.01
<i>Stipa nelsonii</i>	4.79	1.51	1.29	3.29	0.1	0.85			1.86	1.14		0.57	5.64	0.21	1.00	2.21	0.07	0.21			4.64	1.66
<i>Stipa richardsonii</i>	0.1	0.1			0.1	0.14																
# of grass species	12	10	10	12	9	9	4	6	9	8	5	8	7	7	6	9	11	11	7	9	10	9
Native Forb	22.14	35.64	22.86	42.64	18.86	29.21	23.29	28.64	19.43	30.64	23.71	41.93	28.57	45.43	22.79	32.36	19.86	23.50	46.93	29.71	28.71	43.21
<i>Achillea millefolium</i>	2.79	2.29	2.00	9.21	2.36	2.43	2.29	3.36	2.29	7.86	4.21	4.14	2.71	0.1	0.79	1.15	2.00	2.02	4.79	2.29	1.46	6.08
<i>Agoseris glauca</i>	1.00	0.1	0.21	0.09	0.43	1.00	0.86	0.65	0.57	0.86	1.00	1.50	0.36	0.79			0.29	0.94	3.07	0.43	0.71	0.29
<i>Allium cernuum</i>		0.1		0.01												0.10		0.1	0.07	0.07	0.39	0.31
<i>Anemone multifida</i>	0.50	0.86	1.21	3.29	0.29	0.1			1.21	0.36	0.14	0.07	0.07	0.1	0.36		0.64	0.09	0.07	0.07	4.00	4.22
<i>Antennaria anaphaloides</i>			0.21	0.21	0.93	0.86			0.1	0.1		0.1					0.50	0.37	0.50	0.1		
<i>Antennaria racemosa</i>																0.07						
<i>Antennaria rosea</i>	0.1			0.1																		
<i>Antennaria umbrinella</i>	0.79	2.08	0.21	0.93	0.14	0.1			0.36	0.21	0.1	0.07	0.1		0.07	0.14	0.71	0.93			0.61	0.86
<i>Arabis drummondii</i>				0.01														0.02				
<i>Arabis hirsuta</i>					0.1					0.01	0.1	0.16	0.1									
<i>Arabis nuttallii</i>		0.07		0.04		0.01															0.21	0.01
<i>Arabis glabra</i>																	0.1	0.07				
<i>Arabis</i> sp.																0.1						
<i>Arnica sororia</i>	0.64	3.36	0.21	3.58	0.07	0.1				0.14		0.1	0.21	0.14	0.71	11.93			0.64	0.1	1.36	6.93
<i>Aster conspicuus</i>							0.1	1.07														
<i>Aster laevis</i>		0.1		0.71	2.36	4.14	3.14	2.14	0.71	0.86	2.50	3.79	0.21	0.1			0.1	0.1	4.29	4.57		
<i>Artemisia ludoviciana</i>													1									
<i>Astragalus adsurgens</i>		0.1																				
<i>Astragalus alpinus</i>																		0.36				
<i>Astragalus agrestis</i>													0.1									
<i>Astragalus australis</i>																					0.1	
<i>Astragalus robbinsii</i>									0.1		0.1											
<i>Astragalus tenellus</i>															1.64	0.1						
<i>Astragalus</i> spp.							0.14	0.08										0.14				
<i>Balsamorhiza sagittata</i>	1.79	2.44																				
<i>Besseyia wyomingensis</i>	0.14	0.36																0.21	0.86	0.44		
<i>Bupleurum americanum</i>															0.21	0.14	0.1	0.1				

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 11 plots: 1999-2001 vs 2018

	GRAS-99-005		GRAS-99-013		GRAS-99-015		GRAS-99-017		GRAS-99-021		GRAS-99-022		GRAS-99-024		GRAS-99-027		GRAS-99-038		GRAS-00-013		GRAS-01-021	
	Two Dog Flats		Two Dog Flats		Belly River		Belly River		Belly River		Belly River		Rising Sun		St. Mary Flats		Many Glacier		Many Glacier		Two Dog Flats	
	Meadow 1A		2 Dog - 3		Veldt South		Veldt North		3 Mile S		3 Mile N		Rising Sun W		High Ridge		Swiftc Ridge		Jule's Creek		#3, Lower W	
	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	2001	2018
<i>Calochortus apiculatus</i>					0.21	1.16	0.07		0.14	0.15	0.1	0.14						0.08	0.36	0.07		
<i>Campanula rotundifolia</i>	0.21	1.00		1.16	0.07	0.58	0.36	1.15	0.14	1.36	0.43	2.57	0.07	0.21		0.09	0.50	0.73	0.29	0.23	0.57	0.53
<i>Castilleja cusickii</i>																					0.04	0.07
<i>Castilleja sulphurea</i>	0.14	0.50														0.1			0.29			
<i>Cerastium arvense</i>	0.57	2.94	0.36	1.86	0.36	3.36	0.57	0.22	0.29	0.37	2.29	4.57	0.43	2.01		0.64	0.50	2.64	2.36	1.58	1.50	1.03
<i>Cirsium bookerianum</i>							0.1					0.36							0.1			
<i>Collomia linearis</i>														0.21				0.07				
<i>Comandra umbellata</i>	0.14	2.00	0.1										0.36	0.64	1.07	0.21					0.89	1.52
<i>Cryptantha celosioides</i>															0.1	0.01						
<i>Delphinium bicolor</i>		0.10		0.29																		
<i>Dodecatheon conjugens</i>		0.04				0.16		0.1		0.34		0.03		0.02			0.07	0.03	1.07	0.02	0.18	
<i>Draba nemorosa</i>		0.01		0.01												0.03						
<i>Draba spp.</i>						0.01																
<i>Epilobium brachycarpum</i>								0.01														
<i>Erigeron caespitosus</i>							0.57								0.36	0.1	0.64	1.43				
<i>Erigeron speciosus</i>		0.21				0.64		0.43	0.1	0.1		1.79		1.57		0.1			0.86	1.14		0.07
<i>Eriogonum flavum</i>																					0.1	
<i>Eriogonum umbellatum</i>											0.1		2.57	0.64								
<i>Fragaria virginiana</i>				0.1	3.14	1.21	3.21	5.07	0.1	0.1	2.79	4.36		0.1			1.36	1.07	4.79	3.50	0.14	0.93
<i>Gaillardia aristata</i>	0.64	2.00	0.07	0.79	0.07	0.1			0.93	0.1	0.14	0.36		0.1	0.07	0.1			0.21		0.46	0.58
<i>Galium boreale</i>	1.21	5.29	0.86	4.08	1.57	2.22	1.07	2.72	2.93	4.29	1.86	4.64	0.50	17.71	1.14	5.29	2.29	1.29	3.86	2.01	0.75	2.36
<i>Geranium viscosissimum</i>		0.1			0.1	0.01	2.93	2.36					0.79	0.21			0.1	0.1	0.29	0.07	0.04	0.14
<i>Geum triflorum</i>	0.14	0.29					0.29		0.1	0.29					0.36	0.51						
<i>Happlopappus carthamoides</i>													0.07									
<i>Hedysarum alpinum</i>					0.07																	
<i>Hedysarum sulphurescens</i>			1.07	2.94	0.29	1.57			0.14	0.21							0.21	0.01				
<i>Heterotheca villosa</i>	0.57	0.36													0.07	0.1						
<i>Heuchera cylindrica</i>	0.1	0.07	0.14	0.14		0.1	0.1		0.07	2.29			0.14	1.07	0.1	0.14		0.1			0.43	0.64
<i>Heuchera parvifolia</i>		0.1																				
<i>Hieracium scouleri</i> var. <i>albertinum</i>	0.14	0.43	0.1	0.29									0.29	0.07							0.75	2.71
<i>Hieracium umbellatum</i>																				0.14		
<i>Lathyrus ochroleucus</i>							0.86	0.93										0.1	1.64	0.57		
<i>Linum lewisii</i>											0.07											
<i>Lithospermum ruderales</i>	0.14	0.07	0.21	1.44					0.1	0.1			0.57	5.71	0.50	0.29					2.21	4.36
<i>Lomatium macrocarpum</i>													0.14					0.1				
<i>Lomatium triternatum</i>	0.07	0.29	0.07		1.79	4.36	1.50	1.15	0.50	4.07	1.50	5.36	1.29	3.00	0.1		0.79	0.80	4.79	4.79	0.89	
<i>Lupinus sericeus</i>	2.86	10.57	7.93	18.00	0.93	1.36	0.64	1.00	8.57	8.21	2.21	2.79	11.43	18.57	0.64	0.01	2.29	3.14	0.07	0.36	10.61	11.51
<i>Maianthemum stellatum</i>					0.14	0.36	0.14	0.57			0.21	0.01			0.43	1.79						
<i>Microsteris gracilis</i>														0.1								

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 11 plots: 1999-2001 vs 2018

	GRAS-99-005		GRAS-99-013		GRAS-99-015		GRAS-99-017		GRAS-99-021		GRAS-99-022		GRAS-99-024		GRAS-99-027		GRAS-99-038		GRAS-00-013		GRAS-01-021	
	Two Dog Flats		Two Dog Flats		Belly River		Belly River		Belly River		Belly River		Rising Sun		St. Mary Flats		Many Glacier		Many Glacier		Two Dog Flats	
	Meadow 1A		2 Dog - 3		Veldt South		Veldt North		3 Mile S		3 Mile N		Rising Sun W		High Ridge		Swiftc Ridge		Jule's Creek		#3, Lower W	
	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	2001	2018
<i>Minnartia rubella</i>																					0.07	
<i>Monarda fistulosa</i>			0.07	0.36	0.14		0.29	0.29			1.50	1.29	0.1								0.07	0.57
<i>Orthocarpus luteus</i>																						0.01
<i>Orthocarpus tenuifolius</i>															0.29	0.38						
<i>Oxytropis campestris</i>	2.14	0.07	0.50	0.1		0.14						0.1	0.1	0.1							0.07	
<i>Oxytropis sericea</i>																	0.29	0.71				
<i>Oxytropis splendens</i>					0.07	0.1			0.07		0.29	0.71						0.1				
<i>Penstemon confertus</i>	0.1	0.1	0.1	1.44		2.73	2.64	5.64		0.2	0.1	4.86					0.36	3.07	0.50	1.00	0.18	0.71
<i>Perideridia gairdneri</i>		0.1				0.36		0.44				0.36								1.36		
<i>Phlox boottii</i>	0.29	0.71							0.43	0.36					1.36	2.00	0.1	0.29				
<i>Polygonum bistortoides</i>																		0.01	1.71	0.02		
<i>Polygonum douglasii</i>																		0.01				
<i>Potentilla arguta</i>			0.14	0.1														0.1				
<i>Potentilla glandulosa</i>	0.1	0.01																			0.96	0.93
<i>Potentilla gracilis</i>	1.21	0.57		0.29	0.71	1.29	0.86	0.14	0.43	0.21	0.57	1.07	0.36	0.29	0.07	0.1	0.21	0.07	4.14	4.86	1.79	0.87
<i>Potentilla hippiana</i>	0.14	0.07	0.29	0.29					0.14	0.14						0.36	0.36	0.21				
<i>Potentilla pensylvanica</i>															0.1							0.1
<i>Prenanthes sagittata</i>																				0.1		
<i>Rhinanthus crista-galli</i>						0.36			0.07	0.1		0.64					0.07	0.1	0.14			
<i>Saxifraga occidentalis</i>		0.1														0.1						
<i>Sedum lanceolatum</i>			0.1			0.1					0.1							0.1				
<i>Selaginella densa</i>	1.79	2.00	3.07	2.50									5.07		11.00	7.43	0.79	0.14			0.97	
<i>Senecio canus</i>															0.07	0.07						1.59
<i>Senecio pseudoreus</i>					0.07	0.21	0.29	0.07														
<i>Senecio streptanthifolius</i>									0.1													
<i>Silene parryi</i>		0.1	0.1																			
<i>Sisyrinchium montanum</i>		0.31			0.1					0.01	0.14	0.07									0.07	0.24
<i>Solidago spp. (mostly multiradiata)</i>	0.93	0.43	1.29	0.29	0.50	0.57	0.64	0.14	0.71	0.86	0.57	0.86		0.1	0.50		3.00	2.64	0.07		0.54	1.64
<i>Stellaria longipes</i>								0.1												0.01		
<i>Thalictrum occidentale</i>																		0.07	1.14	1.79		
<i>Veronica peregrina</i>													0.1									0.14
<i>Vicia americana</i>					0.14	0.1	1.57	1.07			0.79	0.57					0.57	0.51	3.57	0.71		
<i>Viola adunca</i>													0.07		0.29							
<i>Zigadenus elegans</i>										0.1											0.57	0.08
<i>Zigadenus venenosus</i>		0.1	0.14	3.14											0.57							
# of forb species	29	43	26	32	27	33	25	25	26	31	24	32	27	26	25	33	27	43	29	28	33	31

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 11 plots: 1999-2001 vs 2018

	GRAS-99-005		GRAS-99-013		GRAS-99-015		GRAS-99-017		GRAS-99-021		GRAS-99-022		GRAS-99-024		GRAS-99-027		GRAS-99-038		GRAS-00-013		GRAS-01-021	
	Two Dog Flats		Two Dog Flats		Belly River		Belly River		Belly River		Belly River		Rising Sun		St. Mary Flats		Many Glacier		Many Glacier		Two Dog Flats	
	Meadow 1A		2 Dog - 3		Veldt South		Veldt North		3 Mile S		3 Mile N		Rising Sun W		High Ridge		Swiftc Ridge		Jule's Creek		#3, Lower W	
	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	1999	2018	2001	2018
Exotic Grass	0.29	0.51	0.07	0.50	1.79	9.07	13.64	25.57	2.64	10.29	11.64	6.71	2.07	5.65	0.14	0.01	2.43	3.44	18.21	35.86	0.79	0.60
<i>Bromus inermis</i>									1.57	0.24	0.14	0.71										
<i>Pbleum pratense</i>	0.29	0.51	0.14	0.50	1.79	4.16	13.43	19.79	2.21	1.79	11.50	5.43	2.21	3.44		0.1	0.36	1.29	18.21	35.86	0.79	0.39
<i>Poa compressa</i>														0.21								
<i>Poa pratensis</i>		0.08		0.08	0.1	4.93	0.21	6.16	0.36	8.36	0.14	0.57	0.07	2.23	0.14		2.07	2.15		0.1		0.22
# of exotic grass species	1	2	1	2	2	2	2	2	3	3	3	3	2	3	1	1	2	2	1	2	1	2
Exotic Forb	0.07	18.14	0.07	0.10	0	0.51	2.50	2.15	2.07	0.79	2.71	0.72	0.86	1.31	0.86	2.30	0.71	1.72	5.64	4.50	0.07	3.79
<i>Alyssum alyssoides</i>													0.1			0.01						0.01
<i>Centaurea maculosa</i>	0.1	18.00		0.04									0.86	0.43	0.86	2.24						3.79
<i>Erysimum cheiranthoides</i>								0.1														
<i>Taraxacum officinale</i>	0.07		0.07			0.50	2.50	2.08	2.07	0.79	2.93	0.01		0.07			0.71	1.65	5.64	4.50	0.07	
<i>Tragopogon dubius</i>		0.21		0.01		0.01		0.07			0.1	0.71		0.82		0.07						0.01
# of exotic forb species	2	2	1	2	0	2	1	3	1	1	2	2	2	3	1	3	1	1	1	1	1	3

III. WEST ENTRANCE STATION

A. BACKGROUND AND PURPOSE

The West Entrance Station is the primary entrance to Glacier National Park from the west side and receives heavy use during the summer months. The existing entrance station and approach lanes are often insufficient to handle traffic volumes during peak summer months, which often causes lengthy vehicle backups. Construction on the Going-to-the-Sun Road, which is an on-going project, brings increased vehicular traffic through the entrance, further contributing to congestion at the entrance.

In the fall of 2008, a new approach lane was added to the West Entrance Station, starting at the Headquarters turn-off and continuing to the north along the existing road. An extra entrance lane for employees and concessionaires was added in an attempt to expedite traffic flow. Additional developments in the area include enhancing the utility line to the station and replacing the existing vault toilet with an accessible restroom, storage, and break room for entrance station staff. Disturbance to native vegetation spanned approximately 20 to 30 feet out from the pre-existing asphalt. A 2007 survey revealed that this area contained a *Pinus contorta* / *Clintonia uniflora*–*Xerophyllum tenax* Forest (lodgepole pine/queencup beadlily–beargrass), *Larix occidentalis* / *Vaccinium membranaceum* / *Xerophyllum tenax* Forest (Western larch/black huckleberry/beargrass), and a *Pseudotsuga menziesii* / *Calamagrostis rubescens* Forest (Douglas-fir/pinegrass).

In the spring of 2008, prior to construction, the revegetation crew salvaged plants from the disturbance corridor and stored them in containers in the nursery where they were watered and cared for. Since the construction area contained a Montana Natural Heritage Program Species of Concern, *Vaccinium myrtilloides* (Velvetleaf Blueberry; G5, S2), this species was specifically targeted for salvage. *V. myrtilloides* is only known in Montana from several sites in the vicinity of West Glacier. Numerous other native plants were also extracted from the disturbance corridor and stored, including difficult to grow species such as black huckleberry (*Vaccinium membranaceum*), dwarf huckleberry (*Vaccinium caespitosum*) and grouse whortleberry (*Vaccinium scoparium*). Individual plants were mostly salvaged, but some mats of vegetation containing several species of vascular plants and mosses were extracted as well. Salvaged material was planted in the disturbance area adjacent to the entrance station in the fall of 2008. This area was also hand seeded after planting (see Table 5 for seed prescription). Additionally, the disturbed road corridor south of the planting site was mechanically hydroseeded in the fall of 2008.

In 2009, an employee room and restroom were constructed on the west side of the entrance station, on the opposite side of the road from the monitoring plots. During construction, the exit lane was closed. To accommodate incoming and outgoing traffic, much of which consisted of large construction vehicles, a new bypass lane needed to be temporarily created. The bypass lane needed to accommodate construction vehicles, which could not utilize existing lanes which had overhead restrictions. This new lane traversed some of the 2008 revegetation area. Plant material was subsequently salvaged again from this area, including many *Vaccinium myrtilloides* shrubs included in monitoring plots.

B. METHODS

Two salvage monitoring plots were installed in October 2008 and two hydroseed monitoring plots were installed in September 2009 (Figure 8). Plots of different sizes were installed to encompass most of the planted material in this narrow road corridor. Of the salvage monitoring plots, plot 1 measured 2m x 12m and plot 2 measured 3m x 17m. Of the hydroseed plots, plot 1 measured 2m x 12m and plot 2 measured 4m x 12m. GPS points were recorded at the upper left and lower right corners of each plot and permanent plot markers (12" nails) were placed at all four corners of each salvage plot and in the upper left and lower right corners of the hydroseeded plots.

Level II monitoring for revegetation plots included ocular estimates of canopy cover for all native and exotic species within the plot, as well as estimates of ground cover. Photographs were taken of each plot at each monitoring event. All *Vaccinium myrtilloides* plants in each salvage plot were flagged with a pin flag and tagged with a pre-numbered metal tag, so that survival of individual plants could be monitored. Tags were slightly buried in the soil so as to be less visible in this high traffic area. Additionally, three photomonitoring sites were established in 2009 to document progress of hydroseeding throughout the project (Table 6).

Plots had subsequently been monitored for progress in 2009, 2010, 2011 and 2013. In July 2018, salvage and hydroseeded plots were monitored, at 9/10 years after planting and seeding, respectively. Photomonitoring also occurred at this time. Ocular covers of all species in all plots were recorded (Tables 9, 10). Originally, special note was taken to determine if plant material was salvaged or naturally occurring to assess the success of each in the salvage plots. However, by 2010, it was difficult to distinguish the origin of many of the plants, and thus categories were often merged. *Vaccinium myrtilloides* in the salvage plots were assessed for health, and height and width were measured.

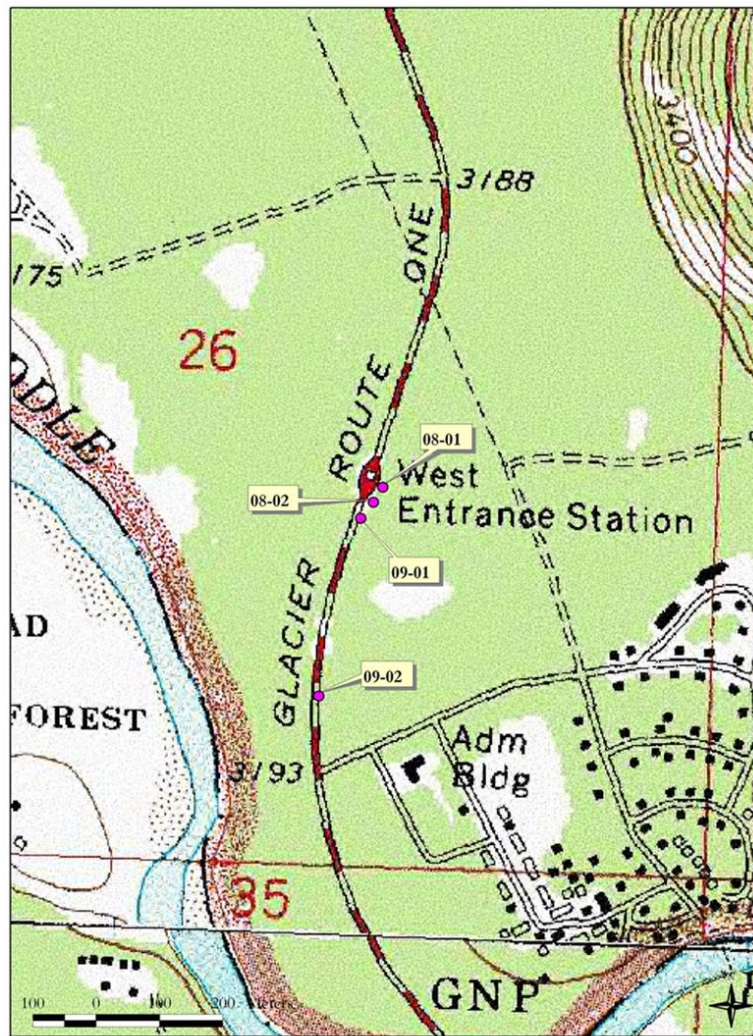
Table 5. West Entrance Station: Seed Prescription, Fall 2008. (Approx. 3 acre)

Forbs/Shrubs	Collection #	Grams of seed	Seeds/ft ²
<i>Achillea millefolium</i>	03-110, 02-135	11.2 g, 10.6 g	3 seed/ ft ²
<i>Aquilegia flavescens</i>	98-175	30.30 g	0.16 seed/ ft ² .
<i>Anaphalis margaritacea</i>	05-136, 9087364	30.55 g, 0.5 g	4 seed/ ft ²
<i>Antennaria</i> sp.	9087370	14 g	1.5 seed/ ft ²
<i>Arnica cordifolia</i>	05-022, 07-003	4.9 g, 40 g	0.16 seed/ ft ²
<i>Aster laevis</i>	03-118, 02-512	1 g, 86.46 g	2.1 seed/ ft ²
<i>Symphyotrichum laeve</i>	9081447	70 g	1.63 seed/ ft ²
<i>Aster</i> sp.	9087432	5 g	0.11 seed/ ft ²
<i>Campanula rotundifolia</i>	04-189	0.35 g	0.06 seed/ ft ²
<i>Eurybia conspicua</i>	9087433	300 g	6.9 seed/ ft ²
<i>Geum macrophyllum</i>	9087654	600 g	7.7 seed/ ft ²
<i>Heracleum maximum</i>	95-205	23.7 g	0.02 - old seed
<i>Iliamna rivularis</i>	06-089	600 g	1.3 seed/ ft ²
<i>Penstemon confertus</i>	06-090	21.66 g	0.97 seed/ ft ²
<i>Potentilla gracilis</i>	03-091	107 g	3 seed/ ft ²
<i>Rubus parviflorus</i>	07-041, 06-038	23.48 g, 25 g	17 seed/ ft ²
<i>Solidago canadensis</i>	04-192, 03-090	14 g, 88 g	10.5 seed/ ft ²
<i>Spiraea betulifolia</i>	9082154	5 g	0.10 seed/ ft ²
<i>Xerophyllum tenax</i>	03-029	269 g	0.98 seed/ ft ²
Grasses			
<i>Bromus carinatus</i>	9087805	655 g	1.3 seed/ ft ²
<i>Bromus marginatus</i>	9054510	49 g	0.10 seed/ ft ²
<i>Bromus vulgaris</i>	07-017	314 g	0.58 seed/ ft ²
<i>Calamagrostis rubescens</i>	00-022, 00-021	400 g, 550 g	42.4 seed/ ft ²
<i>Carex athrostachya</i>	04-297, 9081443	368 g, 704 g	40.27 seed/ft ²
<i>Carex deweyana</i>	05-074, 02-513	17 g, 44 g	0.10 seed/ ft ²
<i>Carex douglasii/deweyana</i>	9078646, 01-523	122 g, 33 g	0.30 seed/ ft ²
<i>Carex pachystachya</i>	03-513, 66-869 (2000), 9078645	291 g, 200 g, 1360 g	25.75 seed/ ft ²
<i>Elymus glaucus</i>	06-053	156.41 g	0.35 seed/ ft ²

Table 6. West Entrance Station: Photomonitoring Sites.

Site #	Photo	Description	Purpose
1	1: north	From Speed Limit 25 sign	to document downhill slope with hydroseed
	2: south		
2	1: south	From Overheight Vehicles sign	to document upslope and narrow ditch with hydroseed
	2: north		
3	1: north	From Right Lane Employees Only	to document planted beargrass salvage success
	2: south		to document hydroseed success

Figure 8. West Entrance Station: Location of Revegetation Monitoring Plots.



C. RESULTS

1. Salvage Plots

In general, revegetation has been successful in both salvage plots after ten years. Plot 1 is slower to recover partly due to recurring disturbance, including temporary bypass construction in the fall of 2009 and road construction in 2017-2018 that actually denuded an area at the north end of this plot. Overall vegetation cover continues to increase in both plots. Native cover in both plots has been steadily increasing, corresponding with a decrease in exotic cover (Figure 9). This trend has been less rapid in plot 1, however, likely due to recurring disturbance.

As seems to be a trend in several revegetation projects, shrub cover has increased and grass cover has decreased as the project approaches ten and twenty years after restoration (Figure 10, Table 9). In both plots, shrub cover has increased substantially over the past five years, while cover of native and exotic grass lifeforms have mostly declined. In 2011, grasses, both native and exotic, dominated both plots. While native grasses still dominate plot 1, there has been a shift in dominant grass species from temporary nurse grasses to more long-term species. Shrubs now dominate plot 2 and may outcompete many grasses in the future. Shrub cover has increased considerably in plot 1 as well but increases are less, probably due to continued disturbance.

Exotic species cover declined in both plots over the past five years. Due to the proximity of the entrance station to headquarters, it is likely targeted for herbicide treatment often and there was a decline in both cover and

number of exotic forb species in both plots. Exotic grass cover also declined in both plots, which is not always the case in many revegetation projects. This is potentially due to the increase in shrubs which may be outcompeting exotic grasses in these areas.

Salvaged material has had mixed success. Several shrub species, such as *Spiraea betulifolia* and *Symphoricarpos albus*, have been slow to take off but are beginning to establish after 10 years. Other salvaged species have declined, disappeared, or persisted with low covers.

Figure 9. West Entrance Station: Native vs. Exotic Cover in Salvage Plots, 2008-2018.

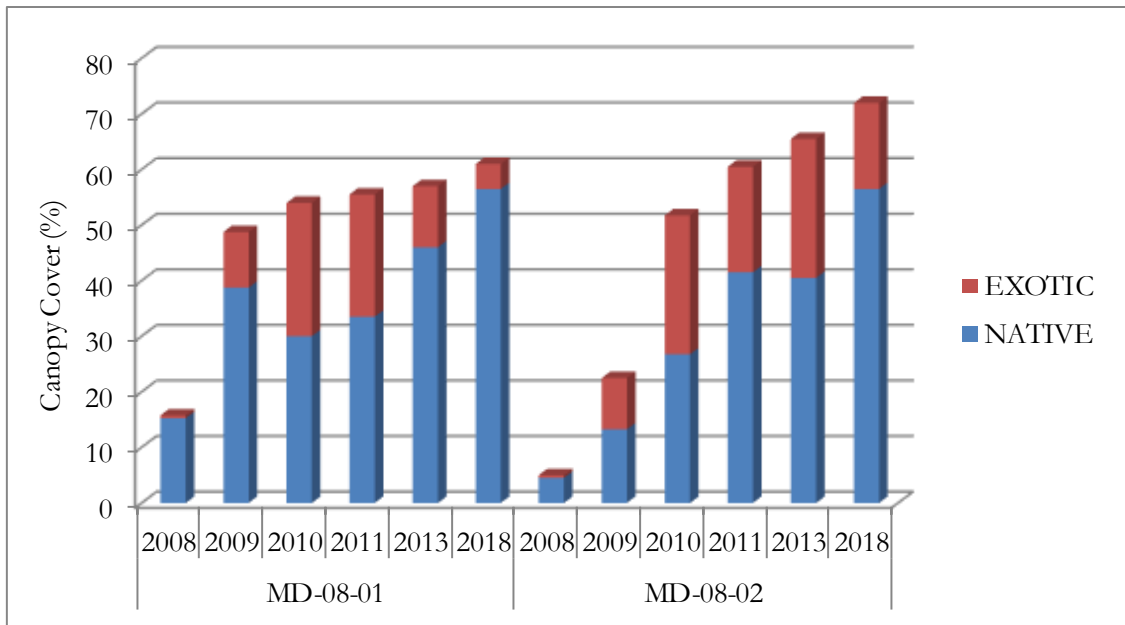
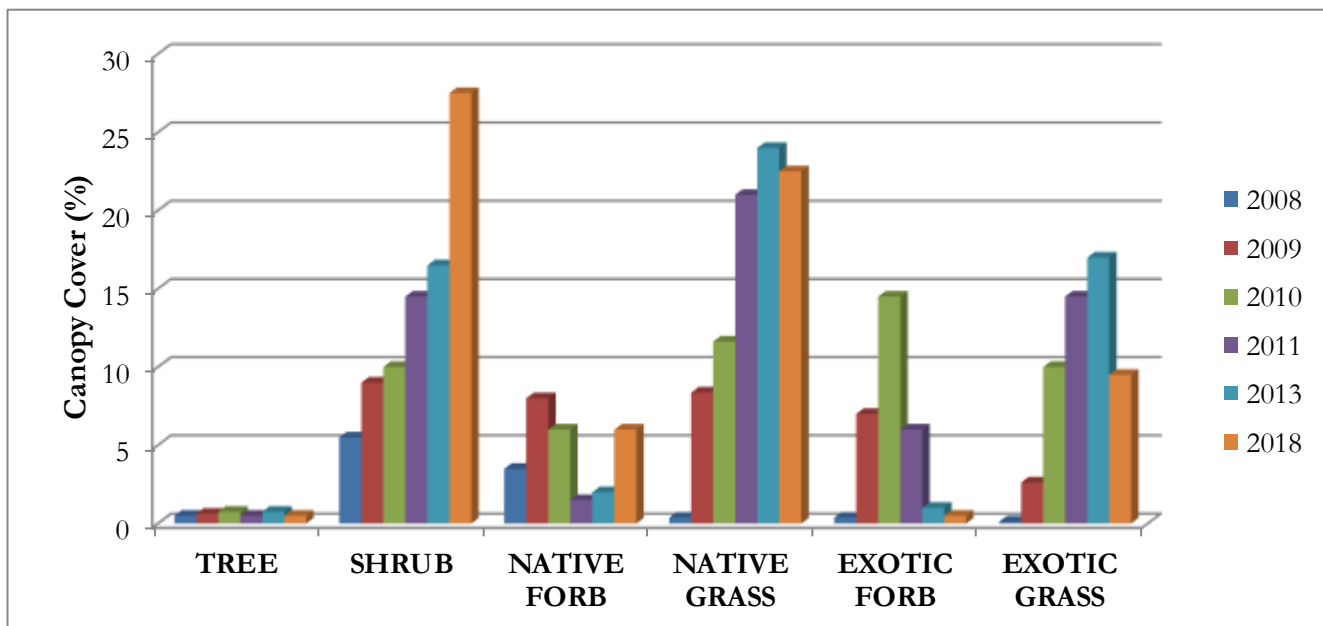


Figure 10. West Entrance Station: Average Cover by Life Form on Salvage Plots, 2008-2018.



1a. Trees and Shrubs:

Tree cover remains very low on both plots with only trace cover (Figure 10, Table 9). Each plot lost two species of trees. *Abies lasiocarpa* was present in both plots with trace cover in 2013 and disappeared from both plots. Additionally, *Populus balsamifera* disappeared from plot 1 and *Pinus monticola* was lost from plot 2. Only two tree species remain on each plot with trace cover.

Shrub cover has increased in both plots, especially in undisturbed plot 2 (Figure 10, Table 9). In plot 1, shrub cover increased from 8% to 15% with the largest increases coming from salvaged *Spiraea betulifolia*, which increased by 3%, and *Symphoricarpos albus*, which increased by 2%. Most species remain relatively stable in this plot, although *Mahonia repens* was lost. In plot 2, shrub cover increased from 25% to 40%. The largest increases in shrub cover in plot 2 also came from salvaged *S. betulifolia*, which increased by 6%, and *Symphoricarpos albus*, which increased by 8%. Additionally, *Amelanchier alnifolia* cover rose from trace to 3% in this plot. *Chimaphila umbellata* was lost from this plot, while *Shepherdia canadensis* was newly observed. Most other species remained stable with trace cover. Shrub diversity has dropped in both plots. Plot 1, which currently contains 8 shrub species, initially had 12 species. Plot 2 currently has 12 shrub species, only down one species from the time of revegetation.

In 2009, construction of the temporary bypass lane forced the removal of several *Vaccinium myrtilloides* shrubs from plot 1 that had been transplanted the previous fall. These plants were moved outside the plot and therefore subjected to a second transplant (one of these shrubs was relocated into plot 2). After notable declines in cover in 2010, *V. myrtilloides* is no longer present in plot 1 and remains with only trace cover in plot 2 where no shrubs were removed. Only 2 shrubs remain of the 44 shrubs that were transplanted. Surviving shrubs do not appear to be thriving, as they are both smaller overall than these individuals were in 2013. Looking at average sizes of all shrubs is a bit deceiving, as many of the shrubs alive in 2013 were smaller and have now perished (Table 7, Figure 11). Both of the remaining shrubs were given a “5” or “good” for health (Table 8), although #23 was given a 5 -.

Figure 11. West Entrance Station: Height and Width of *Vaccinium myrtilloides* shrubs, 2009-2018.

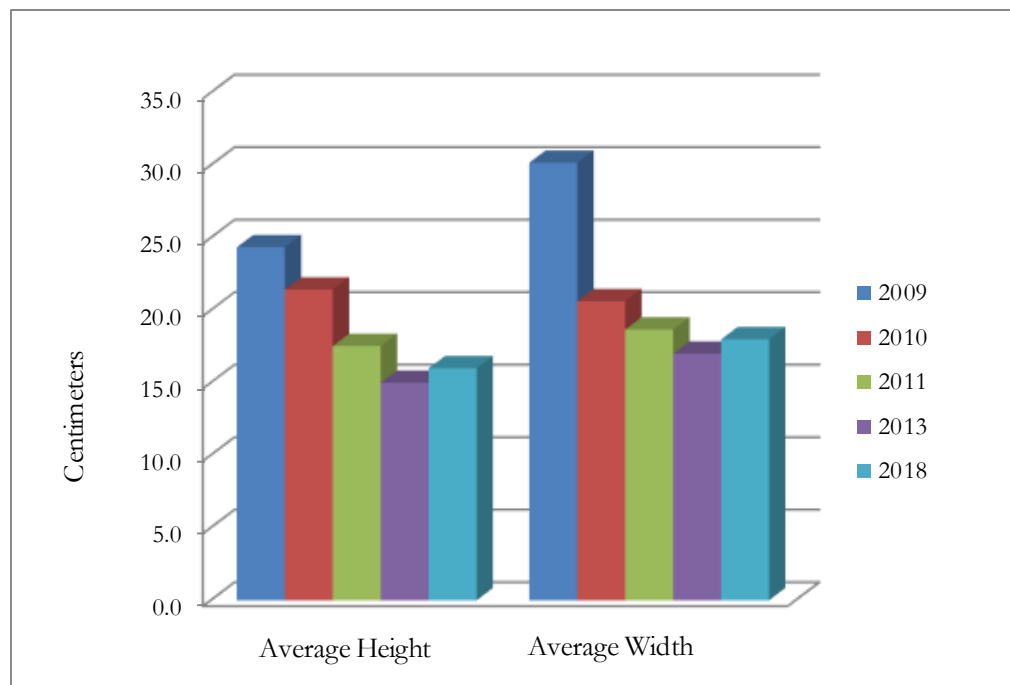


Table 7. West Entrance Station: Change in Average Plant Size of *Vaccinium myrtilloides*, 2009-2018.

Plot# MD-08-01	Health					Height					Width				
Tag #	2009	2010	2011	2013	2018	2009	2010	2011	2013	2018	2009	2010	2011	2013	2018
1	5	4	3	1	1	30	28	24	-	-	33	27	25	-	-
2	4	4	4	4	2	38	15	13	7	-	42	10	9	8	-
3	5	4	4	4	2	28	31	30	24	-	20	24	21	20	-
4	5	4	3	4	2	34	15	15	20	-	30	14	10	10	-
5	5	4	4	4	2	20	22	19	22	-	30	33	23	22	-
6	5	3	1	1	1	19	18	-	-	-	23	11	-	-	-
7	4	3	1	1	1	37	26	-	-	-	34	20	-	-	-
8	3	4	2	2	2	17	26	-	-	-	35	16	-	-	-
9	4	4-	2	2	2	30	24	-	-	-	22	22	-	-	-
10	5	4	4-	2	2	34	30	19	-	-	30	23	20	-	-
Plot# MD-08-01	Health					Height					Width				
Tag #	2009	2010	2011	2013	2018	2009	2010	2011	2013	2018	2009	2010	2011	2013	2018
11	3	4	4-	2	2	17	25	22	-	-	25	32	22	-	-
12	1	1	2	2	2	-	-	-	-	-	-	-	-	-	-
13	3	1	2	2	2	25	-	-	-	-	29	-	-	-	-
14	3	1	2	2	2	17	-	-	-	-	22	-	-	-	-
15	1	1	2	2	2	-	-	-	-	-	-	-	-	-	-
16	1	1	2	2	2	-	-	-	-	-	-	-	-	-	-
17	3	1	2	2	2	21	-	-	-	-	25	-	-	-	-
18	3	2	2	2	2	11	-	-	-	-	26	-	-	-	-
19	3	1	2	2	2	8	-	-	-	-	11	-	-	-	-
20	1	1	2	2	2	-	-	-	-	-	-	-	-	-	-
21	2	1	2	1	1	-	-	-	-	-	-	-	-	-	-
22	3	4	2	2	2	28	16	-	-	-	35	10	-	-	-
23	5-	4	5-	5	5	12	18	16	9	18	22	21	28	21	9
24	4	4	4	5	2	42	42	28	21	-	45	36	7	13	-
25	5	3	2	2	2	29	20	-	-	-	34	14	-	-	-
26	3	1	2	2	2	31	-	-	-	-	52	-	-	-	-
27	3	1	2	2	2	14	-	-	-	-	44	-	-	-	-
28	5	5	4-	2	2	20	17	13	-	-	40	22	12	-	-
29	5-	2	2	2	2	23	-	-	-	-	17	-	-	-	-
30	4-	4	5	5	5	36	26	17	14	14	38	37	30	38	27
31	5-	4	4	2	2	20	17	19	-	-	24	14	20	-	-
32	3	4	4	4	2	32	9	8	9	-	42	13	14	12	-
33	5-	4	4	5	2	13	8	7	9	-	12	15	12	9	-
34	?	5	4	1	1	20	17	13	-	-	33	19	27	-	-

Health: 1 = dead; 2 = missing; 3 = almost dead; 4 = fair; 5 = good.
Height and width measurement in centimeters

Table 8. West Entrance Station: Survival of *Vaccinium myrtilloides* and summary of health rank, 2009-2018.

Year	# survived	# dead/missing	% survival	5	4	3	2	1
2009	29	5	85%	13	5	11	1	4
2010	21	13	62%	2	16	3	2	11
2011	15	19	44%	2	11	2	17	2
2013	9	25	26%	4	5	0	20	5
2018	2	32	6%	2	0	0	0	0

Health: 1 = dead; 2 = missing; 3 = almost dead; 4 = fair; 5 = good.

1b. Native Grasses:

Native grass cover has been relatively stable over the past five years in salvage plots (Figure 10, Table 9). Each plot has slightly differently trends, however. Overall native grass cover decreased by 3% in plot 1, from 35% to 32%, while remaining stable at 13% in plot 2. This lifeform remains the dominant class in plot 1, which has been the case for the past nine years. Native grasses have never dominated plot 2 and have declined from their apex in 2011 as shrubs began to proliferate.

Most native grass species have remained relatively stable (within 1% cover) with the exception of a few species. *Bromus carinatus* declined in both plots; from 3% to trace cover in plot 1 and from 6% to trace cover in plot 2. This is not surprising as this species often acts as a nurse grass, establishing early, providing cover while other species establish, and then declining. *Calamagrostis rubescens* notably increased in both plots. This species was both salvaged and seeded. It was slow to establish but by 2018, ten years after revegetation, it has begun to flourish. Cover increased from 2% to 12% in plot 1 and from trace to 6% in plot 2 over the past five years. Other notable changes in species cover include the disappearance of *Elymus trachycaulus* ssp. *trachycaulus* from plot 1, when it had 6% cover five years previously. *Festuca occidentalis* declined by 3% in plot 1 but increased by 1% in plot 2, resulting in no clear trend. Regardless of trend, it still remains the dominant grass species and most prolific species overall in plot 1 and co-dominates native grass cover with *C. rubescens* in plot 2. While much of this plant material was originally seeded or was salvaged, *F. occidentalis* also may be encroaching from the adjacent forest.

Some seeded grasses are not performing as well, however. *Elymus glaucus*, another common nurse grass, has never had more than trace cover in either plot, although it persists in both plots. Seeded sedges also continue to show little success in these plots, still with only trace cover ten years after revegetation. Sedges have proven to be highly successful revegetation species in other projects, so should not fail to be considered in planning for future projects.

1c. Native Forbs:

Native forb cover appears to be establishing very slowly. Cover is increasing, although remaining relatively low on both plots (Figure 10, Table 9). The 7% increase in plot 1 is mostly due to *Penstemon confertus* cover increasing by 5%. *Xerophyllum tenax*, a slow to establish and slow growing species, is finally beginning to take hold. Previous projects have shown that this species finally begins to provide some notable cover after about 20 years. Recruitment of *Maianthemum stellatum*, which now has 1% cover, has helped to offset the disappearance of four other species. The only other species present with more than trace cover is *Symphytotrichum leave* with 1% cover. With continued herbicide treatment, this species may have a difficult time persisting. Native forb cover in Plot 2 has increased only slightly with small increases in *X. tenax* and *P. confertus*. Both of these species should be somewhat resistant to herbicide, which should aid in future success as well. Herbicide treatment may have played a role keeping native forb cover low overall, especially certain species in the Aster family.

1d. Exotic Forbs:

Exotic forb cover continued to decline in both plots. After reaching an apex in 2010 with about 15% cover, it now has only trace cover in both plots (Figure 10, Table 9). Diversity has also decreased in both plots; from 10 to 4 species in plot 1 and from 6 to 3 species in plot 2. The only remaining exotic forb species in plot 1 is *Plantago major*, while *Plantago lanceolata*, *Prunella vulgaris* and *Veronica officinalis* remain in plot 2, each with just trace cover. Although it is not considered noxious in the state of Montana, *V. officinalis* can be aggressive. Areas within West Glacier and Apgar harbor high population levels of this invasive plant which can thrive in shady conditions under the forest canopy. So far this has not been the trend in this project, where this species actually disappeared from plot 1 and only remains with trace cover in plot 2.

Many of the species which have had high covers in the past are species of clover. Clover species tend to be cyclical in their population trends, especially during wet springs, a possible explanation of their increase during 2010. All of these species have now disappeared from these plots.

Only two species of noxious weeds have been observed in this project; *Chrysanthemum leucanthemum* and *Cirsium arvense*. Neither species remains in 2018, likely due to diligent herbicide application.

1e. Exotic Grasses:

Interestingly, exotic grass cover has actually declined in both plots over the past five years, which is highly unusual (Figure 10, Table 9). Once established, exotic grasses usually continue to increase and dominate areas. Exotic

grass cover was on an increasing trend as of the last monitoring event, specifically with increases of aggressive rhizomatous grasses such as *Elymus repens* and *Agrostis stolonifera*. *Agrostis stolonifera*, however, has declined in both plots over the past 5 years to just 1% cover. *Elymus repens* also decreased from 20% to 14% in plot 2, but rose slightly in plot 1 from 1 to 3%. A possible explanation for the overall decline of exotic grasses is the increase in shrub cover, which could outcompete these species. Additionally, the disturbance and denuding of areas in plot 1 could have obliterated some species in this area.

One last positive note is that the diversity of exotic grasses continues to decline in plot 1 from 4 species to 2 species. The number of exotic grass species in plot 2 remained stable at 5.

2. Hydroseed Plots

Vegetation cover on hydroseed plots continued its “roller coaster” trend since being seeded (Figure 12). In 2018, 10 years after hydroseeding, overall vegetation has again decreased in both plots. Overall native cover has dropped substantially as well, especially in plot 2. Exotic cover has also increased dramatically, mostly due to a large increase in exotic grasses. Native grasses showed an inverse relationship with exotic grasses, which responded with a drop in cover, while shrubs are beginning to establish and proliferate (Figure 13, Table 10). Results for individual lifeforms are discussed below.

Figure 12. West Entrance Hydroseeded Plots: Percent Cover of Native and Exotic Species, 2009-2018.

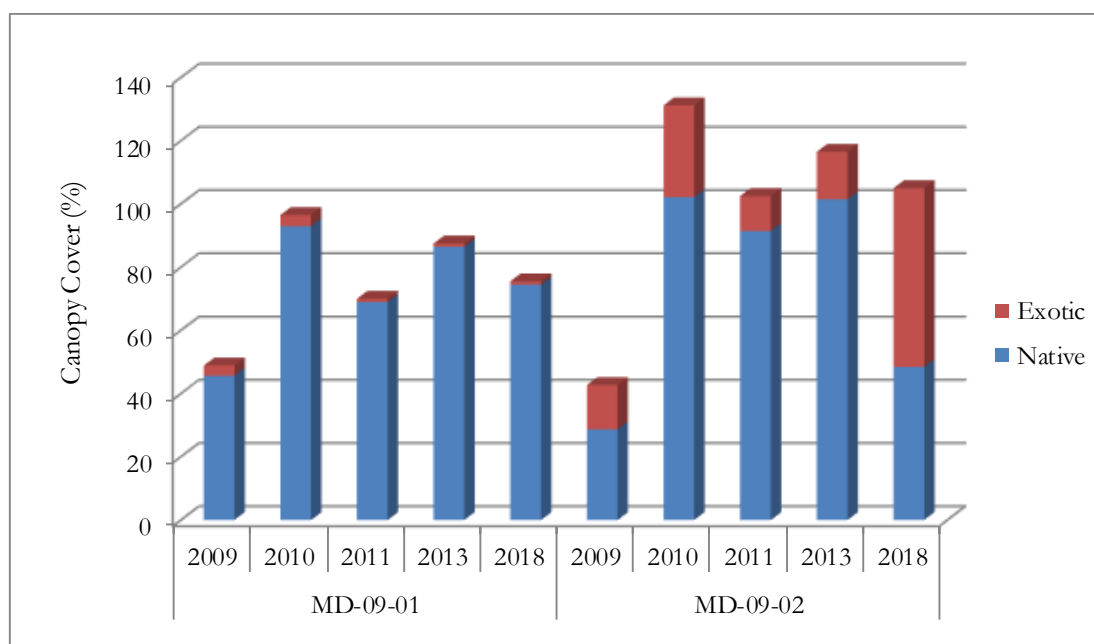


Figure 13. West Entrance Hydroseeded Plots: Average Cover of Life Forms, 2009-2018.

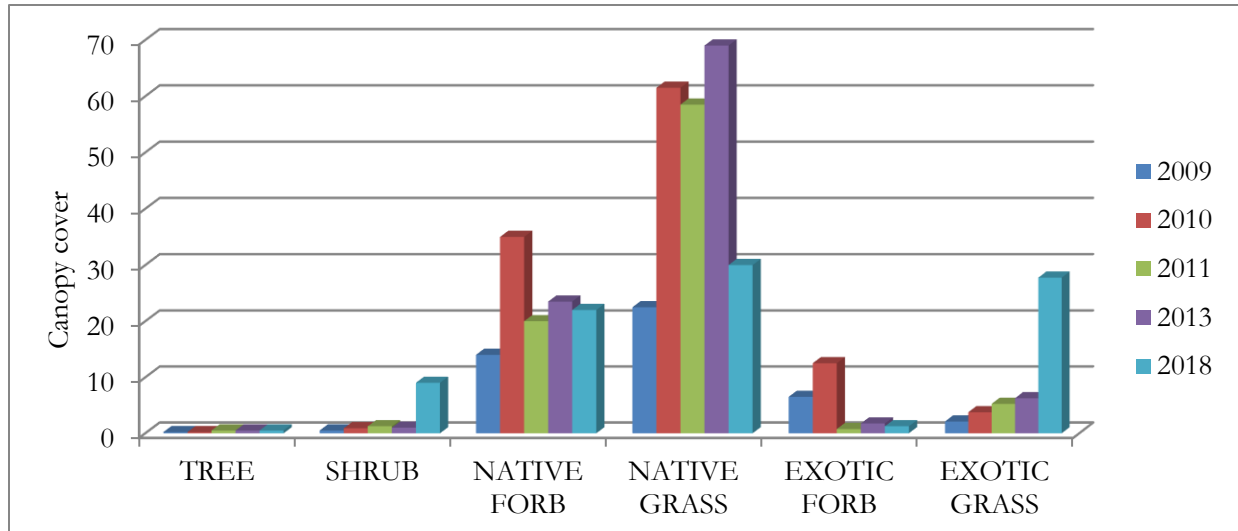
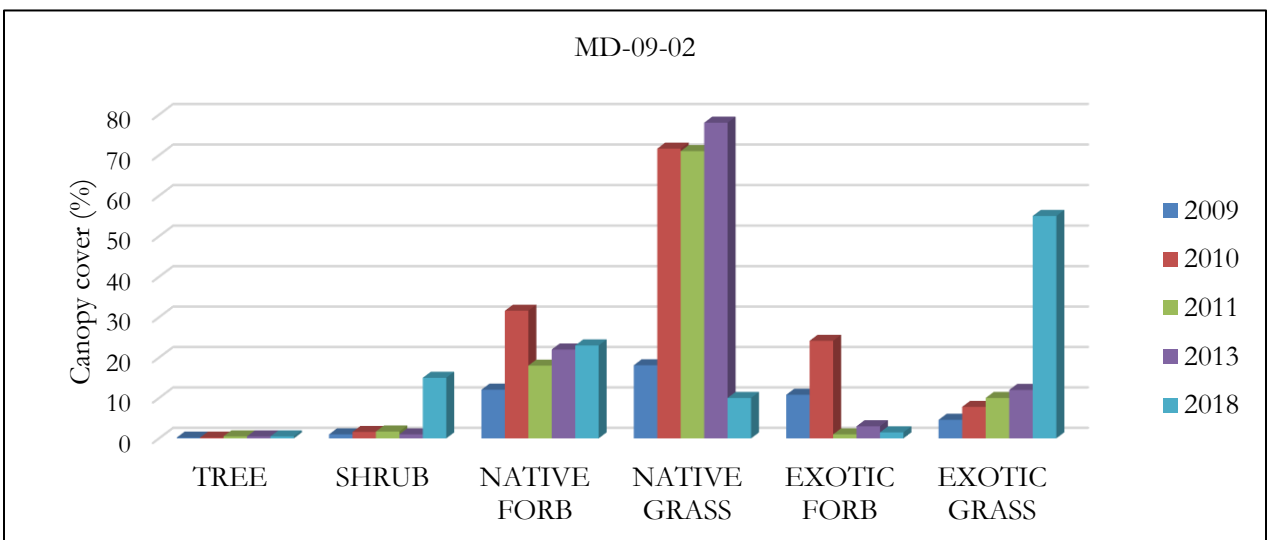
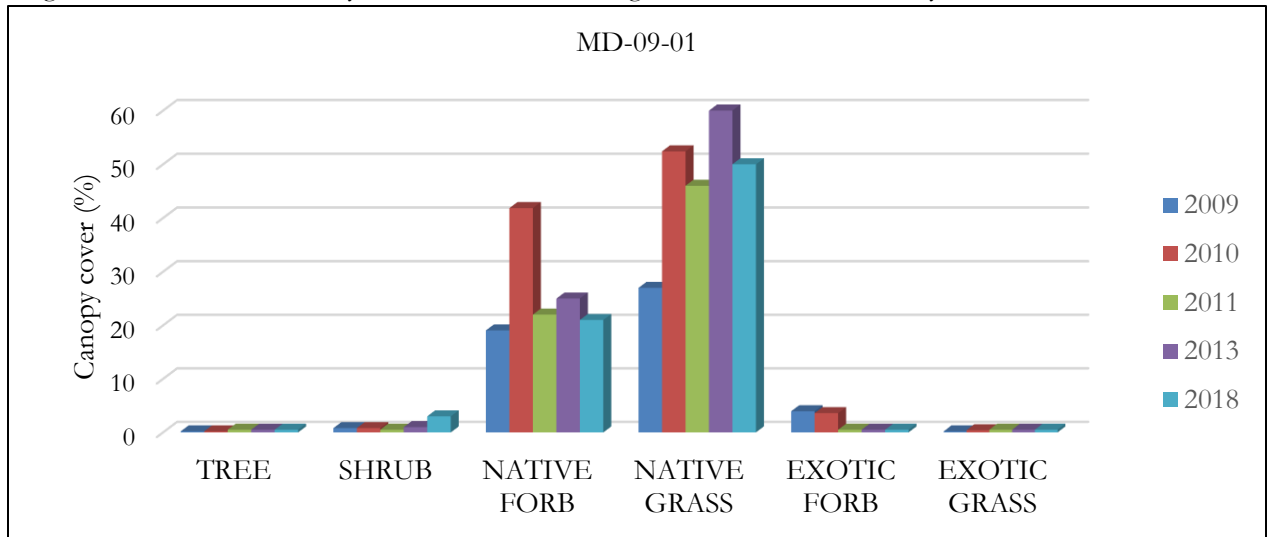


Figure 14. West Entrance Hydroseeded Plots: Average Cover of Life Forms, By Plot, 2009-2018.



2a. Trees and Shrubs:

Cover of trees, all of which are naturally regenerating, continued to be negligible in 2018 with just trace cover of all species (Figure 13, Table 10). Shrubs, however, are finally beginning to increase. The two hydroseeded species, *Spiraea betulifolia* and *Rubus parviflorus*, are beginning to increase in most cases. *Spiraea betulifolia* increased on both plots by 2 or 3% after only having trace cover in 2013. *Rubus parviflorus* disappeared from plot 1 in 2011 but has increased from trace to 2% cover in plot 2. It seems that seeded shrubs may take a while to establish, but once established, can contribute measurable cover and potentially compete with exotic species in the future. While shrub cover remains relatively low in plot 1, it has increased slightly (from trace to 2%) and several new species have recruited to the plot. Shrub cover in plot 2, however, has increased from 1% to 15% (Figure 14). Regenerating *Symphoricarpos albus* was responsible for most of this increase, which now has 10% cover after only being found with trace cover five years previously.

2b. Native Grasses:

Native grasses dominated both plots in 2013, and although they have declined overall in both plots over the past five years, they continue to have the highest cover of any lifeform in plot 1 (Figures 13 & 14, Table 10). Native grass cover decreased dramatically in plot 2, however, from 78% to 10%, and exotic grasses now dominate that plot. Several species decreased substantially in both plots. Seeded *Carex* species had the most notable declines, decreasing in cover from 40% to 5% in plot 2 and from 20% to 10% in plot 1. It is unknown why this species has not been successful in this project, as it has been effective in other projects. *Elymus glaucus* cover dropped from 35% to 1% in plot 2 and from 10% to 4% in plot 1. This is a common trend seen in other projects that this nurse grass species establishes quickly and subsequently declines as it does not compete well with dense vegetation. *Festuca idahoensis* also declined from 5% to trace cover in plot 2.

Exceptions to this trend were found in a few species. Seeded *Calamagrostis rubescens*, which increased dramatically between 2011 and 2013, increased again by 5% in plot 1 and now has the highest cover of all native grasses at 35%. As seen in seeded shrubs, it takes some time for seeded pinegrass to establish. Several other projects have also demonstrated that this species can increase over time from seed if it is able to get established and does not get outcompeted early on. Its success appears to be variable, however. In plot 2, seeded pinegrass established well the first year after seeding with 8% cover, but declined thereafter and is no longer present in that plot. Regenerating *Festuca idahoensis* is slowly increasing in plot 1 from trace to 1% cover but increased from 0% to 4% cover over the past five years.

2c. Native Forbs:

Hydroseeding appears to have initiated an early spike in native forb establishment, followed by a decline and variable changes thereafter. On both plots, native forb cover peaked in 2010 at 30%-40%, two years after hydroseeding (Figures 13 & 14, Table 10). Cover decreased fairly substantially the following year in both plots to 18%-22%. Since then, each plot has responded slightly differently, although changes have been small. In plot 1, native forb cover increased slightly again in 2013, followed by another small decline in 2018. Plot 2 has seen small incremental increases since 2011. Currently, native forb cover is 21% in plot 1 and 23% in plot 2.

Some consistent changes in individual native forb species have occurred in both plots. Several seeded species have declined to only trace cover or disappeared since establishing well early on. *Geum macrophyllum* established very well in both plots, reaching 23% cover in plot 2 in 2010 and 12% cover in plot 1 that year. Since then, this plant decreased to only trace cover in plot 2 and disappeared completely from plot 1. *Anaphalis margaritacea* has declined to only trace cover in both plots after reaching 6% cover in 2013 in both plots. Mowing these road shoulder areas may be detrimental, as plants may not be able to reproduce or withstand disturbance. Herbicide application likely also impacts both native and exotic forbs, each of which have seen declines at times.

A few species are showing positive trends. *Penstemon confertus*, which was hydroseeded, has slowly increased in both plots to 8% and 3% by 2018. This species is less vulnerable to herbicide application. In plot 2, *Solidago canadensis*, another hydroseeded species, has increased considerably in the past several years to 17% cover in 2018. This species, being in the aster family, may be more susceptible to the negative effects of herbicide, however. *Symphytotrichum laeve* is contributing 9% cover to plot 1 and 2% cover to plot 2, steadily increasing in both plots.

Other seeded species are not contributing as significantly. A few seeded species are persisting with low covers, including *Achillea millefolium*, which peaked at 18% cover in 2010 but has subsequently declined to trace cover, *Antennaria howellii*, *Arnica cordifolia*, *Eurybia conspicua* and *Potentilla gracilis*. To date, seeded species *Aquilegia flavescens*, *Campanula rotundifolia*, *Heracleum maximum*, and *Xerophyllum tenax* have not yet been observed on either plot. *Iliamna rivularis* was found with trace cover in plot 2 in 2013 but has subsequently disappeared.

The native forb diversity on plot 2 increased from 9 species in 2013 to 12 species in 2018, while the native forb diversity on plot 1 decreased slightly since 2013 with 11 native forb species, down one since 2013. Native forbs remain the most significant component of plot cover except for grasses.

2d. Exotic Forbs:

Exotic forbs have had low cover since 2010, likely due to a combination of herbicide application and the cyclical decline of species of clover (Figure 13, Table 10). All species since 2010 have remained at trace levels or disappeared with the exception of the noxious weed species *Hypericum perforatum*, which currently has remained at 1% cover in plot 2 since 2013. *Cynoglossum officinale*, another noxious weed species, has recently recruited to this plot and *Veronica serpyllifolia* has reappeared in this plot in 2018, although both species have only trace cover. *Veronica officinalis* was the only exotic forb species found in plot 1 in 2018 with trace cover. Plot 2 has 7 exotic forb species, up one from 2013, with 1% overall cover. Herbicide treatment and competition from denser native vegetation are likely causes for keeping exotic cover under control.

Three noxious weed species, specifically *H. perforatum*, *C. officinale* and *Leucanthemum vulgare*, were found in hydroseed plots this year, all Priority 2B noxious weeds in the state of Montana. *Cirsium arvense*, present in 2010, has not been observed since then. Continued herbicide application should help to keep these species at bay.

2e. Exotic Grasses:

After remaining relatively low for the past ten years, exotic grasses are increasing and pose a serious threat to the success of hydroseeded plots in this project (Figures 13 & 14, Table 10). Although exotic grass continues to only have trace cover in plot 1, diversity has increased from 2 to 5 species present since 2013. In plot 2, however, exotic grass cover has increased greatly. In 2013, only 12% exotic grass cover was observed; by 2018, this has increased to 55%. Additionally, diversity in this plot has increased from 7 to 8 species. *Elymus repens* has been the species with the highest impact, increasing from trace to 45% cover over the past five years. *Poa pratensis* has also increased in this plot from 5% to 10% in the past five years. Interestingly, several exotic grass species actually declined in cover, which is not usually observed. *Agrostis stolonifera* decreased from 5% to trace cover in plot 2, while *Phleum pratense* dropped from 2% to 1% cover in the same plot. It was earlier thought that exotic grasses would not be able to dominate these roadsides due to the high cover of native species. This presumed that the native cover would remain intact, but there was a fair amount of decline in native grasses to open up new habitat for aggressive exotic grasses.

D. CONCLUSIONS AND RECOMMENDATIONS

Differences between the development of hydroseeded and salvaged plots continue to be found ten years after planting and seeding. In many ways, the two treatments have responded in an opposite pattern from each other. Over the past five years, overall vegetative cover and native cover increased in salvage plots, while they decreased in hydroseeded plots. Exotic grasses declined in salvage plots, while they dramatically increased in one of the hydroseeded plots. Similarities among treatments do exist, however, and include shrubs beginning to establish well with increased covers, decreased native grass cover, and continued low exotic forb cover in both salvage and hydroseeded plots.

The most striking change over the past five years may be in the decline of native grasses in hydroseeded plots, where this lifeform appeared successful early on. The success of nurse grasses and *Carex* species contributed most to initial high cover, but these species subsequently diminished by 2018. It is understandable that nurse grasses such as *Elymus glaucus* and *Bromus carinatus* have declined over time, but it is surprising that seeded *Carex* species decreased substantially over the past five years. Seeded sedges never established extremely well in salvage plots, but were the dominant species in hydroseeded plots in 2010. All plots in both treatments have seen declines in both sedge and

nurse grasses. Despite these declines, all of these grasses have proven to provide excellent cover in various projects. Nurse grasses should continue to be used as colonizers before exotic species get established and sedge species should continue to be seeded, as they have been quite successful long term in other projects. Other native species may take advantage of open areas left behind when nurse grasses decline, such as *Festuca occidentalis* and *Calamagrostis rubescens* have in this project. While it is now difficult to distinguish between salvaged and seeded *C. rubescens* material at this point, this species has done very well in hydroseeded plots. Pinegrass usually does not do well seeded under competitive scenarios, so data supporting a successful seeding regime of this species is extremely helpful, as this is a very common grass species in surrounding forests and would be an excellent roadside revegetation species.

Other species also took advantage of open ground left behind mostly by declining native grasses. Particularly in one hydroseeded plot, exotic grasses proliferated under these circumstances. Understandably, existing aggressive, rhizomatous grasses are often able to quickly colonize open space. Oddly enough, this was not the case in other plots where native shrubs and forbs increased. Exotic grass cover actually decreased in both salvage plots, which is highly unusual.

Other seeded material has had varied results across the project. Several seeded species had stellar initial cover, but have plummeted after ten years. These include *Geum macrophyllum*, *Anaphalis margaritacea* and *Achillea millefolium*. The best longer-term results of seeded forbs have been from *Penstemon confertus*, which increased in all plots, and *Solidago canadensis* and *Symphytotrichum laeve*, although these have not increased consistently across all plots. Seeded shrubs are finally beginning to establish in hydroseeded plots. *Spiraea betulifolia* is finally starting to increase in both plots as is *Rubus parviflorus* in the plot where it remains.

It is difficult to attribute the low overall success of seeded species to a specific cause. Disturbance may have played a role in the lack of success of salvaged plots, as this area was impacted by the formation of the temporary bypass lane and continued subsequent disturbances. Seeded species in these plots may not have been able to establish or were disturbed early after germination. Hydroseeded areas experienced higher success for seeded species, especially initially. Hydroseeded areas were provided with light mulch, which may have aided in water retention and thus better germination and survival. Additionally, seeding methods and timing differed between treatments.

Shrub establishment has been successful in all plots. This success is a mixture between regenerating species, especially *Symphoricarpos albus*, the seeded shrub species mentioned above, as well as several salvaged species that are increasing in cover fairly quickly. *Spiraea betulifolia* and *Symphoricarpos albus* currently show the most success of the transplanted shrubs. Many other salvaged species are consistently increasing in cover, including *Arctostaphylos uva-ursi*, *Amelanchier alnifolia* and *Vaccinium membranaceum*. Transplanting appears to be an effective method where shrub cover is desired and the material for transplanting exists, and shrub cover may prove to be the long-term savior of this project. Future monitoring can help determine which species ultimately are the most successful.

Transplanting *Vaccinium myrtilloides* has not proved to be very successful in this project. Only two of the original 44 plants monitored persisted ten years later. Stress from the second transplantation event may have been the final setback to their survival and success. Transplanting this sensitive species, particularly onto a sunny roadside area, does not appear to be a good restoration strategy.

Both exotic and native forbs were likely altered by herbicide treatments. A few species of native forbs appear to be affected negatively by herbicide, although not consistently across members of the Aster family as might be expected with herbicides that target this family. Exotic forbs appeared to be most affected in both types of plots, showing a benefit of herbicide application, with decreases in both cover and diversity in most cases. Noxious weed cover is also being kept to low amounts with herbicide application although a few species were still observed in 2018, including *Cynoglossum officinale*, *Leucanthemum vulgare* and *Hypericum perforatum*.

Rhizomatous weedy grasses, such as *Elymus repens*, *Agrostis stolonifera*, *Phleum pratense*, and *Poa pratensis*, pose the biggest threat to the overall success of this project, since there is no effective way to control them at this time. Noxious weeds have been continuously controlled along roadsides but a few exotic forbs still pose threats to the project. *Veronica officinalis*, a member of the Scrophulariaceae family, is not affected by most herbicides. Although this species is not thriving in these restoration areas, it has been particularly aggressive in the Headquarters/Apgar area and is shade tolerant as well. *Hypericum perforatum* is an increasingly problematic noxious weed species that also does not respond to the commonly used roadside herbicides.

This project should be monitored next in 2028 at year 20 after planting.

Table 9. West Entrance Station: Percent Cover for all Species in Salvage Plots, 2008-2018.

		MD-08-01						MD-08-02					
GROUND COVER		2008	2009	2010	2011	2013	2018	2008	2009	2010	2011	2013	2018
Basal vegetation		3	5		5	5	5	2	4		5		5
Litter/Duff		30	34		15	20	35	35	34		50		55
Moss			0		0	0	0		0		0		1
Bare Soil		62	20		8	2	15	57	50		5		10
Gravel			30		71	73	44		10		46		25
Rock		5	1		1	1	1	5	1		3		3
Wood			0		0	0	0	1	1		1		1
TOTAL TREE	source	1	1-	1	T	1	T	0	T	T+	T	T	T
<i>Abies lasiocarpa</i>	?	T	T	T	T	T				T		T	
<i>Betula papyrifera</i>	salvage	T											
<i>Picea engelmannii</i>	salvage	1 (1 tree)	T+	T	T	T	T			T			
<i>Pinus contorta</i>	regen										T	T	T
<i>Pinus monticola</i>	salvage	T (1 tree)	T-	T (1 tree)	T	T	T			T	T	T	
<i>Populus balsamifera</i>	natural	T	T			T		hanging over					
<i>Pseudotsuga menziesii</i>	natural	hanging over						hanging over	T	T	T	T (sdlg)	T
<i>unknown conifer seedlings</i>			T						T				
# of Tree Species Present		6	5	3	3	4	2	2	2	4	3	4	2
TOTAL SHRUB	source	9	9	7	7	8	15	2	9	13	22	25	40
<i>Arctostaphylos uva-ursi</i>	salvage	2-	2-	1	1	T	T	T	T+	T	T	T	2-
<i>Alnus viridis</i>	?		T+										
<i>Amelanchier alnifolia</i>	salvage	1-	T	T	1	T	1-	T	T	T	1	T	3
<i>Chimophila umbellata</i>	regen										T	T	
<i>Mahonia repens</i>	salvage	T	T		T	T		T	T	T	T	T	T
<i>Paxistima myrsinites</i>	salvage	T	T					T		T	T	T	T
<i>Prunus virginiana</i>				T									
<i>Rubus parviflorus</i>	seeded		T (1 plant)						T	T	T		
<i>Rosa acicularis</i>	salvage	T								T	T		
<i>Rosa woodsii</i>	salvage	1-	1	1	1	T	1-	T	2-	3	5	6	5
<i>Shepherdia canadensis</i>	natural			T									T
<i>Spiraea betulifolia</i>	salvage	1-	2+	2+	3	5	8	T	4-	5	6	8	14
<i>Symphoricarpos albus</i>	salvage	1-	1+	1+	1	1	3	T	2-	5	8	10	18
<i>Vaccinium caespitosum</i>	salvage	T+	T	T	T	T	T+	T	T	T	T	T	T
<i>Vaccinium membranaceum</i>	salvage	1-	1-	T	T	1	2	T	T	T	T	T	T
<i>Vaccinium myrtilloides</i>	salvage	2	1+	0 (moved)				2-	1+	T	T	T	T
<i>Vaccinium myrtilloides</i>	natural							T					
<i>Vaccinium myrtilillus</i>	natural	T+	T+	T	T	T	T	T	T	T	T	T	T
<i>Unknown</i>								T					
<i>Vaccinium myrtilloides</i> # of plants	salvage	10	10	0 (moved)	0	0	0	24	20	12 *	8	5	2
# of Shrub Species Present		12	13	11	9	9	8	13	11	13	14	12	12

Table 9 con't. West Entrance Station: Percent Cover for all Species in Salvage Plots, 2008-2018.

		MD-08-01						MD-08-02					
		2008	2009	2010	2011	2013	2018	2008	2009	2010	2011	2013	2018
NATIVE FORB	source	5	14	5	1	2	9	2	2	7	2	2	3
<i>Achillea millefolium</i>	salvage	T	T	1		T	T	T	T+	3	T	1	1+
<i>Achillea millefolium</i>	seeded		4+						T+				
<i>Anaphalis margaritacea</i>	seeded		T	T	T	T			T		T		
<i>Antennaria bonellii</i>	seeded		T	T									
<i>Arenaria serpyllifolia</i>	regen		T	T					T	1+			
<i>Cardamine pensylvanica</i>	regen			T									
<i>Chamerion angustifolium</i>	regen		T	T						T			
<i>Chimaphila umbellata</i>	salvage	T	T					T	dead	T			
<i>Clintonia uniflora</i>	regen			T					T				
<i>Epilobium brachycarpum</i>	regen		T	T					T	T	T		
<i>Fragaria vesca</i>	salvage	1-	1+	1	T	T		T	1-	2	T	T	
<i>Fragaria virginiana</i>	regen		2+	T	T	T	T		T	T	T	T	T
<i>Galium triflorum</i>	regen								T	T			
<i>Geum macrophyllum</i>	seeded		1	T	T	T			T	T	T	T	
<i>Gnaphalium palustre</i>	regen		T								T		
<i>Gnaphalium macounii</i>	salvage	T			T					T?			
<i>Linnaea borealis</i>	salvage	2-	3-	T		T		1	1-	1-	T	T	T
<i>Maianthemum racemosum</i>	regen			T	T					T	T		T
<i>Maianthemum stellatum</i>	regen		T	T	T		1		T	T	T		T
<i>Orthillia secunda</i> (?)	regen										T	T	
<i>Penstemon confertus</i>	regen			T	T	T	5					T	1-
<i>Polygonum douglasii</i>	regen			T									
<i>Potentilla gracilis</i>	seeded			T						T			
<i>Solidago canadensis</i>	seeded		2	T	T	T	T			T		T	T
<i>Symphyotrichum leave</i>	seeded		T	T		T	1-				T	T	T
<i>Vicia americana</i>	regen		T	T					T				
<i>Viola orbiculata</i>	salvage			T	T			T	T-				
<i>Xerophyllum tenax</i>	salvage	1	T+(some dying)	1	1	1+	2	1	T	T	T+	T	1-
<i>Xerophyllum tenax</i>	natural	1						T	T				
# of Native Forb Species Present		6	17	22	11	10	7	6	16	16	13	10	9
NATIVE GRASS	source	T	15	17	25	35	32	T	2-	6+	17	13	13
<i>Agrostis scabra</i>					T	T					T		T
<i>Bromus carinatus</i>	seeded		7	6	6	3	T		1+	4	15	6	T+
<i>Calamagrostis rubescens</i>	seeded	T	1	1		2	12	T	1	1	T	T	6
<i>Calamagrostis rubescens</i>	salvage		2-										
<i>Carex concinnoides</i>	salvage	T	1-	T				T	T				
<i>Carex rossii</i>	regen			T		T	T			T		T	T
<i>Carex</i> sp. (<i>cramfordii</i> , others)	seeded		3	T	2	1			T	T	T	T	
<i>Danthonia intermedia</i>	regen		T		1	T	T		T				
<i>Elymus glaucus</i>	seeded		T		T	T	T		T				T

Table 9 con't. West Entrance Station: Percent Cover for all Species in Salvage Plots, 2008-2018.

		MD-08-01						MD-08-02					
		2008	2009	2010	2011	2013	2018	2008	2009	2010	2011	2013	2018
<i>Elymus trachycaulus ssp. trachycaulus</i>	?			5	4	6				T+	T	1	T
<i>Festuca occidentalis</i>	salvage	T	1+	5	9	23	20	T	T	1	2	5	6
<i>Oryzopsis asperifolia</i>	salvage	T	T	T				T	T				T
<i>Panicum capillare</i>	regen			T						T			
<i>Pseudoroegneria spicata</i>	regen				3						T		
Grass spp. (unknown)	?	T	T+					T					
# of Native Grass Species Present		7	9	10	8	9	6	7	9	8	7	6	8
EXOTIC FORB		T	8	14	10	1	T	T	6	15	2	1	T
<i>Amaranthus retroflexus</i>				T				T	T	T			
<i>Capsella bursa-pastoris</i>				T						T			
<i>Chenopodium album</i>										T			
<i>Cirsium arvense</i>				T									
<i>Cirsium vulgare</i>			T	T					T	T			
<i>Filago arvensis</i>			T-	T					T	T	T		
<i>Chrysanthemum leucanthemum</i>			1-	T	T	T (pulled)			T	T	T	T	
<i>Lactuca serriola</i>			T	T						T			
<i>Madia glomerata</i>			T	T									
<i>Matricaria matricarioides</i>										T			
<i>Melilotus alba</i>				T	T	T				1			
<i>Medicago lupulina</i>			6	7		T			T+	3	T		
<i>Melilotus officinale</i>			T	2	T	T				3		T	
<i>Plantago lanceolata</i>				T							T		T
<i>Plantago major</i>			1+	5	5	T	T		T	T	T	T	
<i>Potentilla argentea</i>			T	T				T	T	T	T		
<i>Potentilla norvegica</i>		T								T			
<i>Prunella vulgaris</i>			T	T	T	T				T	T	T	T
<i>Rumex acetosella</i>				T									
<i>Spergularia rubra</i>				T	T								
<i>Taraxacum officinale</i>			T	T	T	T				T	T		
<i>Trifolium agrarium</i>				T		T					T	T	
<i>Trifolium pratense</i>			T										
<i>Trifolium hybridum</i>				T					5	7			
<i>Verbascum thapsus</i>				T	T	T			T	T	T		

Table 9 con't. West Entrance Station: Percent Cover for all Species in Salvage Plots, 2008-2018.

		MD-08-01						MD-08-02					
		2008	2009	2010	2011	2013	2018	2008	2009	2010	2011	2013	2018
<i>Veronica officinalis</i>			T	T	T	T		T (pulled)	T	T	1	T+	T
<i>Veronica serpyllifolia</i>			T	T					T	T	T		
<i>Unknown Mustard</i>		T (pulled)	T	T					T	T			
<i>Unknown</i>			T						T				
# of Exotic Forb Species Present		4	17	25	9	10	1	5	14	22	12	6	3
EXOTIC GRASS		T	2	10	12	10	4	0	3+	10	17	24	15
<i>Agrsotis stolonifera</i>				2	5	9	1			T	1	2	1-
<i>Bromus inermis</i>										T	T		
<i>Dactylis glomerata</i>		T		T					T				
<i>Elymus repens</i>		T	1+	7	6	1	3		3+	10	15	20	14
<i>Phleum pratense</i>			T+	T	1	T				T	T	T	T
<i>Poa compressa</i>			T-	T		T				T	T+	1	T
<i>Poa pratensis</i>				T							1	T	T
# of Exotic Grass Species Present		2	3	6	3	4	2	0	2	5	6	5	5

* 2010: one *Vaccinium myrtilloides* transferred from plot 1 to plot 2; others from plot 1 moved outside of plot

Cells that are highlighted in lt. orange = merging of seeded, salvage and/or natural (cannot distinguish anymore)

Species names in red text are designated as Montana Noxious Weeds

Table 10. West Entrance Station: Percent Cover for all Species in Hydroseed Plots, 2008-2018.

GROUND COVER	Source	MD-09-01					MD-09-02				
		2009	2010	2011	2013	2018	2009	2010	2011	2013	2018
Basal vegetation		5		8	10	7	6	10		15	8
Litter/Duff		49		55	78	64	60	48		71	78
Moss		0		1	5	8	1	7		1	5
Bare Soil		20		2	1	5	10	22		1	5
Gravel		25		33	5	15	20	10		10	2
Rock		1		1	1	1	1	2		1	1
Wood		0		0	0	T	2	1		1	1
Other		0		0	0	0	0	0		0	0
TREE	Source	T	T	T	T	T	T	T	T	T	T
<i>Betula papyrifera</i>	regen			T	T				T	T	
<i>Larix occidentalis</i>	regen					T					
<i>Populus balsamifera</i>	regen					T				T	T
<i>Pseudotsuga menziesii</i>	regen		T	T	T			T			
Unknown conifer seedlings	regen	T					T			T	
# of tree species present		1	1	2	2	2	1	1	1	3	1
SHRUB	Source	T	T+	T	1	3	T	1	2	1	15
<i>Alnus viridus</i>	regen	T	T				T				
<i>Amelanchier alnifolia</i>	regen										T
<i>Arctostaphylos uva-ursi</i>	regen			T	T						
<i>Betula papyrifera</i>	regen						T				
<i>Mahonia repens</i>	regen					T					
<i>Paxistima myrsinites</i>	regen			T							
<i>Rosa acicularis</i>	regen				T	T	T	T	T		
<i>Rubus parviflorus</i>	seeded	T	T					T	T	T	2-
<i>Spiraea betulifolia</i>	seeded	T	T	T	T+	2-	T	T	T	T	3-
<i>Symphoricarpos albus</i>	regen	T	T			T	T	1	1+	T+	10
<i>Vaccinium caespitosum</i>	regen					T					
<i>Vaccinium membranaceum</i>	regen			T	T	1					
# of shrub species present		4	4	4	4	6	5	4	4	3	4
NATIVE FORB	Source	18	40	22	25	21	10	30	18	22	23
<i>Achillea millefolium</i>	seeded	8	18	3	T	T	1-	1	T	T	T
<i>Arenaria serpyllifolia</i>	regen						T				
<i>Aquilegia flavescens</i>	seeded										
<i>Anaphalis margaritacea</i>	seeded	1	5	5	6	T	T	1	2	6	T
<i>Antennaria bonellii</i>	seeded	T	T	T	T	T	T		T		
<i>Aralia nudicaulis</i>	regen						T	T			
<i>Arnica cordifolia</i>	seeded			T	T	T					T
<i>Campanula rotundifolia</i>	seeded										
<i>Castilleja miniata</i>					T	T					
<i>Chamerion angustifolium</i>	regen	1+	T				T	T	T		
<i>Cerastium arvense</i>	regen						T				
<i>Eurybia conspicua</i>	seeded				T	T				T	1

Table 10 con't. West Entrance Station: Percent Cover for all Species in Hydroseed Plots, 2008-2018.

		MD-09-01					MD-09-02				
		2009	2010	2011	2013	2018	2009	2010	2011	2013	2018
<i>Epilobium brachycarpum</i>	regen	T	T	T			T	T			
<i>Equisetum arvense</i>	regen						1	T	T	T	T
<i>Fragaria vesca</i>	regen	T									
<i>Fragaria virginiana</i>	regen	T	T	T			T	T			
<i>Geum macrophyllum</i>	seeded	6	12	12	3		6+	23	15	5	T
<i>Galium triflorum</i>	regen							T	T		
<i>Geranium bicknellii</i>	regen							T			
<i>Heracleum maximum</i>	seeded										
<i>Iliamna rivularis</i>	seeded									T	
<i>Osmorhiza berteroi</i>	regen						T		T		T
<i>Penstemon confertus</i>	seeded	T	T	T	4	8	T	T	T	1	3
<i>Potentilla gracilis</i>	seeded	T	T	T	T	T	T				T
<i>Potentilla sp. (pinnate)</i>	regen		T								
<i>Prosartes trachycarpa</i>	regen										T
<i>Solidago canadensis</i>	seeded	1	3	1	3	3	T	2	1-	8	17
<i>Symphyotrichum laeve</i>	seeded	T	1+	1	8	9	1+	3	T+	1	2
<i>Thalictrum occidentale</i>									T		
<i>Viola orbiculata</i>	regen	T	T	T			T				
<i>Xerophyllum tenax</i>	seeded										
<i>Xerophyllum tenax</i>	salvage										
<i>Xerophyllum tenax</i>	natural/regen	T	1		T	T	T				
# of native forb species present		14	14	12	12	11	18	14	12	9	12
NATIVE GRASS	Source	27	52	46	60	50	18	71	71	78	10
<i>Agrostis scabra</i>	regen						T	1	1	T	
<i>Bromus carinatus</i>	seeded	14	2	T	T	T	7	5	3	1	T
<i>Bromus marginatus</i>	seeded										
<i>Bromus vulgaris</i>	seeded			T							
<i>Calamagrostis rubescens</i>	seeded	3	10	8	30	35	8	2	T		
<i>Carex athrostachya</i>	seeded										
<i>Carex concinnoides</i>	regen		T					T			
<i>Carex deneyana/ douglassii</i>	seeded										
<i>Carex pachystachya</i>	seeded										
<i>Carex sp.</i>	seeded	6	25	25	20	10	1-	48	35	40	5
<i>Danthonia intermedia</i>	regen					T	T	T		T	
<i>Elymus glaucus</i>	seeded	3+	15	12	10	4	1-	10	30	35	1
<i>Festuca campestris</i>	regen							T			
<i>Festuca idahoensis</i>	regen				T	T	1	5	3	5	T
<i>Festuca occidentalis</i>	regen		T	T	T	1					4
<i>Hordeum jubatum</i>	regen								T		
<i>Oryzopsis asperifolia</i>	regen					T					
<i>Poa palustris</i>	regen	T+				T					T
<i>Pseudoroegneria spicata</i>	regen						T	T	T	T	T
# of native grass species present		5	6	6	6	9	8	10	8	7	7

Table 10 con't. West Entrance Station: Percent Cover for all Species in Hydroseed Plots, 2008-2018.

		MD-09-01					MD-09-02				
		2009	2010	2011	2013	2018	2009	2010	2011	2013	2018
EXOTIC FORB	Source	3	3	T	T	T	10	22	1	3	1+
<i>Artemisia absinthium</i>	regen	T									
<i>Capsella bursa-pastoris</i>	regen	T					T				
<i>Cirsium arvense</i>	regen							T			
<i>Cirsium vulgare</i>	regen							T			
<i>Cynoglossum officinale</i>	regen										T
<i>Galium aparine</i>	regen							T			
<i>Hypericum perforatum</i>	regen						T	1	T+	1	1
<i>Filago arvensis</i>	regen	T						T			
<i>Lactuca serriola</i>	regen	T						T			
<i>Leucanthemum vulgare</i>	regen						T	T	T	T	T
<i>Medicago lupulina</i>	regen	T	T	T			3	T			
<i>Melilotus officinalis</i>	regen		T					20	T		
<i>Melilotus sp.</i>	regen						3				
<i>Plantago lanceolata</i>	regen						T	T	T	1	T
<i>Plantago major</i>	regen						1-	T			
<i>Taraxacum officinale</i>	regen						T	T	T	T	T
<i>Trifolium agrarium</i>	regen		3		T						
<i>Trifolium sp.</i>	regen	T					T				
<i>Verbascum thapsus</i>	regen	3-	T	T	T		3	1-	T	T	T
<i>Veronica officinalis</i>	regen					T	T	T	T	1	
<i>Veronica serpyllifolia</i>	regen						T	T	T		T
unknown	regen				T		T				
# of exotic forb species present		7	4	2	3	1	13	15	8	6	7
EXOTIC GRASS	Source	T	T	T	T	T	4	7	10	12	55
<i>Agrostis stolonifera</i>	regen			T	T	T		3	3	5	T
<i>Bromus inermis?</i>	regen						T				
<i>Bromus tectorum</i>	regen	T (pulled)									
<i>Dactylis glomerata</i>	regen					T	1	T		T	T
<i>Elymus repens</i>	regen								T	T	45
<i>Festuca arundinacea</i>	regen								T	T	T
<i>Phleum pratense</i>	regen					T	3	4	2	2	1
<i>Poa compressa</i>	regen		T	T	T	T	T	T	T	T	T
<i>Poa pratensis</i>	regen		T			T			5	5	10
<i>Setaria viridis</i>	regen										T
unknown	?						T				
# of exotic grass species present		1	2	2	2	5	5	5	6	7	8

Species names in **red** text are designated as Montana Noxious Weeds

IV. CAMAS CREEK ROAD ROADSIDE REVEGETATION

A. BACKGROUND AND PURPOSE

Camas Creek Road (Route 11) is an 11.66-mile long roadway between the North Fork Flathead River Road and the West Entrance Station Road intersection. Rehabilitation of this road, originally built in the 1960s, took place during 1997 when 7.1 miles of the western-most portion of the road underwent improved pavement structure including a three-inch overlay. The remaining 4.5 miles of road are slated to be completed when funding is secured.

Rehabilitation of the Camas Road generally did not impact the vegetation along the road shoulder. Instead, areas requiring revegetation included turnouts that were modified or obliterated, reconstructed vistas, an improved intersection at Apgar, and improved trailhead parking areas. In total, 1.5 acres required replanting at thirteen locations along the 7.1 miles of road.

Prior to restoration efforts, 12 site analyses were conducted at 10 sites on the Camas Road in 1994 and 1995 (Asebrook et. al. 1995). These plots documented the pre-disturbance condition of the roadside and parking areas prior to construction and provided baseline data to guide the selection of plant material for revegetation (Tables 12, 13, 14). Areas that were sampled included turnouts #1, #2, #5, #7 and turnouts at Apgar Range, Camas Lookout, McGee meadow, and at the fire exhibit, as well as the Huckleberry Mountain Nature Trail and the Huckleberry Lookout Trailhead parking areas.

Revegetation began in the spring of 1998 when soil was salvaged from the new Huckleberry Lookout Trailhead parking area and transferred to the old parking area across the street. Approximately 600 plants were planted in the old parking lot at this time. Another 6,500 plants were installed in the fall of 1998 in the remaining disturbed areas and over 20kg of seed were sown in all revegetation units.

Monitoring the success of planted and seeded material took place in 2000, 2002, 2003, 2008 and 2018, years 2, 4, 5, 10 and 20 after planting, respectively. The purpose of monitoring the Camas Road is to document the success of seeded and planted material throughout the project. Monitoring aims to:

- (1) Determine the canopy cover of all native and exotic species in each monitoring plot;
- (2) Track the success of seeded and planted material through estimates of canopy cover and density;
- (3) Document the instances of soil erosion; and
- (4) Determine if specific revegetation goals and objectives are being met.

B. METHODS

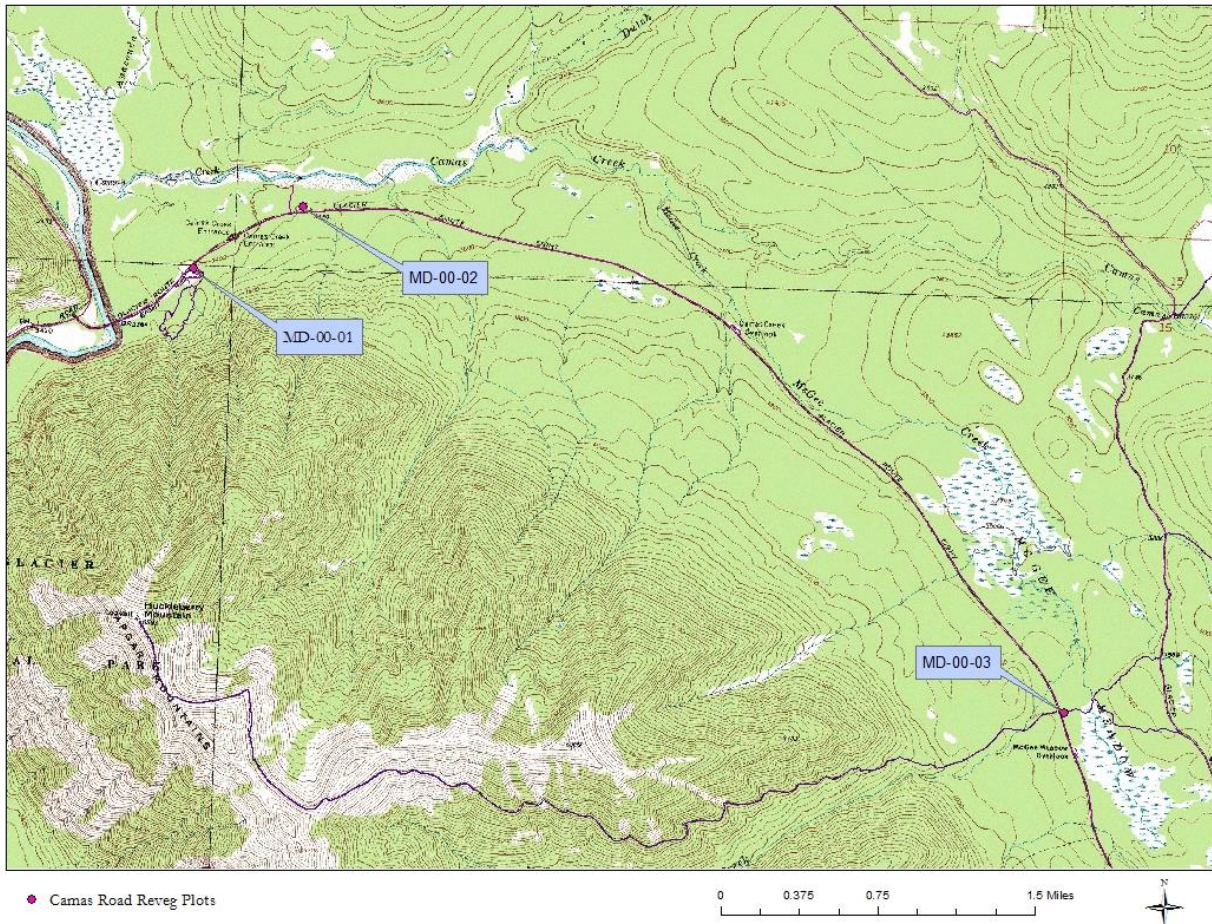
In 2000, three 100m² plots were established in three locations: (1) the Huckleberry Mountain Nature Trail parking island (renamed as the Forest and Fire Trail in the early 2000's); (2) the obliterated Turnout #1; and (3) the old Huckleberry Lookout Trailhead parking area (Figure 15). Based on the size of the revegetation area, the plots at the first two locations are 20m x 5m, while the plot at the Huckleberry Lookout Trailhead parking area is 14m x 7m. Level II monitoring was conducted on all plots in 2000, 2002, 2003, 2008 and 2018, encompassing ocular estimates of canopy cover for all native and exotic species.

Pre-disturbance photographs were taken of monitoring plots as well as of photopoints along the Camas Road determined in 1997. Plot photographs have subsequently been taken in 2000, 2002, 2003, 2008 and 2018. Post-restoration photographs along established roadside photopoints were also taken in 1998, 1999, 2000, 2002, 2008 and 2018.

C. RESULTS AND DISCUSSION

Plots were monitored on July 11 and 19, 2018, using Level II monitoring protocols. Canopy cover was determined for all species within the plot using ocular estimates. Photomonitoring of all plots and pre-determined photopoints along the Camas Road also took place at this time.

Figure 15. Camas Creek Road: Location of Revegetation Monitoring Plots.



1. Overall Results

2018 marks the twentieth year after revegetating this section of the Camas Creek Road. Results from each plot twenty years after restoration is varied. Each plot has responded differently and therefore will be discussed separately in the sections below. The most prominent life form trend across all plots from establishment to the present is an increase in shrub cover. Additionally, all plots have displayed at least a slight decrease in native grass cover from ten years ago to the present.

Fire has altered the environment in all three monitoring plots since their establishment. Plots 1 and 2 were burned in the Moose Fire of 2001. Monitoring results from 2002 to the present encompass fire effects in these plots. Plot 3 was burned in the Robert Fire of 2003 after monitoring had taken place. Fire initially reduced or eliminated tree cover. All trees originally in plots 1 and 2 were killed by fire and tree cover was reduced in plot 3 after burning. Some shrubs were also killed by fire in plot 2. Other lifeforms were not consistently affected by fire.

2. Native vs. Exotic Cover

For the first time since establishing monitoring plots, native cover is higher than exotic cover in all three plots (Table 11, Figure 16). Encouragingly, native cover has also increased at a faster rate than exotic cover in two of the three plots over the past 10 years. In plots 1 (Huckleberry Nature Trail; now the Forest and Fire Trail) and plot 3 (across from the Huckleberry Lookout Parking Area), native cover has increased by 18% and 37%, respectively, since 2008. Native cover remained essentially stable in plot 2 (obliterated Turnout #1, near the old shooting range). Much of the observed escalation has been due to flourishing shrub species. In plot 1, *Arctostaphylos uva-ursi* increased substantially while a number of shrub species cumulatively increased in plot 3, including *Spiraea betulifolia*, *Rosa woodsia*

and *Salix drummondiana*. Native forbs also contributed to the native proliferation in this plot, particularly *Fragaria virginiana*.

Exotic species also increased but less substantially than native cover. Plots 1 and 3 have had relatively high exotic cover since the beginning of monitoring. In 2000, two years after restoration, these plots already consisted of 21% and 45% exotic cover, respectively. In 2018, twenty years after restoration, exotic cover has risen to 47% and 63%, respectively, in these plots. This increase was mostly due to increases of exotic grasses. Once exotic species have established in an area, it is difficult to prevent their return after restoration, especially along transportation corridors. Site analysis data from 1995 indicate that roadsides along this restoration corridor had high weed cover prior to restoration (Asebrook et. al, 1995). Exotic seed likely remained in the seedbank and has had a detrimental effect on restoration efforts in this area. This trend was not observed in plot 2 which has maintained a lower exotic cover. Exotic plant cover has actually decreased since the beginning of the project from 11% in 2000 to 5% in 2018. This plot has low overall vegetative cover, however, and appears scoured for unknown reasons. Cover of all lifeforms was low on this plot and all lifeforms decreased in cover in the past 20 years with the exception of shrubs, which increased slightly. If disturbance does not continue, exotic grasses have the potential to take advantage of the open habitat and increase in the future in this plot as well, since several invasive and rhizomatous exotic grass species are present in this plot.

Table 11. Camas Creek Road: Overall Native and Exotic cover (%) by Plot, 2000 - 2018.

	MD-00-01					MD-00-02					MD-00-03				
	2000	2002	2003	2008	2018	2000	2002	2003	2008	2018	2000	2002	2003	2008	2018
Native Cover	32%	33%	26%	30%	48%	15%	10%	9%	24%	23%	20%	20%	19%	36%	73%
Exotic Cover	21%	17%	20%	42%	47%	11%	4%	14%	10%	5%	45%	61%	43%	53%	63%

S:\VegUnit\CAMAS\Camas Rd Reveg\Camas2018.xlsx (Table tab)

3. Lifeform Results

While results were not consistent among plots, results in the two plots that were not recently disturbed show fairly substantial increases in tree, shrub, native forb and exotic grass cover. Native grass cover decreased in all three plots.

Initially, exotic grasses were listed as the biggest threat to the success of restoration on this project. Exotic grasses continue to be the dominant life form in two of the three plots, although cover has risen slowly over the past 10 years.

Shrub cover has continuously increased in all three plots since 2003, increasing quite substantially in two of the three plots. Tree cover also increased substantially one plot and slightly in another plot over the past 10 years. Woody plant material may be strong competitors to the high exotic grass cover in this project.

Results pertaining to vegetative cover by plot are illustrated in Table 15 and Figure 16. Seeded and planted species in this project area are included in Tables 16 and 17.

3a. Trees

In plot 3, across from the Huckleberry Lookout trail, tree cover has increased substantially from 5% in 2008 to 24% in 2018 (Table 15, Figure 17). The largest increase in this plot was from *Pinus contorta* which increased from 2% to 16% during this timeframe. Two to four percent increases in cover were also seen in *Picea engelmannii*, *Populus balsamifera* and *Pseudotsuga menziesii*. This plot burned in the 2003 Robert Fire which did not kill most trees and surviving trees have flourished in the subsequent years. Fast-growing tree species, such as *P. contorta*, may be instrumental in restoring this area to more closely resemble the surrounding area.

Tree cover remains relatively low in the remaining two plots at 2% and 1% in plots 1 and 2, respectively. The Moose Fire killed all trees in plots 1 and 2 in 2001. After no new tree recruitment in these plots in 2002, *Populus balsamifera* has established in both plots but remains at low cover (2% and 1% cover, respectively). It is uncertain why *P. balsamifera*, another fast-growing species, has not flourished in these two plots since the burn. It would be advantageous to restoration if these species would establish more readily in these plots.

3b. Shrubs

The single common trend across all plots is an increase in shrub cover by 19% in plot 1, 4% in plot 2, and 11% in plot 3 (Table 15, Figure 17). Shrub cover has continuously increased in all three plots since 2003, particularly in plots 1 and 3, to where shrubs consist of 46% and 48% cover in each plot, respectively.

This common trend in increasing shrub cover is where the similarity ends. Most of the increase in cover in plot 1 is due to *Arctostaphylos uva-ursi* which increased by 16%. In plot 3, this species actually declined by 3%, however. *Symphoricarpos albus* and *Alnus viridis* accounted for most of the increase in shrub cover in plot 2 by 1% to 3% for each species. *Spiraea betulifolia*, *Rosa woodsia* and *Salix drummondiana* showed the biggest increases in plot 3, each increasing between 2 and 6%.

Continued increases in woody cover may help inhibit exotics from taking over the project area.

3c. Native Grass

Native grass cover declined in all three plots over the course of the past 10 years. Cover decreased in plot 1 from 9% to 2%, in plot 2 from 15% to 12%, and in plot 3 from 5% to 1% (Table 15, Figure 17). No species exhibited dramatic changes in cover but cumulative small decreases in most native grass species accounted for the overall decline. The only increase in cover came from *Festuca idahoensis* in plot 2 which only rose from 2% to 3%. *Koeleria macrantha* consistently declined in all plots from 1 to 5% in each plot and disappeared from plot 3 where it had only 1% cover in 2008. *Bromus carinatus* has disappeared from all plots after declining in all plots since year one. Often this species is planted as a nurse grass to germinate quickly and compete with exotics while other native grasses establish. *Elymus glaucus*, also a nurse grass, has also disappeared from two plots and declined to trace cover in plot 3, the only plot in which it remains.

3d. Native Forbs

Native forb cover increased in the two non-disturbed plots (1 & 3) by 5% and 11%, respectively, while it decreased slightly in plot 2, the scoured plot, by 3% (Table 15, Figure 17). Again, there were few consistencies in species trends across plots. *Penstemon confertus* increased by 5% in both plots 1 and 3 and remained stable in plot 2. *Fragaria virginiana* showed a substantial increase in plot 3 from 1% to 10%, but actually slightly declined in the other two plots. Other small changes were found in a few species; *Potentilla gracilis* increased by 2% in plot 1 and *Symphyotrichum laeve* (*Aster laevis*) decreased by 2% in plot 3. All other changes in cover were small (1% or less) and cumulatively accounted for overall changes in native forb cover. Most other native forbs are currently present with only trace cover.

Some decreases were observed in members of the Aster family, such as in *Achillea millefolium* and *S. laeve*, which may have declined due to herbicide application. The Camas Road is regularly sprayed with a boom, targeting non-native members of the Aster family such as spotted knapweed and oxeye daisy.

3e. Exotic Grass

In 2018, at year 20, exotic grass cover had increased in two of the three plots but not substantially over the course of the past 10 years (Table 15, Figure 17). Exotic grasses continue to be the dominant life form in two of the three plots with 46% cover in plot 1 and 48% cover in plot 3. This only represents a 6% and 3% increase in cover since 2008, however. Plot 2, at obliterated turn out #1, actually showed a decline in exotic grass cover from 7% to 3%. Every life form except shrubs decreased in this plot, however, and it appears to be scoured. Exotic grasses continue to be the main concern on this project, as they are nearly impossible to control.

Different species are dominant and are responsible for causing the overall increase in each plot with rhizomatous grasses proving to be the most prolific. *Elymus repens* has been dominant and was responsible for the increase in plot 1 from 40% to 46% in the last 10 years. No other exotic grass species have more than trace cover in this plot. In plot 3, *Bromus inermis* continued to dominate, increasing from 30% to 35%. *Phleum pratense* showed a small (2%) increase, while *Poa pratensis* actually decreased in cover by 4%. *Elymus repens* increased slightly in plot 3 to only

1% cover, but may prove detrimental in the future as it is aggressive rhizomatous grass. In plot 2, slight decreases in *Bromus tectorum*, *E. repens* and the disappearance of 1% of *P. pratensis* accounted for the overall decrease in exotic grasses. Again, this plot showed signs of scouring which resulted in lower cover in almost all life forms.

3f. Exotic Forbs

Exotic forb cover reacted differently across plots, decreasing slightly in plots 1 and 2 and increasing in plot 3 (Table 15, Figure 16). The reduction in exotic forb cover in the first two plots may be due to diligent herbicide application, as sprayed weeds were observed in the area, as well as cyclical life cycles of plants such as *Trifolium* species. Exotic forb cover remains low in both of these plots (1% and 2%, respectively). Meanwhile, exotic forb cover jumped from 8% to 15% in plot 3. Species that can be controlled by herbicide increased in this plot in the past 10 years, including *Centaurea maculosa*, which increased by 9%, *Chrysanthemum leucanthemum*, which increased by 1%, and *Hieracium aurantiacum*, which increased by 1%. This data suggest that perhaps this area has not been treated with herbicide as recently.

Noxious weeds that were found in one or more plots include *Centaurea maculosa*, *Cirsium arvense*, *Chrysanthemum leucanthemum*, *Hieracium aurantiacum* and *Hypericum perforatum*.

D. CONCLUSIONS AND RECOMMENDATIONS

- **It may take longer than expected for revegetation projects to become successful:** At year ten, only one plot (plot 2) had higher native cover than exotic cover. Twenty years after revegetation, all plots have higher native cover than exotic cover. While exotic grass continues to dominate two of the three plots, the increase in woody material, particularly shrubs, has helped these areas to become more native and more closely approach the pre-disturbance condition.
- **The recovery of woody species is variable:** Woody material was lost in all plots in 2002 – 2003 due to fire. By 2018, shrubs have recovered in all plots but the rate of recovery and the species that are thriving are variable. Trees are slow to recover in two of the three plots, but trees are flourishing in plot 3. *Pinus contorta* is known to recover well after fire but never re-established in two of the three plots. This species is now the dominant tree in plot 3 and contributes to a good portion of the native cover. *Populus balsamifera* is slowly recruiting to plots 1 and 2 but covers have not increased much, if at all. The dominant shrub species is different in each plot despite the presence of the same species in other plots. This suggests that each site contains different variables that contribute to a single species' success, reiterates that there is not a "one size fits all" prescription for revegetation species, and confirms that a variety of woody species should be utilized in revegetation projects.
- **Shrubs may be important in defending against exotic species:** Shrub cover increased in all plots in the past ten years. Exotic grass also increased in two of the three plots but at a slower rate than shrubs increased. Exotic forbs decreased in two of the three plots as well. Shrubs create shade and ground cover that may over time be able to outcompete many non-native species or keep their covers low and should routinely be used in revegetation.
- **Native grasses may not thrive in certain restoration projects:** Nurse species, such as *Bromus carinatus* and *Elymus glaucus*, have declined or disappeared over time, as expected. The only nurse grass remaining is a trace of *E. glaucus* in plot 3. Native bunch graminoids, such as *Carex rossii*, *Danthonia intermedia*, *Festuca idahoensis*, and *Koeleria macrantha* have remained with low covers or even declined or disappeared. It appears that these species are not able to compete very well with rhizomatous exotic grasses and woody material. It is not recommended to stop using nurse grasses or bunch grasses in restoration, since often nurse grasses can act as place holders as native species establish, especially in more pristine areas. It is challenging to compete with exotic grasses in areas with high cover prior to restoration, however, especially rhizomatous species, and perhaps more effort should be placed on planting woody material in these areas.
- **Thriving native forbs are mostly not in the Aster family:** The species showing the largest increase in cover over the past ten years include *Fragaria virginiana*, *Penstemon confertus* and *Potentilla* species. These species have all proven

to be excellent revegetation species and appear to be more resistant to herbicide use than members of the Aster family, such as *Achillea millefolium* and *Symphyotrichum laeve* (*Aster laevis*). Additionally, species such as *F. virginiana* provide good ground cover as they are stoloniferous.

- **Herbicides should continue to be used to control exotic forbs in the area:** Weed spraying appears to be keeping noxious weeds at bay but they are slightly increasing on plot 3, which showed no evidence of recent herbicide application. *Centaurea maculosa* cover has increased to 10% in this plot. Four other noxious weed species, specifically *Cirsium arvense*, *Chrysanthemum leucanthemum*, *Hieracium aurantiacum* and *Hypericum perforatum*, are present across the project and have not increased in cover beyond 2%. In road corridors such as this, herbicides should continue to be used as vehicles provide a conduit for continued noxious weed invasion.
- **Scouring in plot 2 may allow for an increase in exotic species:** It is unknown why plot 2 appears to be scoured and vegetative cover has been reduced. This plot has much lower cover overall than in 2008. Approximately 60% of ground cover consisted of bare soil with 23% non-vascular cover. It seems that this area never quite recovered after being burned. Additionally, the past few summers have been extremely hot and dry, creating conditions for non-native species to proliferate. It is possible that this area may recover on its own, however, if shrubs and trees continue to grow and provide more shade and protection from invasion of exotic species.
- **Trend Monitoring:** Many concerns listed as threats in 2003 appear to be moving in a positive direction. Overall native cover is higher than exotic cover in all plots. Tree and shrub recruitment and growth have improved and show good potential. Exotic clover cover, listed as a potential threat after the fires, has declined. Little recruitment of new noxious weeds has been observed, although diligent herbicide application is necessary, especially with previous recruitment of some very aggressive species such as orange hawkweed. Exotic grasses, however, have increased dramatically and are the biggest threat to the project. These aggressive species often take over entire areas. It is uncertain if this project will continue to be monitored beyond year 20.

Table 12. Camas Creek Road: 1995 Site Analysis for Huckleberry Mt. Parking Area (Plot MD-00-01 Area).

Since only a strip of roadside was to be rehabilitated in this area, only a species list and their general covers were recorded. Along the edge of the parking lot, the vegetation is dominated by *Bromus inermis* (50% cover) and *Poa pratensis* (10-20% cover). The following species only had a trace to 1% cover:

Overstory trees:	<i>Betula papyrifera</i> , <i>Larix occidentalis</i> , <i>Picea engelmannii</i> , <i>Pinus contorta</i> , <i>Pseudotsuga menziesii</i>
Small trees:	<i>Populus tremuloides</i> , <i>Populus trichocarpa</i>
Native Shrubs:	<i>Salix</i> spp., <i>Spiraea betulifolia</i>
Native Forbs:	<i>Achillea millefolium</i> , <i>Antennaria microphylla</i> , <i>Epilobium angustifolium</i> , <i>Equisetum arvense</i> , <i>Fragaria virginiana</i> , <i>Penstemon procerus</i> , <i>Senecio pauperculus</i>
Native Grasses:	<i>Carex</i> spp.
Exotic Forbs:	<i>Cirsium</i> spp., <i>Prunella vulgaris</i> , <i>Taraxacum officinale</i>
Exotic Grasses:	<i>Phleum pratense</i>

Since the parking island had been continuously mowed, it was difficult to differentiate species, particularly grasses. Like the parking lot edge, it appears that the island is dominated by *Bromus inermis* and *Poa pratensis*. *Phleum pratense*, *Achillea millefolium*, *Taraxacum officinale*, and *Fragaria virginiana* comprised 1% of the island.

Figure 16. Camas Creek Road: Percent Cover of Native vs. Exotic Species by Plot, 2000-2018.

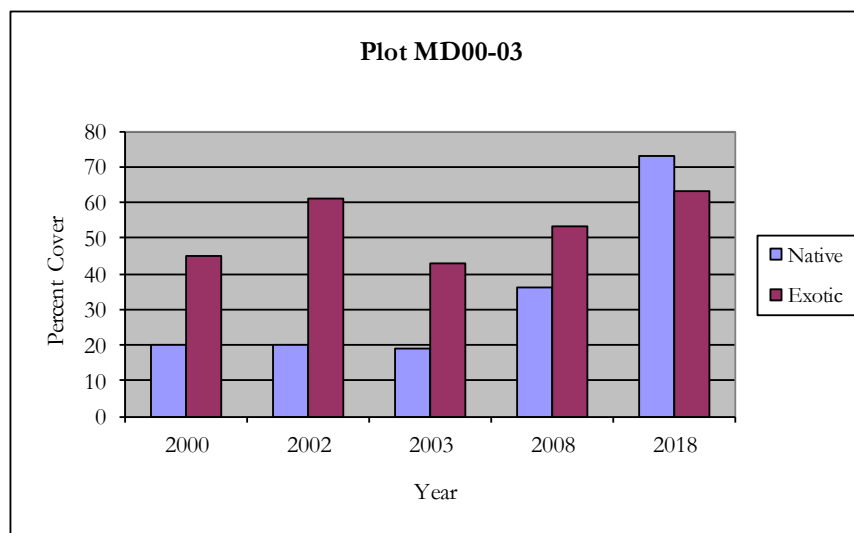
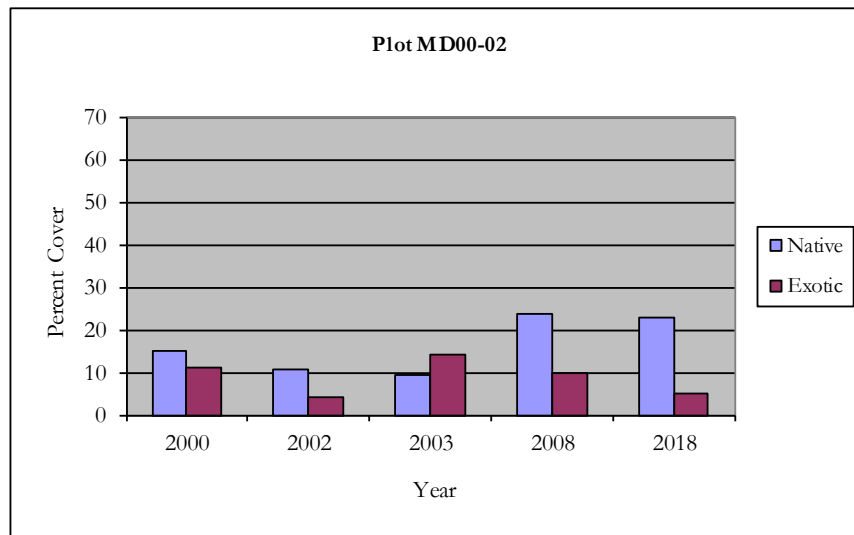
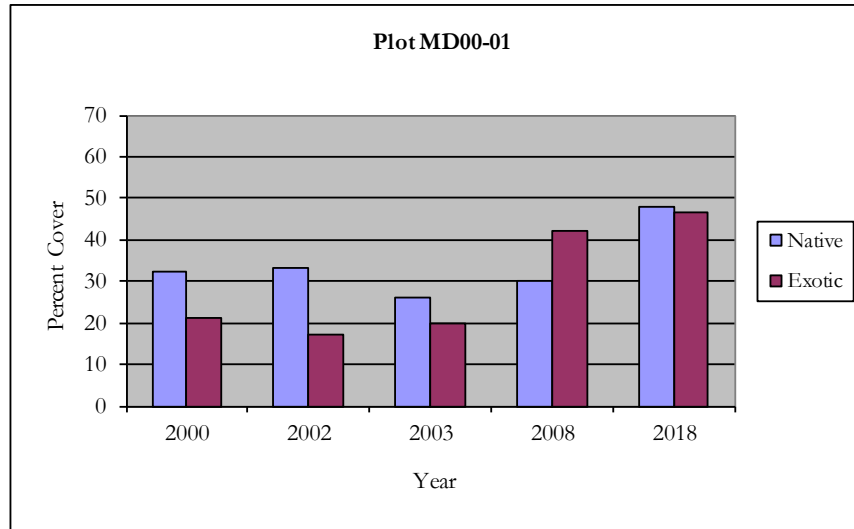


Table 13. Camas Creek Road: 1995 Site Analysis Results of Turnout #1 (Plot MD-00-02 area).

SPECIES	COVER (%): edge of forest	COVER (%): turnout island
TOTAL NATIVE TREES	70	1
<i>Larix occidentalis</i>	5	
<i>Pinus contorta</i>	60	1
<i>Populus trichocarpa</i>	2	
TOTAL NATIVE SHRUBS	40	1
<i>Arctostaphylos uva-ursi</i>	20	outside plot
<i>Rubus idaeus</i>		outside plot
<i>Spiraea betulifolia</i>	30	1
<i>Symphoricarpos albus</i>		1
<i>Vaccinium scobarium</i>	1	
TOTAL NATIVE FORBS	10	20
<i>Achillea millefolium</i>	1	
<i>Antennaria microphylla</i>	1	
<i>Antennaria neglecta</i>	1	
<i>Arabis holboellii</i>	1	1
<i>Arnica cordifolia</i>	1	
<i>Aster laevis</i>	1	1
<i>Campanula rotundifolia</i>		outside plot
<i>Cerastium spp.</i>		1
<i>Collomia linearis</i>	1	
<i>Equisetum arvense</i>	1	
<i>Fragaria virginiana</i>	5	3
<i>Hieracium albiflorum</i>	1	
<i>Melampyrum lineare</i>	1	
<i>Microsteris gracilis</i>	1	10
<i>Penstemon confertus</i>		outside plot
<i>Solidago canadensis</i>	1	
TOTAL NATIVE GRASSES	20	0
<i>Calamagrostis rubescens</i>	20	
<i>Carex spp.</i>		outside plot
TOTAL EXOTIC FORBS	1	3
<i>Centaurea maculosa</i>	1	3
<i>Prunella vulgaris</i>	1	
<i>Trifolium spp.</i>	1	
<i>Verbascum thapsus</i>		1
TOTAL EXOTIC GRASSES	3	40
<i>Bromus inermis</i>	3	10
<i>Dactylis glomerata</i>	1	
<i>Festuca rubra</i>	2	
<i>Pbleum pratense</i>	1	20
<i>Poa pratensis</i>		10

Table 14. Camas Creek Road: 1995 Site Analysis Results of Huckleberry Mountain Trailhead Parking (Plot MD-00-03 area).

SPECIES	COVER (%)
TOTAL NATIVE TREES	30
<i>Picea engelmannii</i>	1
<i>Pinus contorta</i>	30
TOTAL NATIVE SHRUBS	40
<i>Arctostaphylos uva-ursi</i>	5
<i>Linnaea borealis</i>	1
<i>Pachystima myrsinites</i>	1
<i>Rosa woodsii</i>	1
<i>Salix</i> spp.	1
<i>Spiraea betulifolia</i>	5
<i>Vaccinium scoparium</i>	20
<i>Vaccinium</i> spp.	1
TOTAL NATIVE FORBS	5
<i>Achillea millefolium</i>	1
<i>Anaphalis margaritacea</i>	1
<i>Antennaria microphylla</i>	1
<i>Antennaria neglecta</i>	1
<i>Cornus canadensis</i>	2
<i>Epilobium angustifolium</i>	1
<i>Fragaria virginiana</i>	3
<i>Hieracium albiflorum</i>	1
<i>Melampyrum lineare</i>	1
<i>Penstemon confertus</i>	1
<i>Rhinanthus crista-galli</i>	1
<i>Senecio pauperculus</i>	1
<i>Viola</i> spp.	1
<i>Xerophyllum tenax</i>	1
TOTAL NATIVE GRASSES	10
<i>Bromus carinatus</i>	5
<i>Carex</i> spp.	5
<i>Elymus glaucus</i>	1
<i>Festuca scabrella</i>	1
TOTAL EXOTIC FORBS	1
<i>Centaurea maculosa</i>	1
<i>Chrysanthemum leucanthemum</i>	1
<i>Prunella vulgaris</i>	1
<i>Taraxacum officinale</i>	1
TOTAL EXOTIC GRASSES	3
<i>Agrostis alba</i>	2
<i>Bromus inermis</i>	1
<i>Dactylis glomerata</i>	1
<i>Festuca arundinacea</i> (?)	1
<i>Phleum pratense</i>	1
<i>Poa pratensis</i>	1

Table 15. Camas Creek Road: Canopy Cover (%) by Plot, 2000-2018.

	MD-00-01					MD-00-02					MD-00-03				
Species	2000	2002*	2003	2008	2018	2000	2002*	2003	2008	2018	2001	2002	2003	2008*	2018
TREE	T	0	0	1	2	1	0	T	1	1-	3	5	8	5	24
<i>Larix occidentalis</i>											T	T	T	T	T
<i>Picea engelmannii</i>	T					T	Dead (burned)				1	2 -	3+	1	2
<i>Pinus contorta</i>	T					T	Dead (burned)				1	2+	4	2	16
<i>Pinus monticola</i>											T	T		T	
<i>Populus balsamifera</i>				1	2			T	1	1-	T	T	T	T	2
<i>Pseudotsuga menziesii</i>							Dead (burned)	T			T	T	T+	T+	4
SHRUB	2	1	1+	6+	25	2	T	1	3	7	3	3	4	12	23
<i>Alnus viridis</i>						1	Dead (burned)		1-	2					
<i>Amelanchier alnifolia</i>	T		T	T	T	T		T	T	T					T
<i>Arctostaphylos uva-ursi</i>	T	T (some burned)	T	2	18	T					T	1	1+	5	2
<i>Crataegus douglasii</i>								T							
<i>Mabonia repens</i>	T														
<i>Rosa acicularis</i>	1	1-	1			T	T	T			2	1	1		
<i>Rosa woodsii</i>				5	6	T			T					4	9
<i>Rubus idaeus</i>														T	T
<i>Rubus parviflorus</i>				T	out of plot	T									
<i>Salix drummondiana</i>											T	T	T	1 (ID?)	3
<i>Salix scouleriana</i>												T	T	T	
<i>Spiraea betulifolia</i>	T	T	T	T	1	T					T	T	T+	2-	8
<i>Symphoricarpos albus</i>						T	T	T	2	5					
<i>Vaccinium membranaceum</i>													T		
<i>Vaccinium scoparium</i>											T	T	T	outside plot	T+
NATIVE FORB	15	15	14	14	19	7	2	3	5-	3	4	4	3	14	25
<i>Achillea millefolium</i>	10	10	8	T	T+	3	1	1	T+	T	1	1	T	1-	T+
<i>Anaphalis margaritacea</i>		T									T	T		T	T
<i>Antennaria bonellii</i>		T	T		T				T	T		T	T	T	T+
<i>Antennaria rosea</i>	T														
<i>Aster laevis</i>	T	T+	T+	T	T	T	T	T	T	T	1	2 -	2	7 (+ other?)	5
<i>Campanula rotundifolia</i>							T	T							
<i>Chamerion angustifolium</i>	T	T	1	T	T							T	T	T	
<i>Collinsia parviflora</i>	T	Dead		T		T	T	T	T	T				T	
<i>Epilobium brachycarpum</i>	T	T		T		T	T	T	T	T					
<i>Epilobium balleianum</i>	T										T				
<i>Equisetum arvense</i>	T														
<i>Filago arvensis</i>										T					
<i>Fragaria virginiana</i>	1	T+	T	2	1	T	T	T	1	T+	1	T	T+	1	10
<i>Geum macrophyllum</i>	T	T	T					T			T	T	T	T	
<i>Geum triflorum</i>	T	T	T	T+	T+										
<i>Gnaphalium macounii</i>	T	T		T											
<i>Gnaphalium palustre</i>	T		T			T	T+	T+	T	T					
<i>Heuchera cylindrica</i>	T	T													
<i>Hieracium albiflorum</i>											T	T	T		
<i>Hieracium umbellatum</i>												T			
<i>Lupinus sericeus</i>		T	T												
<i>Microsteris gracilis</i>						3		T	T	T	T	T	T	T+	T

Table 15, con't. Camas Creek Road: Canopy Cover (%) by Plot, 2000-2018.

	MD-00-01					MD-00-02					MD-00-03				
Species	2000	2002*	2003	2008	2018	2000	2002*	2003	2008	2018	2001	2002	2003	2008*	2018
NATIVE FORB, con't															
<i>Pacistima myrsinites</i>															T
<i>Penstemon confertus</i>	1	2	1+	7	12	T	T	1	2-	2-	T	T	T	3	8
<i>Polemonium pulcherrimum</i>						T	T	T	T	T					
<i>Polygonum douglasii</i>	T					T	T	T							
<i>Potentilla gracilis</i>	T	T	1+	3	5	T	T	T	T+	T	T	T	T	1-	2-
<i>Potentilla hippiana</i>		T	T	T+	T					T	T	T	T	T	T
<i>Potentilla pensylvanica</i>	T	T	T	T	T		T	T		T			T	T	1-
<i>Solidago canadensis</i>		T	T		T		T	T							
<i>Stellaria</i> spp.		T													
<i>Vicia americana</i>	T	T		T	T	T	T								
<i>Viola orbiculata</i>											T				
<i>Xerophyllum tenax</i>												T	T	T	T+
NATIVE GRASS	15	17	11	9	2	5	8	5	15	12	10	8	4	5	1
<i>Agrostis scabra</i>												T			
<i>Bromus carinatus</i>	2	T	T			1	T	T	T		5	T		T	
<i>Calamagrostis rubescens</i>							T	T				T		T	
<i>Carex athrostachya</i>											T	1 -	T	T	
<i>Carex bebbii</i>												T			
<i>Carex concinnoides</i>															
<i>Carex foenea</i>												T			
<i>Carex petaseta</i>														T (ID?)	
<i>Carex praegracilis</i>											T		T		
<i>Carex rossii</i>			T				T	T	T	T				T	
<i>Danthonia intermedia</i>		T		T	T		T	T	T	T	T	T+	T	1	T
<i>Deschampsia caespitosa</i>	1	T	T				T	T					T	T+	
<i>Elymus glaucus</i>	3	7	4	1		2	5	2	T		3	5	4	T+	T
<i>Elymus trachycaulus</i> v. <i>trachyc</i>	8	8+	2			2	1+	1	1	T	T	T+	T	T	
<i>Festuca idahoensis</i>	T	T	1-	2	1+	T	T	T	2	3		T	T	T	T
<i>Festuca campestris</i>															T
<i>Koeleria macrantha</i>	1	1	3+	5	T	T	T	1-	10	9	T	T	T	1	
<i>Poa palustris</i>												T			
<i>Pseudoroegneria spicata</i>	T	T	T+	T+					T			T	T	T	T
<i>Stipa nelsonii</i>				T					T	T					
EXOTIC FORB	20	1	7	2	1-	10	3	13	3	2	5	6	6	8	15
<i>Achillea nobilis</i>	T	T													
<i>Amsinckia menziesii</i>	T														
<i>Arenaria serpyllifolia</i>	T									T					
<i>Capsella bursa-pastoris</i>	T	T				T									
<i>Centaurea maculosa</i> *				T	T+ (sprayed)	T		T (pulled)	1 (sprayed)	2-		out of plot		1-	10
<i>Chenopodium album</i>						T									
<i>Chrysanthemum leucanthemum</i>	T	T (pulled)									T	T	1	1+	2-
<i>Descurainia sophia</i>								T							
<i>Cirsium arvense</i> *	T	T	T	T	T	T									
<i>Cirsium vulgare</i>	T										T	T			
<i>Erodium cicutarium</i>						T	T	T							

Table 15, con't. Camas Creek Road: Canopy Cover (%) by Plot, 2000-2018.

	MD-00-01					MD-00-02					MD-00-03				
Species	2000	2002*	2003	2008	2018	2000	2002*	2003	2008	2018	2001	2002	2003	2008*	2018
EXOTIC FORB, con't															
<i>Hieracium aurantiacum</i> *													T (pulled)	T	1-
<i>Hypericum perforatum</i> *	out of plot													T	T
<i>Lactuca serriola</i>	T					T	T	T			T				
<i>Medicago lupulina</i>	3	T	T+	T	T	2	1	10	T (sprayed)	T	T	T		T	T
<i>Melilotus alba</i>			T			3		1		T		T+	T		
<i>Melilotus officianalis</i>	4	T	5			2	T	T+			T	T			
<i>Myosotis micrantha</i>	T	Dead		T		T			T						
<i>Plagiobothrys scouleri</i>						T				T					
<i>Plantago major</i>	T	T				T					T				
<i>Polygonum convolvulus</i>	T					T									
<i>Potentilla argentea</i>	T										T	T			
<i>Potentilla norvegica</i>	T														
<i>Potentilla recta</i> *			T												
<i>Prunella vulgaris</i>	T										T	T	T	T+	T
<i>Rumex acetosella</i>							1	1-	T	T				T	T
<i>Silene conoidea</i>						T		T							
<i>Silene cucubalis</i>											1	1	1+	1	1+
<i>Silene latifolia</i>	T	T	T			T	T		T						
<i>Sisymbrium altissimum</i>	T					T	T								
<i>Taraxacum officinale</i>		T	T			T	T	T	T	T	3	2	1+	2	1
<i>Tragopogon dubius</i>					T		T		T	T				T	T
<i>Trifolium agrarium</i>	6	1-	1	1	T	T						2	1+	T	
<i>Trifolium hybridum</i>				T			T	T	T		T	T	T	T	
<i>Trifolium pratense</i>	T					1	T	T			1	T	1	1	T
<i>Trifolium repens</i>						T									
<i>Unknown forb (pink, dried)</i>									T+						
<i>Verbascum thapsus</i>	T	T	T			T	T	T	T		T	T	T		
<i>Veronica serpyllifolia</i>	T			T							T	T			
<i>Vicia villosa</i>								T	T	T (dying)					
<i>Viola arvensis</i>	T					T									
EXOTIC GRASS	1	16	13	40	46	1-	1	1-	7	3	40	55	37	45	48
<i>Agrostis stolonifera</i>	T	T	T	T		T	T	T	T	T	T	T	T		T
<i>Avena sativa</i>						T									
<i>Bromus inermis</i>		T	T	T							2	30	15	30	35
<i>Bromus tectorum</i>	T	T	T	outside plot		T	T+	T+	2	T					
<i>Elymus repens</i>		15*	8	40	45				1	1-		T		T	1
<i>Phleum pratense</i>	T	T	4	1	T+	T	T	T	2	2+	25	20	20	10	12
<i>Poa compressa</i>		T	T	T	T				T	T	T		T		
<i>Poa pratensis</i>	T	T	T	T+	T+		T	T	T		10	5	2	5	1
<i>unknown grass (small, awned)</i>									1						

* MD-00-01 and MD-00-02 burned in Moose Fire, Fall, 2001

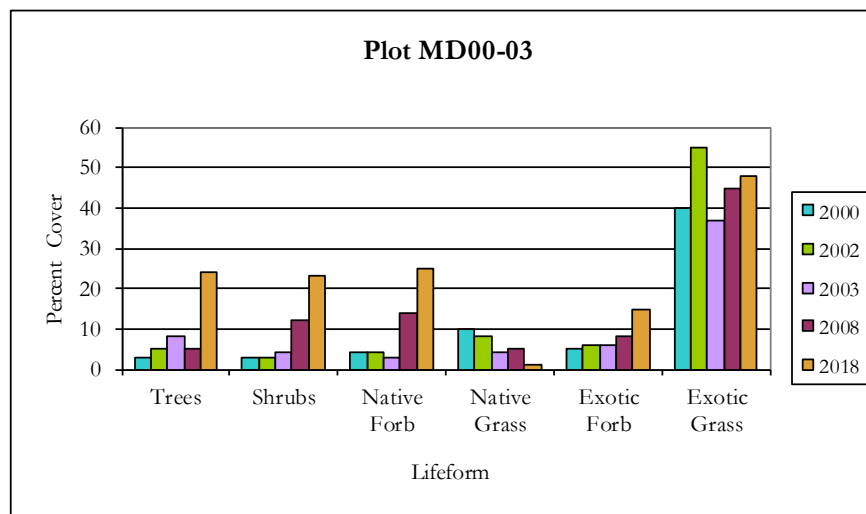
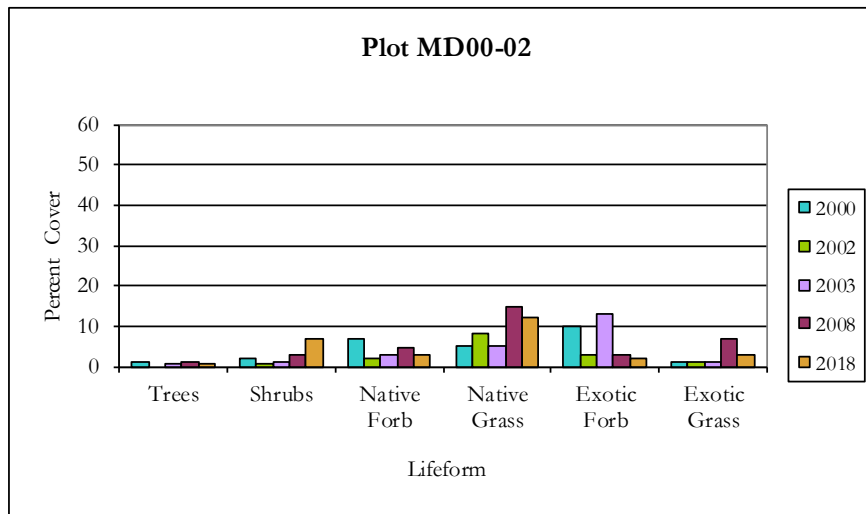
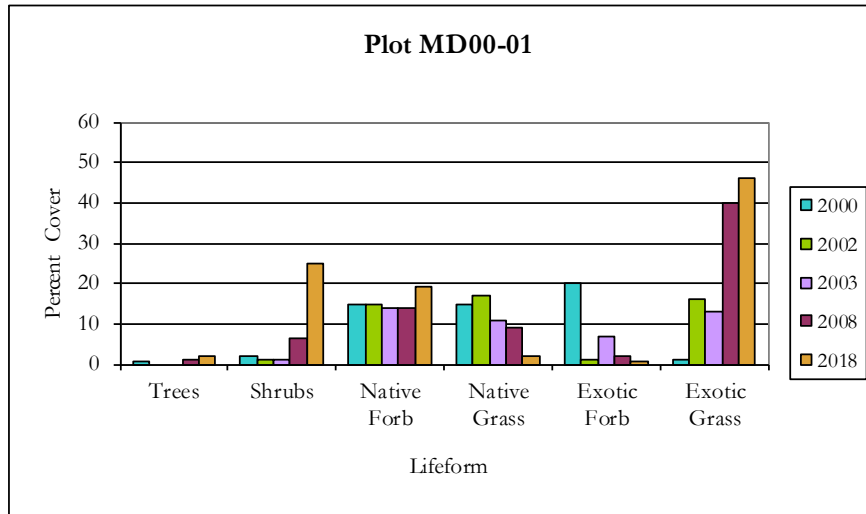
* MD-00-03 burned in Robert Fire, Summer 2003

*In 2000, ELYREP was not identified - was probably lumped with ELYTRA due to lack of seed head

* on Montana State Noxious Weed list

S:\VegUnit\CAMAS\Camas Rd Reveg\Data\Camas.2018.xlsx (Camas 2018 tab)

Figure 17. Camas Creek Road: Percent Cover of lifeforms by Plot, 2000-2018.



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Table 16. Camas Creek Road: Seeded Species and Their Seed Rates (seeds/ft²)

	MD-00-01	MD-00-02	MD-00-03
GRASSES			
<i>Bromus carinatus</i>	23	23	23
<i>Calamagrostis rubescens</i>	58	58	15
<i>Carex athrostachya</i>	tr	tr	tr
<i>Danthonia intermedia</i>	8	8	2
<i>Deschampsia caespitosa</i>	6	6	3
<i>Elymus glaucus</i>	17	17	29
<i>Elymus trachycanthus</i>	11	11	9
<i>Festuca idahoensis</i>	7	7	
<i>Festuca campestris</i>	tr	tr	
<i>Koeleria macrantha</i>	9	9	10
<i>Pseudoroegneria spicata</i>	1	1	3
FORBS			
<i>Achillea millefolium</i>	19	19	12
<i>Aster laevis</i>	5	5	13
<i>Chamerion angustifolium</i>	5	5	3
<i>Dryas drummondii</i>	4	4	
<i>Geum macrophyllum</i>	4	4	4
<i>Lupinus sericeus</i>	tr	tr	
<i>Penstemon confertus</i>	5	5	9
<i>Potentilla gracilis</i>	5	5	unk
<i>Solidago canadensis</i>	25	25	6
<i>Xerophyllum tenax</i>	5	5	5
SHRUBS			
<i>Spiraea betulifolia</i>	5	5	unk

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Reveg\Camas_seeded&planted.xlsx

Table 17. Camas Creek Road: Planted Species

	MD-00-01	MD-00-02	MD-00-03
TREES			
<i>Betula papyrifera</i>	x		
<i>Larix occidentalis</i>	x	x	x
<i>Picea engelmannii</i>	x	x	x
<i>Pinus contorta</i>	x	x	x
<i>Pinus monticola</i>			x
<i>Populus balsamifera</i>	x	x	
<i>Populus tremuloides</i>	x		
<i>Pseudotsuga menziesii</i>	x	x	x
SHRUBS			
<i>Alnus viridis</i>		x	
<i>Amelanchier alnifolia</i>	x	x	
<i>Arctostaphylos uva-ursi</i>	x	x	x
<i>Cornus sericea</i>	x		x
<i>Juniperus communis</i>	x		
<i>Linnaea borealis</i>	x		x
<i>Mahonia repens</i>	x	x	
<i>Paxistima myrsinites</i>	x		
<i>Rosa woodsii</i>	x	x	x
<i>Rubus parviflorus</i>	x	x	
<i>Salix spp.</i>	x		x
<i>Shepherdia canadensis</i>		x	
<i>Spiraea betulifolia</i>	x	x	x
<i>Symphoricarpos albus</i>		x	
<i>Vaccinium membranaceum</i>			x
<i>Vaccinium scoparium</i>		x	
GRASSES			
<i>Carex athrostachya</i>	x		
<i>Koeleria macrantha</i>		x	
FORBS			
<i>Anaphalis margaritacea</i>		x	
<i>Antennaria spp.</i>	x		
<i>Arnica cordifolia</i>		x	
<i>Arnica spp.</i>	x		
<i>Aster laevis</i>	x	x	
<i>Castilleja miniata</i>	x		
<i>Fragaria virginiana</i>	x	x	x
<i>Geum macrophyllum</i>	x	x	
<i>Geum triflorum</i>	x		
<i>Penstemon confertus</i>	x	x	
<i>Potentilla gracilis</i>	x	x	
<i>Solidago canadensis</i>	x	x	
<i>Xerophyllum tenax</i>			x

V. WHITEBARK AND LIMBER PINE RESTORATION PROJECT

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*), is a long-lived, slow-growing mid- to high-elevation five-needled pine tree. In Glacier National Park, this species is found on the east and west sides of the Continental Divide, although it is more abundant on the east side. Whitebark pine is considered a keystone species because of the important role it plays in the ecosystem. It is a hardy subalpine conifer that tolerates poor soils, steep slopes, windy exposures, and tree-line environments (Arno and Hoff 1990). This species provides valuable cover, shelter and nesting opportunities for many wildlife species. The grizzly bear and Clark's nutcracker rely on their seed for food. These trees also influence vegetation patterns by pioneering dry, exposed sites where no other tree species can grow. Because they establish on windy ridges and have broad crowns, they accumulate and retain snow which lengthens the snow melt period.

Another five-needled pine, limber pine (*Pinus flexilis*), is also considered to be a keystone species. In Glacier National Park, this tree is found only on the east side of the Continental Divide, mostly along the eastern margin of the Park. Glacier has many fewer limber pine stands than whitebark pine stands and limber pine is more abundant on the Flathead Indian Reservation adjacent to the eastern boundary of the Park. Small to medium in size, it often grows on rocky ridges and its form is frequently irregular. At the lower tree line it mixes with other conifers. Being relatively shade-intolerant, it is mostly a pioneer species and maintains its presence only on somewhat severe sites. Like whitebark pine, this species also provides valuable cover, shelter and nesting opportunities. The large seeds of both species are a nutritious food source for birds, rodents, and bears.

Whitebark and limber pine populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the Park. Severe climatic events, mistletoe, fire exclusion, and/or mountain pine beetles may have also contributed to the poor health of these trees. Whitebark pine mortality has been estimated at 44% within the park with approximately 78% of the remaining live trees infected (Kendall and Keane 2001). Kendall and Keane (2001) have also estimated limber pine mortality in Glacier National Park at 39% with 78% of the remaining live trees infected. Recent anecdotal evidence indicates that current mortality and infection rates for both species have increased since 2001.

Some mature whitebark and limber pine individuals have shown phenotypic genetic resistance to blister rust including few to no blister rust cankers, healthy needles, and cone production. These "plus trees" continue to be identified in the Park. Restoration efforts for these two species began in 1997 when seeds were collected from trees that showed phenotypic genetic resistance.

In 1998, Glacier National Park received funding from the Intermountain Region Natural Resource Fund to continue collection efforts, grow seedlings from collected seeds, and plant seedlings at specific sites around the park. These seedlings have been planted in an effort to restore the ecosystem with presumed disease-resistant trees. Limber pine seedlings have been planted at 21 sites on the east-side of the Park and whitebark pine seedlings have been planted at 20 sites, 16 on the east-side and 4 on the west-side. Sites were selected based on accessibility for planting and appropriate habitat characteristics. If possible, sites were chosen in areas with recent burn activity, since these areas most mimic seed caching sites from Clark's nutcrackers, as well as provide the most advantageous growing conditions. Due to a shortage of burned habitat, limber pine seedlings had been planted exclusively in non-burned sites until 2016 when the Reynolds Fire offered suitable limber pine restoration habitat. Whitebark seedlings, on the other hand, have been planted in both burned and non-burned sites throughout the park from the inception of restoration efforts. Planting years have been chosen based on the availability of seedlings.

Taking advantage of natural blister rust resistance may be an effective strategy for restoration of whitebark and limber pine. Natural genetic resistance has been found in several species of five-needled pines and there is growing evidence that whitebark pine exhibits natural resistance (Schwandt 2006). Glacier National Park has been attempting to utilize naturally resistant trees in its restoration program for the past 20 years. Cones have been collected from phenotypic-resistant whitebark pine trees since 1997.

A protocol has been implemented by U.S. Forest Service nurseries whereby potential rust-resistant seedlings are tested for genetic resistance. Preliminary tests have revealed resistance in many whitebark pine seedlings (Maholovich et al. 2006). In 2009, Glacier National Park had the opportunity to join the U.S. Forest Service's study

on genetic resistance in whitebark pine plus trees. Since then, collection efforts have centered on caging from trees that meet requirements for the study.

Another experimental program that Glacier has adopted utilizes a symbiotic relationship between trees and fungi that are known to enhance growth and survival. Studies have shown that inoculation of the soil surrounding nursery-raised seedlings with ectomycorrhizal fungi can further benefit survival of whitebark pine seedlings (Cripps et al, 2014). It is suspected that the fungus aids the tree in nitrogen uptake. Seedlings in several plantings in the Park have been inoculated by Montana State University scientists with an ectomycorrhizal slurry obtained from *Suillus sibiricus* mushrooms, and data have been taken, when available, to compare seedlings that have been inoculated versus those that have not. To date, only whitebark pine seedlings have been inoculated. Limber pine seedlings have not yet been utilized in ectomycorrhizal inoculation study. Some seedlings raised at the Coeur d'Alene Nursery, however, have been found to have naturally occurring ectomycorrhizal fungi in their root systems that are known to enhance health and survival. Therefore, it is possible that some seedlings grown for GNP at the Coeur d'Alene Nursery may be somewhat naturally inoculated. Trees within plots that have been inoculated are identified to determine survival success of inoculated vs. non-inoculated seedlings.

Due to the mortality and expense associated with growing and planting seedlings, another restoration approach was initiated in 2006 and continued in 2007. To date, seeds from potentially resistant whitebark pine trees were directly planted at three sites, two of which have burned in recent years. Seeds were cached in groups, mimicking planting schemes of Clark's nutcrackers. The idea behind this strategy is not only to minimize expense, but also to provide a more natural scenario whereby seed can germinate when environmental conditions are favorable. Seedlings were also planted at two of the sites for comparison.

1. Limber Pine Restoration

Limber pine seedlings have been planted at 21 sites, 16 of which continue to support live trees in monitoring plots (Tables 18, 19 & Figure 18). A total of 10,209 seedlings have been planted in the park between 2002 and 2016. No limber pine seedlings were planted in 2017 or 2018. Earlier plantings typically occurred in the fall, but an increasing number of plantings have taken place in the spring. Monitoring plots have captured 25% of total planted seedlings overall.

During the first wave of limber pine planting, between 2002 and 2006, seedlings were planted at 13 sites. Nearly 5,000 seedlings were planted in the Park during this time. Since limber pine seedling survival was poor during these drought years, no limber pine seedlings were planted in the Park between 2006 and 2012. After weather patterns became more favorable and new insights had been reached regarding planting techniques, a concerted limber pine planting effort re-emerged in 2012.

Due to lack of suitable limber pine habitat that had burned, no limber pine seedlings prior to 2016 were planted in burn areas. The Reynolds Creek fire of 2015 provided the first burned limber pine planting habitat since the restoration program began, which was capitalized upon in 2016. A total of 1,039 limber pine seedlings were planted in 2016, all within burned habitat.

Seedlings have been planted in both the spring and the fall. The first few years of restoration, more sites were planted in the fall than in the spring, but subsequent plantings were distributed between spring and fall. Planting time has been based on favorable short-term weather patterns.

Several planting techniques to enhance health and survival have been utilized and refined over the 19 years of 5-needle pine restoration in Glacier. The use of microsites, either existing or constructed, is now almost universal in all plantings. Care is taken to plant during favorable weather conditions and during seasons where the probability of survival is greatest. Additionally, the level of genetic resistance in parent trees is being determined which will influence seed collection in the future.

Seedlings have often been grown in the nursery with several trees in one container. The result is that more trees are often planted than the number of cones would suggest during restoration plantings. To determine the number of actual trees planted in an area, a multiplier was applied based on the estimated average number of trees per cone and the number of cones was multiplied by this number to obtain an estimate of number of trees planted. Additionally, seedlings from multiple cones are often planted together in one microsite to mimic clumping of seedlings produced from Clark's Nutcracker seed caches.

Table 18. Limber Pine Monitoring Plot Establishment to Date.

<i>Site</i>	<i>Year</i>	<i># of Plots Established</i>	<i># of Cones Planted</i>	<i>Multiplier*</i>	<i># of Trees Planted Overall</i>	<i>Total # Trees Captured</i>	<i>% Trees Monitored</i>
Apikuni Flats	2002	2			160	25	16%
	2012	2			662	123	19%
Total		4			822	148	18%
Baring Creek	2004	5			450	91	20%
	2006	3			250	71	28%
	2016	2	104	1	104	29	28%
Total		10			804	191	24%
Base Altyn Peak	2002	1			160	27	17%
	2004	2			200	40	20%
Total		3			360	67	19%
Cutbank	2012	2			286	82	29%
Total		2			286	82	29%
Dead Horse Point	2002	5			800	188	24%
	2004	2			250	53	21%
	2006	1			262	20	8%
(lower)	2016	1	98	1	98	64	65%
(upper)	2016	1	147	1	147	65	44%
Total		9			1557	390	25%
Firebrand Pass Trail	2002	2			140	38	27%
Total		2			140	38	27%
Golden Staircase (lower)	2016	2	98	1	98	42	43%
Total		2			98	42	43%
Lost Lake	2016	2	312	1	312	63	20%
Total		2			312	63	20%
Many Glacier Well	2012	1			196	64	33%
		1			196	64	33%
Otokomi (lower)	2016	1	179	1	179	52	29%
Total		1			179	52	29%
Poia Lake TH	2002	2			160	41	26%
Total		2			160	41	26%
Rising Sun CG	2012	2			570	140	25%
		2			570	140	25%
Rocky Point	2002	2			150	37	25%
Total		2			150	37	25%
Scenic Point	2002	4			200	74	37%
	2005	6			700	149	21%
	2012	4			1264	335	27%
Total		14			2164	558	26%
Spot Mountain	2013 (spring)	4	352	1.9	669	134	20%
	2013 (fall)	3	392	1.9	745	201	27%
Total		7			1414	335	24%
Sun Point	2002	2			220	53	24%
	2004	2			250	54	22%
Total		4			470	107	23%
Turnout 6: St. Mary	2016	2	101	1	101	44	44%
Total		2			101	44	44%
Two Medicine CG	2002	2			160	35	22%
Total		2			160	35	22%
Two Medicine CS	2003	1			26	26	100%
Total		1			26	26	100%
Two Medicine RS	2002	2			140	38	27%
Total		2			140	38	27%
Wild Goose Island TO	2002	1			100	29	29%
Total		1			100	29	29%
Overall Total		65			10209	2527	25%

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Figure 18. Limber Pine Seedling Monitoring Sites

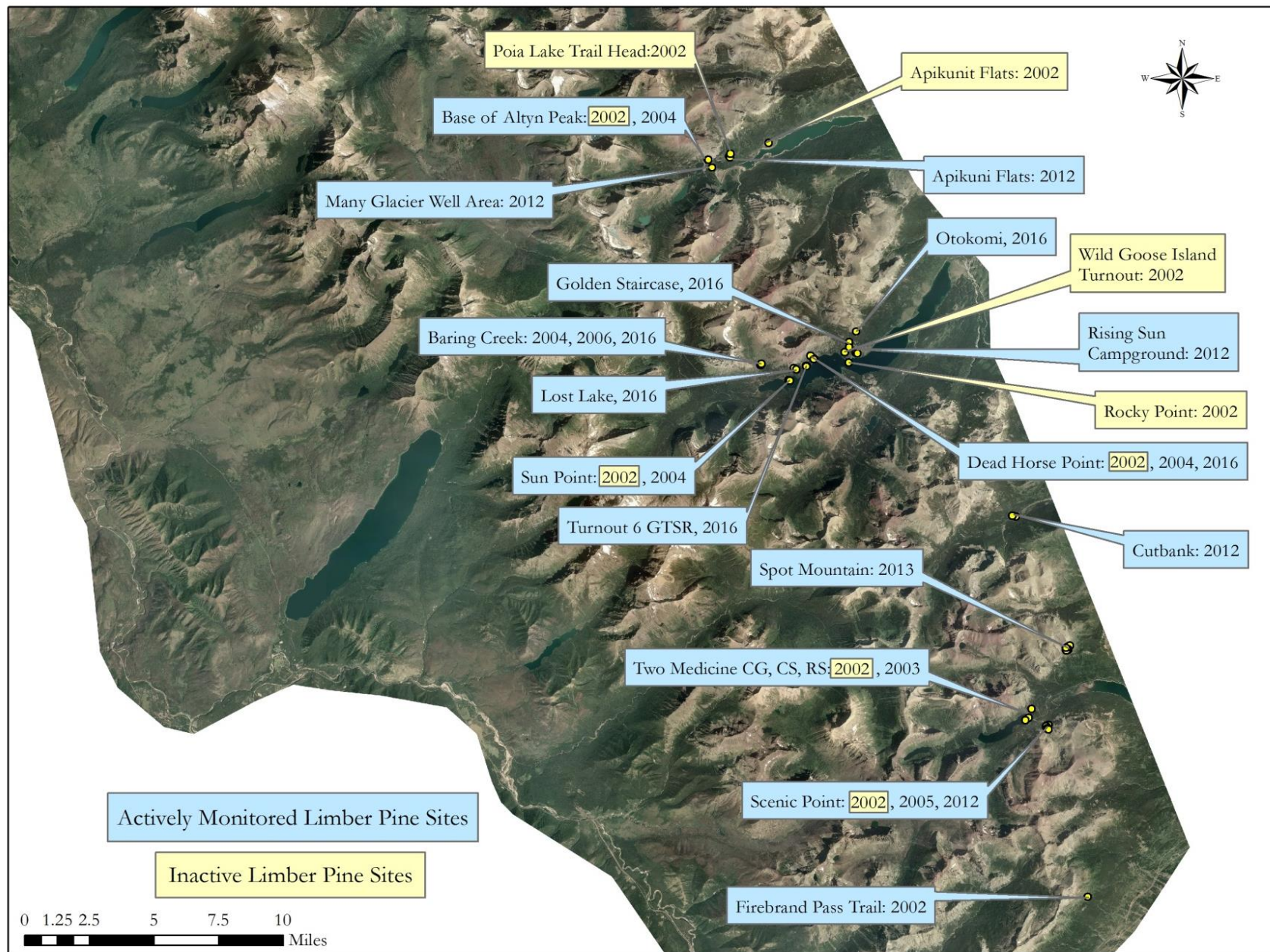


Table 19. Limber Pine Planting Site Characteristics.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Elevation of Plots (feet)</i>	<i>In burn?</i>	<i>Inoculated?</i>
Apikuni Flats	2002	Fall	4,830 - 4,850	No	No
	2012	Spring	4,905	No	No
	2012	Fall	4,925	No	No
Baring Creek	2004	Spring	5,040 - 5,130	No	No
	2006	Spring	5,280 - 5,520	No	No
	2016	Spring	5,165	Yes	No
Base of Altyn Peak	2002	Fall	5,115	No	No
(Many Glacier Hotel Slope)	2004	Fall	5,080 - 5,090	No	No
Cutbank	2012	Spring	5,185 - 5,240	No	No
Dead Horse Point	2002	Fall	4,720 - 4,920	No	No
	2004	Fall	4,720 - 4,780	No	No
	2006	Spring	4,730	No	No
lower	2016	Spring	4,725	Yes	No
upper	2016	Spring	5,185	Yes	No
Firebrand Pass Trail	2002	Fall	5,670 - 5,710	No	No
Golden Staircase (lower)	2016	Spring	5,025 - 5,195	Yes	No
Lost Lake	2016	Fall	4,775 - 4,940	Yes	No
Many Glacier Well	2012	Fall	5,125	No	No
Otokomi (lower)	2016	Spring	5,585	Yes	No
Poia Lake Trail Head	2002	Fall	4,900	No	No
Rising Sun	2012	Spring	4,527 - 4,541	No	No
		Fall	N/A	No	No
Rocky Point	2002	Fall	4,560	No	No
Scenic Point	2002	Fall	5,670 - 5,775	No	No
	2005	Fall	5,765 - 5,800	No	No
	2012	Spring	5,575 - 5,740	No	No
	2012	Fall	5,575 - 5,735	No	No
Spot Mountain	2013	Spring	6,245 - 6,480	No	No
	2013	Fall	6,175 - 6,400	No	No
Sun Point	2002	Fall	4,600	No	No
	2004	Fall	4,560	No	No
Turnout 6, St. Mary	2016	Spring	4,690 - 4,720	Yes	No
Two Medicine Campground	2002	Fall	5,165	No	No
Two Medicine Camp Store	2003	Fall	5,165	No	No
Two Medicine Ranger Station	2002	Fall	5,200	No	No
Wild Goose Island Turnout	2002	Fall	4,650	No	No

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2. *Whitebark Pine Restoration*

Whitebark pine seedlings have been planted at 23 sites between 2000 and 2018, all of which continue to support live trees (Figure 18; Tables 20 and 21). A total of 23,761 seedlings have been planted in the park between 2000 and 2018. A few other small plantings have occurred that were too small to warrant monitoring plots and are not included in the tally of planted 5-needle pines in the Park. These include small plantings in late summer of 2013, at Morning Star and Atlantic Creek, on the Blackfeet Reservation near the Park boundary on Divide Mountain, at the eastern saddle of Divide Mountain and above the limber pine planting site on Otokomi Mountain. Additionally, small plantings have taken place over the years during general revegetation projects and memorial tree plantings in areas such as Old Man Lake Campground.

Monitoring plots have captured 21% of total planted whitebark pine seedlings (Table 20). The number of plots created at each site was dependent on planting densities and number of seedlings planted at the site. Data on the survival and health of individuals were collected during each monitoring event.

As with limber pine restoration, collecting and planting techniques to enhance health and survival have been refined over the 18 years of restoration in Glacier, including the use of microsites, planting during favorable weather conditions and during seasons when the probability of survival is greatest. Genetic resistance of parent trees is being determined for both limber and whitebark pine plus trees in the Park, which will influence seed collection in the future. Also as in limber pine seedlings, whitebark pine seedlings have recently been grown in the nursery with several trees in one container.

Specific to whitebark pine, there have been four experimental plantings where whitebark seed has been directly seeded in the ground (Table 22). This strategy has been moderately successful in Waterton Lakes National Park and a few other areas, prompting experiments in Glacier.

Figure 19. Whitebark Pine Seedling and Seed Monitoring Sites.

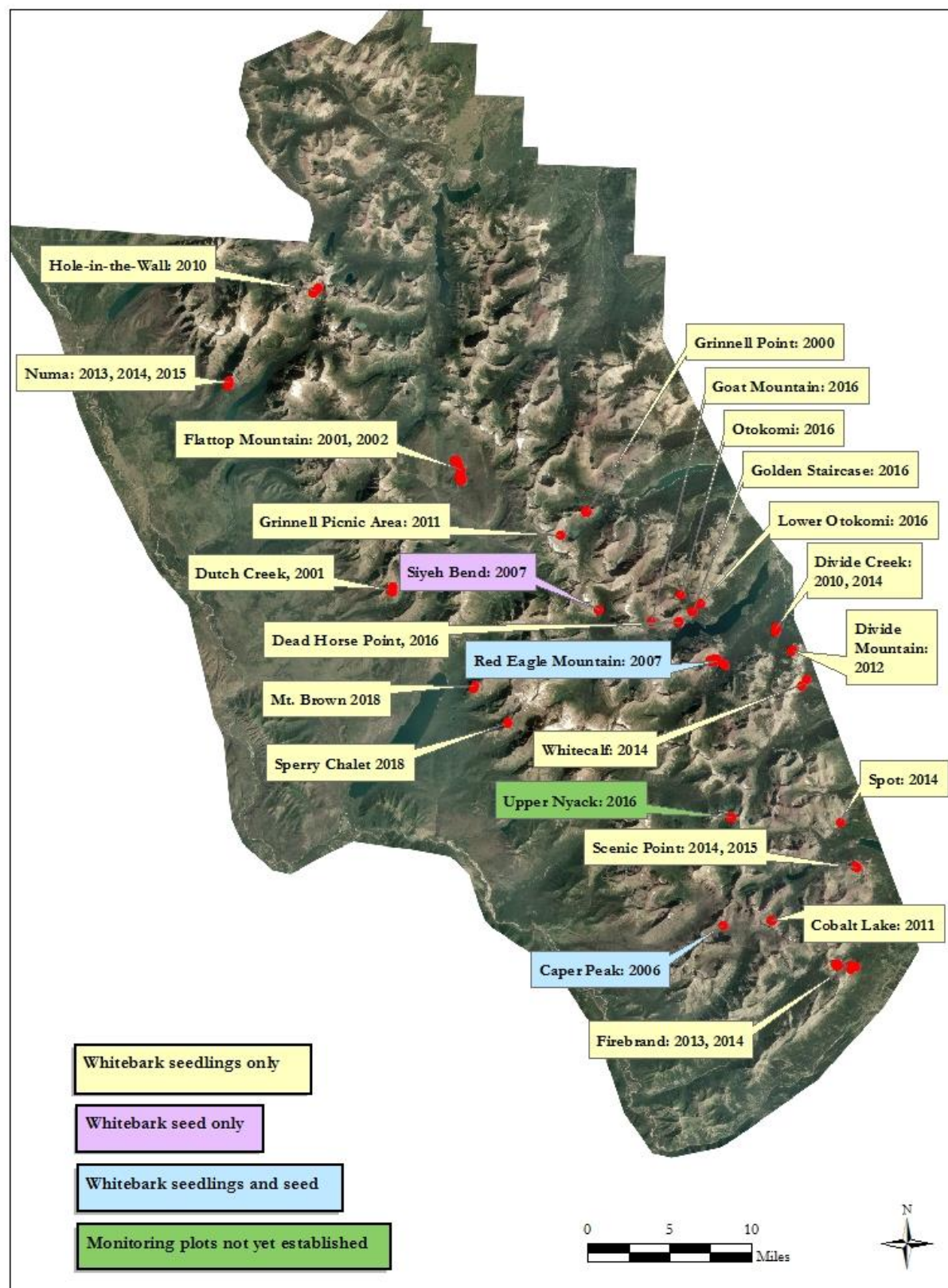


Table 20. Whitebark Pine Seedling Monitoring Plot Establishment to Date.

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Cones Planted</i>	<i>Multiplier</i>	<i># of Trees Planted</i>	<i># of Trees Monitored</i>	<i>% Trees Monitored</i>
Caper Peak	2006 (fall)	2			139	139	100%
Cobalt Lake	2011 (late summer)	3	250	2.04	510	108	21%
Dead Horse Point (Upper)	2016 (spring)	2	171	1.3	227	52	23%
Divide Creek	2010 (fall)	5			1,126	263	23%
	2014 (fall)	3	933	1.1	1,026	216	21%
Divide Mountain	2012 (fall)	4	686	2	1,283	216	17%
Dutch Creek	2001 (fall)	4	100	1	100	100	100%
Firebrand	2013 (spring)	4	516	2	1,032	208	20%
	2013 (fall)	5	1,175	2	2,350	375	16%
	2014 (spring)	2	238	1.9	452	102	23%
	2014 (fall)	3	517	1.1	569	133	23%
Flattop Mtn.	2001 (spring)	16			1,500	285	19%
	2001 (fall)	11			1,438	350	24%
	2002 (fall)	11			2,222	292	13%
Goat Mountain	2016 (spring)	1	104	1.4	145	34	23%
Golden Staircase	2016 (spring)	2	196	1.5	294	59	20%
Grinnell Glacier Picnic	2011 (late summer)	2	150	2	300	98	33%
Grinnell Point	2000 (fall)	7			96	96	100%
Hole-in-the-Wall	2010 (fall)	5	222		830	159	19%
Mount Brown	2018 (fall)	3	443	1	443	110	25%
Numa	2013 (fall)	3	310	1.8	558	167	30%
	2014 (fall)	4	473	1.5	710	208	29%
	2015 (fall)	2	219	1.1	222	64	29%
Otokomi (upper)	2016 (spring)	1	123	1.96	241	65	27%
Otokomi (lower)	2016 (fall)	3	406	1.0	406	98	24%
Red Eagle	2007 (fall)	9			2,000	422	21%
Scenic Point	2014 (spring)	2	422	1.9	802	188	23%
	2015 (fall)	2	219	1.1	222	68	31%
Sperry Chalet	2018 (fall)	3	564	1	564	121	21%
Spot Mtn.	2014 (spring)	1	219	1.9	416	36	9%
Upper Nyack	2016 (fall)	0	750	1.0	750	0	N/A
Whitetail Mtn.	2014 (fall)	2	657	1.2	788	146	19%
Overall Total					23,761	4,878	21%

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Table 21. Whitebark Pine Seed Plot Establishment.

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Seeds Monitored</i>	<i>Source of Seed</i>
Caper Peak	2006 (fall)	2	423	unknown
Siyeh Bend	2007 (summer)	3	101	Preston Park, 2005 (#155)
Red Eagle Mtn.	2007 (fall)	1	102	Preston Park, 2005 (#155)
Red Eagle CG	2007 (fall)	1	98	Preston Park, 2005 (#155)
Total		7	724	

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Table 22. Whitebark Pine Planting Site Characteristics.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Elevation of Plots (feet)</i>	<i>In burn?</i>	<i>Burn</i>	<i>Inoculated w/ ectomycorrhizae?</i>
Grinnell Point	2000	Fall	6,500 - 7,320	Yes	Grinnell Point Fire, 2000	No
Durch Creek	2001	Fall	6,800 - 7,200	Yes/No	Moose Fire, 2001	No
Flattop Mountain	2001	Spring	6,340 - 6,750	Yes	McDonald Creek Fire, 1998	No
	2001	Fall	6,750 - 6,840	Yes	McDonald Creek Fire, 1998	No
	2002	Fall	6,750	Yes	McDonald Creek Fire, 1998	No
Caper Peak	2006	Fall	6,520	Yes	Rampage Fire, 2003	No
Red Eagle	2007	Fall	5,700 - 5,900	Yes	Red Eagle Fire, 2006	No
Divide Creek	2010	Fall	5,720 - 5,760	Yes	Red Eagle Fire, 2006	Yes, 27%
	2014	Fall	5,753 - 5,775	Yes	Red Eagle Fire, 2006	Yes, some
Hole-in-the-Wall	2010	Fall	6,349 - 6,922	No	N/A	No
Grinnell Glacier Picnic	2011	Late summer	6,240 - 6,280	No	N/A	No
Cobalt Lake	2011	Late summer	6,570 - 6,670	No	N/A	No
Divide Mountain	2012	Fall	7,070 - 7,150	Yes/No	Red Eagle Fire, 2006	Yes, 47%
Numa Lookout	2013	Fall	6,896 - 6,920	No	N/A	Yes, most
	2014	Fall	6,710 - 6,870	No	N/A	No
	2015	Fall	6,780 - 6,850	No	N/A	No
Firebrand Pass Trail	2013	Spring	6,515 - 6,540	No	N/A	No
	2013	Fall	6,037 - 6,404	No	N/A	Yes, some
	2014	Spring	6,506 - 6,520	No	N/A	No
	2014	Fall	6,500 - 6,850	No	N/A	No
Scenic Point	2014	Spring	7,164 - 7,210	No	N/A	No
	2015	Fall	7,100	No	N/A	No
Spot Mountain	2014	Spring	6,232	No	N/A	No
Whitetail Mountain	2014	Fall	6,736 - 6,763	No	N/A	No
Dead Horse Point	2016	Spring	5,415 - 5,435	Yes	Reynolds Creek Fire, 2016	No
Otokomi (upper)	2016	Spring	6,200	Yes	Reynolds Creek Fire, 2016	No
Otokomi (lower)	2016	Spring	6,160 - 6,210	Yes	Reynolds Creek Fire, 2016	No
Goat Mountain	2016	Spring	6,400	Yes	Reynolds Creek Fire, 2016	No
Golden Staircase (high)	2016	Spring	5,900 - 6,035	Yes	Reynolds Creek Fire, 2016	No
Upper Nyack	2016	Fall	7,340 - 7,445	Yes	Thompson Fire, 2016	No
Sperry Chalet	2018	Fall	6,645 - 6,690	Yes	Sprague Fire, 2017	No
Mount Brown Lookout	2018	Fall	7,420 - 7,460	Yes	Sprague Fire, 2017	No

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B. METHODS

1. Seedling Monitoring Plots

Shortly after seedlings are planted, monitoring plots are installed. Plot locations are chosen based on areas that are representative of the planting site and that contain a relatively high concentration of newly planted trees. UTM coordinates are taken at plot center and directions to the plot are recorded. To further assist with center stake location, a photo is taken of each stake and its associated location and azimuth are recorded.

Plot center is permanently marked with a large nail and tagged with the plot number. Plot numbers are either engraved on brass tags or hand pressed on aluminum tags. Plot center is chosen in order to capture as many trees in all directions as possible. Descriptive data are recorded for the plot, including slope, aspect, elevation, light availability, landform, moisture regime, dominant lifeform cover, potential animal disturbance and soil type. Special attention is given to describing the location of the center nail.

Each planted seedling within the plot is located and assigned a number. For each seedling, the distance from plot center, in meters, and azimuth from plot center are recorded. The health of each tree is assessed and recorded, using the following scale: 1=dead, 2=missing (not found), 3=almost dead, 4=fair, 5=good (healthy). Comments that

further describe the tree's health or may have a bearing on its ability to survive (e.g. growth, dead needles, number of seedlings planted together, presence and type of microsite, and whether or not a seedling was inoculated with ectomycorrhizal fungi) are recorded as well. In 2015, recording the cardinal direction that the tree is located from the microsite was added.

Plots are distributed throughout the planting site to avoid over-sampling any given area, if possible. Monitoring plots attempt to capture approximately 20% of the total seedlings planted at each site. The number of seedlings captured per plot and plot radius varies between plots but ideally plots contain 15 to 50 trees with a radius not much larger than 10 meters. It is difficult to obtain accurate distances or see all seedlings in plots with radii greater than 10 meters.

Subsequent monitoring events entail locating each plot and each seedling within the plot and utilizing the 5 point scale of health and survival assessment with comments as deemed necessary. Trees assigned a "2" (missing) were either previously dead and subsequently had disintegrated or were not found. At times, a tree can be given a "2" one year and then be found alive the next year. Additionally, beginning in 2007, height and width of whitebark pine seedlings began to be measured (in cm), although only height was recorded the first year at Red Eagle (2007). As seedlings become larger and more susceptible to infection with blister rust, they are examined for infection with active or inactive cankers, indicating blister rust infection.

Initially, plots were scheduled to be monitored at years 1, 2, 3, 5, 10, 15 and 20 years after planting. Due to high numbers of scheduled plantings between 2013 and 2016, however, it was decided to skip year 2 monitoring. This ensures that there is time to establish plots at new sites, as well as visit existing monitoring plots. Monitoring intervals may be re-examined in the future to reflect the amount of time, personnel and budget available.

2. *Whitebark Pine Seed Monitoring Transects*

There have been two methodologies used to install plots that monitor whitebark pine seed that is planted directly into the ground. On Caper Peak, two plots were installed in 2006 that resembled the whitebark and limber pine seedling plots. A center nail was installed, tagged, and documented with a GPS. Azimuth and distance from plot center measurements were then recorded for each seed cache, similar to the seedling plots described above. Multiple plantings occurred at each azimuth but with different distances from the center point. In this case, seed caches were interspersed with planted seedlings so that these two plots contain both seedlings and seed in the same plot. Plots ranged in size from 18 to 19 foot radius. Thirty eight and twenty nine caches of seed were installed in these plots, respectively, with each cache containing 4 to 13 seeds. Due to their remote location, these plots have only been monitored in 2008, two years after seeding, and in 2016, ten years after seeding.

A different methodology was used in 2007 near Siyeh Bend and Red Eagle Campground to monitor whitebark pine seed. In both locations, transects ranging from 20 to 30m were installed along relatively flat benches or mild slopes. These locations were chosen for their stability and the fact that large-scale snow movement that could take out both seedlings and monitoring stakes did not seem likely. Transects generally ran parallel to any slope that existed and were staked at the start and end of the transect line. GPS locations were recorded for the start and end points. A tape was laid out between these two points and then planting sites were haphazardly located at different distances either upslope or downslope originating from different lengths along the center line. Eight to thirteen caches of seed were then planted along the transect with 3 to 5 seeds per cache at Siyeh Bend and 6 to 10 seeds per cache at Red Eagle. The location of each cache was staked with a tagged nail, and several parameters were recorded, including the distance along the transect line and direction and distance up or down from the transect line. Attempts were made to plant the seed caches in appropriate microsites for shade or to prevent erosion and snow damage. Attempts were also made to plant the seed caches within relatively open areas to reduce competition from other vegetation. Associated species, microsite slope, and description of the microsite were recorded for each cache site.

C. RESULTS AND DISCUSSION

1. *Limber Pine Seedling Results*

Limber pine seedlings have been planted at 21 sites, 16 of which continue to support live trees in monitoring plots (Figure 17). Table 23 is a summary of all the limber plantings to date indicating the number of trees that have survived to date, percent survival, and the health ratings at each site. Overall, survival rate of monitored seedlings across all projects is 31%.

Two sites were monitored in 2018; one site fifteen years after planting, and one site five years after planting. The Two Medicine Camp Store was the only site with that was planted with limber pine in 2003, with only one tree surviving to be monitored. Results below pertain only to sites monitored in 2018.

Table 23. Parkwide: Health and Survival of Remaining Live Limber Pine Seedlings as of Latest Monitoring Event, 2002 – 2018.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Dead / Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unk.</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Various	2002	fall	2004	547	0	0	0	0	0	547	0%
Firebrand Pass Trail	2002	fall	2017	37	0	0	1	0	1	38	3%
Total 2002				584	0	0	1	0	1	585	0.2%
Two Med Camp Store	2003	fall	2012	25	0	0	1	0	1	26	4%
Total 2003				25	0	0	1	0	1	26	4%
Baring Creek	2004	spring	2014	62	0	4	17	0	21	92	23%
Base of Altyn Peak	2004	fall	2014	30	0	0	10	0	10	40	25%
Dead Horse Point	2004	fall	2014	52	0	0	0	0	1	53	2%
Sun Point	2004	fall	2014	51	0	0	4	0	4	55	7%
Total 2004				195	0	4	31	0	36	240	15%
Scenic Point	2005	fall	2015	138	0	2	9	0	11	149	7%
Total 2005				128	1	5	15	0	21	149	14%
Baring Creek	2006	spring	2016	68	0	2	1	0	3	71	4%
Dead Horse Point	2006	spring	2009	20	0	0	0	0	0	20	0%
Total 2006				68	0	2	1	0	3	91	3%
Cutbank	2012	spring	2017	39	3	20	20	0	43	82	52%
Apikuni Flats (Spring)	2012	spring	2017	56	0	4	19	0	23	79	29%
Apikuni Flats (Fall)	2012	fall	2017	40	1	1	7	0	9	49	18%
Rising Sun CG	2012	spring	2017	128	0	4	8	0	12	140	9%
Scenic Point (Spring)	2012	spring	2017	86	1	4	64	0	69	155	45%
Scenic Point (Fall)	2012	fall	2017	134	0	2	59	0	61	195	31%
Many Glacier Well Area	2012	fall	2017	49	0	3	11	0	14	63	22%
Total 2012				532	5	38	188	0	231	763	30%
Spot Mountain	2013	spring	2018	108	0	4	31	0	35	143	24%
Spot Mountain	2013	fall	2018	129	1	10	66	2	77	208	37%
Total 2013				237	1	14	97	2	112	349	32%
Baring Creek	2016	spring	2017	3	0	3	23	0	26	29	90%
Dead Horse Point (lower)	2016	spring	2017	7	0	7	114	0	121	128	95%
Dead Horse Point (upper)	2016	spring	2017	4	0	9	118	0	127	131	97%
Golden Staircase	2016	spring	2017	7	3	9	23	0	35	42	83%
Lost Lake	2016	fall	2017	1	1	5	57	0	63	64	98%
Otokomi (lower)	2016	spring	2017	15	2	6	29	0	37	52	71%
Turnout 6 (GTSR, St. Mary)	2016	spring	2017	12	2	4	27	0	33	45	73%
Total 2016				49	8	43	391	0	442	491	90%
Overall Total				1818	15	106	725	2	847	2694	31%
Percentage of Surviving Trees					2%	13%	86%	0%			
Percentage of Monitored Trees				67%	0.6%	4%	27%	0%			

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a. Fifteen Year Old Plantings

The only site planted in 2003 was the Two Medicine Camp store. Only 26 trees were planted here, and all were captured in a single monitoring plot. After 15 years, there continues to be a 4% survival rate in this plot. Only one tree has survived in this plot since 2012. The surviving tree was thriving, however, and measured 70 cm tall by 74 cm wide, which was 27 cm taller and 33 cm wider since five years previous.

b. Five Year Old Plantings

Spot Mountain was the only site planted with limber pine seedlings in 2013 which included both spring and fall plantings. Approximately 669 trees were planted on the toeslope of Spot Mountain in the spring of 2013 and an additional 745 seedlings were planted in the fall (Figure 19). Four monitoring plots were established in the spring and three plots were established in the fall at this site, capturing 20% and 27% of planted trees, respectively. All plots were monitored in 2014, one year after planting, in 2016, three years after planting and in 2018, five years after planting. Similar to all other limber pine planting areas prior to 2016, this site had not been burned.

Overall five year survival at Spot Mountain was 32%, down 15% from three year survival (Table 24). Survival continues to be higher in fall-planted seedlings, at 37%, compared to 24% survival in spring-planted seedlings. This survival rate is slightly above average for all limber pine seedlings five years after planting, calculated at 24% for all limber pine seedlings planted in the park (Table 25). Survival at Spot Mountain was above average for the first three years after planting, but death rates have increased between three and five years post planting. This is a relatively open, rocky, dry habitat, which might not have supported seedlings well over the past two summers which were very hot and dry. Between 2016 and 2018, survival declined by 17% in fall-planted seedlings, while survival declined by 12% in spring-planted seedlings.

Spring-planted seedlings had lower survival than fall-planted seedlings, but grew more in width than fall planted seedlings over the past two years (Table 24). Width in seedlings planted in the spring averaged 1.9 cm wider as seedlings planted in the fall, but height was virtually the same as in fall planted seedlings. Average height increased 1.08 cm in fall-planted seedlings over the past two years, while average width increased 2.44 cm in seedlings planted in the spring. Seedlings planted in the fall increased 1.94 cm in height and 1.72 cm in width.

To date, there have been no clear trends in limber or whitebark pine plantings in Glacier as to whether spring or fall plantings have better survival. Many factors appear to play a role in survival, including weather, specific site conditions, planting techniques, and experience of planters. At this site, inexperienced planters were utilized in the spring and it was noted that several of the seedlings were not planted deep enough, exposing their roots. This may have accounted for the initial higher death rate in spring-planted sites, but it is unknown why there was a subsequent spike in the death-rate of fall-planted seedlings that was not mirrored in spring-planted trees. Site differences may be at least partially responsible.

Table 24. Spot Mountain: Health, Survival and Average Height and Width of Limber Pine Seedlings Planted in 2013.

Site	Monitoring Year	Years Post Planting	Dead/ Missing	Almost Dead	Fair	Good	Unknown	# of Trees Monitored	# of Trees Survived	% Survival	Average Height	Average Width
Spot Mtn. - Spring	2013	0	0	2	1	131	0	134	134	100%	9.09	9.6
	2014	1	72	3	25	42	0	142	70	49%	7.59	8.11
	2016	3	92	4	13	34	0	143	51	36%	9.18	8.82
	2018	5	108	0	4	31	0	143	35	24%	10.26	11.26
Spot Mtn.- Fall	2013	0	0	0	1	200	0	201	201	100%	8.87	8.87
	2014	1	22	14	33	135	0	204	182	89%	7.45	7.53
	2016	3	95	2	30	80	0	207	112	54%	8.33	7.63
	2018	5	129	1	10	66	2	208	77	37%	10.27	9.35
Overall	2013	0	0	2	2	331	0	335	335	100%	8.98	9.235
Overall	2014	1	94	17	58	177	0	346	252	73%	7.52	7.82
Overall	2016	3	187	6	43	114	0	350	163	47%	8.76	8.23
Overall	2018	5	237	1	14	97	2	351	112	32%	10.27	10.31

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Planted 2013 tab)

Figure 20. Spot Mountain: Limber Pine Monitoring Plots, Planted in the Spring and Fall of 2013.

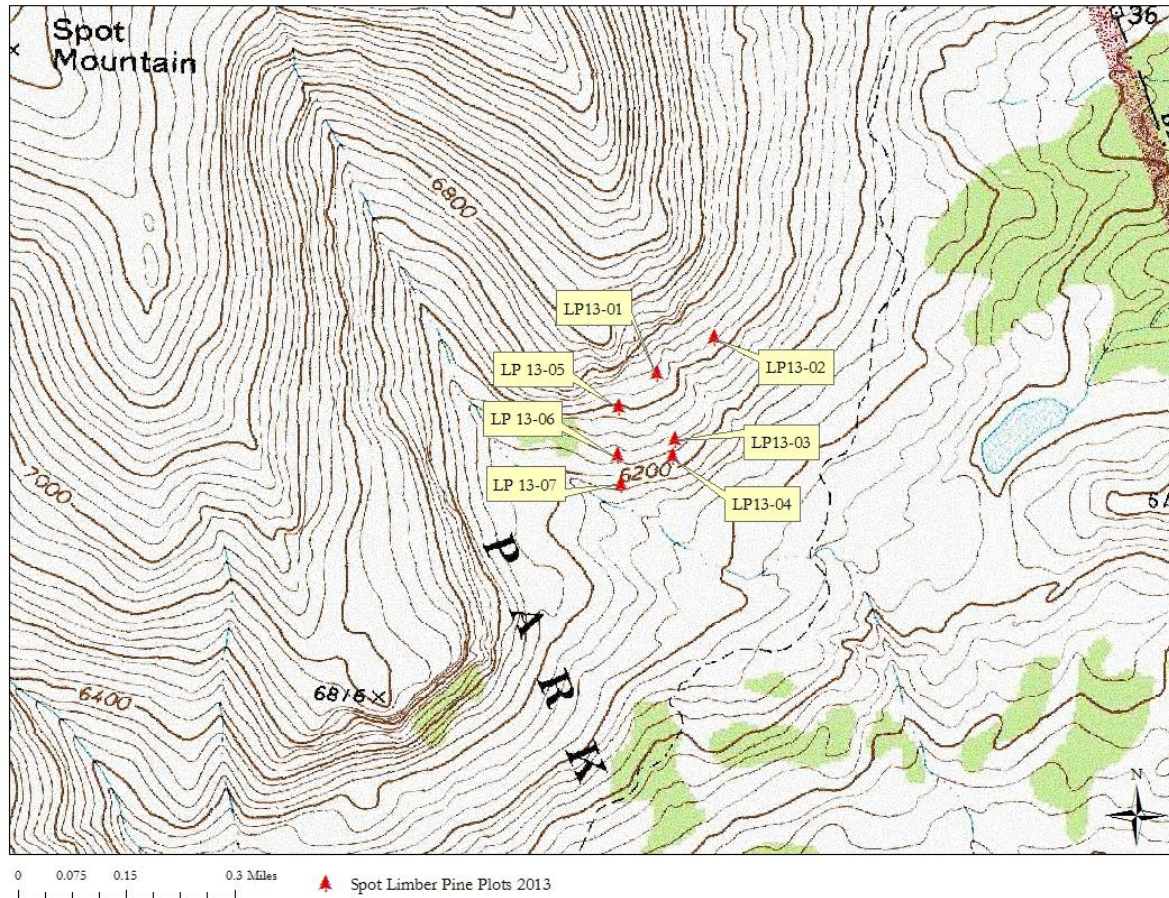


Table 25. Parkwide: Average Survival, Height and Width for All Limber Pine Seedling Monitoring Projects Across the Park at Five Years Post Planting.

	<i>Planting Year</i>	<i>Monitoring Year</i>	<i>Total # Of Trees Monitored</i>	<i>Total # of Trees Survived</i>	<i>% of Trees Survived</i>	<i>Average Height</i>	<i>Average Width</i>
Baring Creek	2004	2009	90	20	22%	19.7	12.95
Base of Altyn Peak	2004	2009	40	12	30%	10.17	9.42
Dead Horse Point	2004	2009	53	1	2%	27	9
Sun Point	2004	2009	55	4	7%	13	12.25
Scenic Point	2005	2010	149	21	14%	14.52	13.05
Baring Creek	2006	2011	71	3	4%	20.33	9.67
Dead Horse Point	2006	2011	20	0	0%	-	-
Apikuni Flats (Spring)	2012	2017	79	23	29%	15.04	8.83
Apikuni Flats (Fall)	2012	2017	49	9	18%	11.11	8.89
Cutbank	2012	2017	82	43	52%	11.40	10.58
Many Glacier Well	2012	2017	63	14	22%	15.21	14.43
Rising Sun	2012	2017	140	12	9%	12.75	13.75
Scenic Point (Spring)	2012	2017	195	61	31%	12.31	10.77
Scenic Point (Fall)	2012	2017	195	61	31%	12.31	10.77
Spot Mountain (Spring)	2013	2018	143	35	24%	10.26	11.26
Spot Mountain (Fall)	2013	2018	351	112	32%	10.27	9.35
Total/Average			1775	431	24%	14.36	11.00

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Limber health and survival tab)

2. *Whitebark Pine Seedling Results*

Whitebark pine seedlings have been planted at 23 sites between 2000 and 2018, all of which continue to support live trees (Figure 70). Tables 26 and 27 are summaries of all the whitebark plantings to date, indicating the number of trees that have survived to date, percent survival, the overall health rating and average sizes of seedlings at each site. Overall survival for monitored whitebark pine seedlings planted in the park is 52% based on the most recent monitoring event at each site.

Further discussion in this report only reflects the sites monitored this year. Three whitebark pine planting sites were re-monitored in 2018; Firebrand Pass Trail at five years after planting, Scenic Point at three years after planting, and Numa Lookout at five years and three years after planting

Whitebark pine seedlings were planted at two new sites this year, both inside the burn perimeter of the Sprague Fire of 2017. In 2018, in the fall, 1,007 seedlings were planted between these two sites.

Table 26. Parkwide: Survival and Average Height & Width for Whitebark Pine Seedlings from the Most Recent Monitoring Year.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>% Survival</i>	<i>Monitoring Year</i>	<i>Average</i>	
						<i>Height</i>	<i>Width</i>
Grinnell Point	2000	fall	2015	65%	15	53.81	66.66
Flattop Mtn. Spring 2001	2001	spring	2016	25%	15	82.47	50.65
Flattop Mtn. Fall 2001	2001	fall	2016	33%	15	85.70	66.52
Average 15 year-old-trees				41%		73.99	61.28
Flattop Mtn. Fall 2002	2002	fall	2016	38%	14	72.62	61.38
Average 14 year-old-trees				38%		72.62	61.38
Caper Peak	2006	fall	2016	34%	10	35.72	32.68
Red Eagle - upper	2007	fall	2017	52%	10	72.81	63.55
Average 10 year-old-trees				43%		54.27	48.12
Divide Creek	2010	fall	2015	94%	5	19.42	20.71
Divide Mountain	2012	fall	2017	55%	5	11.18	12.36
Firebrand Pass Area	2013	spring	2018	74%	5	13.75	14.03
Firebrand Pass Area	2013	fall	2018	53%	5	11.22	12.69
Hole-in-the-Wall	2010	fall	2015	28%	5	11.92	11.06
Cobalt Lake	2011	late summer	2016	6%	5	14.83	11.00
Numa Lookout	2013	fall	2018	36%	5	14.47	10.66
Grinnell Picnic Area	2011	late summer	2016	40%	5	18.55	21.60
Average 5 year-old-trees				48%		14.42	14.26
Divide Creek	2014	fall	2017	75%	3	14.63	14.58
Firebrand Pass Area	2014	spring	2017	66%	3	12.87	13.36
Firebrand Pass Area	2014	fall	2017	3%	3	9.25	10.00
Numa Lookout	2014	fall	2017	50%	3	12.77	10.13
Numa Lookout	2015	fall	2018	15%	3	9.00	8.90
Scenic Point	2014	spring	2017	53%	3	9.58	9.87
Scenic Point	2015	fall	2018	32%	3	10.59	10.23
Spot Mountain	2014	spring	2017	46%	3	9.45	9.36
Whitetail	2014	fall	2017	31%	3	9.72	9.53
Average 3 year-old-trees				41%		10.87	10.66
Red Eagle - lower	2007	fall	2008	0%	1	8.79	8.82
Dead Horse Point (upper)	2016	spring	2017	89%	1	11.73	12.33
Goat Mountain Slope	2016	spring	2017	94%	1	13.50	14.13
Golden Staircase (upper)	2016	spring	2017	100%	1	11.88	12.86
Otokomi (lower)	2016	spring	2017	97%	1	11.62	12.51
Otokomi (upper)	2016	spring	2017	95%	1	12.77	12.45
Average 1 year-old-trees				79%		11.72	12.18

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab)

Table 27. Parkwide: Overall Health and Survival of Whitebark Pine Planted in Glacier National Park, 2001-2018; as of Latest Monitoring Event.

Site	Year Planted	Season Planted	Last Year Monitored	Monitoring Year	Dead / Missing	Almost Dead	Fair	Good	Unk.	# Survived	# of Trees Monitored	% Survival
Grinnell Point	2000	fall	2015	15	34	0	1	61	0	62	96	65%
Total 2000					34	0	1	61	0	62	96	65%
Flattop Mtn. Spring 2001	2001	spring	2016	15	286	1	9	85	0	95	381	25%
Flattop Mtn. Fall 2001	2001	fall	2016	15	170	0	3	79	0	82	252	33%
Dutch Creek Fall 2001*	2001	fall	2001	0	0	0	0	100	0	100	100	100%
Total 2001					456	1	12	264	0	177	633	28%
Flattop Mtn. Fall 2002	2002	fall	2016	14	182	0	7	103	0	110	292	38%
Total 2002					182	0	7	103	0	110	292	38%
Caper Peak	2006	fall	2016	10	93	3	4	40	0	47	140	34%
Total 2006					93	3	4	40	0	47	140	34%
Red Eagle - upper	2007	fall	2017	10	170	1	21	165	1	187	358	52%
Red Eagle - lower	2007	fall	2017	10	55	0	0	0	0	0	55	0%
Total 2007					225	1	21	165	1	187	413	45%
Divide Creek (Lower)	2010	fall	2015	5	16	0	0	249	0	249	265	94%
Hole-in-the-Wall	2010	fall	2015	5	123	2	5	42	0	49	172	28%
Total 2010					139	2	5	291	0	298	437	68%
Cobalt Lake	2011	late summer	2016	5	102	0	2	4	0	6	108	6%
Grinnell Picnic Area	2011	late summer	2016	5	63	0	0	42	0	42	105	40%
Total 2011					165	0	2	46	0	48	213	23%
Divide Mountain	2012	fall	2017	5	101	1	7	117	0	125	226	55%
Total 2012					101	1	7	117	0	125	226	55%
Firebrand Pass Area (upper)	2013	spring	2018	5	55	0	7	147	0	154	209	74%
Firebrand Pass Area (Lower)	2013	fall	2018	5	180	0	26	181	0	207	387	53%
Numa Lookout	2013	fall	2018	5	115	2	5	57	0	64	179	36%
Total 2013					350	2	38	385	0	425	775	55%
Divide Creek (Upper)	2014	fall	2017	3	55	1	15	151	0	167	222	75%
Firebrand Pass Area (Lower)	2014	spring	2017	3	36	0	6	64	0	70	106	66%
Firebrand Pass Area (Upper)	2014	fall	2017	3	149	0	2	2	0	4	153	3%
Numa Lookout	2014	fall	2017	3	59	9	15	37	0	61	120	51%
Scenic Point (Upper)	2014	spring	2017	3	89	6	9	85	0	100	189	53%
Spot Mountain	2014	spring	2017	3	24	0	2	10	0	12	36	33%
Whitecalf	2014	fall	2017	3	105	0	24	23	0	47	152	31%
Total 2014					517	16	73	372	0	461	978	47%
Numa Lookout	2015	fall	2018	3	56	1	3	6	0	10	66	15%
Scenic Point (Upper)	2015	fall	2018	3	46	1	2	19	0	22	68	32%
Total 2015					102	2	5	25	0	32	134	24%
Dead Horse Point (Upper)	2016	spring	2017	1	6	0	5	43	0	48	54	89%
Goat Mountain Slope	2016	spring	2017	1	2	0	0	32	0	32	34	94%
Golden Staircase (High)	2016	spring	2017	1	0	1	8	50	0	59	59	100%
Otokomi (High)	2016	spring	2017	1	3	2	1	59	0	62	65	95%
Otokomi (Lower)	2016	fall	2017	1	3	7	13	77	0	97	100	97%
Upper Nyak	2016	fall	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A
Total 2016					14	10	27	261	0	298	312	96%
Overall Total					2378	38	202	2130	1	2270	4649	49%
Percentage of Surviving Trees						2%	9%	94%	0%			
Percentage of Monitored Trees					51%	0.8%	4%	46%	0%			

*Dutch Creek numbers are not included in totals, since they have not been monitored since plot installation

S:VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Whitebark Health and Survival tab).

a. Five-Year-Old Plantings

i. Firebrand Pass Area (spring and fall 2013)

Four plantings have taken place near Firebrand Pass on flanks of Calf Robe Mountain. Whitebark pine seedlings were planted in the spring and fall of 2013 and in the spring and fall of 2014. Only 2013 plantings were scheduled to be monitored this year.

The Upper Firebrand Pass Area was planted in the spring of 2013. On July 2, approximately 1,032 seedlings were planted on a relatively flat bench below the cirque of Firebrand Pass. Four monitoring plots were installed to follow survivorship and health over time, capturing 20% of the seedlings planted during this event (Figure 20). Seedlings were again planted at the Firebrand Pass Trail area in the fall of 2013, but at slightly lower elevations. Two spots, about 400 meters apart, were planted on October 22 with a total of 2,350 trees. Sixteen percent of seedlings were captured in a total of five monitoring plots, including three plots on an upper bench and two plots on a lower bench.

a. Spring 2013 (Upper Firebrand Pass Area)

Five years after planting, 74% of whitebark pine seedlings have survived at the Upper Firebrand Pass Area, planted in the spring of 2013 (Table 28). This survival rate is substantially higher than found in the trees planted in the fall at the lower site at Firebrand Pass in the same year, and much higher than the overall average of 46% survival for all five-year-old whitebark pine monitoring plots in the park (Table 29). Survival among the four plots at this site ranged from 65% to 84%, declining between 5% and 10% in each plot since 2016. The death rate in each plot was similar to the number of trees rated in fair condition in each plot in 2013.

This site is one of several unburned sites that have been chosen for planting. Trends over time should be tracked to determine if unburned locations can produce high survival. Certain parameters are unknown, such as the amount of nutrients available for developing seedlings in unburned soil, or the presence or absence of mycorrhizal fungi in the soil which could affect health and survival. No seedlings in this planting were inoculated with an ectomycorrhizal slurry.

As is the trend in most plantings after year one, seedlings decreased in size the first year after planting, but increased in size in subsequent years. Seedlings grew 3.1 cm in height and 3.7 cm in width from years 3 to 5 after planting (Table 30). Average three-year height for seedlings in 2018 was 13.75 cm and average width was 14.03 cm.

Figure 21. Firebrand Pass Trail: Whitebark Pine Seedling Monitoring Plots Established along the Firebrand Pass Trail, 2013 - 2014.

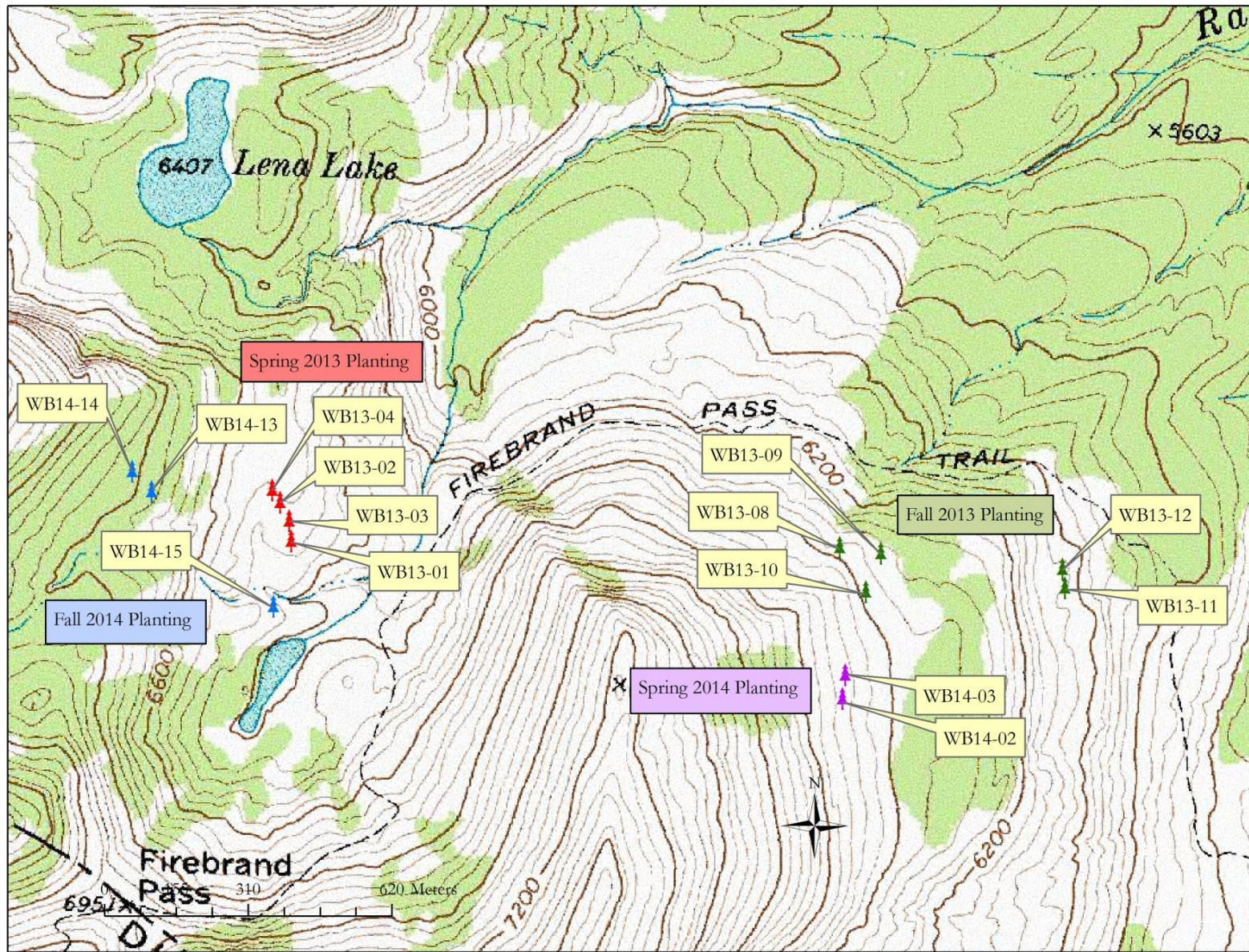


Table 28. Upper Firebrand Pass Area, Planted Spring 2013: Health and Survival of Whitebark Pine Seedlings Monitored in 2013-2018.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-13-01	Old Man	0	0	0	44	44	44	100%
WB-13-02	Old Man	0	0	0	51	51	51	100%
WB-13-03	Old Man	0	0	0	59	59	59	100%
WB-13-04	Old Man	0	0	2	52	54	54	100%
	Total 2013	0	0	2	206	208	208	100%
WB-13-01	Old Man	6	0	16	22	38	44	86%
WB-13-02	Old Man	1	1	11	38	50	51	98%
WB-13-03	Old Man	2	1	23	34	58	60	97%
WB-13-04	Old Man	5	0	2	47	49	54	91%
	Total 2014	14	2	52	141	195	209	93%
WB-13-01	Old Man	10	0	3	31	34	44	77%
WB-13-02	Old Man	3	0	5	43	48	51	94%
WB-13-03	Old Man	11	0	5	44	49	60	82%
WB-13-04	Old Man	16	0	3	35	38	54	70%
	Total 2016	40	0	16	153	169	209	81%
WB-13-01	Old Man	13	0	3	28	31	44	70%
WB-13-02	Old Man	8	0	2	41	43	51	84%
WB-13-03	Old Man	15	0	1	44	45	60	75%
WB-13-04	Old Man	19	0	1	34	35	54	65%
	Total 2018	55	0	7	147	154	209	74%

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Firebrand tab).

Table 29. Parkwide: Percent Survival and Average Height and Width for All Whitebark Pine Seedling Monitoring Plots to Date, Monitored Five Years After Planting.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>% Survival</i>	<i>Year 5</i>	
					<i>Height</i>	<i>Width</i>
Flattop Mtn. Spring 2001	2001	spring	2006	33%	20.30	14.47
Flattop Mtn. Fall 2001	2001	fall	2006	36%	19.86	17.26
Red Eagle - upper	2007	fall	2012	55%	27.81	26.94
Hole-in-the-Wall	2010	fall	2015	28%	11.92	11.06
Divide Creek - lower	2010	fall	2015	94%	19.42	20.71
Cobalt Lake	2011	late summer	2016	6%	14.83	11.00
Grinnell Picnic Area	2011	late summer	2016	40%	18.55	21.60
Divide Mountain	2012	fall	2017	55%	11.18	12.36
Firebrand Upper	2013	spring	2018	74%	13.75	14.03
Firebrand Lower	2013	fall	2018	53%	11.22	12.69
Numa	2013	fall	2018	36%	14.47	10.66
Average 5- year-old-trees				46%	16.66	15.71

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab)

Table 30. Upper Firebrand Pass Area, Planted Spring 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2013-2018.

Year	Survival	Height (cm)	Average Width (cm)
2013	100%	10.11	9.25
2014	93%	8.82	8.31
2016	81%	10.63	10.35
2018	74%	13.75	14.03

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Firebrand tab).

b. Fall 2013 – Lower Firebrand Pass Area

Overall, whitebark pine seedlings planted at the Firebrand Pass Area Lower planting site did not fare as well as the upper planting site at the Firebrand Pass area after three years. Survival averaged 53% at this site with high variability among sites (Table 31). Survival in individual plots varied greatly, and ranged from 3% to 76%. Plots 8, 9 and 10 were grouped together on an open bench further upslope. Survival rates at these sites were 3%, 53% and 76%, respectively. Plot 8, with only 3% survival, is located in an open, dry site which likely contributed the most to the demise of all but one tree in this plot. Plots 11 and 12 were located on benches further downslope at lower elevations. These plots had survival rates of 41% and 61%. Initially, one year after planting, the plots at higher elevations showed slightly better survival and it was thought that may have reflected environmental conditions that are more favorable at the higher elevation sites. However, continued variability among all plots suggests that individual site differences may be more important to survival than elevation.

One year after planting, in 2014, survivorship was slightly higher in the fall planting than the spring planting further upslope. Additionally, a much higher percent of seedlings were rated in good health in the fall planting than in the spring planting. This trend had flipped by year three, and continued by year five. Results of spring versus fall plantings is still inconclusive at this time but seems to depend more on specific site and weather conditions for each planting. Seedlings in the lower plots also originated from seed from different parent seed sources than in the upper plots as well. Lower plot seed sources were from the Old Man Lake area and Triple Divide, while seedlings in the upper plots originated from seed from Rising Wolf and White Calf. At this point, no conclusions can be made regarding parent seed source and survival.

As seen in the spring planting near this site and similar to most one-year plantings, seedlings decreased in size since the time of planting, only to grow again in subsequent years, with an accelerating growth rate. Seedlings were 2.2 cm taller and 3.3 cm wider than in 2016, two years prior (Table 32), with a growth rate of over 1 cm greater than the previous two-year growth rate. Average height for seedlings in 2018 was 11.22 cm and average width was 12.69 cm.

Some seedlings in this planting were inoculated with ectomycorrhizal fungi prior to planting, all of which were planted in the upper bench area. Fifty seedlings in plot 9 (43%) and all seedlings from plot 8 were inoculated. No seedlings in plot 10, on the upper bench, or plots 11 and 12, on the lower bench, were inoculated. All but one tree died in plot 8, most likely due to environmental conditions and with no correlation to inoculation. In plot 9, however, 53% of the planted seedlings remain alive with a disproportionate number of surviving trees that were inoculated (64% versus 45%, Tables 33, 34). Inoculated trees averaged 0.25 cm taller than non-inoculated trees, and 1.32 cm wider. It is difficult to ascertain whether these survival and size differences can be attributed to inoculation, but results are consistent with other results on inoculated seedlings at Divide Creek. Many other variables exist in the field and can never be discounted, but since these seedlings were intermixed within a plot, many environmental conditions among seedlings were similar. More comparisons should be made over time and across multiple sites to reach conclusions on the success of inoculation, but preliminary results look promising.

Table 31. Lower Firebrand Pass Area, Planted Fall 2013: Health and Survival of Whitebark Pine Seedlings Monitored in 2013-2018.

<i>Plot</i>	<i>Monitoring Year</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-13-08	2013	Rising Wolf	0	0	0	33	33	33	100%
WB-13-09	2013	Rising Wolf	0	0	1	112	113	113	100%
WB-13-10	2013	Whitecalf	0	0	0	88	88	88	100%
WB-13-11	2013	Old Man	1	0	3	70	73	74	99%
WB-13-12	2013	Triple Divide*	0	0	0	68	68	68	100%
Total Year 0			1	0	4	371	375	376	99.7%
WB-13-08	2014	Rising Wolf	0	0	0	33	33	33	100%
WB-13-09	2014	Rising Wolf	3	1	1	110	112	115	97%
WB-13-10	2014	White Calf	4	0	0	89	89	93	96%
WB-13-11	2014	Old Man	6	7	7	56	70	76	92%
WB-13-12	2014	Triple Divide*	8	2	5	55	62	70	89%
Total Year 1			21	10	13	343	366	387	95%
WB-13-08	2016	Rising Wolf	32	0	1	0	1	33	3%
WB-13-09	2016	Rising Wolf	39	0	10	66	76	115	66%
WB-13-10	2016	White Calf	16	0	56	21	77	93	83%
WB-13-11	2016	Old Man	42	1	16	17	34	76	45%
WB-13-12	2016	Triple Divide*	22	0	10	38	48	70	69%
Total Year 3			151	1	93	142	236	387	61%
WB-13-08	2018	Rising Wolf	32	0	0	1	1	33	3%
WB-13-09	2018	Rising Wolf	54	0	3	58	61	115	53%
WB-13-10	2018	White Calf	22	0	16	55	71	93	76%
WB-13-11	2018	Old Man	45	0	4	27	31	76	41%
WB-13-12	2018	Triple Divide*	27	0	3	40	43	70	61%
Total Year 5			180	0	26	181	207	387	53%

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Table 32. Lower Firebrand Pass Area, Planted Fall 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2013-2018.

Year	Survival	Average Height (cm)	Average Width (cm)
2013	99.7%	8.73	8.94
2014	95%	7.96	8.05
2016	61%	9.04	9.36
2018	53%	11.22	12.69

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Table 33. Lower Firebrand Pass Area, Planted Fall 2013: Survival and Average Height and Width of Inoculated and Non-inoculated Whitebark Pine Seedlings, 2013-2018.

Year	Survival		Average Height (cm)		Average Width (cm)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2013	100%	100%	8.51	7.39	9.02	8.36
2014	96%	98%	8.21	6.94	7.46	6.77
2016	78%	57%	8.21	7.54	9.64	8.16
2018	64%	45%	10.84	10.59	13.25	11.93

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Firebrand Inoculated tab).

*Calculations differ slightly from previous reports; inoculation data was re-assessed

Table 34. Lower Firebrand Pass Area, Planted Fall 2013: Health Ratings of Inoculated and Non-inoculated Whitebark Pine Seedlings, 2013-2018.

Year	5 (Good)		4 (Fair)		3 (Almost Dead)		2 or 1 (Dead or Missing)	
	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated	Inoculated	Not inoculated
2013	48(98%)	64(100%)	1(2%)	0	0	0	0	0
2014	48(96%)	62(95%)	0	1(2%)	0	1(2%)	2(4%)	1(2%)
2016	32(64%)	34(52%)	7(14%)	3(6%)	0	0	11(22%)	28(43%)
2018	30(60%)	28(43%)	2(4%)	1(2%)	0	0	18(36%)	36(55%)

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Firebrand Inoculated tab).

*Calculations differ slightly from previous reports; inoculation data was re-assessed

ii. *Numa Lookout (fall 2013)*

The Numa Lookout area was planted with whitebark pine seedlings in both the fall of 2013 and the fall of 2014. Only seedlings planted in 2013 were due for monitoring in 2018. On September 24, 2013, approximately 558 seedlings were planted at Numa Ridge on south-facing slopes just below the lookout. Three monitoring plots were installed at this site, monitoring 167 trees or 30% of planted seedlings (Figure 22). Seedlings were grown from seed collected from the Numa Lookout area. This site has not burned.

Survival in this planting plummeted dramatically five years after planting, after experiencing excellent early success. Five year survival was 36%. (Table 35). First year survival, at 99%, was the best that Glacier National Park had seen to date (Table 25). By year three, survival declined, but not drastically, averaging 87% across plots.

There are several potential reasons why initial survival was so high at this unburned site. The weather was cold and wet at the time of planting, prime conditions for tree survival. Seedlings were not required to experience a lack of adequate water supply or heat exchange challenges. Seedlings were also watered in well after planting. These trees were also planted late in the season so that they likely went straight into dormancy. Additionally, mostly experienced planters were planting trees at this site and great care was taken to plant in appropriate sites with high quality microsites of logs, rocks or standing snags. Seedlings were also in good shape at the time of planting.

The most likely factor causing the slight decline in subsequent survival is weather related. It is typical for most tree death to take place within the first few years after planting when seedlings are still establishing a root system. During this time, heat and drought stress are particularly damaging to developing seedlings. The summers of 2014, 2017 and 2018 were unusually hot and dry, which could have stressed and eventually killed many seedlings.

Some seedlings in this planting were inoculated with ectomycorrhizal fungi prior to planting. All seedlings in plots 5 and 6 were inoculated. Ironically, survival continued to be lower in these plots, at 17% and 47%. In plot 7, where 58% of seedlings were inoculated, survival was higher, at 58%. In plot 7, where some trees were inoculated and some were not, higher survival was found in those seedlings not inoculated (72% vs. 48% of inoculated seedlings). Environmental conditions tend to be most important to seedling survival, so it is difficult to make conclusions from plot to plot regarding the success of inoculation. Future monitoring should track success of inoculated versus non-inoculated seedlings at this site.

Surviving seedlings did grow, however, since the last monitoring event. Seedlings grew in height by an average of 2.3 cm, and in width by 1.2 cm, although they are still smaller than average seedlings five years after planting (Tables 36, 25).

Figure 22. Numa Lookout: Whitebark Pine Seedling Monitoring Plots Established in, 2013 – 2014.

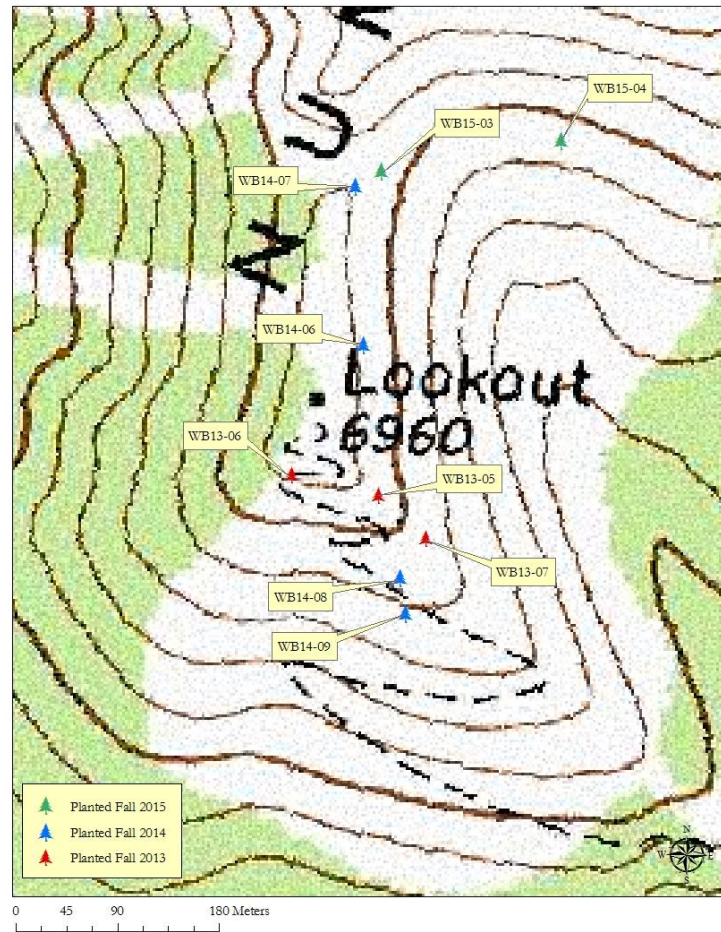


Table 35. Numa Lookout, Planted Fall 2013: Health and Survival of Whitebark Pine Seedlings Monitored in 2013-2018.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-13-05	Numa	0	0	0	75	75	75	100%
WB-13-06	Numa	0	0	0	49	49	49	100%
WB-13-07	Numa	0	0	0	43	43	43	100%
	Total 2013	0	0	0	167	167	167	100%
WB-13-05	Numa	1	0	1	80	81	82	99%
WB-13-06	Numa	1	1	4	44	49	50	98%
WB-13-07	Numa	0	0	0	43	43	43	100%
	Total 2014	2	1	5	167	173	175	99%
WB-13-05	Numa	12	0	9	62	71	83	86%
WB-13-06	Numa	11	0	6	36	42	53	79%
WB-13-07	Numa	0	1	5	37	43	43	100%
	Total 2016	23	1	20	135	156	179	87%
WB-13-05	Numa	69	2	1	11	14	83	17%
WB-13-06	Numa	28	0	3	22	25	53	47%
WB-13-07	Numa	18	0	1	24	25	43	58%
	Total 2018	115	2	5	57	64	179	36%

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Numa tab)

Table 36. Numa Lookout, Planted Fall 2013: Overall Survival and Average Height and Width of Whitebark Pine Seedlings, 2013-2018.

Year	Survival	Average Height (cm)	Average Width (cm)
2013	100%	10.03	10.14
2014	99%	9.11	9.55
2016	87%	12.18	9.44
2018	36%	14.47	10.66

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Numa tab)

b. Three-Year-Old Plantings

i. Scenic Point (Fall 2015)

The Scenic Point planting site is located southeast and downslope from Scenic Point proper (Figure 23). Historically, this area supported one of the larger whitebark pine stands in the Park. It remains one of the Park's healthiest stands with a fair amount of live trees and documented plus trees despite a substantial amount of blister rust present on all age classes. There is also a notable amount of natural regeneration of whitebark pine here. This area has not been burned.

On September 22, 2015, this area was planted for the second time with 222 whitebark pine seedlings. Plantings took place southeast of the fall 2014 planting area and of the plus trees identified in the area. This site is located among an existing whitebark pine stand with open, gravelly soil between trees. Two monitoring plots were installed on the same day, encompassing 68 trees or 31% of planted seedlings.

Survival rates after three years confirmed what had been expected from the beginning, that these trees were unlikely to be very successful, mostly due to heat stress. Overall survival had decreased to 32% three years after planting, with 19% survival in plot 1 and 44% survival in plot 2 (Table 37). While surviving trees grew an average of 1.9 cm in height over the past two years, they were 2.1 cm less in width. Average height was 10.59 cm and average width was 10.23 cm, smaller than most third-year seedlings (Table 38). Most surviving trees were rated in good health, however.

First year survival at 97% was surprisingly high at this site and one of the best observed in Glacier to date. Most trees were in good health at the time of monitoring with 85% of surviving trees rated "good". This high initial survival rate was unexpected for several reasons. This site is relatively rocky and open, which is often detrimental to seedling success, although the soil was determined to be good for planting. Additionally, all seedlings had burnt needle tips at the time of planting, which the Coeur d'Alene Nursery reported were from heat stress. At the time of planting, weather was warm and dry, following an excessively warm and dry summer. This weather pattern continued over the fall of 2015, which was followed by a winter with low precipitation. Even given the unusually wet summer and fall of 2016, many seedlings were unable to survive the subsequent extreme heat and drought of the summers of 2017 and 2018.

Table 37. Scenic Point, Fall 2015: Health and Survival of Whitebark Pine Seedlings Monitored in 2018.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-15-01	Rising Wolf	0	0	0	32	32	32	100%
WB-15-02	Rising Wolf	0	0	1	35	36	36	100%
	Total 2015	0	0	1	67	68	68	100%
WB-15-01	Rising Wolf	0	0	4	28	32	32	100%
WB-15-02	Rising Wolf	2	0	6	28	34	36	94%
	Total 2016	2	0	10	56	66	68	97%
WB-15-01	Rising Wolf	26	0	1	5	6	32	19%
WB-15-02	Rising Wolf	20	1	1	14	16	36	44%
	Total 2018	46	1	2	19	22	68	32%

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Scenic Point tab)

Figure 23. Whitebark Pine Seedling Monitoring Plots Established at Scenic Point, 2013 - 2015.

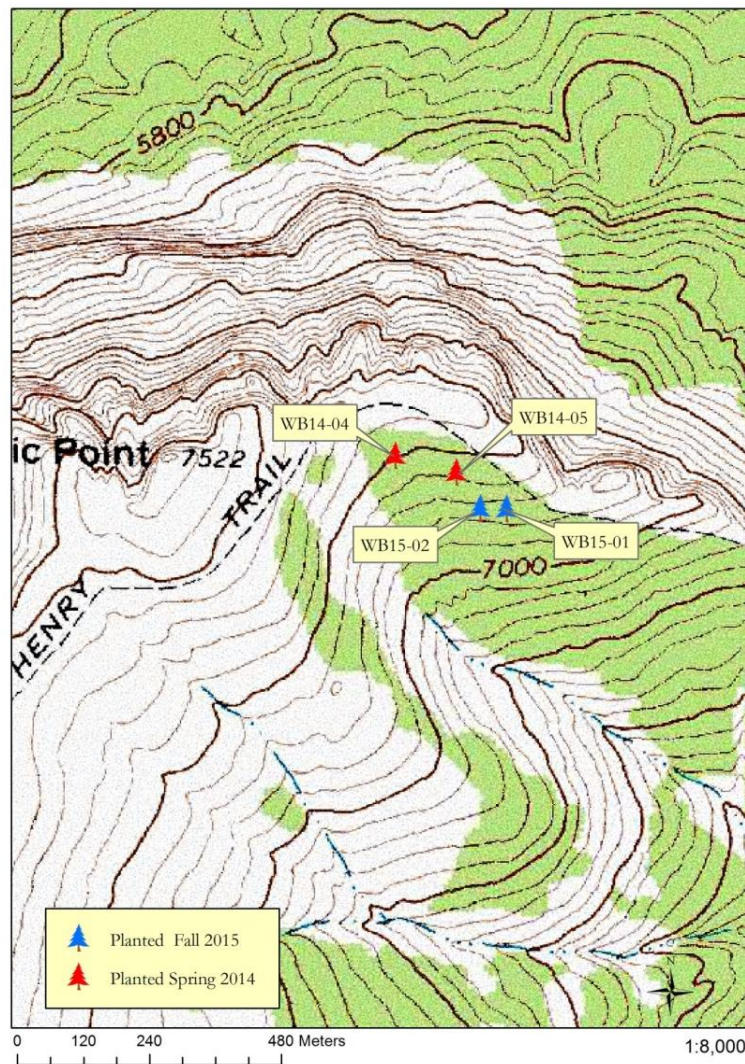


Table 38. Scenic Point, Fall, 2015: Overall Survival and Average Height and Width of Whitebark Pine, 2018.

Year	Survival	Average Height (cm)	Average Width (cm)
2015	100%	10.76	12.07
2016	97%	8.71	12.29
2018	32%	10.59	10.23

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Scenic Point tab)

Table 39. Parkwide: Percent Survival and Average Height and Width for All Whitebark Pine Seedling Monitoring Plots to Date, Monitored Three Years After Planting.

Site	Year Planted	Season Planted	Year Monitored	% Survival	Year 3	
					Height	Width
Flattop Mtn. Fall 2002	2002	fall	2005	48%	*	*
Red Eagle - upper	2007	fall	2010	57%	15.87	17.55
Divide Creek - lower	2010	fall	2013	94%	12.37	14.52
Grinnell Picnic Area	2011	late summer	2014	40%	12.79	15.81
Cobalt Lake	2011	late summer	2014	10%	13.00	11.27
Divide Mountain	2012	fall	2015	59%	9.96	10.45
Firebrand (upper)	2013	spring	2016	81%	10.63	10.35
Firebrand (lower)	2013	fall	2016	61%	9.04	9.36
Numa	2013	fall	2016	87%	12.18	9.44
Divide Creek	2014	fall	2017	75%	14.63	14.58
Firebrand (lower)	2014	spring	2017	66%	12.87	13.36
Firebrand (upper)	2014	fall	2017	3%	9.25	10.00
Numa	2014	fall	2017	50%	12.77	10.13
Scenic Point (upper)	2014	spring	2017	53%	9.58	9.87
Spot	2014	spring	2017	33%	9.50	9.58
Numa	2015	fall	2018	15%	9.00	8.90
Whitecalf	2014	fall	2017	31%	9.72	9.53
Scenic Point (upper)	2015	fall	2018	32%	10.59	10.23
Average 3- year-old-trees				50%	11.40	11.47
Average spring only				58%	10.65	10.79
Average fall only				51%	11.40	11.34

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Whitebark Height and Width tab)

ii. Numa Lookout (fall 2015)

On September 24, 2015, the area north of the lookout on the flank of Numa Peak was planted with 222 whitebark pine seedlings. This site is the furthest north that seedlings have been planted in the area. Plantings took place in short stature open forested areas that were dominated by subalpine fir, whitebark pine and/or subalpine larch. The understory was relatively thick with beargrass and big huckleberry. Two monitoring plots were installed on the same day, encompassing 64 trees or 29% of planted seedlings (Figure 22).

Survival after three years fell drastically, to just 15%, after decent initial survival (Table 40). Year one survival for seedlings in this planting had been 86%. All trees have died in one of the plots, which is located in a more open, unsheltered area. Ten trees continue to survive in the more shaded plot, a 27% survival rate for that plot.

Surviving seedlings were actually smaller in both height and width, on average, than two years previously (Table 41). Average height was 2.8 cm shorter and average width was 2.5 cm less than in 2016. Survival and size of trees at this site is well below average for seedlings three years after planting.

At the time of planting, all seedlings had burnt needle tips which resulted from heat stress in the Coeur d'Alene Nursery, so it is somewhat surprising that survival rates were high at this site. It likely points to good conditions following planting and good planting techniques. However, subsequent weather patterns did not bode well for seedling establishment, as the summers of 2017 and 2018 were extremely hot and dry. Unsheltered seedlings especially seemed to fare poorly.

Table 40. Numa, Fall 2015: Health and Survival of Whitebark Pine Seedlings Monitored in 2018.

<i>Plot</i>	<i>Seed Source</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
WB-15-03	Rising Wolf	0	0	0	35	35	35	100%
WB-15-04	Numa	0	0	0	29	29	29	100%
	Total 2015	0	0	0	64	64	64	100%
WB-15-03	Rising Wolf	9	2	1	25	28	37	76%
WB-15-04	Numa	0	0	0	29	29	29	100%
	Total 2016	9	2	1	54	57	66	86%
WB-15-03	Rising Wolf	27	1	3	6	10	37	27%
WB-15-04	Numa	29	0	0	0	0	29	0%
	Total 2018	56	1	3	6	10	66	15%

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

Table 41. Scenic Point, Fall, 2015: Overall Survival and Average Height and Width of Whitebark Pine, 2018.

Year	Survival	Average Height (cm)	Average Width (cm)
2015	100%	11.55	12.09
2016	86%	11.83	11.39
2018	15%	9.00	8.90

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Numa tab)

c. New Plantings (fall 2018)

Whitebark pine seedlings were planted at two sites in 2018: Sperry Chalet and Mount Brown Lookout (Figures 24, 25). In total, 1,007 trees were planted, all in the fall (Table 20).

All of the plantings were within the burn perimeter of the Sprague Fire of 2017. Care was taken to find suitable planting sites within the burn that previously supported whitebark pine populations and were suitable planting sites. Planting sites were established in areas that provided protection, good soil, microsites, and good planting conditions.

In addition to environmental differences brought about by spatial separation, there were several other differences between plots. Parent tree populations for planted seedlings differed and was noted. In some cases, the individual parent tree of seedlings planted in a plot was identified (Table 42). Additionally, the age of seedlings planted differed. Normally, seedlings are two years old at the time of planting, but because planting conditions were poor in 2016-2017, with extreme heat and drought, the trees slated to be planted in the fall of 2016 and all of the trees slated to be planted during 2017 were held over in the nursery in Glacier for one or two years. Another crop of seedlings arrived from the nursery in Coeur d'Alene to be planted in 2018. This generally resulted in older seedlings being larger than younger seedlings at the time of planting, and therefore sizes differed among trees. At Sperry Chalet, 190 of the planted seedlings were 2 years old, while 374 of the seedlings were 3-4 years old. At Mt. Brown, 189 of the seedlings were 2 years old, while 254 of the planted seedlings were 3-4 years old.

Monitoring plots were established shortly after planting at both of the sites. A total of 21% of planted seedlings from Sperry Chalet and 25% of planted seedlings at Mount Brown were captured in monitoring plots. At the time of planting, 100% of all monitored seedlings were rated as “good” in all plots (Table 42). No whitebark pine seedlings planted in 2018 were inoculated with an ectomycorrhizal slurry. Plots at both sites are scheduled for revisiting in 2019.

Table 42. Survival and Average Height and Width of Whitebark Pine Seedlings Planted in 2018.

Sperry Chalet - Fall 2018											
<i>Plot</i>	<i>Parent Tree/Population</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
WB18-01	Rising Wolf (1409)	2018	0	0	0	68	68	68	100%	11.1	10.30
WB18-02	Numa	2018	0	0	0	28	28	28	100%	14.4	11.10
WB18-03	Siyeh (831)	2018	0	0	0	25	25	25	100%	18.1	11.60
Total/Average						121	121	121	100%	13.3	10.76

Mount Brown Lookout - Fall 2018											
<i>Plot</i>	<i>Parent Tree</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
WB18-04	Triple Divide	2018	0	0	0	25	25	25	100%	6.4	7.04
WB18-05	Numa (1502), Siyeh 831	2018	0	0	0	43	43	43	100%	15.1	10.8
WB18-06	Numa *	2018	0	0	0	42	42	42	100%	20.2	13.5
Total/Average						110	110	110	100%	15.06	10.98

* A few trees from Rising Wolf

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (WB Planted 2018 tab).

Figure 24. Whitebark Pine Seedling Monitoring Plots Established at Sperry Chalet, 2018.

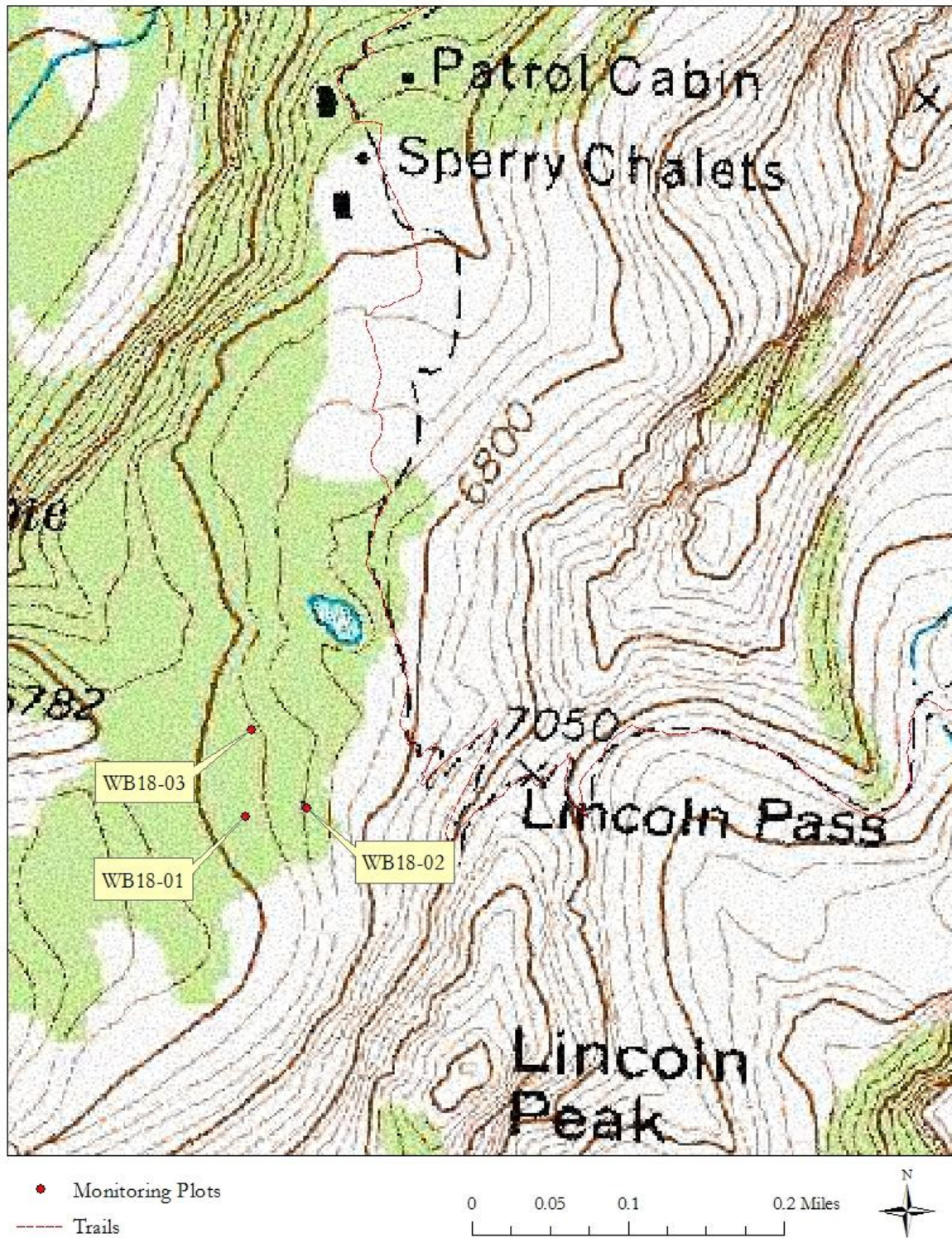


Figure 25. Whitebark Pine Seedling Monitoring Plots Established at Mount Brown Lookout, 2018.



D. RECAP, CONCLUSIONS AND RECOMMENDATIONS

1. *Limber Pine*

Overall survival of all monitored limber pine seedlings to date in the Park is 31%. The limber pine survival rate has generally improved over time due to more favorable climatic conditions at opportune times, increased knowledge and skill, and recently being able to plant in burned areas.

In 2018, only two limber pine planting sites were monitored; Spot Mountain 5 years after planting, plus a single tree remaining from a 15 year-old planting at the Two Medicine Camp Store. Five year survival for trees at Spot Mountain was 32%, while 15-year survival at the Two Medicine Camp Store was 4%. No new limber pine seedlings were planted in 2018.

The Spot Mountain planting was more successful than average for five-year-old plantings, which is 24%. However, there is a wide range of five-year survival rates across the Park, from 0% to 52%. This large range of survival rates across sites may reflect differences in environmental conditions, season of planting, and human impacts in areas with potential trampling.

At Spot Mountain, fall plantings have fared better than spring plantings five years after planting, with 37% and 24% survival, respectively. To date, there has been no clear trend in limber or whitebark pine plantings in Glacier as to whether spring or fall plantings have better survival. Many factors appear to play a role in survival, including weather, long term climatic trends, specific site conditions, planting techniques, and experience of planters. High variability across all sites in the park where seedlings were planted in both the spring and the fall suggests that local environmental factors may be more pertinent to survival than planting season. Trends should continue to be tracked over time to determine if clear guidelines can be given regarding planting season. It appears that plantings should be assessed on a case by case basis, taking into account specific conditions at each site in conjunction with short-term weather and longer-term climatic predictions.

Only two limber pine plantings have reached the fifteen years post-planting mark, both with very low survivals. Only one tree has survived of the 585 trees planted in 2002, and only one of 26 trees planted in 2003 has survived. The timeframe where these seedlings were planted and attempting to establish was plagued by heat and drought, which likely affected their success. Subsequent plantings are showing more promise, however, as planting crews improve upon factors that can be controlled.

Information from Waterton Lakes National Park (WLNP) has proven to be especially helpful in determining planting strategies in Glacier National Park. Results from a smaller planting of limber pine seedlings at WLNP (which came from the same source of seed as GNP limber pine seedlings) in 2003 had an 85% survival rate at year one after planting, 76% survival rate at year two after planting, and 72% survival rate at year three after planting (Smith et al., 2007). While the number of monitored trees is lower than GNP's data set and only looked at one planting location, survival rates of this one trial in WLNP were much higher than plantings in GNP at that time. In their study, they began to see three trends that explained our earlier low survival rates and confirm some of our observations over the past few years. They first found that limber pine seedling survival was marginally better in seedlings planted near cover (Smith et al., 2007). Supporting the theory that seedlings may need some shade and some protection from wind to prevent desiccation, cover from microsites appears to increase survival of limber pine seedlings. Glacier's planting technique has changed to incorporate microsites that offer cover that did not occur during many of the earlier plantings where high mortality resulted. Following advice from these studies has increased limber pine survival rate in the park dramatically.

Additionally, Smith et al. also found that survival and seedling health was improved when more seedlings were planted together in a clump. Singly-planted seedlings had the lowest survival rate at the end of three monitoring seasons while three- and five-clumped seedlings had higher survival rates. They argue that once emerged, seedling growth and survivorship are enhanced by the presence of other vegetation or seedlings (Powell 1996; Feldman et al. 1999) that may alleviate the abiotic effects of the surrounding environment, thus making the microclimate more suitable. The presence of other vegetation may promote growth since soil nutrients, density, and moisture are retained due to an established root system from the other plants. On the whole, a significant majority of limber pine trees planted in GNP prior to 2012 were planted as single trees, possibly putting them at a disadvantage to retain soil moisture and nutrients, as well as to obtain protection from nearby vegetation. There is also conjecture that the survival benefit of being in a larger clump may not be a long-term effect. It is conceivable that the increased competition from being surrounded by more seedlings may result in lower survival once the seedlings are large

enough to compete with one another (Smith et al., 2007). In subsequent plantings in GNP, trees were often planted in clumps, which consisted of between 2 to 4 trees per clump.

The WLNP study also showed that seedling health was marginally better in burned areas than unburned areas within the experimental area. In general, burned soils carry a higher mineral load and more nutrients than unburned soils, thus having a positive effect on the growth of seedlings. Until last year, no limber pine seedlings had been planted in burned areas in GNP. Current studies with whitebark pine in GNP support the positive effects of planting in burned areas, which is consistent with initial results from last year's plantings.

More studies throughout the west are continuing to find similar results and suggest new planting techniques for limber pine. In addition to documentation of the importance of microsites for successful seedling survival, one study in the southern Rocky Mountains found higher survival of limber pine seedlings when planted under a dense canopy (Casper 2011). They found 80% of planted limber pines survived under a dense canopy compared to a 60% survival rate for limber pines planted in open canopy, indicating that overstory vegetation may be beneficial. Similar results have been found in Glacier with ten-year-old Baring Creek limber pine seedlings, which are surviving completely underneath krummholz Douglas fir trees. They also documented higher limber pine survival when the seedlings were planted on the north or west side of microsites. In addition, they documented that spring plantings in moist soils can be highly successful. Overall limber pine survival was 76% after 3 years when trees were planted during a time of good precipitation. From this research, spring plantings of limber pine were experimented with in Glacier in 2012, 2013 and 2016 at eleven locations, and seedlings are being planted on cooler aspects of microsites when possible at all planting locations in the park.

Continued monitoring is critical as results become even more complicated with impacts from annual changes in precipitation and temperature. On the east side of GNP, where all of the limber pine sites are located, there was considerably low precipitation and higher temperatures in 2002, 2003, 2017 2018. Increased rain and cooler temperatures from 2004 to 2015 may have contributed to higher survival rates during those time periods (Appendix A). Another warm, dry regime began in 2015, with a brief reprieve in 2016, followed by extreme warm and dry conditions in 2017 and 2018. While October of 2016 was the wettest month ever recorded throughout the history of climate data collection, followed by an above average snowpack winter, potentially benefitting planted seedlings, it was followed by extreme heat and flash drought in 2017. The early growing season of 2018 was benefitted by a high snow-pack year the previous winter, but temperatures quickly soared and precipitation was sparse throughout the summer. West Glacier reached a record 101 degrees in August, the day before the Howe Ridge Fire started.

Climate change research on five-needled pines is still in its infancy but early results from these studies have documented the importance of soil moisture for the survival of limber pine (Kueppers, in press). Research has shown that limber pine seedlings shut down if there is no moisture due to zero stomatal conductance during this time. This study showed that watering clearly aids in survival across the study's entire elevation gradient. While seedlings are watered in at the time of planting in Glacier, perhaps supplemental watering should occur during the first year when possible and especially in dry years.

2. *Whitebark Pine*

Overall survival of all monitored whitebark pine seedlings to date in Glacier National Park is 49%, versus 31% for limber pine. Traditionally, revegetation of whitebark pine seedlings has shown better progress than limber pine restoration. In the years from 2012 on, however, limber pine seedlings are beginning to show better success, especially now that burned habitat has been available and utilized.

Two cohorts of whitebark pine seedlings were monitored in 2018; five year old plantings at Firebrand Pass, planted in both the spring and fall, as well as at Numa Lookout; and three year old plantings at Scenic Point and Numa Lookout. Overall survival at Firebrand Pass monitored at five years after planting was good, at 61%, with 74% survival in the spring (upper) planting and 53% survival in the fall (lower) planting. These rates are all higher than the average survival for all seedlings monitored Parkwide at five years after planting, which is 46%. Numa seedlings did not perform as well, with 36% overall survival five years after planting.

Three year plantings did not fare as well. Survival of seedlings at Scenic Point and Numa Lookout was only 32% and 15%, respectively, three years after planting. Both of these survival rates were well below the Parkwide average for three-year survival, which is 50%. High variability among plots suggests that localized environmental conditions may be more important to survival than season or elevation.

Without a clear trend linking success with planting season, these results highlight that each site is individual and needs to be assessed for planting suitability on a case by case basis. Variable conditions within sites, as well as weather following planting times, often appear to be more important to survival. Similar to limber pines, no overall trend is emerging considering spring-planted versus fall-planted trees. Spring plantings appear to do well when there is a relatively wet spring following planting, as well as a cooler, moister summer. Fall sites planted in burns and/or in areas where there was ample vegetation to provide shade and/or moisture retention also appear to do well. Sites such as Scenic Point, with open, gravelly soil show the lowest survival rates, particularly if planted in the fall followed by warmer and drier than average conditions.

Whitebark pine seedlings were planted using most of the recommendations learned from previous plantings (see bulleted list below), including planting in burned areas when possible, planting in microsites, and not using shade netting. However, due to lack of accessible burned whitebark pine habitat in the park, many of the planting sites from 2010 to 2015 occurred in non-burned areas. Additionally, several sites lacked adequate natural shelter or available microsite materials. Fires in 2015, 2017 and 2018 have provided and will continue to provide good planting habitat for plantings.

Most of these results are in keeping with, or better than, results from other whitebark pine planting projects. Izlar (2007) compiled data from 37 whitebark planting events over the last 15 years in Montana, Wyoming, and Idaho. That summary reported that typical year one survival of planted whitebark seedlings is 74% (59-92% range), typical year three survival is 38% (31-47% range), and typical year five survival is 30% (19-42% range). Many of our first year plantings are now well exceeding this survival rate at year one with several sites having survivorship in the 90% range. As with limber pine plantings, sites have been and will continue to need to be critically assessed as appropriate whitebark pine planting sites in GNP.

Direct seeding of whitebark pine seed has not been very successful so far at Glacier National Park. Only two of the five seed plots established to date have seen any germination and only one plot continues to support seedlings, with two live trees. Site selection was likely at least part of the problem at Siyeh Bend, which experiences frequent avalanches or snow slides and where seed predation by small mammals appeared high. If seed plots are to be experimented with again in the future, sites should be carefully selected and small screens should be installed to protect the seeds from herbivory. Seeds were not scarified or treated in any way prior to planting, which may also play a role. Additionally, seed was not extremely fresh or stored perfectly, which should also be taken into consideration. Future direct seeding projects should not be ruled out if preparation and precautions take place before seeding.

In recent years, Glacier staff has been more critical about choosing sites that are appropriate for limber pine planting. Greater care has also been taken in planting techniques for each seedling. The following recommendations have recently been and should continue to be considered when choosing a site and when planting limber and whitebark pine seedlings:

- Continue to assess planting conditions on a case by case basis rather than following blanket recommendations, especially concerning short-term weather and long-term climate.
- Plant in burn areas when available.
- Plantings should ideally occur in the fall when temperatures are lower and precipitation is more reliable
- For fall plantings, plant only in later September and October when precipitation is more likely. In cases when a hot, dry summer continues into the fall, consider postponing or cancelling planting if no weather change is predicted.
- Continue spring plantings if climate is conducive. Plant when precipitation is high at or near the time of planting to increase soil moisture. Consider supplemental watering in areas that are accessible during the first year of planting if precipitation levels are not as expected during the spring.
- Consider planting at higher elevations as climate changes to a warmer, drier regime.
- Plant in areas with good microsite availability that provides some shade and wind protection. Consider planting under tree canopy, when available, for additional shade.
- Plant on the north and west sides of microsites to the extent that is possible.
- Try to plant in areas that have decent to good soil moisture and soil nutrients, including low to moderate vegetation and/or an area that has burned. Consider supplemental watering in areas that are accessible during the first year of planting.

- Do not plant in areas that have on-going disturbance that would cause soil movement or trampling. Do not plant in avalanche-prone areas.
- Continue to grow seedlings in short containers to prevent j-rooting in shallow soils.
- Plant seedlings in groups of 3 to 5 seedlings, as this appears to increase survival.
- Assess the health of the seedlings prior to planting to assure that the healthiest material is being planted.
- Plant in appropriate habitat to prevent competition. Assess the influence of slopes within planting areas, the possibility of falling bark of dead trees, and the impacts of competition from regenerating vegetation.
- Do not use netting on seedlings, as it does not appear to be increasing their survival.
- Do not use water polymers or hydrogels with seedlings when planted. If these amendments are still of interest, a more controlled experiment should be conducted to determine the benefits of its use.
- Continue to research the effectiveness of fertilizer amendments on the success of planted limber pine.

3. Future Monitoring

In 2019, eight limber pine monitoring sites are scheduled to be revisited (Table 43). Four sites will be monitored at 15 years after planting; Baring Creek, Many Glacier Hotel Slope (Base of Altyn Peak), Sun Point and Dead Horse Point. Four sites planted in the Reynolds Creek Burn will be monitored three years after planting; Turnout #6 on the GTSR, Lower Golden Staircase, the lower bench on Otokomi and Lost Lake.

Nine whitebark pine planting sites are also due for monitoring. Five sites will be monitored at five years post-planting; Firebrand (upper and lower), Numa, Spot, Divide Creek Upper and Whitecalf. Four plots are due for monitoring three years after planting; Dead Horse Point Upper, Otokomi Upper, Goat Mountain Slope and Golden Staircase Upper.

In 2019, if climate cooperates, plans are to plant 500 whitebark pine seedlings. At this point, there are no plans to plant limber pine in 2019. Monitoring plots will be installed at planting areas to capture a targeted 20% of seedlings.

Table 43. Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2000	2001	2002	2003	2004	2005	2006	2007
None installed	Whitebark pine	Dutch Creek	2000?								
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000	X (year 0)						X (year 6)	
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 0)	X (year 1)			X (year 4)	X (year 5)	
FT02 -01 to -11	Whitebark pine	Flattop	2002			X (year 0)			X (year 3)	X (year 4)	
LP02 -01 to -25	Limber pine	Various	2002			X (year 0)	X (year 1)	X (year 2) ALL DEAD			
LP02-05	Limber pine	Many Glacier Hotel Slope	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT
LP02-22	Limber pine	Sun Point	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	X (year 5) 1 TREE LEFT
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT	
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 0)	X (year 1)		X (year 3)	
LP04 -01 to -05	Limber pine	Baring Creek	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -08	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -09	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -10	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP04 -11	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)	X (year 3)
LP05 -01 to -06	Limber pine	Scenic Point	2005						X (year 0)	X (year 1)	X (year 2)
LP06 -02	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)
LP06 -01 & -03	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)
LP06 -04	Limber pine	Dead Horse Point	2006							X (year 0)	X (year 1)
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006							X (year 0)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007								X (year 0)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007								
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007								X (year 0)
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010								
WB10-06 to -10	Whitebark pine	Divide Creek	2010								
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011								
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011								
WB12-01 to -04	Whitebark pine	Divide Mountain	2012								
LP12-01 to -02	Limber pine	Cutbank	2012								
LP12-03; 11	Limber pine	Apikuni Flats	2012								
LP12-04 to -05	Limber pine	Rising Sun CG	2012								
LP12-06 to -07	Limber pine	Scenic Point	2012								
LP12-10	Limber pine	Many Glacier Well Area	2012								

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Table 43, con't. Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2008	2009	2010	2011	2012
None installed	Whitebark pine	Dutch Creek	2000?			X (year 10)		
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000			X (year 10)		
FT01 -01 to -27	Whitebark pine	Flattop	2001		X (year 8)		X (year 10)	
FT02 -01 to -11	Whitebark pine	Flattop	2002		X (year 7)		X (year 9)	
LP02 -01 to -25	Limber pine	Various	2002					
LP02-05	Limber pine	Many Glacier Hotel Slope	2002		X (year 7) ALL DEAD			
LP02-22	Limber pine	Sun Point	2002		X (year 7) ALL DEAD			
LP02-24	Limber pine	Firebrand Pass Trail	2002	X (year 6)				X (year 10)
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 5)				
LP04 -01 to -05	Limber pine	Baring Creek	2004	X (year 4)	X (year 5)			
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 5)			
LP04 -08	Limber pine	Sun Point	2004		X (year 5) ALL DEAD			
LP04 -09	Limber pine	Sun Point	2004		X (year 5)			
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 5) 1 TREE LEFT			
LP04 -11	Limber pine	Dead Horse Point	2004		X (year 5) ALL DEAD			
LP05 -01 to -06	Limber pine	Scenic Point	2005	X (year 3)		X (year 5)		
LP06 -02	Limber pine	Baring Creek	2006	X (year 2)	X (year 3)		X (year 5)	
LP06 -01 & -03	Limber pine	Baring Creek	2006	X (year 2) ALL DEAD				
LP06 -04	Limber pine	Dead Horse Point	2006	done: all dead but 1 mis	X (year 3) ALL DEAD			
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006	X (year 2)			X (year 5)	
WB07 -01 to -09	Whitebark pine	Red Eagle (seedlings)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5)
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5)
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007	X (year 1)	X (year 2)	X (year 3)		X (year 5) NOTHING COMING UP
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010			X (year 0)	X (year 1)	X (year 2)
WB10-06 to -10	Whitebark pine	Divide Creek	2010			X (year 0)	X (year 1)	X (year 2)
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011				X (year 0)	X (year 1)
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011				X (year 0)	X (year 1)
WB12-01 to -04	Whitebark pine	Divide Mountain	2012					X (year 0)
LP12-01 to -02	Limber pine	Cutbank	2012					X (year 0)
LP12-03; 11	Limber pine	Apikuni Flats	2012					X (year 0)
LP12-04 to -05	Limber pine	Rising Sun CG	2012					X (year 0)
LP12-06 to -07	Limber pine	Scenic Point	2012					X (year 0)
LP12-10	Limber pine	Many Glacier Well Area	2012					X (year 0)

black text = completed

orange text = scheduled but not completed

red text = notes about trees in plots with high mortality

blue text = scheduled for future

Table 43, con't. Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019
None installed	Whitebark pine	Dutch Creek	2000?			X (year 15)				
GP00 -01 to -07	Whitebark pine	Grinnell Point	2000			X (year 15)				
FT01 -01 to -27	Whitebark pine	Flattop	2001				X (year 15)			
FT02 -01 to -11	Whitebark pine	Flattop	2002				X (year 14)			
LP02 -01 to -25	Limber pine	Various	2002							
LP02-05	Limber pine	Many Glacier Hotel Slope	2002							
LP02-22	Limber pine	Sun Point	2002							
LP02-24	Limber pine	Firebrand Pass Trail	2002					X (year 15) 1 TREE LEFT		
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 10)					X (year 15)	
LP04 -01 to -05	Limber pine	Baring Creek	2004		X (year 10)					X (year 15)
LP04 -06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 10)					X (year 15)
LP04 -08	Limber pine	Sun Point	2004							
LP04 -09	Limber pine	Sun Point	2004		X (year 10)					X (year 15)
LP04 -10	Limber pine	Dead Horse Point	2004		X (year 10) 1 TREE LEFT					X (year 15) 1 TREE LEFT
LP04 -11	Limber pine	Dead Horse Point	2004							
LP05 -01 to -06	Limber pine	Scenic Point	2005			X (year 10)				
LP06-02	Limber pine	Baring Creek	2006				X (year 10)			
LP06 -01 & -03	Limber pine	Baring Creek	2006				X (year 10)			
LP06 -04	Limber pine	Dead Horse Point	2006				X (year 10)			
WB06 -01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006				X (year 10)			
WB07 -01 to -09	Whitebark pine	Red Eagle (seeds + trees)	2007					X (year 10)		
WBS07 -04 to -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 10)		
WBS07 -01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007							
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010	X (year 3)		X (year 5)				
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 3)	X (year 4)	X (year 5)				
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011		X (year 3)		X (year 5)			
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 3)		X (year 5)			
WB12-01 to -04	Whitebark pine	Divide Mountain	2012	X (year 1)	X (year 2)	X (year 3)		X (year 5)		
LP12-01 to -02	Limber pine	Cutbank	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-03 and -11	Limber pine	Apikuni Flats	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-04 to -05	Limber pine	Rising Sun CG	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-06 to -09	Limber pine	Scenic Point	2012	X (year 1)		X (year 3)		X (year 5)		
LP12-10	Limber pine	Many Glacier Well Area	2012	X (year 1)		X (year 3)		X (year 5)		
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-13 to -15	Whitebark pine	Firebrand Pass upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015			X (year 0)	X (year 1)		X (year 3)	
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015			X (year 0)	X (year 1)		X (year 3)	
LP16-01	Limber pine	Dead Horse Point (lower)	2016				X (year 0)	X (year 1)		X (year 3)
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016				X (year 0)	X (year 1)		X (year 3)
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016				X (year 0)	X (year 1)		X (year 3)
LP16-06	Limber pine	Dead Horse Point (upper)	2016				X (year 0)	X (year 1)		X (year 3)
LP16-07	Limber pine	Otokomi (lower bench)	2016				X (year 0)	X (year 1)		X (year 3)
LP16-08	Limber pine	Baring Creek	2016				X (year 0)	X (year 1)		X (year 3)
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016				X (year 0)	X (year 1)		X (year 3)
WB16-03	Whitebark pine	Otokomi (upper)	2016				X (year 0)	X (year 1)		X (year 3)
WB16-04	Whitebark pine	Goat Mountain Slope	2016				X (year 0)	X (year 1)		X (year 3)
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016				X (year 0)	X (year 1)		X (year 3)
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016				X (year 0)	X (year 1)		X (year 3)

Table 43, con't. Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2020	2021	2022	2023	2024	2025	2026	2027
DC01-01 to -04	Whitebark pine	Dutch Creek	2001	X (year 20)					X (year 25)		
GP00-01 to -07	Whitebark pine	Grinnell Point	2000	X (year 20)					X (year 25)		
FT01-01 to -27	Whitebark pine	Flattop	2001		X (year 20)					X (year 25)	
FT02-01 to -11	Whitebark pine	Flattop	2002		X (year 19)					X (year 24)	
LP02-01 to -25	Limber pine	Various	2002								
LP02-05	Limber pine	Many Glacier Hotel Slope	2002								
LP02-22	Limber pine	Sun Point	2002								
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 20) 1 TREE LEFT					X (year 25) 1
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 20)				
LP04-01 to -05	Limber pine	Baring Creek	2004					X (year 20)			
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 20)			
LP04-08	Limber pine	Sun Point	2004								
LP04-09	Limber pine	Sun Point	2004					X (year 20)			
LP04-10	Limber pine	Dead Horse Point	2004					X (year 20) 1 TREE LEFT			
LP04-11	Limber pine	Dead Horse Point	2004								
LP05-01 to -06	Limber pine	Scenic Point	2005	X (year 15)					X (year 20)		
LP06-02	Limber pine	Baring Creek	2006		X (year 15)					X (year 20)	
LP06-01 & -03	Limber pine	Baring Creek	2006								
LP06-04	Limber pine	Dead Horse Point	2006								
WB06-01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006		X (year 15)					X (year 20)	
WB07-01 to -07 (-08 & -09)	Whitebark pine	Red Eagle (trees)	2007			X (year 15)					X (year 20)
WBS07-04 & -05	Whitebark pine	Red Eagle (seeds)	2007			X (year 15)					X (year 20)
WBS07-01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007								
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010	X (year 10)					X (year 15)		
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 10)					X (year 15)		
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011		X (year 10)					X (year 15)	
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 10)					X (year 15)	
WB12-01 to -04	Whitebark pine	Divide Mountain	2012			X (year 10)					X (year 15)
LP12-01 to -02	Limber pine	Cutbank	2012			X (year 10)					X (year 15)
LP12-03 and -11	Limber pine	Apikuni Flats	2012			X (year 10)					X (year 15)
LP12-04 to -05	Limber pine	Rising Sun CG	2012			X (year 10)					X (year 15)
LP12-06 to -09	Limber pine	Scenic Point	2012			X (year 10)					X (year 15)
LP12-10	Limber pine	Many Glacier Well Area	2012			X (year 10)					X (year 15)
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013				X (year 10)				
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013				X (year 10)				
WB13-05 to -07	Whitebark pine	Numa Ridge	2013				X (year 10)				
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013				X (year 10)				
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014					X (year 10)			
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014					X (year 10)			
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014					X (year 10)			
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014					X (year 10)			
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014					X (year 10)			
WB14-13 -14 -15	Whitebark pine	Firebrand Pass upper (fall)	2014					X (year 10)			
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014					X (year 10)			
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015	X (year 5)					X (year 10)		
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015	X (year 5)					X (year 10)		
LP16-01	Limber pine	Dead Horse Point (lower)	2016		X (year 5)					X (year 10)	
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016		X (year 5)					X (year 10)	
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016		X (year 5)					X (year 10)	
LP16-06	Limber pine	Dead Horse Point (upper)	2016		X (year 5)					X (year 10)	
LP16-07	Limber pine	Otokomi (lower bench)	2016		X (year 5)					X (year 10)	
LP16-08	Limber pine	Baring Creek	2016		X (year 5)					X (year 10)	
LP16-09 to -10	Limber pine	Lost Lake	2016		X (year 5)					X (year 10)	
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016		X (year 5)					X (year 10)	
WB16-03	Whitebark pine	Otokomi (upper)	2016		X (year 5)					X (year 10)	
WB16-04	Whitebark pine	Goat Mountain Slope	2016		X (year 5)					X (year 10)	
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016		X (year 5)					X (year 10)	
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016		X (year 5)					X (year 10)	
WB18-01 to -03	Whitebark pine	Sperry Chalet	2108		X (year 3)		X (year 5)				
WB18-04 to -06	Whitebark pine	Mt. Brown Lookout	2108		X (year 3)		X (year 5)				

Table 43, con't. Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
DC01-01 to -04	Whitebark pine	Dutch Creek	2001			X (year 30)								
GP00-01 to -07	Whitebark pine	Grinnell Point	2000			X (year 30)								
FT01-01 to -27	Whitebark pine	Flattop	2001				X (year 30)							
FT02-01 to -11	Whitebark pine	Flattop	2002				X (year 29)							
LP02-01 to -25	Limber pine	Various	2002											
LP02-05	Limber pine	Many Glacier Hotel Slope	2002											
LP02-22	Limber pine	Sun Point	2002											
LP02-24	Limber pine	Firebrand Pass Trail	2002					X (year 30) 1 TREE LEFT						
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 25)										
LP04-01 to -05	Limber pine	Baring Creek	2004		X (year 25)									
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 25)									
LP04-08	Limber pine	Sun Point	2004											
LP04-09	Limber pine	Sun Point	2004		X (year 25)									
LP04-10	Limber pine	Dead Horse Point	2004		X (year 25)									
LP04-11	Limber pine	Dead Horse Point	2004											
LP05-01 to -06	Limber pine	Scenic Point	2005			X (year 25)								
LP06-02	Limber pine	Baring Creek	2006				X (year 31)							
LP06-01 & -03	Limber pine	Baring Creek	2006											
LP06-04	Limber pine	Dead Horse Point	2006											
WB06-01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006				X (year 25)							
WB07-01 to -07 (-08 & -09)	Whitebark pine	Red Eagle (trees)	2007					X (year 25)						
WBS07-04 & -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 25)						
WBS07-01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007											
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010			X (year 20)								
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010			X (year 20)								
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011				X (year 20)							
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011				X (year 20)							
WB12-01 to -04	Whitebark pine	Divide Mountain	2012					X (year 20)						
LP12-01 to -02	Limber pine	Cutbank	2012					X (year 20)						
LP12-03 and -11	Limber pine	Apikuni Flats	2012					X (year 20)						
LP12-04 to -05	Limber pine	Rising Sun CG	2012					X (year 20)						
LP12-06 to -09	Limber pine	Scenic Point	2012					X (year 20)						
LP12-10	Limber pine	Many Glacier Well Area	2012					X (year 20)						
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 15)					X (year 20)					
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 15)					X (year 20)					
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 15)					X (year 20)					
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013	X (year 15)					X (year 20)					
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014							X (year 20)				
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014						X (year 20)					
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014						X (year 20)					
WB14-06 to -09	Whitebark pine	Numa Ridge (fall)	2014						X (year 20)					
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014						X (year 20)					
WB14-13 -14 -15	Whitebark pine	Firebrand Pass upper (fall)	2014						X (year 20)					
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014						X (year 20)					
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015			X (year 15)				X (year 20)				
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015			X (year 15)				X (year 20)				
LP16-01	Limber pine	Dead Horse Point (lower)	2016				X (year 15)					X (year 20)		
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016				X (year 15)					X (year 20)		
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016				X (year 15)					X (year 20)		
LP16-06	Limber pine	Dead Horse Point (upper)	2016				X (year 15)					X (year 20)		
LP16-07	Limber pine	Otokomi (lower bench)	2016				X (year 15)					X (year 20)		
LP16-08	Limber pine	Baring Creek	2016				X (year 15)					X (year 20)		
LP16-09 to -10	Limber pine	Lost Lake	2016				X (year 15)					X (year 20)		
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016				X (year 15)					X (year 20)		
WB16-03	Whitebark pine	Otokomi (upper)	2016				X (year 15)					X (year 20)		
WB16-04	Whitebark pine	Goat Mountain Slope	2016				X (year 15)					X (year 20)		
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016				X (year 15)					X (year 20)		
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016				X (year 15)					X (year 20)		
WB18-01 to -03	Whitebark pine	Sperry Chalet	2108	X (year 10)					X (year 15)					X (year 20)
WB18-04 to -06	Whitebark pine	Mt. Brown Lookout	2108	X (year 10)					X (year 15)					X (year 20)

VI. WHITEBARK AND LIMBER PINE PLUS TREE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). White pine blister rust is a disease of five-needled pines and has been linked to the decline of all five-needled pines in the park. Spores from a secondary host infect trees through the needles and the fungus subsequently grows into the stem, producing fusiform cankers, almost always eventually killing the tree (Hoff 1992). Glacier National Park not only has a high mortality rate associated with blister rust, but it also has an extremely high blister rust infection rate of remaining live trees. Infection is estimated at 78% for both whitebark and limber pine trees that remain in the Park (Kendall and Keane 2001). A massive effort at removing secondary hosts for white pine blister rust in the Park was attempted between 1930 and 1970. Enormous numbers of *Ribes* species were removed by hand pulling and chemical control with no success at curtailing the disease (USGS 2003). Additionally, climate change may favor conditions that enhance distribution of blister rust spores. Recent climatic conditions produce frequent “wave years” that promote massive numbers of infections (Koteen 2002). Therefore, it does not appear that preventing the spread of blister rust is an effective strategy for preservation of whitebark or limber pine.

Taking advantage of natural blister rust resistance may be a more effective strategy for restoration of whitebark and limber pine. Natural genetic resistance has been found in several species of five-needled pines and there is preliminary evidence that whitebark pine may also exhibit natural resistance (Schwandt 2006). A protocol has been implemented by U.S. Forest Service nurseries whereby potential rust-resistant seedlings are tested for resistance. Preliminary tests have revealed resistance in many whitebark pine seedlings (Maholovich et al. 2006).

Glacier National Park has been attempting to utilize naturally resistant trees in its restoration program for the past 18 years. Cones have been collected from phenotypic-resistant whitebark pine trees since 1997. Phenotypic indicators of blister rust resistance include no or very few active blister rust cankers, no or very few inactive blister rust cankers, no to little impact to canopy cover of tree (flags, dead branches, etc.), and the presence of cones. Wire cages are placed around cones during seed production for protection from predators with seed then collected later in the season. Despite best intentions, seed was combined from years 1997 to 2006 so that it is now impossible to tell which seedlings were grown from which potential rust resistant cone tree. Beginning in 2007, seedlings were able to be tracked to a parent tree in a particular location in the park (i.e., Preston Park) but surviving seedlings have not been traceable with their seed source tree.

Occasionally, trees were inadvertently caged that were infected with blister rust, and over time some of the potentially rust resistant trees have become infected. This influenced the decision to expand upon the initial purpose for monitoring potential plus trees purely as a seed source. Previously, cone trees have not been monitored over time for long-term health and resistance. Initially the purpose of this study was to identify and build baseline data for potential phenotypically rust resistant whitebark pine trees (“plus trees”) for field monitoring over time, as well as to identify potential cone collection trees for the future. Since whitebark pine often grow in very remote and isolated areas, this survey was also designed to reduce the amount of time and effort required when searching for cone trees to cage. Information is now being gathered concerning the trees’ ability to resist infection, how quickly the infection spreads and how long a tree may survive with infection. Additionally, more is now known about multiple forms of blister rust resistance in whitebark pine. Varying degrees of resistance exist, from showing no symptoms when exposed to spores to active cankers on trees that never die (Maholovich, pers. comm.). While this information may aid in future cone collection, it may also help answer questions about resistance of specific trees in Glacier’s populations that are highly infected with blister rust, as well as the fate of trees that have mild blister rust infection.

In 2009, Glacier National Park had the opportunity to join the U.S. Forest Service’s study on genetic resistance in whitebark pine plus trees. Since then, collection efforts have centered on caging from trees that meet requirements for the study. In order to be accepted into this experiment, seed must be collected from 25 individual trees, with no more than three trees per stand and individual trees being at least 300 feet apart. Protocol requires 1,800 seeds per tree to be donated to the program. One-third of the seeds will be grown into seedlings for exposure to blister rust and resistance testing, one-third will go into a seed bank and one-third will be grown into seedlings for an off-site seed orchard, if Glacier decides to participate in this. Glacier met the seed requirements for all 25 trees in 2012 and genetic testing began. Beginning in 2015, GNP has begun to receive preliminary results about the resistance in

some trees, but full results are not yet available. Glacier NP may also have the option to add additional trees to the genetics study in the near future.

In addition to blister rust, whitebark pine is also susceptible to attack from mountain pine beetle (*Dendroctonus ponderosae*), a native bark beetle. While alpine environments in Glacier have not experienced much pine beetle exposure, it has caused extensive damage to whitebark pine forests in other areas in the state in recent years. Pine beetle infestation has been moderate in the Middle Fork region of Glacier over the last few years and potentially could reach some plus tree sites. Additionally troublesome is that there seems to be an inverse relationship between blister rust resistance and mountain pine beetle resistance, meaning that plus trees that have survived blister rust invasion may be more at risk from pine beetle attack (Maholovich, pers. comm.). Beginning in 2011, verbenone patches have been applied to plus trees in an attempt to protect trees from a pine beetle attack. Verbenone is an anti-aggregation pheromone thought to trick beetles into thinking the tree is already infected and that they need to look elsewhere for a suitable host tree.

B. METHODS

Beginning in 2007, whitebark pine tree populations were scouted for potential plus trees. Limber pine was also targeted in a few sites. For each population, trees were assessed for the presence of blister rust as well as overall health. Mostly blister rust canker-free trees were chosen for inclusion in the monitoring pool. Occasionally, trees that looked healthy but were mildly infected were also selected for monitoring to document the impacts of mild infestation on whitebark pine trees. Resistant trees can suppress cankers by a defense reaction whereby the tree builds a periderm around the infection (Hoff 1992). As cone production is variable by year, the presence of cones was not initially a determining factor for including a tree in the monitoring pool. Monitoring these plus trees on an annual to biannual basis should provide information on cone production trends over time.

Potential plus trees were each numbered and their locations were recorded using a GPS unit. In 2007 and 2008, identification numbers were written on each tree bole with a waterproof marker to reduce impacts to the tree. By 2009, after realizing that this marking does not persist over time, some of the plus trees were marked with nails and flagging in the ground at the base of the tree to further assist with re-location. This method is working well for tree identification and will be continued for all plus trees in the future. Trees were assessed for percent live canopy and measured for DBH and height. Presence and number of cones was noted. A digital photograph was taken of each tree with the distance and azimuth from the tree recorded. Evidence of blister rust on the bole or branches of the tree was recorded and categorized as active or inactive canker. Additional information about the site, such as the canopy cover of the surrounding forest, state of surrounding whitebark pine trees, whitebark regeneration in the area, and general site characteristics, was documented. Also noted were associated species, particularly any known or potential secondary hosts to blister rust, such as *Ribes* or *Castilleja* species. Presence of Clark's nutcrackers, whitebark pine seed dispersers, was also recorded.

Blister rust was identified in trees by the presence of active cankers, inactive cankers, or by old dead cankers evidenced by bark cracking or spindle-shaped branches (Hoff 1992). Signs of active (sporulating) cankers were orange-colored spore casings emerging from small cracks in the branches. Inactive cankers were identified by empty white fruiting bodies leftover from sporulation from the current year or spindle-shaped limbs characterized by extensive bark cracking. Early infections, prior to fruiting, were more difficult to identify but were recorded when recognized. Heavy sap flow and discoloration on the outside of the bark can be an early sign of blister rust (Hagle et al. 2003) and was also recorded when sighted. Yellow-orange patches on the stem and the beginnings of spindle-shaped stems may also be one of the only signs of blister rust infection for the first 4-5 years. Additionally, "bark stripping" was noted as possible evidence of cankers. High amounts of sugars are produced in cankers and animals such as rodents, ants and grasshoppers feed on them (Hoff, 1992) causing areas where bark has been scraped or chewed off. "Flagging", or ends of branches where needles have died that leave a red-needled branch tip, was also recorded as a potential sign of blister rust infection. Whenever signs were encountered that were most likely the early signs of blister rust, but could not be definitively called so, it was recorded as "probable".

Currently, there are 129 whitebark pine trees that are being monitored in the plus tree pool at 16 different locations. Cone information was only collected on 107 trees in 2018 due to missed trees (13 trees at Old Man, 2 trees at Two Medicine, 3 potential trees at Old Man, and 4 potential trees at Kupunkamint) (Figure 26; Table 44). This is down slightly from 115 trees monitored in 2017. Currently, there are 24 limber pine trees at 6 different locations

present in the plus tree monitoring pool (Figure 26; Table 45). Cone information was collected on all trees except for one limber pine at Spot Mtn.

In 2018, due to time and money constraints, the only data taken on whitebark and limber pine plus trees were cone counts. This is similar to data collected from 2012 through 2017. Cone counts were done at the time the revegetation crew applied verbenone patches to plus trees in the spring, as well as while climbing trees for cone caging and collection.

Table 44. Numbers of Whitebark Pine Plus Trees Monitored from 2007-2018.

Year	# Trees Added	Plus Trees Died	# Trees in Pool	# Trees Monitored	Trees Not Monitored	# Trees Not Monitored that are Potential Trees
2007	57 (7 Numa, 7 OM, 6 OL, 20 PP, 6 RW, 7 SP, 3 SB)	0	56	56	0	
2008	4 (TD)	0	60	41	19	
2009	13 (5 SP, 5 Numa, 3 PP)	0	73	53	20	
2010	9 (1 PP, 1 SP, 7 WC)	0	82	61	21	
2011	18 (4 WC, 2 TD, 3 FB, 9 OM*)	0	100	91	9	
2012		0	100	94	6	6 OM
2013	2 (1 Spot, 1 FB)	1 (Numa)	101	95	6	6 OM
2014		1 (TD - avalanche)	100	92	8	4 OM
2015	11 (8 KM, 3 TM)		111	104	7	4 OM
2016	3 (1 Numa, 1 KM, 1 TM)		114	110	4	3 OM
2017	4 (KM**)		118	115	3	3 OM
2018	11 (1 OL; 3 CL; 5 GG; 2 LR)		129	107	22	9 (3 OM; 4 KM)

*6 of these were potential plus trees

** potential trees

DHP = Dead Horse Point
 FB = Firebrand Pass Trail
 GG = Grinnell Glacier Trail
 KM = Kupunkamint Mtn.
 LR = Lee Ridge
 MG = Many Glacier
 OL = Otokomi Lake
 CL = Cobalt Lake

OM = Old Man Lake Trail
 PP = Preston Park
 RW = Rising Wolf
 SB = Siyeh Bend
 SP = Scenic Point
 TD = Triple Divide Trail
 TM = Two Medicine
 WC = Whitecalf

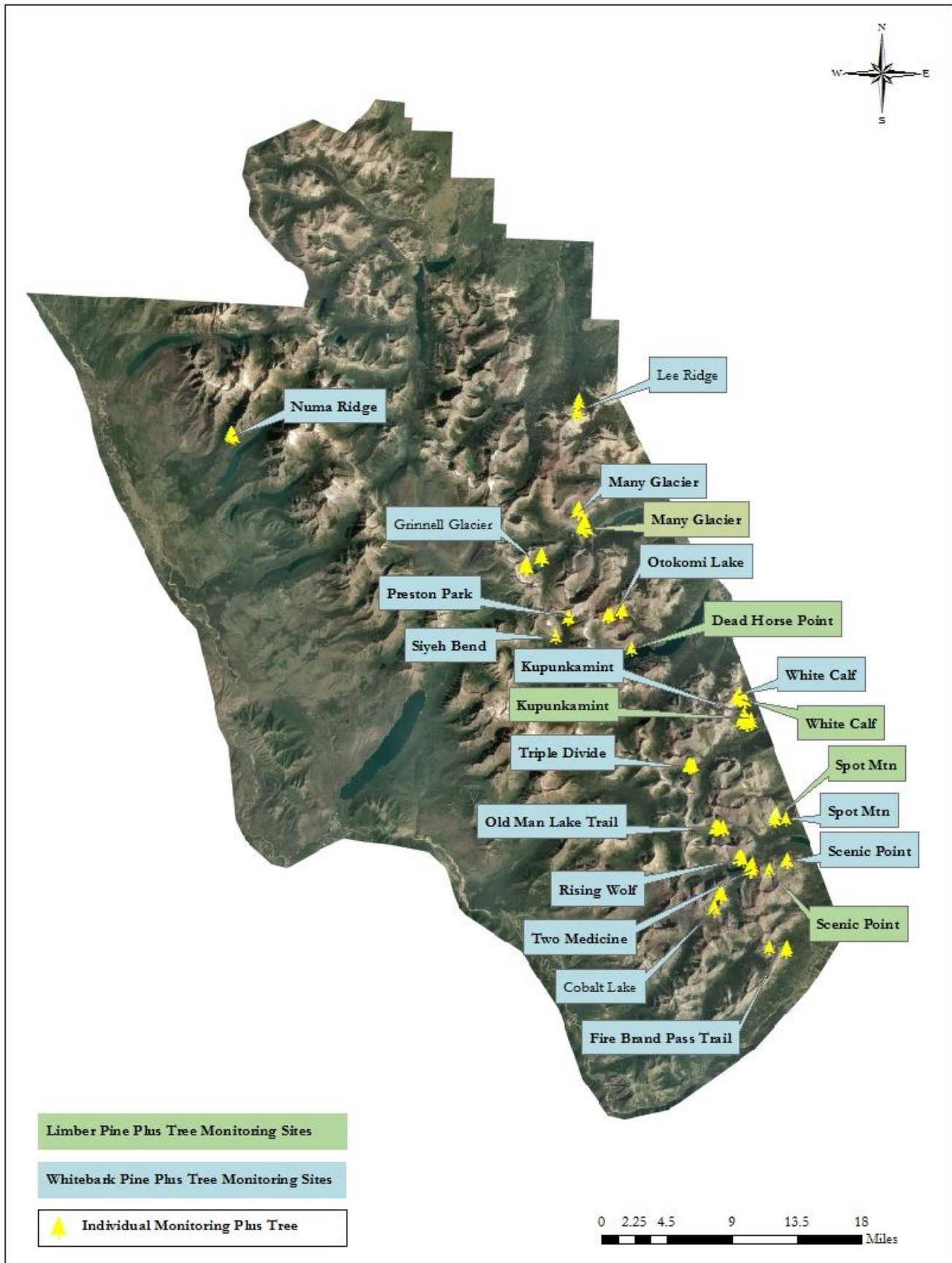
Table 45. Numbers of Limber Pine Plus Trees Monitored from 2007-2018.

Year	# of Trees Added	Plus Trees that Died	Total # of Trees in Pool	# of Trees Monitored	Trees not Monitored
2007	2 (1 DHP, 1 SP)	0	2	2	0
2008	0	0	2	2	0
2009	0	0	2	1	1
2010	2 (1 DHP, 1 WC)	0	4	4	0
2011			4	2	2
2012	1 (WC)		5	4	1
2013			5	4	1
2014			5	3	2
2015	18 (8 MG; 6 Spot; 3 KM; 1 SP)	1 (DHP)	22	22	
2016	2 (1 WC; 1 KM)		24	23	1
2017			24	23	1
2018			24	23	1

DHP = Dead Horse Point
 SP = Scenic Point
 WC = Whitecalf

Spot = Spot Mt.
 MG = Many Glacier
 KM = Kupunkamint Mtn.

Figure 26. Location of Whitebark and Limber Pine Plus Trees.



C. RESULTS

As stated above, 107 of the existing 129 whitebark pine plus trees were monitored for cone production in 2018. Health of individual plus trees was not assessed this year. Overall, 2018 was a banner year for the number of trees with cones and the average number of cones per tree. Since 2007 when this data started being collected, this year had the highest percentage of trees with cones, at 99%, since monitoring started. This year also had the second highest average number of cones per tree, at 54, since 2007 (Figure 27; Tables 46 & 47).

After a banner whitebark pine cone year in 2011, cone production dropped in 2012, resulting in a low percentage of trees with cones and a low average number of cones per tree (Figure 27; Table 46 & 47). 2012 results were very similar to data from 2008 when cone production was also very low. Since 2012, cone production has been slowly on the rise. While there was a slight decline in 2015 of both percentage of trees with cones and average of number of cones per trees, cone production has been generally increasing over the past three years (Figure 27). While it is beginning to show patterns of predictability, more data that spans spanning a larger timeframe is needed to attempt to decipher overall patterns of cone production, if it is possible.

The average number of cones per tree was slightly less variable this year. While in years past, the average number of cones had a wide range, the average number of cones per tree in most stands in 2018 were quite similar. In 11 of 14 stands where cones were present, the average number of cones per tree ranged from 30 cones to 57 cones (Table 47). Only 1 stand (Firebrand Pass Trail) had a low 17 cones per tree, while 3 of the 14 stands (Lee Ridge, Kupunkamint Mt. and Two Medicine) had much higher average cones per tree, ranging from 97 cones to 162 cones. There seems to be no clear pattern across time, as stands rarely have high or low numbers of cones consistently over consecutive years. Within a stand, cone production also varied from tree to tree. In recent years, trees at Kupunkamint Mt. have been the most reliable in terms of a good cone crop (Table 47).

As stated, the average number of cones per tree for 2018 was 54, which is the second highest average since cone data has been collected. This is only slightly lower than in 2011, GNP's most recent 'mast' year, when the average number of cones per tree was 61. Very little is known about the frequency of mast years in whitebark pine, although it has been found that healthy stands of whitebark pine in the Greater Yellowstone area had moderate or large cone crop years two or three times from 1980-1990 (Morgan and Bunting 1990). It appears that we may be on about a three to four year cycle (Figure 27) in terms of a high percentage of trees with cones, but trends are unclear about true mast years with high numbers of cones per tree. Data for percent trees with cones and average number of cones per trees generally follow similar patterns (Figure 27), although the rate of increase and decrease is much steeper with average number of cones per tree, the more reliable indicator of a mast year.

It should be noted that the healthiest whitebark pine trees, now that they have been identified, are currently being targeted for cone monitoring. The actual cone production rate for the overall stand could indeed be much lower. It should also be noted that many of these cone counts were assessed from the ground looking up at the tree. After comparing cone counts from the ground to cone counts when the observer has climbed the tree, we have observed that cone estimates can be two to three times lower from the ground. Since most of the cone numbers listed in the tables were estimated from the ground over time, the data is comparable but it should be noted that actual cone estimates may be significantly underestimated.

Twenty-three limber pine trees were also monitored in 2018. No new plus trees were added to the pool this year. All limber pine trees in the monitoring pool again produced cones in 2018 (Figure 28; Table 48). This is actually a typical result, as 10 out of the past 12 monitoring years have had 100% of the monitored limber pine trees with cones. The more important result, however, is the average number of cones per limber pine tree this year. With an average of 135 of cones per tree in 2018, this was by far the highest number of cones per tree since monitoring started in 2007 (Figure 28; Table 49). Cone production this year surpassed the past high 100 average cones per tree in 2009 and 91 average cones per tree in 2015. While it was speculated in past reports that higher average cones may be a result of adding trees from new, apparently productive sites, limber pine trees that have been monitored since 2007

had some of the highest cone counts this year, particularly at Dead Horse Point and Whitecalf. Trends are still being assessed for limber pine cone production given the small sample size and only twelve years of data.

Of note, cones were collected from two trees on Kupunkamint Mt. as part of the genetic testing program with the USFS. These two trees needed additional seed to be entered into the testing pool. Cones were also collected this year as part of a collaborative project with the High Five working group. This project required collection of seed from trees that are ranked in the upper 25% of rust resistant trees as determined by the USFS. This year, seed was collected from 1 whitebark pine at Kupunkamint Mt., 2 whitebark pine at Numa Lookout, 1 whitebark pine at Scenic Point, 1 whitebark pine on the Old Man Lake Trail, and 1 whitebark pine at Siyeh Bend for this program. Seed was also collected from 5 limber pines at Many Glacier and 2 limber pines at Kupunkamint Mt. for this program. Finally, scion was collected from one tree at Numa Lookout, Scenic Point, Old Man Lake Trail, and Siyeh Bend.

D. CONCLUSIONS AND RECOMMENDATIONS

Monitoring data is beginning to document the cyclic nature of cone production in whitebark pine trees. While 2008 and 2009 showed a decline in whitebark pine cone production throughout the park, cone production was higher in 2010 at 77% and much higher in 2011 with 93% of plus trees having cones. Data from 2012 showed a decline in cone production again, similar to 2009 and 2010 levels, along with a lower average number of cones per tree. In 2013 and 2014, cone production increased again to 84% and 85%, respectively, although the average number of cones per tree only went up slightly, resulting in just moderate numbers of cones per tree. Typical of the pattern after higher cone production, cone production declined again in 2015 to 72%, but increased again in 2016 to 86%, and remained relatively stable at 87% in 2017. It appears that 2018 reached “mast-year” like conditions with 99% of monitored whitebark pine trees having cones and an average of 135 cones per tree. While a longer-term data set is necessary to make absolute predictions about whitebark pine cone cycles, the data that has been collected supports a 3 to 4 year cycle for achieving a higher percentage of trees with cones and a higher average number of cones per tree (Figure 27). While limber pine tends to consistently have some cone crop, the average number of cones per tree also follows a 3 to 4 year cycle for achieving a higher number of average cones (Figure 28). It is important to note that the overall park-wide cone production is likely lower, given that the healthiest trees were targeted for cone collection and thus monitoring. Future monitoring over the next several years will begin to document the local trends of cone production in the park, as well track the impacts of increasing blister rust on cone production of the plus tree pool.

Since the future of healthy whitebark and limber pine trees is unknown, a larger pool of trees is imperative for seed collection and genetic integrity of our seedling stock. In the last 4 years, GNP has added 29 trees to the whitebark pine plus tree monitoring pool and 20 trees to the limber pine plus tree monitoring pool (Tables 45 and 46). There continue to be areas within known whitebark stands that could be scouted for additional plus trees, including White Calf, Preston Park, Old Man Lake, Firebrand Pass Trail, Spot Mountain, and Scenic Point. Other possible sites to search for healthy whitebark pine include additional trails in the Many Glacier sub-district, the Morning Star Lake trail, and Bighorn Basin.

Additionally, protection of currently identified plus trees continues to be a goal. Since 2008, limbs with active cankers have been removed or cut off, a recent practice that may prolong the life of certain whitebark pine plus trees in the monitoring pool. Since 2011, verbenone patches have been applied to plus trees for the in an effort to protect them from mountain pine beetle attacks. A Whitebark Pine Management Plan needs to be written to address the continued care of these trees, including protection from encroaching subalpine fire and from wildfire.

Due to time and money constraints, very little data on the health of plus trees was taken this year, similar to past years. As time and money permit, health data should continue to be collected to learn more about the potential resistance of these trees. Now that more is known about varying levels of resistance to blister rust in whitebark pine trees, it is more encouraging that some infected trees may be able to remain functional for some time. The highest level of resistance is obtained when a tree contains two recessive “no spot genes”; there is no evidence these trees have been infested even after exposure. Needle shed resistance, from a single recessive gene, is another form of

defense whereby blister rust spores penetrate stomates and grow down needles, but the tree is able to shed infected needles and not become further infected. A third form of defense, fascicle shed resistance, is observed when the entire 5-needled fascicle is shed after infection. A fourth form of resistance, bark reactive resistance, is a polygenetic form. The bark forms a callus or “scab” and walls off the disease. This can even happen at the bole, so contrary to popular belief, bole cankers can still be present on a resistant tree. Finally, trees can still have a form of resistance while harboring active cankers that never die. As long as cankers do not girdle the tree, some trees are able to survive with one or more persistent active cankers (Maholovich pers. comm.).

As mentioned in the introduction, Glacier is participating in a genetic resistance program with the U.S. Forest Service to test the resistance of whitebark pine plus trees to blister rust. Recently, we have received blister rust resistance information on 24 plus trees that are in that program (Table 50). Based on tree data from GNP and many other locations throughout Montana and the Pacific Northwest, the USFS is now recommending that seed should only be collected from trees that have $\geq 20\%$ rust resistance (Maholovich pers. comm.). To date, 11 of our 24 whitebark pine plus trees meet this criteria. While we are following this tree selection criteria for seed and scion collection for the current High Five seed program, GNP resource staff is still discussing when or if the park will continue to collect seed from the remaining plus trees. As many of these trees are alive and appear relatively healthy, GNP will continue to protect all plus trees with Verbenone to prevent potential mountain pine beetle invasion.

A few additional whitebark and limber pine trees are currently being added to the genetics study for more information on new five-needle pine stands in the park. On-going information from this study will continue to provide us with guidance for whitebark seed collection in the future and protection of our plus tree pool. As both physical tree and genetics monitoring continues, data may help to answer whether some trees that exhibit mild blister rust infection can fend off lethal infection and remain healthy. It may also help us determine a timeline for survival of trees that succumb to infection. Data may also determine whether trees that appear healthy in the midst of dead and dying trees can remain blister rust free. Monitoring plus trees should also provide data on cone production cycles that could help plan future seed collection efforts.

Cone counts for all whitebark and limber pine plus trees should be continued in 2019 when Verbenone packets are attached to the trees. As part of creating a Whitebark and Limber Pine Management Plan, GNP staff needs to discuss and determine the following items:

- Finalize ways to efficiently and effectively assess the health/blister rust infection of our plus tree pool. There are a number of proposed methods to determine health of a tree that each take time and have differing degrees of monitor error. GNP needs to determine which method is most effective and the time frame at which plus trees get monitored for their health;
- Determine if there are areas where we need to search for additional whitebark and limber pine plus trees, including within existing stands or in new stands;
- Determine if there are whitebark and limber pine trees that should be taken out of the plus tree pool; and
- Determine if mapping whitebark and limber pine with each stand is a necessary effort for management and protection of these trees.

Table 46. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2018.

<i>Site</i>	<i>Year</i>	<i># of Trees in pool</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Numa Lookout	2007	7	7	5	1	0	2	7
	2008	7	7	4	3	2	1	1
	2009	12	12	6	5	4	1	6
	2011	12	12	3	8	5	1	11
	2012	12	12	n/a	n/a	n/a	n/a	8
	2013	11	11 *	n/a	n/a	n/a	n/a	9
	2014	11	10	n/a	n/a	n/a	n/a	9
	2015	11	11	n/a	n/a	n/a	n/a	11
	2016	12	12	n/a	n/a	n/a	n/a	8
	2017	12	12	n/a	n/a	n/a	n/a	1
	2018	12	12	n/a	n/a	n/a	n/a	11
Old Man Lake Trail	2007	7	7	5	1	2	0	2
	2010	7	7	4	3	3	2	2
	2011	16	16	7	7	6	5	16
	2012	16	10	n/a	n/a	n/a	n/a	8
	2013	16	10	n/a	n/a	n/a	n/a	8
	2014	16	12	n/a	n/a	n/a	n/a	10
	2015	16	10	n/a	n/a	n/a	n/a	10
	2016	16	13	n/a	n/a	n/a	n/a	13
	2017	16	13	n/a	n/a	n/a	n/a	13
	2018	16	0					0
Otokomi Lake	2007	6	6	4	0	0	2	4
	2010	6	6	3	2	3	4	3
	2012	6	6	n/a	n/a	n/a	n/a	5
	2013	6	6	n/a	n/a	n/a	n/a	6
	2014	6	6	n/a	n/a	n/a	n/a	6
	2015	6	6	n/a	n/a	n/a	n/a	6
	2016	6	6	n/a	n/a	n/a	n/a	3
	2017	6	6	n/a	n/a	n/a	n/a	6
	2018	7	7	n/a	n/a	n/a	n/a	7
Preston Park	2007	20	20	13	5	4	1	20
	2008	20	20	13	7	3	1	13
	2009	23	23	12	4	8	3	18
	2010	24	24	13	9	7	8	21
	2011	24	24	n/a	n/a	n/a	n/a	19
	2012	24	24	n/a	n/a	n/a	n/a	21
	2013	24	24	n/a	n/a	n/a	n/a	23
	2014	24	24	n/a	n/a	n/a	n/a	18
	2015	24	23	n/a	n/a	n/a	n/a	5
	2016	24	24	n/a	n/a	n/a	n/a	17
	2017	24	24	n/a	n/a	n/a	n/a	24
	2018	24	24	n/a	n/a	n/a	n/a	24
Rising Wolf	2007	6	6	5	0	0	1	2
	2009	6	6	2	3	4	1	3
	2011	6	6	1	3	4	0	6
	2012	6	6	n/a	n/a	n/a	n/a	3
	2013	6	6	n/a	n/a	n/a	n/a	6
	2014	6	6	n/a	n/a	n/a	n/a	6
	2015	6	6	n/a	n/a	n/a	n/a	6
	2016	6	6	n/a	n/a	n/a	n/a	6
	2017	6	6	n/a	n/a	n/a	n/a	6
	2018	6	6	n/a	n/a	n/a	n/a	6

Table 46, continued. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2018.

<i>Site</i>	<i>Date</i>	<i># of Trees in pool</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Scenic Point	2007	7	7	4	1	1	2	7
	2008	7	7	2	1	3	2	5
	2009	12	12	3	6	6	2	8
	2010	13	13	2	8	8	3	13
	2011	13	13	5	6	7	2	13
	2012	13	13	n/a	n/a	n/a	n/a	12
	2013	13	13	n/a	n/a	n/a	n/a	10
	2014	13	12	n/a	n/a	n/a	n/a	8
	2015	13	13	n/a	n/a	n/a	n/a	11
	2016	13	12	n/a	n/a	n/a	n/a	12
	2017	13	13	n/a	n/a	n/a	n/a	13
	2018	13	13	n/a	n/a	n/a	n/a	13
Siyeh Bend	2007	3	3	1	2	2	0	0
	2008	3	3	0	3	3	0	1
	2012	3	3	n/a	n/a	n/a	n/a	0
	2013	3	3	n/a	n/a	n/a	n/a	2
	2014	3	3	n/a	n/a	n/a	n/a	3
	2015	3	3	n/a	n/a	n/a	n/a	3
	2016	3	3	n/a	n/a	n/a	n/a	2
	2017	3	3	n/a	n/a	n/a	n/a	3
	2018	3	3	n/a	n/a	n/a	n/a	3
Triple Divide	2008	4	4	3	1	0	0	3
	2010	4	4	3	0	1	0	1
	2011	6	6	4	1	2	1	6
	2012	6	6	n/a	n/a	n/a	n/a	5
	2013	6	6	n/a	n/a	n/a	n/a	3
	2014	5	5	n/a	n/a	n/a	n/a	5
	2015	5	5	n/a	n/a	n/a	n/a	5
	2016	5	5	n/a	n/a	n/a	n/a	5
	2017	5	5	n/a	n/a	n/a	n/a	5
	2018	5	5	n/a	n/a	n/a	n/a	5
White Calf	2010	7	7	2	4	4	0	7
	2011	11	11	5	5	6	3	11
	2012	11	11	n/a	n/a	n/a	n/a	11
	2013	11	11	n/a	n/a	n/a	n/a	9
	2014	11	10	n/a	n/a	n/a	n/a	9
	2015	11	11	n/a	n/a	n/a	n/a	10
	2016	11	11	n/a	n/a	n/a	n/a	11
	2017	11	11	n/a	n/a	n/a	n/a	8
	2018	11	11	n/a	n/a	n/a	n/a	11
Firebrand Pass Trail	2011	3	3	0	1	2	2	3
	2012	3	3	n/a	n/a	n/a	n/a	0
	2013	4	4	n/a	n/a	n/a	n/a	3
	2014	4	3	n/a	n/a	n/a	n/a	3
	2015	4	4	n/a	n/a	n/a	n/a	4
	2016	4	4	n/a	n/a	n/a	n/a	4
	2017	4	4	n/a	n/a	n/a	n/a	4
	2018	4	4	n/a	n/a	n/a	n/a	4

Table 46, continued. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2018.

<i>Site</i>	<i>Date</i>	<i># of Trees in pool</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Spot Mountain	2013	1	1	n/a	n/a	n/a	n/a	1
	2014	1	1	n/a	n/a	n/a	n/a	1
	2015	1	1	n/a	n/a	n/a	n/a	1
	2016	1	1	n/a	n/a	n/a	n/a	1
	2017	1	1	n/a	n/a	n/a	n/a	1
	2018	1	1	n/a	n/a	n/a	n/a	1
Kupunkamint	2015	8	8	n/a	n/a	n/a	n/a	3
	2016	9	9	n/a	n/a	n/a	n/a	9
	2017	13	13	n/a	n/a	n/a	n/a	12
	2018	13	9	n/a	n/a	n/a	n/a	9
Two Medicine	2015	3	3	n/a	n/a	n/a	n/a	0
	2016	4	4	n/a	n/a	n/a	n/a	4
	2017	4	4	n/a	n/a	n/a	n/a	4
	2018	4	2	n/a	n/a	n/a	n/a	2
Cobalt Lake	2018	3	3	n/a	n/a	n/a	n/a	3
Grinnell Glacier Trail	2018	5	5	n/a	n/a	n/a	n/a	5
Lee Ridge	2018	2	2	n/a	n/a	n/a	n/a	2
TOTAL 2007		56	56	37	10	9	8	42
TOTAL 2008		60	41	22	15	11	4	23
TOTAL 2009		73	53	23	18	22	7	35
TOTAL 2010		82	61	27	26	26	17	47
TOTAL 2011		100	91	25	31	32	14	85
TOTAL 2012		100	94	n/a	n/a	n/a	n/a	73
TOTAL 2013		101	95	n/a	n/a	n/a	n/a	80
TOTAL 2014		100	92	n/a	n/a	n/a	n/a	78
TOTAL 2015		111	104	n/a	n/a	n/a	n/a	75
TOTAL 2016		114	110	n/a	n/a	n/a	n/a	95
TOTAL 2017		118	115	n/a	n/a	n/a	n/a	100
TOTAL 2018		129	107	n/a	n/a	n/a	n/a	106
% 2007				66%	18%	16%	14%	75%
% 2008				54%	37%	27%	10%	56%
% 2009				43%	34%	42%	13%	66%
% 2010				44%	43%	43%	28%	77%
% 2011				27%	34%	35%	15%	93%
% 2012				n/a	n/a	n/a	n/a	78%
% 2013				n/a	n/a	n/a	n/a	84%
% 2014				n/a	n/a	n/a	n/a	85%
% 2015				n/a	n/a	n/a	n/a	72%
% 2016				n/a	n/a	n/a	n/a	86%
% 2017				n/a	n/a	n/a	n/a	87%
%2018				n/a	n/a	n/a	n/a	99%

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1 Some of these trees have active, inactive and/or probable cankers on the same tree.

Table 47. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2018.

	<i>2007</i>			<i>2008</i>			<i>2009</i>		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Numa Lookout	7	165	24	7	5	1	12	52	4
Old Man Trail	7	38	5	0	n/a	n/a	0	n/a	n/a
Otokomi Lake	6	14	2	0	n/a	n/a	0	n/a	n/a
Preston Park	20	925	46	20	176	9	23	267	12
Rising Wolf	6	16	3	0	n/a	n/a	6	89	15
Scenic Point	7	237	34	7	10	1	12	109	9
Siyeh Bend	3	4	1	3	10	3	0	n/a	n/a
Triple Divide	0	n/a	n/a	4	4	1	0	n/a	n/a
TOTAL	56	1395	25	41	195	5	53	517	10

	<i>2010</i>			<i>2011</i>			<i>2012</i>		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.				3	246	82	3	0	0
Numa Lookout	0	n/a	n/a	12	305	25	12	193	16
Old Man Trail	7	9	1	16	1399	45	10	95	10
Otokomi Lake	6	25	4	0	n/a	n/a	6	171	29
Preston Park	24	718	30	24	219	9	24	189	8
Rising Wolf	0	n/a	n/a	6	500	83	6	31	5
Scenic Point	13	599	46	13	631	56	13	152	12
Siyeh Bend	0	n/a	n/a	0	n/a	n/a	3	0	0
Triple Divide	4	1	0	6	723	121	6	44	7
White Calf	7	232	33	11	1484	135	11	269	24
TOTAL	61	1584	26	91	5507	61	94	1144	12

	<i>2013</i>			<i>2014</i>			<i>2015</i>		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Fire Brand Pass Tr.	4	62	15.5	3	34	11.3	4	38	10
Numa Lookout	11	145	13.2	10	61	6.1	11	285	26
Old Man Trail	10	151	15.1	12	251	20.9	10	226	23
Otokomi Lake	6	172	28.7	6	63	10.5	6	203	34
Preston Park	24	876	36.5	24	185	7.7	23	32	1
Rising Wolf	6	80	13	6	368	61.3	6	104	17
Scenic Point	13	66	5	12	25	2.1	13	97	7
Siyeh Bend	0	n/a	n/a	3	104	34.7	3	93	31
Spot Mtn.	1	1	1	1	250	250.0	1	60	60
Triple Divide	6	16	3	5	316	63.2	5	76	15
White Calf	11	62	6	10	563	56.3	11	269	24
Kupunkamint							8	271	34
Two Medicine							3	0	0
TOTAL	92	1631	18	92	2220	24	104	1754	17

Table 47, continued. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2018.

<i>Site</i>	<i>2016</i>			<i>2017</i>			<i>2018</i>		
	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Cobalt Lake							3	72	24
Fire Brand Pass Tr.	4	82	20.5	4	90	22.5	4	69	17.25
Grinnell Glacier Trail							5	193	38.6
Lee Ridge							2	324	162
Numa Lookout	12	113	9.4	12	1	0.1	12	365	30.4
Old Man Trail	13	376	28.9	13	689	53.0	0	n/a	n/a
Otokomi Lake	6	52	8.7	6	239	39.8	7	301	43.0
Preston Park	24	290	12.1	24	834	34.8	24	1094	45.6
Rising Wolf	6	330	55.0	6	56	9.3	6	272	45.3
Scenic Point	12	165	13.8	13	280	21.5	13	430	33.1
Siyeh Bend	3	10	3.3	3	92	30.7	3	119	39.7
Spot Mtn.	1	5	5.0	1	302	302.0	1	52	52.0
Triple Divide	5	41	8.2	5	142	28.4	5	231	46.2
White Calf	11	370	33.6	11	178	16.2	11	631	57.4
Kupunkamint	9	1791	199.0	13	684	52.6	9	1449	161.0
Two Medicine	4	141	35.3	4	68	17.0	2	195	97.5
TOTAL	110	3766	34	115	3655	32	107	5797	54

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Figure 27. Trends in Whitebark Pine Cone Production 2007-2018.

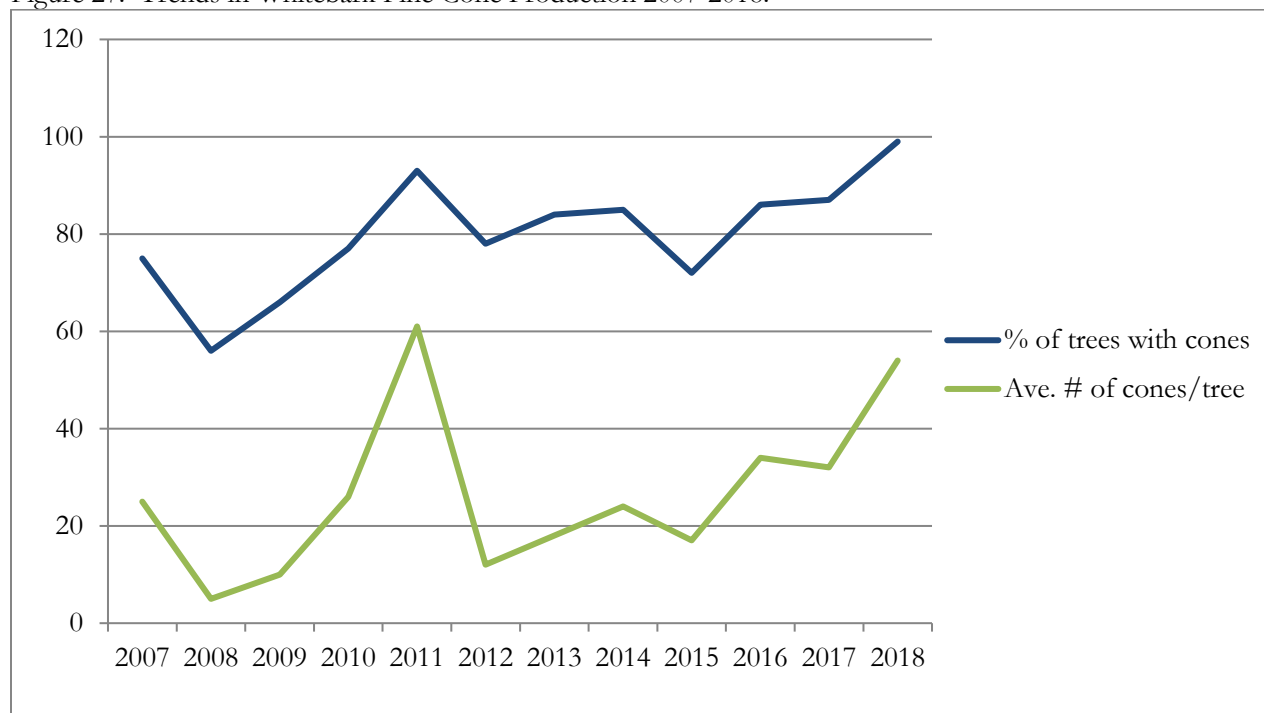


Table 48. Limber Pine Plus Trees: Health and Cone Production, 2018.

<i>Site</i>	<i>Date</i>	<i># of Trees Monitored</i>	<i># of Healthy Trees¹</i>	<i># with Active Cankers</i>	<i># with Inactive Cankers</i>	<i># with Possible Cankers</i>	<i># With Cones</i>
Dead Horse Point	2018	1	n/a	n/a	n/a	n/a	1
Scenic Point	2018	2	n/a	n/a	n/a	n/a	2
White Calf	2018	3	n/a	n/a	n/a	n/a	3
Spot	2018	5	n/a	n/a	n/a	n/a	5
Many Glacier	2018	8	n/a	n/a	n/a	n/a	8
Kupunkamint	2018	4	n/a	n/a	n/a	n/a	4
	TOTAL	23	n/a	n/a	n/a	n/a	23
	2007 PERCENT		100%	0%	0%	0%	100%
	2008 PERCENT		100%	0%	0%	0%	100%
	2009 PERCENT		100%	0%	0%	0%	50%
	2010 PERCENT		75%	0%	25%	0%	100%
	2011 PERCENT		100%	0%	0%	0%	100%
	2012 PERCENT		n/a	n/a	n/a	n/a	100%
	2013 PERCENT		n/a	n/a	n/a	n/a	75%
	2014 PERCENT		n/a	n/a	n/a	n/a	100%
	2015 PERCENT		n/a	n/a	n/a	n/a	100%
	2016 PERCENT		n/a	n/a	n/a	n/a	100%
	2017 PERCENT		n/a	n/a	n/a	n/a	91%
	2018 PERCENT		n/a	n/a	n/a	n/a	100%

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Figure 28. Trends in Limber Pine Cone Production 2007-2018.

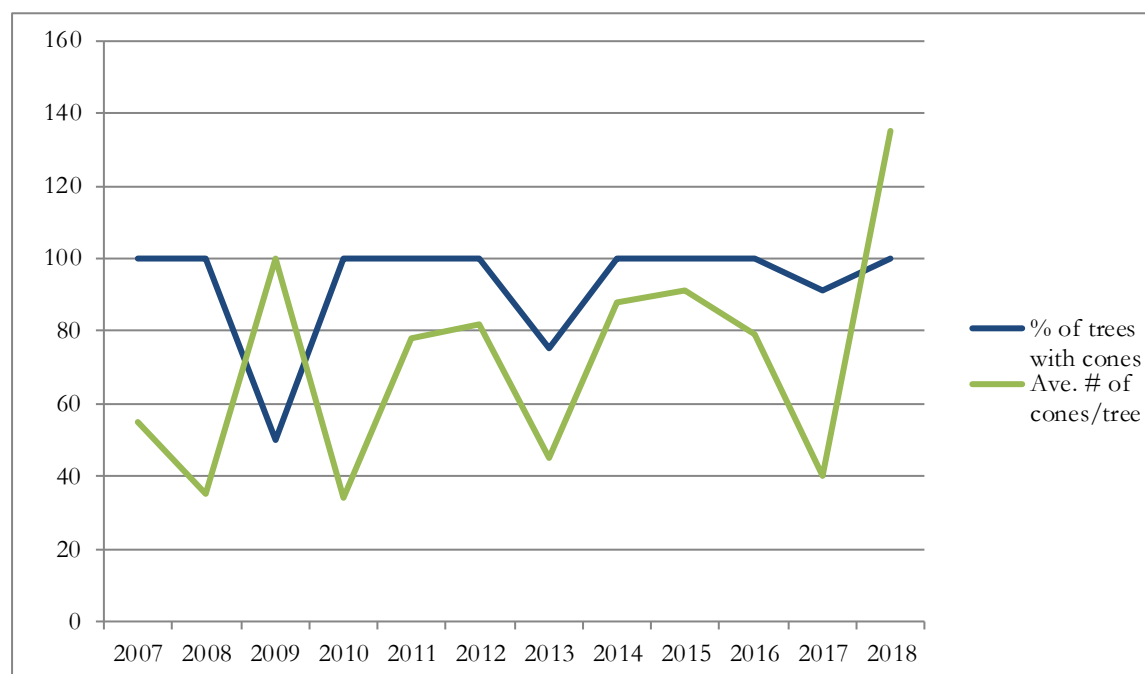


Table 49. Limber Pine Plus Trees: Average Cones Per Tree, 2007 – 2018.

	2007			2008		2009		2010		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per Tree</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>
Dead Horse Point	1/2	100	100	50	50	200	200	1	46	23
Scenic Point	1	10	10	20	20	0	0	1	15	15
Whitecalf	0							1	75	75
TOTAL	2/4	110	55	70	35	200	100	3	136	34

	2011			2012			2013		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>
Dead Horse Point	0	n/a	n/a	1	40	40	1	50	50
Scenic Point	1	55	55	1	40	40	1	0	0
Whitecalf	1	100	100	2	249	125	2	130	65
TOTAL	2	155	78	4	329	82	4	180	45

	2014			2015			2016		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>
Dead Horse Point	1	149	149	1	35	35	1	120	120
Scenic Point	1	10	0	2	161	81	2	103	52
Whitecalf	1	105	105	2	90	45	3	109	36
Spot				6	324+	54	5	446	89
Many Glacier				8	945	118	8	846	106
Kupunkamint				3	441+	147	4	187	47
TOTAL	3	264	88	22	1996	91	23	1811	79

	2017			2017			2018		
<i>Site</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>
Dead Horse Point	1	100	100	1	100	100	1	221	221
Scenic Point	2	19	10	2	19	10	2	128	64
Whitecalf	3	26	9	3	26	9	3	671	224
Spot	5	276	55	5	276	55	5	683	137
Many Glacier	8	394	49	8	394	49	8	904	113
Kupunkamint	4	110	28	4	110	28	4	501	125
TOTAL	23	925	40	23	925	40	23	3108	135

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Table 50. Blister Rust Resistance Results from 24 Whitebark Pine Plus Trees (cycles 3 and 4).

Cycle	Family	Elevation	Location	Bark Reaction	No Spot	Needle Shed	Short Shoot	Total	% Resistant	Index Rank
4	7157	6546	Numa Lookout	19	9	2	19	144	34.0	43
4	7147	6082	Firebrand Pass	10	6	0	31	143	32.9	49
4	7155	5248	Rising Wolf	7	5	1	33	144	31.9	72
4	7150	6357	Old Man Trail	15	2	1	21	141	27.7	54
4	7145	5944	Firebrand Pass	5	5	2	21	143	23.1	107
4	7156	6100	Rising Wolf	13	5	1	12	144	21.5	95
4	7158	5890	Triple Divide	2	10	1	14	128	21.1	167
4	7160	5654	Triple Divide	7	10	0	13	144	20.8	108
4	7159	5658	Triple Divide	9	6	1	11	143	18.9	123
4	7149	6000	Old Man Trail	7	1	1	17	144	18.1	174
4	7148	6050	Old Man Trail	3	2	0	14	143	13.3	250
4	7146	6029	Firebrand Pass	4	1	0	8	138	9.4	209
3	6828	5950	Rising Wolf	37	0	0	14	142	35.9	84
3	6821	6000	Siyeh Bend	38	0	0	3	142	28.9	26
3	6847	7140	Scenic Point	26	1	0	8	141	24.8	93
3	6833	7222	Scenic Point	17	0	0	9	143	18.2	119
3	6845	7019	Preston Park	24	0	0	2	144	18.1	135
3	6835	7075	Preston Park	19	0	0	3	143	15.4	101
3	6840	7225	Preston Park	14	0	0	2	143	11.2	109
3	6843	7300	Preston Park	7	0	0	8	139	10.8	174
3	6841	7134	Preston Park	4	0	0	5	87	10.3	181
3	6838	7085	Preston Park	10	0	0	1	144	7.6	143
3	6848	6860	White Calf	3	0	0	0	141	2.1	202
3	6837	7103	Preston Park	2	0	0	0	144	1.4	190

VII. OVERALL RECOMMENDATIONS FOR REVEGETATION AND REVEGETATION MONITORING

The revegetation and revegetation monitoring programs have made positive strides in restoring disturbed communities in Glacier National Park. One area in which we have made improvements is assessing appropriate species to use in specific revegetation areas. Listed below are recommendations for general plant species that are typically found in common forest, grassland, and subalpine meadow types. While these lists should not override the use of specific information found in site analysis data, these general lists should help guide the nursery and restoration planners in common plants that we consistently see across the park in common habitats. Due to the complexity and site specific nature of wetland, shrubland, and alpine types, there are no general lists for these areas. A few additional recommendations are also listed that address communication between programs.

SPECIES SELECTION:

Certain plant species are common in Glacier National Park and have a wide amplitude of habitats in which they grow. From our observations, the following species are often present in these common plant communities. As a result, we have found that we recommend them frequently for revegetating areas. Adding to the complexity of the restoration process, many of these listed species are generally difficult to grow in the nursery. Species listed with a * are species that have been difficult to grow in the past and are species that are currently being experimented with in the nursery. Given their common presence in a number of plant communities, however, these species should be salvaged whenever possible.

Moist cedar-hemlock forest (montane - west side):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Betula papyrifera</i>	<i>Acer glabrum</i>	<i>Adenocaulon bicolor</i> *	<i>Bromus vulgaris</i>
<i>Larix occidentalis</i>	<i>Amelanchier alnifolia</i>	<i>Aralia nudicaulis</i> *	<i>Calamagrostis rubescens</i>
<i>Picea engelmannii</i>	<i>Linnaea borealis</i> *	<i>Athyrium filix-femina</i>	<i>Carex concinnoides</i>
<i>Pinus monticola</i>	<i>Lonicera utahensis</i>	<i>Chimaphila umbellata</i> *	<i>Carex rossii</i>
<i>Pseudotsuga menziesii</i>	<i>Menziesia ferruginea</i>	<i>Clintonia uniflora</i> *	<i>Elymus glaucus</i>
<i>Thuja plicata</i>	<i>Paxistima myrsinites</i>	<i>Cornus canadensis</i>	
<i>Tsuga heterophylla</i>	<i>Rosa acicularis</i>	<i>Disporum hookeri/trachycarpum</i> *	
	<i>Rubus parviflorus</i>	<i>Dryopteris expansa</i>	
	<i>Spiraea betulifolia</i>	<i>Goodyera oblongifolia</i> *	
	<i>Vaccinium membranaceum</i> *	<i>Gymnocarpium dryopteris</i>	
		<i>Maianthemum stellatum</i> *	
		<i>Orthilia secunda</i> *	
		<i>Osmorhiza berteroi</i> *	
		<i>Thalictrum occidentale</i> *	
		<i>Tiarella trifoliata</i> *	
		<i>Viola orbiculata</i> *	
		<i>Xerophyllum tenax</i> *	

Engelmann spruce-subalpine fir forest (montane – east and west):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Abies lasiocarpa</i>	<i>Acer glabrum</i>	<i>Arnica cordifolia</i>	<i>Bromus vulgaris</i>
<i>Larix occidentalis</i>	<i>Amelanchier alnifolia</i>	<i>Clintonia uniflora</i> *	<i>Calamagrostis rubescens</i>
<i>Picea engelmannii</i>	<i>Linnaea borealis</i> *	<i>Disporum hookeri</i> *	<i>Elymus glaucus</i>
<i>Pinus contorta</i>	<i>Mahonia repens</i>	<i>Disporum trachycarpum</i> *	<i>Festuca occidentalis</i>
	<i>Paxistima myrsinites</i>	<i>Eurybia conspicua</i>	<i>Festuca subulata</i>
	<i>Salix scouleriana</i>	<i>Maianthemum racemosum</i> *	
	<i>Sorbus scopulina</i>	<i>Oryzopsis asperifolia</i>	
	<i>Spiraea betulifolia</i>	<i>Osmorhiza berteroi</i> *	
	<i>Symphoricarpos albus</i>	<i>Thalictrum occidentale</i> *	
	<i>Vaccinium caespitosum</i> *	<i>Viola orbiculata</i> *	
	<i>Vaccinium membranaceum</i> *	<i>Xerophyllum tenax</i> *	
	<i>Vaccinium myrtillus</i> *		

Engelmann spruce-subalpine fir forest (subalpine – east and west):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Abies lasiocarpa</i>	<i>Alnus viridis</i>	<i>Arnica cordifolia/ latifolia</i>	<i>Calamagrostis rubescens</i>
<i>Picea engelmannii</i>	<i>Arctostaphylos uva-ursi</i>	<i>Erigeron peregrinus</i>	<i>Carex geyeri</i>
<i>Pinus contorta</i>	<i>Menziesia ferruginea</i>	<i>Erythronium grandiflorum*</i>	
	<i>Paxistima myrsinites</i>	<i>Eucephalus engelmannii</i>	
	<i>Ribes lacustre</i>	<i>Luzula glabrata var. hitchcockii</i>	
	<i>Rubus parviflorus</i>	<i>Mitella breweri*</i>	
	<i>Sorbus scopulina</i>	<i>Pedicularis bracteosa</i>	
	<i>Spiraea betulifolia</i>	<i>Thalictrum occidentale*</i>	
	<i>Vaccinium membranaceum*</i>	<i>Valeriana sitchensis</i>	
	<i>Vaccinium myrtillus*</i>	<i>Veratrum viride</i>	
	<i>Vaccinium scoparium*</i>	<i>Viola orbiculata*</i>	
		<i>Xerophyllum tenax*</i>	

Douglas fir forest (mesic montane – east and west):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Abies lasiocarpa</i>	<i>Acer glabrum</i>	<i>Achillea millefolium</i>	<i>Calamagrostis rubescens</i>
<i>Larix occidentalis</i>	<i>Amelanchier alnifolia</i>	<i>Arnica cordifolia</i>	<i>Carex geyeri</i>
<i>Pinus contorta</i>	<i>Linnaea borealis*</i>	<i>Clintonia uniflora*</i>	<i>Carex rossii</i>
<i>Pseudotsuga menziesii</i>	<i>Lonicera utahensis</i>	<i>Eurybia conspicua</i>	<i>Festuca occidentalis</i>
	<i>Mahonia repens</i>	<i>Goodyera oblongifolia*</i>	
	<i>Menziesia ferruginea (higher)</i>	<i>Orthilia secunda*</i>	
	<i>Paxistima myrsinites</i>	<i>Thalictrum occidentale*</i>	
	<i>Rosa woodsii</i>	<i>Xerophyllum tenax*</i>	
	<i>Rubus parviflorus</i>		
	<i>Shepherdia canadensis</i>		

Douglas fir and/or ponderosa pine forest (drier montane – mostly west): species listed in Douglas fir forest above plus these additional species

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Pinus ponderosa</i>	<i>Arctostaphylos uva-ursi</i>	<i>Antennaria rosea</i>	<i>Festuca campestris</i>
	<i>Dasiphora floribunda</i>	<i>Heuchera cylindrica</i>	<i>Danthonia intermedia</i>
	<i>Juniperus communis</i>	<i>Penstemon confertus</i>	<i>Pseudoroegneria spicata</i>
	<i>Vaccinium caespitosum*</i>	<i>Potentilla gracilis</i>	

Lodgepole pine and/or western larch forests (montane – mostly west):

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Larix occidentalis</i>	<i>Acer glabrum</i>	<i>Arnica cordifolia</i>	<i>Calamagrostis rubescens</i>
<i>Pinus contorta</i>	<i>Amelanchier alnifolia</i>	<i>Chamerion angustifolium</i>	<i>Carex concinnoides</i>
<i>Pseudotsuga menziesii</i>	<i>Linnaea borealis*</i>	<i>Chimaphila umbellata*</i>	<i>Carex geyeri</i>
<u>Subcanopy:</u>	<i>Mahonia repens</i>	<i>Clintonia uniflora*</i>	<i>Oryzopsis asperifolia</i>
<i>Abies lasiocarpa</i>	<i>Rosa woodsii</i>	<i>Eurybia conspicua</i>	
<i>Pseudotsuga menziesii</i>	<i>Rubus parviflorus</i>	<i>Symphyotrichum laeve var. laeve</i>	
<i>Thuja plicata</i>	<i>Spiraea betulifolia</i>	<i>Xerophyllum tenax*</i>	
<i>Tsuga heterophylla</i>	<i>Symphoricarpos albus</i>		
	<i>Vaccinium caespitosum*</i>		
	<i>Vaccinium membranaceum*</i>		
	<i>Vaccinium myrtillus*</i>		

Quaking aspen (montane – east and west):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta
Populus tremuloides

Shrubs

Acer glabrum
Amelanchier alnifolia
Mahonia repens
Prunus virginiana
Rosa acicularis
Rubus parviflorus
Salix scouleriana
Spiraea betulifolia
Symphoricarpos albus

Forbs/Ferns

Aster conspicuus
*Castilleja miniata**
Chamerion angustifolium
Equisetum arvense
Fragaria virginiana
Heracleum sphondylium
*Maianthemum racemosum**
*Maianthemum stellatum**
*Osmorhiza occidentalis**
*Thalictrum occidentale**
Veratrum viride
*Viola canadensis**

Grasses

Bromus carinatus
Calamagrostis canadensis
Calamagrostis rubescens
Carex geyeri
Elymus glaucus

Quaking aspen/black cottonwood/conifer (montane – east and west):Trees

Abies lasiocarpa
Betula papyrifera
Picea engelmannii
Pinus contorta
Populus tremuloides
Populus balsamifera

Shrubs

Alnus viridis
Amelanchier alnifolia
Cornus sericea
Lonicera utahensis
Ribes inerme
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus/occidentalis

Forbs/Ferns

Actaea rubra
*Angelica arguta**
Chamerion angustifolium
*Disporum trachycarpum**
*Equisetum arvense**
Eurybia conspicuus
Fragaria virginiana
Geranium viscosissimum
Heracleum sphondylium
*Maianthemum stellatum**
*Osmorhiza occidentalis**
Pteridium aquilinum
*Thalictrum occidentale**
*Viola canadensis**

Grasses

Calamagrostis canadensis
Carex geyeri
Elymus glaucus
Melica smithii

Idaho Fescue/rough fescue (montane – east and west):Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda

Forbs/Ferns

Achillea millefolium
Agoseris glauca
Anemone multifida
Antennaria rosea
Antennaria umbrinella
Cerastium arvense
Eriogonum umbellatum
Fragaria virginiana
Gaillardia aristata
Galium boreale
Geranium viscosissimum
Geum triflorum
Hedysarum sulphureum
Heuchera cylindrica
Lithospermum ruderales
Lomatium triternatum
Lupinus sericeus
Penstemon confertus
Potentilla glandulosa
Potentilla gracilis
Sedum lanceolatum

Grasses

Achnatherum occidentale
Achnatherum richardsonii
Carex obtusata
Carex petasata
Carex rossii
Danthonia intermedia
Elymus trachycaulus var. subsecundus
Elymus trachycaulus var. trachycaulus
Festuca campestris
Festuca idahoensis
Koeleria macrantha
Pseudoroegneria spicata

Subalpine meadow (subalpine – east and west):

Trees

Abies lasiocarpa

Shrubs

Dasiphora floribunda

Salix arctica

*Vaccinium caespitosum**

*Vaccinium scoparium**

Forbs/Ferns

Achillea millefolium

Agoseris glauca

Anemone occidentalis

Antennaria alpina/umbrinella

Arenaria capillaris

Arnica diversifolia/ mollis

*Castilleja spp.**

Chamerion angustifolium

Epilobium anagallidifolium

Erigeron compositus

Erigeron peregrinus

Eriogonum flavum

Galium boreale

Hedysarum sulphurescens

Heracleum sphondylium

Hypericum scouleri

Oxyria digyna

Pedicularis bracteosa

Phacelia hastata

Polygonum bistortoides

Potentilla diversifolia

Senecio cymbalarioides

Sibbaldia procumbens

Solidago multiradiata

Symphyotrichum foliaceum var. foliaceum

Symphyotrichum laeve var. laeve

Valeriana sitchensis

Veratrum viride

Veronica wormskjoldii

*Xerophyllum tenax**

Zigadenus elegans

Grasses

Agrostis variabilis

Carex haydeniana

Carex nigricans

Carex paysonis

Carex phaeocephala

Carex spectabilis

Deschampsia atropurpurea

Juncus drummondii

Juncus mertensianus

Juncus parryi

Luzula glabrata / spicata

Phleum alpinum

Poa alpina

Poa secunda

Trisetum spicatum

See 2008 Revegetation Monitoring Report to see suggestions about which species should be seeded or grown in containers, or both.

Road sides (montane – east and west):

Trees

various by site

Shrubs

Arctostaphylos uva-ursi

Juniperus communis

*Linnaea borealis**

Mahonia repens

Rosa woodsii

Spiraea betulifolia

Symphoricarpos albus

Forbs/Ferns

Achillea millefolium

Anaphalis margaritacea

Antennaria howellii

Antennaria rosea

*Aralia nudicaulis**

Arnica cordifolia/ latifolia

Chamerion angustifolium

Eurybia conspicua

Fragaria virginiana/ vesca

Geranium viscosissimum

Geum macrophyllum

Heracleum sphondylium

*Maianthemum stellatum**

*Osmorhiza berteroi**

Solidago canadensis

Symphyotrichum laeve var. laeve

*Xerophyllum tenax**

Grasses

Bromus carinatus

Bromus vulgaris

Calamagrostis rubescens

Carex concinnoides

Carex geyeri

Carex microptera

Carex rossii

Deschampsia elongata

Elymus glaucus

Elymus trachycaulus v.

trachycaulus

Festuca occidentalis

Festuca subulata

Oryzopsis asperifolia

Other generally good revegetation species to use that have wide ecological amplitude:

Achillea millefolium
Anaphalis margaritacea
Antennaria bonellii
Fragaria virginiana/vesca
Symphyotrichum laeve var. *laeve*

Species to continue experimenting with in the nursery:

<i>Adenocaulon bicolor</i> *	<i>Maianthemum stellatum</i> *
<i>Angelica arguta</i> *	<i>Orthilia secunda</i> *
<i>Aralia nudicaulis</i> *	<i>Osmorhiza berteroi</i> *
<i>Castilleja</i> spp.*	<i>Osmorhiza occidentalis</i> *
<i>Chimaphila umbellata</i> *	<i>Thalictrum occidentale</i> *
<i>Clintonia uniflora</i> *	<i>Tiarella trifoliata</i> *
<i>Disporum bookeri</i> *	<i>Vaccinium</i> spp.*
<i>Disporum trachycarpum</i> *	<i>Viola canadensis</i> *
<i>Hieracium albiflorum</i> *	<i>Viola orbiculata</i> *
<i>Linnaea borealis</i> *	<i>Xerophyllum tenax</i> *
<i>Maianthemum racemosum</i> *	

COMMUNICATION:

- (1) Continue to conduct revegetation monitoring meetings for discussion about the monitoring data and evaluation of revegetation program. It may be more useful to hold several meetings that focus on certain revegetation issues. These issues could include: (1) use of fertilizers; (2) road shoulder revegetation strategies; (3) setting goals and objectives; (4) evaluation of monitoring techniques; (5) seed bank analysis and its impact on revegetation; and (6) research ideas for the field and for the nursery.

VIII. MONITORING SCHEDULE: 1992 - 2024

1992

- 303-B - Level III (year 1)

1993

- 303-B - Level III, photomonitor (year 2)
- 303-B road shoulders - Level II (year 1)
- 303-C - Level II, photomonitor (year 1)
- Rob Tyser's Two Dog Flats plots - Level IV (year 1)
- 303-D - site analysis, photomonitor
- 303-E - site analysis, photomonitor
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor
- Swiftcurrent Apartments - Level II
- Three Bears Lake - Level II
- St. Mary Housing - Level II

1994

- 303-B - Level III, photomonitor (year 3)
- 303-B road shoulders - Level II, photomonitor (year 2)
- 303-C - Level II, photomonitor (year 2)
- 303-C road shoulders - Level II, photomonitor (year 1)
- 303-D - set up first series of shrub plots and established monitoring plots for Level IV experiment
- 303-F - site analysis along road corridor
- Granite Park Chalet - site analysis, photomonitor
- Two Medicine Housing Area - site analysis, photomonitor
- Camas Road - site analysis (2 sites)

1995

- 303-B road shoulders - Level II, photomonitor (year 3)
- 303-C - Level II, photomonitor (year 3)
- 303-C road shoulders - Level II, photomonitor (year 2)
- Rob Tyser's Two Dog Flats plots - Level IV (year 3)
- 303-D - Level IV, photomonitor (year 1)
- 303-E - photomonitor, wrote preliminary monitoring plans
- 303-F - continued site analysis along road corridor
- Camas Road - site analysis (10 sites)

1996

- 303-B - Level III, photomonitor (year 5)
- 303-D - Level IV, photomonitor (year 2)
- 303-D road shoulders - Level II, photomonitor (year 1)
- 303-E - photomonitor, set up Level IV experiments
- 303-F - Avalanche campground site analysis

1997

- Rob Tyser's Two Dog Flats plots - Level IV (year 5)
- 303-D - Level IV, photomonitor (year 3)
- 303-D road shoulders - Level II, photomonitor (year 2)
- 303-E - Level IV (year 1), photomonitor, set up additional experiments
- 303-F (Avalanche Picnic Area) - photomonitor (pre-disturbance)
- Camas Road - photomonitor (pre-disturbance)

1998

- 303-B road shoulders - Level II, photomonitor (year 6)
- 303-C - Level II, photomonitor (year 6)
- 303-C road shoulders - Level II, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 1 and 2)
- Polebridge Developed Area - Level II, photomonitor
- Polebridge Bridge - Level II, photomonitor
- Bowman Creek Campground - Level II, photomonitor
- River Campground - Level II, photomonitor

1999

- 303-D - Level IV, photomonitor (year 5)
- 303-E - Level IV, photomonitor (year 2 and 3)
- Camas Road - photomonitor (year 1)

2000

- 303-F - Level II, photomonitor (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 4)
- Camas Road - Level II, photomonitor (year 2)
- Three Bears Lake - Level II
- Oberlin Bend / Jones Flat Social Trail Assessment
- Logan Pass Visitor's Center Handicapped Access Trail Assessment
- Lunch Creek Social Trail Assessment

2001

- 303-B - Level III, photomonitor (year 10)
- 303-E - Level IV, photomonitor (year 4 and 5)
- 303-F - Level II, photomonitor (year 2)

2002

- Camas Road - Level II, photomonitor (year 4)
- Rob Tyser's Two Dog Flats plots - Level IV (year 10)
- 303-F – Level II, photomonitor (year 3)

2003

- 303-C - Level II, photomonitor (year 10)
- Camas Road - Level II, photomonitor (year 5)
- Hidden Lake – Level II (year 3)

2004

- 303-D – Level III, photomonitor (year 10)

- 303-F - Level II, photomonitor (year 5)
- GTSR Phase VII Site Analysis

2005

- 303D Shrub Monitoring – Level IV (year 11)
- Apgar-Headquarters Bike Path – Level II (year 1)
- Camas Road Hydromulch – Level II (year 1)
- Hidden Lake Social Trails – Level II (year 5)

2006

- 303-E - Level IV, photomonitor (year 10)
- Apgar Transit Center Site Analysis

2007

- Apgar-Headquarters Bike Path – Level II (year 3)
- Camas Road Hydromulch – Level II (year 3)
- Apgar Transit Center – Level II (year they were planted)
- Apgar Transit Center Experimental Plots - Level IV (year they were planted)
- GTSR Phase VI Site Analysis

2008

- Camas Road - Level II, photomonitor (year 10)
- Apgar Transit Center – Level II (year 1)
- Apgar Transit Center Experimental Plots - Level IV (year 1)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 12)
- Above St. Mary Campground Weed/Reveg. (site analysis)
- Camas Creek Overlook Weed/Reveg. (site analysis)
- West Entrance (site analysis)

2009

- 303-F - Level II, photomonitor (year 10)
- Apgar-Headquarters Bike Path – Level II (year 5)
- Camas Road Hydromulch – Level II (year 5)
- Apgar Transit Center – Level II (year 2)
- Apgar Transit Center Experimental Plots - Level IV (year 2)
- Above St. Mary Campground Weed Rev. (year 1 after spraying)
- Camas Creek Overlook Weed Rev. (year 1)
- West Entrance (year 1)
- Lake McDonald Dorms (site analysis)

2010

- Hidden Lake Social Trails – Level II (year 10)
- Apgar Transit Center – Level II (year 3)
- Apgar Transit Center Experimental Plots - Level IV (year 3)
- Above St. Mary Campground Weed Rev. (year 2 after spraying)
- Camas Creek Overlook Weed Rev. (year 2)
- West Entrance (repeat site analysis when construction is completed)
- Lake McDonald Dorms (year 1)

- GTSR – Phase 6 (year of planting)

2011

- 303-B - Level III, photomonitor (year 20)
- 303-E – Level IV, photomonitor (year 15)
- West Entrance (year 3)
- Lake McDonald Dorm (year 2)
- GTSR – Phase 6 (year 1)
- St. Mary Visitor Center (year 1)

2012

- Rob Tyser's Two-Dog Flats (year 20) – did not do: NOT MONITORING THIS ANYMORE
- Apgar Transit Center – Level II (year 5) – did not do: NOT MONITORING THIS ANYMORE
- Apgar Transit Center Experimental Plots - Level IV (year 5)
- Lake McDonald Dorm (year 3) – did not do
- GTSR – Phase 6 (year 2)
- St. Mary Visitor Center (year 2) – did not do
- Above St. Mary Campground Weed Reveg. (year 1 after seeding)
- Camas Creek Overlook Weed Reveg. (year 1 after seeding) – did not do: NOT MONITORING THIS ANYMORE

2013

- 303-C - Level II, photomonitor (year 20)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 17) – did not do
- Above St. Mary Campground Weed Reveg. (year 2 after seeding) – did not do
- West Entrance (year 5)
- GTSR – Phase 6 (year 3)
- St. Mary Visitor Center (year 3)
- GTSR – Phase XI: Lunch Creek (year 1)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 1)

2014

- 303-D – Level III, photomonitor (year 20) – did not do
- Apgar-Headquarters Bike Path – Level II (year 10)
- Camas Road Hydromulch – Level II (year 10)
- Lake McDonald Dorm (year 5): LAST YEAR OF MONITORING
- GTSR – Phase XI: Lunch Creek (year 2)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 2)

2015

- 303-D – Level III, photomonitor (year 21)
- GTSR – Phase 6 (year 5)
- St. Mary Visitor Center (year 5)
- GTSR – Phase XII: Siyeh Bend to Rising Sun (plot installation)
- Hidden Lake Social Trails – Level II (year 15) – did not do

2016

- 303-E - Level IV, photomonitor (year 20)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 20) – did not do

- Above St. Mary Campground Weed Reveg. (year 5 after seeding) – did not do
- Hidden Lake Social Trails – Level II (year 16)
- GTSR – Phase XI: Lunch Creek (year 5)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 5)
- GTSR – Phase XII: Siyeh Bend to Rising Sun (year 1)

2017

- Apgar Transit Center Experimental Plots - Level IV (year 10)
- Logan Pass Unit D: seed vs. seed & plant experimental plots (year 21)

2018

- West Entrance (year 10)
- Camas Road - Level II, photomonitor (year 20)
- Peter Lesica's tundra monitoring plots (year 28)

2019

- 303-F - Level II, photomonitor (year 20)
- GLORIA monitoring (year 15)
- Peter Lesica's tundra monitoring plots (year 29)
- Peter Lesica's wetland monitoring plots (year 14)

2020

- GTSR – Phase 6 (year 10)
- St. Mary Visitor Center (year 10)
- Hidden Lake Social Trails – Level II (year 20): ONLY MONITOR IF THERE HAS BEEN ADDITIONAL PLANTING OR BARRIERS ON TRAILS
- Peter Lesica's tundra monitoring plots (year 30)
- Peter Lesica's wetland monitoring plots (year 15)

2021

- 303-B: Level III, photomonitor (year 30)
- GTSR – Phase XI: Lunch Creek (year 10)
- GTSR – Phase VIIb: West tunnel to Avalanche (year 10)
- GTSR – Phase XII: Siyeh Bend to Rising Sun (year 5)

2022

2023

- 303-C - Level II, photomonitor (year 30)

2024

- 303-D – Level III, photomonitor (year 30)
- GLORIA monitoring (year 20)
- Apgar-Headquarters Bike Path – Level II (year 20)
- Camas Road Hydromulch – Level II (year 20)

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APPENDIX A. TEMPERATURE AND PRECIPITATION DATA *
WEST GLACIER

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1948-2017	41.7	50.8	57.6	63.9	62.7	53.3	42.4	31.5
1993	43.2	55.7	56.1	56.3	59.0	51.2	43.7	24.0
1994	43.8	53.4	56.8	65.7	65.4	55.5	42.5	28.4
1995	41.1	51.4	56.2	63.1	58.5	54.0	40.2	32.6
1996	42.0	46.3	58.5	65.0	61.5	51.0	40.2	26.4
1997	36.0	51.5	57.4	63.1	63.5	54.5	42.5	31.8
1998	44.0	54.9	56.4	68.4	64.5	59.4	42.3	36.0
1999	41.5	49.3	55.2	60.5	65.7	51.8	42.8	37.7
2000	43.0	50.2	56.7	63.4	63.0	51.0	42.8	28.3
2001	40.0	52.4	55.4	62.8	64.8	57.6	42.7	35.5
2002	39.7	47.8	57.4	67.0	60.3	54.1	37.5	33.2
2003	43.1	50.9	59.7	68.7	67.9	56.8	46.0	26.6
2004	45.8	51.5	58.5	66.7	64.9	52.4	43.2	33.7
2005	43.9	52.7	57.1	65.9	63.3	52.8	44.4	32.6
2006	44.4	53.7	61.8	68.5	64.2	55.3	43.3	30.7
2007	44.0	53.4	60.0	72.3	63.8	54.2	43.5	33.4
2008	37.4	51.3	56.6	65.4	64.2	52.9	43.4	36.4
2009	40.9	51.8	58.2	66.2	63.3	57.9	37.6	34.2
2010	42.2	47.3	56.5	62.7	60.3	53.4	45.1	28.7
2011	37.4	48.8	54.1	62.1	64.9	57.0	44.2	31.8
2012	45.7	49.1	56.7	67.1	63.7	56.2	41.5	35.2
2013	40.4	53.0	58.6	68.2	66.3	57.7	40.3	29.7
2014	41.7	52.2	55.5	66.3	62.4	52.7	46.4	26.6
2015	44.1	52.8	64.3	66.0	65.8	54.9	49.1	31.6
2016	49.1	52.2	60.4	63.8	63.8	53.1	43.0	38.1
2017	41.7	53.3	60.1	68.5	65.3	53.6	39.9	32.1
2018	38.7	55.8	56.8	65.8	63.1	52.1	#	#
Precipitation (inches)								
1948-2017	1.9	2.6	3.4	1.6	1.5	2.0	2.6	3.1
1993	3.2	1.9	4.5	5.1	2.2	2.3	1.0	0.7
1994	1.2	2.2	3.1	0.6	0.2	0.5	4.2	2.7
1995	1.7	1.2	6.9	3.4	2.1	1.4	5.2	7.5
1996	3.0	6.1	1.9	1.2	1.9	3.1	4.1	4.4
1997	2.0	1.8	3.0	1.5	1.4	3.0	3.0	1.6
1998	2.0	4.6	4.9	2.6	1.2	1.7	1.0	3.3
1999	0.9	1.2	3.1	1.8	1.1	0.5	3.8	3.2
2000	1.8	1.6	3.0	1.0	0.4	3.2	0.9	0.7
2001	3.0	1.3	4.0	0.6	0.1	1.2	3.8	2.3
2002	2.4	2.7	3.0	1.5	0.7	1.7	0.5	2.5
2003	1.4	1.9	1.8	0.04	0.1	2.0	2.7	4.1
2004	2.2	2.4	2.2	2.5	4.4	3.7	4.3	3.2
2005	1.7	2.1	7.5	0.5	1.1	4.4	4.6	3.0
2006	1.4	2.3	4.2	0.6	0.8	1.4	1.9	6.2
2007	1.4	2.6	2.4	0.6	0.2	2.1	2.5	0.6
2008	1.2	3.0	3.2	0.9	1.9	1.5	1.4	3.2
2009	1.0	4.0	1.4	2.7	1.6	0.3	3.3	1.4
2010	2.6	3.5	6.6	1.3	1.9	3.9	2.4	3.7
2011	4.7	3.3	4.4	1.7	0.2	1.7	3.9	1.5
2012	3.6	2.5	7.9	2.8	0.5	0.3	6.2	4.6
2013	1.9	2.4	3.0	0.4	1.8	3.9	0.6	4.3
2014	2.5	1.2	5.3	1.2	2.4	1.0	2.4	5.8
2015	0.8	1.1	1.7	0.8	0.4	1.3	1.9	2.5
2016	1.2	6.4	3.0	1.3	2.3	2.5	10.6	2.7
2017	4.8	1.3	3.9	0.0	0.3	1.4	3.4	4.5
2018	2.6	1.5	1.8	0.6	0.5	0.5	#	#

SAINT MARY (# = Missing Data)

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1981-2017	39.6	48.0	55.4	62.4	61.8	52.6	43.4	31.4
1993	42.5	53.8	54.1	54.9	57.6	52.4	44.1	27.7
1994	42.1	52.0	56.9	62.8	63.1	58.9	43.0	27.6
1995	38.8	46.4	54.3	61.9	59.8	53.9	40.4	32.5
1996	43.2	45.0	56.6	64.7	64.0	50.2	42.0	21.0
1997	35.8	47.9	56.2	62.5	62.6	58.3	45.1	34.8
1998	42.1	53.8	53.0	67.8	62.3	58.5	45.8	33.1
1999	39.7	46.9	53.7	59.2	65.7	52.1	43.0	40.1
2000	43.7	50.1	65.3	65.7	65.5	52.6	43.9	28.0
2001	38.2	53.1	56.3	64.7	67.7	59.1	43.5	38.5
2002	34.4	43.9	52.7	63.8	56.6	50.3	36.1	38.2
2003	39.9	52.9	55.7	66.5	66.6	54.5	46.0	26.9
2004	42.5	43.5	52.7	62.6	59.3	49.8	41.1	35.8
2005	38.3	46.9	51.6	63.0	57.2	49.3	42.4	33.6
2006	40.5	48.7	55.8	65.8	59.2	52.5	39.0	26.4
2007	39.1	49.4	56.9	69.0	60.2	52.1	44.5	32.5
2008	35.4	46.5	53.0	61.2	60.7	50.6	44.4	37.2
2009	34.8	47.2	52.2	62.0	58.8	57.2	34.7	35.0
2010	36.0	38.7	48.3	56.6	53.0	46.3	45.8	15.4
2011	29.6	42.2	52.3	60.0	61.1	54.9	41.4	28.6
2012	40.6	44.3	52.7	62.3	60.2	52.0	36.1	32.7
2013	32.1	48.1	54.2	62.0	62.1	52.5	38.4	30.2
2014	38.8	47.3	51.9	64.1	60.2	50.4	48.0	25.7
2015	39.2	43.8	59.2	60.1	61.2	50.8	47.3	30.5
2016	43.1	46.1	55.5	60.7	58.8	50.6	42.7	40.4
2017	39.0	49.6	56.6	67.0	62.5	53.0	41.0	30.5
2018	34.7	52.4	54.7	62.5	61.0	47.8		
Precipitation (inches)								
1981 - 2017	2.0	3.0	3.5	1.6	1.5	1.9	2.1	2.5
1993	0.8	1.9	3.1	6.3	3.6	3.1	0.9	2.0
1994	2.7	2.8	1.4	2.2	0.5	0.2	4.4	1.9
1995	1.9	5.5	7.2	3.3	1.2	3.2	4.2	5.1
1996	1.8	5.0	4.1	0.8	0.4	2.2	1.3	3.6
1997	1.4	3.6	4.1	0.9	2.6	1.1	1.6	0.8
1998	2.2	3.7	5.1	1.7	0.3	1.0	0.2	4.9
1999	1.5	1.5	1.8	0.9	2.2	1.7	3.1	4.1
2000	2.0	1.5	3.8	0.3	0.7	2.2	0.6	0.5
2001	3.8	1.2	3.9	0.7	0.03	0.8	2.3	0.5
2002	1.1	2.0	5.1	0.6	1.5	2.3	1.0	0.2
2003	1.5	1.2	1.6	0.1	0.0	1.0	1.0	2.2
2004	1.6	2.6	3.2	0.7	1.8	1.1	0.8	2.4
2005	1.6	1.3	7.4	0.2	2.0	3.8	2.0	2.0
2006	2.3	2.4	4.3	0.5	0.8	1.9	1.3	5.7
2007	1.5	2.7	1.1	0.4	0.7	2.8	2.0	1.8
2008	0.6	6.7	3.9	0.9	0.7	#	0.6	1.6
2009	2.9	1.2	1.4	4.9	1.8	0.1	2.7	1.5
2010	2.0	4.4	4.7	1.3	1.9	2.4	0.1	2.1
2011	4.0	3.1	2.5	0.6	0.7	0.9	3.1	2.5
2012	1.1	1.0	3.9	0.7	0.6	1.2	3.1	2.7
2013	2.6	2.1	2.8	0.3	1.6	3.0	0.5	1.7
2014	2.2	1.2	7.2	1.0	2.4	1.5	1.7	3.8
2015	1.4	2.3	1.7	1.4	1.0	1.7	1.2	2.0
2016	0.4	3.8	0.9	1.1	2.0	3.0	3.9	1.8
2017	1.8	1.9	1.7	0.1	0.3	0.4	1.7	3.0
2018	1.1	1.9	3.1	1.0	0.7	0.9	#	#

* This data was obtained from U.S./NOAA weather stations operated by Glacier NP and from the Western Regional Climate Center.

** Mean temperature calculated by summing the daily maximum temperature and daily minimum temperature and dividing by two.