

Glacier National Park: Restoration Monitoring Report

2019

By: Jennifer Asebrook and Jennifer Hintz

Division of Resource Management
October 2019



Table of Contents

I. INTRODUCTION	1
II. EASTSIDE GRASSLAND MONITORING	4
A. Introduction.....	4
B. Study Methods.....	5
C. Results.....	7
D. Conclusions and Action Items	19
III. 303-F: UPPER MCDONALD CREEK OF GTSR	34
A. Background and Purpose.....	34
B. Methods	36
C. Results and Discussion.....	36
D. Conclusions and Recommendations	43
IV. WHITEBARK AND LIMBER PINE RESTORATION PROJECT	49
A. Introduction	49
1. Limber Pine Restoration.....	50
2. Whitebark Pine Restoration.....	54
B. Methods	57
C. Results and Discussion.....	59
1. Limber Pine Seedling Results.....	59
2. Whitebark Pine Seedling Results	69
D. Conclusions and Recommendations	89
1. Limber Pine.....	89
2. Whitebark Pine	91
3. Future Monitoring.....	93
V. WHITEBARK AND LIMBER PINE PLUS TREE MONITORING	96
A. Introduction.....	96
B. Methods	97
C. Results	100
D. Conclusions and Recommendations	101
VI. OVERALL RECOMMENDATIONS FOR REVEGETATION AND MONITORING.....	112
VII. MONITORING SCHEDULE: 1992 - 2024.....	117
VIII. RESOURCES AND REFERENCES.....	122

List of Tables

Table 1. Levels of Monitoring.....	1
Table 2. Monitoring projects to date.....	2
Table 3. Eastside Grasslands: Shrub cover changes from 1999-2001 to 2018-2019.....	9
Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species: 1999-2001 vs 2018-2019	22
Table 5. 303-F: Seeding rates for the McDonald Creek section of GTSR.....	34
Table 6. 303-F: Planted Species by Turnout	35
Table 7. 303-F: Goals and Objectives.....	36
Table 8. 303-F: Overall Native and Exotic Cover by Plot, 2000-2019.....	38
Table 9. 303-F: Canopy Cover by Plot for the Upper McDonald Creek section of GTSR, 2000-2019.....	45
Table 10. Limber Pine Monitoring Plot Establishment to Date	51
Table 11. Limber Pine Planting Site Characteristics	53
Table 12. Whitebark Pine Seedling Monitoring Plot Establishment to Date	56
Table 13. Whitebark Pine Seed Plot Establishment	56
Table 14. Whitebark Pine Planting Site Characteristics	57
Table 15. Parkwide: Health and Survival of Remaining Live Limber Pine Seedlings as of Latest Monitoring Event, 2002 – 2019	59
Table 16. Parkwide: Survival of Limber Pine Seedlings Planted in 2004	63
Table 17. Parkwide: Survival, Average Height and Width of All Whitebark and Limber Pine Seedlings Planted in the Park Fifteen Years After Planting.....	64
Table 18. Limber Pine Plot Establishment, Seedlings Planted in 2016	64
Table 19. Limber Pine Seedlings Planted in 2016: Survival and Average Height and Width	68
Table 20. Parkwide: Survival, Average Height and Width of All Limber Pine Seedlings Planted in the Park Three Years After Planting.....	69
Table 21. Parkwide: Survival and Average Height & Width for Whitebark Pine Seedlings from the Most Recent Monitoring Year.	70
Table 22. Parkwide: Overall Health and Survival of Whitebark Pine Planted in Glacier National Park, 2001-2019; as of Latest Monitoring Event	71
Table 23. Whitebark Pine Seedlings Planted in 2014: Survival and Average Height and Width.....	74
Table 24. Parkwide: Survival and Average Height and Width of All Whitebark Pine Seedlings Planted in the Park, Five Years After Planting.....	75
Table 25. Whitebark Pine Seedlings Planted in 2016: Health, Survival and Size, 2016-2019	83
Table 26. Parkwide: Survival and Average Height and Width of All Whitebark Pine Seedlings Planted in the Park, Three Years After Planting.....	85
Table 27. Survival and Average Height and Width of Whitebark Pine Seedlings Planted in 2018.....	88
Table 28. Mt. Brown: Survival and Average Height & Width of Whitebark Pine Seedlings Planted in 2019	88
Table 29. Whitebark and Limber Pine Monitoring Schedule.....	94
Table 30. Numbers of Whitebark Pine Plus Trees Monitored from 2007-2019	98
Table 31. Numbers of Limber Pine Plus Trees Monitored from 2007-2019.....	98
Table 32. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2019	103
Table 33. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2019.....	106
Table 34. Limber Pine Plus Trees: Health and Cone Production, 2019	109
Table 35. Limber Pine Plus Trees: Average Cones Per Tree, 2007 – 2019	110
Table 36. Blister Rust Resistance Results from 24 Whitebark Pine Plus Trees (cycles 3 and 4).....	111

List of Figures

Figure 1. Location of Eastside Grassland Plots Monitored in 2018-2019	6
Figure 2. Eastside Grasslands: Tree cover comparison over time: 1999-2001 vs 2018-2019	8
Figure 3. Eastside Grasslands: Shrub cover comparison over time: 1999-2001 vs 2018-2019	10
Figure 4. Eastside Grasslands: Native grass cover comparison over time: 1999-2001 vs 2018-2019	12
Figure 5. Eastside Grasslands: Native forb cover comparison over time: 1999-2001 vs 2018-2019	14
Figure 6. Eastside Grasslands: Exotic grass cover comparison over time: 1999-2001 vs 2018-2019	16
Figure 7. Eastside Grasslands: Exotic forb cover comparison over time: 1999-2001 vs 2018-2019	18
Figure 8. 303-F: Location of Upper McDonald Creek Section of GTSR Revegetation Monitoring Plots	37
Figure 9. 303-F: Percent Canopy Cover by Lifeform for Plot MD00-04	39
Figure 10. 303-F: Percent Canopy Cover by Lifeform for Plot MD00-05	39
Figure 11. 303-F: Percent Canopy Cover by Lifeform for Plot MD00-06	39
Figure 12. 303-F: Percent Canopy Cover by Lifeform for Plot MD00-07	40
Figure 13. 303-F: Percent Canopy Cover by Lifeform for Plot MD00-08	40
Figure 14. Limber Pine Seedling Monitoring Sites	52
Figure 15. Whitebark Pine Seedling and Seed Monitoring Sites	55
Figure 16. Baring Creek: Limber Pine Monitoring Plots, Planted in the Spring of 2004	61
Figure 17. Dead Horse Point: Limber Pine Monitoring Plots, Planted in the Spring of 2004	61
Figure 18. Sun Point: Limber Pine Monitoring Plots, Planted in the Spring of 2004	62
Figure 19. Base of Altyn Peak: Limber Pine Monitoring Plots, Planted in the Spring of 2004	62
Figure 20. Limber Pine Monitoring Plots Installed and Planted in 2016	67
Figure 21. Divide Creek: Whitebark Pine Seedling Monitoring Plots Established in 2010 and 2014	72
Figure 22. Firebrand Pass Trail: Whitebark Pine Seedling Monitoring Plots Established in 2013 – 2014	76
Figure 23. Numa Lookout: Whitebark Pine Seedling Monitoring Plots, Planted in 2014 – 2015	79
Figure 24. Scenic Point: Whitebark Pine Seedling Monitoring Plots, Planted in 2013 – 2015	79
Figure 25. Spot Mtn: Whitebark Pine Seedling Monitoring Plots, Planted in 2014	80
Figure 26. White Calf Mtn: Whitebark Pine Seedling Monitoring Plots, Planted in 2013-2014	80
Figure 27. Whitebark Pine Monitoring Plots Installed and Planted in 2016	82
Figure 28. Whitebark Pine Seedling Monitoring Plots Established at Sperry Chalet, 2018	87
Figure 29. Whitebark Pine Seedling Monitoring Plots Established at Mt. Brown Lookout, 2018	87
Figure 30. Whitebark Pine Seedling Monitoring Plots Established at Mt. Brown Lookout, 2018-2019	89
Figure 31. Location of Whitebark and Limber Pine Plus Trees	99
Figure 32. Trends in Whitebark Pine Cone Production 2007-2019	108
Figure 33. Trends in Limber Pine Cone Production 2007-2019	109

Appendices

Appendix A. Temperature and Precipitation Data	125
--	-----

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, 2019
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 2019 season. The report includes: (1) results from monitoring 12 eastside grassland plots nearly 20 years after their establishment; (2) data from one revegetation project (303-F 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: 2018-2019

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: 2018-2019

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 and 12 permanent monitoring plots in X discreet meadows were re-read in 2019 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 2018-2019



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: 2018-2019

Monitoring methods remained the same for repeat surveys in 2018 and 2019. A total of 11 plots in 10 discreet meadows were monitored in 2018 and 12 plots in X discreet meadows were monitored in 2019. Plots in both years were 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 in 2018 and all 12 plots in 2019. 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.

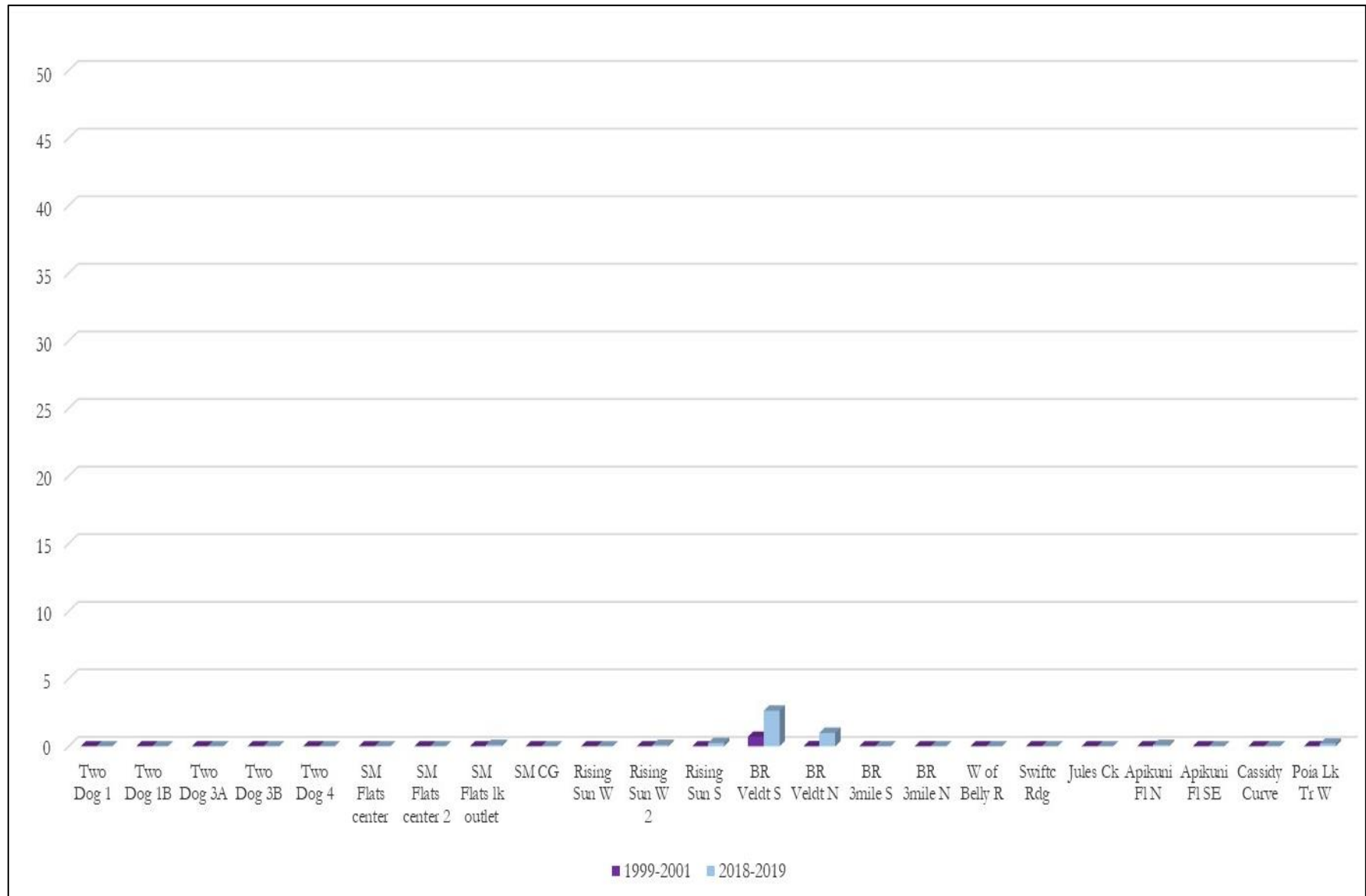
As we aim to define a new baseline of the grassland conditions on the east side of the park prior to the potential introduction of bison, the plan is to re-read 10-15 additional grassland plots on the east side each year over a time period of 5 years. The intent is not to re-read all 155 original plots 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 only present in 7 of the 23 plots that were monitored in 2018-2019. Trees were found, however, in 5 of these 7 plots for the first time during this most recent monitoring event. New trees species include *Betula papyrifera* in 1 plot, *Populus tremuloides* in 1 plot, *Pinus contorta* in 1 plot, and *Pseudotsuga menziesii* in 3 plots. In the two plots in Belly River where trees were present 20 years ago, *Populus tremuloides* remains the only tree present. 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, all plots with the presence of trees could see increased spread tree cover through root sprouting, continued growth of existing stems, and establishment of new tree seedlings.

Figure 2. Eastside Grasslands: Tree cover comparison over time: 1999-2001 vs 2018-2019



2. Shrubs

Shrub cover underwent some of the most notable changes in the past two decades. All 23 plots increased in shrub cover by a range of 2% to 48% and 11 of the 23 plots picked up 1 to 2 new shrub species that were not present 20 years ago. In 1999-2001, shrub cover ranged from 0.71% to 36.43% cover with 15 plots having less than 5% shrub cover, 6 plots having shrub cover ranging from 6-25%, and only 2 plots having shrub cover over 25%. In 2018-2019, shrub cover ranged from 2.94% to 84.57% cover with only 5 plots having less than 5% shrub cover, 13 plots having 6-25% shrub cover, and 5 plots reaching shrub cover ranging from 25-85% (Table 3).

Table 3. Eastside Grasslands: Shrub cover changes from 1999-2001 to 2018-2019.

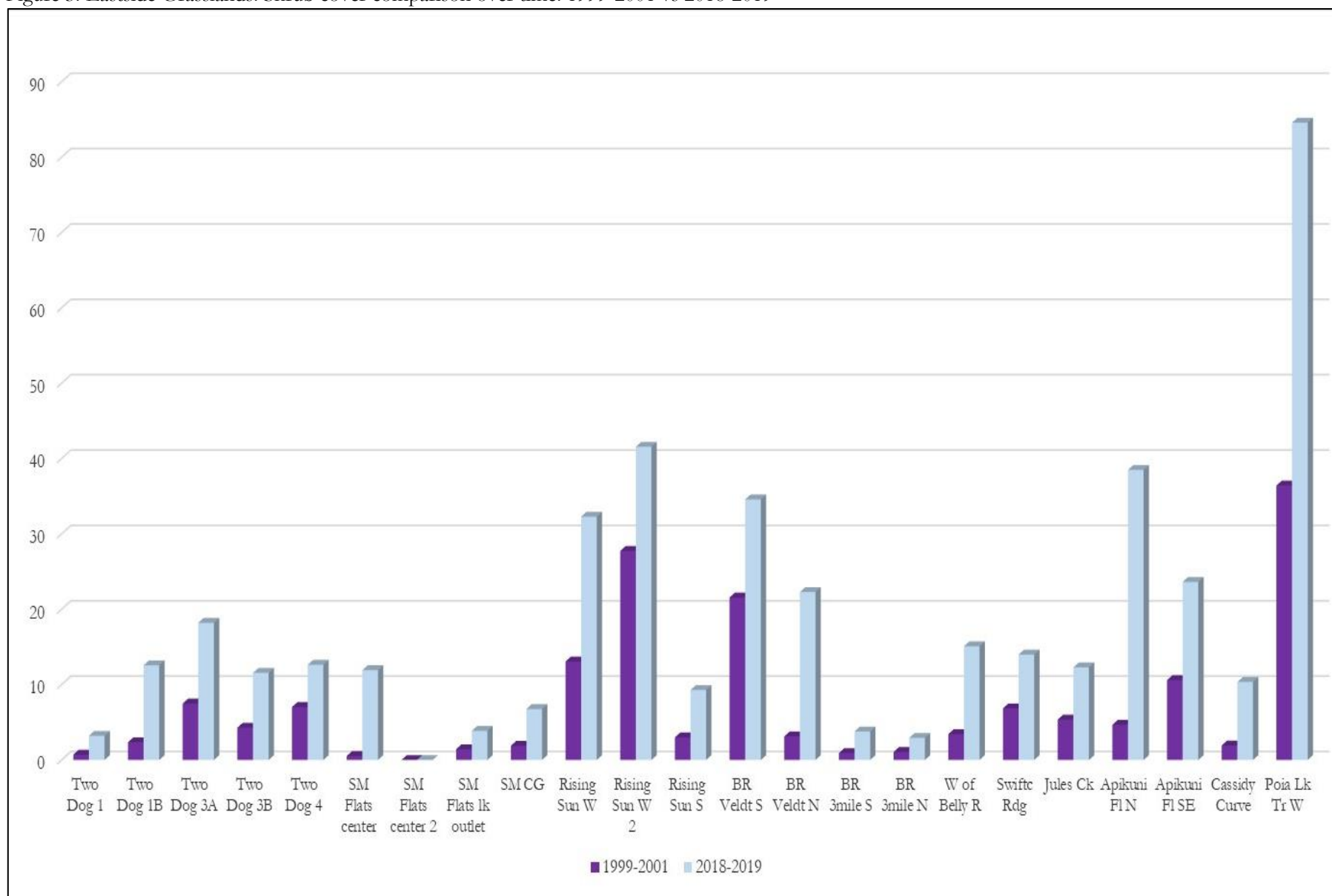
Range of cover (%)	1999-2001 plots	2018-2019 plots
>1	Two Dog 1, SM Flats center (2 plots), Belly River 3-mile S	SM Flats center 2
1 -5	Two Dog 1B, Two Dog 3B, SM Flats lake outlet, SM CG, Rising Sun S, Belly River Veldt N, Belly River 3-mile N, W of Belly R, Apikuni Fl N, Cassidy Curve, Jule's Ck	Two Dog 1, SM Flats lake outlet, Belly River 3-mile S, Belly River 3-mile N
6 - 15	Two Dog 3A, Two Dog 4, Rising Sun W, Swiftc Ridge, Apikuni Fl SE	Two Dog 1B, Two Dog 3B, Two Dog 4, SM Flats center, SM CG, Rising Sun S, Swiftc Ridge, Jule's Ck, Cassidy Curve
15 - 25	Belly River Veldt S	Two Dog 3A, Belly River Veldt N, W of Belly R, Apikuni Fl SE
25 - 85	Rising Sun W 2, Poia Lk Tr W	Rising Sun W (2 plots), Belly River Veldt S, Apikuni Fl N, Poia Lk Tr W

The shrub species that experienced the largest changes were *Rosa* spp., *Amelanchier alnifolia*, and *Arctostaphylos uva-ursi*, and *Mabonia repens* where it was present. *Rosa* spp. (either *R. woodsia* or *R. acicularis*) was present on 22 of the 23 plots, increasing on 15 plots by a range of 1-6% cover over the past two decades. On the 15 out of 23 plots where *Amelanchier alnifolia* is now present, this shrub became newly established on 5 plots over the past twenty years and increased by a range of 0.7% to 6.7% cover on 9 plots. On the 12 plots where *Arctostaphylos uva-ursi* is currently present, this low-growing shrub newly established on 1 plot and increased by a range of 3% to 39% cover on 9 plots. Although *Mabonia repens* is only present on 1 plot, it increased in cover by 15% over the last 20 years.

Pentaphylloides floribunda remains a shrub with high frequency within these fescue grassland plots, present on 19 plots in 2018-2019 compared to 17 plots in 1999-2001. Generally, this plot is also increasing at most sites as it was newly found at 2 sites over the past two decades and increased by 0.6% to 17.5% cover on 12 plots. It is important to note, however, that this shrub remained with the same low cover (>1%) 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 5 shrubs documented within these plots typically remain with low cover, although each of these shrub species experienced small increases in cover. *Prunus virginiana* maintained generally low cover on the 5 plots where it was previously present, while *Juniperus horizontalis* and *Shepherdia canadensis* remained with low cover each on 1 plot where they were previously present. *Symphoricarpos albus* became newly established on 2 plots, now present on 4 plots, while *Spiraea betulifolia* became newly established on 1 plot, now present on 2 plots. Each of these species maintains relatively low cover.

The grasslands that experienced the largest increase in shrub cover (10-48%) were in various areas in the park and due to different increases in shrub species. Shrub cover in Two Dog Flats meadows 1B and 3A increased by 10-11% due

Figure 3. Eastside Grasslands: Shrub cover comparison over time: 1999-2001 vs 2018-2019



to increases in cover of *Amelanchier alnifolia* and *Rosa* spp. Shrub cover in St. Mary Flats/high ridge and in the south Veldt area of the Belly River increased by 11-13% due primarily to a 10-13% increases of *Arctostaphylos uva-ursi*, while shrub cover in the north Veldt and west areas of the Belly River increased by 12-19% due to dramatic increases of *Pentaphylloides floribunda* and *Rosa* spp. Shrub cover within plots at Rising Sun West increased by 14-19% over the past 20 years due to an increase of *Mahonia repens* on one plot, increase of *Arctostaphylos uva-ursi* on another, and increases of *Rosa* spp. on both plots. Finally, shrub cover in grasslands in Many Glacier, including Apikuni Flats N and SE and Poia Lake Trail W, showed dramatic increases in several areas. Shrub cover in Apikuni Flats SE increased by 13% due to increases of *Arctostaphylos uva-ursi* and *Pentaphylloides floribunda*, while shrub cover in Apikuni Flats N increased by 34% due to increases of *Arctostaphylos uva-ursi*, *Pentaphylloides floribunda*, *Rosa woodsia*, and *Amelanchier alnifolia*. Most notably, shrub cover in the area along the Poia Lake Trail W increased by 48%, the largest shrub increase over the past two decades. This was primarily due to a 38% increase of *A. uva-ursi*, however *P. floribunda* and *A. alnifolia* also increased here.

The Poia Lake W plot currently has the highest shrub cover at 84.57%. With a 48% increase in shrub cover over the past 20 years, resulting in a decline of native grass from 8.93% to 4.29%, this area is hard to classify as a grassland anymore. Without naturally recurring fire in some of these areas, plots such as this one will officially become shrublands.

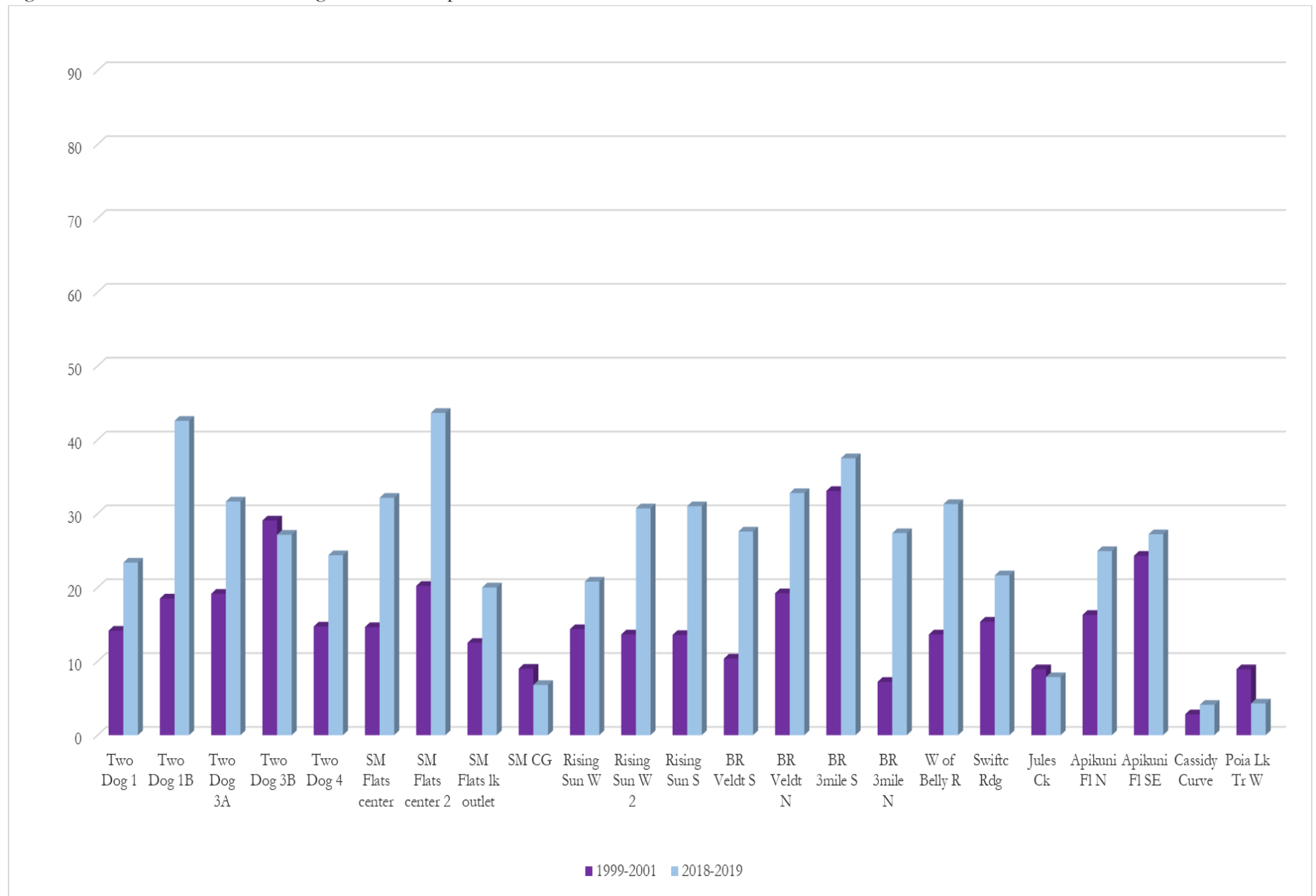
3. Native Grasses

Similar to last year, 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 4.11% to 43.64%. However, 16 of the 23 plots had notable increases in grass cover, increasing by 6-24%, while 3 of the remaining plots had small increases of 2-4% cover. Currently, 10 plots have native grass cover that ranges from 20-30%, 7 plots have native grass cover that ranges from 30-40%, and 2 plots have native grass cover that is over 40%. These totals are due to the fact that over the past 20 years, 9 plots increased in native grass cover by 1-10%, 8 plots increased in native grass cover by 10-20%, and 2 plots increased in native grass cover by 20-30%. Areas that had consistent increases in native grass cover include Rising Sun, Belly River, Apikuni Flats, and most areas in Two Dog and St. Mary Flats.

Overall, native grasses with the highest frequency across grassland plots and the most notable cover include typical species of fescue grasslands: *Festuca idahoensis*, *Festuca campestris*, *Koeleria macrantha*, *Danthonia intermedia*, *Pseudoroegneria spicata*, *Stipa nelsonii*, and *Carex* spp. (predominantly *Carex petasata*, *C. obtusata*, *C. rossii*, and *C. filifolia*). *F. idahoensis*, *F. campestris*, *K. macrantha*, and *Carex* spp. are present on almost all plots, while *D. intermedia*, *P. spicata*, and *S. nelsonii* are present on 13 to 17 out of the 23 plots.

Increases in overall native grass cover were due to notable increases in cover of *Festuca idahoensis* and *Festuca campestris* across many grassland areas. *F. idahoensis* increased in cover on 17 of the 23 plots by 4-16% and newly established on 1 plot. *F. campestris* increased by 2-12% on 14 of the 23 plots. At the same time, *Carex* spp. increased in cover on 12 of the 23 plots and newly established on 1 plot, *Koeleria macrantha* had small increases in many grassland plots, and *Pseudoroegneria spicata* generally increased where it was originally present and newly established on 5 plots. While the following species are less dominant grasses within the fescue grassland type, *Elymus lanceolatus* also increased where it was originally present and newly established on 2 plots, *Elymus trachycaulus* ssp. *trachycaulus* newly established on 7 plots, *Poa secunda* newly established on 10 plots, *Carex filifolia* newly established on 4 plots, and *Stipa nelsonii* newly established on 3 plots. All of these changes contributed to the overall increase in native grass cover in many areas.

Figure 4. Eastside Grasslands: Native grass cover comparison over time: 1999-2001 vs 2018-2019



Only 4 plots did not experience increases in native grass cover. Plots in Two Dog Flats meadow 3B, St. Mary Campground, Jule's Creek, and along the lower Poia Lake Trail had 1-4% decreases in cover over the past two decades. Most of this decrease in cover was due to decreases of *Danthonia intermedia* and *Stipa nelsonii* in the Two Dog 3B plot, a decrease of *Carex* spp. at St. Mary Campground, a decrease of *Festuca idahoensis* at Jule's Creek, and a decrease of *Festuca campestris* along the Poia Lake Trail. Reasons for these declines are varied. At St. Mary Campground, livestock trespass and sporadic, intense herbicide treatment of spotted knapweed in this area has negatively impacted many native species. At the remaining 3 areas, competition from other lifeforms is likely causing the decline of native grasses. Increased shrub and native forb cover could be outcompeting native grasses at Two Dog 3B and along the Poia Lake Trail, while increased exotic grass cover is likely outcompeting native grasses at Jule's Creek. Increased shrub cover along the Poia Lake Trail has been so dramatic in fact that this area is more closely aligned as a dwarf shrubland instead of a fescue grassland at this point. It is important to note that such small decreases (or increases) may be a result of observer error, particularly when assessing grass cover. Bunch grasses are typically easier to gauge ocular cover, however,

Additionally, there appear to be a few native grass species that are declining over time. *Danthonia intermedia* and *Elymus trachycaulus* ssp. *subsecundus* decreased slightly in cover in several areas (although *D. intermedia* increased notably on the Belly River plot west of the river) and these grass species, along with *Pascopyrum smithii* and *Helictotrichon bookeri* were not observed at all in several plots compared to 20 years ago. *Agrostis scabra*, *Carex concinnoides*, *Carex geyeri*, and *Luzula spicata*, each found on one plot two decades ago, were not observed in any plots in 2018-2019.

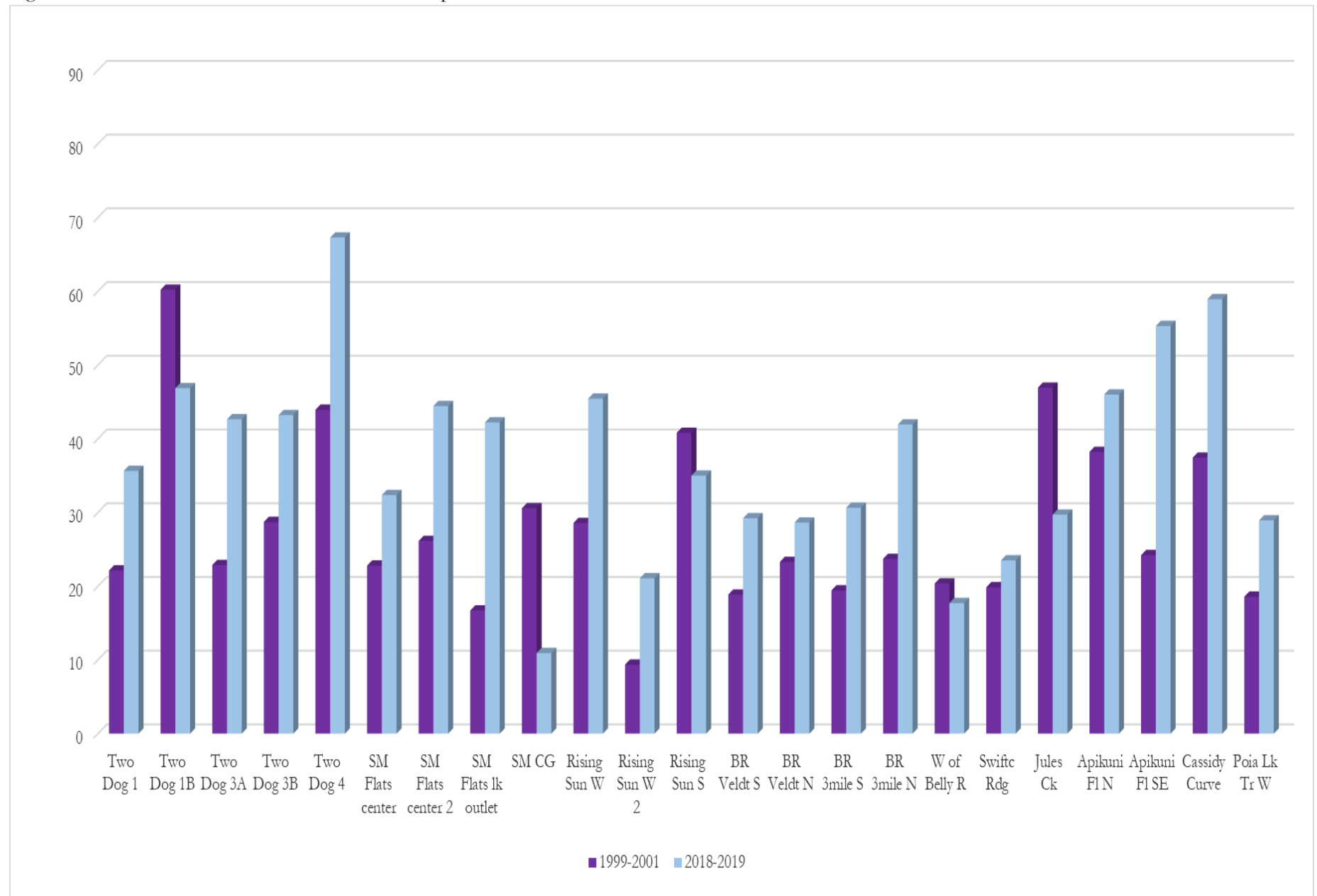
4. Native Forbs

Similar to native grasses, when looking at the overall ranges of native forb cover over time, it would appear that this lifeform has also not changed dramatically. Native forb cover ranged from 9.36% to 60.21% in 1999-2001 and now ranges from 10.93% to 67.29%. However, 12 of the 23 plots that were monitored in 2018-2019 increased in native forb cover by 10-31%, while 3 of the remaining plots had smaller increases of 4-8% cover. Currently, 7 plots have native forb cover that ranges from 20-30%, 11 plots have native forb cover that ranges from 31-46%, and 3 plots have native forb cover that ranges from 55-67%. These totals are due to the fact that over the past 20 years, 3 plots increased in native forb cover by 4-8%, 11 plots increased in native forb cover by 10-20%, and 4 plots increased in native forb cover by 21-31%.

Similar to the native grasses, a few native forbs have both the highest frequency throughout the fescue grassland plots (present on 13 to 23 plots), as well as the highest covers. These include *Achillea millefolium*, *Arnica sororia*, *Cerastium arvense*, *Fragaria virginiana*, *Galium boreale*, *Lomatium triternatum*, *Lupinus sericeus*, *Penstemon confertus*, *Potentilla gracilis*, *Solidago* spp. (*S. missouriensis* and *S. multiradiata*), and *Symphylotrichum laeve*. Over the past two decades, these species generally had notable increases on at least 8 to 14 plots throughout the project, affirming their native forb dominance. Species with particular increases include *A. millefolium*, *A. sororia*, *C. arvense*, *G. boreale*, and *L. sericeus*.

Other native forb species that had high frequency (present on 13 to 23 plots) but generally lower or variable cover include *Agoseris glauca*, *Anemone multifida*, *Antennaria umbrinella*, *Campanula rotundifolia*, *Dodecatheon conjugens*, *Gaillardia aristata*, *Geranium viscosissimum*, *Heuchera cylindrica*, and *Lithospermum ruderales*. 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 (3 to 9 plots) but notable cover in certain areas include *Allium cernuum*, *Balsamorhiza sagittata*, *Calochortus apiculatus*, *Comandra umbellata*, *Eriogonum umbellatum*, *Geum triflorum*, *Hedysarum sulphurescens*, *Hieracium scouleri*, *Mainanthemum stellatum*, *Phlox hoodii*, *Selaginella scopulorum*, and *Zigadenus venenosus*. Many of these forb species increased in cover where they were present two decades ago.

Figure 5. Eastside Grasslands: Native forb cover comparison over time: 1999-2001 vs 2018-2019



Several new forb species were observed for the first time in these 23 meadows. New plants that were newly documented in these plots include *Allium textile*, *Antennaria howellii*, *Antennaria racemosa*, *Arabis drummondii*, *Arabis boelboellii*, *Astragalus adsurgens*, *Astragalus alpinus*, *Astragalus robbinsii*, *Collomia parviflora*, *Collomia linearis*, *Delphinium bicolor*, *Epilobium brachycarpum*, *Heuchera parvifolia*, *Musineon divaricatum*, *Myosotis alpestris*, *Orthocarpus luteus*, *Oxytropis borealis*, *Perideridia gairdneri*, *Piperia unalascensis*, *Polygonum douglasii*, *Prenanthes sagittata*, *Stellaria longipes*, *Veronica peregrina*, *Viola nuttallii*, and *Zizia aptera*. Most of these species were only newly documented in one plot.

It is important to note that on the five plots where native forb cover did decrease, the decline was often quite dramatic. Plots in the meadows at Two Dog Flats 1B, St. Mary Campground, and Jule's Creek decreased in native forb cover by 14-20% over the past twenty years. At Two Dog 1B, this is likely a result of large increases in shrub, native grass and *Centaurea maculosa* cover in this meadow. A notable increase of exotic grasses likely caused the decline of native forbs at Jule's Creek, while a notable increase of *C. maculosa*, sporadic herbicide application, and an increase of exotic grasses likely negatively impacted native forbs above St. Mary Campground. Currently, this area above the St. Mary Campground has the lowest overall native forb cover at 10.93%, a decline from 30.57% cover in 1999. Two plots at Rising Sun below the GTSR and West of the Belly River also had small declines in native forb cover, however, their overall native forb cover remains moderate to high.

It is also important to note that some species, even the dominant ones, did decrease in certain meadows. Competition from other lifeforms, herbicide application and other disturbances, and varying temperature and precipitation levels over the past twenty years has negatively impacted certain species in certain areas, even those that have typically increased across most grasslands. At the same time, several species were no longer found on these 23 plots that were observed two decades ago. These include *Anemone patens*, *Artemisia ludoviciana*, *Astragalus australis*, *Botrychium lunaria*, *Erigeron compositus*, *Eriogonum flavum*, *Gentianella amarella*, *Happlopappus carthamoides*, *Polemonium pulcherrimum*, *Saxifraga rhomboidea*, and *Senecio streptanthifolius*.

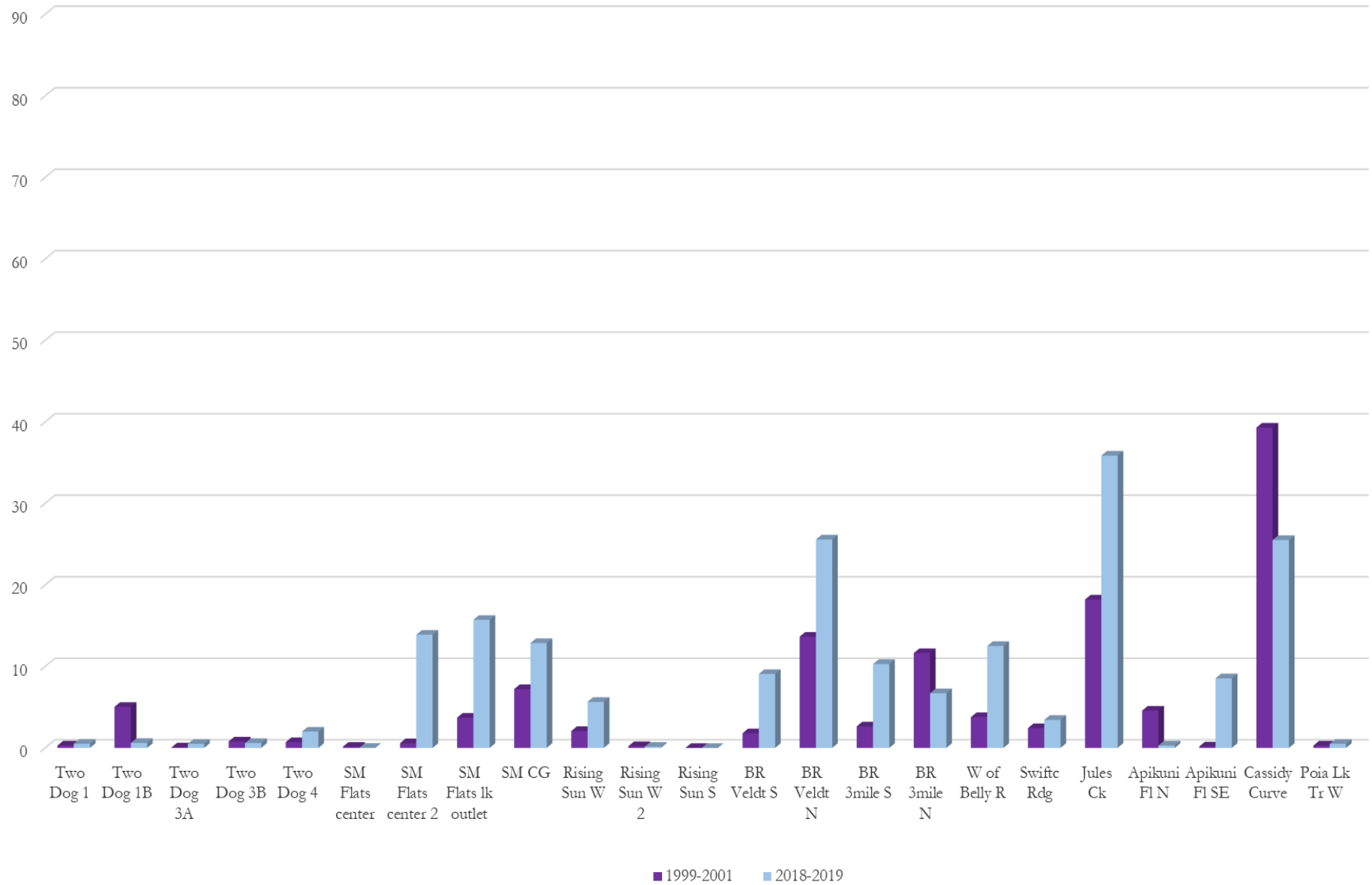
5. Exotic Grasses

There was no overall trend for changes in exotic grass cover over the past two decades. Exotic grass cover did not change dramatically on 9 of the 23 plots, remaining with the same relatively low cover that ranged from 0% to 3.44% twenty years ago. Interestingly, the areas that have remained with low exotic grass cover include many areas in St. Mary: all the Two Dog Flats plots, Rising Sun W and Rising Sun below the GTSR, and the high ridge within St. Mary Flats. Low exotic grass cover also remains on Swiftcurrent Ridge in Many Glacier.

Additionally, exotic grass cover actually decreased on 4 plots over the past 20 years. Two of these plots now have very low exotic grass cover as exotic grasses decreased from 5.04% to 0.61% at Two Dog 1B and decreased from 4.57% to 0.29% at Apikuni Flats N. In total, 11 of the 23 grassland plots monitored to date have no more than 3.44% exotic grass cover, a positive trend. The remaining plots that experienced decreases in exotic grass cover include Belly River 3-mile N where exotic grasses decreased in cover from 11.64% to 6.71% and Cassidy Curve where exotic grasses decreased from 39.29% to 25.5%. While the reasons for this decrease in exotic grass cover are uncertain, native grasses and native forbs increased dramatically on the 3-Mile N plot, while shrubs and native forbs increased dramatically on the Cassidy Curve plot, likely outcompeting certain exotic grasses. It is also important to note that despite a decrease in exotic grass cover at the Cassidy Curve site, exotic grasses still remain relatively high with 25.5% cover.

Exotic grass cover notably increased, however, on 9 other plots, particularly in the Belly River area, St. Mary Flats, St. Mary Campground, and in the Jule's Creek ridge off the Chief Mountain Road. Exotic grasses increased by 5-17% in these areas, with the largest increase in exotic grass cover occurring 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 2-17% on 7 plots, and *Poa pratensis*, which increased from 5-

Figure 6. Eastside Grasslands: Exotic grass cover comparison over time: 1999-2001 vs 2018-2019



8% on 8 plots. *Phleum pratense* was observed on 22 of the 23 plots, while *Poa pratensis* increased in frequency over the past twenty years, now found on 20 plots compared to 16 plots in 1999-2001. *Dactylis glomerata* was also a new exotic grass, found on one plot with low cover in 2019.

6. Exotic Forbs

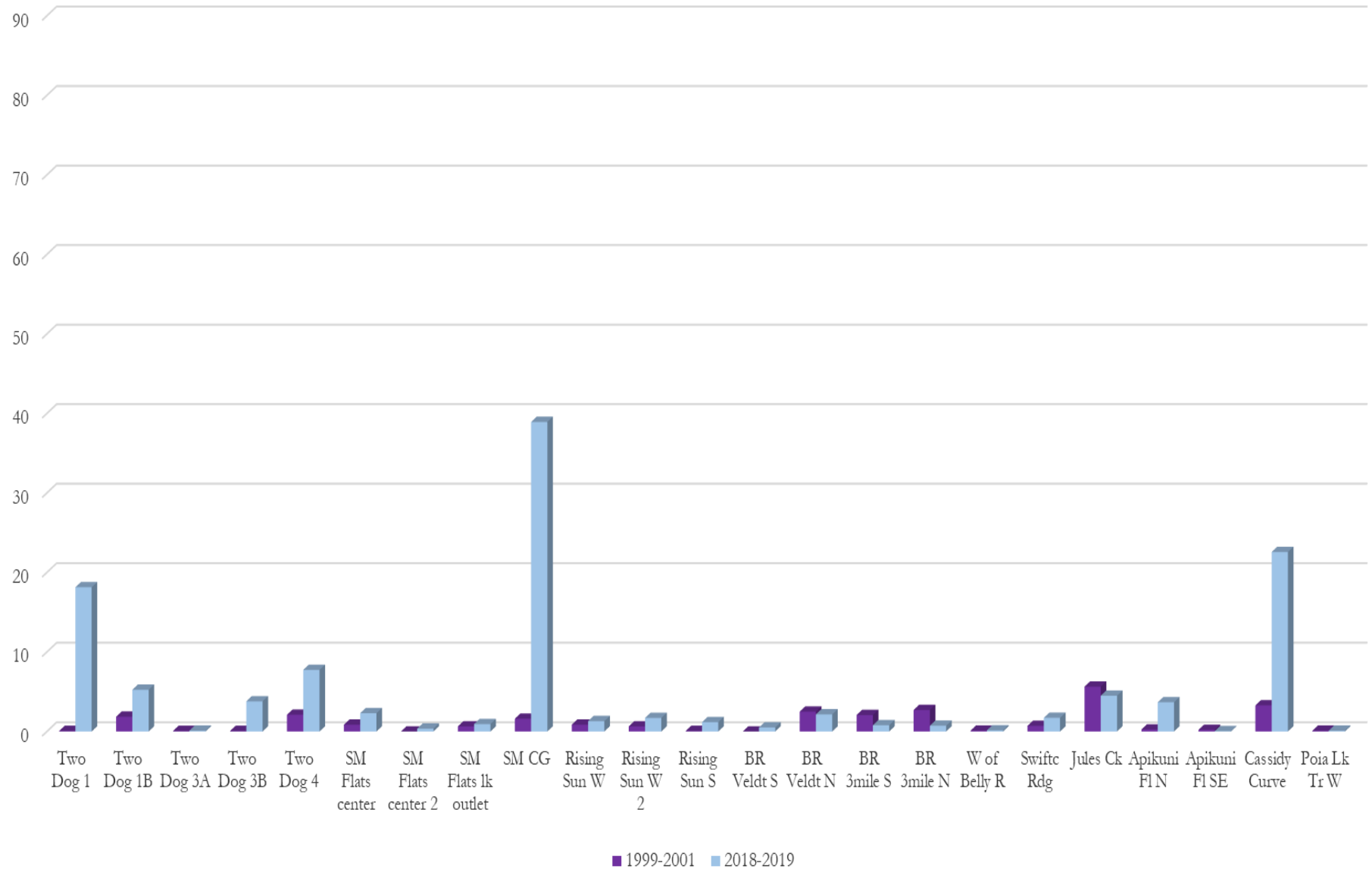
Overall, exotic forb cover has remained relatively low on the majority of the grassland plots monitored in 2018-2019. While there have been small increases in exotic forb cover in some areas, 19 of the 23 plots have no more than 5% exotic forb cover. This includes all plots in Rising Sun, St. Mary Flats, the Belly River, and most areas in Two Dog Flats and Many Glacier. Four plots actually decreased in exotic forb cover by 1-2% over time, due to decreases in cover of *Taraxacum officinale* and *Descurainia sophia* and no establishment of new exotic forb species. These areas include the Belly River 3-mile south and north areas, Jule's Creek, and Apikuni Flats SE.

Exotic forb cover did notably increase, however, on two plots in Two Dog Flats, on one plot at the St. Mary Campground, and on one plot at Cassidy Curve in Many Glacier. Exotic forb cover increased by 5 to 18% on plots in Two Dog Flats meadows 1A and 4 due exclusively to increases of *Centaurea maculosa*. Exotic forb cover increased by 19% in the Cassidy Curve plot due to increases in cover of *Cirsium arvense* and *Taraxacum officinale*. Finally, exotic forb cover increased a considerable 37% in the St. Mary Campground plot due primarily to large increases in cover of *C. maculosa*, and to a lesser extent, increases in cover of *T. officinale*. *C. maculosa* increased in frequency across the project, now present on 12 plots compared to 7 plots in 1999-2001. This trend should be watched over time and documented if it is happening in other grassland areas. Grassland areas where *C. maculosa* is on the rise should be actively treated.

It is interesting to note that the two plots in Two Dog Flats that experienced increases in *C. maculosa* also had dramatic increases in native species. Native grasses and forbs increased in the Two Dog 1A plot, while shrubs, native grasses and native forbs increased in the Two Dog 4 plot. High native cover in grassland communities does not make these areas immune to invasion and increase of this aggressive noxious weed. While shrubs and native forbs increased at Cassidy Curve over the past two decades, native grass in this area remains low, reducing the ability of native species to compete with invading exotic forbs. Finally, due to heavy weed control, historic grazing, and disturbance at the St. Mary Campground plot, both native grasses and native forbs declined over time. It is not surprising that both exotic forbs and exotic grasses increased dramatically at this site over the last twenty years.

Unlike plots monitored in 2018 where there were very few new exotic species establishing in grassland areas, plots monitored in 2019 saw the introduction of several new exotic forb species to these grasslands. Overall, 9 new exotic forb species were observed for the first time in these grassland plots, including 3 new species of noxious weeds. New exotic forb species include *Arenaria serpyllifolia*, *Chenopodium album*, *Erysimum chieranthoides*, *Medicago lupulina*, *Trifolium hybridum*, and *Veronica arvensis*, as well as noxious weed species *Cirsium arvense*, *Hypericum perforatum*, and *Linaria vulgaris*. In addition to *C. maculosa* increases in frequency, *Achysum alyssoides*, *Thlaspi arvense* and *Tragopogon dubius* also had notable increases in frequency across plots over the past twenty years. Based on their ability to increase in grassland communities, all noxious weed species should be closely watched in addition to *T. dubius*, which has been documented to significantly increase in grasslands in other Montana parks.

Figure 7. Eastside Grasslands: Exotic forb cover comparison over time: 1999-2001 vs 2018-2019



D. CONCLUSIONS AND ACTION ITEMS

The 23 plots that were monitored in 2018 and 2019 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 second 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 and 2019.

A major change over the past two decades is that all 23 plots increased in shrub cover by a range of 2% to 48% and 11 of the 23 plots picked up a 1 to 2 new shrub species that were not present 20 years ago. The shrub species that experienced the largest changes were *Rosa* spp., *Amelanchier alnifolia*, *Arctostaphylos uva-ursi*, and *Mahonia repens* where it was present. Tree species are also becoming established in several plots where they were not present in the past. New trees species include *Betula papyrifera* in 1 plot, *Populus tremuloides* in 1 plot, *Pinus contorta* in 1 plot, and *Pseudotsuga menziesii* in 3 plots. 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 23 plots indicate that shrub increase, and possibly tree increase, is a problem in most 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, 19 of the 23 plots exhibited an increase in native grass cover over the past two decades, ranging from a 2% to 24% increase. The remaining four plots only had small decreases in native grass cover. While there are changes in cover and frequency of certain native grasses, overall dominant native grasses remained the same and the overall diversity of native grasses is not dramatically changing.

Currently, there are no action items to address the health of native grasses within these grassland communities. Monitoring should continue to assess if certain native grasses are indeed declining, such as the data indicate for *Danthonia intermedia*, *Elymus trachycaulus* ssp. *subsecundus*, *Pascopyrum smithii* and *Helictotrichon hookeri*. 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 campestris*. 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, 15 of the 23 plots that were monitored in 2018-2019 had increases in native forb cover over the past two decades, ranging from a 4% to 31% increase. Generally, the dominant native forbs remained the same, and while there were species that disappeared from these 23 plots, there were more new species that were documented for the first time. Plots that experienced dramatic decreases in native forb cover were likely due to competition from other lifeforms, as well as extreme herbicide application. Increased exotic grass cover at Jule's Creek off the Chief Mountain Road, increased shrub, native grass and *Centaurea maculosa* cover at Two Dog 1B, and increased exotic grass cover and intense herbicide application at St. Mary Campground likely negatively impacted native forbs in these areas.

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 5% to 17%, 9 of the 23 plots monitored in 2018-2019, specifically in meadows in the Belly River, St. Mary Flats, St. Mary Campground, 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, 13 of the 23 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 2018-2019. While there have been small increases in exotic forb cover in some areas, 19 of the 23 plots have no more than 5% exotic forb cover, similar to values in 1999-2001. Four plots actually decreased in exotic forb cover by 1-2% over time.

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 2 plots in 1999-2001 to 14 plots in 2018-2019. 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. Finally, 9 new exotic forb species were observed for the first time in these grassland plots, including noxious weed species *Cirsium arvense*, *Hypericum perforatum*, and *Linaria vulgaris*, that is cause for concern.

Due to the fact that overall exotic forb cover remains low, 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, particularly some of the newly invaded meadows; (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 2020 as part of this on-going study to determine a new baseline health for these eastside grasslands, especially prior to potential bison reintroduction.

Table 4. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate (not in micrplots).

	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
Ground Cover																						
Bare soil		0.23	0.04	2.79	1.29	6.50	0.36	4.21	1.14	5.00	1.57	2.07	1.68	1.36	1.43	0.64	4.14	14.00		0.43	0.61	2.21
Basal vegetation	6.86	3.57	5.14	7.86	7.50	5.36	5.14	5.07	5.64	6.79	4.07	4.57	4.14	5.00	6.93	7.43	4.79	5.00	7.00	5.57	3.64	6.07
Gravel					0.07	0.29		0.22	0.75	0.71	0.07	0.07			0.11		0.64	4.21			1.00	0.75
Lichen	0.29		0.07	0.71	0.29	2.14	0.18	0.23	0.32	1.07	1.21	9.36			0.04						1.89	4.86
Litter	49.36	65.64	58.36	66.14	84.57	75.14	40.36	76.21	84.47	76.93	74.00	73.50	90.79	93.64	81.57	89.64	82.64	75.93	87.71	91.36	53.29	44.93
Moss	37.00	27.43	32.86	12.36	1.00	6.86	49.57	9.93	0.64	3.07	0.14	6.86	3.29			1.71	6.07			2.79		18.50
Rock	1.43	1.07			1.29	0.93	0.25	0.57	0.07	0.07	1.00	1.07					0.07	0.86	0.07		10.5	8.50
Wood			0.21						0.54								0.14					
SELSCO ground cover			1.36	10.9					6.43	6.50			0.04		6.00						27.9	13.2
Other	3.36				0.86						6.57								0.07			
Other (domestic scat)																						
Other (elk scat)		1.73	2.68			1.93	2.32	2.16	0.29	0.18		3.94	0.50		4.04	0.57	1.68				1.39	0.25
Tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.25
<i>Betula papyrifera</i>														0.1								
<i>Pinus contorta</i>																						
<i>Populus tremuloides</i>																						
<i>Pseudotsuga menziesii</i>										0.04												0.25
# of tree species	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1
Shrub	0.71	3.21	2.36	12.57	7.50	18.21	4.29	11.57	7.04	12.64	0.53	11.93	1.43	3.87	0	0	1.89	6.77	13.07	32.29	3.00	9.29
<i>Amelanchier alnifolia</i>	0.14	0.71	1.43	8.29	1.86	7.51	1.36	5.79	4.64	6.79								0.86			1.07	0.57
<i>Arctostaphylos uva-ursi</i>						0.1			0.1	15.00	0.43	10.71					0.1	0.1			0.1	5.50
<i>Juniperus horizontalis</i>																						
<i>Mahonia repens</i>				0.1															4.50	20.36		
<i>Pentaphylloides floribunda</i>	0.1	0.71			2.86	3.86	1.43	0.43				1.21		0.3			1.79	4.50			0.1	0.25
<i>Prunus virginiana</i>					0.07	0.51													0.1	0.1	0.1	0.1
<i>Rosa acicularis</i>																						
<i>Rosa spp.</i>	0.57	1.79			2.71	7.36					0.1	0.14	1.43	3.57					8.57	13.43		
<i>Rosa woodsii</i>			0.93	4.39			1.86	5.43	2.43	3.79							0.1	0.1			1.86	2.5
<i>Shepherdia canadensis</i>																						
<i>Spiraea betulifolia</i>																					0.07	0.79
<i>Symphoricarpos albus</i>									0.1	0.1								1.21				
# of shrub species	3	3	2	3	4	5	3	3	4	4	2	3	1	2	0	0	3	5	3	3	6	6
Native Grass	14.14	23.36	18.50	42.57	19.14	31.64	29.07	27.14	14.71	24.36	14.64	32.14	12.50	20.00	20.21	43.64	9.00	6.79	14.36	20.79	13.57	31.00
<i>Agrostis scabra</i>													0.1									
<i>Bromus carinatus</i>	0.07																					
<i>Bromus pumellianus</i>													0.11	0.1	1.25	0.36						
<i>Carex concinnoides</i>																						
<i>Carex obtusata</i>	3.36	5.50	3.25		5.14	3.72			1.18		0.93	0.81	0.36		4.00		5.61		0.57	1.10	0.86	
<i>Carex filifolia</i>		4.43		3.50	4.71	4.50	0.21	0.36			1.93	2.46									0.21	0.21
<i>Carex geyeri</i>			0.1																			

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-99-005		GRAS-00-001		GRAS-99-013		GRAS-01-021		GRAS-01-005		GRAS-99-027		GRAS-99-030		GRAS-99-053		GRAS-01-001		GRAS-99-024		GRAS-99-025	
	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
<i>Carex petasata</i>	0.14		0.1		0.07	0.14			1.79	4.07					0.04	5.50	0.71		0.1			
<i>Carex raynoldsii</i>																						
<i>Carex spp. (obtusata, petasata, rossii)</i>				3.75			6.54	9.43					1.21	9.29				1.89				0.35
<i>Danthonia intermedia</i>	2.64	1.57	1.21	0.71	1.21	3.86	5.39	2.57	2.11	1.14			1.00	1.25	0.29	0.14	0.25	0.43			1.68	0.11
<i>Elymus lanceolatus</i>												4.93			1.14	6.75						
<i>Elymus trachycaulus ssp. subsecundus</i>	0.07		0.1		1.43	1.03							0.96	0.57	0.86	0.96						
<i>Elymus trachycaulus ssp. trachycaulus</i>														0.79		0.79		0.04				
<i>Festuca idahoensis</i>	1.21	4.86	7.93	24.07	2.79	7.07	4.71	6.50	5.79	10.43	4.00	8.14	1.71	0.93	0.79	5.71	0.11	2.36	4.29	15.64	3.07	8.07
<i>Festuca campestris</i>	1.00	4.71	0.36	3.29	1.86	5.43	3.96	3.29	0.71	2.00	4.43	10.29	4.71	7.00	10.43	22.64	2.07	1.43	2.50	3.94	3.14	6.43
<i>Helictotrichon hookeri</i>	0.07	0.14			0.1		0.64								0.32						0.11	
<i>Juncus balticus</i>													0.46	0.61								
<i>Koeleria macrantha</i>	0.29	1.07	1.00	2.14	0.29	3.43	1.39	3.71	0.50	1.93	1.14	2.36	0.32	0.07	0.39	1.79	0.46	0.43	0.50	0.08	0.64	3.36
<i>Luizula multiflora</i>						0.1																30.58
<i>Luizula spicata</i>																						
<i>Muhlenbergia richardsonis</i>															0.96	0.07						
<i>Pascopyrum smithii</i>							0.93	0.31					1.25	0.50								
<i>Poa fendleriana</i>															0.14	0.64						
<i>Poa secunda</i>				0.50		0.36	0.11	0.01		0.29		1.08								0.01		3.54
<i>Pseudoroegneria spicata</i>	0.07	0.86	0.79	3.21		0.51			2.36	4.14		0.43	0.32			0.14		0.14	0.57	0.14	2.68	6.93
<i>Stipa nelsonii</i>	4.79	1.51	4.18	3.57	1.29	3.29	4.64	1.66	0.50	1.11	1.00	2.21			0.07	0.07		0.04	5.64	0.21	1.39	2.64
<i>Stipa richardsonii</i>	0.1	0.1											0.32				0.11	0.39				
# of grass species	12	10	10	9	10	12	10	9	8	8	6	9	13	10	13	13	7	9	7	7	9	9
Native Forb	22.14	35.64	60.21	46.86	22.86	42.64	28.71	43.21	43.93	67.29	22.79	32.36	16.71	42.21	26.14	44.43	30.57	10.93	28.57	45.43	40.79	35.00
<i>Achillea millefolium</i>	2.79	2.29	2.61	6.14	2.00	9.21	1.46	6.08	3.32	5.00	0.79	1.15	0.57	4.21	1.25	1.11	1.61	0.07	2.71	0.1	1.57	2.39
<i>Agoseris glauca</i>	1.00	0.1	1.00	0.57	0.21	0.09	0.71	0.29	0.61	0.93				1.29			1.36	1.29	0.36	0.79		0.1
<i>Allium cernuum</i>		0.1		0.36		0.01	0.39	0.31		0.29		0.10									0.1	1.29
<i>Allium textile</i>																0.04						
<i>Androsace septentrionalis</i>				0.07									0.11									
<i>Anemone multifida</i>	0.50	0.86	0.1	0.29	1.21	3.29	4.00	4.22	2.86	2.64	0.36		0.36	0.07	0.18	0.14	0.1		0.07	0.1	0.25	0.39
<i>Anemone patens</i>			0.04														0.46					
<i>Antennaria anaphaloides</i>				0.1	0.21	0.21			0.21								0.1	0.21				
<i>Antennaria bonellii</i>																						
<i>Antennaria racemosa</i>												0.07										
<i>Antennaria rosea</i>	0.1		0.1	0.1		0.1			0.71	0.64			0.04	2.00	0.04	0.1	0.29	0.1				
<i>Antennaria umbrinella</i>	0.79	2.08	0.57	1.61	0.21	0.93	0.61	0.86	2.36	4.00	0.07	0.14							0.1		1.32	2.86
<i>Arabis drummondii</i>						0.01																
<i>Arabis hirsuta</i>															0.1				0.1		0.04	0.04
<i>Arabis hoelboellii</i>																						
<i>Arabis nuttallii</i>		0.07	0.25	0.36		0.04	0.21	0.01	0.07	0.18							0.04				0.11	

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-99-005		GRAS-00-001		GRAS-99-013		GRAS-01-021		GRAS-01-005		GRAS-99-027		GRAS-99-030		GRAS-99-053		GRAS-01-001		GRAS-99-024		GRAS-99-025	
	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
<i>Arabis glabra</i>																						
<i>Arabis</i> sp.												0.1										
<i>Arnica sororia</i>	0.64	3.36	1.71	2.86	0.21	3.58	1.36	6.93	1.43	2.93	0.71	11.93				0.57	0.57		0.21	0.14	0.50	1.79
<i>Artemisia ludoviciana</i>																			1			
<i>Astragalus adsurgens</i>		0.1												0.25								
<i>Astragalus alpinus</i>																						
<i>Astragalus agrestis</i>																			0.1			
<i>Astragalus australis</i>							0.1															
<i>Astragalus robbinsii</i>																						
<i>Astragalus tenellus</i>											1.64	0.1										
<i>Astragalus</i> spp.															0.11	0.07						
<i>Balsamorhiza sagittata</i>	1.79	2.44	1.50	2.00					10.29	12.21												
<i>Besseyia wyomingensis</i>	0.14	0.36								0.14												
<i>Botrychium lunaria</i>																						
<i>Bupleurum americanum</i>											0.21	0.14										
<i>Calochortus apiculatus</i>			1.61	0.75					0.79	1.79												
<i>Campanula rotundifolia</i>	0.21	1.00	0.1	0.39		1.16	0.57	0.53	0.54	1.36		0.09	0.21	0.54		0.14	0.36	0.14	0.07	0.21	0.04	0.21
<i>Castilleja cusickii</i>							0.04	0.07														
<i>Castilleja hispida</i>									0.79	0.43												
<i>Castilleja sulphurea</i>	0.14	0.50										0.1					3.36					
<i>Cerastium arvense</i>	0.57	2.94	1.29	0.82	0.36	1.86	1.50	1.03	2.71	6.79		0.64	0.29	0.04	0.25	1.64	1.86	1.82	0.43	2.01	1.36	3.61
<i>Cirsium hookerianum</i>																	0.07					
<i>Collinsia parviflora</i>										0.04												
<i>Collomia linearis</i>										0.46										0.21		
<i>Comandra umbellata</i>	0.14	2.00	0.1	0.75	0.1		0.89	1.52			1.07	0.21							0.36	0.64	0.50	0.1
<i>Cryptantha celosioides</i>											0.1	0.01										
<i>Delphinium bicolor</i>		0.10				0.29				0.07												
<i>Dodecatheon conjugens</i>		0.04	0.71				0.18		0.75	0.29										0.02		0.50
<i>Draba nemorosa</i>		0.01	0.11	0.43		0.01						0.03										0.07
<i>Draba</i> spp.																						
<i>Epilobium brachycarpum</i>																						
<i>Equisetum laevigatum</i>													0.50	1.57								
<i>Erigeron caespitosus</i>											0.36	0.1									0.29	0.36
<i>Erigeron compositus</i>																					0.04	
<i>Erigeron speciosus</i>		0.21						0.07	0.29	0.71		0.1								1.57		
<i>Erigeron subtrinervis</i>																	0.21					
<i>Eriogonum flavum</i>							0.1															
<i>Eriogonum umbellatum</i>									1.18	4.57									2.57	0.64		0.1
<i>Erysimum inconspicuum</i>			0.1																			
<i>Eurybia conspicua</i>																						
<i>Fragaria virginiana</i>						0.1	0.14	0.93	0.21	0.79			9.75	14.3	1.00	0.14	12.6	0.14		0.1		0.1
<i>Gaillardia aristata</i>	0.64	2.00	0.21	0.64	0.07	0.79	0.46	0.58	0.29	0.21	0.07	0.1					0.14			0.1	0.36	0.07

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-99-005		GRAS-00-001		GRAS-99-013		GRAS-01-021		GRAS-01-005		GRAS-99-027		GRAS-99-030		GRAS-99-053		GRAS-01-001		GRAS-99-024		GRAS-99-025	
	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
<i>Galium boreale</i>	1.21	5.29	0.86	1.29	0.86	4.08	0.75	2.36	0.46	2.71	1.14	5.29	0.29	3.29	0.14	0.18	0.14	0.68	0.50	17.71	0.07	0.46
<i>Gentianella amarella</i>																						
<i>Geranium viscosissimum</i>		0.1	0.50	1.43			0.04	0.14					0.61	4.14			0.79	0.14	0.79	0.21		
<i>Geum macrophyllum</i>													0.14									
<i>Geum triflorum</i>	0.14	0.29	0.1	0.29							0.36	0.51	0.61	0.64	6.07	17.43					0.1	0.14
<i>Happlopappus carthamoides</i>																			0.07		0.68	
<i>Hedysarum alpinum</i>													0.86	1.71								
<i>Hedysarum sulphurescens</i>					1.07	2.94																
<i>Heterotheca villosa</i>	0.57	0.36									0.07	0.1									0.1	
<i>Heuchera cylindrica</i>	0.1	0.07	0.07	0.14	0.14	0.14	0.43	0.64			0.1	0.14							0.14	1.07		0.1
<i>Heuchera parvifolia</i>		0.1													0.14							0.1
<i>Hieracium scouleri</i> var. <i>albertinum</i>	0.14	0.43	0.21	0.36	0.1	0.29	0.75	2.71	1.50	3.00									0.29	0.07	0.07	0.1
<i>Hieracium umbellatum</i>																						
<i>Lathyrus ochroleucus</i>														0.1								
<i>Linum lewisii</i>																						
<i>Lithophragma parviflora</i>									0.1	0.25												
<i>Lithospermum ruderale</i>	0.14	0.07	0.1	0.50	0.21	1.44	2.21	4.36	0.21	0.36	0.50	0.29	0.1	0.1	0.46	1.25		0.1	0.57	5.71	0.11	1.07
<i>Lomatium dissectum</i>				0.07																		
<i>Lomatium macrocarpum</i>									0.86	0.07									0.14		0.39	4.29
<i>Lomatium triternatum</i>	0.07	0.29	0.07		0.07		0.89		3.79	4.36	0.1						2.29	4.14	1.29	3.00		
<i>Lupinus sericeus</i>	2.86	10.57	4.86	7.93	7.93	18.00	10.61	11.51	4.14	8.29	0.64	0.01			2.46	16.93	1.00	0.1	11.43	18.57	3.64	6.29
<i>Maianthemum stellatum</i>											0.43	1.79	0.1	0.64	0.29	7.79						
<i>Microseris nutans</i>									0.1	0.04												
<i>Microsteris gracilis</i>									0.57	0.79										0.1		
<i>Minnuartia rubella</i>				0.39			0.07															
<i>Moebria lateriflora</i>									0.07													
<i>Monarda fistulosa</i>			0.1	0.1	0.07	0.36	0.07	0.57									0.14	0.1			0.1	
<i>Musineon divaricatum</i>																						0.07
<i>Myosotis alpestris</i>				0.64																		
<i>Orthocarpus luteus</i>								0.01		0.14												
<i>Orthocarpus tenuifolius</i>			0.89	0.96							0.29	0.38			0.04						0.43	
<i>Oxytropis borealis</i>																						
<i>Oxytropis campestris</i>	2.14	0.07	0.25		0.50	0.1	0.07										0.21		0.1	0.1		
<i>Oxytropis sericea</i>																						
<i>Oxytropis splendens</i>			0.04												0.32						0.18	
<i>Pedicularis contorta</i>									0.1	0.04												
<i>Penstemon confertus</i>	0.1	0.1		0.11	0.1	1.44	0.18	0.71		0.50			0.21	3.04	4.50	0.32	0.1	0.1				
<i>Perideridia gairdneri</i>		0.1																				
<i>Pblox boodii</i>	0.29	0.71									1.36	2.00									0.04	
<i>Piperia unalasensis</i>										0.36												
<i>Polemonium pulcherrimum</i>													0.11									

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-99-005		GRAS-00-001		GRAS-99-013		GRAS-01-021		GRAS-01-005		GRAS-99-027		GRAS-99-030		GRAS-99-053		GRAS-01-001		GRAS-99-024		GRAS-99-025	
	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
<i>Polygonum bistortoides</i>																						
<i>Polygonum douglasii</i>				0.07						0.18												
<i>Potentilla arguta</i>					0.14	0.1																
<i>Potentilla glandulosa</i>	0.1	0.01					0.96	0.93	0.68	0.71												
<i>Potentilla gracilis</i>	1.21	0.57	1.61	1.86		0.29	1.79	0.87	0.1		0.07	0.1	1.68	5.86	0.1	0.07	2.21	0.1	0.36	0.29	0.29	0.71
<i>Potentilla hippiana</i>	0.14	0.07			0.29	0.29						0.36	0.1	0.1			0.1				0.1	0.1
<i>Potentilla pensylvanica</i>			0.64	0.29				0.1			0.1											
<i>Prenanthes sagittata</i>																						
<i>Ranunculus</i> spp.														0.1								
<i>Rhinanthus crista-galli</i>									0.04	0.14												
<i>Saxifraga occidentalis</i>		0.1										0.1										0.14
<i>Saxifraga rhomboidea</i>			0.04																			
<i>Sedum lanceolatum</i>					0.1								0.04								0.50	
<i>Selaginella scopulorum</i>	1.79	2.00	1.36	10.89	3.07	2.50	0.97		6.43	6.50	11.00	7.43	0.04		6.00				5.07		27.9	13.2
<i>Senecio canus</i>								1.59			0.07	0.07									0.50	
<i>Senecio pseudoreus</i>														0.46								
<i>Senecio streptanthifolius</i>																						
<i>Silene parryi</i>		0.1		0.04	0.1																	
<i>Sisyrinchium montanum</i>		0.31					0.07	0.24	0.04												0.07	
<i>Solidago missouriensis</i>			1.50	3.50					1.54	0.43			0.57	0.71			1.50	0.93				
<i>Solidago</i> spp. (mostly <i>multiradiata</i>)	0.93	0.43	1.50		1.29	0.29	0.54	1.64			0.50				1.61	0.04				0.1	0.14	
<i>Stellaria longipes</i>										0.25												
<i>Symphyotrichum falcatum</i>				0.04									0.11	0.86		0.14						
<i>Symphyotrichum laeve</i>		0.1				0.71			0.1	0.21				0.32			0.1	1.18	0.21	0.1		
<i>Thalictrum occidentale</i>																						
<i>Veronica peregrina</i>								0.14											0.1			
<i>Vicia americana</i>									0.21								0.14	0.04				
<i>Viola adunca</i>			1.43	0.43								0.29	0.21	0.43					0.07			
<i>Viola nuttallii</i>																0.21						
<i>Zigadenus elegans</i>							0.57	0.08														
<i>Zigadenus venenosus</i>		0.1	2.00	1.39	0.14	3.14			0.68	0.29		0.57				0.43						0.07
<i>Zizia aptera</i>														0.1								
# of forb species	29	43	37	39	26	32	33	31	38	43	25	33	24	26	18	21	25	19	27	26	32	29
Exotic Grass	0.29	0.51	5.04	0.61	0.07	0.50	0.79	0.60	0.71	2.00	0.14	0.01	3.71	15.71	0.57	13.89	7.21	12.86	2.07	5.65	0	0
<i>Bromus inermis</i>																						
<i>Dactylis glomerata</i>																0.07						
<i>Pbelen pratense</i>	0.29	0.51	4.82	0.54	0.14	0.50	0.79	0.39	0.71	2.00		0.1	3.29	7.00	0.1	8.07	3.71	5.79	2.21	3.44		
<i>Poa compressa</i>													0.32				3.54	0.07		0.21		
<i>Poa pratensis</i>		0.08	0.21	0.07		0.08		0.22			0.14		0.21	8.64	0.57	5.75		7.14	0.07	2.23		
# of exotic grass spp.	1	2	2	2	1	2	1	2	1	1	1	1	3	2	2	3	2	3	2	3	0	0

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-99-005		GRAS-00-001		GRAS-99-013		GRAS-01-021		GRAS-01-005		GRAS-99-027		GRAS-99-030		GRAS-99-053		GRAS-01-001		GRAS-99-024		GRAS-99-025	
	Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		Two Dog Flats		St. Mary Flats		St. Mary Flats		St. Mary Flats		St. Mary CG		Rising Sun		Rising Sun	
	Meadow 1A		Meadow 1B		2 Dog - 3		#3, Lower W		Meadow 4		High Ridge		Lake outlet		Center		Above CG		Rising Sun W		Below GTSR	
	1999	2018	2000	2019	1999	2018	2001	2018	2001	2019	1999	2018	1999	2019	1999	2019	2001	2019	1999	2018	1999	2019
Exotic Forb	0.07	18.14	1.86	5.25	0.07	0.10	0.07	3.79	2.11	7.75	0.86	2.30	0.64	0.93	0	0.36	1.61	38.93	0.86	1.31	0.07	1.18
<i>Alyssum alyssoides</i>				0.54				0.01				0.01						0.04	0.1			
<i>Arenaria serpyllifolia</i>										0.21												
<i>Centaurea maculosa</i>	0.1	18.00		4.32		0.04		3.79		6.43	0.86	2.24	0.61				0.1	33.93	0.86	0.43	0.07	0.79
<i>Chenopodium album</i>																						
<i>Cirsium arvense</i>														0.1								
<i>Descurainia sophia</i>																						
<i>Erysimum cheiranthoides</i>																						
<i>Hypericum perforatum</i>										0.29												
<i>Linaria vulgaris</i>																						
<i>Medicago lupulina</i>																						
<i>Taraxacum officinale</i>	0.07		1.86	0.50	0.07		0.07		1.54	0.11			0.07	0.89		0.21	1.54	5.29		0.07		
<i>Thlaspi arvense</i>									0.61	0.89				0.04								
<i>Tragopogon dubius</i>		0.21		0.18		0.01		0.01				0.07		0.04		0.14	0.07	0.86		0.82		0.07
<i>Trifolium agrarium</i>																						
<i>Trifolium hybridum</i>																						
<i>Veronica arvensis</i>										0.04												0.54
# of exotic forb spp.	2	2	1	4	1	2	1	3	2	6	1	3	2	4	0	2	3	4	2	3	1	3

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999- 2018-	
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
Ground Cover																										
Bare soil		0.79	1.36	3.50		0.71	3.57	3.07		6.50	9.71	6.64	5.79	5.36		3.79	0.21	0.21	0.57	2.14	3.14	3.50	0.14	0.07		
Basal vegetation	5.93	8.43	8.43	6.79	9.50	7.64	7.21	6.43	10.07	7.86	5.79	6.57	7.21	5.07	6.07	12.79	7.50	10.29	9.43	5.43	8.93	5.86	7.21	5.21		
Gravel	0.25		0.29	0.71		0.14	0.29	0.21		0.93	0.71	2.07	0.71	1.14		0.36	0.14				0.14					
Lichen	1.29	7.54						0.07								0.46							1.07	0.21		
Litter	77.07	57.14	89.86	88.07	90.50	91.29	87.07	89.71	85.00	83.00	83.64	83.64	78.71	81.79	85.21	81.86	88.36	84.14	89.21	92.21	75.71	90.64	91.21	89.14		
Moss	10.71	25.14		0.79				0.43	6.14	1.21		0.21		2.00	1.86	0.86	2.71	5.36					1.14	5.36		
Rock	0.36	0.50		0.14		0.14		0.07		0.50	0.14	0.14	0.50	0.36	0.43		0.79		0.14		0.07		0.14			
Wood															0.04		0.04				0.04					
SELSCO ground cover	2.21	1.57					2.14								6.04		0.21	0.07						0.07		
Other									0.21			0.07	6.21						0.64							
Other (domestic scat)														4.43						0.21						
Other (elk scat)	1.96	0.50				0.07									0.43		0.18				0.46		0.14			
Tree	0	0.1	0.71	2.64	0.01	1.00	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.2		
Betula papyrifera																									0	1
Pinus contorta																								0.1	0	1
Populus tremuloides			0.71	2.64	0.1	1																		0.1	2	3
Pseudotsuga menziesii		0.1														0.1									0	4
# of tree species	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2		
Shrub	27.75	41.57	21.57	34.59	3.14	22.29	3.43	15.10	0.93	3.79	1.07	2.94	6.86	14.00	4.68	38.50	10.61	23.64	5.36	12.29	1.93	10.36	36.43	84.57		
Amelanchier alnifolia	0.29	1.00		3.07	0.36	3.57		0.07						0.43	1.07	5.71	0.1						1.64	4.36	10	15
Arctostaphylos uva-ursi	26.79	37.93	6.71	24.01					0.21	0.80				1.14	4.29	27.64	7.43	17.8					24.07	62.9	11	12
Juniperus horizontalis																							0.04	1.07	1	1
Mabonia repens		0.1															0.04								2	3
Pentaphylloides floribunda	0.1	1.00	12.71	9.71	1.64	14.00	3.25	14.93	0.36	0.36	0.86	0.87	4.29	5.71	0.43	5.36	1.68	5.14	2.64	4.71	0.07	2.50	9.43	26.93	17	19
Prunus virginiana					0.21	1.29			0.1	0.1															5	5
Rosa acicularis							0.21	0.1							0.46	0.50			2.57	7.57					3	3
Rosa spp.			1.57	1.86	0.93	4.86					0.21	2.07	1.36	3.57											9	9
Rosa woodsii	0.71	3.61							0.36	2.64						1.07	1.54	1.50			1.46	6.93	1.29	2.07	10	11
Shepherdia canadensis															0.1	0.70									1	1
Spiraea betulifolia		0.1																							1	2
Symphoricarpos albus												0.2									0.43	1.00			2	4
# of shrub species	4	6	3	4	4	4	2	3	4	4	2	3	3	4	5	6	4	4	2	2	3	3	5	5		
Native Grass	13.64	30.71	10.36	27.57	19.21	32.79	13.64	31.29	33.07	37.50	7.21	27.36	15.36	21.64	16.29	24.93	24.29	27.21	8.93	7.86	2.82	4.11	8.93	4.29		
Agrostis scabra													0.1												2	0
Bromus carinatus													0.64	1.50					0.36	0.39	1.71	0.68			4	3
Bromus pumpeIIianus																			0.1						3	2
Carex concinnoides															0.29										1	0
Carex obtusata				2.29									2.07		2.07	0.93	0.96								13	6
Carex filifolia		1.21																						0.1	4	8
Carex geyeri																									1	0

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999- 2018-	
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
<i>Carex petasata</i>			0.1			3.07	0.1	0.61	2.36	3.57					6.00	0.14	0.21				0.32	1.21	1.89	1.21	14	9
<i>Carex raynoldsii</i>																			0.1	0.1	0.1				2	1
<i>Carex spp. (obtusata, petasata, rossii)</i>	1.36	3.64											0.57	0.1	5.64			2.14	0.21	1.79					5	11
<i>Danthonia intermedia</i>	0.54	0.46	1.79	0.50			3.11	13.5	1.00				0.21	0.37	2.29	0.86	0.18			0.09			0.86	0.71	17	15
<i>Elymus lanceolatus</i>			0.71	5.86	0.21	2.64			0.71	0.94	2.43	9.79										0.64			5	7
<i>Elymus trachycaulus ssp. subsecundus</i>	0.32	0.1	0.57	0.22	0.43	0.79	1.00	0.04	0.50	0.16	0.07	0.14	1.50	1.36	0.11	0.43	0.14				0.1		0.04		16	11
<i>Elymus trachycaulus ssp. trachycaulus</i>														1.00				0.07		0.29		0.1			0	7
<i>Festuca idahoensis</i>	2.86	9.18	0.57	6.86		0.07	1.43	5.89	1.64	4.07	0.14	5.08	7.21	6.72	3.11	17.79	3.93	12.79	4.21	1.46	0.68	1.43	0.57	1.14	22	23
<i>Festuca campestris</i>	6.50	11.00	6.36	11.86	18.79	27.58	6.86	10.21	23.57	28.43	4.07	9.07	2.00	3.29	1.25	1.25	18.00	10.50	3.57	3.66			5.79	1.36	22	22
<i>Helictotrichon hookeri</i>	0.04								0.21														0.1		8	1
<i>Juncus balticus</i>															0.46	0.29	0.68	1.29			0.21	0.07	0.11	0.11	5	5
<i>Koeleria macrantha</i>	1.11	0.61	0.1	0.57	0.1	0.01	0.04		0.43	0.15	0.29	2.86	0.79	0.66	0.07	0.96	0.04	0.57		0.21			0.1	0.14	21	21
<i>Luzula multiflora</i>																									0	1
<i>Luzula spicata</i>																							0.04		1	0
<i>Muhlenbergia richardsonis</i>																									1	1
<i>Pascopyrum smithii</i>							0.04						0.43	1.02	0.86				0.14	0.54					6	4
<i>Poa fendleriana</i>																						0.21			1	2
<i>Poa secunda</i>		0.21								0.1		0.08		0.01											1	11
<i>Pseudoroegneria spicata</i>	1.11	4.57														0.07	0.07	0.57				0.1			8	13
<i>Stipa nelsonii</i>		1.04	0.1	0.85					1.86	1.14		0.57	0.07	0.21	0.07	0.68	0.29	0.36							14	17
<i>Stipa richardsonii</i>			0.1	0.14			1.32	1.64																	5	4
# of grass species	8		9	9	4	6	8	6	9	8	5	8	11	11	11	11	10	8	7	9	6		9	7		
Native Forb	9.36	21.07	18.86	29.21	23.29	28.64	20.36	17.71	19.43	30.64	23.71	41.93	19.86	23.50	38.21	46.00	24.21	55.29	46.93	29.71	37.43	58.93	18.57	28.93		
<i>Achillea millefolium</i>	0.29	3.54	2.36	2.43	2.29	3.36	3.29	1.07	2.29	7.86	4.21	4.14	2.00	2.02	4.46	0.61	1.68	3.93	4.79	2.29	7.71	6.00	0.64	0.39	23	23
<i>Agoseris glauca</i>			0.43	1.00	0.86	0.65	1.21	0.07	0.57	0.86	1.00	1.50	0.29	0.94	0.50	1.43	0.79	0.36	3.07	0.43	2.21	3.07	0.46	0.64	18	20
<i>Allium cernuum</i>		1.64												0.1		0.1			0.07	0.07			0.1		4	11
<i>Allium textile</i>																									0	1
<i>Androsace septentrionalis</i>																0.04									1	2
<i>Anemone multifida</i>	0.46	1.64	0.29	0.1			0.07		1.21	0.36	0.14	0.07	0.64	0.09	2.64	0.32	0.50	1.21	0.07	0.07	0.1	0.21	0.64	1.07	22	19
<i>Anemone patens</i>	0.93																								3	0
<i>Antennaria anaphaloides</i>			0.93	0.86			1.39	0.64	0.1	0.1		0.1	0.50	0.37					0.50	0.1		0.07			8	10
<i>Antennaria bowellii</i>																2.64									0	1
<i>Antennaria racemosa</i>																									0	1
<i>Antennaria rosea</i>								0.1							0.43	2.21							0.36	0.14	8	9
<i>Antennaria umbrinella</i>	2.00	1.00	0.14	0.1					0.36	0.21	0.1	0.07	0.71	0.93	0.1	1.57	0.04	0.1						0.1	15	15
<i>Arabis drummondii</i>								0.46						0.02											0	3
<i>Arabis hirsuta</i>			0.1				0.1			0.01	0.1	0.16													6	3
<i>Arabis hoelboellii</i>																0.04									0	1
<i>Arabis nuttallii</i>	0.11	0.1		0.01																	0.1		0.04		8	6

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999- 2018-	
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
<i>Arabis glabra</i>													0.1	0.07			0.1				0.1	0.1	0.1	0.07	4	3
<i>Arabis</i> sp.																									0	1
<i>Arnica sororia</i>	1.04	2.29	0.07	0.1			0.04	0.04		0.14		0.1					0.18	0.21	0.64	0.1	0.57	3.07			15	17
<i>Artemisia ludoviciana</i>																									1	0
<i>Astragalus adsurgens</i>																									0	2
<i>Astragalus alpinus</i>														0.36											0	1
<i>Astragalus agrestis</i>																					0.1	0.79			2	1
<i>Astragalus australis</i>																									1	0
<i>Astragalus robbinsii</i>										0.1		0.1													0	2
<i>Astragalus tenellus</i>																									1	1
<i>Astragalus</i> spp.					0.14	0.08								0.14									0.04		3	3
<i>Balsamorhiza sagittata</i>																									3	3
<i>Besseyia wyomingensis</i>														0.21				0.11	0.86	0.44	0.21			0.1	3	6
<i>Botrychium lunaria</i>															0.04										1	0
<i>Bupleurum americanum</i>													0.1	0.1			0.1	0.1							3	3
<i>Calochortus apiculatus</i>			0.21	1.16	0.07				0.14	0.15	0.1	0.14		0.08					0.36	0.07					7	7
<i>Campanula rotundifolia</i>		0.1	0.07	0.58	0.36	1.15	0.32	0.86	0.14	1.36	0.43	2.57	0.50	0.73	0.32	0.32	0.36	0.07	0.29	0.23	0.50	0.86	0.71	1.50	19	23
<i>Castilleja cusickii</i>																									1	1
<i>Castilleja hispida</i>																									1	1
<i>Castilleja sulphurea</i>																			0.29						3	2
<i>Cerastium arvense</i>	0.43	3.75	0.36	3.36	0.57	0.22	0.75	0.1	0.29	0.37	2.29	4.57	0.50	2.64	0.46	4.21	1.00	3.21	2.36	1.58	1.61	6.29	2.14	0.71	22	23
<i>Cirsium bookerianum</i>					0.1								0.36						0.1		0.29	0.36			4	2
<i>Collinsia parviflora</i>																									0	1
<i>Collomia linearis</i>														0.07											0	3
<i>Comandra umbellata</i>															0.07	0.50	0.07	0.71							9	8
<i>Cryptantha celosioides</i>																									1	1
<i>Delphinium bicolor</i>																									0	3
<i>Dodecatheon conjugens</i>	0.79	0.07		0.16		0.1	0.18	2.04		0.34		0.03	0.07	0.03			0.07	0.29	1.07	0.02	0.71	0.25	0.36	0.1	10	15
<i>Draba nemorosa</i>																									1	5
<i>Draba</i> spp.				0.01																					0	1
<i>Epilobium brachycarpum</i>						0.01																			0	1
<i>Equisetum laevigatum</i>																									1	1
<i>Erigeron caespitosus</i>		0.43			0.57								0.64	1.43			0.1	2.00							5	5
<i>Erigeron compositus</i>																									1	0
<i>Erigeron speciosus</i>				0.64		0.43			0.1	0.1		1.79							0.86	1.14					3	10
<i>Erigeron subtrinervis</i>																					1.50	2.21			1	2
<i>Eriogonum flavum</i>																									1	0
<i>Eriogonum umbellatum</i>															2.25	1.43									3	5
<i>Erysimum inconspicuum</i>																0.1					0.1				2	1
<i>Eurybia conspicua</i>					0.1	1.07																			1	1
<i>Fragaria virginiana</i>			3.14	1.21	3.21	5.07			0.1	0.1	2.79	4.36	1.36	1.07	10.96	4.32	0.93	2.93	4.79	3.50	5.29	7.43		1.46	14	18
<i>Gaillardia aristata</i>	0.1	0.43	0.07	0.1					0.93	0.1	0.14	0.36			0.43	0.93	0.71	1.57	0.21			0.64	0.1	0.1	16	16

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999- 2018-	
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
<i>Galium boreale</i>	0.11	4.68	1.57	2.22	1.07	2.72	2.54	2.36	2.93	4.29	1.86	4.64	2.29	1.29	3.64	0.96	1.71	7.07	3.86	2.01	1.25	2.57	2.14	2.93	23	23
<i>Gentianella amarella</i>															0.04										1	0
<i>Geranium viscosissimum</i>			0.1	0.01	2.93	2.36							0.1	0.1		0.1	1.86	5.93	0.29	0.07	0.61	5.11	0.14	0.1	12	14
<i>Geum macrophyllum</i>																										
<i>Geum triflorum</i>	0.1	0.50			0.29				0.1	0.29							0.93	6.07							10	9
<i>Happlopappus carthamoides</i>																									2	0
<i>Hedysarum alpinum</i>			0.07																						2	1
<i>Hedysarum sulphurescens</i>			0.29	1.57					0.14	0.21			0.21	0.01			1.29	5.43					1.36	2.68	6	6
<i>Heterotheca villosa</i>		0.1																							3	3
<i>Heuchera cylindrica</i>	2.14	0.04		0.1	0.1				0.07	2.29				0.1	0.68	0.71	1.29	5.64							11	13
<i>Heuchera parvifolia</i>																	0.07								0	4
<i>Hieracium scouleri</i> var. <i>albertinum</i>																									7	7
<i>Hieracium umbellatum</i>																0.1				0.14			0.1	0.1	1	3
<i>Lathyrus ochroleucus</i>					0.86	0.93								0.1					1.64	0.57	0.21	0.21	0.54	0.32	4	6
<i>Linum lewisii</i>											0.07							0.04			0.1	0.07			2	2
<i>Lithophragma parviflora</i>																									1	1
<i>Lithospermum ruderale</i>	0.29	0.86							0.1	0.1					0.1	0.70	0.1	0.07			0.1		0.14		16	15
<i>Lomatium dissectum</i>															0.1	1.43									1	2
<i>Lomatium macrocarpum</i>	0.18	0.21												0.1									0.1	0.1	5	5
<i>Lomatium triternatum</i>			1.79	4.36	1.50	1.15	1.71	4.43	0.50	4.07	1.50	5.36	0.79	0.80			0.04		4.79	4.79	3.00	8.21	0.25	2.46	18	13
<i>Lupinus sericeus</i>	0.11	0.96	0.93	1.36	0.64	1.00	1.39	1.29	8.57	8.21	2.21	2.79	2.29	3.14			6.21	9.25	0.07	0.36	0.1	0.1	3.14	4.11	21	21
<i>Maianthemum stellatum</i>			0.14	0.36	0.14	0.57					0.21	0.01													6	6
<i>Microseris nutans</i>																									1	1
<i>Microsteris gracilis</i>																									1	2
<i>Minnartia rubella</i>																									1	1
<i>Moebria lateriflora</i>															0.07	0.04	0.07	0.07							3	2
<i>Monarda fistulosa</i>			0.14		0.29	0.29					1.50	1.29			0.36	1.57									9	7
<i>Musineon divaricatum</i>																									0	1
<i>Myosotis alpestris</i>																									0	1
<i>Orthocarpus luteus</i>																									0	2
<i>Orthocarpus tenuifolius</i>																									4	2
<i>Oxytropis borealis</i>																					0.1				0	1
<i>Oxytropis campestris</i>				0.14			0.1					0.1											0.1		8	5
<i>Oxytropis sericea</i>													0.29	0.71											1	1
<i>Oxytropis splendens</i>	0.1		0.07	0.1					0.07		0.29	0.71		0.1	0.04		0.71							0.1	9	4
<i>Pedicularis contorta</i>																									1	1
<i>Penstemon confertus</i>				2.73	2.64	5.64	0.14	1.14		0.2	0.1	4.86	0.36	3.07	1.61	6.96	0.25	1.50	0.50	1.00	0.14	0.21	2.11	5.00	15	19
<i>Perideridia gairdneri</i>				0.36		0.44							0.36							1.36		0.57			0	6
<i>Phlox hoodii</i>									0.43	0.36			0.1	0.29											5	4
<i>Piperia unalascentis</i>																									0	1
<i>Polemonium pulcherrimum</i>																					0.43				2	0

Table 4, continued . Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999- 2018-	
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
<i>Polygonum bistortoides</i>													0.01						1.71	0.02	1.29	0.50		0.1	2	4
<i>Polygonum douglasii</i>													0.01												0	3
<i>Potentilla arguta</i>													0.1												1	2
<i>Potentilla glandulosa</i>							0.43	0.50																	4	4
<i>Potentilla gracilis</i>			0.71	1.29	0.86	0.14	0.57	2.39	0.43	0.21	0.57	1.07	0.21	0.07	1.29	0.71	0.14	0.43	4.14	4.86	3.18	4.21	0.04	0.1	21	21
<i>Potentilla hippiana</i>	0.1	0.1					0.82	0.14	0.14	0.14			0.36	0.21			0.1	0.1							10	10
<i>Potentilla pensylvanica</i>																									2	2
<i>Prenanthes sagittata</i>																			0.1						0	1
<i>Ranunculus spp.</i>																									0	1
<i>Rhinanthus crista-galli</i>				0.36					0.07	0.1		0.64	0.07	0.1					0.14				0.04		5	5
<i>Saxifraga occidentalis</i>	0.1	0.07																							1	4
<i>Saxifraga rhomboidea</i>																									1	0
<i>Sedum lanceolatum</i>				0.1							0.1		0.1		0.04		0.04	0.1							6	3
<i>Selaginella scopulorum</i>	2.21	1.57					2.14						0.79	0.14	6.04		0.21	0.07					0.07		15	10
<i>Senecio canus</i>	0.21	0.1													0.1	0.1	0.71	0.07					0.29		6	5
<i>Senecio pseud aureus</i>			0.07	0.21	0.29	0.07									0.29	0.14	0.07								4	4
<i>Senecio streptanthifolius</i>							0.07		0.1																2	0
<i>Silene parryi</i>																									1	2
<i>Sisyrinchium montanum</i>			0.1				0.04			0.01	0.14	0.07			0.1	0.14	0.07						0.07	0.07	9	6
<i>Solidago missouriensis</i>															1.54	12.43									5	5
<i>Solidago spp. (mostly multiradiata)</i>			0.50	0.57	0.64	0.14	1.32		0.71	0.86	0.57	0.86	3.00	2.64			1.64	5.71	0.07				1.43	3.86	16	12
<i>Stellaria longipes</i>						0.1														0.01					0	3
<i>Symphyotrichum falcatum</i>																									1	3
<i>Symphyotrichum laeve</i>			2.36	4.14	3.14	2.14	2.21	0.75	0.71	0.86	2.50	3.79	0.1	0.1	0.21	0.57	0.1		4.29	4.57	3.86	9.64	1.29	3.64	14	16
<i>Thalictrum occidentale</i>													0.07		0.1				1.14	1.79	0.50	0.1			3	3
<i>Veronica peregrina</i>																									0	2
<i>Vicia americana</i>			0.14	0.1	1.57	1.07					0.79	0.57	0.57	0.51			0.89		3.57	0.71	2.57	2.93	0.50	0.14	5	5
<i>Viola adunca</i>								0.1																	3	4
<i>Viola nuttallii</i>																									0	1
<i>Zigadenus elegans</i>										0.1															1	2
<i>Zigadenus venenosus</i>	0.68	0.21																							4	8
<i>Zizia aptera</i>																									0	1
# of forb species	21		27	33	25	25	22	18	26	31	24	32	27	43	30	31	35	31	29	28	29	28	30	29		
Exotic Grass	0.21	0.14	1.79	9.07	13.64	25.57	3.78	12.50	2.64	10.29	11.64	6.71	2.43	3.44	4.57	0.29	0.17	8.54	18.21	35.86	39.29	25.50	0.29	0.50		
<i>Bromus inermis</i>									1.57	0.24	0.14	0.71													2	2
<i>Dactylis glomerata</i>																									0	1
<i>Phleum pratense</i>	0.11	0.1	1.79	4.16	13.43	19.79	3.68	5.21	2.21	1.79	11.50	5.43	0.36	1.29	4.07	0.14	0.1	0.04	18.21	35.86	39.29	15.96	0.18	0.1	21	22
<i>Poa compressa</i>																									2	2
<i>Poa pratensis</i>	0.11	0.04	0.1	4.93	0.21	6.16	0.1	7.50	0.36	8.36	0.14	0.57	2.07	2.15	0.61	0.14	0.07	8.54		0.1	0.04	10.86	0.11	0.46	16	20
# of exotic grass spp.	2	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2	2	2	1	2	2	2	2	2		

Table 4, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 23 plots: 1999-2001 vs 2018-2019. *Ocular cover estimate

	GRAS-01-002		GRAS-99-015		GRAS-99-017		GRAS-99-018		GRAS-99-021		GRAS-99-022		GRAS-99-038		GRAS-00-004		GRAS-01-039		GRAS-00-013		GRAS-01-013		GRAS-01-043		Plot	
	Rising Sun		Belly River		Belly River		Belly River		Belly River		Belly River		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Many Glacier		Frequency	
	Rising Sun W		Veldt South		Veldt North		W of Belly R		3 Mile S		3 Mile N		Swiftc Ridge		Apikuni Flts N		Apikuni Flts SE		Jule's Creek		N Cassidy Crv		Poia Lk Tr W		1999-2001	2018-2019
	2001	2019	1999	2018	1999	2018	1999	2019	1999	2018	1999	2018	1999	2018	2000	2019	2001	2019	2000	2018	2001	2019	2001	2019	2001	2019
Exotic Forb	0.64	1.71	0	0.51	2.50	2.15	0.11	0.14	2.07	0.79	2.71	0.72	0.71	1.72	0.25	3.68	0.21	0.04	5.64	4.50	3.29	22.57	0.1	0.1		
<i>Alyssum alyssoides</i>		0.07														0.14									1	6
<i>Arenaria serpyllifolia</i>																									0	1
<i>Centaurea maculosa</i>	0.43	1.61														1.07						0.14			7	12
<i>Chenopodium album</i>		0.04																							0	1
<i>Cirsium arvense</i>																						8.36			0	2
<i>Descurainia sophia</i>																	0.14								1	0
<i>Erysimum cheiranthoides</i>						0.1																			0	1
<i>Hypericum perforatum</i>																									0	1
<i>Linaria vulgaris</i>																0.1									0	1
<i>Medicago lupulina</i>																						0.07			0	1
<i>Taraxacum officinale</i>	0.21			0.50	2.50	2.08	0.11	0.14	2.07	0.79	2.93	0.01	0.71	1.65	0.21	1.07	0.07	0.04	5.64	4.50	3.29	7.21	0.1		18	16
<i>Thlaspi arvense</i>		0.04																				0.1	0.1		1	5
<i>Tragopogon dubius</i>				0.01		0.07					0.1	0.71										0.04			2	14
<i>Trifolium agrarium</i>															0.04	1.43									1	1
<i>Trifolium hybridum</i>																						7.86			0	1
<i>Veronica arvensis</i>		0.04																							0	3
# of exotic forb spp.	2	5	0	2	1	3	1	1	1	1	2	2	1	1	2	5	2	1	1	1	1	7	1	1		

III. 303-F: UPPER MCDONALD CREEK SECTION OF GTSR

A. BACKGROUND AND PURPOSE

The Upper McDonald Creek section of the Going-To-The-Sun Road (GTSR), from the head of Lake McDonald to just north of Avalanche Campground, was reconstructed during 1998. A total of 4.3 miles of road surface was repaved and numerous turnouts were modified, resulting in 4.9 acres (212,160 ft²) of disturbed road shoulders and turnouts.

Prior to restoration efforts, four site analyses were conducted at four locations along the GTSR in 1995 (Asebrook *et al* 1995). These plots documented the pre-disturbance condition of the roadside and existing turnouts prior to construction and provided baseline data to guide the selection of plant material for revegetation. Areas that were sampled included an open roadside community south of Avalanche Campground, a sunny roadside community north of the Mt. Brown turnout, a shrubby, shady roadside community near McDonald Falls, and a moist roadside community at Moose Country.

Restoration of these areas was conducted in the fall of 1999 and the summer of 2000. Revegetation included a seed treatment of grasses and forbs and a planting treatment of trees, shrubs, forbs, and grasses. In total, 4,106 plants were installed and 60 kg of native seed was sown. Turnouts were seeded with grasses, sedges, and forbs at a rate of 168 seeds/ft², while road shoulders were seeded with a grass mix at 125 seeds/ft² and a forb mix of 65 seeds/ft² (Tables 5 and 6). All planted material was treated with a 13:13:13 (N:P:K) slow-release fertilizer, peat moss, and a Vitamin B1 anti-shock transplant solution.

Table 5. 303-F: Seeding Rates (seeds/ft²) for the McDonald Creek section of GTSR

	road shoulder	modified turnouts
GRASSES		
<i>Bromus carinatus</i>	15	
<i>Calamagrostis rubescens</i>	50	30
<i>Carex athrostachya</i>		20
<i>Carex douglasii</i>		2
<i>Carex hoodii</i>		9
<i>Carex spp.</i>		17
<i>Deschampsia cespitosa</i>	15	20
<i>Elymus glaucus</i>	20	
<i>Elymus trachycaulus</i>	15	
<i>Stipa occidentalis</i>	7	
<i>Stipa richardsonii</i>	3	
<i>Trisetum spicatum</i>		1
FORBS		
<i>Achillea millefolium</i>	15	5
<i>Anaphalis margaritacea</i>	6	5
<i>Anemone multifida</i>		10
<i>Antennaria bonellii</i>		10
<i>Antennaria rosea</i>	5	
<i>Aster laevis</i>	5	10
<i>Gaillardia aristata</i>	2	
<i>Geum macrophyllum</i>	5	5
<i>Penstemon albertinus</i>	3	10
<i>Penstemon confertus</i>	7	10
<i>Penstemon lyallii</i>		5
<i>Phacelia hastata</i>		tr
<i>Prenanthes sagittata</i>		tr
<i>Ranunculus uncinatus</i>		tr
<i>Senecio triangularis</i>		5
<i>Solidago canadensis</i>	12	tr
<i>Spiraea betulifolia</i>	5	5

Table 6. 303-F: Planted species by turnout

	Turnout #1	Turnout #2	Moose Country turnout
FORBS/GRASSES			
<i>Antennaria howellii</i>	x	x	
<i>Aster laevis</i>	x	x	
<i>Castilleja rhexifolia</i>	x	x	
<i>Carex deneyana</i>	x	x	
<i>Carex hoodii</i>	x	x	
<i>Carex spp.</i>	x	x	
<i>Fragaria vesca</i>	x		
<i>Fragaria spp.</i>		x	
<i>Geum macrophyllum</i>	x	x	
<i>Geum triflorum</i>	x	x	
<i>Heracleum sphondylium</i>			x
<i>Penstemon confertus</i>	x	x	
LOW SHRUBS			
<i>Arctostaphylos uva-ursi</i>	x	x	
<i>Linnaea borealis</i>	x	x	
MEDIUM SHRUBS			
<i>Paxistima myrsinites</i>	x	x	
<i>Rosa woodsii</i>	x	x	x
<i>Rubus parviflorus</i>	x	x	x
<i>Spiraea betulifolia</i>	x	x	
<i>Symphoricarpos albus</i>	x	x	x
<i>Vaccinium membranaceum</i>		x	
TALL SHRUBS			
<i>Acer glabrum</i>	x	x	x
<i>Amelanchier alnifolia</i>	x		
<i>Cornus sericeus</i>			x
<i>Prunus virginiana</i>	x		x
<i>Salix scouleriana</i>		x	
TREES			
<i>Abies bifolia</i>	x		
<i>Betula papyrifera</i>	x	x	x
<i>Juniperus communis</i>	x		
<i>Larix occidentalis</i>	x		
<i>Picea engelmannii</i>	x	x	
<i>Pinus contorta</i>	x		
<i>Pinus monticola</i>	x		
<i>Populus balsamifera</i>	x	x	x
<i>Pseudotsuga menziesii</i>	x		
<i>Thuja plicata</i>	x	x	
<i>Tsuga heterophylla</i>	x	x	

The purpose of monitoring these restoration efforts 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 (Table 7) are being met.

Table 7. 303F: Goals and Objectives

Goals and Objectives	Year 1	Year 2	Year 5	Year 10	Year 20
Surface soil stability	X				
Native species cover					
20%	X				
30%		X			
40%			X	X	X
Noxious weed cover (under herbicide use plan)					
< 10%	X	X	X		
< 5%				X	X
Other exotic species cover (under herbicide use plan)					
< 30%	X	X			
< 20%			X	X	X
Species composition and diversity					
Restore 75% of target restoration native community					X
Significant growth ($p > 0.05$) of nursery stock			X	X	X

B. METHODS

In June of 2000, five monitoring plots of various sizes were established, depending on the size of the area that was revegetated. Three plots were placed in modified turnout areas and two plots were placed along road shoulders (Figure 8). Plots begin at the first turnout (#1) north of the intersection of the GTSR and the road to the Ranger Station at the head of Lake McDonald. They are located in the following places and have these dimensions: (MD00-04) 25m x 4m plot at the parking island in turnout #1; (MD00-05) 20m x 5m plot north of modified turnout #2; (MD00-06) 20m x 2m plot along the Moose Country turnout; (MD00-07) 20m x 5m plot along the road shoulder across from the Moose Country turnout; and (MD00-08) 20m x 1m plot on the road shoulder just south of turnout #5. Level II monitoring was conducted on all plots in 2000, 2001, 2002, 2004, 2009, and 2019 including information on soil erosion and ocular estimates of canopy cover for native and exotic species. Estimated density for seeded species from each plot was estimated during the first years of the project to determine germination success.

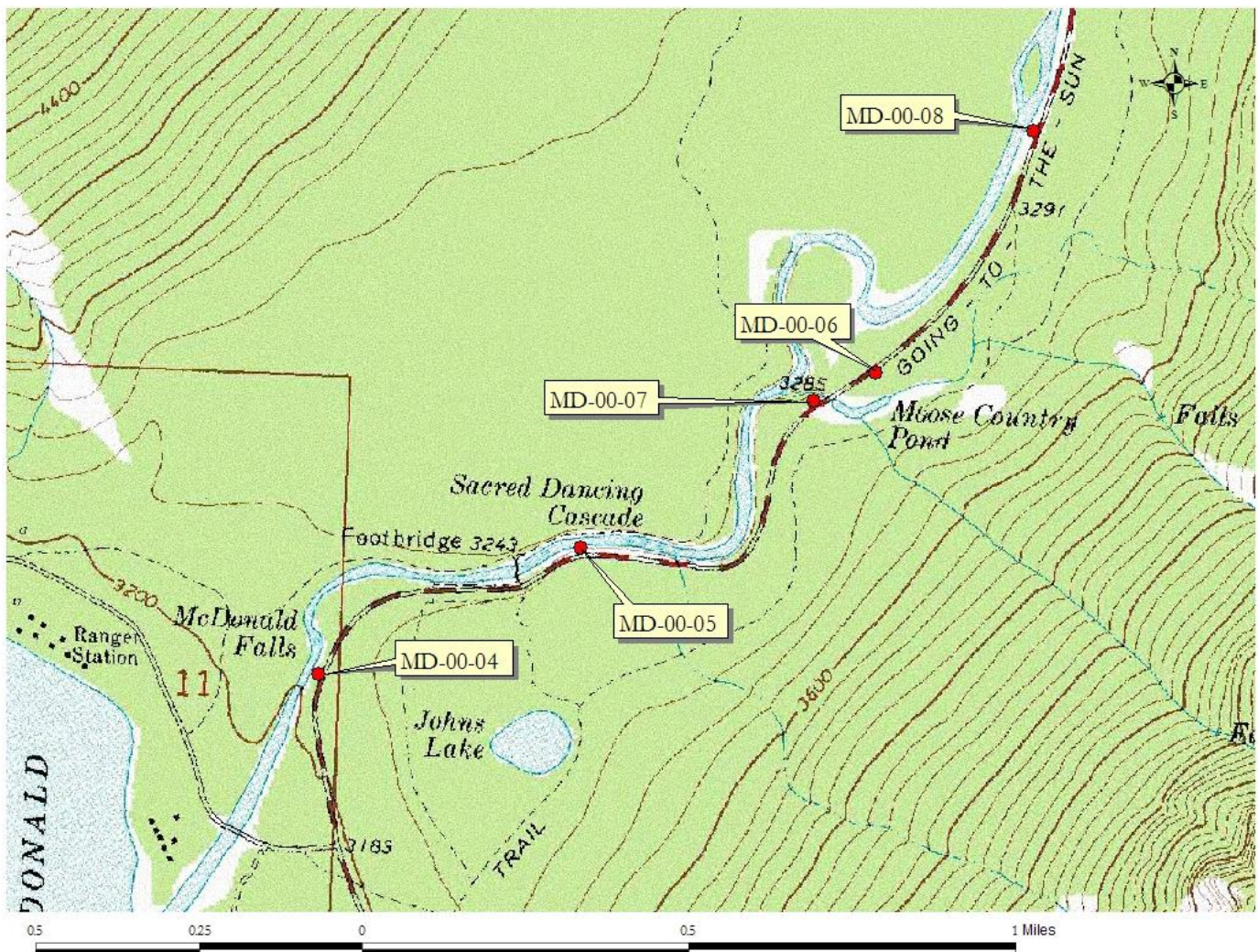
Pre-disturbance photographs were taken in 1998. Photomonitoring at established photopoints was continued in 2000, 2001, 2002, 2004, and 2019 and should be carried out in future years. Due to time constraints, photomonitoring was not conducted at all in 2009 and was not conducted in the Avalanche Campground in 2019.

C. RESULTS AND DISCUSSION

1. Meeting Revegetation Goals

Pre-disturbance site analysis data documented a fair diversity of native species along this road corridor with certain areas dominated by shrubs and forbs. Exotic species, however, were common in most areas prior to

Figure 8. 303F: Location of Upper McDonald Creek Section of GTSR Revegetation Monitoring Plots



restoration efforts, particularly exotic grasses. The historic presence of these weeds will continue to affect the overall success of revegetation on 303-F.

Year twenty goals for Project 303-F include the following: $\geq 40\%$ native cover, $\leq 20\%$ exotic cover, $\leq 5\%$ noxious weed cover, and significant growth of nursery stock (Table 7). While all the plots met the noxious weed goal with less than 5% noxious weed cover, none of the plots met all of the vegetation goals (Table 8). Plot MD-00-04, a turnout plot, came the closest as the only plot to reach the native cover goal with 94% native cover and reach the exotic cover goal with only 4% exotic cover. Planted nursery stock on this plot, however is not significantly growing. Plot MD-00-05, another turnout plot, did not meet the native cover goal but came relatively close to meeting the exotic cover goal with 23% exotic cover. Finally, plots MD-00-06, MD-00-07 and MD-00-08 did not meet any of the twenty year vegetation goals with the exception of soil stability as a first year goal. Shrub cover is moderate on plot MD-00-06, however, shrubs on this plot have increased from adjacent undisturbed vegetation and not from planted nursery stock.

Although native cover increased overall on 3 plots from year ten to year twenty after replanting, native cover currently remains lower than exotic cover on all plots except for MD-00-04. Exotic cover did not change dramatically

over the past ten years, but remains higher than native cover in most areas. On a positive note, most species of noxious weeds appear to be lower or gone from plots compared to 2009. *Centaurea maculosa* and *Linaria vulgaris* can now only be found on 1 plot, while *Cirsium arvense* and *Hypericum perforatum* were not observed in any plots. *Hieracium aurantiacum* and *Chrysanthemum leucanthemum* each disappeared from one plot and remain with very low cover in the plots where they are present. All of the noxious weed species should be carefully monitored and managed.

Table 8. 303F: Overall Native and Exotic cover (%) by Plot, 2000-2019

	MD-00-04						MD-00-05						MD-00-06					
	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019
Native Cover	18%	30%	31%	28%	33%	94%	16%	44%	41%	32%	22%	15%	21%	35%	45%	42%	41%	22%
Exotic Cover	9%	13%	5%	22%	8%	4%	5%	9%	4%	11%	19%	23%	26%	62%	56%	61%	68%	68%
	MD-00-07						MD-00-08											
	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019						
Native Cover	7%	27%	31%	15%	4%	18%	5%	37%	31%	12%	10%	17%						
Exotic Cover	9%	18%	17%	29%	34%	33%	5%	9%	11%	26%	62%	74%						

2. Trees

Since trees were not planted along road shoulders, only the three turnout plots had tree cover (Table 9; Figures 9-13). Tree cover has remained with trace cover in all three of these plots with only small seedlings of *Populus balsamifera*, *Pinus contorta*, and *Betula papyrifera*. All other tree species that once were established have disappeared. The low cover and inability of other tree species to survive is likely due to mowing that annually occurs on these roadsides. For road maintenance and view safety, it is the intent of park managers to prevent trees from growing along the road edge.

3. Shrubs

Overall, shrub cover did not change dramatically from year ten to year twenty after planting (Table 9; Figures 9-13). Three plots (MD00-05, MD00-07 and MD00-08) remain with very low shrub cover, ranging from 0-1%. As expected, and similar to tree results above, shrub cover in road shoulder plots remained very low or absent, since no shrub species were planted in road shoulder areas. In the two turnout plots where shrubs are present (MD00-04 and MD00-06), shrub cover has remained essentially the same since 2009. This trend is an improvement, since cover had declined in these plots over the first few years of the project.

Shrub cover remains a relatively low 4% on plot MD00-04. *Arctostaphylos uva-ursi* remains the shrub with the most notable cover, while *Paxistima myrsinites*, *Spiraea betulifolia*, and *Symphoricarpos albus* each have low cover. All of these species are likely surviving road maintenance along the GTSR, such as mowing and plowing, as they currently have adapted to grow as low growing shrubs. Given on-going road maintenance and the fact that they have remained with 3-4% cover since 2002, shrub cover will not likely increase on this plot in the future.

Shrub cover is higher on plot MD00-06 but remains steady at 15%, similar to its cover since 2004. *Symphoricarpos albus* and *Rubus parviflorus* remain the shrubs with the highest cover, with *Acer glabrum*, *Cornus sericea*, and *Rosa woodsia* having 1-2% cover. Shrub cover is higher in this turnout plot due to the fact that vegetation occurs behind a log barrier, protecting it from plowing and mowing operations. However, maintenance of this turnout includes using a weed whacker to minimize the height of vegetation around the barrier, impacting planted vegetation in this area. Almost all, if not all, of the shrub cover in this plot is not from nursery stock but is occurring as shrubs move in from adjacent undisturbed vegetation. If weed whacking continues at this site, which is likely should, shrub cover will likely remain the same in future.

Figure 9. 303F: Percent Canopy Cover by Lifeform for Plot MD00-04 (Turnout)

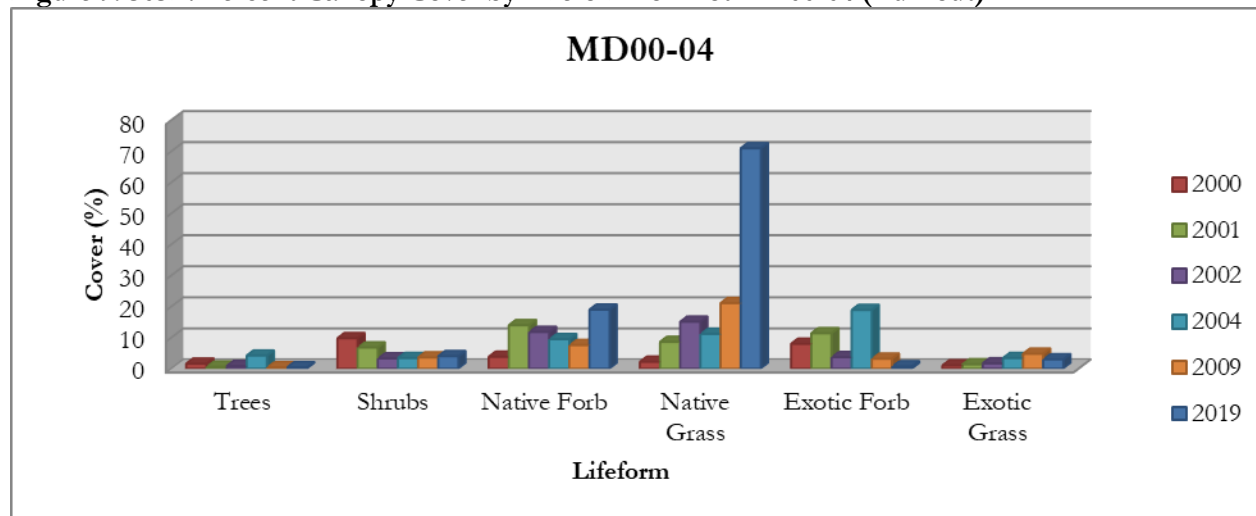


Figure 10. 303F: Percent Canopy Cover by Lifeform for Plot MD00-05 (Turnout)

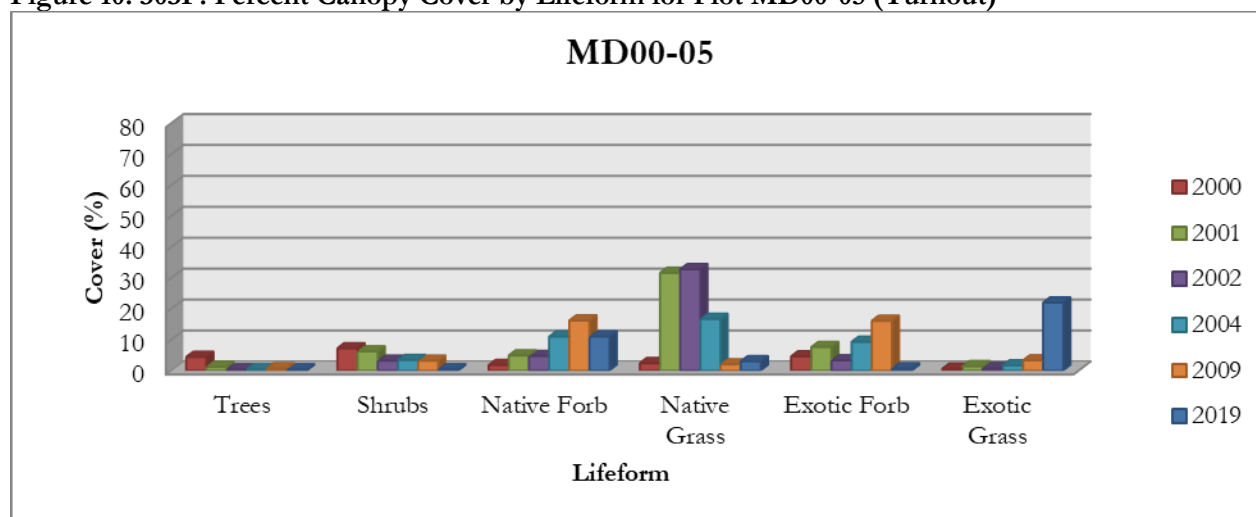


Figure 11. 303F: Percent Canopy Cover by Lifeform for Plot MD00-06 (Turnout)

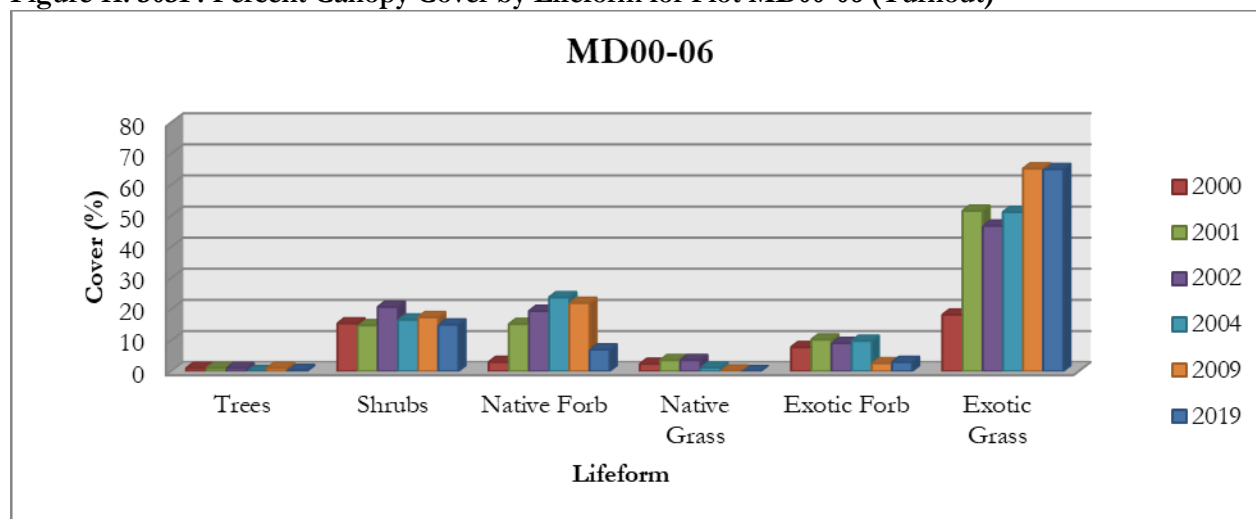


Figure 12. 303F: Percent Canopy Cover by Lifeform for Plot MD00-07 (Road Shoulder)

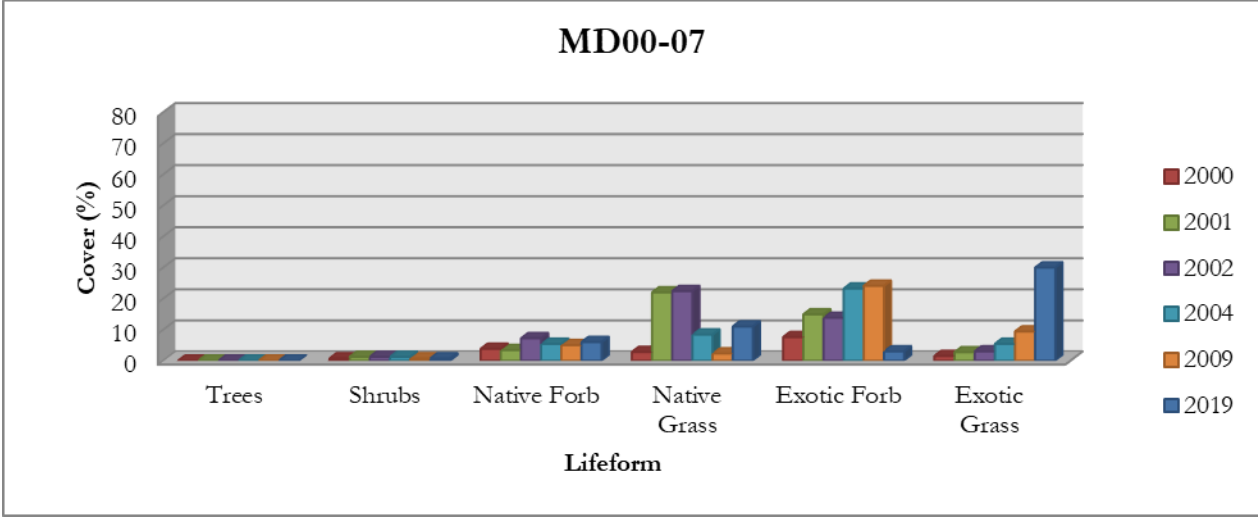
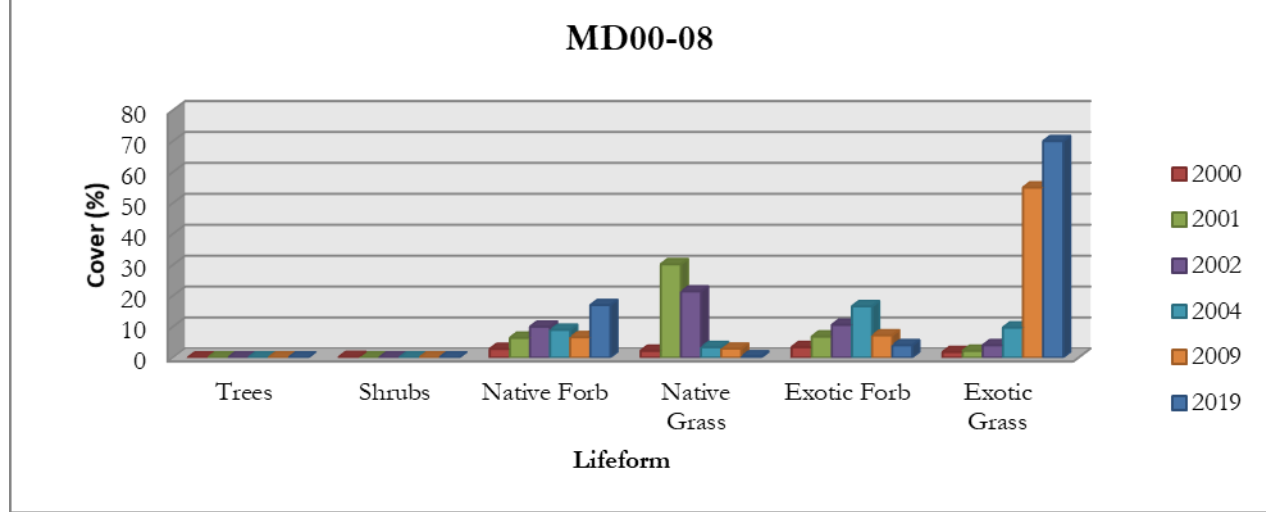


Figure 13. 303F: Percent Canopy Cover by Lifeform for Plot MD00-08 (Road Shoulder)



4. Native Forbs

Over the past ten years, there has been no consistent trend concerning native forbs (Table 9; Figures 9-13). Overall native forbs increased on three plots (turnout MD00-04 and road shoulder plots MD00-07 and MD00-08) and decreased on two plots (turnout plots MD00-05 and MD00-06). On the plots where native forbs increased, this increase was due exclusively to an increase of *Penstemon confertus* on each of these plots. *P. confertus*, now the most dominant native forb on all of the plots, increased by 12% on plot MD00-04, increased by 2% on plot MD00-07, and increased by 11% on plot MD00-08. Even on plots where there was an overall decrease in native forbs, *P. confertus* increased by 5% on plot MD00-05 and remains the most dominant native forb on plot MD00-06. On plots that increased in native forb cover, other consistently present native forb species include *Aster laevis*, *Achillea millefolium*, and *Fragaria virginiana* or *vesca*, each seeded and/or planted species.

While native forbs do have a notable presence on 3 of the plots, it is concerning that these areas are dominated by only one native forb species and have decreased in native forb diversity over time. All plots have fewer native forb species than they have in the past as indicated below. This loss of species diversity is likely tied to a number of factors including being outcompeted by exotic vegetation, herbicide spraying along the road corridor, gravel accumulation along the road edges after chip sealing or graveling the road, and mowing the road edges.

Plot	Highest # of native forb species	Year of highest count	2019 # of native forb species
MD00-04	15	2001	6
MD00-05	11	2009	10
MD00-06	14	2002	9
MD00-07	17	2002	10
MD00-08	10	2004	4

At the same time, several seeded species that were present on at least one plot in the past have disappeared. These include *Anaphalis margaritacea*, *Anemone multifida*, *Penstemon albertinus*, *Phacelia hastata*, *Prenanthes sagittata*, and *Ranunculus uncinatus*. Many of these species had relatively low seed rates and were not present in great amounts in the past, but circumstances along the road corridor unfortunately did not let them survive. In addition to these six species, three of the seventeen seeded forb species (Table 5) have not been observed at all twenty years after replanting. These include *Antennaria rosea*, *Penstemon lyallii*, and *Senecio triangularis*.

On a positive note, other seeded and planted native forb species continue to be present twenty years after restoration efforts and have made an impact on overall native cover with their frequency and cover. In addition to seeded species *P. confertus*, *A. laevis*, *A. millefolium*, and *Fragaria virginiana/vesca* that are listed above as the dominant native forbs, other notable seeded native forbs that are persisting twenty years after seeding include *Antennaria howellia* and *Solidago canadensis*. Many of these plants have proven to be reliable and persistent native forb species when re-introduced to a roadside community and should be considered for future projects. Also, despite some decreases, native forb cover still remains higher than exotic forb cover in all plots by 3-19% cover at year twenty after replanting, reiterating the importance of seeding native species on these road projects.

5. Native Grasses

After a pattern of increasing native grass cover through year three and then a consistent decline of native grass cover from year 5 to year 10, there appears to be no consistent trend for native grass cover from year 10 to year 20 after replanting (Table 9; Figures 9-13). Currently, only one plot has significant native grass cover at 71%, one plot has moderate native grass cover at 11%, and three plots have very low native grass cover that ranges from 0-3%.

Turnout plot MD00-04 is the only plot to see an increase in native grass cover over time. Over the past 10 years, native grasses have increased from 21% cover to 71% cover, making native grass the dominant lifeform on this plot. This increase is due exclusively to a 50% increase in cover of *Festuca saximontana*. While *Festuca saximontana*, or any other *Festuca* for that matter, was not listed in the seed mix, it is speculated that this grass was indeed seeded throughout this project as this grass species is present with notable cover on several plots. It remains uncertain where its seed source came from and, to a certain extent, about the identity of this grass as cultivars can look similar to *F. saximontana*. Regardless, this grass clearly dominates plot MD00-04, as well as plots MD00-05 and MD00-07 where it has also increased slightly over time. Given the low growth form of *F. saximontana* that can withstand mowing, as well as its extremely high cover, this grass is likely to persist and dominate this plot in the future.

Road shoulder plot MD00-07 experienced a small increase in native grass cover over the past ten years, although native grass cover remains half of what it was three years after replanting. Native grass cover increased from 2% to 11% from year 10 to year 20, due to small increases in cover from *Bromus carinatus*, *F. saximontana*, and *Stipa occidentalis*. Most of the cover on this plot in the past was due to *Elymus glaucus* and *Elymus trachycaulus v. trachycaulus* which have both notably decreased over time. As this road shoulder plot is relatively steep and has large boulders along its edge, allowing this area to avoid mowing and illegal parking, native grasses could continue to increase here in the future without disturbance. This plot has the highest diversity of native grasses with 8 species present, another encouraging result that could lead to higher native grass cover in the future.

Finally, the three remaining plots, MD00-05, MD00-06, and MD00-08, have very low native grass cover, resulting from a decline in native grasses over time. Currently, plot MD00-06 has 0% native grass cover, although

native grasses have never been high here with only 4% cover three years after planting. All native grasses have disappeared from this plot due to competition from very high exotic grass cover, moderate shrub cover, and continued weed whacking behind the wooden barrier. Plots MD00-05 and MD00-08, which each had at least 30% native grass cover 2 to 3 years after planting, now have 3% and trace cover of native grasses, respectively. Most of this decrease in native grass cover is due to a dramatic decline of *Elymus trachycaulus* v. *trachycaulus* on both plots. *Elymus glaucus*, *Bromus carinatus*, and *Deschampsia cespitosa* have also decreased on these plots over time.

Reduction in cover of *Elymus glaucus* and *Bromus carinatus* is expected by year five to ten, since they are often planted as nurse grasses to establish quickly and compete with invasive exotic species. Similarly, *Deschampsia cespitosa* has declined on nearby 303-B, requiring moister environments. The decline of *Elymus trachycaulus* ssp. *trachycaulus* is less expected, however, as this grass has been successful in other projects. Typically, this grass requires mineral soil and low competition to germinate (Steele, 1995; Hassell, 1983) so it is possible that competition from weedy grasses, such as *Bromus inermis*, *Elymus repens*, and *Poa pratensis*, is preventing the establishment of this grass. Similar to other west-side roadside projects, *Calamagrostis rubescens*, the seeded grass species with the highest seed rate, was only present on two plots with trace cover at year twenty. Like *E. trachycaulus*, *C. rubescens* also requires mineral soil and low competition to germinate. It has been observed that when *C. rubescens* is seeded in a seed mix with larger grasses and a number of forbs, its germinate rate is very low if it germinates at all. Finally, it is uncertain why planted or seeded *Carex* species did not establish well in this project, as *Carex* species have established well in other revegetation projects.

Several seeded grass species still have not been observed within the monitoring plots since they were revegetated. These include *Carex douglasii*, *Stipa richardsonii*, and *Trisetum spicatum*. *Carex hoodii* was observed on one plot in 2000 but has not been observed since. *Carex douglasii*, *Trisetum spicatum*, and *Stipa richardsonii* had very low seed rates (≤ 3 seeds/ft²), likely resulting in the lack of observations. These grass species may have germinated elsewhere on the project, however. Similar to *Festuca saximontana*, it is speculated that *Festuca idahoensis* was seeded on the modified turnout plots even though it is not listed as a seeded species. This grass would not naturally occur in habitat types along McDonald Creek; however it remains present on one turnout plot.

6. Exotic Forbs

A very positive trend across this entire project is that exotic forb cover decreased on all plots from year ten to year twenty after planting (Table 9; Figures 9-13). Currently, exotic forb cover is now low on all plots, ranging from trace to 4%. While exotic forb cover decreased only slightly on turnout plots MD00-04 and MD00-06 and shoulder plot MD00-08 by 1-3%, exotic forb decreased dramatically on turnout plot MD00-05 by 15% and on shoulder plot MD00-07 by 22%.

The large decrease of exotic forb cover on plot MD00-05 was due to a 10% decrease of *Medicago lupulina* and a 2% decrease of *Medicago sativa*. This plot, near a popular turnout, has suffered heavy traffic and foot trampling over the years which has inadvertently negatively impacted these weedy ground covers. The large decrease of exotic forb cover on plot MD00-07 was due 4-5% decreases of several species, including *M. lupulina* and noxious weeds *Chrysanthemum leucanthemum*, *Hieracium aurantiacum* and *Hieracium caespitosum*. Herbicide application on these roadsides could be causing these declines, along with smaller decreases of *Achillea nobilis*, *Artemisia absinthium*, *Taraxacum officinale*, and *Centaurea maculosa*. Similar species had smaller decreases in cover on the other plots, including small declines of *M. lupulina* on plots MD00-04 and MD00-08 and small declines of *C. leucanthemum* and *Hypericum perforatum* on plot MD00-06.

While these decreases in exotic forbs across the project are an encouraging trend, several species of noxious weeds still exist along these roadsides that should continue to be controlled. These include low cover of *Centaurea maculosa*, *Chrysanthemum leucanthemum*, *Hieracium aurantiacum*, *Hieracium caespitosum*, and *Linaria vulgaris*. *Cirsium arvense* and *Hypericum perforatum* were not observed in any plot in 2019.

7. Exotic Grasses

While exotic forbs showed declining trends in cover over the past ten years, unfortunately exotic grasses are experiencing the opposite trend (Table 9; Figures 9-13). From year ten to year twenty after planting, exotic grasses for the most part either dramatically increased in cover or remained with exceptionally high cover. The only plot that does not have high exotic grass cover is turnout plot MD00-04. This plot has very high native grass cover, as well as the highest native forb cover of any plot, that are likely keeping both exotic grasses and exotic forbs from increasing on this plot.

Road shoulder plots MD00-07 and MD00-08 experienced 15-21% increases in exotic grass cover and now have 30% and 70% exotic grass cover, respectively. This is the dominant lifeform on each of these plots by far. *Dactylis glomerata* notably increased on both plots, particularly on plot MD00-08, but there were also increases of *Poa pratensis* and *Poa compressa* on each plot. In addition, *Elymus repens* and *Phleum pratense* remain with moderate cover throughout road shoulder areas. As road shoulder plots, these areas are continually disturbed by mowing, traffic driving or parking on road edges, and gravel accumulation from the winter months and/or chip sealing. This continued disturbance has likely prevented native species from becoming established here, leaving open ground for exotic species, particularly exotic grasses, to invade and increase. It is also known that these exotic grasses were present along these roadsides prior to road construction activities, resulting in their presence in the seed bank and their ability to take advantage of disturbance.

Exotic grass cover also increased on turnout plot MD00-05 by 19%, resulting in 22% total exotic grass cover, the dominant lifeform on this plot as well. This increase was due to a notable increase of *Poa compressa* and, to a lesser extent, an increase of *Poa pratensis*. As native shrubs, forbs, and grasses declined on this plot over the past ten years, it appears that exotic grasses are filling in the open space. Exotic grass cover also remained very high on turnout plot MD00-06 where it maintained 65% cover, similar to year ten. *Bromus inermis* remains both the dominant exotic grass and overall plant species on this plot and exotic grasses are again the dominant lifeform. This plot has had high exotic grass cover since the beginning of the project as *B. inermis* became established with high cover at year one after planting.

Overall, exotic grass cover remained higher than native grass cover on four plots this year, compared to only two plots in 2004. *Bromus inermis*, *Dactylis glomerata*, *Elymus repens*, *Phleum pratense*, *Poa compressa*, and *Poa pratensis* remain the dominant exotic grasses on the project.

A few other exotic grass species are present on this project, each with low covers ranging from a trace to 5%. While most of these are very difficult to control, it may be beneficial to try to control *Bromus tectorum* in the few areas where it is present along this stretch of GTSR. *B. tectorum* has shown the ability to overtake large swaths of roadside habitat in other areas in the west, and recently in Glacier National Park, in the last few years. This species is present in only trace amounts in this project and may be fairly easily eliminated at this point.

D. CONCLUSIONS AND RECOMMENDATIONS

As with many roadside revegetation projects, non-native plants that were in the seed bank at the start of the project are hard to overcome. From year ten to year twenty, native cover decreased on four out of five plots by 7% to 19%. At the same time, exotic cover increased in two out of five plots by 4% to 12%. Native cover currently ranges from 15% to 94%, while exotic cover ranges from 4% to 74%. Currently, exotic cover dominates on four out of the five plots, particularly on the road shoulder plots where exotic cover is two to four times as high as native cover. One of the turnout plots, however, has higher native cover than exotic cover and one turnout plot has nearly equal native cover to exotic cover. These turnout areas are larger and tend to be easier to revegetate than road shoulders due to less disturbance. These are the areas to look for restoration successes including increasing shrub cover, higher native forb cover, higher native grass cover, and generally lower exotic cover, particularly of exotic forbs. Revegetation species that are doing well within this project include native forbs *Achillea millefolium*, *Antennaria howellii*, *Aster laevis*, *Fragaria virginiana* and *vesca*, *Solidago canadensis*, and *Penstemon confertus* and native grasses *Bromus carinatus*, *Elymus glaucus*,

Elymus trachycaulus, and *Stipa occidentalis*. *Festuca occidentalis*, *Carex rossii*, and *Carex geyeri* should be considered as a revegetation species in future west side road projects and consideration should be given to seeding *Calamagrostis rubescens* alone or with a few forbs in certain areas to encourage its establishment. *Symphoricarpos albus*, *Rosa woodsii*, and *Arctostaphylos uva-ursi* are consistent shrubs that have high survival rates within revegetation areas. Care should be taken not to plant shrubs within 5 to sometimes 10 feet of the road edge due to impacts from annual mowing of these roadside communities.

Road shoulder areas continue to be a problem to restore with native vegetation. Continual disturbance to these areas is preventing native species from getting established and perpetuating weed species. As suggested in the past, perhaps study trials should be conducted along road shoulders to determine what seed mix works for these areas.

Given that most of these plots are now dominated by exotic species and vegetation on all the plots is annually disturbed by road maintenance activities (plowing, mowing, weed whacking, herbicide application), these plots should not be monitored again in the future. Twenty year data from these plots has given the park interesting information concerning our restoration efforts but it is unlikely that any new information can be learned from this project.

Table 9. 303-F: Canopy Cover (%) by Plot for the Upper McDonald Creek section of GTSR, 2000-2019

Species:	MD-00-04 Turnout #1						MD-00-05 Turnout #2						MD-00-06 Moose Cntry turnout						MD-00-07 Moose Country shoulder						MD-00-08 Turnout #5 shoulder					
	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019
TREE	2	T	T	4	T	T	5	1	T	T	1	T	1	1	1	0	1	T	0	0	0	0	0	0	0	0	0	0	0	0
<i>Betula papyrifera</i>	1			2		T	1						1	1	1		1	T												
<i>Larix occidentalis</i>																														
<i>Picea engelmannii</i>	T	T	T	1			T	T	T	T	T																			
<i>Pinus contorta</i>			T		T (dying)	T																								
<i>Pinus monticola</i>	T	T	T	1	T																									
<i>Populus balsamifera</i>							2	1-	T	T	T+	T																		
<i>Pseudotsuga menziesii</i>		T	T	T																										
<i>Thuja plicata</i>							T																							
<i>Tsuga heterophylla</i>	T						1																							
SHRUB	10	6	3	4	3+	4	8	6	4	4	3	T	15	15	21	16+	17	15	1	1	1	1	1-	1-	T	0	0	0	0	0
<i>Acer glabrum</i>							4	3	1+	2	1	T	2	T	1	T	T	1												
<i>Amelanchier alnifolia</i>														T	1	T	T													
<i>Arctostaphylos uva-ursi</i>	1	1	1	1+	3	3 -																								
<i>Cornus sericea</i>													2	T	T+	1	2	1												
<i>Juniperus communis</i>	T	T	T	T																										
<i>Paxistima myrsinites</i>	T	T	T	T	T	T																								
<i>Prunus spp.</i>													1	1	5	5														
<i>Prunus virginiana</i>													T																	
<i>Ribes inermis</i>																									T					
<i>Rosa woodsii</i>	T	T	T				T	T	T	T	1-	T	T	T	T	T	2	2	T+	1	1	1	T+	T+						
<i>Rubus idaeus</i>													1+	3	3	2	1													
<i>Rubus parviflorus</i>	5	3	T+	1	T		1	1	1	T	T	T	3	3	3	3	4	4												
<i>Spiraea betulifolia</i>	T	T	T		T	T																								
<i>Symphoricarpos albus</i>	3	2	1+	1		1 -	2	2	1	1+	1	T	6	7	7	5	8	7	T	T	T	T	T	T						
NATIVE FORB	3	13	11	9	7	19	1	4	4	10	16	11	2	15	18	23	21	7	2	1	5	4-	4	6	2	6	9	9	7	17
<i>Achillea millefolium</i>	T+	8	7	2	T	T	T	3	3	5	3	T	T+	10	9	8	5	T	T	1	4	2	1	T	1+	4	4	1	T	
<i>Anaphalis margaritacea</i>		T	T	T	T															T	T	T	T							
<i>Anemone multifida</i>		T	T	T	T						T											T	T					T		
<i>Antennaria howellii</i>		T	T			T		T	T	1	2	T+									T	T				T	T	T		
<i>Arabis drummondii</i>														T	T															
<i>Arnica cordifolia</i>																								T						
<i>Aster foliaceous</i>																	5	T					1-	T					1	
<i>Aster laevis</i>	T	2	2	1	3	3	T	T+	T+	4	6	2	T	T	2	3	outside plot	T	T	T	T	T	T	1+	T	T	2	1-		2
<i>Aster spp.</i>																					T									
<i>Campanula rotundifolia</i>	T	T		T	T					T									T			T+	T+							
<i>Castilleja miniata</i>		T	T	T	T							T																		
<i>Chamerion angustifolium</i>															T						T		T							
<i>Circaea alpina</i>																			T											
<i>Collinsia parviflora</i>				2+														T												
<i>Collomia linearis</i>																								T+	T					

Species:	MD-00-04 Turnout #1						MD-00-05 Turnout #2						MD-00-06 Moose Cntry turnout						MD-00-07 Moose Country shoulder						MD-00-08 Turnout #5 shoulder					
	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019
<i>Coryza canadensis</i>																		T												
<i>Draba nemerosa</i>												T																		
<i>Epilobium halleanum</i>							T	T			T		T	T	T	T			T		T									
<i>Equisetum arvense</i>													T						T											
<i>Fragaria vesca</i>										T					T	T	T	T		T	T	T	T			T	T	2		
<i>Fragaria virginiana</i>	T	1	T	T	T	T	T	T	T	T	T	T			T	1-									T					
<i>Galium triflorum</i>																			T											
<i>Gaillardia aristata</i>											T	T											T				T	T		
<i>Geum aleppicum</i>														T	1	1	T					T							T	T
<i>Geum macrophyllum</i>	1	T+	T				T	T	T				T	1	2	1	T	T	T	T	T	T			T	1	1	3	T	
<i>Geum triflorum</i>	T	T	T	T+	T	T																								
<i>Heracleum sphondylium</i>													T+	1	1	1	T	T	T	T	T	T								
<i>Hieracium albiflorum</i>																					T									
<i>Heuchera cylindrica</i>																							T							
<i>Maianthemum stellatum</i>																				T										
<i>Microsteris gracilis</i>	T	T			T						T	T																T		
<i>Myosotis spp.</i>							T																							
<i>Osmorhiza chilensis</i>			T										T		T				T	T										
<i>Penstemon albertinus</i>								T	T		T											T								
<i>Penstemon confertus</i>	T+	T+	1	3	3	15	T	T	T	T	3	8	T	T	1	2-	7+	5			T	T	T	2	T	T	T	1	4	15
<i>Phacelia hastata</i>	T																													
<i>Polygonum douglasii</i>	T						T						T						T						T					
<i>Prenanthes sagittata</i>																						T								
<i>Ranunculus uncinatus</i>	T	T					T												1-	T	T		T							
<i>Rhinanthus crista-galli</i>																								T						
<i>Senecio pauperculus</i>																				T		T+	T	T		T				
<i>Senecio pseudanreus</i>													T		T	T	T		T		T		T	T	T					
<i>Solidago canadensis</i>		T	T					T	T	T	1	T	T	2	2	6	4		T	T	T	T	T+	1	T	T	T	T	1+	T
<i>Stellaria spp.</i>																		T												
<i>Veronica serpyllifolia</i>		T											T	T	T					T	T					T	2			
<i>Viola adunca</i>																			T	T	T									
NATIVE GRASS	3	8	15	11	21	71	3	30	32	16	2	3	2	4	4	1	T	0	2	22	22	8+	2	11	2	30	20	3+	3	T
<i>Agrostis scabra</i>				T+																T										
<i>Bromus carinatus</i>							1	1	T		T		2-	1	1	T	T		T	1	2	T	1	4	1	3	2			
<i>Calamagrostis rubescens</i>				T		T						T																		
<i>Carex athrostachya</i>					T	T				T		T																		
<i>Carex bebbii</i>						T																								
<i>Carex hoodii</i>																			T											
<i>Carex microptera</i>	1+	3	4	5																			T	T						
<i>Carex pachystachya</i>					T+																									
<i>Carex rossii</i>																								T						T
<i>Carex spp.</i>					T	T		T				T																		

	MD-00-04 Turnout #1						MD-00-05 Turnout #2						MD-00-06 Moose Cntry turnout						MD-00-07 Moose Country shoulder						MD-00-08 Turnout #5 shoulder							
Species:	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019		
Danthonia intermedia		T								T											T	T			T					T		
Deschampsia caespitosa	1	5	10	2			T	2	2	T+			T	T	T						T					T	2	4	3	1		
Elymus glaucus			T					3	5	5	T	1	T	T	1	1-				2	15	15	5	T	T	1	T	T	T			
Elymus trachycanlus v. trachycanlus				T+			1	25	25	7	T	T		2	1					T	5	5	3	T+	1		25	15	T			
Festuca campestris					T																											
Festuca idahoensis		T	T	2				T	T	3	T	2																				
Festuca saximontana		T	T+	1	20	70				1	1+									T	T	T	T	T	3					T+	T	
Lolium multiflorum																														T		
Poa palustris	T		T					T	T					T	T					T								T				
Stipa occidentalis						T									T									T	2					1-	T	
EXOTIC GRASS	T	T	1	3	4	3	1	T	1	1+	3	22	18	51	46	51	65	65	1	2	3	5+	9	30	2	2	5	10	55	70		
Agrostis stolonifera			T		T			T						T	T	T			T	T+	1	1	1	2	T	T	T	1-	10	5		
Avena sativa	T			T			T	T							T				T													
Bromus inermis		T			T								15	50	45	40	50	60						T	T+	T	T	1	5	6	2	
Bromus tectorum	T	T	T	T			T	T	T	T	T								T					T	1							
Dactylis glomerata		T	T	T+	T	T+		T										T	T	T	T	T	1	6	T		1	1	15	40		
Elymus repens	T	T	T+	T+	1-	T+					1	2	T			1	10	4		T	T	1	2-	6		T	T	T	2-	1		
Lolium multiflorum	T																			T								T				
Phleum pratense		T	T	1-	1-	T+		T	T	1	T	T	2	1	1	10	2	1	T+	T	T	1	1	6	1	1	1	1+	16	5		
Poa annua														T						T	T					T						
Poa compressa		T	T	1+	2+	T		T	T	T+	1	15			T		T			T	T	T	1	2		T	T	T+	1	2		
Poa pratensis		T	T		T	1		T	T		T+	5	1	T	T		3	T	T	1	1	2	3	6	T	T	T	1	5	15		
EXOTIC FORB	7	10	2	19	3	T+	3	5	2	8	15	T+	7	9	8	8	4	3	5	12	13	18	25	3	2	6	10	18	6	4		
Achillea nobilis		T		T+	T					T	T	T										T+	T+									
Amaranthus retroflexus																		T														
Arenaria serpyllifolia	T	T	T				T	T			T	T								T	T									T		
Artemisia absinthium		T	T	T				T	T											T	T	1	1+	T		T	T	T				
Camelina microcarpa	T	T	T				T	T		T	T								T	T						T	T					
Capsella bursa-pastoris	T	T					T	T	T	T	T							T								T						
Centaurea maculosa *			T		T			T			T+									T	T	T	T	2	T				T			
Cerastium fontanum																				T	T	T					T		T	T		
Chenopodium album	T																	T+														
Chorispota tenella	T																															
Chrysanthemum leucanthemum *		T	T		T	T							1	7	6	4	1	T+	T	5	5	3	5	1	T	T	1	3-	T			
Cirsium arvense *		T	T										T		T					T	T		T									
Cirsium vulgare														T				T		T	T							T				
Descurainia sophia	T						1						T	T				T	T	T						T						
Gnaphalium palustre										T	T																					
Hieracium aurantiacum *											T	T					T					T	4	T	T							
Hieracium caespitosum																							5	T				T				
Hieracium?															T		T											T				

Species:	MD-00-04 Turnout #1						MD-00-05 Turnout #2						MD-00-06 Moose Cntry turnout						MD-00-07 Moose Country shoulder						MD-00-08 Turnout #5 shoulder						
	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	2000	2001	2002	2004	2009	2019	
<i>Hypericum perforatum</i> *													T	T+	T	1	2-						T						T		
<i>Lactuca biennis</i>											T+								T	T+											
<i>Lactuca serriola</i>	T	T					T	T+	T				T		T	T			T	T	T	8	T	T+							
<i>Linaria vulgaris</i> *													T	T	T	1+	T	T		T	T	T									
<i>Marrubium vulgare</i>	T						T																								
<i>Matricaria matricarioides</i>	T																	T													
<i>Medicago lupulina</i>	1-	5	T+	1+	2	T	T	3	1	1-	10		T	T	T	T	T		1	1	T	T	5		1	2	3	1-	2		
<i>Medicago sativa</i>								T	T	1	2	T+																			
<i>Melilotus albus</i>								T+		T												T+									
<i>Melilotus officinalis</i>	T	3	T	15			T	1		5	T		T						T	2	1	5	T			T	T	2-			
<i>Myosotis micrantha</i>											T																			T	
<i>Plagiobothrys snyderi</i>	3						T			T			3-												T						
<i>Plantago major</i>		T	T			T		T	T			T		T+	T	1	T	T+	T	1	1	T	T	T		3	4	4	2	1	
<i>Polygonum achoreum</i>								T						T				T													
<i>Polygonum convolvulus</i>	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	1-	2	
<i>Satureja vulgare</i>																				T											
<i>Silene conoidea</i>	T						T																		T						
<i>Silene latifolia</i>																T	1	T	T			T									
<i>Sisymbrium altissimum</i>	1						1						1	T	T			T	T	T					T						
<i>Sonchus asper</i>																															
<i>Tanacetum vulgare</i>											T																				
<i>Taraxacum officinale</i>	T	T	T			T		T	T	T	T	T	1	T		T	T	T	T	1	1	2	1-	T						T	
<i>Thlaspi arvense</i>	T						T						T					T	T						T						
<i>Tragopogon dubius</i>		T									T												T	T	T						
<i>Trifolium agrarium</i>						T										T			T	T	T	T		T		T					
<i>Trifolium hybridum</i>		1	1	2	T	T		T	T					T	T				3	T								1			
<i>Trifolium pratense</i>								T	T	T	1	T							T	T	T	T			T	T	T	T			
<i>unknown mustard</i>	T						T												T												
<i>Verbascum thapsus</i>		T	T	T	T		T	T	T+	T	T	T		T	T+	T				T	T	T		T							
<i>Veronica officinalis</i>			T			T		T	T					T	T	1	mis-ID?		T	1	3	1+	T	T	T	T	T	T	5	T	T
<i>Veronica serpyllifolia</i>						T											T	T												1	T+
<i>Veronica</i> spp.												T																			

Basal Veg					6					3							8						3						6		
Rock					1	scattd				4	30						1						30	2					0		
Gravel					5	edges				4								1						10						2	
Bare soil					1	0				2								3						1						10	10
Moss/Lichen					5	high				15							3						35	65					6		
Litter					82					72							84						21						76	high	
Wood					0					0							0						T						T		
Other					0					0							0						0						0		

IV. 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 10, 11 & Figure 14). 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 10. 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%

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

Figure 14. Limber Pine Seedling Monitoring Sites

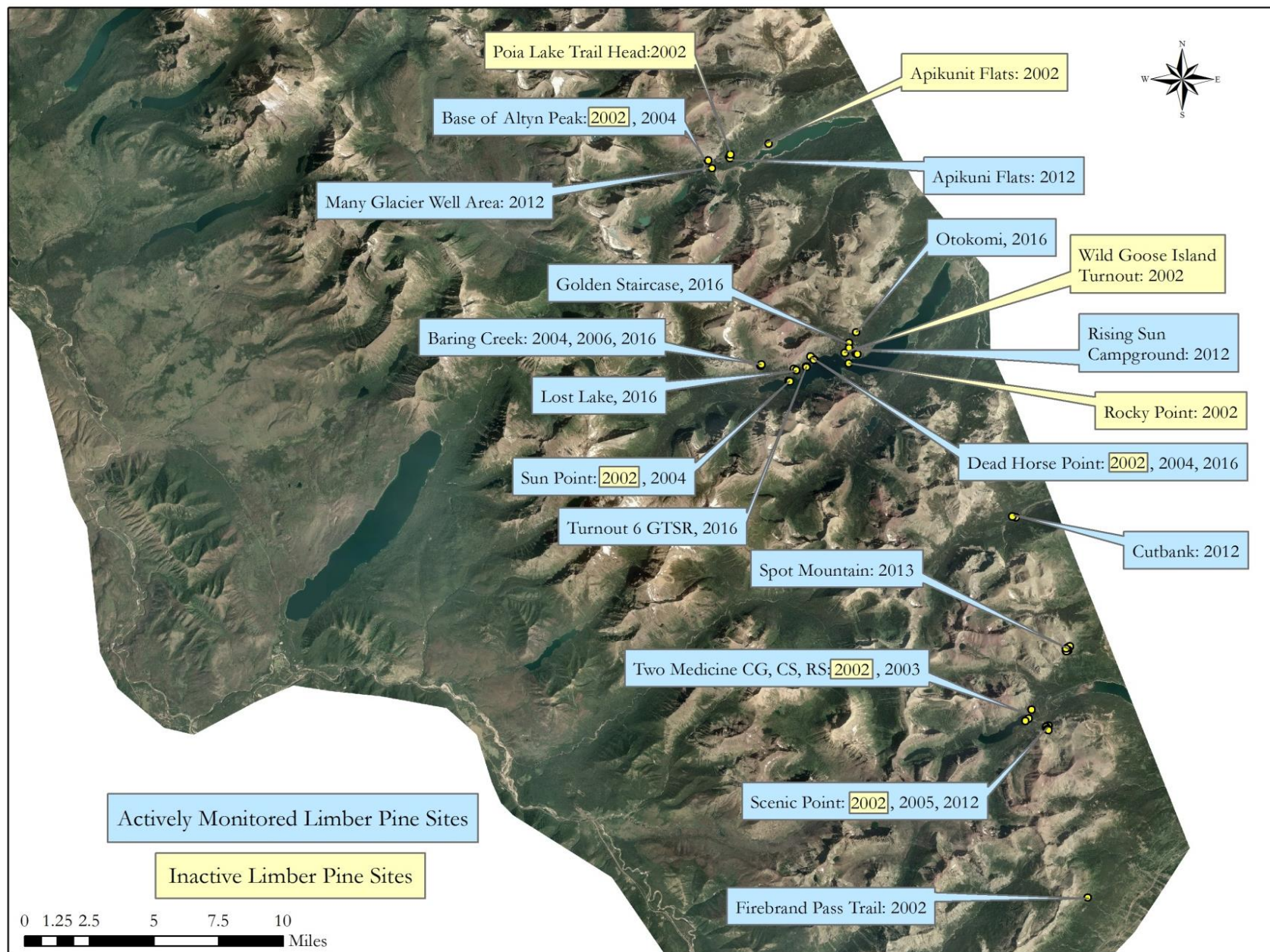


Table 11. Limber Pine Planting Site Characteristics.

<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

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

2. *Whitebark Pine Restoration*

Whitebark pine seedlings have been planted at 23 sites between 2000 and 2019, all of which continue to support live trees (Figure 15; Tables 12 and 14). A total of 24,341 seedlings have been planted in the park between 2000 and 2019. 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 Blackfoot 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 12). 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 19 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 13). This strategy has been moderately successful in Waterton Lakes National Park and a few other areas, prompting experiments in Glacier.

Figure 15. Whitebark Pine Seedling and Seed Monitoring Sites.

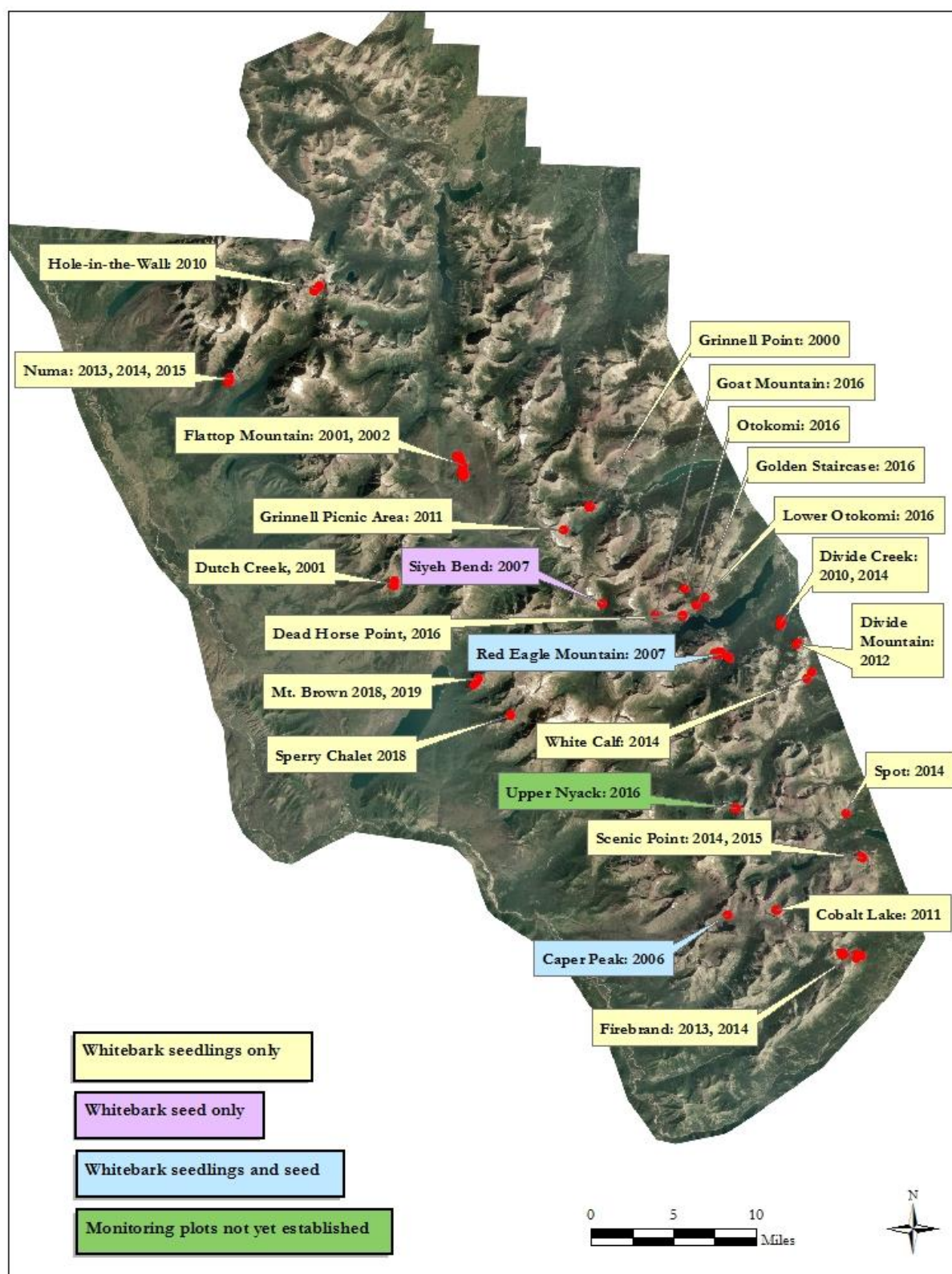


Table 12. Whitebark Pine Seedling Monitoring Plot Establishment to Date.

<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%
	2019 (fall)	4	580	1	580	117	20%
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
White Calf Mtn.	2014 (fall)	2	657	1.2	788	146	19%
Overall Total		131			24,341	5,095	21%

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

Table 13. 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	unkown
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	

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

Table 14. 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
White Calf 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
	2019	Fall	6,785 - 7,450	Yes	Sprague Fire, 2017	No

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

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 14). Table 15 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 21%.

Ten plantings were monitored in 2019; four sites fifteen years after planting, and six sites three years after planting. Results below pertain only to sites monitored in 2019.

Table 15. Parkwide: Health and Survival of Remaining Live Limber Pine Seedlings as of Latest Monitoring Event, 2002 – 2019.

<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>
Various	2002	fall	2004	547	0	0	0	0	0	547
Firebrand Pass Trail	2002	fall	2012	37	0	0	1	0	1	38
Total 2002				584	0	0	1	0	1	585
Two Med Camp Store	2003	fall	2018	25	0	0	1	0	1	26
Total 2003				25	0	0	1	0	1	26
Baring Creek	2004	spring	2014	62	0	4	17	0	21	92
Base of Altyn Peak	2004	fall	2014	30	0	0	10	0	10	40
Dead Horse Point	2004	fall	2014	52	0	0	0	0	1	53
Sun Point	2004	fall	2014	51	0	0	4	0	4	55
Total 2004				195	0	4	31	0	36	240
Scenic Point	2005	fall	2015	138	0	2	9	0	11	149
Total 2005				128	1	5	15	0	21	149
Baring Creek	2006	spring	2016	68	0	2	1	0	3	71
Dead Horse Point	2006	spring	2009	20	0	0	0	0	0	20
Total 2006				68	0	2	1	0	3	91
Cutbank	2012	spring	2015	27	3	7	45	0	55	82
Apikuni Flats (Spring)	2012	spring	2015	51	1	5	22	0	28	79
Apikuni Flats (Fall)	2012	fall	2015	36	0	7	6	0	13	49
Rising Sun CG	2012	spring	2015	118	2	1	19	0	22	140
Scenic Point	2012	spring	2015	78	0	37	40	0	77	155
Scenic Point	2012	fall	2015	88	4	19	83	1	106	195
Many Glacier Well Area	2012	fall	2015	36	0	1	26	0	27	63
Total 2012				434	10	77	241	1	328	762
Spot Mountain	2013	spring	2018	108	0	4	31	0	35	143
Spot Mountain	2013	fall	2018	129	1	10	66	2	77	208
Total 2013				237	1	14	97	2	112	351
Baring Creek	2016	spring	2016	0	0	0	29	0	29	29
Dead Horse Point (lower)	2016	spring	2016	0	0	0	64	0	64	64
Dead Horse Point (upper)	2016	spring	2016	0	0	2	63	0	65	65
Golden Staircase	2016	spring	2016	0	0	7	35	0	42	42
Lost Lake	2016	fall	2016	0	0	4	59	0	63	63
Otokomi (lower)	2016	spring	2016	0	0	2	50	0	52	52
Turnout 6 (GTSR, St. Mary)	2016	spring	2016	0	0	3	41	0	44	44
Total 2016				0	0	18	341	0	359	359
Overall Total				1671	12	120	728	3	861	2563
Percentage of Surviving Trees					1%	14%	85%	0%		
Percentage of Monitored Trees				65%	0.5%	5%	28%	0%		

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

a. *Fifteen Year Old Plantings*

Four sites were planted with limber pine seedlings in 2004, Baring Creek, Dead Horse Point, the Many Glacier Hotel Slope (Base of Altyn Peak) and Sun Point. Of these sites, the only planting that had any surviving trees was the Many Glacier Hotel slope, with 20% survival (8 trees). This was also the only site that did not burn in the 2015 Reynolds Creek Fire. Specifics on each site are outlined below. Overall survival for 2004 seedlings fifteen years after planting is 3%, well below the 16% average of all limber and whitebark pine plantings in the Park monitored 15 years after planting (Table 16). Although this is not a fair assessment of survival, since three of the four planting sites burned, average ten year survival was already slightly lower in these plantings than the parkwide fifteen year average, at 15%.

i. *Baring Creek*

On May 24, 2004, 450 limber pine seedlings were planted in the lower Baring Creek area (Figure 16). Five monitoring plots were established, encompassing 92 trees and following 20% of planted trees. This area had not burned prior to planting. At the last monitoring event, in 2014, ten years after planting, 23% of monitored seedlings were alive, most of which were in good condition. Unfortunately, fifteen years after planting at Baring Creek, all monitored seedlings were dead or missing (Tables 16, 17). Since these plots were all within the fire perimeter of the 2015 Reynolds Creek Fire (Figure 16), likely all seedlings were lost to the fire. This site had fared better than most of the other 2004 limber pine plantings prior to the fire. Many of the seedlings at Baring Creek were planted underneath krumholz Douglas-fir trees, which may have offered protection.

ii. *Dead Horse Point*

On September 14, 2004, 250 seedlings were planted at Dead Horse Point (Figure 17). Two monitoring plots were established, encompassing 53 seedlings or 21% of planted trees.

Fifteen years after planting, the one remaining live tree at this site had died, likely burned in the 2015 Reynolds Creek Fire (Tables 16, 17). This site has historically seen avalanche activity, which has buried seedlings in previous plantings. The cause for low survival in this planting in previous years is unknown, but it is not recommended to plant in this area in the future due to low success and frequent avalanche activity.

iii. *Sun Point*

On September 14, 2004, 250 seedlings were planted at Sun Point (Figure 18). Two monitoring plots were established, capturing 54 seedlings or 22% of planted trees. The four seedlings that had survived to 10 years after planting at this site had died by the fifteen year mark (Tables 16, 17). Although this planting area does not show to be included in the perimeter of the 2015 Reynold's Creek Fire (Figure 18), it was noted that the plot was within the burned area, and the seedlings appear to have burned in the fire.

iv. *Base of Altyn Peak (Many Glacier Hotel Slope)*

On September 14, 2004, 200 limber pine were planted at the base of Altyn Peak (the Many Glacier Hotel Slope). Two plots were established, monitoring 40 trees or 20% of planted seedlings (Figure 19).

Fifteen year survival at this site was 20%, with 8 remaining live trees (Tables 16,17). This is the only limber pine seedling monitoring site planted in 2004 that did not burn, but it was also the site with the highest survival five years ago, prior to the burn. Seedlings had a 25% survival rate 10 years after planting. This site is rocky and exposed with very few protective microsites, so there is no clear hypothesis as to why this site had higher survival. This area historically harbored a relatively large limber pine stand, and several small but mature limber pine trees still survive here, so conditions are likely favorable for these trees once they are established.

Figure 16. Baring Creek: Limber Pine Monitoring Plots, Planted in the Spring 2004.

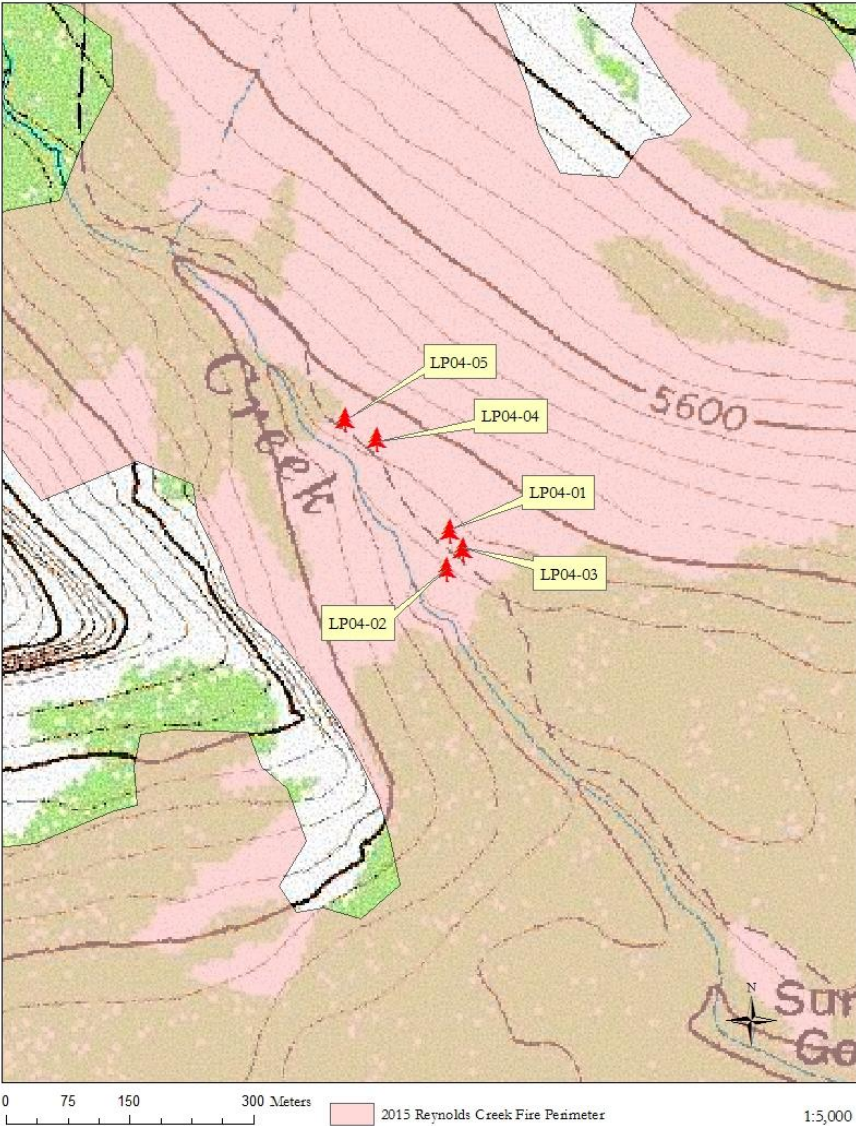


Figure 17. Dead Horse Point: Limber Pine Monitoring Plots, Planted in the spring of 2004.

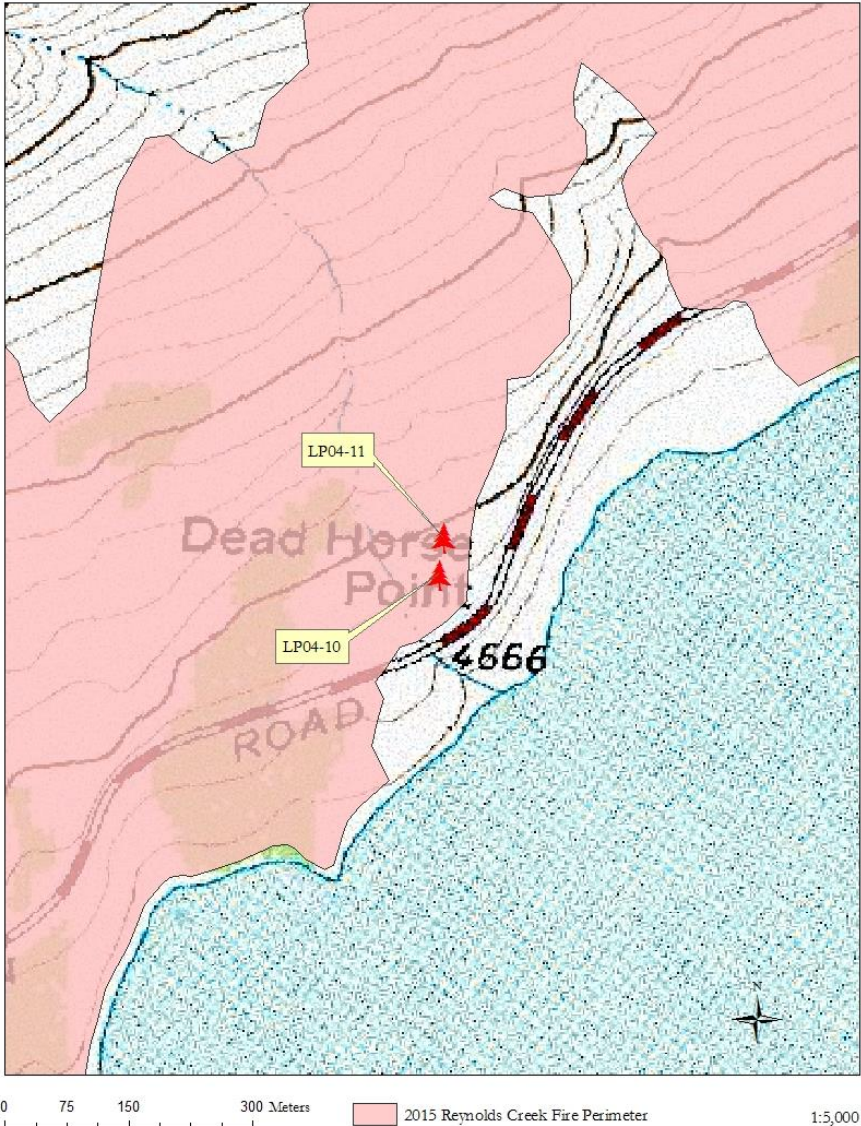


Figure 18. Sun Point: Limber Pine Monitoring Plots, Planted in the Spring of 2004.

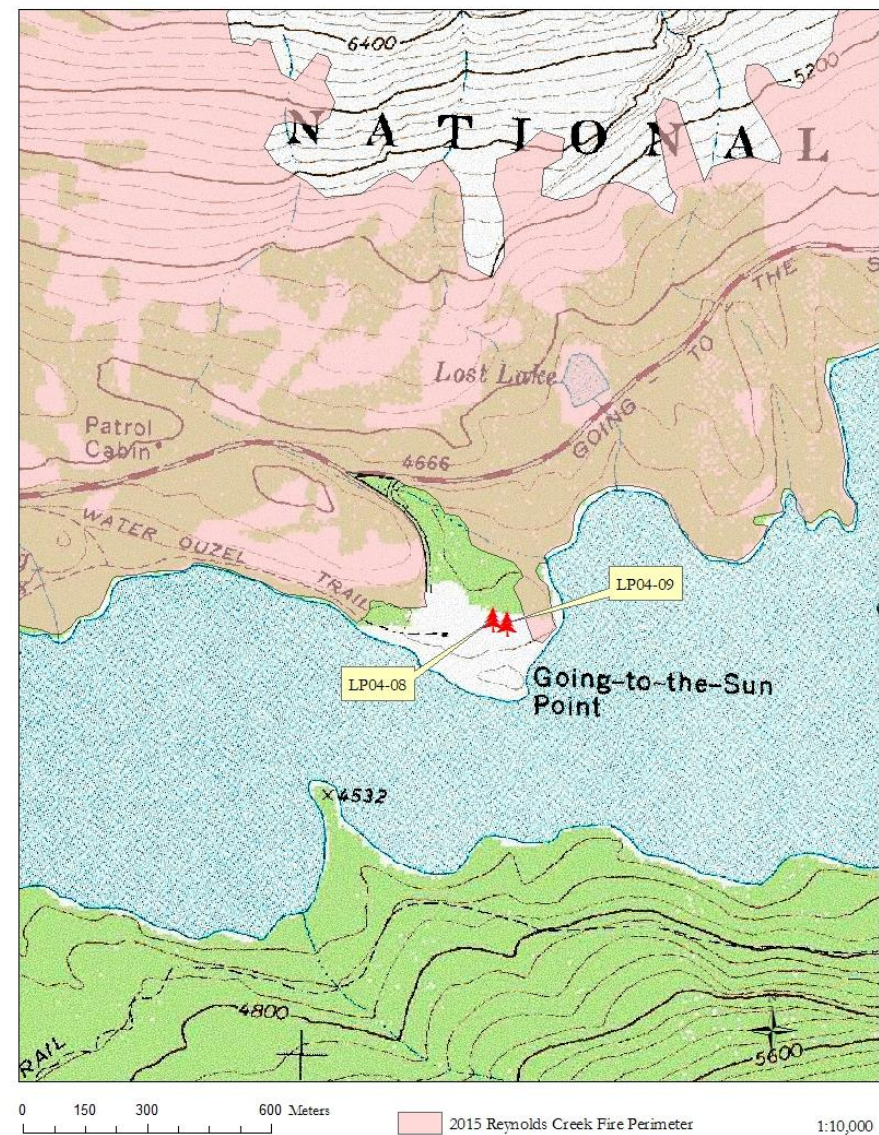


Figure 19. Base of Altyn Peak: Limber Pine Monitoring Plots, Planted in the Spring of 2004.

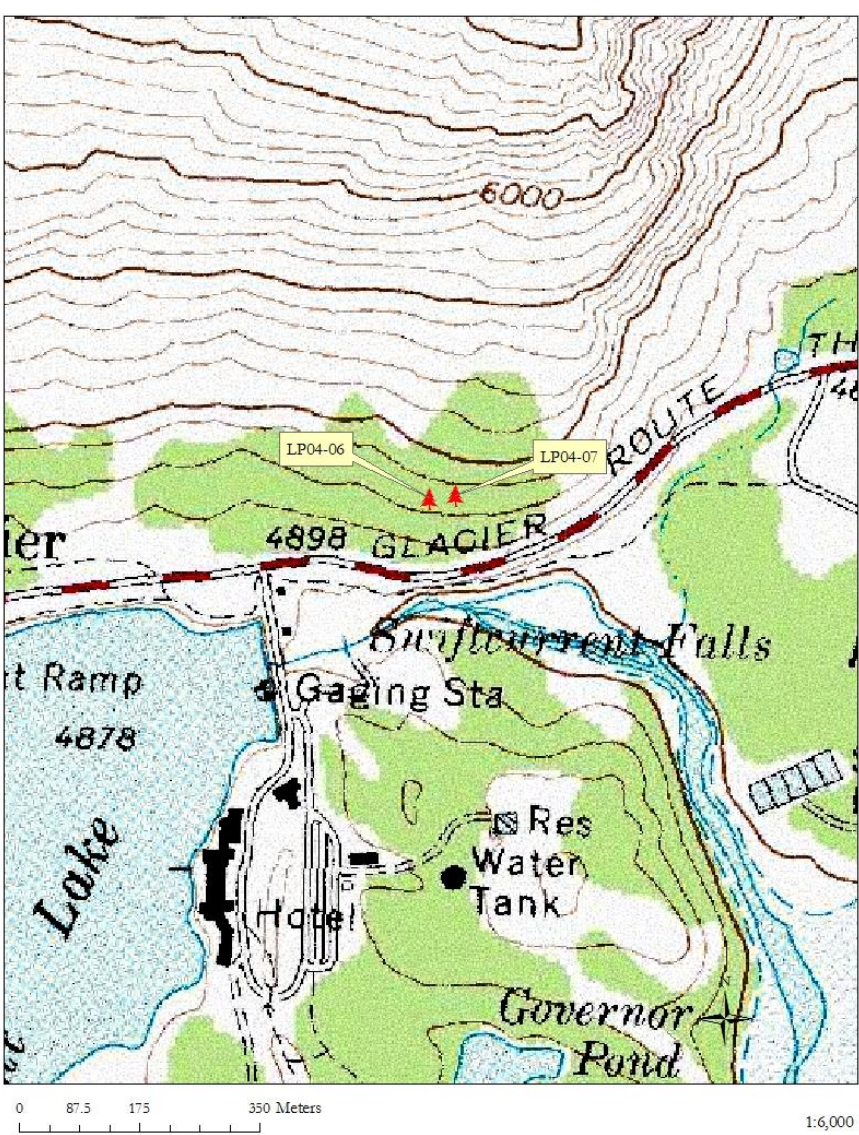


Table 16. Parkwide: Survival of Limber Pine Seedlings Planted in 2004.

<i>Site</i>	<i>Monitoring Year</i>	<i># Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>	<i>Average Height (cm)</i>	<i>Average Width (cm)</i>
Baring Creek	2005	90	47	52%	*	*
	2006	90	39	43%	*	*
	2007	90	28	31%	*	*
	2008	90	20	22%	*	*
	2009	90	20	22%	19.7	13.0
	2014	92	21	23%	30.7	23.9
	2019	92	0	0%	N/A	N/A
Base of Altyn Peak	2005	39	23	59%	*	*
(slope above MG Hotel)	2006	40	21	53%	*	*
	2007	40	13	33%	*	*
	2009	40	12	30%	10.2	9.4
	2014	40	10	25%	19.3	23.9
	2019	41	8	20%	33.4	49.0
Dead Horse Point	2005	53	11	21%	*	*
	2006	53	7	13%	*	*
	2007	53	3	6%	*	*
	2009	53	1	2%	27.0	9.0
	2014	53	1	2%	61.0	39.0
	2019	53	0	0%	N/A	N/A
Sun Point	2005	51	28	55%	*	*
	2006	54	26	48%	*	*
	2007	54	18	33%	*	*
	2009	55	4	7%	13.0	12.3
	2014	55	4	7%	22.3	28.0
	2019	55	0	0%	N/A	N/A
Total One Year Survival	2005	233	109	47%		
Total Two Year Survival	2006	237	93	39%		
Total Three Year Survival	2007	237	62	26%		
Total Four Year Survival	2008	90	20	22%	Height Ave.	Width Ave.
Total Five Year Survival	2009	238	37	16%	17.5	10.9
Total Ten Year Survival	2014	240	36	15%	33.3	28.7
Total Fifteen Year Survival	2019	241	8	3%	33.4	49.0

* Height and Width not recorded

Burned in Reynolds Fire of 2015

S: VegUnit/Whitebark & Limber Pine/Whitebark and Limber Pine report tables.xls (Planted 2004 tab)

Table 17. Parkwide: Survival, Average Height and Width of all Whitebark and Limber Pine Seedlings Planted in the Park, Fifteen Years After Planting.

<i>Site</i>	<i>Species</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 WBP	Whitebark	2000	fall	2015	65%	15	53.81	66.66
Flattop Mtn. Spring WBP	Whitebark	2001	spring	2016	25%	15	85.7	66.52
Flattop Mtn. Fall WBP	Whitebark	2001	fall	2016	33%	15	82.47	50.65
Firebrand Pass Trail LP	Limber	2002	fall	2017	0.2%	15	87	135
Two Med Camp Store	Limber	2003	fall	2018	4%	15	70	74
Baring Creek	Limber	2004	spring	2019	0%	15	N/A	N/A
Dead Horse Point	Limber	2004	fall	2019	0%	15	N/A	N/A
Sun Point	Limber	2004	fall	2019	0%	15	N/A	N/A
Base of Altyn Peak (MG Hotel Slope)	Limber	2004	fall	2019	20%	15	33.4	49
Average 15 year-old-trees					16%		68.73	73.64

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

b. Three Year Old Plantings

Limber pine seedlings were planted at six different sites in 2016 (Figure 18): Baring Creek, Dead Horse Point (lower and upper), Golden Staircase (lower), Lost Lake, Otokomi Mtn. (bench on lower slope), and Turnout #6 along the GTSR (below the road between Sun Point and Dead Horse Point). A total of 1,039 limber pine seedlings were planted. All plantings except the one at Lost Lake took place in the spring and all plantings were within the burn perimeter of the Reynolds Creek Fire of 2015. This is the first time that burned habitat has been available for limber pine planting since the inception of the restoration program in the Park. Extra care was taken to find suitable planting sites within the burn that previously supported limber pine populations and that provided protection, good soil, microsites, and good planting conditions. A total of 35% of planted seedlings were captured in monitoring plots (Table 18).

Three years after planting, survival across all monitoring sites averaged only 30% (Table 19). The range of survival was 6% (at lower Dead Horse Point) to 66% (at Lost Lake, the only site planted in the fall). This is slightly lower than average survival for all three year old limber pine plantings in the Park, which is currently 36% (Table 20).

High early survival may have been artificial, since all sites were monitored relatively early in the season the first year after planting (in July, 2017), which began an extreme heat wave and was followed by a “flash drought”. The summer of 2018 was also notoriously hot and dry. Lower subsequent survival rates could potentially be due to this combination of hot and dry conditions, particularly at lower elevations, where limber pine tend to be planted.

Table 18. Limber Pine Plot Establishment, Seedlings Planted in 2016.

<i>Site</i>	<i>Year</i>	<i>Season Planted</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>
Baring Creek	2016	spring	1	104	1	104	29	28%
Dead Horse Point (lower)	2016	spring	1	98	1	98	64	65%
Dead Horse Point (upper)	2016	spring	1	147	1	147	65	44%
Golden Staircase (lower)	2016	spring	2	98	1	98	42	43%
Lost Lake	2016	fall	2	312	1	312	63	20%
Otokomi (lower)	2016	spring	1	179	1	179	52	29%
Turnout 6: St. Mary	2016	spring	2	101	1	101	44	44%
Overall			10	1039		1039	359	35%

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

i. Baring Creek

In the spring of 2016, 104 seedlings were planted in the Baring Creek area, approximately 0.7 miles up the trail, in the first opening (Figure 20). Twenty-eight percent of trees were captured in a single monitoring plot (Table 18). All trees were alive and in good condition at the time of planting.

Three years after planting, 48% of seedlings were alive, a significant decrease from one-year survival of 90%, but higher than average for limber pine seedlings planted in 2016 (Table 19). Trees at this site continue to be slightly larger than average for this planting cohort. Given the extreme hot, dry nature of the summers of 2017 and 2018, a drop in survival rates was not unexpected. Three year survival of this cohort is lower than the overall park average for three-year old trees, which is 54% (Table 20.)

ii. Dead Horse Point

Limber pine seedlings were planted at two sites in the Dead Horse Point area in 2016; one on the bench just above the road, which was planted by Browning High School students and revegetation crew, and one about 475 feet higher on an upper bench (Figure 20). Both areas were planted in the spring. The lower plot captured 64 of 98 planted trees (65%), and the upper plot captured 65 of 147 planted trees (44%, Table 18).

Seedlings at both sites had the lowest survival rates of all limber pine seedlings planted in 2016, with just 6% survival at the lower site and 12% survival at the upper site (Table 19). This was a substantial decline from one-year post planting, when 95% and 97% of seedlings survived in the lower and upper plots, respectively. The lower bench area has not historically seen success in previous plantings, partially due to low elevation, perhaps, or other site-specific characteristics. The upper site is one of the higher elevation planting areas of 2016, so elevation probably played less of a role there. It is unknown why that planting experienced such low survival, but climate likely played a large role. Trees in both plots were near average in size compared to all limber pine seedlings planted in 2016 (Table 19).

i. Golden Staircase

In the spring of 2016, 98 seedlings were planted on a bench in the lower Golden Staircase area (Figure 20). Two monitoring plots were established in this planting in the spring, encompassing 42 seedlings, or 43% of planted trees (Table 18). All trees were alive, and most (83%) were in good condition at the time of planting. The rest were considered in fair health.

Seedlings at this site also performed below average for the 2016 plantings, with only 17% survival (Table 19). Again, this was a substantial decrease from first year survival of 83%. A considerable amount of these surviving trees were only rated as fair (26%) or almost dead (9%) at that time, however. Seedlings at this site were slightly taller and thinner than average. These plots are around average in elevation, but are on a bench in a relatively exposed area, which may be proving detrimental. Whitebark pine seedlings that were planted about 1,200 m higher up on this slope had a 71% survival rate, with 98% of living trees in good condition. There may be a general trend in which there is better survival at higher elevations where conditions are likely to be slightly cooler, with a shorter summer season, but this tends to be highly site specific.

ii. Lost Lake

Lost Lake, located east of Sun Point, on the north side of the road (Figure 20) was the only site planted in the fall of 2016. All other sites were planted in the spring. The highest number of seedlings was also planted here, with 312 trees. Monitoring plots encompassed 63 trees, or 20% of planted seedlings (Table 18). All trees were alive, and most were in good condition (94%) at the first monitoring event shortly after planting.

Third-year survival was the highest of all 2016 plantings at Lost Lake, at 66% (Table 19). Although there was a considerable decline in survival at this site over the past two years, from 98% first year-survival, death rate tied for the lowest of any other site of this cohort over the past two years. The elevation at Lost Lake is on the lower end of the range from this planting, but seedlings were planted in late fall (early October) just prior to dormancy, which may have been an advantage over the other spring-planted trees. Seedlings at this site continue to be some of the smallest of limber pine seedlings planted in 2016. This may reflect that they were some of the smallest trees when planted, and potentially that they were planted in late fall.

iii. Otokomi Bench

In the spring of 2016, 179 seedlings were planted on a bench on lower Otokomi Mountain (Figure 20). Monitoring plots were established shortly thereafter, and 53 trees, 29% of planted seedlings, were included in monitoring plots (Table 18). All seedlings were alive at first monitoring, and most were considered in good condition.

Survival was 38% at this site three years after planting (Table 19). Although this is a considerable drop from first year survival of 71%, the death rate was tied for the lowest of the 2016 limber pine plantings over the past two years. First year survival was the lowest of all sites in this planting, while three year survival is slightly above average. This is somewhat surprising, since only 78% of surviving trees were rated in good condition one year after planting. These seedlings continue to be some of the smallest seedlings after one year of out-planting, but they were also some of the smallest seedlings planted. Perhaps some of the recent relative success at Otokomi Bench is due to it being the highest elevation site of all limber pine plantings from 2016.

iv. Turnout #6

Seedlings were planted in an area termed Turnout 6, west of Dead Horse Point and south of the Going-to-the-Sun Road (Figure 20). This is the lowest elevation limber pine planting of 2016. This was one of the earliest plantings in the spring of 2016, with 101 seedlings. Monitoring plots encompassed 44 trees (44% of planted trees, Table 18).

Third year survival at this site was 31%, slightly above average for limber pine seedlings planted in 2016 (Table 19). As in all of the seedlings planted at this time, survival dropped considerably over the past two years, from 73% at one year after planting.

As hypothesized earlier, perhaps the lower elevation negatively affected seedlings, providing slightly warmer temperatures. Surviving seedlings continue to be some of the largest, on average, of all limber pine monitoring sites from 2016, however.

Figure 20. Limber Pine Monitoring Plots Installed and Planted in 2016.

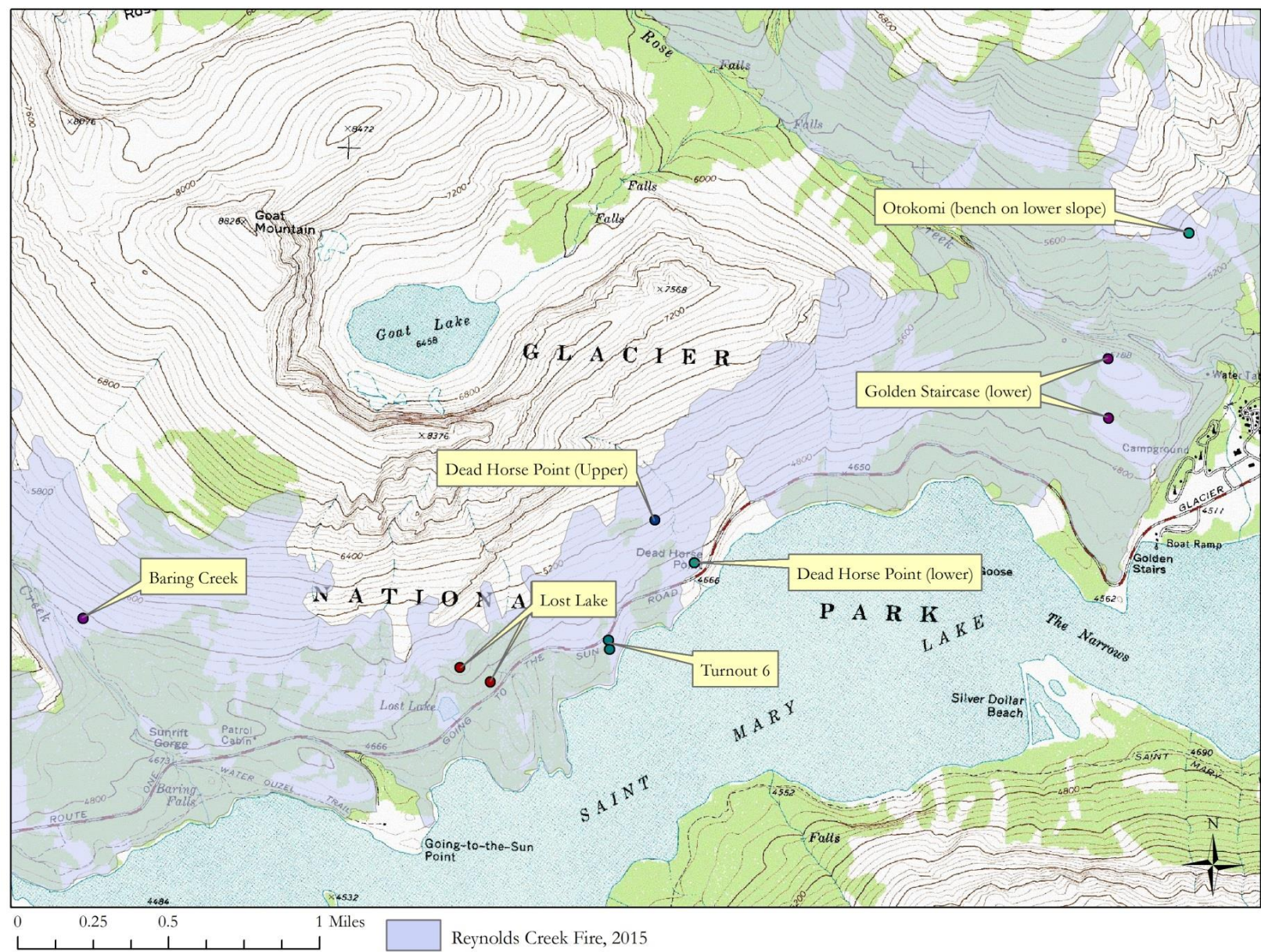


Table 19. Limber Pine Seedlings Planted in 2016: Survival and Average Height and Width.

<i>Site</i>	<i>Season Planted</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>Average Height</i>	<i>Average Width</i>
Baring Creek	spring	2016	0	0	0	29	29	29	100%	8.3	10.0
		2017	3	0	3	23	26	29	90%	9.6	12.1
		2019	15	0	1	13	14	29	48%	14.0	16.6
Dead Horse Point (lower)	spring	2016	0	0	0	64	64	64	100%	8.5	8.7
		2017	7	0	7	50	57	64	89%	10.2	13.4
		2019	60	0	2	2	4	64	6%	12.8	14.5
Dead Horse Point (upper)	spring	2016	0	0	2	63	65	65	100%	8.5	10.6
		2017	4	0	7	55	62	66	94%	9.7	11.9
		2019	58	0	2	6	8	66	12%	11.9	15.5
Golden Staircase (lower)	spring	2016	0	0	7	35	42	42	100%	8.6	10.0
		2007	7	3	9	23	35	42	83%	9.6	11.0
		2019	35	0	0	7	7	42	17%	13.7	14.9
Lost Lake	fall	2016	0	0	4	59	63	63	100%	7.5	9.5
		2017	1	1	5	57	63	64	98%	8.2	10.1
		2019	22	0	6	36	42	64	66%	12.5	14.3
Otokomi (bench on lower slope)	spring	2016	0	0	2	50	52	52	100%	8.0	10.6
		2017	15	2	6	29	37	52	71%	8.9	9.2
		2019	32	1	10	9	20	52	38%	11.8	14.8
Turnout #6	spring	2016	0	0	3	41	44	44	100%	7.8	10.2
		2017	12	2	4	27	33	45	73%	10.4	12.6
		2019	31	0	1	13	14	45	31%	13.9	15.5
Total Year 0 Survival							359	359	100%		
Total Year 1 Survival							313	362	86%		
Total Year 3 Survival							109	362	30%		
Average Year 0 Height/Width										8.17	9.92
Average Year 1 Height/Width										9.50	11.47
Average Year 3 Height/Width										12.94	15.16

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (LP Planted 2016 tab).

Table 20. Parkwide: Survival, Average Height and Width of all Limber Pine Seedlings Planted in the Park, Three Years After Planting.

Site	Year Planted	Season Planted	Year Monitored	Year 3		Number Alive	Percent Alive
				Height	Width		
Two Medicine Camp Store	2003	fall	2006	*	*	8	31%
Baring Creek	2004	spring	2007	*	*	18	30%
Dead Horse Point	2004	fall	2007	*	*	3	6%
Base of Altyn Peak (MG Hotel Slope)	2004	fall	2007	*	*	13	33%
Sun Point	2004	fall	2007	*	*	18	33%
Scenic Point Trail	2005	fall	2008	*	*	21	14%
Apikuni Flats (Spring)	2012	spring	2015	11.04	7.39	28	35%
Apikuni Flats (Fall)	2012	fall	2015	9.54	6.54	13	27%
Cutbank (spring)	2012	spring	2015	9.8	8.13	55	67%
Many Glacier Well (Fall)	2012	fall	2015	11.37	10.07	27	43%
Rising Sun (Spring)	2012	spring	2015	12.18	8.59	22	16%
Scenic Point (Spring)	2012	spring	2015	9.01	8.13	77	50%
Scenic Point (Fall)	2012	fall	2015	10.04	8.86	106	54%
Spot Mountain (Spring)	2013	spring	2016	9.18	8.82	51	36%
Spot Mountain (Fall)	2013	fall	2016	8.33	7.63	112	54%
Baring Creek	2016	spring	2019	14	16.6	14	48%
Dead Horse Point (lower)	2016	spring	2019	12.8	14.5	4	6%
Dead Horse Point (upper)	2016	spring	2019	11.9	15.5	8	12%
Golden Staircase (lower)	2016	spring	2019	13.7	14.9	7	17%
Lost Lake	2016	fall	2019	12.5	14.3	42	66%
Otokomi (bend on lower slope)	2016	spring	2019	11.8	14.8	20	38%
Turnout #6	2016	spring	2019	13.9	15.5	14	31%
Overall Average				11.32	11.27	31.0	36%

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

2. Whitebark Pine Seedling Results

Whitebark pine seedlings have been planted at 23 sites between 2000 and 2019, all of which continue to support live trees (Figure 15). Tables 21 and 22 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 47% based on the most recent monitoring event at each site.

Six five-year-old whitebark pine planting sites were monitored in 2019; Divide Creek (upper), Firebrand Pass Trail (upper and lower), Numa Lookout, Scenic Point (upper), Spot Mountain and White Calf Mountain. Additionally, four three-year-old sites were monitored; Dead Horse Point (upper), Goat Mountain, Golden Staircase (upper) and Otokomi (upper and lower sites), as well as two one-year-old sites, Mount Brown Lookout and Sperry Chalet.

Whitebark pine seedlings were planted at one site this year. In September, 580 seedlings were planted near Mount Brown Lookout, near last year's planting site. All seedlings were planted inside the burn perimeter of the Sprague Fire of 2017. Further discussion in this report only reflects the sites monitored this year.

Table 21. 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
Divide Creek	2014	fall	2019	71%	5	19.68	17.29
Firebrand Pass Area (lower)	2014	spring	2019	58%	5	16.52	16.86
Firebrand Pass Area (upper)	2014	fall	2019	3%	5	11.5	13.25
Numa Lookout	2014	fall	2019	34%	5	14.1	10.83
Scenic Point	2014	spring	2019	22%	5	11.93	10.64
Spot Mountain	2014	spring	2019	6%	5	10.5	11.5
White Calf	2014	fall	2019	11%	5	9.75	10.5
Average 5 year-old-trees				48%		13.95	13.67
Numa Lookout	2015	fall	2018	15%	3	9.00	8.90
Scenic Point	2015	fall	2018	32%	3	10.59	10.23
Dead Horse Point (upper)	2016	spring	2019	43%	3	15.13	18.78
Goat Mountain Slope	2016	spring	2019	62%	3	17.33	18.10
Golden Staircase (upper)	2016	spring	2019	71%	3	15.52	16.76
Otokomi (lower)	2016	spring	2019	75%	3	16.65	17.95
Otokomi (upper)	2016	spring	2019	85%	3	21.22	19.71
Average 3 year-old-trees				27%		15.06	15.78
Red Eagle - lower	2007	fall	2008	0%	1	8.79	8.82
Mount Brown Lookout	2018	fall	2019	92%	1	14.19	11.23
Sperry Chalet	2018	fall	2019	99%	1	12.5	12.55
Average 1 year-old-trees				64%		11.83	10.87
Mount Brown Lookout	2019	fall	2019	100%	0	9.04	10.23
Average 0 year-old-trees				100%		9.04	10.23
Overall Average Survival				47%			

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

Table 22. Parkwide: Overall Health and Survival of Whitebark Pine Planted in Glacier National Park, 2001-2019; as of Latest Monitoring Event.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i>Monitoring Year</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>
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	2019	5	65	4	12	141	0	157	222	71%
Firebrand Pass Area (Lower)	2014	spring	2019	5	45	0	3	60	0	63	108	58%
Firebrand Pass Area (Upper)	2014	fall	2019	5	155	0	1	3	0	4	159	3%
Numa Lookout	2014	fall	2019	5	78	2	5	34	1	41	120	34%
Scenic Point (Upper)	2014	spring	2019	5	146	0	8	34	1	42	189	22%
Spot Mountain	2014	spring	2019	5	34	0	2	0	0	2	36	6%
White Calf	2014	fall	2019	5	136	0	11	5	0	16	152	11%
Total 2014					659	6	42	277	2	325	986	33%
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	2019	3	31	0	1	22	0	23	54	43%
Goat Mountain Slope	2016	spring	2019	3	13	0	5	16	0	21	34	62%
Golden Staircase (Upper)	2016	spring	2019	3	17	0	1	41	0	42	59	71%
Otokomi (Upper)	2016	spring	2019	3	10	0	7	48	0	55	65	85%
Otokomi (Lower)	2016	fall	2019	3	25	2	7	67	0	76	101	75%
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					96	2	21	194	0	217	313	69%
Mt Brown Lookout	2018	fall	2019	1	9	2	31	68	0	101	110	92%
Sperry Chalet	2018	fall	2019	1	1	4	11	106	0	121	122	99%
Total 2018					10	6	42	174	0	222	232	96%
Mt Brown Lookout	2019	fall	2019	0	0	0	0	117	0	117	117	100%
Total 2019					0	0	0	117	0	117	117	100%
Overall Total					2612	26	207	2259	3	2392	5007	48%
Percentage of Surviving Trees						1%	9%	94%	0%			
Percentage of Monitored Trees					52%	0.5%	4%	45%	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. 5-Year-Old Plantings

Whitebark pine seedlings were planted at six sites in 2014; Divide Creek, Firebrand Pass (upper and lower), Numa, Scenic Point, Spot and White Calf. An estimated 4,763 seedlings were planted, and 22% of planted seedlings were captured in monitoring plots. Five years after planting, all monitoring plots were revisited, and survival across all monitoring areas averaged 33% (Table 23). The range of survival across sites was 3% to 71%.

i. Divide Creek

Due to the success of the 2010 planting at Divide Creek, it was decided to plant more whitebark pine seedlings at this site in 2014. This planting took place further upslope from the 2010 planting on open slopes and knobs where competition from lodgepole pine was lower (Figure 21). In September of 2014, 1,026 whitebark pine seedlings were planted at the Divide Creek planting site on the flank of Curly Bear Mountain. This site also burned in the Red Eagle fire of 2006 and all seedlings were planted within the burn. Most seedlings were grown in the nursery as single trees per cone, but occasionally more than one seedling was present in a cone. Therefore, a multiplier of 1.1 was utilized to estimate the number of trees planted at this site. In 2014, 933 cones were planted in the upper Divide Creek area resulting in an estimated total of 1,026 trees. Often more than one cone was planted in a microsite, mimicking multiple whitebark pine trees often found in clumps as a result of seed caches buried by Clark's nutcrackers. These seedlings originated from White Calf parent trees, and none were inoculated with an ectomycorrhizal slurry in the 2014 planting.

Figure 21. Divide Creek: Whitebark Pine Seedling Monitoring Plots Established in 2010 and 2014.



Three monitoring plots were installed in 2014, tracking 216 seedlings. This captured 21% of planted seedlings. At the time of monitoring, 100% of the seedlings were alive, almost all of which were rated in good health.

Monitoring the plots planted in 2019 revealed that 71% of seedlings had survived five years after planting (Table 23). This site continues to demonstrate the highest survival in comparison with all 2014 whitebark plantings in the Park, which had an overall average survival of 33% (Table 23). Survival at these plots is also much higher than average for all five-year-old whitebark pine plantings in the Park, at 40% (Table 24). Divide Creek is the only site planted in 2014 that had previously burned, continuing to support the hypothesis that seedlings planted in burned areas are the most successful.

Seedlings from Divide Creek also continue to be the largest on average of all whitebark pine seedlings planted in 2014 (Table 23), but are not the largest of all seedlings in five-year-old whitebark plantings Park wide (Table 24). Seedlings at Flattop and Red Eagle, also sites that had previously burned, were larger five years after planting. Seedlings again grew substantially since the last monitoring event, in 2017. However, over the course of the past two years, they grew disproportionately in height, in contrast to the previous two years when they grew more equally in both height and width. Seedlings in this planting grew in an average of 5.1 cm in height and 2.7 cm in width, on average, over the course of the past two years.

Divide Creek has supported some of the highest survivorship across the Park. Seedlings planted in 2010 had a 94% survival rate at five years post-planting, the highest five-year survival rate to date. These trees were planted in cool, wet conditions during an early season snow event, followed by cool, autumn or early winter weather. As a result, seedlings were probably induced to go into dormancy relatively quickly after planting. Additionally, this area burned, but not so hot as to sterilize the soil, which likely benefitted both plantings at this site. Other vegetation has responded well to these conditions, indicating a flush of nutrients released post-burning as well as preservation of beneficial soil fungi. The future threat to continued success at this site will most likely be from competition from lodgepole pine seedlings and saplings that are also thriving post-burn. Lodgepole seedlings were up to several meters tall in this area, sometimes forming dense stands in or near planting areas. Thriving lodgepole pines may also provide some shade and protection to establishing whitebark seedlings, however, if competition remains low. This site is at the lower extent of whitebark pine habitat, and while the environmental conditions appear to be less harsh than many higher elevation sites, perhaps the tradeoff is higher vegetative competition and perhaps warmer temperatures.

ii. Firebrand Pass Trail

Four plantings have taken place near Firebrand Pass and on the flanks of Calf Robe Mountain (Figure 22). Whitebark pine seedlings were planted in both the upper and lower regions of the Firebrand Pass area in the spring and fall of 2013 and 2014. This year, seedlings planted in the spring and fall of 2014 were monitored, five years after planting.

a. Lower Firebrand Pass Trail (Spring)

On June 23, 2014, approximately 452 trees were planted on a bench on an open slope on the eastern flank of Calf Robe Mountain (Figure 22). This planting was upslope and south/southeast of the fall 2013 lower Firebrand Pass Trail planting. Two monitoring plots were established in this area, tracking 102 trees or 23% of planted seedlings.

Survival continued to drop in this planting, but the rate of decline has lessened. After five years, 58% of monitored trees of this planting are alive, only an 8% decline over the past two years. One year after planting, overall survival at this site was very high, but declined by 25% in the subsequent two years (Table 23). Survival may continue to decline, since quite a few trees were rated only fair or almost dead.

Seedlings at this site are faring better than average for this planting cohort (planted in 2014), where average survivorship was only 33%. Survival at this planting is substantially higher than survival at the upper Firebrand Pass Trail site, planted in the fall, where only 3% of seedlings are alive. Traditionally, fall-planted seedlings have fared better than spring-planted seedlings, but success seems to be more on a case-by-case basis. Many spring-plantings such as this one are showing that under good planting conditions, spring can be as good as or better for planting than fall.

Seedlings at the Firebrand Pass area planted in the spring of 2014 were larger than average for all whitebark seedlings planted in 2014, and larger than average for all five year seedlings planted in the Park (Tables 23 and 24). These seedlings have shown good field growth rates, since they were smaller than average size for first year seedlings in the Park.

Table 23. Whitebark Pine Seedlings Planted in 2014: Survival and Average Height and Width.

<i>Site</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Unknown</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
Divide Creek	fall	2014	0	0	2	214	0	216	216	100%	10.0	9.5
		2015	28	0	37	154	0	191	219	87%	10.4	9.7
		2017	55	1	15	151	0	167	222	75%	14.6	14.6
		2019	65	4	12	141	0	157	222	71%	19.7	17.3
Firebrand (lower)	spring	2014	0	2	3	97	0	102	102	100%	8.5	8.4
		2015	10	0	6	90	0	96	106	91%	8.4	8.9
		2017	36	0	6	64	0	70	106	66%	12.9	13.4
		2019	45	0	3	60	0	63	108	58%	16.5	16.9
Firebrand (upper)	fall	2014	0	0	16	131	0	147	147	100%	10.5	9.7
		2015	112	17	25	5	0	47	159	30%	7.4	8.9
		2017	155	0	2	2	0	4	159	3%	9.3	10.0
		2019	155	0	1	3	0	4	159	3%	11.5	13.3
Numa	fall	2014	0	2	10	108	0	120	120	100%	11.4	10.0
		2015	42	1	15	62	0	78	120	65%	11.2	9.2
		2017	60	9	15	37	0	61	121	50%	12.8	10.1
		2019	78	2	5	34	1	41	120	34%	14.1	10.8
Scenic Point (upper)	spring	2014	1	0	0	187	0	187	188	99%	9.3	8.9
		2015	44	25	31	88	0	144	188	77%	9.0	9.2
		2017	89	6	9	85	0	100	189	53%	9.6	9.9
		2019	146	0	8	34	1	42	189	22%	11.9	10.6
Spot	spring	2014	0	1	0	35	0	36	36	100%	8.6	7.6
		2015	9	1	7	19	0	27	36	75%	9.0	8.6
		2017	24	0	2	10	0	12	36	33%	9.5	9.6
		2019	34	0	2	0	0	2	36	6%	10.5	11.5
White Calf	fall	2014	0	0	1	145	0	146	146	100%	10.6	9.5
		2015	57	41	18	35	0	94	151	62%	9.4	9.6
		2017	105	0	24	23	0	47	152	31%	9.7	9.5
		2019	136	0	11	5	0	16	152	11%	9.8	10.5
Total Year 0 Survival								954	955	100%		
Total Year 1 Survival								677	979	69%		
Total Year 3 Survival								461	985	47%		
Total Year 5 Survival								325	986	33%		
Average Year 0 Height/Width											9.85	9.07
Average Year 1 Height/Width											9.26	9.14
Average Year 3 Height/Width											11.19	11.01
Average Year 5 Height/Width											13.42	12.98

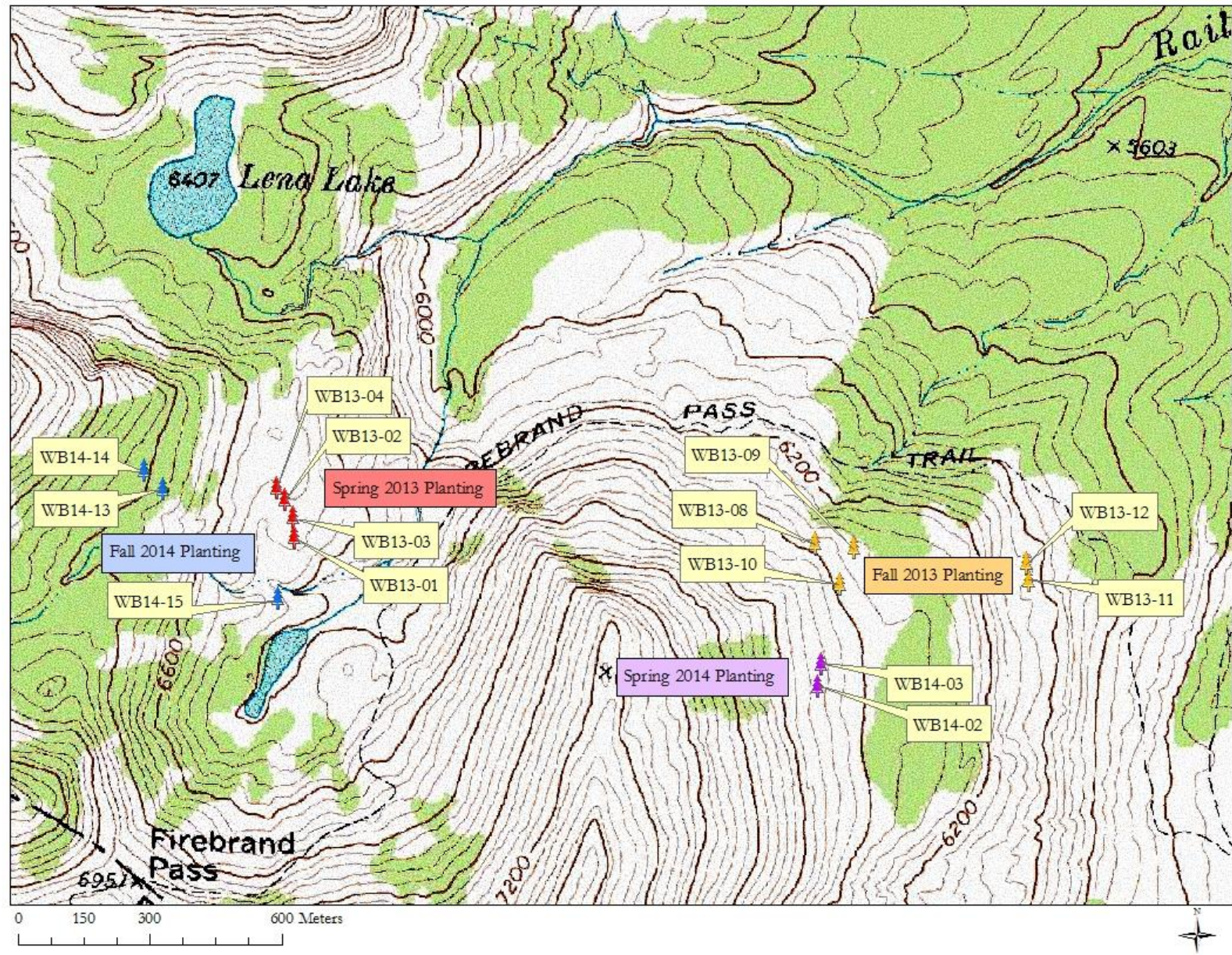
S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (WB Planted 2014 tab).

Table 24. Parkwide: Survival, Average Height and Width of all Whitebark Pine Seedlings Planted in the Park, 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%	20.3	14.5
Flattop Mtn. Fall 2001	2001	fall	2006	36%	19.9	17.3
Red Eagle - upper	2007	fall	2012	55%	27.8	26.9
Hole-in-the-Wall	2010	fall	2015	28%	11.9	11.1
Divide Creek - lower	2010	fall	2015	94%	19.4	20.7
Cobalt Lake	2011	late summer	2016	6%	14.8	11.0
Grinnell Picnic Area	2011	late summer	2016	40%	18.6	21.6
Divide Mountain	2012	fall	2017	55%	11.2	12.4
Firebrand Upper	2013	spring	2018	74%	13.8	14.0
Firebrand Lower	2013	fall	2018	53%	11.2	12.7
Numa	2013	fall	2018	36%	14.5	10.7
Divide Creek	2014	fall	2019	71%	19.7	17.3
Firebrand (lower)	2014	spring	2019	58%	16.5	16.9
Firebrand (upper)	2014	fall	2019	3%	11.5	13.3
Numa	2014	fall	2019	34%	14.1	10.8
Scenic Point (upper)	2014	spring	2019	22%	11.9	10.6
Spot	2014	spring	2019	6%	10.5	11.5
White Calf	2014	fall	2019	11%	9.8	10.5
Average 5- year-old-trees				40%	15.4	14.6

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

Figure 22. Firebrand Pass Trail: Whitebark Pine Seedling Monitoring Plots Established in 2013 - 2014.



b. Upper Firebrand Pass Trail (Fall)

The upper Firebrand Pass area was planted for the second time in the fall of 2014, east of the 2013 planting site. On September 24, a total of 569 seedlings were planted. Three monitoring plots were installed (Figure 22), tracking 159 trees or 23% of planted seedlings.

In 2019, five years after planting, only 3% of seedlings are still alive in monitoring plots (Table 23). Only four trees remain, but no trees have died over the past two years. All trees were dead in the two upper-most plots by 2017. Exposed, gravelly and dry conditions likely contributed to poor survival in those plots. Additionally, planting was followed by a warm dry fall, conditions which persisted throughout the winter, spring and subsequent summer. Average size of surviving seedlings were larger than average for the 2014 plantings, and have grown quite a bit over the past two years (Table 23).

Until recently, the thought was that spring plantings have not fared quite as well as fall plantings. This was mainly concluded from results from just a few sites. At Flattop Mountain, fall survivorship of whitebark pine seedlings planted in 2001 was slightly higher (by 8%) than in spring after 15 years (Table 24). More dramatically, survival in limber pine seedlings planted in the fall of 2013 at Spot Mountain was 40% higher than spring survival after one year. Recently, this trend has seen a reversal in some cases, with several sites supporting higher survival in spring plantings than fall plantings in the same year. At the Firebrand Pass area, seedlings planted in spring of 2014 had a 55% higher survival rate than fall plantings from 2014 five years after planting. This difference may reflect different environmental parameters at each planting site, since the spring planting site was located at a lower elevation on a bench while the fall planting site was at higher elevation on a slope in open gravelly soil, but planting season may also have played a roll. Averaging survival of all greater than one-year-old whitebark pine seedlings monitored in restoration projects across the Park after the latest monitoring event, spring plantings now average higher survival than fall plantings. Trees planted in the spring averaged 49% overall survival compared to 40% survival of fall plantings (Table 24). Many more whitebark pine plantings have taken place in the fall, however (18 in the fall vs. 9 in the spring). It is worth continuing to monitor spring versus fall plantings to ascertain whether a clearer trend emerges. However, it seems that being prudent about planting in areas where environmental parameters are favorable and under good climate trends is probably more important than assuming that one season is always favorable over another for planting.

iii. Numa Lookout (Fall)

In the fall of 2014, whitebark pine seedlings were planted for the second time in the Numa Lookout area. Approximately 710 trees were planted on September 16, 2014. Seedlings were planted below the lookout and mostly below the 2013 planting area at elevations around 6,870 feet (Figure 23). Seedlings were also planted on a bench on the north side of the lookout on the ridge towards Numa Peak at elevations ranging from 6,710 to 6,740 feet. This site has not burned.

Four monitoring plots were established in 2014: two plots south of the lookout below the 2013 plantings and two plots on the bench past and to the north of the lookout. Plots encompassed 208 trees, tracking 29% of seedlings planted in 2014. At the time of planting, all seedlings were alive in monitoring plots with 90% rated in good condition.

Survival five years after planting was 34% (Table 23). This survival just about average for the 2014 whitebark plantings, and slightly below the 40% average for all five-year post planting whitebark pine seedlings in the Park (Table 24). Conditions at the time of and following planting were not favorable. It was unseasonably warm and dry at the time of planting, followed by several very warm days and an extended “Indian summer” through much of the month of October (Appendix A). Generally, whitebark pine seedlings have not survived as well under these types of weather conditions. Additionally, 10% of the trees were rated “fair” or “almost dead” at the time of planting, indicating that future survival may drop. Another factor that may play into survival is that several relatively new planters were used for this project. Experienced planters tend to have developed a better eye for favorable microsite conditions, as well as have better planting skills.

Seedlings planted at Numa in the fall of 2014 were slightly taller and thinner than average for all five-year-old whitebark pine seedlings planted in the Park (Table 24). While seedlings have grown in the past two years, growth continues to be slow, with only a 1.3 cm average increase in height and a 0.7 cm average increase in width.

iv. Scenic Point (Upper, Spring)

Scenic Point is one of three sites that was planted with whitebark pine for the first time in 2014. The Scenic Point planting site is located southeast and downslope from Scenic Point proper (Figure 24). Historically, this area supported one of the larger whitebark pine stands in the Park. Although within a swath of dead trees, this 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 burned.

In June of 2014, approximately 802 whitebark pine seedlings were planted in the Scenic Point area on a southeast facing slope. This site was deemed a very good planting site by the revegetation crew due to good, deep soil conditions. In July of 2014, two monitoring plots were established, encompassing 188 trees or 23% of planted seedlings. At the time that monitoring plots were established, approximately one month after planting, one tree was dead, but all the rest were considered in good health.

Overall survival at this site was 22% five years after planting, below average for all whitebark pine seedlings monitored in the Park five years after planting as well as for all whitebark seedlings planted in 2014 (Tables 23 and 24). Survival at this site has substantially decreased at each monitoring event. Surviving seedlings continued to grow, but remain shorter than average for trees planted in 2014 and for all five-year-old whitebark pine planted in the Park. This likely reflects a harsh site and short growing season at one of the highest elevation, open scree, unburned planting sites in the Park.

v. Spot Mountain (Spring)

Spot Mountain was one of three new sites chosen for planting whitebark pine in 2014. It is located on the eastern margin of the park and supported one of the larger limber pine stands in Glacier National Park before it diminished due to blister rust. Most surviving trees at this site are limber pine, but whitebark pine also exists sparingly in this stand. Ironically, the largest living whitebark pine in the area exists on a bench below and at lower elevation than the limber pine stand. This site has not burned.

In June of 2014, approximately 416 whitebark pine seedlings were planted on the lower flank of Spot Mountain on an east-facing slope. Since the largest surviving whitebark pine plus tree is located nearby, at lower elevation than most of the limber pine, whitebark pine seedlings were planted nearby. A single monitoring plot was established in July of 2014, capturing 36 trees or 9% of planted seedlings (Figure 25). Almost all trees were in good health at the time of plot establishment, except for one tree that was almost dead.

There was another substantial decrease in survival in this plot from 2017 to 2019. Survival at five years after planting was a mere 6%, down from 33% from two years prior and 75% from four years prior. Only two trees remain and are only in fair condition (Table 23). Survival at Spot Mountain is well below average for all sites planted in 2014 as well as for all projects monitored at five years post planting (Tables 23 and 24). This site is unburned, and at relatively low elevation, in a fairly open area with few existing microsites and little material from which to build microsites during planting. Likely many seedlings died from heat and drought stress.

Surviving seedlings grew at a slightly faster rate than during the previous two-year period, although they are smaller than average for seedlings planted in 2014 and for all five-year-old whitebark pine seedlings in the Park (Tables 23 and 24). Again, this may reflect the harshness of the site. The whitebark planting site at Spot Mountain is an open habitat, where little shelter is found naturally or from microsites.

Figure 23. Numa Lookout: Whitebark Pine Seedling Monitoring Plots, Planted in 2014 - 2015.

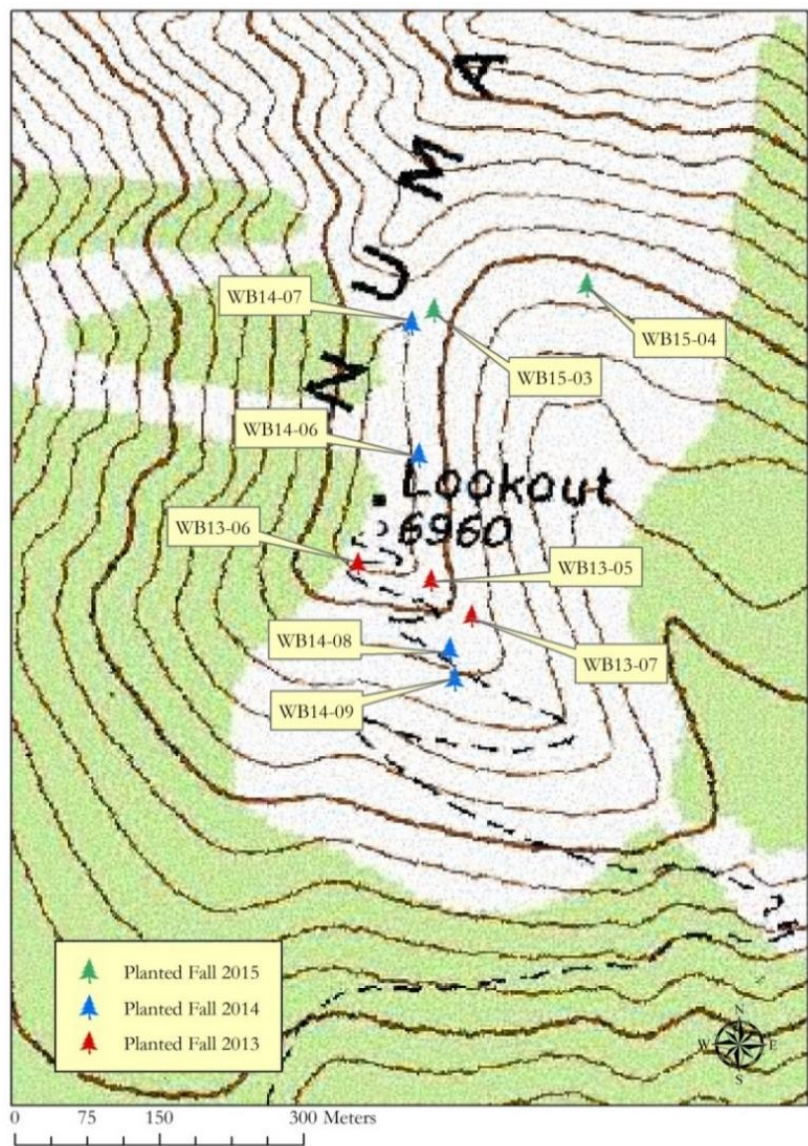


Figure 24. Scenic Point: Whitebark Pine Seedling Monitoring Plots, Planted in 2013 - 2015.

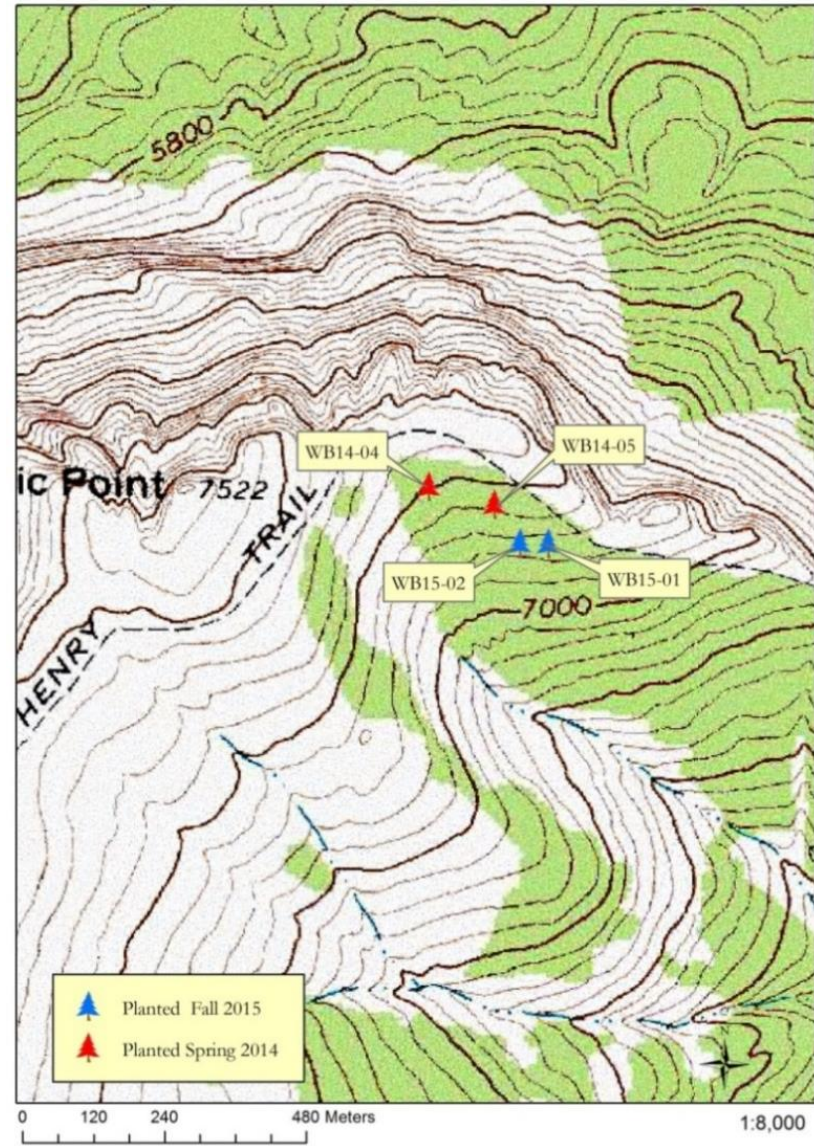


Figure 25. Spot Mountain: Whitebark Pine Seedling Monitoring Plots, Plots Planted in 2014.

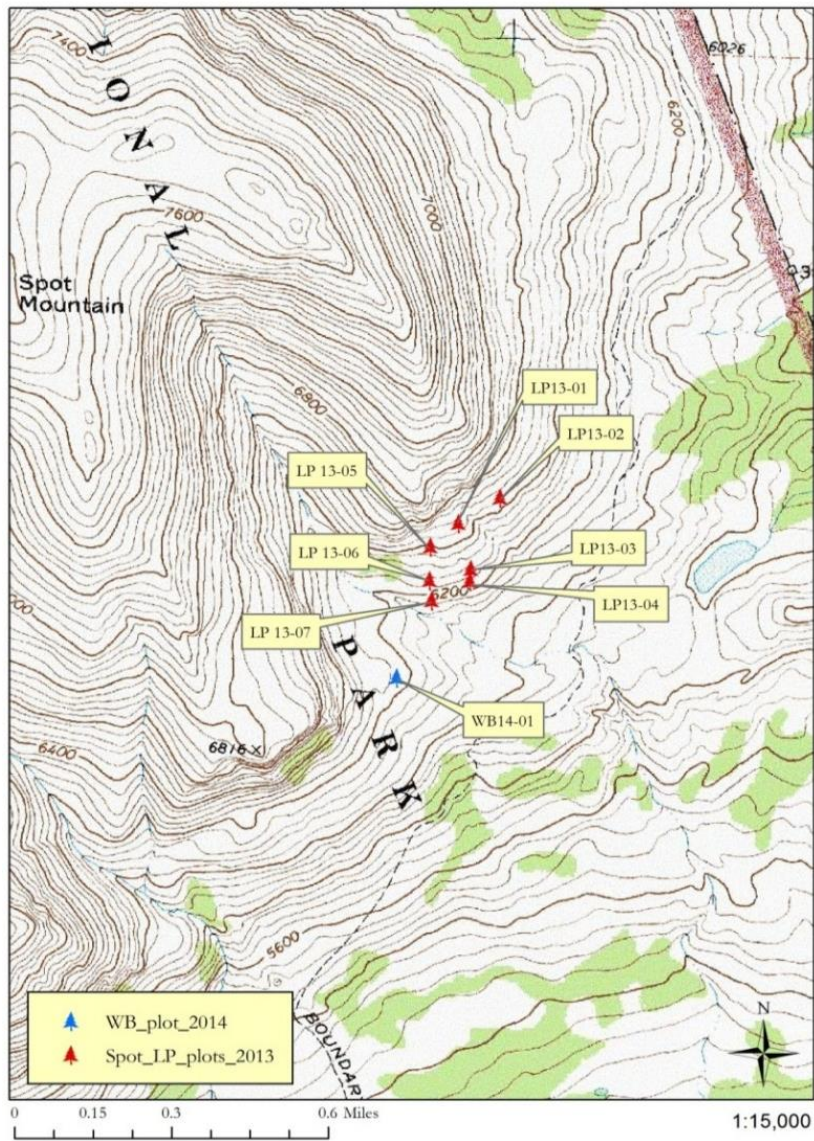
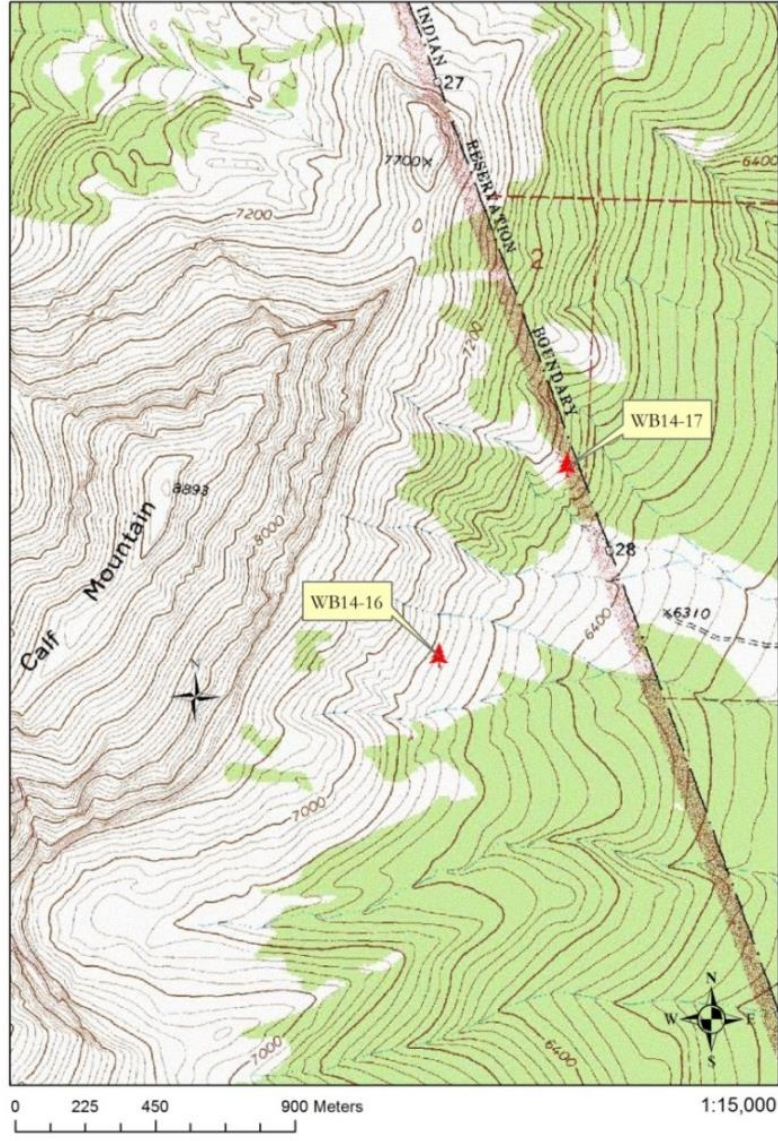


Figure 26. White Calf Mountain: Whitebark Pine Seedling Monitoring Plots Planted in 2013-2014.



b. White Calf Mountain (Fall)

White Calf Mountain was the third of three new whitebark pine planting sites for 2014. This site is located along the eastern margin of the Park about 7 miles south of St. Mary and just south of Divide Mountain. It also historically sustained one of the larger whitebark pine stands in Glacier National Park, which is now mostly dead. This site has not recently burned.

In October of 2014, this area was planted with approximately 788 whitebark pine seedlings on southeast facing slopes on the lower flanks of White Calf Mountain. Two monitoring plots were set up two days after planting in 2014 (Figure 26). Plots captured 146 trees or 19% of planted seedlings. At the time of planting, all trees were alive and only one tree was considered in fair condition. All other trees were considered healthy.

Similar to Spot Mountain, seedlings in monitoring plots at White Calf also has experienced a substantial decrease in survival between 2015 and 2019. Survivorship decreased from 62% in 2015 to 31% in 2017, to 11% in 2019, five years after planting (Table 23). While survival is low in both plots at this site, there is a large discrepancy among environmental conditions at both plots, although both seem vulnerable to heat stress. Plot 16, located further south, was planted in an open area with high low-growing vegetation dominated by kinnikinnick and grasses, with few microsites available for planted seedlings. Survival was much higher at this plot one year after planting, but five years after planting is only slightly higher, at 13%. Plot 17, on the other hand, is within short-stature trees with light ground vegetative cover, and is dominated by scree, which may not be able to hold much soil moisture. Survival at this plot was slightly lower at five years after planting, at 8%. It is interesting to note that these seedlings were planted under cooler conditions than most other plantings in 2014, as well as later in the season. While the trees had a higher likelihood of being able to go directly into dormancy, the subsequent winter was warmer and drier than usual, followed by a hot, dry spring and summer, which may have counteracted these benefits.

Seedlings have not grown much in height at this site since 2015, and are quite a bit smaller than average for seedlings planted in 2014 as well as compared to overall three-year-old seedlings planted in the Park (Tables 23 and 24). Surviving trees are filling out in width a bit more, however, increasing an average of 1 cm in width over the course of the past two years.

c. Three-Year-Old Plantings

Whitebark pine seedlings were planted at six sites in 2016: Dead Horse Point, Goat Mountain, Golden Staircase, Upper Otokomi, Lower Otokomi and Upper Nyack (Figure 27). In total, 1,750 trees were planted, including 907 trees in the spring and 1,156 trees in the fall.

Five of the six plantings were within the burn perimeter of the Reynolds Creek Fire of 2015, whereas the Upper Nyack planting took place within the Thompson Fire perimeter. Care was taken to find suitable planting sites within the burn that previously supported whitebark pine populations. Several sites had scattered live whitebark pine trees nearby. Planting sites were established in areas that provided protection, good soil, microsites, and good planting conditions. All whitebark pine seedlings planted in 2016 were planted within a burn perimeter, and none were inoculated with an ectomycorrhizal slurry.

Monitoring plots were established shortly after planting at five of the six sites. Inclement weather deterred installation of plots after planting at Upper Nyack in 2016. Plans were in place to establish plots in the fall of 2017, but had to be cancelled due to temporary closure of the backcountry for fire danger and subsequent inclement weather. Since monitoring plots have never been established at Upper Nyack, this area is not included in the results below.

A total of 15% of planted seedlings from 2016 were captured in monitoring plots. At the time of planting, 98% of all monitored seedlings were rated as “good”.

Three years after planting, survival across all monitoring areas averaged 69% (Table 25). The range of survival was 43% to 85%. This is a notable decrease from first year survival rates, which averaged 96%. First year monitoring took place before extreme heat waves and “flash droughts” of both 2017 and 2018. Likely this extreme weather took its toll on newly establishing seedlings. However, this three year old survival rate is well above the average three year old survival parkwide, which is 54% (Table 26). Often, survival rates after two years can be predictive of future success, so these plantings may be poised to do well in the future, depending on the weather and other environmental factors.

Figure 27. Whitebark Pine Monitoring Plots Installed and Planted in 2016.

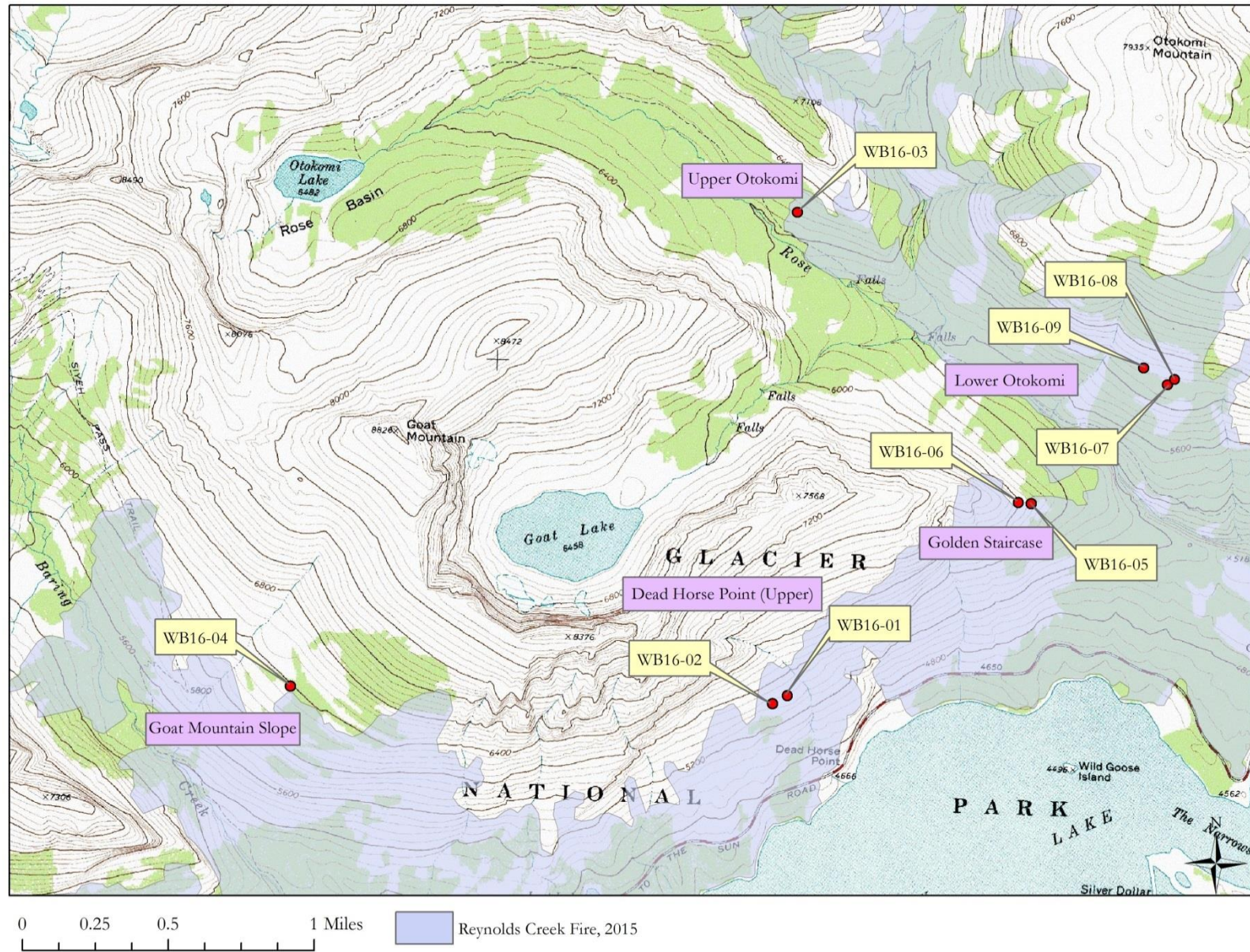


Table 25. Whitebark Pine Seedlings Planted in 2016: Health, Survival and Size, 2016-2019.

<i>Site</i>	<i>Season Planted</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>
Dead Horse Point (Upper)	spring	2016	0	0	5	20	25	25	100%	10.6	10.9
		2017	6	0	5	43	48	54	89%	11.7	12.3
		2019	31	0	1	22	23	54	43%	15.1	18.8
Goat Mountain Slope	spring	2016	0	0	0	34	34	34	100%	10.4	11.3
		2017	2	0	0	32	32	34	94%	13.5	14.1
		2019	13	0	5	16	21	34	62%	17.3	18.1
Golden Staircase (High)	spring	2016	0	0	2	57	59	59	100%	10.0	10.5
		2017	0	1	8	50	59	59	100%	11.9	12.9
		2019	17	0	1	41	42	59	71%	15.5	16.8
Otokomi (Upper)	spring	2016	0	0	0	64	64	64	100%	10.5	10.5
		2017	3	2	1	59	62	65	95%	12.8	12.5
		2019	10	0	7	48	55	65	85%	21.2	19.7
Otokomi (Lower)	fall	2016	0	0	0	98	98	98	100%	11.4	11.3
		2017	3	7	13	77	97	100	97%	11.6	12.5
		2019	25	2	7	67	76	101	75%	16.6	18.0
Total Year 0			0	0	7	273	280	280	100%		
Total Year 1			14	10	27	261	298	312	96%		
Total Year 3			96	2	21	194	217	313	69%		
Average Year 0 Height/Width										10.6	10.9
Average Year 1 Height/Width										12.3	12.9
Average Year 3 Height/Width										17.2	18.3

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (WB Planted 2016 tab).

i. Dead Horse Point

In the spring of 2016, an estimated 227 seedlings were planted on an upper bench of the Dead Horse Point area (Figure 27). Fifty two trees, 23% of planted seedlings, were captured in two monitoring plots. All trees were alive and most (80%) were in good condition at the time of planting; 20% were in fair condition.

Three years after planting, survival had dropped to 43%, the lowest of all 2016 plantings. This site also had the lowest survival one year after planting, at 89%. Surviving seedlings, are shorter than average, but are growing in width, and are no longer the smallest trees of this cohort (Table 25).

This is the lowest elevation whitebark pine planting site in the Park (Table 14), which may induce environmental conditions that are less favorable than other higher, potentially cooler sites. While there are standing snags for shade and protection at this site, they are widely spaced, and open scree dominates the understory, perhaps creating hotter and drier conditions than favorable, especially at this low-elevation location.

ii. Goat Mountain Slope

An estimated 145 seedlings were planted in the spring of 2016 on the slope of Goat Mountain, at the edge of a mosaicked burn that did not seem to have burned excessively hot (Figure 27). Unburned areas surround the planting site. One monitoring plot was established here, encompassing 34 trees, 23% of planted seedlings. All trees were alive and all were in good condition at the time of planting.

Three years after planting, 62% of seedlings have survived, slightly below average for the 2016 plantings. This was a fairly large drop from 94% survival one year after planting. Seedlings were about average in size, after being the largest, on average, in 2017 (Table 25). Several factors may benefit seedlings planted in this area, such as soil that did not burn excessively hot and surrounding islands of live trees for protection, so it is unknown why they are not faring as well as other sites.

iii. Golden Staircase (Upper)

In the spring of 2016, an estimated 294 whitebark pine seedlings were planted on an upper bench of the Golden Staircase area (Figure 27). Parts of this section of the fire perimeter appeared to burn relatively severely, but the planting site is located within a mosaic, and is surrounded by small areas that have not burned. Soil seemed light and dry. Two monitoring plots were established shortly after planting, including 59 trees, or 20% of planted seedlings. All trees were alive at initial monitoring, and all but two trees were in good condition.

Three years after planting, 71% of seedlings were alive, near average for the seedlings planted in 2016 (Table 25). There was 100% survival at this site the first year after planting. Seedlings were smaller than average, which may reflect that this is the highest elevation site from that planting year, perhaps providing fewer optimal growing days. The higher elevation of this site, compared to other whitebark planting sites as well as the limber pine planting site lower on the same slope, may prove beneficial in the long run, with slightly cooler temperatures. Standing snags at this site were small and dispersed, which did not seem to offer a lot of protection to developing seedlings. The soil also was light and dry.

iv. Otokomi (Upper & Lower)

Whitebark pine seedlings were planted in two widely separated areas of Otokomi Mountain in 2016 (Figure 27). In the spring, an estimated 241 seedlings were planted within burned forest on a relatively flat slope. It should be noted that although this site is termed “lower” Otokomi, the elevation of planting sites is nearly as high as the upper site, but is accessed lower on the Otokomi trail, before a long off-trail hike. Shortly after planting, three monitoring plots were established at the “lower” site, encompassing 98 trees, 24% of planted seedlings. All were alive and healthy at the time of initial monitoring.

In the fall of 2016, an estimated 406 seedlings were planted at the “upper” site, accessed from the upper part of the Otokomi Lake trail, on the edge of a burn. This planting area was on a steeper slope within

a burned forest, at the edge of a fire mosaic. One monitoring plot was installed, including 65 trees, 27% of fall-planted seedlings in the area. All trees were alive and healthy at the time of initial monitoring.

Three years after planting, both sites have high survival, at 75% and 85%, for the lower and upper sites, respectively (Table 25). One year after planting, survival was 97% and 95% in these plots, respectively. The “lower” site had more trees that were in poor health at that time. The discrepancy between these sites, although relatively small, isn’t inherently obvious. The “upper” site may have a little less exposure, including a single plot with a southwest aspect. The “lower” site encompasses three plots, with aspects south to southwest.

The spring-planted trees (the “upper” planting), were larger than average for all whitebark pine trees planted in 2016, while the fall-planted trees in the “lower” planting continued to be smaller than average third year trees of this cohort.

Table 26. Parkwide: Survival, Average Height and Width of all Whitebark Pine Seedlings Planted in the Park, Three Years After Planting.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>% Survival</i>	<i>Year 3</i>	
					<i>Height</i>	<i>Width</i>
Flattop Mtn. Fall 2002	2002	fall	2005	48%	*	*
Red Eagle - upper	2007	fall	2010	57%	15.9	17.6
Divide Creek - lower	2010	fall	2013	94%	12.4	14.5
Grinnell Picnic Area	2011	late summer	2014	40%	12.8	15.8
Cobalt Lake	2011	late summer	2014	10%	13.0	11.3
Divide Mountain	2012	fall	2015	59%	10.0	10.5
Firebrand (upper)	2013	spring	2016	81%	10.6	10.4
Firebrand (lower)	2013	fall	2016	61%	9.0	9.4
Numa	2013	fall	2016	87%	12.2	9.4
Divide Creek	2014	fall	2017	75%	14.6	14.6
Firebrand (lower)	2014	spring	2017	66%	12.9	13.4
Firebrand (upper)	2014	fall	2017	3%	9.3	10.0
Numa	2014	fall	2017	50%	12.8	10.1
Scenic Point (upper)	2014	spring	2017	53%	9.6	9.9
Spot	2014	spring	2017	33%	9.5	9.6
Whitetail	2014	fall	2017	31%	9.7	9.5
Numa	2015	fall	2018	15%	9.0	8.9
Scenic Point (upper)	2015	fall	2018	32%	10.6	10.2
Dead Horse Point (upper)	2016	spring	2019	43%	15.1	18.8
Goat Mountain Slope	2016	spring	2019	62%	17.3	18.1
Golden Staircase (high)	2016	spring	2019	71%	15.5	16.8
Otokomi (upper)	2016	spring	2019	85%	21.2	19.7
Otokomi (lower)	2016	fall	2019	75%	16.6	18.0
Average 3- year-old-trees				58%	12.7	13.0
Average spring only				65%	11.8	13.1
Average fall only				59%	11.4	11.3

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

d. One-Year-Old Plantings (fall 2018)

Whitebark pine seedlings were planted at two sites in 2018: Sperry Chalet and Mount Brown Lookout (Figures 28, 29). In total, 1,007 trees were planted, all in the fall.

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. No whitebark pine seedlings planted in 2018 were inoculated with an ectomycorrhizal slurry.

Plots ranged from 7,420 to 7,460 feet in elevation. 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. 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.

Seedlings fared well at both sites one year after planting, with 99% and 92% survival at Sperry Chalet and Mount Brown Lookout, respectively (Table 27). The growing season of 2019, which was cooler and supplied intermittent rain, provided better conditions for establishing seedlings than has been experienced the past two summers, which were exceptionally hot and dry (Appendix A). Quite a few trees were rated fair and a few were rated almost dead at each site, however, so future survival may be lower.

Plots at both sites are scheduled for revisiting in 2021, at three years post-planting.

Figure 28. Whitebark Pine Seedling Monitoring Plots Established at Sperry Chalet, 2018.



Figure 29. Whitebark Pine Seedling Monitoring Plots Established at Mount Brown Lookout, 2018.

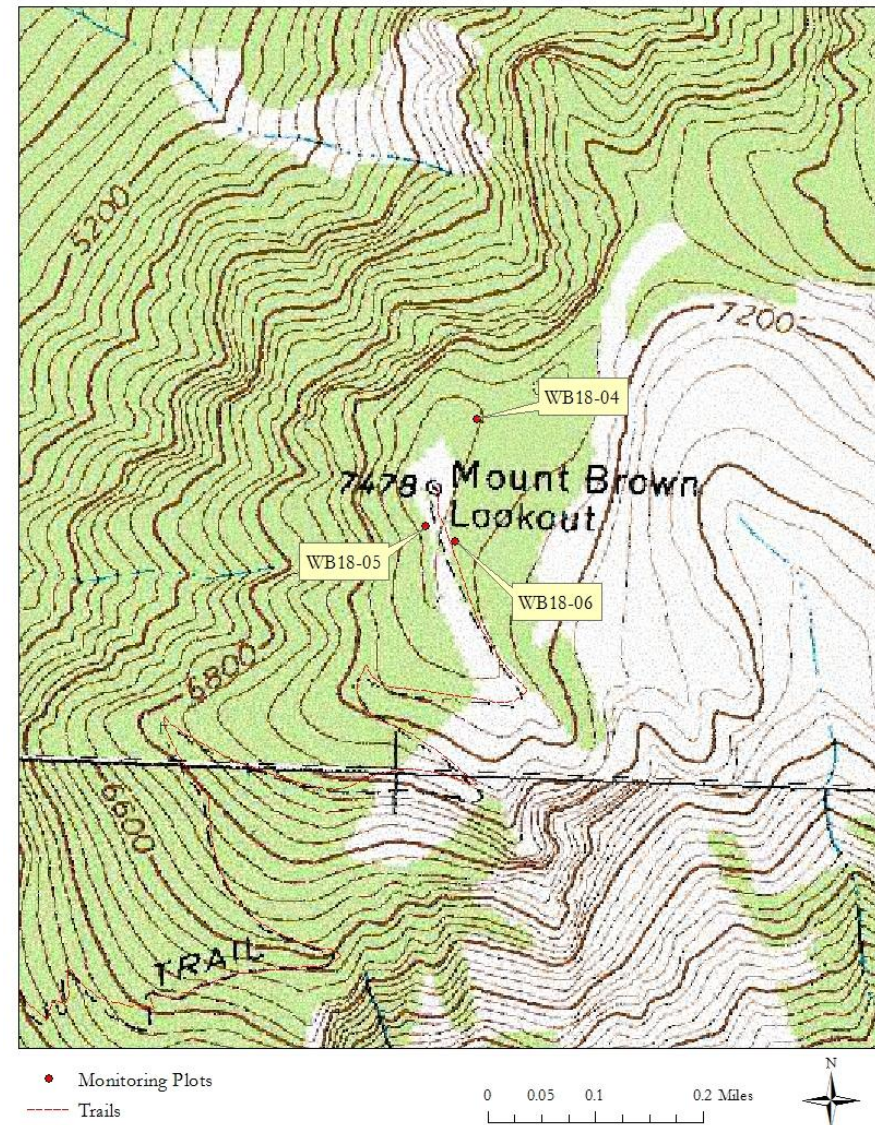


Table 27. Survival and Average Height and Width of Whitebark Pine Seedlings Planted in 2018.

<i>Site</i>	<i>Season Planted</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>
Mount Brown Lookout	fall	2018	0	0	0	110	110	110	100%	15.1	11.0
		2019	9	2	31	68	101	110	92%	14.2	11.2
Sperry Chalet	fall	2018	0	0	0	121	121	121	100%	13.3	10.8
		2019	1	4	11	106	121	122	99%	12.5	12.6
Total Year 0 Survival							231	231	100%		
Total Year 1 Survival							222	232	96%		
Ave. Year 0 Height/Width										14.2	10.9
Ave. Year 1 Height/Width										13.4	11.9

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

e. *New Plantings (fall 2019)*

Whitebark pine seedlings were only planted at one site in 2018, near Mount Brown Lookout (Figure 30). In total, 580 trees were planted in the fall, within the burn perimeter of the Sprague Fire of 2017. Suitable planting sites were chosen within the burn that were near areas that previously supported whitebark pine populations, in locales that provided protection, good soil, microsites, and good planting conditions.

A wider range of elevations for planting sites was utilized in 2019 than in 2018. Plots ranged from 7,450 feet down to 6,785 feet in 2019, while plots ranged from 7,460 to 7,420 feet in 2018. Parent tree (seed source) for planted seedlings differed among planting areas. Seed came from one individual parent tree from each of the following sites: Preston Park, Rising Wolf and Scenic Point (Table 28).

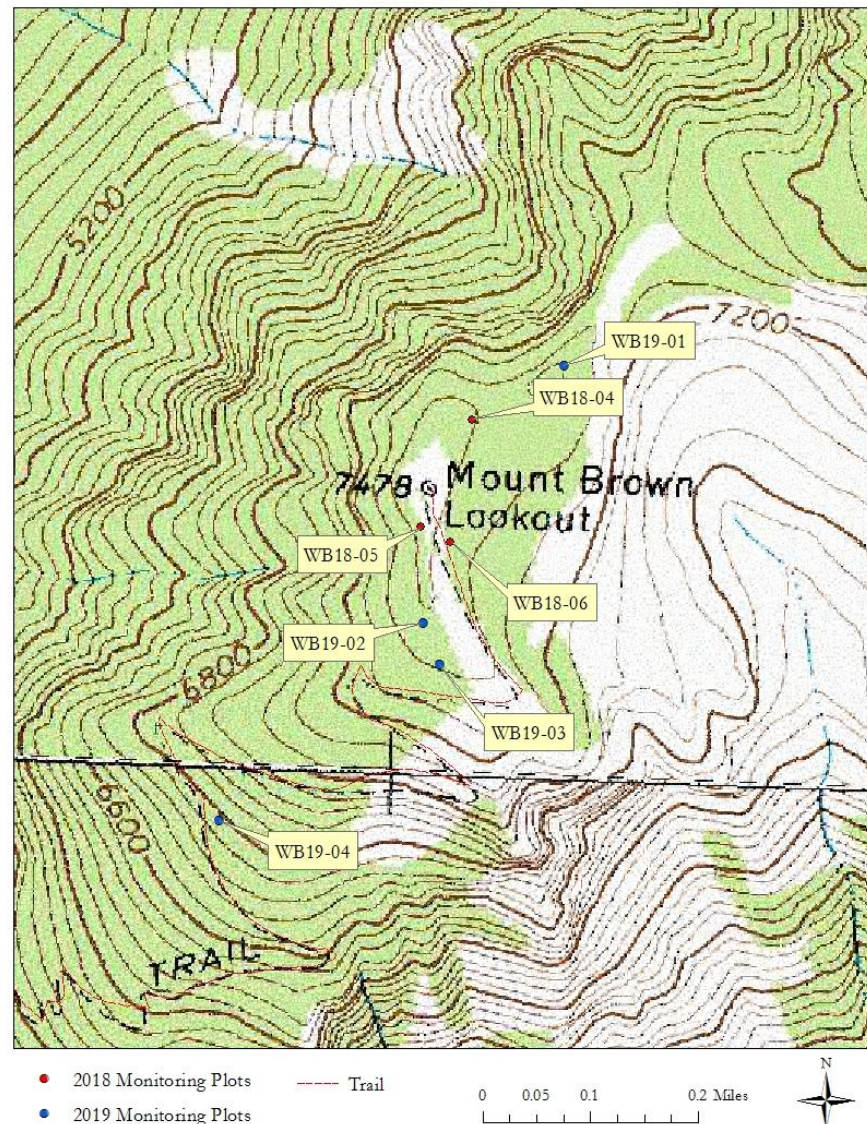
Monitoring plots were established shortly after planting at both of the sites. A total of 20% of planted seedlings were captured in monitoring plots. At the time of planting, 100% of all monitored seedlings were rated as “good” in all plots (Table 28). No whitebark pine seedlings planted in 2019 were inoculated with ectomycorrhizal slurry. Plots at both sites are scheduled for revisiting in 2020.

Table 28. Mount Brown: Survival and Average Height and Width of Whitebark Pine Seedlings Planted in 2019.

<i>Plot</i>	<i>Parent Tree</i>	<i>Plot Elevation</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>
WB19-01	Rising Wolf (WB07-39)	7,450	2019	0	0	0	34	34	34	100%	9.2	10.4
WB19-02	Preston Park (WB07-05)	7,410	2019	0	0	0	21	21	21	100%	9.0	9.5
WB19-03	Scenic Point (WB07-51)	7,350	2019	0	0	0	29	29	29	100%	9.4	11.0
WB19-04	Scenic Point (WB07-51)	6,785	2019	0	0	0	13	13	13	100%	8.1	10.4
Total/Average							97	97	97	100%	9.0	10.2

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (WB Planted 2019 tab).

Figure 30. Whitebark Pine Seedling Monitoring Plots Established at Mount Brown Lookout, 2018 - 2019.



D. CONCLUSIONS AND RECOMMENDATIONS

1. *Limber Pine*

Overall survival of all monitored limber pine seedlings to date in the Park is 21%. Despite this low rate, limber pine survival has generally improved over time due to a number of factors. These likely include more favorable climatic conditions at opportune times, increased knowledge and skill, and recently being able to plant in burned areas.

Three year survival of limber pine seedlings monitored this year was 40%, well above the overall average. These trees have endured unfavorable conditions the first few years after planting, with extreme heat and drought the summers of 2017 and 2018. With more mild conditions over the summer of 2019, perhaps surviving trees will have gained a foothold, and if milder weather persists, survivorship may remain higher.

Information from Waterton Lakes National Park (WLNP) has proven to be 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, 2011). 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. 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. However, the most recent plantings have tended towards single trees per planting site. The correlation between number of trees per clump and survival is worth tracking.

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 2016, 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 that 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 were 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. At this point, results are inconclusive. Most of the recent limber pine plantings have taken place in the spring, and recent survival has been higher. These were also the first limber pine plantings to take advantage of burn sites as well as increased knowledge and experience, so it is difficult to make a correlation with planting season. The one site planted in the fall in 2016 had the highest survival of this cohort three years after planting, however. Overall, spring planting survival is higher than fall planting in

across the Park, but a disproportionate number of plantings have taken place in the spring, especially recently. More research is necessary to determine if there is a clear trend for planting season, but likely results are variable depending on conditions at the time of planting as well as the subsequent growing seasons, which is unpredictable.

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, 2015 and 2018. Increased rain and cooler temperatures from 2004 to 2014 and again in 2016 and 2019 may have contributed to higher survival rates during those time periods (Appendix A).

Climate change research on five-needled pines is still in its infancy but results from studies have documented the importance of soil moisture and lower soil surface temperature for the survival of limber pine (Moyes et al, 2013). 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 48%, versus 21% for limber pine. Traditionally, revegetation of whitebark pine seedlings has shown better progress than limber pine restoration. In the years from 2012 on, however, success in limber pine seedlings has been improving, especially now that burned habitat has been available and utilized.

Seedlings monitored this year have shown mixed success. Five year old plantings averaged lower survival than average for five year old plantings across the Park, but varied wildly. Survival at Divide Creek was the highest of any planting at the five year mark to date, at 71%, while upper Firebrand had the lowest at 3%. Three year survival of sites monitored this year was above average, which may reflect general overall success of whitebark pine planted in the Reynolds Creek burn.

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.

At this point, averaging survival across all sites by season, spring whitebark pine plantings show overall better success than fall plantings. However, nearly twice as many plantings have taken place in the fall, and there is extremely high variability among sites. 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. 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, unburned 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 good planting habitat for plantings.

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.
- Continue to assess spring vs. fall planting.
- 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; continue to record microsite aspect, and analyze results of past plantings where this has been recorded.
- 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.
- Continue to assess whether planting seedlings in groups of 3 to 5 is advantageous over planting single trees in a hole.
- 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 2020, only one limber pine monitoring site, Scenic Point plots planted in 2005, is scheduled to be revisited 15 years after planting (Table 29). Six whitebark pine planting sites are also due for monitoring. One twenty-year-old site is in line for monitoring. Grinnell Point, which was originally accessed by helicopter after the Grinnell Point Fire of 2000, was monitored on foot in 2015 for the first time since planting. Two ten-year-old sites are scheduled to be monitored: Hole-in-the-Wall and Lower Divide Creek. Two sites will be monitored at five years post-planting; Scenic Point and Numa Ridge, and one site, Mount Brown Lookout, will be monitored one year after planting.

In 2020, if climate cooperates, plans are to plant 500 whitebark pine seedlings. At this point, there are no plans to plant limber pine in 2020. Monitoring plots should be installed at planting areas to capture a targeted 20% of seedlings.

Table 29: Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	Monitored:	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DC01-01 to -04	Whitebark pine	Dutch Creek	2001											X (year 10)		
GP00-01 to -07	Whitebark pine	Grinnell Point	2000	X (year 0)						X (year 6)				X (year 10)		
FT01-01 to -27	Whitebark pine	Flattop	2001		X (year 0)	X (year 1)			X (year 4)	X (year 5)			X (year 8)		X (year 10)	
FT02-01 to -11	Whitebark pine	Flattop	2002			X (year 0)			X (year 3)	X (year 4)			X (year 7)		X (year 9)	
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		X (year 7) ALL DEAD			
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		X (year 7) ALL DEAD			
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 0)	X (year 1)	X (year 2)		X (year 4) 1 TREE LEFT		X (year 6)				X (year 10)
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP04-01 to -05	Limber pine	Baring Creek	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)	X (year 4)	X (year 5)		
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5)		
LP04-08	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5) ALL DEAD		
LP04-09	Limber pine	Sun Point	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5)		
LP04-10	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5) 1 TREE LEFT		
LP04-11	Limber pine	Dead Horse Point	2004					X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5) ALL DEAD		
LP05-01 to -06	Limber pine	Scenic Point	2005						X (year 0)	X (year 1)	X (year 2)	X (year 3)		X (year 5)		
LP06-02	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)	X (year 2)		X (year 3)		X (year 5)
LP06-01 & -03	Limber pine	Baring Creek	2006							X (year 0)	X (year 1)	X (year 2) ALL DEAD				
LP06-04	Limber pine	Dead Horse Point	2006							X (year 0)	X (year 1)	Not done: all dead but 1 missing	X (year 3) ALL DEAD			
WB06-01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006							X (year 0)		X (year 2)		X (year 5)		
WB07-01 to -09	Whitebark pine	Red Eagle (seedlings)	2007								X (year 0)	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 0)	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)

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
DC01-01 to -04	Whitebark pine	Dutch Creek	2001				X (year 15)					X (year 20)				
GP00-01 to -07	Whitebark pine	Grinnell Point	2000			X (year 15)					X (year 20)					X (year 25)
FT01-01 to -27	Whitebark pine	Flattop	2001				X (year 15)					X (year 20)				
FT02-01 to -11	Whitebark pine	Flattop	2002				X (year 14)					X (year 19)				
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					X (year 20) 1 TREE LEFT			
LP03-01	Limber pine	Two Med Camp Store	2003	X (year 10)				X (year 15)						X (year 20)		
LP04-01 to -05	Limber pine	Baring Creek	2004		X (year 10)					X (year 15) All dead or missing now					X (year 20)? All dead or missing	
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004		X (year 10)					X (year 15)					X (year 20)	
LP04-08	Limber pine	Sun Point	2004													
LP04-09	Limber pine	Sun Point	2004		X (year 10)					X (year 15) 1 missing tree left now					X (year 20)? 1 missing tree left	
LP04-10	Limber pine	Dead Horse Point	2004		X (year 10) 1 TREE LEFT					X (year 15) All dead now						
LP04-11	Limber pine	Dead Horse Point	2004													
LP05-01 to -06	Limber pine	Scenic Point	2005			X (year 10)					X (year 15)					X (year 20)
LP06-02	Limber pine	Baring Creek	2006				X (year 10)					X (year 15)				
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)					X (year 15)				
WB07-01 to -07 (-08 & -09)	Whitebark pine	Red Eagle (trees)	2007					X (year 10)					X (year 15)			
WBS07-04 & -05	Whitebark pine	Red Eagle (seeds)	2007					X (year 10)					X (year 15)			
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)				X (year 10)					X (year 15)
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 3)	X (year 4)		X (year 5)				X (year 10)					X (year 15)
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011		X (year 3)			X (year 5)				X (year 10)				
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 3)			X (year 5)				X (year 10)				
WB12-01 to -04	Whitebark pine	Divide Mountain	2012	X (year 1)	X (year 2)		X (year 3)		X (year 5)				X (year 10)			
LP12-01 to -02	Limber pine	Cutbank	2012	X (year 1)			X (year 3)		X (year 5)				X (year 10)			
LP12-03 and -11	Limber pine	Apikuni Flats	2012	X (year 1)			X (year 3)		X (year 5)				X (year 10)			
LP12-04 to -05	Limber pine	Rising Sun CG	2012	X (year 1)			X (year 3)		X (year 5)				X (year 10)			
LP12-06 to -09	Limber pine	Scenic Point	2012	X (year 1)			X (year 3)		X (year 5)				X (year 10)			
LP12-10	Limber pine	Many Glacier Well Area	2012	X (year 1)			X (year 3)		X (year 5)				X (year 10)			

Table 29, continued: Whitebark and Limber Pine Monitoring Schedule.

Plot(s)	Species	Location	Year Planted	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB13-05 to -07	Whitebark pine	Numa Ridge	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013	X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)		
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-06, -06A -07, -08, -09	Whitebark pine	Numa Ridge (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB14-13 -14 -15	Whitebark pine	Firebrand Pass upper (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5) 4 TREES LEFT					X (year 10)	
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014		X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)	
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015			X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015			X (year 0)	X (year 1)		X (year 3)		X (year 5)					X (year 10)
LP16-01	Limber pine	Dead Horse Point (lower)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-06	Limber pine	Dead Horse Point (upper)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-07	Limber pine	Otokomi (lower bench)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-08	Limber pine	Baring Creek	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
LP16-09 to -10	Limber pine	Lost Lake	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB16-03	Whitebark pine	Otokomi (upper)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB16-04	Whitebark pine	Goat Mountain Slope	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016				X (year 0)	X (year 1)		X (year 3)		X (year 5)				
WB18-01 to -03	Whitebark pine	Sperry Chalet	2108						X (year 0)	X (year 1)		X (year 3)		X (year 5)		
WB18-04 to -06	Whitebark pine	Mt. Brown Lookout	2108						X (year 0)	X (year 1)		X (year 3)		X (year 5)		
WB19-01 to -04	Whitebark pine	Mt. Brown Lookout	2019							X (year 0)	X (year 1)		X (year 3)		X (year 5)	

Plot(s)	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
WB13-01 to -04			X (year 15)					X (year 20)						
WB13-08 to -12			X (year 15)					X (year 20)						
WB13-05 to -07			X (year 15)					X (year 20)						
LP13-01 to -07			X (year 15)					X (year 20)						
WB14-01									X (year 20)					
WB14-02 to -03									X (year 20)					
WB14-04 to -05									X (year 20)					
WB14-06, -06A -07, -08, -09									X (year 20)					
WB14-10 to -12									X (year 20)					
WB14-13 -14 -15									X (year 20)					
WB14-16 to -17									X (year 20)					
WB15-01 to -02					X (year 15)					X (year 20)				
WB15-03 to -04					X (year 15)					X (year 20)				
LP16-01	X (year 10)					X (year 15)					X (year 20)			
LP16-02 to -03	X (year 10)					X (year 15)					X (year 20)			
LP16-04 to -05	X (year 10)					X (year 15)					X (year 20)			
LP16-06	X (year 10)					X (year 15)					X (year 20)			
LP16-07	X (year 10)					X (year 15)					X (year 20)			
LP16-08	X (year 10)					X (year 15)					X (year 20)			
LP16-09 to -10	X (year 10)					X (year 15)					X (year 20)			
WB16-01 to -02	X (year 10)					X (year 15)					X (year 20)			
WB16-03	X (year 10)					X (year 15)					X (year 20)			
WB16-04	X (year 10)					X (year 15)					X (year 20)			
WB16-05 to -06	X (year 10)					X (year 15)					X (year 20)			
WB16-07 to -09	X (year 10)					X (year 15)					X (year 20)			
WB18-01 to -03			X (year 10)					X (year 15)					X (year 20)	
WB18-04 to -06			X (year 10)					X (year 15)					X (year 20)	
WB19-01 to -04					X (year 10)				X (year 15)					X (year 20)

V. 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 31; Table 30). 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 31; Table 31). Cone information was collected on all trees except for one limber pine at Spot Mtn.

In 2019, 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 2018. 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 30. Numbers of whitebark pine plus trees monitored from 2007-2019.

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)		56	56	0	
2008	4 (TD)		60	41	19	
2009	13 (5 SP, 5 Numa, 3 PP)		73	53	20	
2010	9 (1 PP, 1 SP, 7 WC)		82	61	21	
2011	18 (4 WC, 2 TD, 3 FB, 9 OM*)		100	91	9	
2012			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	7 (3 OM; 4 KM)
2019	1 (1 OL)	1 (1 OL)	129	120	9	

*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

OM = Old Man Lake Trail

PP = Preston Park

RW = Rising Wolf

SB = Siyeh Bend

SP = Scenic Point

TD = Triple Divide Trail

Numa = Numa Lookout

Spot = Spot Mtn.

WC = White Calf

CL = Cobalt Lake

OL = Otokomi Lake

TM = Two Medicine

Table 31. Numbers of limber pine plus trees monitored from 2007-2019.

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)		2	2	0
2008	0		2	2	0
2009	0		2	1	1
2010	3 (1 DHP, 2 WC)		5	5	0
2011	1 (WC)		6	5	1
2012			6	4	2
2013	4 (Spot)		10	4	6
2014			10	3	7
2015	14 (8 MG; 1 Spot; 4 KM; 1 SP)	1 (DHP)	23	22	1
2016			23	23	0
2017			23	23	0
2018	3 (OM)		26	22	4
2019			26	24	2

DHP = Dead Horse Point

SP = Scenic Point

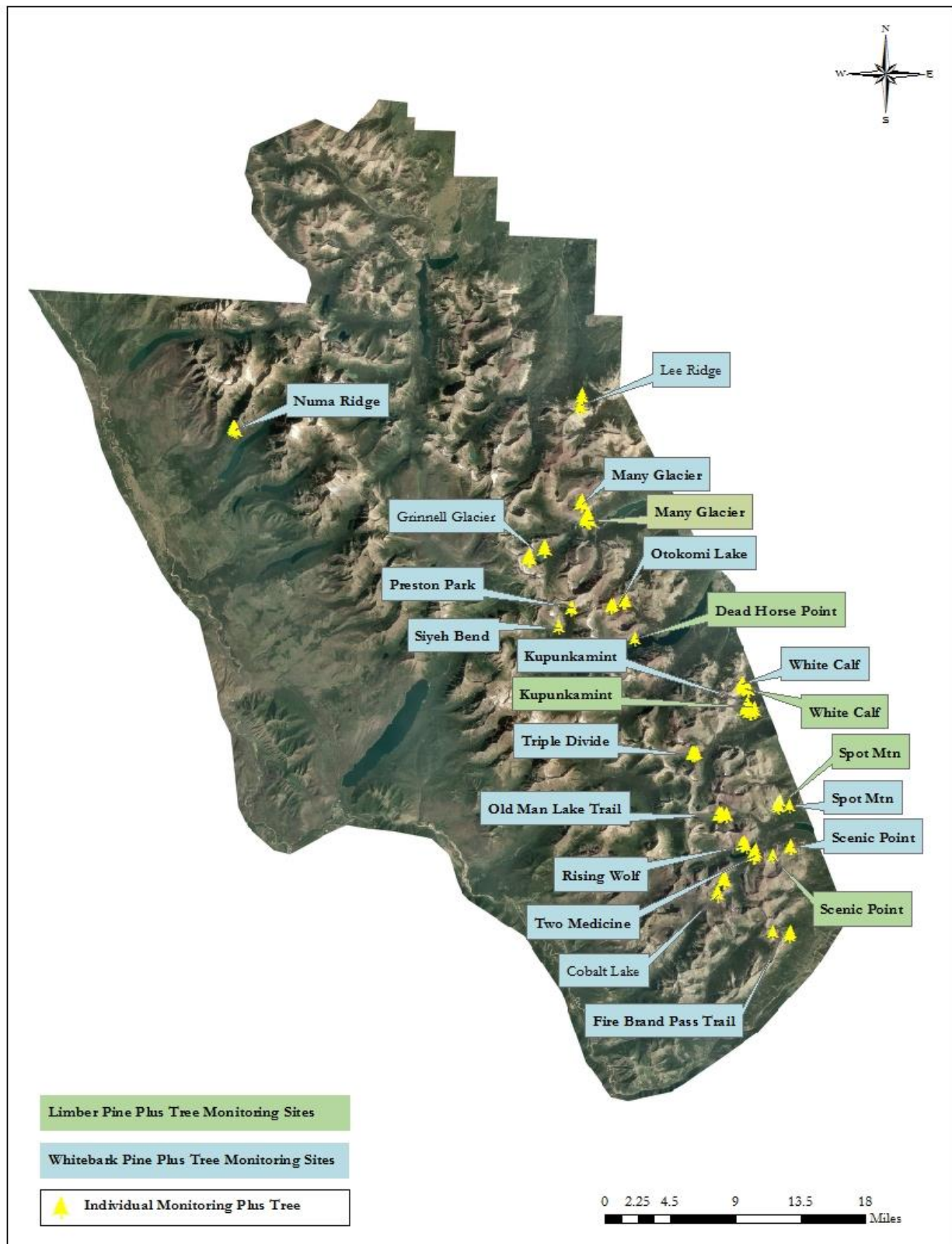
WC = White Calf

Spot = Spot Mt.

MG = Many Glacier

KM = Kupunkamint Mtn.

Figure 31. Location of Whitebark and Limber Pine Plus Trees.



C. RESULTS

In 2019, 120 of the existing 129 whitebark pine plus trees were monitored for cone production. Health of individual plus trees was not assessed this year. Overall, 2019 had the lowest number of trees with cones, at 27%, and the lowest average number of cones per tree (1) since the beginning of data collection, in 2007 (Figure 32; Tables 32 & 33).

After a banner whitebark pine cone year in 2018 (the second highest since the start of data collection), cone production dropped dramatically (Figure 32; Table 32 & 33). This also happened after the “mast” year, a synchronized, heavy reproductive event, in 2011. A potential trend may be unveiling, of mast years followed by a crash in cone production the following year. With only 12 years of data collection, and only two recorded mast years, it is difficult to ascertain whether this is a true trend, however. The periodicity of mast years followed by years of significant decline is also not clear, and likely is not totally predictable. While the data is beginning to show patterns, more data that spans a larger timeframe is needed to attempt to decipher overall trends of cone production, if it is possible. The one clear trend that appears to have emerged is a gradual build up to a mast cone production year, followed by a significant decline.

The average number of cones per tree was slightly less variable again this year, partly because it was so low. Cones were present in 8 of the 15 stands monitored, and the average number of cones per tree ranged from 0.2 cones to 5.5 cones (Table 33). Within a stand, cone production also varied from tree to tree, with most trees having no cones. In the past several years, trees at Kupunkamint Mt. have been the most reliable in terms of a good cone crop, and again averaged the highest average number of cones per tree in 2019, at 5.5 (Table 33). Plus trees along the Old Man Lake Trail had similar cone production as Kupunkamint this year, averaging 5.3 cones per tree, and Rising Wolf trees was similar at 5.3. All other sites averaged around 1 cone per tree or less, with all plus trees at seven sites having no visible cone production.

In 2019, cone trees averaged only a single cone per tree, which is the lowest average since cone data has been collected. This follows the highest mast year recorded so far. The subsequent drop in cone production may be a result of spent resources during a time when environmental conditions were unfavorable. Sala et al. (2012) determined that mast events in whitebark pine trees deplete stored nutrients. Additionally, the summers of 2017 and 2018 were exceptionally hot and dry, which may have further diminished trees’ ability to store resources in order to replenish cone production after high energy expenditure on reproduction the previous year.

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 in the ten year period from 1980-1990 (Morgan and Bunting 1990). In the 12 years since Glacier has taken data on cone production, two years that could be described as mast years have been observed. It appears that we may be on a cycle where cone production gradually increases for 2-4 years before a mast year followed by a crash in production (Figure 32), but trends are not totally clear. Data on the percent of trees with cones and average number of cones per tree generally follow similar patterns, although the rate of increase and decrease is generally 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 different. 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 2019. No new plus trees were added to the pool this year. Only four of the eight limber pine trees in the monitoring pool produced cones in 2019 (Figure 33; Table 35). The average number of cones per limber pine tree also dramatically declined this year at only 8. The previous year averaged 135 of cones per tree in which, this was by far the highest number of cones per tree since monitoring started in 2007. Similar to whitebark pine, limber pine cone production crashed this year after the largest mast year recorded the previous year. So far, it appears that there have been shorter time periods between high cone production years in limber pine, but 2018 may have been the only true mast year recorded. The pattern so far appears to be one low production year followed by one to three moderate cone production years. Trends are still being assessed for limber pine cone production given the small sample size and only twelve years of data.

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 and much higher in 2011. Data from 2012 showed a decline in cone production again, along with a lower average number of cones per tree. In 2013 and 2014, cone production increased again 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, but increased again in 2016 and remained relatively stable 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. A crash followed in 2019 with only 27% of trees producing cones and averaged only one cone per tree. While a longer-term data set is necessary to make better 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 32). Environmental conditions, such as extreme weather patterns, may alter or accentuate this pattern.

Limber pine appears to have a one to three year period of moderate cone production where the average number of cones per tree is higher followed by a one year dip in cone production (Figure 33). Prior to 2019, almost all individual limber pine trees consistently produced cones, but in 2019, both the number of trees producing cones and the average number of cones per tree crashed.

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 continue 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 5 years, GNP has added 30 trees to the whitebark pine plus tree monitoring pool and 17 trees to the limber pine plus tree monitoring pool (Table 36). 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.).

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 of our 25 plus trees that are in that program (Table 36). 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, at least 11 of GNP’s 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.

Additional whitebark and limber pine trees are being added to the genetics study for more information on new five-needle pine stands in the park, as the required 1,800 seeds per tree are collected. 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 2020 when Verbenone packets are attached to the trees. As part of creating a Whitebark and Limber Pine Management Plan, GNP staff need to continue discussion 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 32. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2019.

<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
Old Man Lake Trail	2018	12	12	n/a	n/a	n/a	n/a	11
	2019	12	12	n/a	n/a	n/a	n/a	0
	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
Otokomi Lake	2017	16	13	n/a	n/a	n/a	n/a	13
	2018	16	0	n/a	n/a	n/a	n/a	0
	2019	15	15	n/a	n/a	n/a	n/a	5
	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
Preston Park	2017	6	6	n/a	n/a	n/a	n/a	6
	2018	7	7	n/a	n/a	n/a	n/a	7
	2019	7	6	n/a	n/a	n/a	n/a	0
	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
Rising Wolf	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
	2019	24	24	n/a	n/a	n/a	n/a	0
	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
	2019	6	6	n/a	n/a	n/a	n/a	6

Table 32, continued. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2019.

<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
	2019	13	13	n/a	n/a	n/a	n/a	0
Siych 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
	2019	3	3	n/a	n/a	n/a	n/a	0
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
	2019	5	5	n/a	n/a	n/a	n/a	1
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
	2019	11	8	n/a	n/a	n/a	n/a	4
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
	2019	4	4	n/a	n/a	n/a	n/a	4

Table 32, continued. Whitebark Pine Plus Trees: Comparison of Health and Cone Production, 2007-2019.

<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
	2019	1	1	n/a	n/a	n/a	n/a	0
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
	2019	13	11	n/a	n/a	n/a	n/a	7
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
	2019	4	4	n/a	n/a	n/a	n/a	1
Cobalt Lake	2018	3	3	n/a	n/a	n/a	n/a	3
	2019	3	3	n/a	n/a	n/a	n/a	0
Grinnell Glacier Trail	2018	5	5	n/a	n/a	n/a	n/a	5
	2019	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
	2019	2	0	n/a	n/a	n/a	n/a	0
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
TOTAL 2019		128	105	n/a	n/a	n/a	n/a	28
% 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%
%2019				n/a	n/a	n/a	n/a	27%

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (trees tab)

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

	2007			2008			2009		
<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

	2010			2011			2012		
<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

	2013			2014			2015		
<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 33. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2019.

Table 33, continued. Whitebark Pine Plus Trees: Average Cones Per Tree, 2007 – 2019.

<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

<i>Site</i>	<i>2019</i>		
	<i># of Trees Monitored</i>	<i># of Cones</i>	<i>Ave. # of Cones/Tree</i>
Cobalt Lake	3	0	0
Fire Brand Pass Tr.	4	8	2
Grinnell Glacier Trail	5	6	1.2
Lee Ridge	0	0	n/a
Numa Lookout	12	0	0
Old Man Trail	15	63	4.2
Otokomi Lake	6	0	0
Preston Park	24	0	0
Rising Wolf	6	32	5.3
Scenic Point	13	0	0
Siyeh Bend	3	0	0
Spot Mtn.	1	0	0
Triple Divide	5	1	0.2
White Calf	8	4	0.5
Kupunkamint	11	60	5.5
Two Medicine	4	4	1.0
TOTAL	120	178	1

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (cone averages tab)

Figure 32. Trends in Whitebark Pine Cone Production 2007-2019.

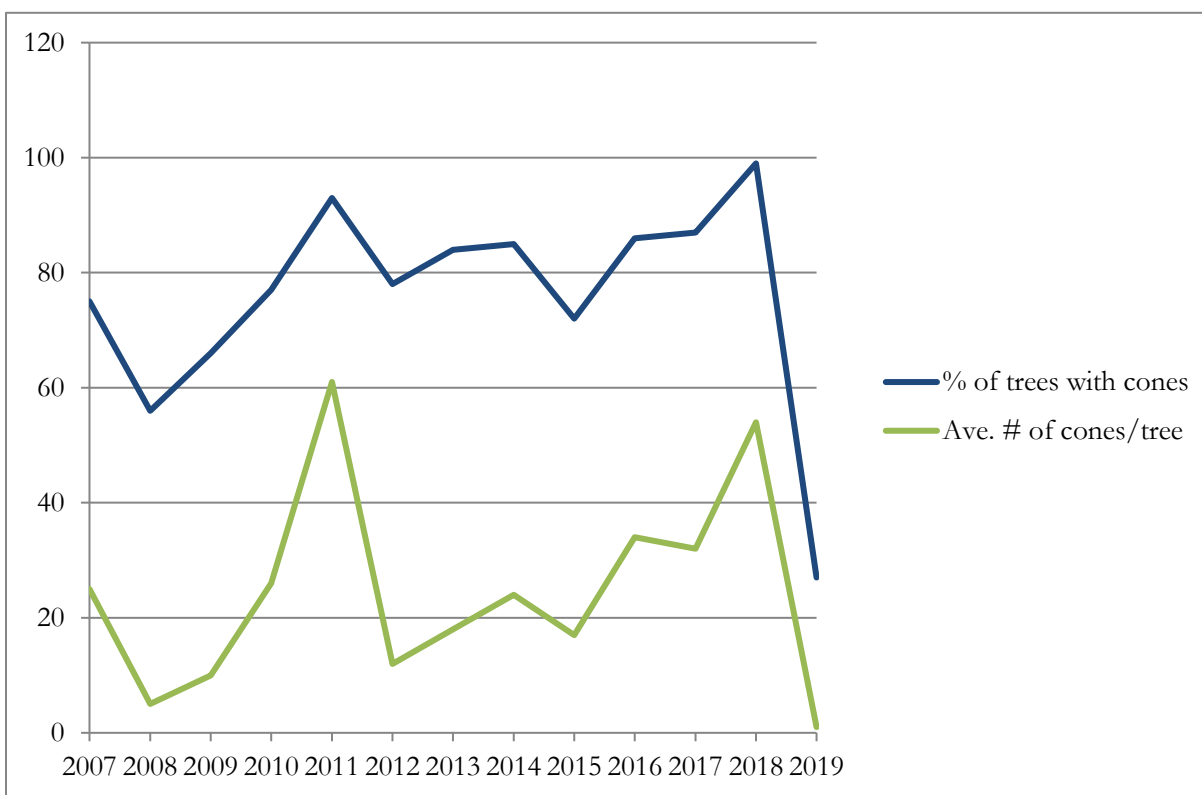


Table 34. Limber Pine Plus Trees: Health and Cone Production, 2019.

<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	2019	1	n/a	n/a	n/a	n/a	1
Scenic Point	2019	2	n/a	n/a	n/a	n/a	0
White Calf	2019	2	n/a	n/a	n/a	n/a	0
Spot	2019	5	n/a	n/a	n/a	n/a	2
Many Glacier	2019	8	n/a	n/a	n/a	n/a	5
Kupunkamint	2019	4	n/a	n/a	n/a	n/a	3
Old Man	2019	1	n/a	n/a	n/a	n/a	0
	TOTAL	23	n/a	n/a	n/a	n/a	11
	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%
	2019 PERCENT		n/a	n/a	n/a	n/a	48%

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (trees tab)

Figure 33. Trends in Limber Pine Cone Production 2007-2019.

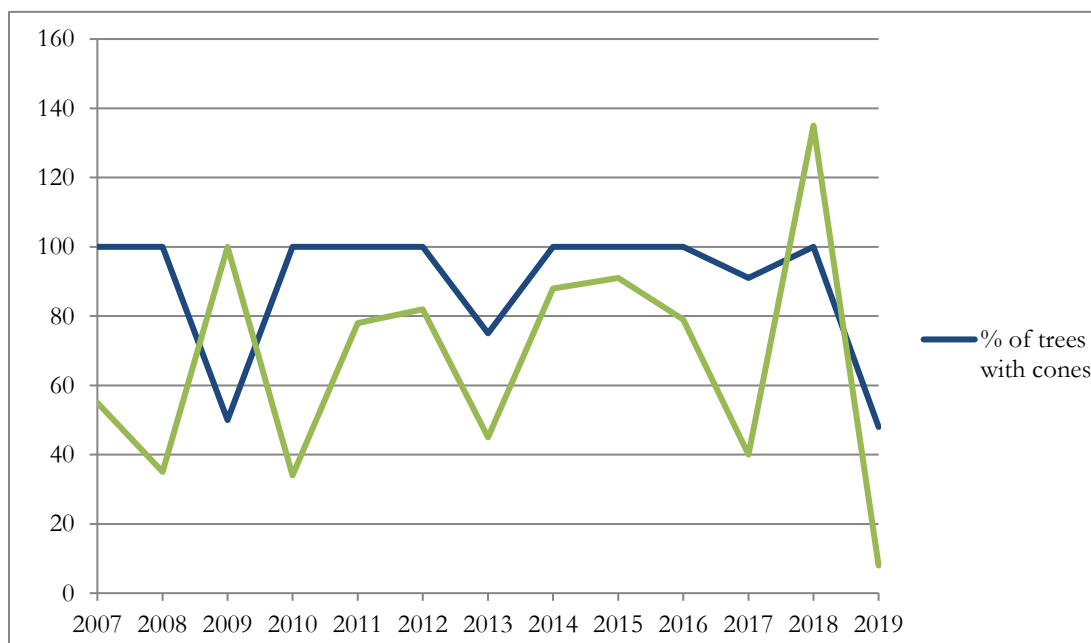


Table 35. Limber Pine Plus Trees: Average Cones Per Tree, 2007 – 2019.

	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
White Calf	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
White Calf	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
White Calf	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			2018			2019		
<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	221	221	1	3	3
Scenic Point	2	19	10	2	128	64	2	0	0
Whitecalf	3	26	9	3	671	224	2	0	0
Spot	5	276	55	5	683	137	5	8	2
Many Glacier	8	394	49	8	904	113	8	128	16
Kupunkamint	4	110	28	4	501	125	4	50	13
Old Man							1	0	0
TOTAL	23	925	40	23	3108	135	23	189	8

S:\VegUnit\Whitebark & Limber Pine\Cones and Seeds\Cone_Tree_Monitoring\Plus tree tables.xls (cones tab)

Table 36. 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

VI. 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):

Trees

Betula papyrifera
Larix occidentalis
Picea engelmannii
Pinus monticola
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Lonicera utahensis
Menziesia ferruginea
Paxistima myrsinites
Rosa acicularis
Rubus parviflorus
Spiraea betulifolia
*Vaccinium membranaceum**

Forbs/Ferns

*Adenocaulon bicolor**
*Aralia nudicaulis**
Athyrium filix-femina
*Chimaphila umbellata**
*Clintonia uniflora**
Cornus canadensis
*Disporum hookeri/trachycarpum**
Dryopteris expansa
*Goodyera oblongifolia**
Gymnocarpium dryopteris
*Maianthemum stellatum**
*Orthilia secunda**
*Osmorhiza berteroi**
*Thalictrum occidentale**
*Tiarella trifoliata**
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Bromus vulgaris
Calamagrostis rubescens
Carex concinnoides
Carex rossii
Elymus glaucus

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

Trees

Abies lasiocarpa
Larix occidentalis
Picea engelmannii
Pinus contorta

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Mahonia repens
Paxistima myrsinites
Salix scouleriana
Sorbus scopulina
Spiraea betulifolia
Symphoricarpos albus

Forbs/Ferns

Arnica cordifolia
*Clintonia uniflora**
*Disporum hookeri**
*Disporum trachycarpum**
Eurybia conspicua
*Maianthemum racemosum**
Oryzopsis asperifolia
*Osmorhiza berteroi**
*Thalictrum occidentale**

Grasses

Bromus vulgaris
Calamagrostis rubescens
Elymus glaucus
Festuca occidentalis
Festuca subulata

<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
Mabonia 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

Symphotrichum foliaceum var. foliaceum

Symphotrichum 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

Symphotrichum 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
Symphotrichum 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.

VII. 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 Reveg. (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)

VIII. RESOURCES AND REFERENCES

- Arno, S. and R. Hoff. 1990. *Pinus albicaulis* Engelm. Whitebark Pine. Pp. 268-279. In: Silvics of North America, Vol. I. Conifers. USDA Forest Service Agricultural Handbook 654.
- Asebrook, J.M., J. Hintz, and others. 1993-2018. *Revegetation Monitoring Reports: Glacier National Park*. Research Reports, Glacier National Park, West Glacier, MT.
- Casper, Anne Marie, Jacobi, William R., Schoettle, Anna W., Burns, Kelly S. 2011. In: Keane, Robert E.; Tomback, Diana F.; Murray, Michael P.; Smith, Cyndi M., eds. The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium. 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 375.
- Chicoine, T. K.; Fay, P. K. 1984. The longevity of viability of spotted knapweed seeds in Montana. Proceedings, Western Society of Weed Science. 37: 204-207. [37406]
- Cripps, C.L. and Mohatt, K. 2005. Ectomycorrhizal fungi and Whitebark pine. Nutcracker Notes, 9: 8-10.
- Cripps, C., Lonergan, E., Smith, C. 2014. Survival of whitebark pine seedlings inoculated with ectomycorrhizae. Nutcracker Notes 26, 15-18.
- Feldman, R., D. F. Tomback and J. Koehler. 1999. *Cost of mutualism: competition, tree morphology, and pollen production on limber pine clusters*. Ecology 80(1): 324-329.
- Hagle, S., K. Gibson and S. Tunnock 2003. *Field Guide to Diseases and Insect Pests of Northern and Central Rocky Mountain Conifers*. Pp.38-39. USDA Forest Service Report R1-03-08.
- Halstvedt, M.B, D.C. Cummings, T. Almquist, L. Samuel, R.G. Lym, K.G. Beck, R.L. Becker, C.A. Duncan, and P.M. Rice. 2010. *Native forb and shrub tolerance to Milestone® VM herbicide*. Dow AgroSciences LLC summary brochure. 010-50813 05/10 DAS. 6 pp.
- Hoekstra, J. M. T. M. Boucher, T.H. Ricketts and C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8:23-29.
- Hoff, R.J. 1992. *How to Recognize Blister Rust Infection on Whitebark Pine*. USDA, Forest Service, Intermountain Research Station, Research Note INT-406, Ogden, UT, 7 p.
- Izlar, D.K. 2007. Assessment for whitebark pine seedling survival for Rocky Mountain plantings. Missoula, MT. University of Montana Thesis. 84 pp.
- Kendall, K.C. and R.E. Keane. 2001. Whitebark pine decline: infection, mortality, and population trends. In: Tombeck, D.F, S.F. Arno, and R.E. Keane, Whitebark pine communities: ecology and restoration. Washington, D.C. Island Press: 221-242.
- Koteen, L. 2002. *Climate change, whitebark pine, and grizzly bears in the Greater Yellowstone Ecosystem*. In: Schneider, S.H., and T.L. Root, (eds.), Wildlife Responses to Climate Change: North American Case Studies. Island Press, Washington, D.C., U.S.A., pp. 343-414.
- Kueppers, Lara. In press. "Limber Pine Germination Responses to Climate Change at Alpine Treeline". UC-Merced. Kurth, L. and R. Potter. 1991. *Instructions for Monitoring Forms*. Glacier National Park, West Glacier, MT.

- Lange, D. 1988. *Vegetation Management Plan: Going-To-The-Sun Road - Lake McDonald Section*. Glacier National Park, West Glacier, MT, 46p.
- Lapp, J. 1994. *Glacier National Park Revegetation Plan: Reconstruct Going-To-The-Sun Road - 303-D*. Glacier National Park, West Glacier, MT, 60p
- Lapp, J. 2004. *Glacier NP Revegetation and Implementation Plans and CRMPS Reports*. Glacier NP, W. Glacier, MT.
- Lapp, J. and L. Turecek. 2004. *Planting of Disturbances resulting from Apgar Waterline Project*. Glacier National Park, West Glacier, MT
- Lesica, Peter. 2002. *Flora of Glacier National Park*. Corvallis: Oregon State University Press.
- Mahalovich, M.F., K.E. Burr, and D.L. Foushee. 2006. *Whitebark pine germination, rust resistance and cold hardiness among seed sources in the Inland Northwest: planting strategies for restoration*. In: National Proceedings: Forest and Conservation Nursery Association; 2005 July 18-20; Park City, UT. RMRS-P-43. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station: 91-101.
- Morgan, Penny; Bunting, Stephen C. 1990. Fire effects in whitebark pine forests. In: Schmidt, Wyman C.; McDonald, Kathy J., compilers. *Proceedings--symposium on whitebark pine ecosystems: ecology and management of a high-mountain resource*; 1989 March 29-31; Bozeman, MT. Gen Tech. Rep. INT-270. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 166-170. [165]
- Moyes, Castanha, Germino and Kueppers, 2013. Warming and the dependence of limber pine (*Pinus flexilis*) establishment on summer soil moisture within and above its current elevation range. *Oecologia* (2013) 171:271–282 DOI 10.1007/s00442-012-2410-0.
- Nature Serve, 2005. *Field Key to Plant Associations of Waterton-Glacier International Peace Park*, June 2005. 54 p.
- Powell, M. L. 1996. *A greenhouse study of the effects of cache size and relatedness on seed germination, seedling survival, robustness, and root grafting in whitebark pine*. Thesis. University of Colorado, Denver, CO.
- Schwandt, J.W. 2006. *Whitebark Pine in Peril, A Case for Restoration*. USDA, Forest Service, Forest Health Protection, Report R1-06-28, Coeur d' Alene, Idaho. 26 p.
- Smith, C.M., G. Poll, C. Gilles, C. Praymak, E. Miranda, and J. Hill. 2007. Limber pine seedling and seed survival project, Waterton Lakes National Park, 2003-2006. Unpublished technical report. Parks Canada, Waterton Lakes National Park, Waterton Park, Alberta, Canada.
- Smith, Poll, Gillies, Praymak, Miranda and Hill, 2011. Limber Pine Seed and Seedling Planting Experiment in Waterton Lakes National Park, Canada. In: Keane, Robert E.; Tomback, Diana F.; Murray, Michael P.; and Smith, Cyndi M., eds.. *The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium*. 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 376 p. Online at http://www.fs.fed.us/rm/pubs/rmrs_p063.html
- Stanley A.G., Kaye T.N., Dunwiddie P.W. 2008. *Regional strategies for restoring invaded prairies: observations from a multisite, collaborative research project*. *Native Plants Journal* 9(3):247–254.
- Sala, Hopping, McIntire, Delzone and Crone, 2012. *Masting in whitebark pine (Pinus albicaulis) depletes stored nutrients*. *New Phytologist* (2012) 196: 189–199.

- Tomback, D.F., Arno, S.F., and Keane, R.E. (Editors). 2001. *Whitebark Pine Communities, Ecology and Restoration*. Island Press, Washington, D.C.
- Tomback, D.F., Keane, R.E. and McCaughey, W.W. 2003. *Methods for Surveying and Monitoring Whitebark Pine for Blister Rust Infection and Damage – Draft*. Whitebark Pine Ecosystem Foundation, Missoula, Montana.
- Tyser, R.T. and J.M. Asebrook. In press. *St. Mary Roadside Revegetation Experiment*. Research Report. Glacier National Park, West Glacier, MT.
- USDA Forest Service and USDI National Park Service Interagency Report. 2003. *Interagency Burned Area Emergency Stabilization and Rehabilitation Plan, Robert and Trapper Fires*. Glacier National Park, West Glacier, MT.
- USA National Pehnology Network, 2014. *Pinus flexilis*. https://www.usanpn.org/nn/Pinus_flexilis
- USGS. 2003. *Blister Rust Wars in Western National Parks*. <http://www.nrmcs.usgs.gov/research/blister.htm>

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	41.0	31.8
2019	42.0	52.3	58.8	63.5	64.4	57.4	#	#
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	2.2	3.2
2019	3.6	1.4	4.2	1.7	1.4	1.9	#	#

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		
2019								
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	#	#
2019								

* 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.

