

Glacier National Park: Restoration Monitoring Report

2020

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I. INTRODUCTION

The Revegetation Monitoring Program, established in 1991, is designed to provide a systematic framework for describing a site prior to disturbance and for monitoring the success of seeded and planted species after revegetation. Please see previous reports (1991 – 2019) for a more detailed explanation of the goals and levels of monitoring utilized throughout the Park. Revegetation monitoring projects to date are listed in Table 1. The monitoring report for the appropriate year should be referenced for further information.

In addition to monitoring revegetation projects, the Vegetation Monitoring Crew also undertakes various vegetation projects as needed and/or as funding sources allow. Grassland plots installed in 1999-2001 have been re-read from 2018 to 2020, for a 20-year assessment of the condition of grasslands and as a baseline for the potential reintroduction of bison.

The objectives of this report are to document the results of the 2020 season. The report includes: (1) results from monitoring 12 eastside grassland plots approximately 20 years after their establishment; (2) data from several revegetation projects (St. Mary Visitor's Center, Phase VI Going-to-the-Sun Road (GTSR) Restoration and Bowman Lake Access Road Restoration); (3) a study design for assessing the effects of long-term herbicide application in Two Dog Flats Meadow; (4) results from whitebark and limber pine restoration projects; (5) results from whitebark and limber pine plus tree monitoring; and (6) overall recommendations for the monitoring program, including a schedule for future monitoring.

Table 1. 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, 2020
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
Bowman Lake Access Road Restoration	Level II	2020
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

Table 1, continued

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, 2020
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

II. EASTSIDE GRASSLAND MONITORING: 2018-2020

A. INTRODUCTION

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

Nationwide, grasslands have been severely impacted by human activities. While Glacier National Park's grassland communities have not faced as many human pressures, they have experienced continual impacts over the past century from natural grazing, development of historic structures, road development, agronomic grass seeding and spread, noxious weed invasion, and change in fire regimes.

Glacier National Park's grasslands are extremely important contributors to the character and ecology of the Park. On the east side of the park, fescue-dominated grasslands are commonly found, which are important to many wildlife species and the overall health of the ecosystem. Realizing the need for grassland assessment and preservation, GNP ecologists secured funding in 1999 to inventory grassland communities east of the Continental Divide over a three-year period. The study was designed to establish permanent vegetation plots, which may be used again in the future for comparative analysis. Goals of the study were to determine plant species composition, monitor the presence and status of exotic plant species, document wildlife utilization of grasslands and to create a management matrix.

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: 2018-2020

For over a decade, the Blackfeet Confederacy, Glacier's neighbors to the east, have been working to reintroduce bison to tribal lands. In 2016, 90 bison calves were shipped from Elk Island in Canada to a 9,000-acre reserve on the Blackfeet reservation near the southeastern boundary of the Park. The Blackfeet have worked with several agencies owning adjacent land to introduce a second herd, a genetically unique wild bison herd that has been transferred to the Chief Mountain area of the Blackfeet reservation. This herd is slated to become free roaming in the future. 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 plots that were established in 1999-2001. Since 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 regarding climate change, weed invasion, and fire ecology.

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 (See maps in Asebrook and Shea, 2010). 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.

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. Each plot was marked with eight-inch spikes placed in the lower right and upper left corners. Within this 100 square meter macroplot, 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 scat, and litter. Ocular cover estimates were made for other species in the 100 square-meter macroplot that were not captured in the microplots. 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.

2. Study Methods for Repeat Monitoring: 2018-2020

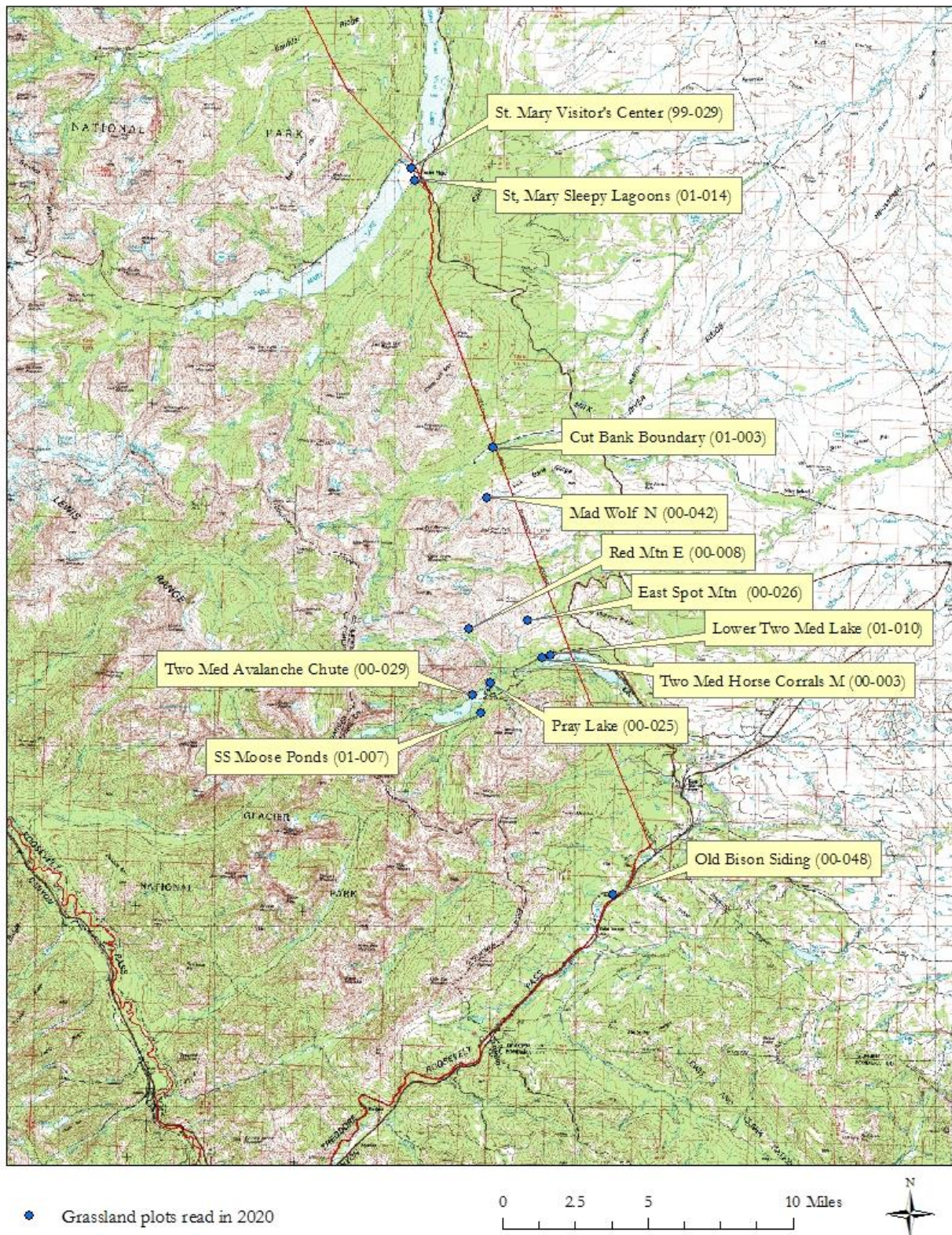
Monitoring methods remained the same for repeat surveys in 2018, 2019 and 2020. Microplots were randomly selected during the initial reading. In order to assess the health of these fescue grasslands approximately 20 years after they were established, 11 permanent monitoring plots were re-read in 2018, 12 plots were re-read in 2019, and 12 plots were re-read in 2020 (Figure 1). The same locations of microplots were retained for subsequent readings, to produce repeated measures.

Initially, it was thought that the tribe would release the bison in the Chief Mountain area in the northeastern portion of the Park. Choosing which plots to re-read in 2018 and 2019 was based on their proximity to this area near the Park border. More recently, it appeared that the herd may be released from the Badger Two Medicine area, and in 2020, plots were chosen in the Two Medicine and southern Park boundary areas. Plots were also chosen based on the number and quality of photographs from the previous reading, as these have proven instrumental in re-finding plots.

To relocate plots, a high-quality metal detector was used to find the two original nails in the lower right and upper left corners. To assist with finding these plots in the future, two additional nails 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.

This study aims 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.

Figure 1. Location of Eastside Grassland Plots Monitored in 2020.



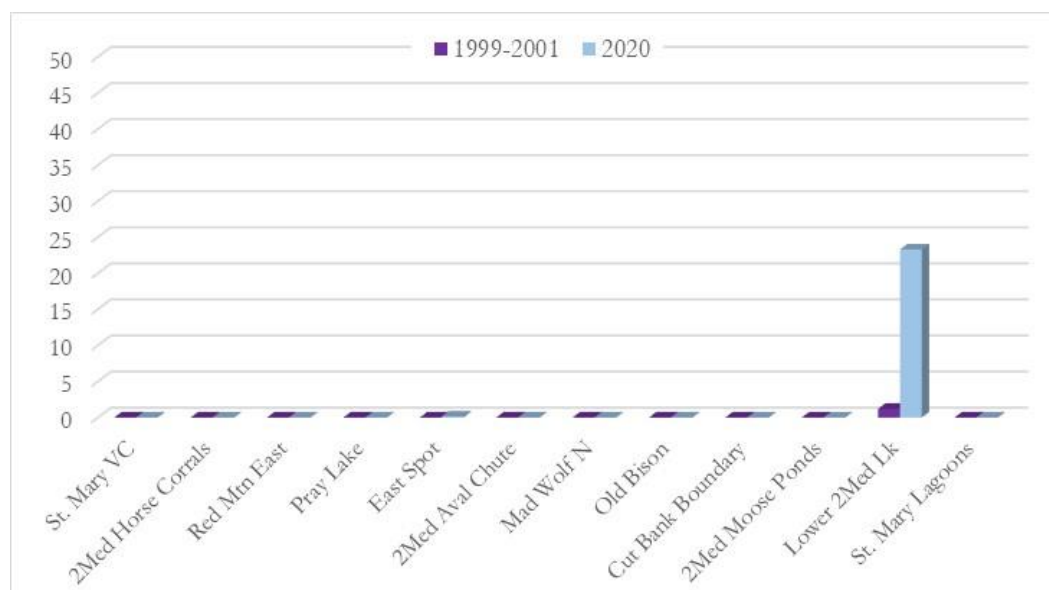
C. RESULTS

The following results pertain to grassland monitoring plots that were re-read in 2020. Some trends from results of plots re-read in 2018 and 2019 are referenced here, but for full results from 2018 and 2019, please refer to the Glacier National Park Vegetation Monitoring Reports from these years (Asebrook and Hintz, 2018, 2019). A table with results from all plots monitored in 2020, with percent covers for all species and lifeforms encountered, is included in Appendix B.

1. Trees

Trees were only present in two of the twelve plots that were monitored in 2020 (Figure 2). Trees were newly established in one of these plots, Spot Mountain, with 0.14% average cover of *Pseudotsuga menziesii* seedlings. Tree cover increased greatly in the other plot, on the shore of Lower Two Medicine Lake, from 1.2% in 2001 to 23.3% in 2020, largely due to a large increase in *Populus tremuloides* and a smaller cover of newly established *Pinus contorta*. This follows the trend seen in several plots read in 2018 and 2019 of an increase in tree cover where trees have established over the past few decades. Lack of a fire regime in grasslands which have historically burned periodically will likely result in more tree and shrub encroachment in grasslands in the future.

Figure 2. Eastside Grasslands: Tree cover comparison over time: 1999-2001 vs. 2020.



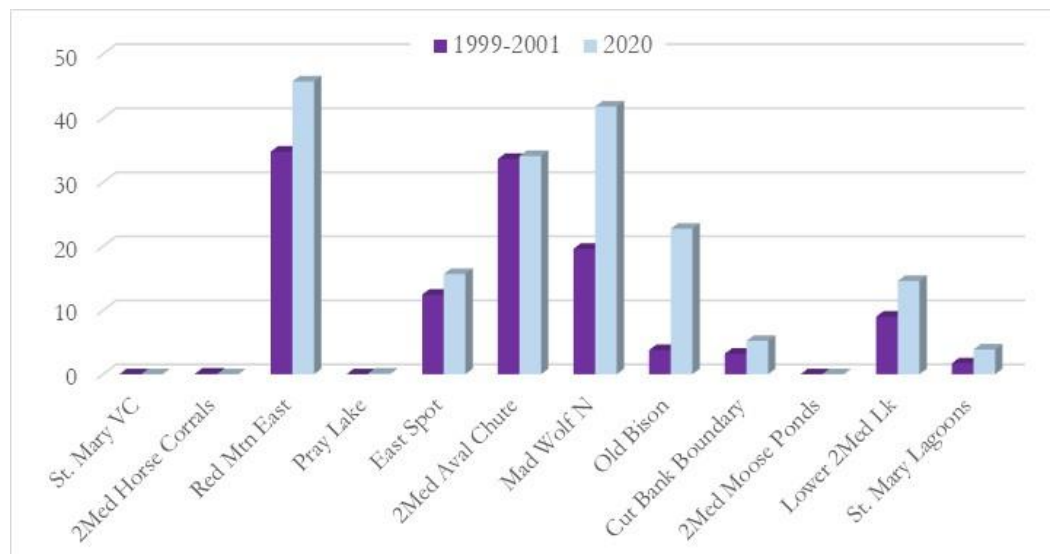
2. Shrubs

As was found in 2018-2019, shrubs were often observed encroaching grasslands. In 2020, in the plots where shrubs were present, cover increased relatively substantially in most of the plots (Figure 3). Several of the plots saw sizeable increases in shrub cover, with three plots experiencing an 11% to 22% increase in cover from 20 years prior. Two plots continued to be without shrubs after ~20 years. One plot, the Two Medicine Horse Corrals, defied the trend and lost the slight shrub cover that it had two decades previously.

The largest increase was found in *Pentaptylloides floribunda*. In each of the six plots where it was present, it grew in cover. The largest increases were found at Old Bison Siding and Mad Wolf North, with a 9.5% and 19% expansion in these plots, respectively. At Old Bison Siding, *P. floribunda* was the only shrub present, but at Mad Wolf North, it was one of a suite of shrub species which flourished over the past several decades. *Salix brachycarpa*, *Rosa sp.* and *Arctostaphylos uva-ursi* also increased considerably in this plot. The number of shrub species also increased from four to seven at this site over this time frame. One other plot, Red Mountain East, showed substantial shrub cover increase. At this site, overall shrub cover increased by 11% over the past 20 years, highlighted by *Amelanchier alnifolia*, which increased by 5.5% and *Juniperus communis*, which increased by 5%.

Generally, the frequency of shrubs is increasing. The number of shrub species present increased by 1 to 3 species in half of the plots. One plot decreased by one species and the rest remained the same.

Figure 3. Eastside Grasslands: Shrub cover comparison over time: 1999-2001 vs. 2018-2020.



3. Native Grasses

In general, native grass cover increased in most plots over the past 20 years (Figure 4). Double digit increases were found at the St. Mary Visitor's Center (29%), Cut Bank Boundary (19%), St. Mary Sleepy Lagoons (18%), East Spot Mountain (17%), Two Medicine Avalanche Chute (13%) and the Two Medicine Moose Ponds (13%).

At least part of the story is rooted in a substantial increase in *Festuca campestris* at several of these sites. This was especially seen at the St. Mary Visitor's Center, which experienced a 23% jump in rough fescue cover, at East Spot Mountain, with a 16% bump, at Cut Bank Boundary (19%) and at the Two Medicine Moose ponds, with a 13% increase. Single-digit increases were seen at other sites, with the exception of two plots, where rough fescue cover actually declined.

Lower Two Med Lake experienced a 7.5% decline in *F. campestris*, while Old Bison Siding saw an incredible 23% loss. Rough fescue had almost completely disappeared in this plot. Dead rough fescue bases were still observed in this plot, but it is uncertain what killed them. Shrubs increased dramatically at Old Bison Siding (by 19%), which could very well outcompete *F. campestris*. However, there was also a notable

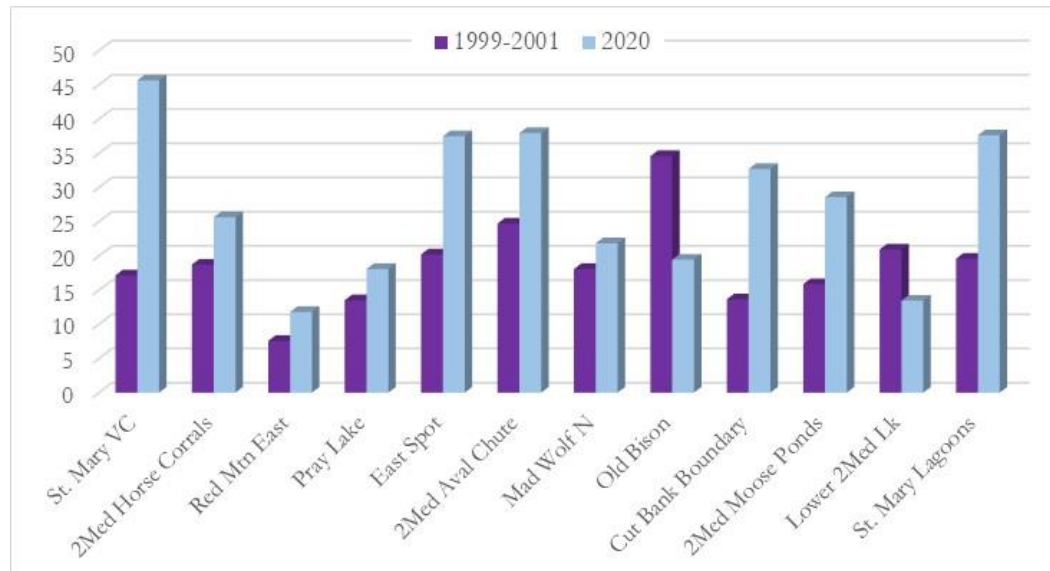
increase in native forbs (by 17%), and exotic grasses (by 5%), which would not be as likely to outcompete a large bunchgrass, such as rough fescue. A similar story was seen at Lower Two Med Lake. There was a substantial increase in trees (by 22%) and shrubs (by 6%) at this site. Similar to Old Bison Siding, native forbs increased (by 30%) as well as exotic grasses (by 7%). It is possible that woody materials outcompeted rough fescue, but likely there is an additional cause for the decline. Overgrazing from trespassing cattle may have been heavy enough to kill most of the rough fescue at Old Bison Siding, allowing native forbs and exotic grasses to subsequently fill those empty niches. Cattle trespass has been problematic along the southern and eastern boundary of the Park. Fire may have a similar effect, but this plot does not fall within a known fire perimeter.

Consistent with grassland plots that were re-read in 2018 and 2019, both fescue species were largely responsible for increases in native grass cover over time. An increase in *Festuca idahoensis* was observed in many plots in 2020, although by a much smaller amount than *Festuca campestris*. Idaho fescue increased by single digits at most sites, which could be solely because it is a much smaller bunch grass. The biggest increases were found at St. Mary Sleepy Lagoons (10%) and at Mad Wolf North (9%).

A few other native grass species were considerable players in increasing native grass cover at certain sites. *Elymus lanceolatus* increased substantially at the St. Mary Sleepy Lagoons (by 9%) and St. Mary Visitor's Center (by 5%). This rhizomatous grass can be a significant component of a grassland ecosystem once it gets established. *Carex geyerii* increased by 8% at the Two Med Avalanche Chute site, while a 4% increase in sedge species contributed at Pray Lake. In addition to both fescue species, which were present in every plot, the other native grass species present with the most frequency include *Carex petasata*, *Carex obtusata*, *Danthonia intermedia* and *Koeleria macrantha*.

It is uncertain why such a high rise in native grass cover was seen at several sites. In many cases, there was a corresponding increase in multiple other lifeforms within the same plot, including native forbs. Even exotic grass cover has increased in a few plots with substantially higher native grass cover. Although some changes in cover may be a result of observer differences, particularly when assessing grass cover; bunch grasses are typically easier to gauge in ocular cover and should not reflect large observer error.

Figure 4. Eastside Grasslands: Native grass cover comparison over time: 1999-2001 vs. 2020.



4. Native Forbs

As in native grasses, native forbs also increased dramatically in cover in most of the plots sampled in 2020 over the past several decades (Figure 5). Native forb cover increased in 10 of the 12 plots, with double-digit increases in all but one of those plots. Increases met or approached 30% in three plots: Lower Two Medicine Lake (30%), Two Medicine Horse Corrals (28%) and Two Medicine Avalanche chute (27%). The increase in native forb cover at these sites appears more likely to be due to increases in cover of individual species rather than in diversity. While there was some change in species composition in these plots, the number of species present remained the same in two of these three plots and increased by only two species at Lower Two Medicine Lake.

Similar to 2018 and 2019, some of the most notable cover increases (by 3% to 11%) were found in *Achillea millefolium*, *Cerastium arvense* and *Galium boreale*. Also increasing by 3 to 10 % in at least one of these three plots were *Eriogonum umbellatum*, *Heuchera cylindrica*, *Lupinus sericeus*, *Microseris nutans*, *Penstemon confertus* and *Potentilla arguta*. Several of these species do well with disturbance, which is likely a factor at the horse corrals and avalanche chute sites, and potentially at Lower Two Medicine Lake from ground squirrel disturbance. Additionally, the spring of 2020 was particularly wet, which may have enhanced growth in many species.

At other sites, a myriad of species increased substantially in cover (by 3% to 13%), including *Antennaria umbrinella*, *Cerastium arvense*, *Eriogonum flavum*, *Eriogonum umbellatum*, *Fragaria virginiana*, *Galium boreale*, *Geum triflorum*, *Lupinus argentea*, *Lupinus sericeus*, *Penstemon confertus* and *Solidago multiradiata*.

Diversity did increase substantially at a few sites. East Spot Mountain and Mad Wolf North increased in numbers of species present by 15 and 14 species, respectively. It is worth noting that in 2020, three botanists worked on each of these plots, while only one botanist read these plots in the initial reading. With each botanist having more time to search for species, the number of observed species may potentially increase. This seems like a large difference for that being the case, however. Both of these sites regularly experience grazing by tribal cattle and horses which cross the Park boundary often in these areas. It is possible that this grazing pressure actually stimulates vegetation by keeping it shorter and potentially opening up niches for new individuals and species to sprout and/or recruit. If this is the case, perhaps re-introduced

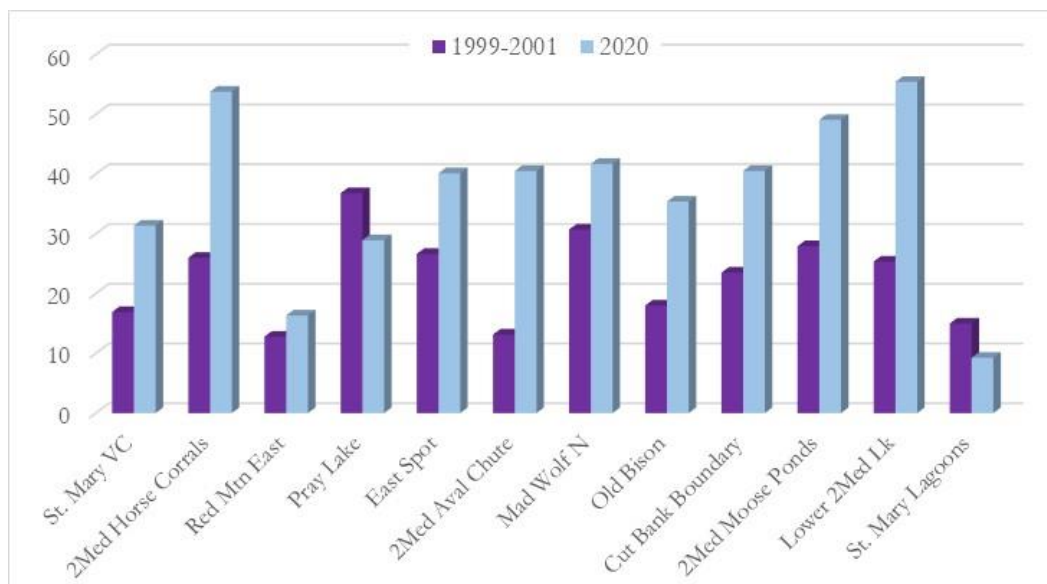
bison will have a similar effect on at least selected grasslands. This trend should continue to be monitored in the future.

It is also important to note that some species did decrease in certain meadows. Competition from other lifeforms, herbicide application and other disturbances, as well as varying temperature and precipitation levels over the past twenty years may have negatively impacted certain species in certain areas, even those that have typically increased across most grasslands. Most conspicuously, *Maianthemum stellatum*, *Pedicularis contorta*, and *Selaginella densa* each declined by 3% to 16% in one or more plots.

Several new forb species were observed for the first time in at least one plot in 2020; most markedly *Allium cernuum*, *Agoseris glauca*, *Antennaria umbrinella*, *Arnica sororia*, *Aster laevis*, *Castilleja cusickii*, *Fragaria virginiana*, *Eriogonum flavum*, *Douglasia montana*, *Erigeron speciosus*, *Heracleum sphondylium*, *Geranium viscosissimum*, *Lomatium triternatum*, *Microsteris gracilis*, *Penstemon confertus*, *Ranunculus pedatifidus*, *Thalictrum occidentale* and *Vicia americana*.

At the same time, several species that were observed two decades ago were no longer found in one or more of these 12 plots. Most notably, these include *Antennaria umbrinella*, *Aster conspicuus*, *Castilleja sulphurea*, *Eriogonum ovalifolium*, *Heuchera cylindrica*, *Phlox boodii* and *Silene paryii*. *Arnica sororia* and *Perideridia gairdneri*.

Figure 5. Eastside Grasslands: Native forb cover comparison over time: 1999-2001 vs 2020.

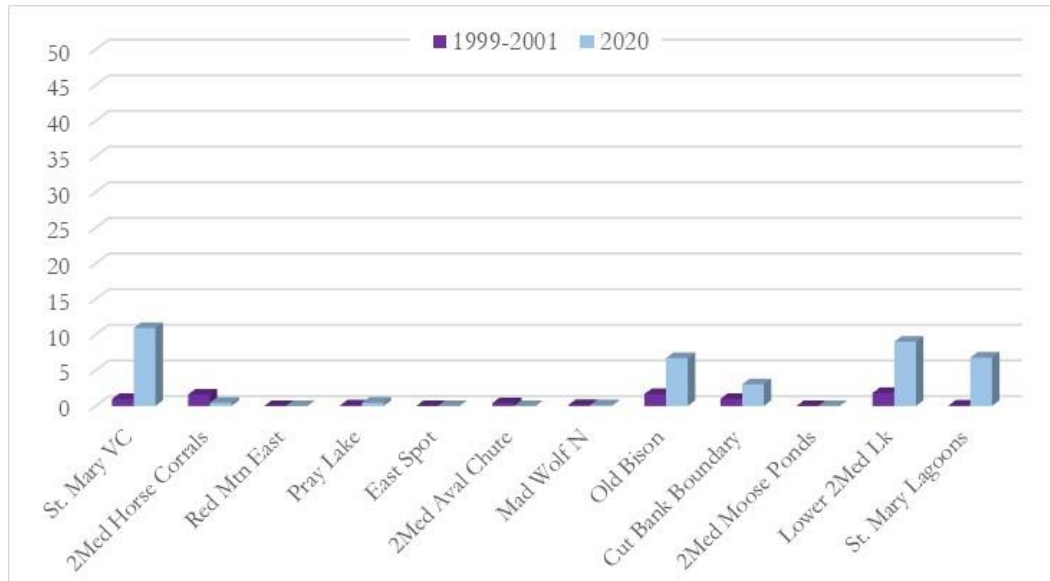


5. Exotic Grasses

Exotic grass cover has remained relatively low on the majority of the grassland plots monitored in 2020 (Figure 6). The highest non-native grass cover was observed at St. Mary Visitor's Center, at 11%. Three of the sampled plots continue to have no exotic grasses present. Three plots have less than 1% non-native grass cover, and two of these plots actually experienced slight decreases in cover over the past two decades. The remaining five plots had between 3 and 11% exotic grass cover. Four of these plots, St. Mary Visitor's Center, Lower Two Medicine Lake, Sleepy Lagoons and Old Bison Siding, showed between 5% and 10% increases in non-native grass cover in the past 20 years, however, a trend that should be followed carefully. Most of this increase in all four plots was due to *Poa pratensis*.

Phleum pratense recruited into two plots since the last monitoring event and was present with very low cover. *Poa compressa* was actually lost from one plot, and recruited into one other, with low cover. Non-native grass diversity remained very low, with no more than three exotic grass species present in any plot.

Figure 6. Eastside Grasslands: Exotic grass cover comparison over time: 1999-2001 vs. 2020.

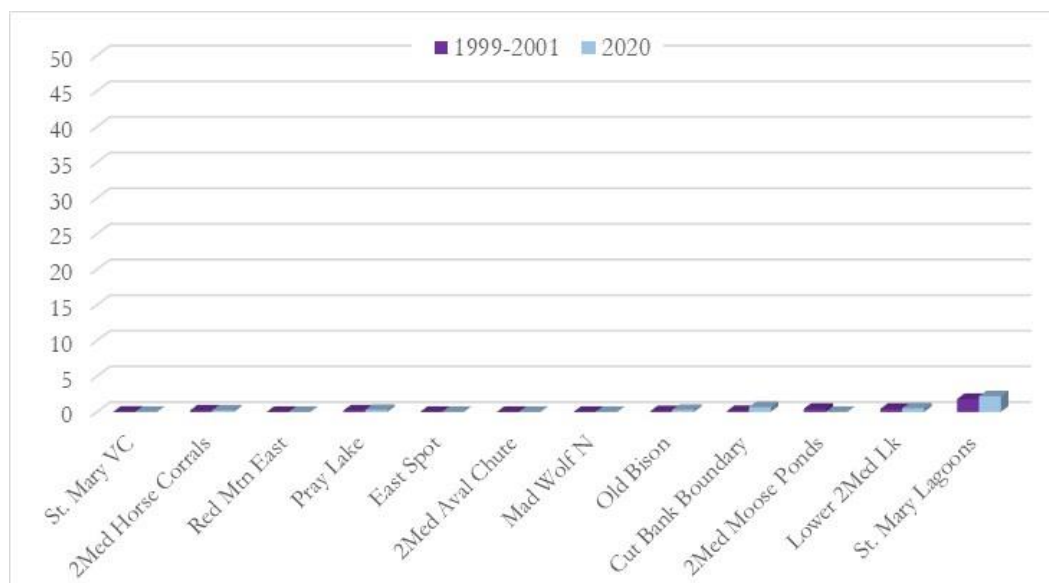


6. Exotic Forbs

Exotic forb cover has remained exceptionally low on the grassland plots monitored in 2020 (Figure 7). Ten of the twelve plots sampled supported less than 1% cover of non-native forbs in 2020. Only one plot, St. Mary Sleepy Lagoons, had higher exotic forb cover, at just 2%. The most commonly found non-native forbs were *Taraxacum officinale*, which was found in six plots, and *Tragopogon dubius*, which was found in five plots. *Centaurea maculosa* was only observed in two plots, St. Mary Visitor's Center and St. Mary Sleepy Lagoons. Spotted knapweed cover actually decreased at the visitor's center, while remaining virtually the same at Sleepy Lagoons. Both of these sites get sprayed with herbicide regularly, keeping it at bay. Non-native forb diversity remained very low. The most species present within a plot was three.

It should be noted that the grasslands sampled in 2020 may not be representative of all grasslands in the front country of Glacier National Park. This subset appears to be more pristine than many front country grasslands, particularly those adjacent to roads, such as Two Dog Flats.

Figure 7. Eastside Grasslands: Exotic forb cover comparison over time: 1999-2001 vs. 2020.



D. CONCLUSIONS AND ACTION ITEMS

The 35 plots that were monitored in 2018, 2019 and 2020 were potentially the first of 50-75 plots that can serve as long-term monitoring plots for assessing the health of fescue grasslands. The intent is not to re-read all 155 original plots from the initial study but to find a subset of plots where management concerns are the highest to monitor every 10-20 years. This year is the third year of a five year effort (2018-2022) to determine that subset of plots and to 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 almost every meadow monitored in 2018, 2019 and 2020.

A major change over the past two decades is that in 32 of 35 plots, shrub cover increased by a range of 0.5% to 48%. Seventeen of the 35 plots gained one or two 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*, *Pentaptylloides floribunda* 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*, *Populus tremuloides*, *Pinus contorta* and *Pseudotsuga menziesii*. Additionally, in the plots where it is present, tree species *Populus tremuloides* also notably increased.

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 35 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, 29 of the 35 plots exhibited an increase in native grass cover over the past two decades, ranging from a 2% to 29% increase. While there are changes in cover and frequency of certain native grasses, overall dominant native grasses remained the same. Overall diversity of native grasses is increasing slightly in some areas but 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*, *Helictotrichon bookeri* and in a few places, *Festuca campestris*. 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, 23 of the 35 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.

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 (Tyer and Asebrook, 2004).

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 0.4% to 17%, 14 of the 35 plots monitored in 2018-2020, experienced an increase in exotic grasses over the past two decades. The highest increases were seen in meadows in the Belly River, St. Mary Flats, St. Mary Campground and Sleepy Lagoons, Lower Two Medicine Lake, Old Bison Siding, on the southern boundary of the Park and off the Chief Mountain Road. These increases were primarily due to increases of *Phleum pratense* and *Poa pratensis*.

Fortunately, 21 of the 35 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, Two Medicine area and the Cut Bank Border.

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 of noxious weeds should continue.

Overall exotic forb cover has remained relatively low on the majority of the grassland plots monitored in 2018-2020. While there have been small increases in exotic forb cover in some areas, 31 of the 35 plots have no more than 5% exotic forb cover, similar to values in 1999-2001. Six plots actually decreased in exotic forb cover by 0.1-2% 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 two plots in 1999-2001 to nineteen plots in 2018-2020. Increases and large infestations 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. Additionally, nine 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.

Since overall exotic forb cover remains low, it is recommended to follow the initial action items laid out in the 2010 report (Asebrook and Hintz, 2010):

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.

III. GOING-TO-THE-SUN ROAD: PHASE VI MONITORING

A. BACKGROUND AND PURPOSE

In July 2007, a 10-year rehabilitation project for the Going to the Sun Road (GTSR) was initiated, funded by Federal Highway dollars. Phase VI of the project, including the roadside from West Tunnel to Haystack Creek, began in 2007 and continued into 2008. Construction during this phase included installation of retaining walls, culverts and drains, as well as base stabilization. Additionally, a day-use and vista area were created across from the “Road Camp” area on the south side of the road. Elevation for this phase of the GTSR Rehabilitation Project ranges from approximately 4,400 feet to 5,230 feet.

A species list was created for this segment of road in 2007 which directed seed collection. Disturbance created from construction of this phase was revegetated in June 2010. Five roadside sites or turnouts in phase VI were planted, seeded, and provided with fencing to deter trampling. Several of these sites were planted with significant plant material and were only lightly seeded with a forb, shrub, and grass mix. Others had less planted material and were seeded more heavily with the same seed mix. In all turnout areas that were seeded, the soil was scarified and seeds were hand raked into the ground. All roadside edges that were disturbed throughout phase VI were then hydroseeded with the same seed mix.

In 2012, the turnout at mile 26.25, east of Alder Creek (containing plot 2), was planted with supplemental material since visitors were climbing over the guardrail and trampling the revegetation to take photographs on a large platform rock that was purposefully put here. The area was also seeded using the remaining seed mix from phase VI. In 2013, the same turnout was determined to be too small and was enlarged for visitor safety, resulting in a smaller revegetation area and reduced the size of plot 2. Fortunately, the bare, trampled areas of this plot were incorporated into the parking surface of the turnout, resulting in no bare areas in the plot and no need for further revegetation. All turnouts now have either guardrail fences or barrier rocks to prevent people from walking on the revegetated area.

For a detailed seed and plant list with rates, please refer to the 2011, 2012, 2013 or 2015 reports.

B. METHODS

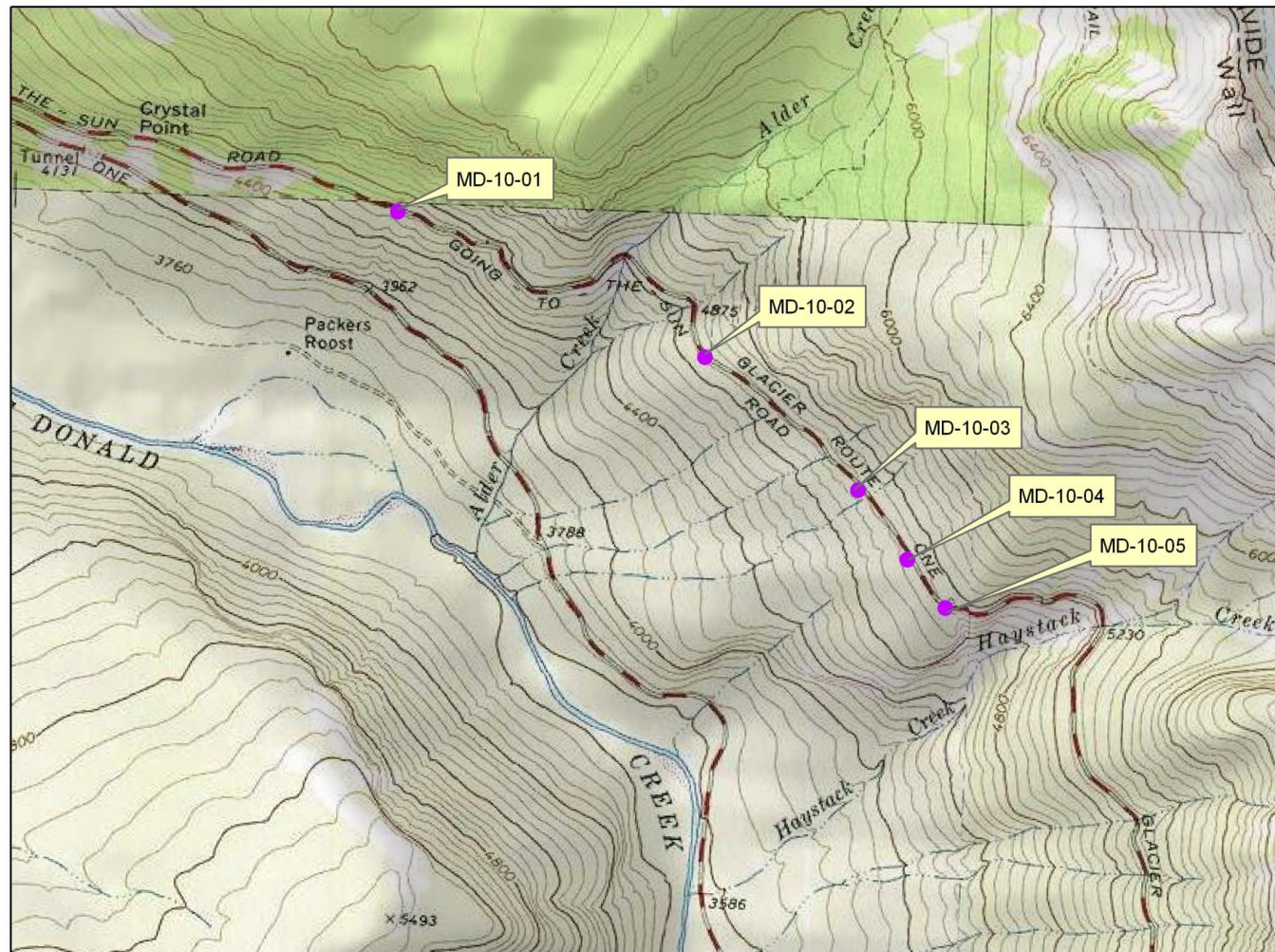
Five monitoring plots were established in September 2010, one at each site that was planted with nursery stock (Figure 8). Due to the narrow width of reseeded roadside on the remaining portion of the project, no additional plots were established to track reseeded road edge areas. Plots are not permanently marked, and the size and shape of plots were determined by site parameters (Table 2). Most plots are located behind wood fencing and vary in width.

Plots were evaluated using Level II protocol. All plants within plots were identified to species and given ocular cover estimates. All plots have been monitored in 2011, 2012, 2013, 2015 and 2020 at years 1, 2, 3, 5 and 10 after restoration.

Table 2. GTSR: Phase VI: Plot Dimensions and Locations.

Plot Number	Plot dimensions	UTM N	UTM E
MD-10-01	24 m x 2 m	5403348	295945
MD-10-02	35 m x 3 m	5402887	296917
MD-10-03	50 m x 2 m	5402469	297398
MD-10-04	25 m x 4 m	5402249	297553
MD-10-05	18 m x 3 m	5402096	297673

Figure 8. GTSR Phase VI: Location of Plots.



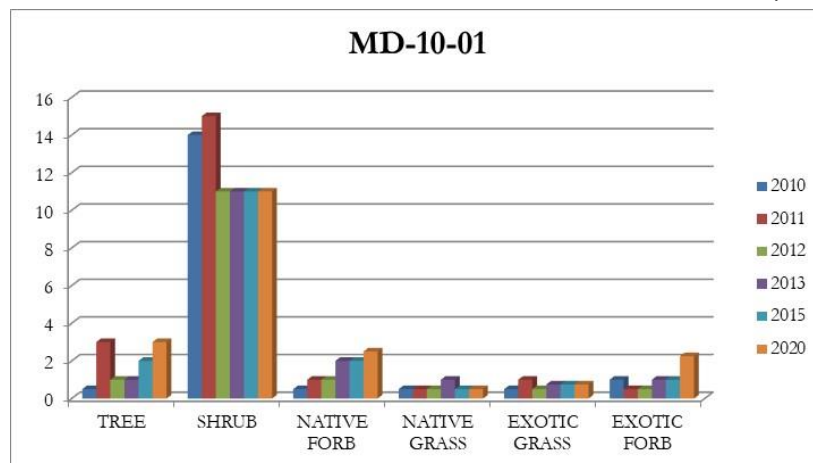
C. RESULTS

Each of the five plots monitored in Phase VI restoration of the Going-to-the-Sun Road responded differently over time. Native cover increased substantially in two plots, while it decreased substantially in two plots and remained relatively stable in one plot. Therefore, results will be discussed for each plot separately.

Plot 1, located behind a log barrier on a turnout, saw slight increases in cover over several lifeforms over the past five years, while other lifeforms remained steady (Figure 9). Very small increases were found in trees, native forbs and exotic forbs. Shrub cover has remained about the same since 2012. Planted *Cornus sericea* and *Acer glabrum* were relatively stable in this plot, although they appear to be thriving in comparative photos of the area. Although there was only a small increase in overall native forb cover, *Achillea millefolium* increased by 5%. Little change was seen in grass cover, both native and exotic. While multiple species of native grasses established early on, no species has persisted with much cover. A likely cause is increased and continual trampling.

As was the trend region-wide this season, *Melilotus officinalis* cover increased, likely as a response to the wet spring. Generally, this species is cyclical, and should retreat in the future. Even though this plot was located behind a more stable log barrier, it appears to have continued disturbance, as the vegetation still appears a bit scoured.

Figure 9. GTSR Phase VI: Percent Ocular Cover of Life Forms for Plot 1, 2010-2020.

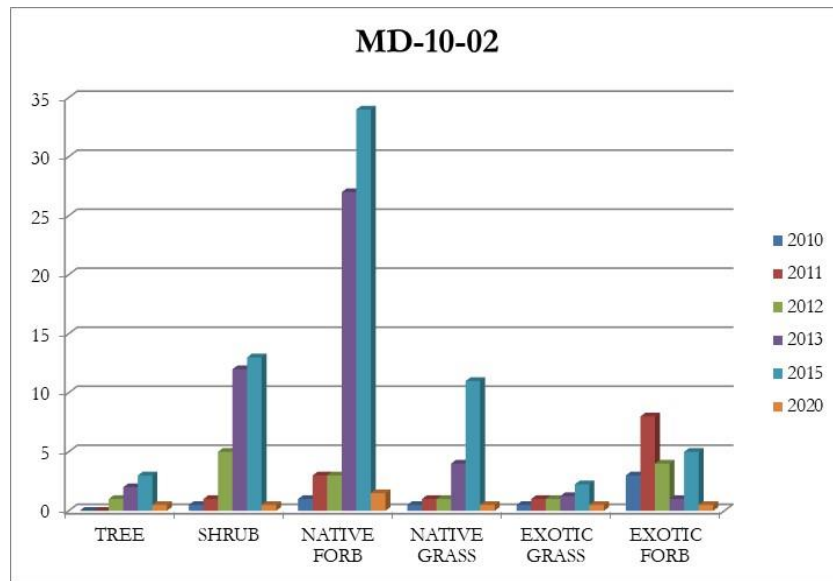


Plot 2 was greatly downsized in 2013, due to an expansion of the turnout which reduced the size of the plot area. There has also been increased trampling beyond the rock barrier, which has denuded a fair amount of the remaining area. As a result, cover in this plot has been steadily declining (Figure 10). The greatest hit was seen in native forbs which drastically reduced in cover from 34% to 2% in the past five years. All lifeforms were severely reduced, largely due to trampling. It is unlikely that most of the demise of vegetative cover in this plot was related to any revegetation efforts.

Most tree and shrub species no longer exist in this plot. A number of native forb species have also been lost from this plot, and a few, such as *Artemisia ludoviciana*, decreased greatly in cover, from 18% to less than 1%. *Solidago canadensis*, a species that was both seeded and planted across the project, also decreased from 10% to less than 1%. This species is quite successful in other, less trampled, areas of the project.

Several native grass species successfully established earlier in the project. As seen in many revegetation projects across the park, *Bromus carinatus* and *Elymus glaucus* often establish well, but have a known short life span. Very often these species decline sharply or even die off, but it is hoped that they serve as placeholders for other native species as ground cover is established. In this plot, both these species established by year two, but *B. carinatus* never gained much cover. *Elymus glaucus* completely disappeared since increasing to 8% cover five years prior. No native grass species was found with over trace cover in 2020.

Figure 10. GTSR Phase VI: Percent Ocular Cover of Life Forms for Plot 2, 2010-2020.

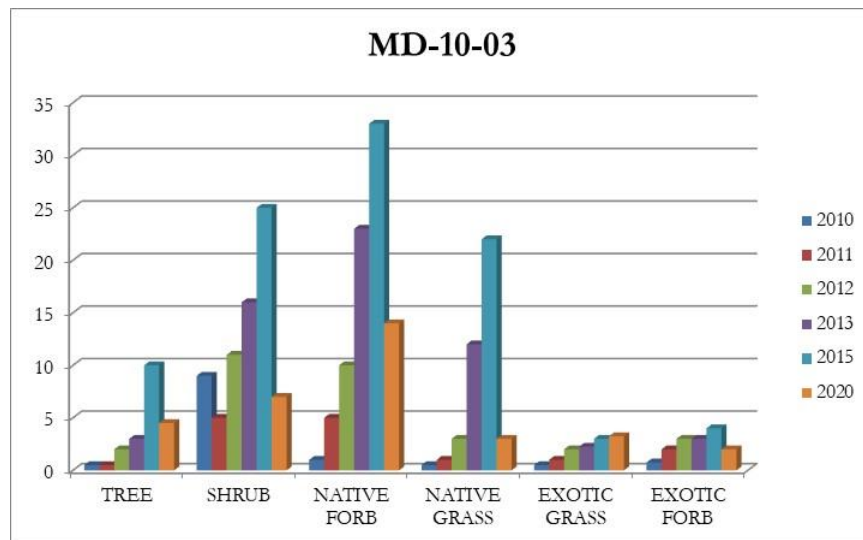


Plot 3, also located behind barrier rocks, saw a substantial decrease in cover in most lifeforms over the past five years (Figure 11). A slight increase was only observed in one lifeform, exotic grasses, in this plot. There was a fairly large decrease in trees and shrubs, especially in *Populus balsamifera*, *Cornus sericea* and *Rosa woodsii*. A cumulative decrease in cover in many native forb species added up to a larger overall native forb decline, with a few notable species. *Solidago canadensis* dropped from 12% to 4% over the past five years, and *Symphytotrichum laeve* decreased from 6% to less than 1%.

The decline in native grass cover was expected, as the nurse grasses *Bromus carinatus* and *Elymus glaucus* often establish and subsequently decline. Exotic grasses may have partly filled this open niche, but not to a great extent.

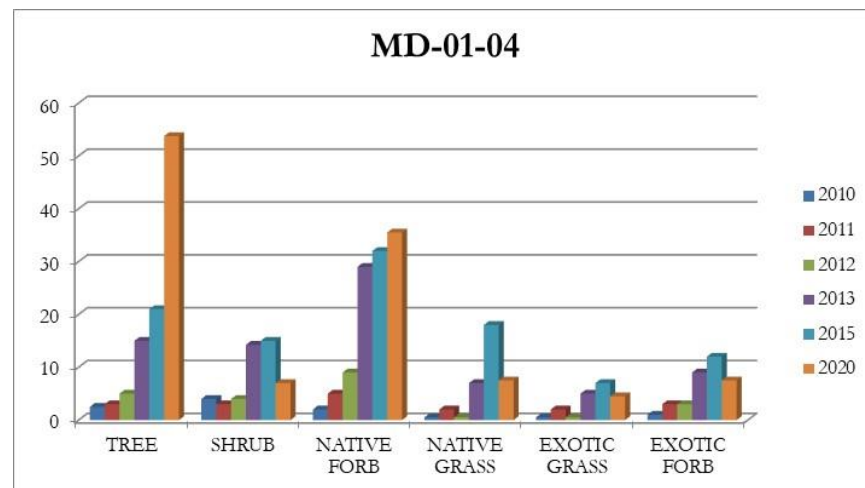
While there may be some discrepancy in plot placement and observer differences, increased tourism has taken its toll on turnouts where people can easily walk behind barriers.

Figure 11. GTSR Phase VI: Percent Ocular Cover of Life Forms for Plot 3, 2010-2020.



In Plot 4, adjacent to the Sun Road with no turnout or shoulder, tree cover increased dramatically, and native forb cover increased to a lesser amount (Figure 12). All other lifeforms declined. Almost all the tree surge was due to naturally occurring *Populus tremuloides*. Overall native forb increase was due to cumulative small increases in several species, including seeded *Solidago canadensis*, and naturally regenerating *Angelica arguta* and *Heracleum sphondylium*. The decline in shrub cover was mostly from a reduction in cover of planted *Cornus sericea* and *Salix boothii*, both species that prefer wetter soil, which this area may not provide. As seen in plot 3, the nurse grasses *Bromus carinatus* and *Elymus glaucus* established followed by a delayed decline. In this case, it appears that they may have acted as placeholders for naturally regenerating species. Exotic cover remained relatively low, so perhaps these nurse grasses have kept non-natives from establishing early. Both exotic grasses and exotic forbs have actually decreased in this plot. *Medicago lupulina* and *Melilotus officinalis*, which tend to be cyclical in nature, were responsible for most of the decline in exotic forbs.

Figure 12. GTSR Phase VI: Percent Ocular Cover of Life Forms for Plot 4, 2010-2020.

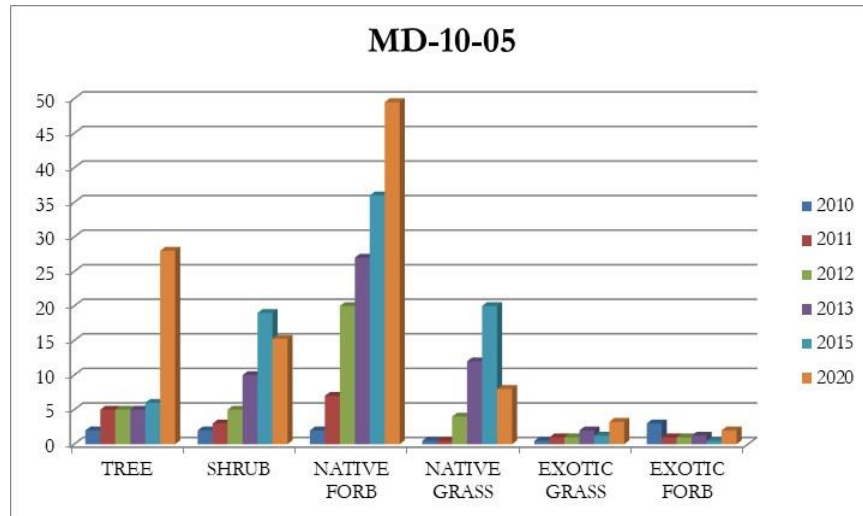


Plot 5, located behind the log barrier in the Road Camp turnout and picnic area, was the most successful by 2020, ten years after planting. Tree cover increased substantially, mostly due to a 20% increase in *Picea engelmannii* (Figure 13). Native forb cover increased by 14%, with the largest growth seen in *Symphyotrichum leave* and *Achillea millefolium*.

The decline in native grasses is consistent across all plots. Similar to the rest of the project, *Bromus carinatus* and *Elymus glaucus* dropped sharply after establishing substantial cover the first five years. Utilizing these seeded grasses as nurse grasses to provide early ground cover appears to be a successful strategy, as exotics never gained much of a foothold, and cover remains low in this plot. *Carex* species appear to be some of the plants that may have taken advantage of open niches left behind by nurse grasses.

Shrub cover also declined slightly in plot 4. As seen across the project, *Cornus sericea* showed the most decline. Perhaps soil in many of these sites doesn't retain enough moisture to support this species that thrives in riparian areas. Exotic species are only increasing slightly in this plot. *Poa pratensis* showed the highest increase, but only by less than 2%. It is worth watching this rhizomatous species, however, as it can readily take over.

Figure 13. GTSR Phase VI: Percent Ocular Cover of Life Forms for Plot 5, 2010-2020.



D. CONCLUSIONS AND RECOMMENDATIONS

Disturbance by visitation appears to be clouding the results of this revegetation effort. While some conclusions can be inferred, it is difficult to tease out the effects of trampling. Several of the revegetated areas are located behind rock barriers. In most cases, people appear to be travelling beyond this barricade, resulting in scoured vegetation. Log barriers appear to be more effective in keeping people off revegetated areas. In some cases, however, there was evidence of trampling behind these barriers as well.

Survival of planted material was variable ten years after planting. In some areas, planted species continue to thrive. While *Populus balsamifera* declined in some areas, it showed fantastic increase in one plot. *Picea engelmannii* also showed substantial increase in one plot. Unfortunately, planted shrubs have shown a decline in most plots, highlighted by *Cornus sericea*. It may be a function of lower than ideal soil moisture for this species, but trampling cannot be discounted.

Some seeded species continue to fare well, at least in certain areas. *Achillea millefolium*, *Solidago canadensis* and *Symphyotrichum laeve* continue to be some of the most successful of the seeded species. As earlier results implied, it appears that a combination of both seeding and planting is advantageous. Ten-year results, though varied, continue to illustrate the importance of planted species for initial ground cover as well as seeding a variety of species to more gradually increase cover and diversity. Species diversity remains high across the project, despite a reduction in cover.

Elymus glaucus and *Bromus carinatus*, seeded native grass species, have declined in most or all plots. While some of this may also be due to human factors, this follows the usual pattern for these species. Early establishers, these grasses often provide early ground cover, but generally do not persist past five or ten years in revegetation projects. By that time, often other seeded, planted and regenerating native plant species have established and can take advantage of open niches to expand.

Sedges can be important components of restoration projects but may require patience when seeded due to slower germination and growth. Two plots are beginning to have more substantial sedge cover after ten years.

Although exotic species cover is still not high at this time, it may become problematic over time if these areas are not consistently weeded and sprayed. While most species of exotic forbs and grasses have very low cover, a few species are slowly increasing. These include exotic grass *Poa pratensis* and exotic forbs *Medicago lupulina* and *Melilotus officinale*. Additionally, although not captured in monitoring plots, *Phalaris*

arundinacea was observed growing on the roadside within the phase VI revegetation area. This extremely aggressive grass has not been historically present in many areas of the park but since the intensification of road rehabilitation in the last several years, it has been observed in several places including small patches at Logan Pass and larger patches along the Packer's Roost Road. It is highly recommended to eradicate this grass when observed since it is known to rapidly overtake sensitive areas such as wetlands.

Montana Priority 2B Noxious Weeds *Centaurea stoebe* (*Centaurea maculosa*), *Cirsium arvense*, *Cynoglossum officinale*, *Hypericum perforatum*, *Leucanthemum vulgare* and *Linnaea vulgaris* were all found in at least one plot and several species were found in two to five plots. While none of these species have more than 1% cover at this time, some species have increased in cover or spread to new plots since the last monitoring event. The spread of weeds across this project should be closely monitored. Herbicide application should continue in this area to reduce noxious weeds. Frequent hand pulling of exotic species is also recommended to enhance native species survival.

Plots should be read again in 2030 at year 20 after planting. Several road projects have now been monitored twenty years after planting documenting valuable information concerning long-term success of seeded and planted material. This long-term monitoring data continues to improve restoration strategies throughout the park and on the GTSR.

IV. ST. MARY VISITOR CENTER MONITORING

A. BACKGROUND AND PURPOSE

Construction surrounding the St. Mary Visitor Center coincided with creation of the park's transit system, which provides shuttle service across the Going-to-the-Sun Road. The parking lot around the St. Mary Visitor Center was renovated while accommodating a new transit stop and was completed in 2008.

Parking lot islands and bare areas surrounding the visitor center were initially planted in the spring and fall of 2008. A total of 3,582 plants were planted in June and September in the various islands in the parking lot (Revegetation Crew Completion Report 2008; Table 5). These areas did not have supplement seed. Bark mulch was used to cover the soil for moisture retention, however, most of this mulch was blown away throughout the winter of 2008-2009. Many plants did not survive the winter due to root exposure when topsoil was blown away along with the mulch. The perimeter of the parking lot and visitor center were also hydroseeded in the fall of 2008. A total of 1.5 acres were hydroseeded in the St. Mary Visitor Center area (Table 4). Weeds recruited due to both the open habitat on parking lot islands and also because much of the hydroseed didn't germinate until the fall of 2009.

To compensate plant losses, additional plants were added to all of the islands in 2009. During May, June, August and September, 1,514 additional forbs, shrubs and grasses were planted in the islands around the St. Mary Visitor Center. The islands were also weeded extensively on multiple occasions. *Cirsium arvense*, *Bromus tectorum*, *Polygonum convolvulus*, *Centaurea stoebe*, *Kochia scoparia*, *Thlapsi arvense*, and *Linaria vulgaris* were the most common weeds found growing in the planting areas (Revegetation Crew Completion Report 2009). Weeds were also prolific in the hydroseeded area and some of these were pulled as well.

Supplemental plant material was again added in 2010. In May and June, 767 forbs, shrubs, and grasses were added to parking lot islands of St. Mary Visitor Center. Additional work to the area is recommended in the future with several islands still in need of more plant material. Non-native grasses continue to dominate areas, particularly those that have previously been mowed, and it is suggested that non-native grasses be removed, or a barrier be placed between these areas and planted areas (Revegetation Crew Completion Report 2010).

B. METHODS

In August 2010, six monitoring plots were established at the St. Mary Visitor Center (Figure 14). Plots are not permanently marked, and the size and shape of plots were determined by site parameters (Table 3). Three plots are located in parking lot islands, each encompassing the entire island. Two plots are located adjacent to the parking lot with dimensions for each measuring 20m x 5m. One plot is located adjacent to the visitor center. This plot is triangular in shape to avoid the pre-construction presence of *Elymus repens* adjacent to the plot.

Plots were evaluated using Level II monitoring protocol. All species within plots were identified and given ocular cover estimates. Ground cover was also estimated within plots, excluding 2011 and 2020.

Table 3. St. Mary Visitor Center: Dimensions and Location of Monitoring Plots

Plot Number	Plot dimensions	UTM N	UTM E
SM-10-01	entire island	5402152	320821
SM-10-02	20 m x 5 m	5402141	320800
SM-10-03	20 m x 5 m	5402189	320812
SM-10-04	entire island	5402189	320778
SM-10-05	triangle	5402266	320725
SM-10-06	entire island	5402329	320711

Figure 14. St. Mary Visitor Center: Location of Plots



Table 4. St. Mary Visitor Center: Seeding Prescription for Areas Adjacent to Parking Lot

Seeds per ft ²	Lifeform	Species:	Weight:
15	grass	<i>Festuca idahoensis</i>	930 g
20	grass	<i>Festuca campestris</i>	2.5 kg
5	grass	<i>Koeleria macrantha</i>	63.7 g
10	grass	<i>Juncus balticus</i>	no seed weight
5	grass	<i>Elymus trachycaulus ssp. subsecundus</i>	1.024 kg
5	grass	<i>Bromus carinatus</i>	1.776 kg
5	grass	<i>Elymus smithii</i>	1.38 kg
5	grass	<i>Carex aurea</i>	no seed weight
5	grass	<i>Carex obtusata</i>	no seed weight
5	grass	<i>Carex filifolia</i>	no seed weight
10	forb	<i>Achillea millefolium</i>	110 g
5	forb	<i>Dasiphora floribunda</i>	104 g
5	forb	<i>Fragaria virginiana</i>	160 g
10	forb	<i>Geum triflorum</i>	451 g
5	forb	<i>Anemone multifida</i>	389 g
5	forb	<i>Heuchera cylindrica</i>	21 g
5	forb	<i>Penstemon confertus</i>	55 g
10	forb	<i>Potentilla gracilis</i>	204 g
10	forb	<i>Solidago sp.</i>	50 g

80 total seeds of grass per square foot; 65 total seeds of forb per square foot

Table 5. St. Mary Visitor Center: Species Planted in Islands within Parking Lot

Shrubs	2008	2009	2010
	<i>Arctostaphylos uva-ursi</i>	<i>Arctostaphylos uva-ursi</i>	<i>Amelanchier alnifolia</i>
	<i>Mahonia repens</i>	<i>Dasiphora floribunda</i>	<i>Arctostaphylos uva-ursi</i>
	<i>Paxistima myrsinites</i>	<i>Mahonia repens</i>	<i>Mahonia repens</i>
	<i>Spiraea betulifolia</i>	<i>Paxistima myrsinites</i>	<i>Paxistima myrsinites</i>
	<i>Symphoricarpos albus</i>	<i>Rosa woodsii</i>	
		<i>Rubus parviflorus</i>	
		<i>Spiraea betulifolia</i>	
		<i>Symphoricarpos albus</i>	
Grasses/Sedges	<i>Danthonia intermedia</i>	<i>Carex microptera</i>	<i>Carex pachystachya</i>
	<i>Festuca idahoensis</i>	<i>Koeleria macrantha</i>	<i>Carex petasata</i>
	<i>Koeleria macrantha</i>		<i>Festuca idahoensis</i>
Forbs	<i>Anaphalis margaritacea</i>	<i>Anemone multifida</i>	<i>Anaphalis margaritacea</i>
	<i>Anemone multifida</i>	<i>Artemisia ludoviciana</i>	<i>Artemisia frigida</i>
	<i>Antennaria sp.</i>	<i>Fragaria sp.</i>	<i>Fragaria sp.</i>
	<i>Aster/Erigeron mix</i>	<i>Gaillardia aristata</i>	<i>Gaillardia aristata</i>
	<i>Aquilegia flavescens</i>	<i>Geum triflorum</i>	<i>Gaillardia aristata</i>
	<i>Erigeron speciosus</i>	<i>Hedysarum boreale</i>	<i>Geum triflorum</i>
	<i>Eriogonum umbellatum</i>	<i>Gaillardia aristata</i>	<i>Heuchera cylindrica</i>
	<i>Fragaria vesca</i>	<i>Fragaria sp.</i>	<i>Penstemon confertus</i>
	<i>Gaillardia aristata</i>	<i>Lupinus sericeus</i>	<i>Phacelia sericea</i>
	<i>Geranium viscosissimum</i>	<i>Polemonium pulcherrimum</i>	<i>Polemonium pulcherrimum</i>
	<i>Geum triflorum</i>		<i>Potentilla bipiana</i>
	<i>Heuchera cylindrica</i>		
	<i>Oxytropis splendens</i>		
	<i>Penstemon albertinus</i>		
	<i>Penstemon confertus</i>		
	<i>Polemonium pulcherrimum</i>		
	<i>Potentilla gracilis</i>		
	<i>Potentilla sp.</i>		

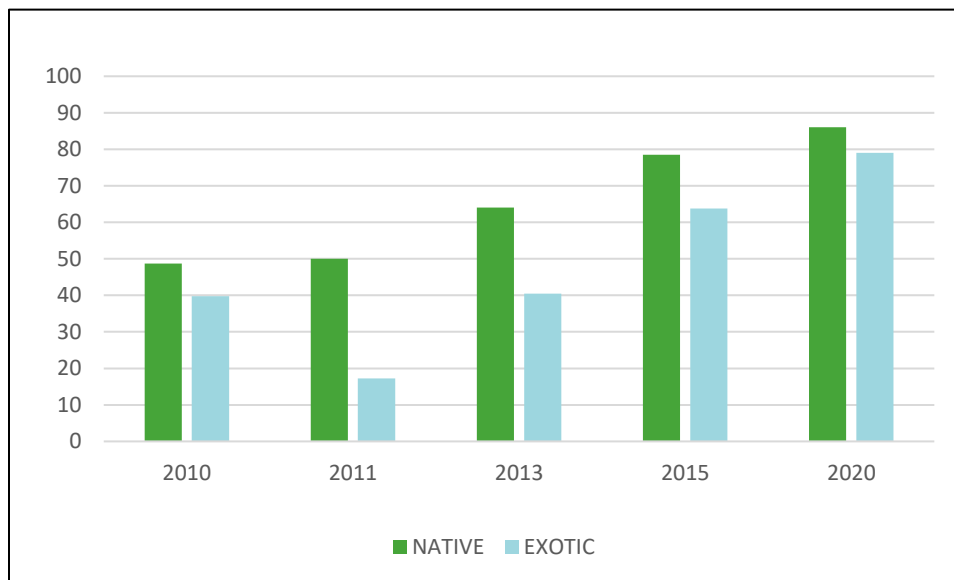
C. RESULTS

Two plots, SM-02 and SM10-03, were not monitored in August 2020. These plots have been rigorously mowed and are no longer suitable for monitoring. As a result, these two edge plots have been removed from the data analysis for all monitoring years. In this way, averages across plots and over time, can still be made. With one edge plot and three island plots remaining, comparison of plot types is no longer feasible.

Overall native cover has increased by 7%, since 2015, for the remaining four plots. Native shrub and forb cover have increased, 9% and 2% respectively. However, overall native grass cover has gone down by 7%. In summary, native forbs collectively persevere while native grass cover is struggling. Shrub cover is slowly increasing but remains a minor component of these plots.

Overall exotic cover in the last five years, has increased by 15% (Figure 15). Exotic forb cover increased by only 1% while exotic grasses made a big jump of 19%. Exotic forbs remain in the balance for now while exotic grass have established themselves with a steady proliferation.

Figure 15. St. Mary Visitor Center: Overall % Native and Exotic Cover, 2010-2020.

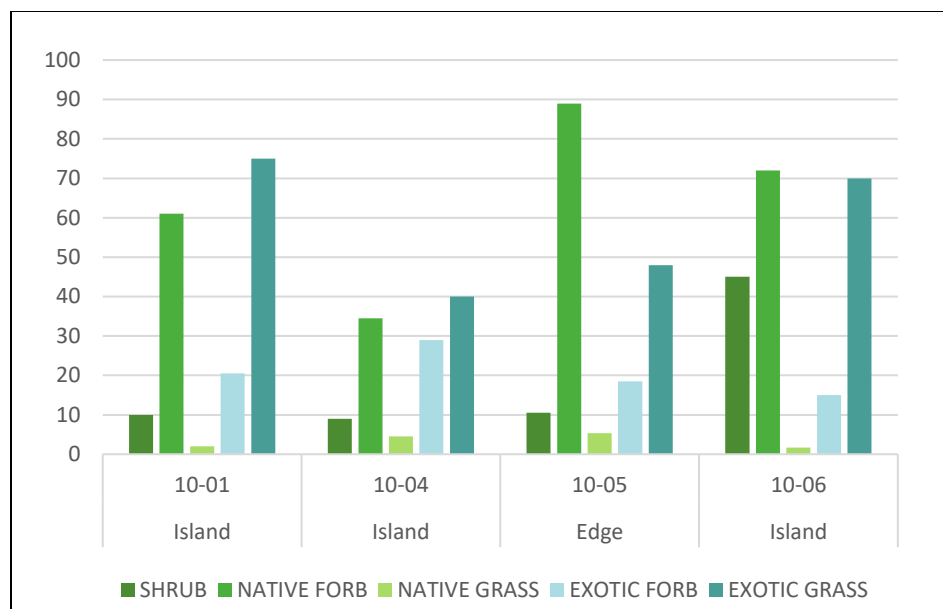


a. Shrubs and Trees

Shrubs remain a minor lifeform in these plots (Figures 16, 17). Overall shrub cover has increased in three of the four plots since 2015. With an increase of 9% since 2015, this boost is largely due to the island plot SM-10-06 where *Rosa woodsii* and *Symphoricarpos albus* continue to thrive. These two species continue to be the most successful of the seven shrub species found in the plots. *Arctostaphylos uva-ursi* and *Dasiphora floribunda* are making small gains in all four plots. *Amelanchier alnifolia* was observed for the first time in a trace amount in the edge plot, SM-10-05.

No tree species were observed in any of the plots.

Figure 16. St. Mary Visitor Center: % Cover of Lifeforms by Plot, 2020.



b. Native Forbs

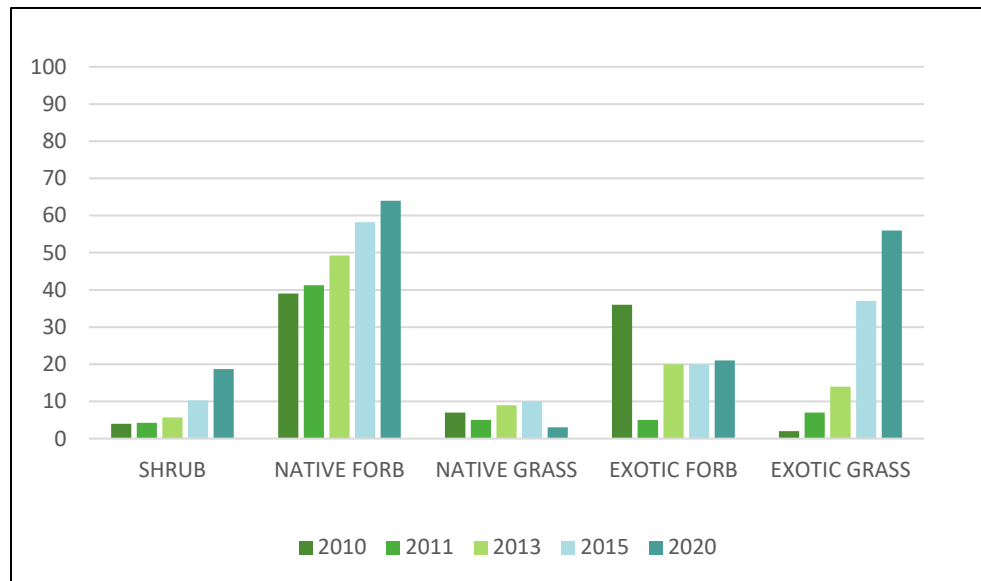
Native forbs, from the onset of this monitoring, have been a prominent and enduring presence in these plots. While cover has fluctuated by plot and individual species, overall cover across plots has been consistently increasing since 2010.

In 2020, 55 native forb species were observed across the four plots. Although overall native forb cover increased by 6% across all plots, individual plot cover was quite variable, with dramatic increase of 44% in plot SM-10-05 and decrease of 14% in SM-10-06. *Artemisia michauxiana*, *Equisetum laevigatum*, *Fragaria virginiana*, and *Solidago canadensis* are the main contributors to the increase in plot SM-10-05. A large drop in *Artemisia ludoviciana* is the main cause of native forb cover loss in SM-10-06. Being a rhizomatous forb that tolerates a wide range of conditions, cause of its decline is not easy to pinpoint. Increasing competition from other lifeforms may be a factor.

Like the gains and losses in cover of the two *Artemisia* species, cover of the Asteraceae family is variable across the plots. Of the 55 forb species observed in the plots, 17 were *Asteraceae* species. Species in this family appear to wax and wane, with no discernible pattern to date.

Equisetum spp. increased in three plots; most of the growth was occurring in cracks of the pavement adjacent to the plots. These cracks may provide a unique niche with water runoff for these rhizomatous forbs.

Figure 17. St. Mary Visitor Center: Overall % Cover of Lifeforms, 2010-2020.



c. Native Grasses

Native grass had the lowest overall cover of any lifeform at three percent. This represents a decrease of 7% from five years ago. Native grass cover went down in three of the four plots. In the eastern-most plot, SM-10-01, *Elymus trachycaulis*, *Festuca idahoensis*, *Koeleria macrantha*, and *Achnatherum nelsonii* covers all decreased, likely due to competition from exotic grasses. Native grass cover dropped by 16% in this plot from five years ago. SM-10-02 also suffered a 7% decrease in native grass cover, due to a decrease in *Koeleria macrantha*.

No individual species of native grass had an increase above 1% in any plot in 2020. It appears that native grasses, although they were both seeded and planted, have never thrived in this project. Native grass cover has consistently remained low, at or below 10%, since 2010. Again, this may simply be due to out-competition by rhizomatous, exotic grasses.

d. Exotic Forbs

Exotic forb cover has increased in three of the four plots since 2015. However, the average across plots only increased by 1%, largely due to a 17% decrease in exotic forb cover in plot SM10-01. In this island plot, *Medicago lupulina* had a sharp decrease in cover. This prostrate, annual legume was quite desiccated and had gone to seed, making it more challenging to monitor.

Centaurea maculosa cover has gone up an average of 4% across all plots. It was observed for the first time in plot SM-10-06, the western-most island plot. *Cirsium arvense* increased in the three plots it was observed before. *Linaria vulgaris* has increased by 1% cover in the one plot it has been observed. *Cynoglossum officinale* was observed for the first time in plot SM-10-06. *Melilotus officinale* cover was down in 3 plots, while *Medicago lupulina* cover was variable across plots.

With the exception of spotted knapweed, exotic forbs have remained tempered since 2013. Many exotic forbs tend to be biennial or annual; conditions may dictate a more cyclical nature for this lifeform.

e. Exotic Grasses

While exotic grasses began with a 2% cover in 2010, they have steadily expanded over ten years. Exotic grasses increased in all four plots, notably from 37% overall cover in 2015 to 56% in 2020. This is the dominant lifeform in three of the four plots. *Elymus repens*, *Poa compressa*, and *Poa pratensis* increased in three of the four plots. *Bromus inermis* increased slightly in two plots. *Bromus tectorum* was only found in one plot at 0.1% cover. Although this annual grass was found in the other three plots in the past, it was not detected in these plots in 2020.

D. DISCUSSION

While native species are holding their own, exotic species have established a presence throughout this project. Many exotic forbs, such as *Medicago lupulina* and *Melilotus officinale* have exhibited cyclical populations and have not been a management priority. Of greater concern are *Centaurea maculosa*, *Cirsium arvense*, and *Linaria vulgaris*. Spraying and hand pulling should continue on a yearly basis in order to stay on top of these aggressive, perennial weeds.

Most striking in 2020 was the steady upward trend of exotic grasses in all four plots, three of which were island plots. *Elymus repens*, *Poa pratensis*, *Poa compressa*, and *Bromus inermis* are all rhizomatous exotic grasses that appear to be outcompeting native grasses. Treatment of grasses with deep roots such as *Elymus repens* is tricky; with mechanical treatment, the goal is to deplete or desiccate the rhizomes. If hand pulling is utilized, it needs to be a consistent and thorough effort. If weeding results in a lot of disturbance, perhaps it would be helpful to supplemental seed or plant after such treatment.

With the success of exotic rhizomatous grasses, it raises the question of using native rhizomatous grasses/graminoids to even the playing field. *Pascopyrum smithii* was the only rhizomatous native grass that germinated from seed or was planted. It was found in trace amounts in earlier years but has since disappeared. *Juncus balticus* and *Carex obtusata* were seeded but never germinated; these would not have been competitive against the likes of *Elymus repens*. *Elymus lanceolatus* was not included in the original seeding and planting. It is not overly common and does not always fare well with heavy exotic competition, but it might be considered for such projects in the future.

Although the St. Mary Visitors Center is a high use area, foot traffic through any of the remaining plots does not appear to be an issue yet. Weed management is critical to establishing, maintaining, and recruiting a diversity of native plants. This diversity, in turn, will be more resilient to variables such as precipitation, competition, wind, or future trampling.

These plots should be monitored in 2025, fifteen years after restoration.

V. BOWMAN LAKE ACCESS ROAD MONITORING: 2020

A. INTRODUCTION

As park visitation increases, the North Fork district has experienced a parallel trend in crowded roads, parking, campgrounds, and water access. At Bowman, the access road to the lake passed through the popular campground and day-use parking areas. To alleviate congestion, the lake access road was re-routed through the picnic area to the south. The road construction for this re-route took place in August 2019. Bowman Campground sits at an elevation 4030' in a *Pinus contorta/Vaccinium caespitosum* forest community. Soils are well-drained silty loam or loam surface layers high in volcanic ash over silty clay loam glacial drift subsoils (Dutton 2001). Prior to construction, native plants were salvaged in the swath of forest and open picnic area that lay within the new roadbed corridor. These native plants were dug up in “clumps” and staged nearby until they could be re-planted a few weeks later within the old roadbed. Approximately 690 ft² of native plant material was salvaged. The old roadbed was converted into a walking path with both sides planted with 1145 units of native conifer, shrub, forb, and grass nursery stock. This planted area is 5460 ft². The old roadbed did not have any soil added to it; it was scarified with a grader ripper prior to planting in September 2019. On October 15th, this revegetation area was supplemented by broadcast seeding 1396 grams of native conifer, shrub, forb, and grass species (Table 6). Many social trails have become well established between the campground, parking areas, and foot of the lake. Some of these social trails were seeded and blocked with downed trees in order to discourage foot traffic through the revegetated area.

This revegetation project is being monitored due to the notable impacts on resources in the North Fork area. The goals of this monitoring are the following:

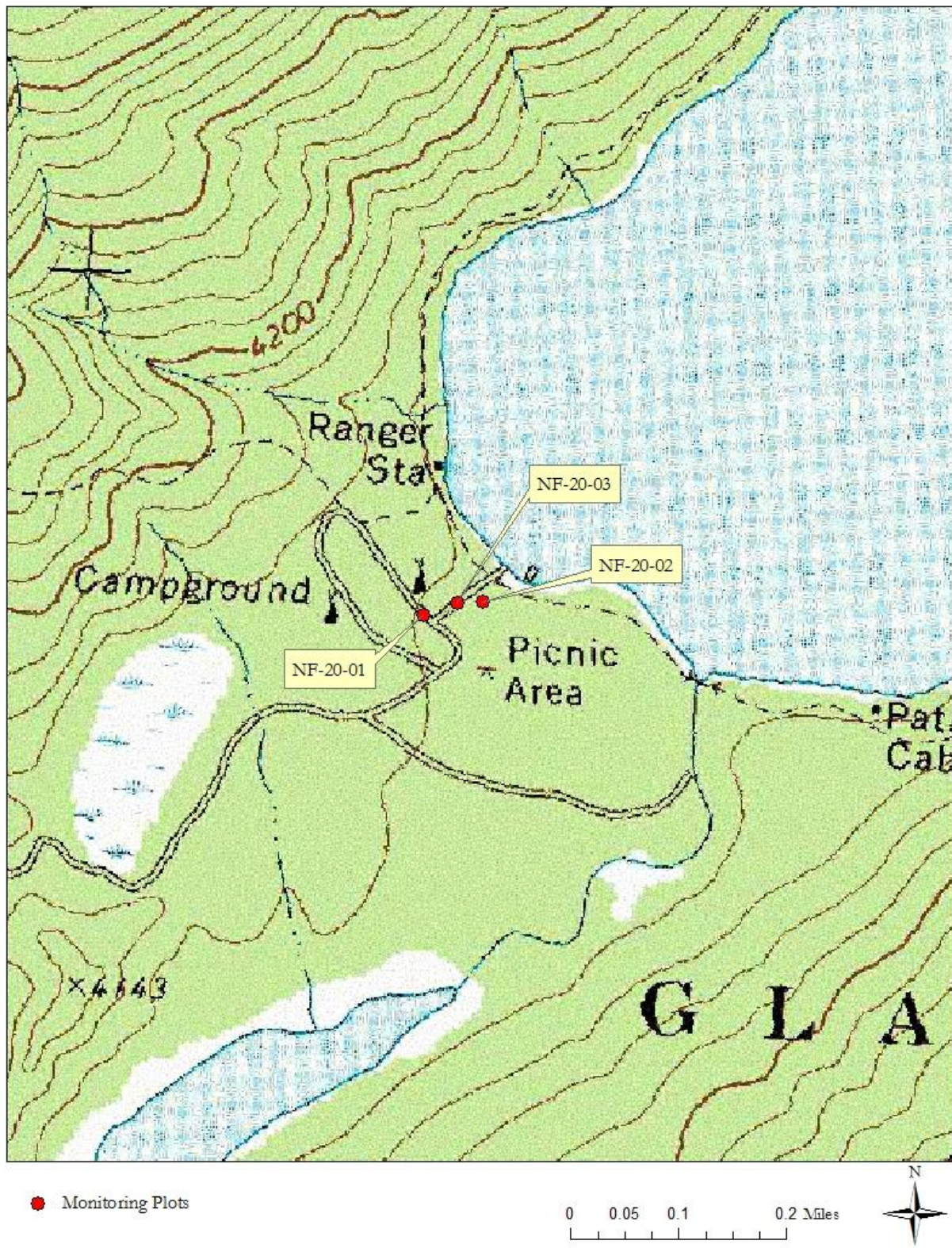
1. Evaluate the effectiveness of salvage plantings as a revegetation method.
2. Evaluate native species composition and cover over time.
3. Monitor the presence of exotic grasses and forbs in a high use area of the park.

B. METHODS

Monitoring plots within the revegetated roadbed were established and read in September 2020. This monitoring date allowed native seed that was sown in October 2019 time to germinate and grow. Three plots, 1m x 12.5m, were installed with nails placed in the lower left and upper right corners as facing the lake. Level II monitoring was performed, with native species being source-identified as salvaged, planted, seeded, or natural regeneration. Canopy cover was calculated for each species with a trace given for cover less than one percent. For our reference, one percent was equivalent to one ¼ m² plot frame. Exotic forbs and grasses were identified and assigned canopy cover. Photos were taken from each end of the plot for reference and qualitative documentation.

The revegetation site is slightly more open on the western end next to the campground with a *Vaccinium caespitosum* and *Arctostaphylos uva-ursi* understory. Towards the lake, species such as *Picea engelmannii*, *Juniperus communis*, *Mahonia repens* close the surrounding understory in a bit more. The three monitoring plots are spread out along this path and capture potential variations in microclimates, soils, and visitor use.

Figure 18. Bowman Lake Access Road Revegetation: Plots installed in 2020.



C. RESULTS

Nearly one year after this revegetation effort, salvaged, planted, seeded, and natural regeneration of native species were all observed in all three plots. As expected, salvaged and planted material were visually evident and most represented in the data, though overall cover of any one species was quite low.

Salvaged

In the monitoring plots, salvaged plants comprised 51 percent of all source-identified species. *Picea engelmannii*, *Vaccinium scoparium*, and *Potentilla gracilis* had the highest overall salvage cover at 0.5, 1.35, and 0.8 percent, respectively. Salvaged *Linnaea borealis* was captured in all three plots with just over 0.2 percent cover. Salvaged *Mahonia repens*, *Antennaria rosea*, and *Fragaria virginiana* had traces in all three plots.

Based on observations during salvage, common forest species were *Picea engelmannii*, *Vaccinium caespitosum*, *Mahonia repens*, *Linnaea borealis*, and *Calamagrostis rubescens*. The dominant species salvaged from the picnic area included *Arctostaphylos uva-ursi*, *Vaccinium caespitosum*, *Antennaria rosea*, *Fragaria virginiana*, *Achillea millefolium*, and *Potentilla gracilis*. Exotic grasses and *Veronica officinalis* and *Prunella vulgaris* were also present, though some attempt to weed them was made. This picnic area was very open and maintained like a lawn. Being mostly herbaceous material with fine, shallow roots, these salvage mats were more intact than the forest salvage. Salvaged mats from the picnic area were mostly planted on the western, more open end of the revegetation site.

Planted

Larix occidentalis had the highest overall cover, at 6.1 percent, for any species captured in the monitoring plots. These larch seedlings were grown in 1-gallon containers and most were 2-3 feet tall when planted. Larch Needle Cast (*Meria laricis*) was observed on many of these trees. Being deciduous conifers, they should recover since low summer rainfall decreases the likelihood of recurring infection. Although twelve *Picea engelmannii* were planted from 1-gallon containers, none were captured in the plots.

Oryzopsis asperifolia that was planted had the highest cover of any source-identified grass species, at 1.2 percent. *Carex* sp. was captured at 0.2 percent cover. Unfortunately, *Poa pratensis* was growing with this *Carex* and had not been weeded out in the nursery. *Spiraea betulifolia*, *Symphoricarpos albus*, and *Fragaria virginiana* had 0.5, 0.3, and 0.5 percent cover, respectively. All other planted species had individual cover below 0.3 percent.

Seeded

Of the 19 species that were seeded, four were observed in the plots. Shrubs, forbs, and grasses were seeded. Any species that had germinated was very small. Germination of some species, especially shrubs, may still occur over time. *Festuca occidentalis* seedlings were evident in trace amounts in all three plots. *Amelanchier alnifolia* seedlings had just put out their first true leaves and had a trace cover in two plots.

Natural Regeneration

Natural regeneration was evident, though minimal. *Vaccinium scoparium*, *Achillea millefolium*, *Chamerion angustifolium*, *Calamagrostis rubescens*, *Elymus glaucus*, and an unknown grass were observed in trace amounts. This seed source may have come from soil in the old roadbed, salvaged mats, or dispersed from the surrounding forest.

Exotic Grasses and Forbs

Six exotic grass species and eight exotic forb species were found in the plots. Individual cover was 0.1 percent or less. These exotic species may have been in the immediate seed bank, inadvertently salvaged as plants, dispersed as seed by humans or wildlife, or brought in with nursery stock. The revegetation site is paralleled by the new foot path that connects the popular campground and lakeshore. This foot path may be a vector for seed of exotic grasses and forbs, as the old road may have been.

Figure 19. Bowman Lake Road, Lifeform Percent Cover by Plot, 2020.

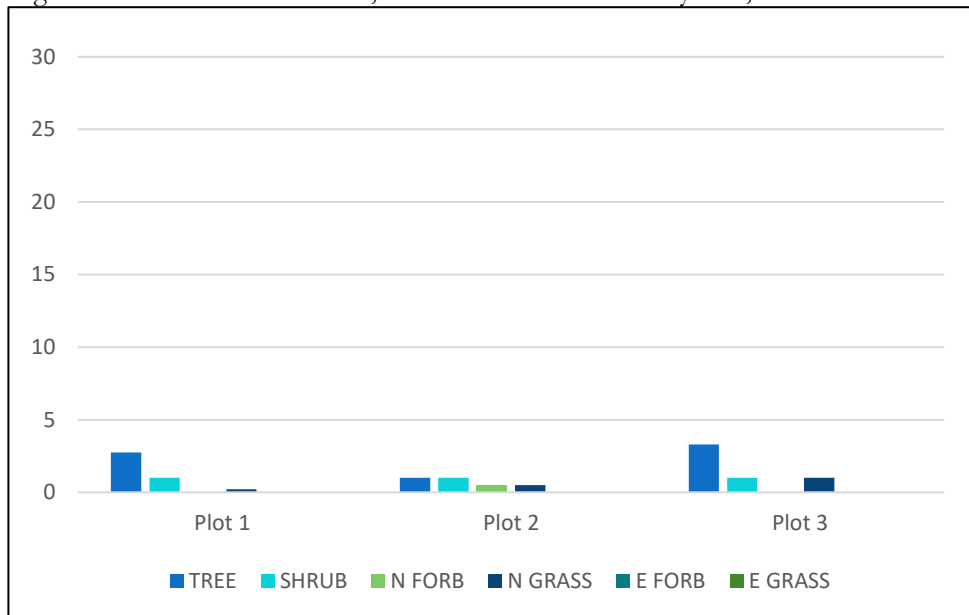


Table 6. Bowman Lake Road Revegetation Project: Seed Prescription

		NF-20-01	NF-20-02	NF-20-03
		2020	2020	2020
	source*	0.25m ² =1%		
TREE		2.75	1	3.3
<i>Abies lasiocarpa</i>	(sal)	0.15	T	
<i>Larix occidentalis</i>	(p)	2.5	0.6	3
<i>Picea engelmannii</i>	(sal)	T	0.2	0.3
<i>Pinus contorta</i>	(sal)	T		
SHRUB		1	1	1
<i>Amelanchier alnifolia</i>	(sal)		T	T
<i>Amelanchier alnifolia</i>	(s)		T	T
<i>Arctostaphylos uva-ursi</i>	(p)			T
<i>Arctostaphylos uva-ursi</i>	(sal)	0.25		
<i>Juniperus communis</i>	(sal)		0.1 (dead)	
<i>Linnaea borealis</i>	(sal)	T	T	0.2
<i>Mabonia repens</i>	(p)		T	
<i>Mabonia repens</i>	(sal)	T	T	T
<i>Rhamnus alnifolia</i>	(sal)	T		
<i>Rosa woodsii</i>	(sal)		T	T
<i>Rubus pubescens</i>	(sal)	T		

<i>Shepherdia canadensis</i>	(p)			T
<i>Spiraea betulifolia</i>	(p)	0.25		0.25
<i>Spiraea betulifolia</i>	(sal)	T	T	
<i>Symphoricarpos albus</i>	(p)	T		0.3
<i>Symphoricarpos albus</i>	(sal)	T	T	
<i>Vaccinium caespitosum</i>	(sal)	0.35	0.75	0.25
<i>Vaccinium membranaceum</i>	(sal)		T	
<i>Vaccinium scoparium</i>	(r)		T	
<i>Vaccinium scoparium</i>	(sal)	T		T
NATIVE FORB		T	0.5	T
<i>Achillea millefolium</i>	(r)	T		
<i>Achillea millefolium</i>	(sal)	T	T	
<i>Antennaria rosea</i>	(p)	T		T
<i>Antennaria rosea</i>	(sal)	T	T	T
<i>Arnica cordifolia</i>	(p '20)	T	T	T
<i>Cardamine pensylvanica</i>	(*)			T
<i>Chamerion angustifolium</i>	(r)	T		
<i>Chamerion angustifolium</i>	(sal)		T	
<i>Cornus canadensis</i>	(sal)	T	T	
<i>Eurybia conspicua</i>	(p)	T		
<i>Fragaria vesca</i>				
<i>Fragaria virginiana</i>	(p)	T	0.5	T
<i>Fragaria virginiana</i>	(sal)	T	T	T
<i>Fragaria virginiana</i>	(s)			
<i>Galium boreale</i>	(sal)		T	
<i>Geum macrophyllum</i>	(sal)			T
<i>Geum macrophyllum</i>	(p)	T		
<i>Heuchera cylindrica</i>	(p)		0.25	
<i>Lupinus sericea</i>				
<i>Penstemon confertus</i>	(sal)	T		T
<i>Potentilla glandulosa</i> (?)	(s)	T		
<i>Potentilla gracilis</i>	(sal)	0.8	T	
<i>Senecio pseud aureus</i>	(sal)		T	
<i>Solidago canadensis</i>	(s)	T		
<i>Solidago canadensis</i>	(p)			0.25
<i>Symphyotrichum laeve</i>	(sal)			T
<i>Tiarella trifoliata</i>	(p)		T	0.1
NATIVE GRASS		0.2	0.5	1
<i>Agrsotis scabra</i>				
<i>Calamagrostis rubescens</i>	(r)			T
<i>Calamagrostis rubescens</i>	(sal)	T		0.1

		NF-20-01	NF-20-02	NF-20-03
		2020	2020	2020
	source*	0.25m ² =1%		
<i>Carex concinnoides</i>	(sal)	T		
<i>Carex rossii</i>	(p)			0.1
<i>Carex sp.</i>	(p)	T		0.2
<i>Carex sp.</i>	(sal)		T	
<i>Elymus glaucus</i>	(r)			0.1
<i>Festuca occidentalis</i>	(p)	T		T
<i>Festuca occidentalis</i>	(sal)	T	T	
<i>Festuca occidentalis</i>	(s)	T	T	T
<i>Oryzopsis asperifolia</i>	(p)	0.2	0.5	0.5
<i>Unknown grass</i>	(r)		T	
EXOTIC FORB				
<i>Cirsium arvense</i>		T		
<i>Cirsium vulgare</i>				
<i>Hieracium sp.</i>			T	
<i>Leucanthemum vulgare</i>				T (pulled)
<i>Melilotus sp.</i>		T	T	T
<i>Plantago major</i>		T		
<i>Prunella vulgaris</i>		T		T
<i>Taraxacum officinale</i>		T		
<i>Veronica officinalis</i>		T	T	
EXOTIC GRASS				
<i>Agrostis stolonifera</i>		T	T	
<i>Dactylis glomerata</i>		T		
<i>Elymus repens</i>		T	0.1	0.1
<i>Phleum pratense</i>		T		
<i>Poa compressa</i>			T	
<i>Poa pratensis</i>		T	0.1	0.1

(p) = planted

(s) = seeded

(r) = regen

(sal) = salvaged from the area where the new road was built

(*) = came in on nursery stock

D. DISCUSSION AND RECOMMENDATIONS

With four different sources of plant material at play in this revegetation site, it will take some time for success to come into focus. For example, some seeded species may not have germinated yet or some salvaged shrubs may appear alive but lack a sufficient root system to persist. Salvaged forest mats included a substantial *Vaccinium* spp. component that was not represented in planted form. It will be interesting to see if survival of a salvaged rhizomatous shrub such as *Vaccinium* will continue to survive as it has so far. Like nature, revegetation plantings are in a state of flux. This first monitoring event provides a baseline for future, long-term trends.

While it was fairly straightforward to distinguish seeded species from natural regeneration and planted species from salvaged plants, this may prove slightly more challenging during later monitoring events.

Salvaging native plant material during a construction project is a dynamic process that requires a window of opportunity and many logistical steps. While this process is labor intensive, salvaging has many potential benefits. Salvage mats often have a diversity of species, and therefore odds are increased that something in the mix will survive. At the very least, salvaged material is a placeholder, a vegetative presence that discourages trampling feet. Simply providing this barrier allows natural regeneration and germinating seed to have better odds of survival. These salvage mats also contribute native soil, mycorrhizae, lichen and moss components, and a native seed bank to the revegetation area. Granted, weed seeds may also be present.

Revegetation and nursery crews will want to be mindful of weeding salvage mats and nursery stock prior to planting. Supplemental watering of the revegetation area the following summer seems especially prudent when July and August precipitation is low.

Ideally, topsoil from the salvaged site would have been transferred by the road construction crew to the revegetation site. This was suggested but not implemented due to a tight timeline. The old roadbed had been scarified with heavy equipment and was quite chunky at planting time. The soil surface is now quite hardened and exposed. With time, perhaps a natural accumulation of forest duff will provide some organic matter to this revegetation site.

VI. TWO DOG FLATS HERBICIDE ASSESSMENT PILOT PROJECT PLAN

A. BACKGROUND AND PURPOSE

The Two Dog Flats grasslands lie in the St. Mary Valley on the eastern edge of Glacier National Park. This fescue-dominated community provides a unique beauty and important ecological function in the park. A diversity of native plants provides a spectacular wildflower display here while a diversity of wildlife provides many photo opportunities for visitors along the Going-to-the-Sun road corridor. These grasslands provide important forage for ungulates such as elk, bighorn sheep, white-tailed deer, and mule deer. Black bears, grizzly bears, coyote, bald eagles, and ground squirrels also utilize this habitat.

This diversity of flora and fauna is being threatened by invasive weeds, most notably, spotted knapweed (*Centaurea maculosa*). This noxious species been treated with herbicide since the mid-1990s and is a management priority throughout the park. The success of this weed may be enhanced by the root-secreting phytotoxin, catechin. This allelopathic chemical has shown to inhibit the growth of plants around it (Thorpe 2009). An aminopyralid-based herbicide is currently being used for spotted knapweed control in these meadows. The effectiveness of this herbicide treatment, along with its long-term impacts to native plant communities and soil health are important questions for park management to address in this study. This project will also examine the restoration of native plant material into these weed-treated disturbances.

Restoration techniques will include hand seeding and planting of containerized native grass and forbs species.

Restoration of such an altered landscape is complex. Fire regimes have been suppressed and may be allowing for tree and shrub encroachment into the meadows. Timothy grass (*Phleum pratense*) was purposefully introduced for livestock grazing and is abundant in Two Dog Flats. Following any reduction of spotted knapweed, this aggressive grass must also be kept in check. The persistence of allelochemicals in the soil from spotted knapweed is an unknown factor in restoration success. Furthermore, the future re-introduction of bison through a collaborative effort with the Blackfoot tribe will introduce yet another variable into the equation for grassland health and restoration.

The three main goals of this study are:

1. To establish research plots to determine effectiveness of herbicide treatments on spotted knapweed in Two Dog Flats.
2. To determine the health of the soils.
3. To experiment with various treatments using native plant materials to fill in niches after weed control.

Soil health is the foundation of any functional native plant community. Healthy soils affect plant productivity and reproduction, invasive plant establishment, erosion, water quality, water holding capacity, wildlife habitat, and carbon sequestration. Soil health is evaluated through physical, chemical, and biological quality indicators. Most valuable to this study would be bulk density (soil compaction), pH, conductivity, total carbon, phosphate and nitrogen, mycorrhizae, and microorganisms (NRCS 2015).

During the course of this study, other questions may be addressed that relate to grassland health and restoration practices. A decrease in native plant species in the *Asteraceae* and *Fabaceae* families has been anecdotally observed during seed collection in Two Dog Flats. *Lupinus* and *Gaillardia*, genera of these two plant families, have shown a resistance to the chemicals in spotted knapweed (Weir 2006). Their presence in these grasslands is valuable for functional and aesthetic reasons. Where herbicide has been applied with a boom sprayer near the road, the abundance of *Selaginella*, mosses, and lichens appears to have declined. These

surface covers play an important role in soil health for these windy east-side meadows. Is herbicide use affecting the cover and diversity of these native species? An increase in shrub cover has been documented by the Grassland Monitoring Project for all plots read in 2018-2019 within the St. Mary Valley. Will tree encroachment follow? It is hoped that this study will provide additional qualitative documentation for these concerns.

Momentum for this project was inspired by Robin Tyser's research in Two Dog Flats between 1992-1995 (Tyser 2004). His study evaluated a clopyralid-based herbicide and seeding treatments on the restoration success of native grassland species. Although these plots, alongside the road, will not be re-read, this research serves as a valuable reference. In herbicide-treated plots, species diversity was lower and non-native grasses were dominant. Tyser was curious about the effect of the seed bank (native and non-native) on restoration efforts. He encouraged the use of native grass species that could provide high canopy cover against non-native grasses.

B. PROPOSED METHODS

During a reconnaissance trip on September 29, 2020, the furthest east meadow of the Two Dog Flats complex was assessed for overall condition, spotted knapweed abundance and distribution, and to plan for logistics for this pilot project (Figure 20). It was determined that the upper edge of this meadow would be an advantageous starting point for this project, with the strategy of moving from the top of the meadow, which receives sporadic spot spraying with herbicide, towards the road edge, where herbicide treatment occurs annually via a boom sprayer. Restoration would occur on a small scale, at least initially, while efficacy of each treatment is assessed.

An area approximately 100m² near the northwest corner of the meadow was identified as a potential study site (Figure 21). This spot contained high spotted knapweed cover, but maintained a diversity of native forbs and grasses, with lower timothy cover than the surrounding areas. An area with low exotic grass cover was chosen so that in the interim following herbicide application and prior to seeding, the opened niches will be less likely to be rapidly colonized by non-native grasses. Additionally, existing native plants may have the opportunity to expand into these open spaces, and native seeds may be more likely to be present in the seed bank.

Three parallel 52-meter transects will be installed in this area in the spring or early summer of 2021, prior to herbicide and hand pulling treatments. At every five meters along each of these transects, 1m² areas will be flagged for application of one of the treatment regimes.

Five treatments are proposed, incorporating herbicide application, hand pulling and/or seeding. In areas treated with herbicide, non-native forb species will be spot sprayed. Each treatment will be repeated once within each of the transects and will occur a total of six times throughout the study site. The location of each treatment along the transect will be randomized. The five different treatments are as follows:

1. Herbicide + seed
2. Hand pulling + seed
3. Herbicide + hand pulling + seed
4. No treatment + seed
5. Control

Treatment areas will be marked with color-coded flags at all four corners. The 1m² treatment areas will start at 5 meters and will repeat every 5 meters until 50 meters and will be placed on the west (upslope) side of the transect line (Figure 22). Before each area is treated, a ¼ m² (0.5 m x 0.5m) plot will be read for vegetative cover by species in the center of the treatment area. This will provide a ¼ m treated buffer on all

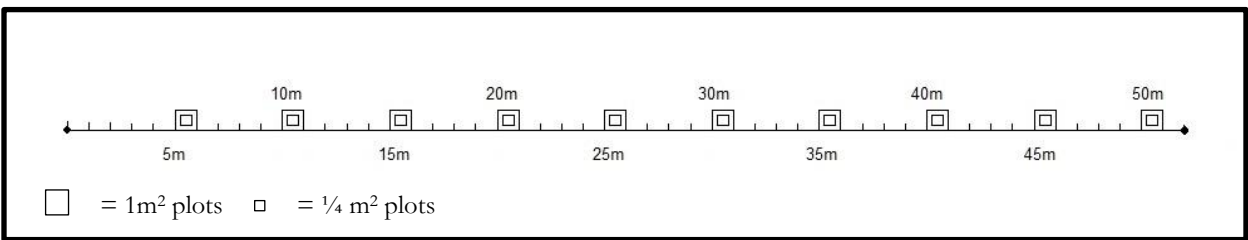
Figure 20. Two-Dog Flats Restoration: Location of Proposed Study Area.



Figure 21. Two-Dog Flats Restoration: Proposed Study Transects.



Figure 22. Two-Dog Flats Restoration: Proposed transect and plot layout.



sides of the plot (Figure 22). Plot locations avoid the ends of the transect which tend to get more trampled. In each plot, all species will be identified to species and will be given an estimated ocular percent cover. Ground cover will also be assessed, with special attention given to biocrust components, such as moss, lichen and *Selaginella*, to determine if herbicide application will have a detrimental effect on these species in the future. Additionally, four soil cores will be collected on each transect. One of these cores, of known volume, will be analyzed for bulk density, to assess soil compaction, and three composite samples per transect will be collected for analysis as a baseline for pesticide residue.

Seeding of native grasses should occur in the fall of 2021, after late-spring/early summer herbicide application (spot spraying) with Milestone® (aminopyralid). Grasses can be seeded as a dormant planting (in the late fall or early winter) in the year of application. Grasses should be seeded when soil temperatures are low enough to ensure that the seeds do not germinate and emerge after application to allow for some aminopyralid degradation. It is recommended in areas with no to very little summer rain to wait a year before planting forb seeds. If it is decided to supplement with native forbs, they should be seeded in the spring of 2022 (Dow AgroSciences).

The suggested native grass seed mix should include a mix of several of the following species, depending on availability: *Festuca idahoensis*, *F. campestris*, *Koeleria macrantha*, *Danthonia intermedia*, *Achnatherum nelsonii*, *A. richardsonii*, *Poa secunda*, *Pseudoregneria spicata*, *Carex petasata*, *C. rossii*, *C. filifolia* and *C. obtusata*. Idaho and rough fescue (*Festuca idahoensis* and *F. campestris*) are some of the best candidates for seeding, as these meadows are generally characterized as fescue grasslands. Both these grasses are bunchgrasses that should establish well and commandeer space.

Supplemental follow-up seeding with forbs should include species that are considered more herbicide-tolerant, since many forbs are susceptible to the detrimental effects of herbicide. Studies in northwest Montana have identified species that are more tolerant to treatment with Milestone® (Rice, 1997; 2012 Dow AgroSciences LLC). From these studies, suggested native forb species for seeding in this project includes *Monarda fistulosa* and *Fragaria virginiana*. Other potential species that occur in the area and may be more tolerant to Milestone® include *Penstemon confertus*, *Geranium viscosissimum*, *Heuchera cylindrica*, *Galium boreale* and *Potentilla glandulosa*. In subsequent years, if time and funding permit, additional native forbs may be added for diversity.

Seeded species may fill in niches vacated by exotic forbs killed by spraying. Pre-existing native forbs and grasses may also expand into some of these areas after spraying. Non-native grasses can be problematic with open niches created by herbicide application, and this area was purposely chosen since it has lower non-native grass cover than surrounding areas, but exotic grass species are still present within the study area.

Plots should be re-read the subsequent spring or early summer (2022). Data will be analyzed, and if any trends appear, recommendations may be reported. Treatments should continue as prescribed in each 1 m² area and plots should be re-read annually as time and funding permit.

VII. WHITEBARK AND LIMBER PINE RESTORATION PROJECT

A. INTRODUCTION

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, 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. Continued 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 initial funding to collect, grow seedlings from collected seeds, and plant seedlings at appropriate sites within the park. These seedlings have been planted in an effort to restore the ecosystem with presumed disease-resistant trees. These efforts have continued, with whitebark and/or limber pine seedlings being planted most years within the park. Limber pine seedlings have been planted at 21 sites on the east side of the Park and whitebark pine seedlings have been planted at 21 sites, 17 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.

A protocol has been implemented by U.S. Forest Service nurseries whereby potential rust-resistant seedlings are tested for genetic resistance. In 2009, Glacier National Park had the opportunity to join this study in order to determine genetic resistance in our whitebark pine “plus trees”. Since then, collection efforts have centered on caging from trees that meet requirements for the study. Many recent plantings consist of seedlings that were collected from trees with some level of known genetic resistance.

1. *Limber Pine Restoration*

Limber pine seedlings have been planted at 21 sites, 15 of which continue to support live trees in monitoring plots (Table 7, Figure 23). A total of 10,209 seedlings have been planted in the park between 2002 and 2016. No limber pine seedlings were planted from 2017 to 2020. 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.

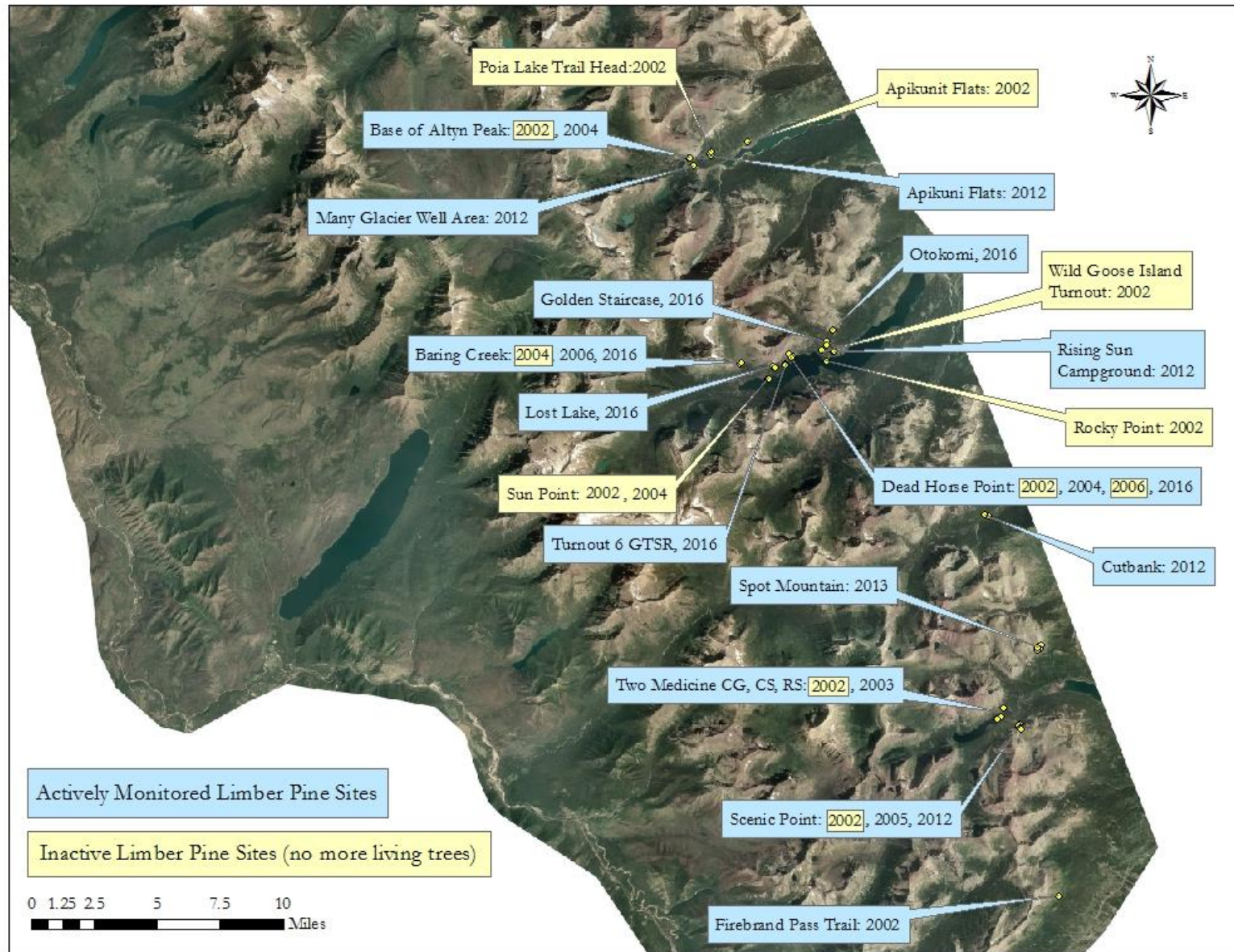
Several planting techniques to enhance health and survival have been utilized and refined over the 19 years of 5-needle pine restoration in Glacier. The use of microsites, either existing or constructed, is now almost universal in all plantings. Care is taken to plant during favorable weather conditions 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 in order to target seeds from the most resistant trees.

Table 7. Limber Pine Monitoring Plot Establishment to Date.

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

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Figure 23. Limber Pine Seedling Monitoring Sites



2. *Whitebark Pine Restoration*

Whitebark pine seedlings have been planted at 24 sites between 2000 and 2020, all of which continue to support live trees (Figure 24; Table 8). A total of 24,841 seedlings have been planted in the park between 2000 and 2020. 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, above the limber pine planting site on Otokomi Mountain, and in 2020 at Sperry Chalet. 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 8). 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 20 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.

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

Figure 24. Whitebark Pine Seedling and Seed Monitoring Sites.

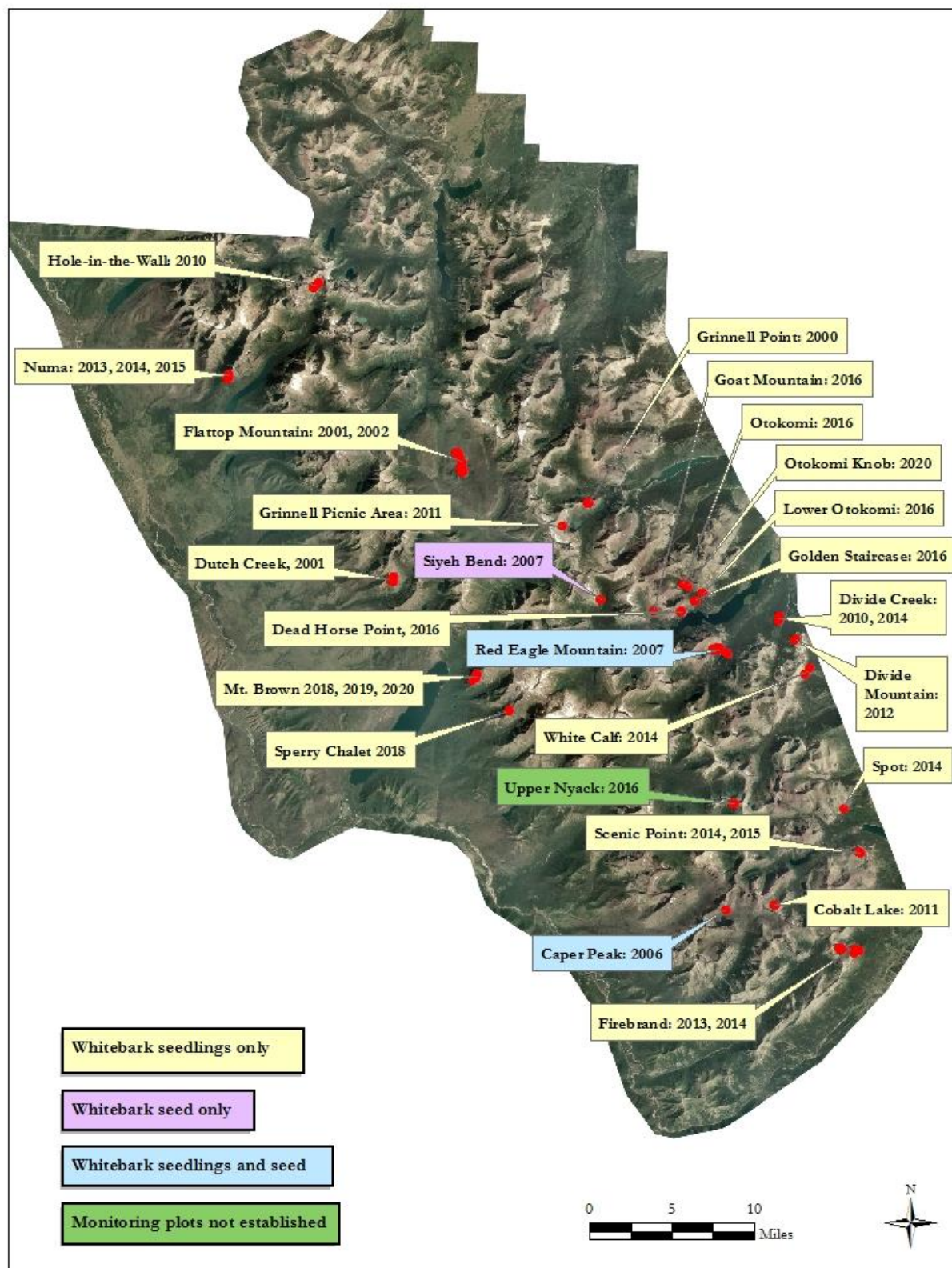


Table 8. Whitebark Pine Seedling Monitoring Plot Establishment to Date.

<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	162	20%
Mount Brown	2018 (fall)	3	443	1	443	110	25%
	2019 (fall)	4	580	1	580	117	20%
	2020 (fall)	1	210	1	210	44	21%
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%
Otokomi Knob	2020 (fall)	2	290	1.0	290	67	23%
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
Whitecalf Mtn.	2014 (fall)	2	657	1.2	788	146	19%
Overall Total		134			24,841	5,209	21%

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B. METHODS

1. *Seedling Monitoring Plots*

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

Plot center is permanently marked with a large nail and usually 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 microsite is located in relation to the tree 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. Rarely, 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*

Direct seedling has only taken place in the Park at two sites in 2007. Please see previous reports (2007 to 2019) for a description of monitoring of direct seed transects.

C. RESULTS AND DISCUSSION

1. Limber Pine Seedling Results

Limber pine seedlings have been planted at 21 sites, 15 of which continue to support live trees in monitoring plots (Figure 23). Table 9 is a summary of all the limber plantings to date indicating the number of trees that have survived to date, percent survival, and the average height and width for seedlings at each site. Overall survival rate of monitored seedlings across all projects is 17%, as of the latest monitoring event for each site.

Only one Limber Pine planting site, Scenic Point planted in the fall of 2005, was due for monitoring and was monitored in 2020. No limber pine seedlings were planted in 2020.

Table 9. Parkwide: Survival, Height and Width of Remaining Live Limber Pine Seedlings as of Latest Monitoring Event, 2002 – 2020.

Site	Year Planted	Season Planted	Last Year Monitored	# of Trees Monitored	# of Trees Survived	% Survival	Monitoring Year	Average	
								Height	Width
Various	2002	fall	2004	547	0	0%	2	N/A	N/A
Total Year 2						0%			
Dead Horse Point	2006	spring	2009	20	0	0%	3	N/A	N/A
Baring Creek	2016	spring	2019	29	14	48%	3	14.0	16.6
Dead Horse Point (lower)	2016	spring	2019	64	4	6%	3	12.8	14.5
Dead Horse Point (upper)	2016	spring	2019	66	8	12%	3	11.9	15.5
Golden Staircase	2016	spring	2019	42	7	17%	3	13.7	14.9
Lost Lake	2016	fall	2019	64	42	66%	3	12.5	14.3
Otokomi (lower bench)	2016	spring	2019	52	20	38%	3	11.8	14.8
Turnout 6 (GTSR, St. Mary)	2016	spring	2019	45	14	31%	3	13.9	15.5
Total Year 3				382	109	29%	Ave size:	12.9	15.1
Cutbank	2012	spring	2017	82	23	28%	5	11.4	10.6
Apikuni Flats (Spring)	2012	spring	2017	79	20	25%	5	15.0	8.8
Apikuni Flats (Fall)	2012	fall	2017	49	9	18%	5	11.1	7.4
Rising Sun CG	2012	spring	2017	140	12	9%	5	12.8	13.8
Scenic Point (Spring)	2012	spring	2017	155	69	45%	5	10.7	9.5
Scenic Point (Fall)	2012	fall	2017	195	61	31%	5	12.3	10.8
Many Glacier Well Area	2012	fall	2017	63	14	22%	5	15.2	14.4
Spot Mountain	2013	spring	2018	143	35	24%	5	10.3	11.3
Spot Mountain	2013	fall	2018	208	77	37%	5	10.3	9.4
Total Year 5				1114	320	29%	Ave size:	12.1	10.6
Baring Creek	2006	spring	2016	71	3	4%	10	24.3	22.3
Total Year 10				71	3	4%	Ave size:	24.3	22.3
Firebrand Pass Trail	2002	fall	2017	38	1	3%	15	87.0	135.0
Two Med Camp Store	2003	fall	2018	26	1	4%	15	70.0	74.0
Baring Creek	2004	spring	2019	92	0	0%	15	N/A	N/A
Base of Altyn Peak	2004	fall	2019	41	8	20%	15	33.4	49.0
Dead Horse Point	2004	fall	2019	53	0	0%	15	N/A	N/A
Sun Point	2004	fall	2019	55	0	0%	15	N/A	N/A
Scenic Point	2005	fall	2020	149	2	1%	15	21.0	40.5
Total Year 15				454	12	3%	Ave size:	52.8	74.6
Average Survival to Date				2568	444	17%			

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a. Fifteen-Year-Old Planting (Scenic Point)

The only site planted with limber pine seedlings in 2005 was Scenic Point. On September 29, 2005, seven hundred limber pine seedlings were planted in the lower Scenic Point Trail area (Figure 25). Six monitoring plots were established in October of that year, encompassing 149 trees and following 21% of planted trees. This area is a relatively open, rocky slope and has not burned.

By 2020, fifteen years after planting, only 2 trees (1%) continue to survive from these monitoring plots (Table 10). The surviving trees continue to be smaller than average 15 years after planting, which likely reflects the harshness of this site. Additionally, both whitebark and limber pine seedlings planted in unburned areas tend to not fare as well as those planted in burns.

Figure 25. Scenic Point: Limber Pine Seedling Monitoring Plots, Planted in 2005.

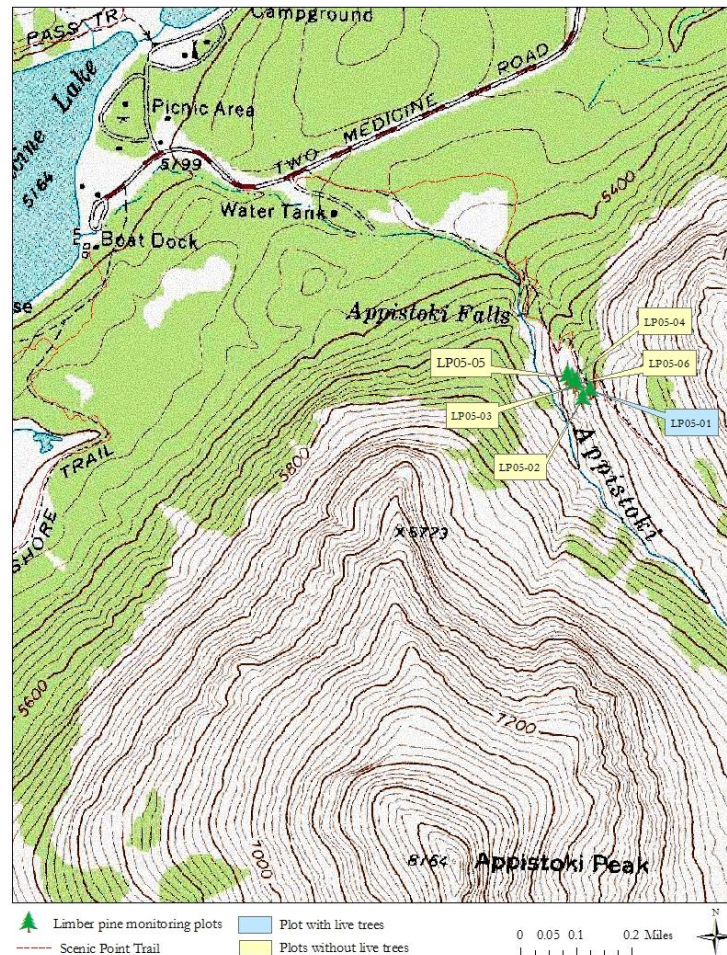


Table 10. Scenic Point: Survival, Height and Width of Limber Pine Seedlings.

<i>Monitoring Year</i>	<i>Years Post Planting</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>	<i>Average Height</i>	<i>Average Width</i>
2005	0	146	98%	*	*
2006	1	37	25%	*	*
2007	2	21	14%	*	*
2008	3	21	14%	*	*
2010	5	21	14%	14.5	13.1
2015	10	11	7%	13.6	21.3
2020	15	2	1%	21.0	40.5

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2. *Whitebark Pine Seedling Results*

Whitebark pine seedlings have been planted at 24 sites between 2000 and 2020, all of which continue to support live trees (Figure 24). Table 11 is a summary of all the whitebark plantings to date, indicating the number of trees that have survived, percent survival and average sizes of seedlings at each site. Overall survival for monitored whitebark pine seedlings planted in the park is 48%, based on the most recent monitoring event at each site.

Six Whitebark Pine planting sites were due for monitoring in 2020: Divide Creek, Grinnell Point, Hole-in-the-Wall, Mount Brown, Numa Lookout and Scenic Point. New whitebark pine seedlings were planted at Mount Brown and Otokomi Knob.

Further discussion in this report only reflects the sites monitored this year. Please see previous years' reports for details about previously monitored sites.

a. *Twenty-Year-old Plantings*

i. *Grinnell Point*

On September 2, 2000, 96 whitebark pine seedlings were planted on Grinnell Point immediately after the subsidence of the Grinnell Point Fire that year (Figure 26). This area was opportunistically planted during a post-fire helicopter operation. Seven plots were installed at the time of planting, encompassing all planted trees. This is the oldest monitored planting site for either whitebark pine or limber pine in the Park.

Due to its remoteness, Grinnell Point had not been monitored by Glacier National Park staff until 2015, fifteen years after planting, at which time 65% of trees were surviving at this site (Table 12). In 2020, twenty years after planting, survival had only dropped slightly, to 57%. As this is the oldest whitebark pine planting site in the Park, this is our only data point for twenty-year survival. However, this is a much higher survival rate than many other younger planting sites in the Park. This site is very exposed and wind-swept, resulting in trees that are showing krummholz growth patterns, where they are wider than tall. They are shorter on average than trees in some younger planting sites that are more protected, but they average the widest of all trees in the monitoring pool. Branches on some trees were all dead on the windward side. Several trees are also growing together at the base so that soon they will be indistinguishable as separate trees.

As in a few of our older plantings, blister rust has infected a few of these planted trees. Three trees had active cankers; two trees had only one canker, but one had more than 10 cankers and all lower branches were dead. All blister rust-infected trees were in one plot. Several other trees in multiple plots had multiple dead tips of unknown cause, and a few had a dead top. It is unknown whether this was caused by blister rust or not. Future monitoring will continue to ascertain the extent and potential spread of blister rust infection in this planting.

Table 12. Grinnell Point: Survival, Height and Width of Planted Whitebark Pine Seedlings.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height (cm)</i>	<i>Average Width (cm)</i>
2000	96	96	100%	*	*
2015	62	96	65%	53.8	66.7
2020	54	95**	57%	62.9	76.1

*Not measured in 2020

**Two trees merged at base - indistinguishable now, so now considered one tree

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Table 11. Parkwide: Survival and Average Height & Width for Whitebark Pine Seedlings from the Most Recent Monitoring Year.

Site	Year Planted	Season Planted	Last Year Monitored	# of Trees Monitored	# of Trees Survived	% Survival	Monitoring Year	Average	
								Height	Width
Grinnell Point	2000	fall	2020	95	54	57%	20	62.9	76.1
Sum/Average 20 year-old-trees				95	54	57%		62.9	76.1
Flattop Mtn. Spring 2001	2001	spring	2016	381	95	25%	15	82.5	50.7
Flattop Mtn. Fall 2001	2001	fall	2016	252	82	33%	15	85.7	66.5
Sum/Average* 15 year-old-trees				633	177	28%		83.8	57.0
Flattop Mtn. Fall 2002	2002	fall	2016	292	110	38%	14	72.6	61.4
Sum/Average 14 year-old-trees				292	110	38%		72.6	61.4
Caper Peak	2006	fall	2016	140	47	34%	10	35.7	32.7
Red Eagle - upper	2007	fall	2017	358	187	52%	10	72.8	63.6
Divide Creek (lower)	2010	fall	2020	265	235	89%	10	47.8	39.3
Hole-in-the-Wall	2010	fall	2020	162	35	22%	10	18.1	16.7
Sum/Average* 10 year-old-trees				925	504	54%		50.4	43.7
Divide Mountain	2012	fall	2017	226	125	55%	5	11.2	12.4
Firebrand Pass Area (upper)	2013	spring	2018	209	154	74%	5	13.8	14.0
Firebrand Pass Area (lower)	2013	fall	2018	387	207	53%	5	11.2	12.7
Cobalt Lake	2011	late summer	2016	108	6	6%	5	14.8	11.0
Numa Lookout	2013	fall	2018	179	64	36%	5	14.5	10.7
Grinnell Picnic Area	2011	late summer	2016	105	42	40%	5	18.6	21.6
Divide Creek	2014	fall	2019	222	157	71%	5	19.7	17.3
Firebrand Pass Area (lower)	2014	spring	2019	108	63	58%	5	16.5	16.9
Firebrand Pass Area (upper)	2014	fall	2019	159	4	3%	5	11.5	13.3
Numa Lookout	2014	fall	2019	120	41	34%	5	14.1	10.8
Scenic Point (upper)	2014	spring	2019	189	42	22%	5	11.9	10.6
Scenic Point (upper)	2015	fall	2020	68	21	31%	3	11.2	11.6
Spot Mountain	2014	spring	2019	36	2	6%	5	10.5	11.5
Whitecalf	2014	fall	2019	152	16	11%	5	9.8	10.5
Numa Lookout	2015	fall	2020	66	9	14%	5	11.9	9.4
Sum/Average* 5 year-old-trees				2334	953	41%		13.4	13.1
Dead Horse Point (upper)	2016	spring	2019	54	23	43%	3	15.1	18.8
Goat Mountain Slope	2016	spring	2019	34	21	62%	3	17.3	18.1
Golden Staircase (upper)	2016	spring	2019	59	42	71%	3	15.5	16.8
Otokomi (lower)	2016	spring	2019	101	76	75%	3	16.7	18.0
Otokomi (upper)	2016	spring	2019	65	55	85%	3	21.2	19.7
Sum/Average* 3 year-old-trees				313	217	69%		17.2	18.3
Mount Brown Lookout	2018	fall	2020	110	84	76%	2	16.3	14.2
Sum/Average 2 year-old-trees				110	84	76%		16.3	14.2
Red Eagle - lower	2007	fall	2008	55	55	100%	1	8.8	8.8
Sperry Chalet	2018	fall	2019	122	121	99%	1	12.5	12.6
Mount Brown Lookout	2019	fall	2020	117	81	69%	1	7.9	9.9
Sum/Average* 1 year-old-trees				294	257	87%		10.0	10.8
Otokomi Knob	2020	fall	2020	67	67	100%	0	12.9	13.1
Mount Brown Lookout	2020	fall	2020	44	44	100%	0	11.1	10.1
Sum/Average* 0 year-old-trees				111	111	100%		12.2	11.9
Overall Sum/Average Survival				5107	2467	48%			

*Height/Weight Averages are calculated weighted averages from table data

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Figure 26. Grinnell Point: Whitebark Pine Seedling Monitoring Plots, Planted in 2000.

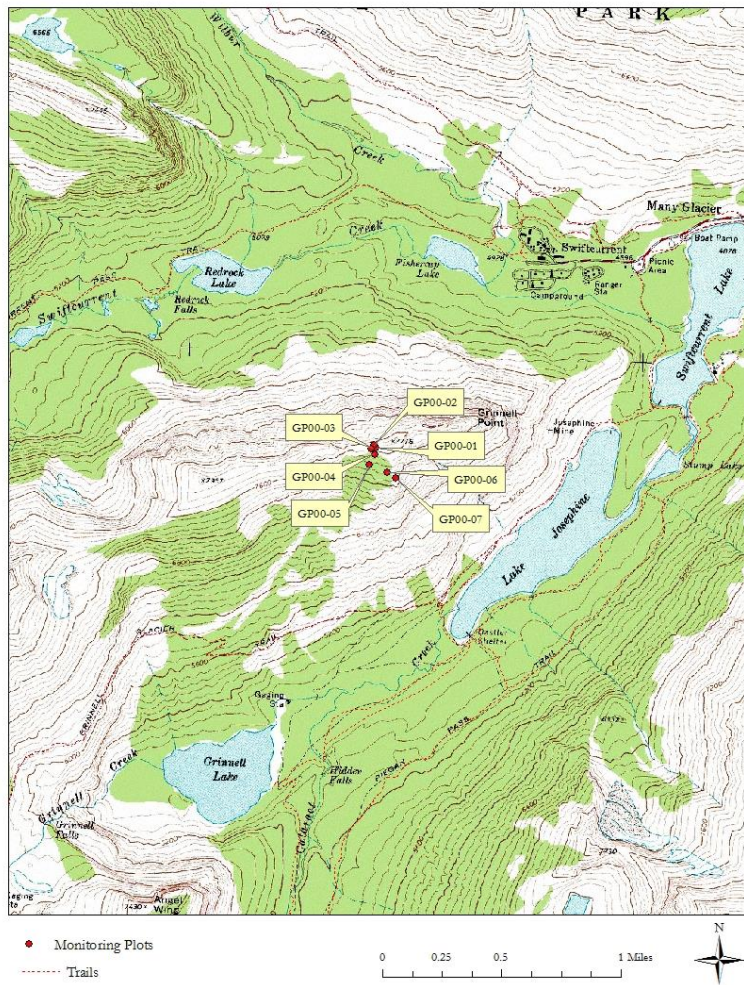
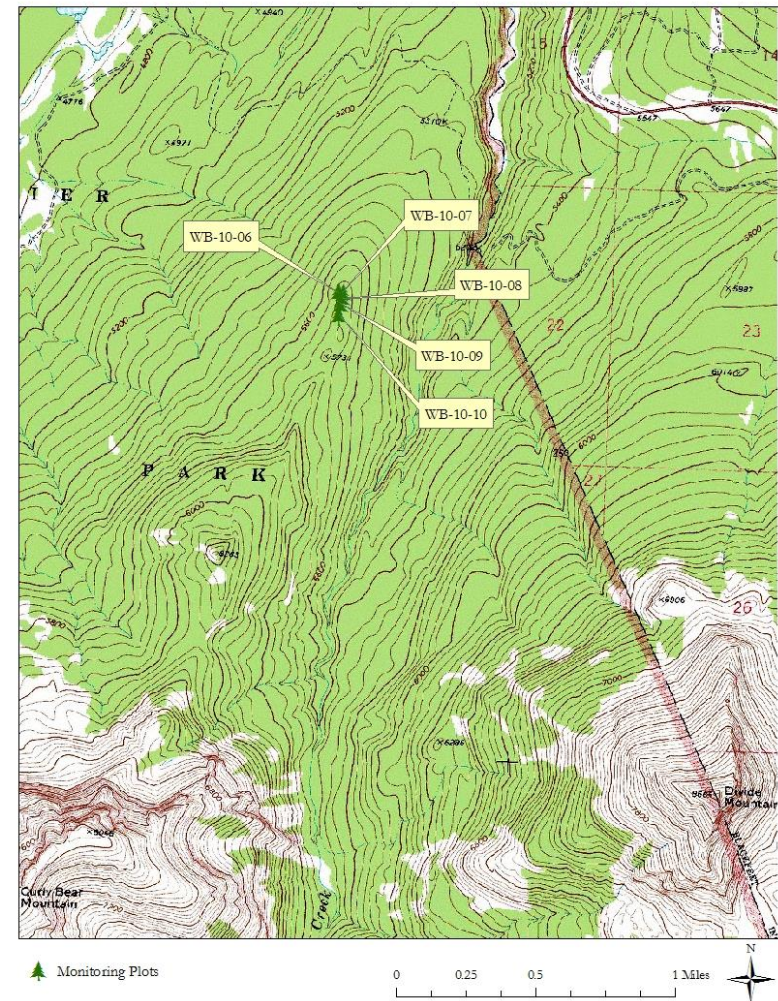


Figure 27. Divide Creek: Whitebark Pine Seedling Monitoring Plots, Planted in 2010.



b. Ten-Year-old Plantings
i. Divide Creek (Lower)

On September 20-22, 2010, a total of 1,126 whitebark pine seedlings were planted on a ridge above Divide Creek (Figure 27). This area burned in the Red Eagle fire of 2006 with moderate severity. This site is the first area where some planted seedlings had been inoculated with a slurry produced from mushroom species known to have ectomycorrhizal relationships with whitebark pine. Three hundred trees from this planting were inoculated. Seedlings were planted together in groupings of 3 seedlings per hole throughout the revegetation site. Five monitoring plots were installed tracking 261 seedlings. This captured 21% of planted seedlings, 40 of which were inoculated.

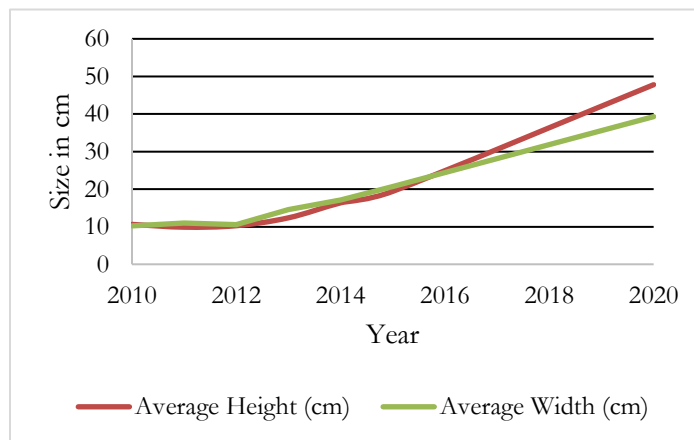
This site continues to be one of the most successful whitebark pine planting sites in the Park, with 89% survival ten years after planting (Table 13). This is an extraordinarily high survival rate. While these trees were not as tall as ten-year-old trees at Red Eagle, they were quite a bit larger than average at the other ten-year-old plantings, at Caper Peak and Hole-in-the-Wall (Table 11.). After about three years, these seedlings appeared to have established well enough to start putting on more growth (Figure 28). Initially, seedlings grew more in width than in height. The growth curve started to steepen after three years, after which trees began growing more quickly in height than in width.

Table 13. Divide Creek: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in 2010.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Ave. Height (cm)</i>	<i>Ave. Width (cm)</i>
2010	262	265	99%	10.6	10.2
2011	253	265	95%	9.8	11.0
2012	253	263	96%	10.3	10.6
2013	249	265	94%	12.4	14.5
2014	249	265	94%	16.4	17.1
2015	249	265	94%	19.4	20.7
2020	235	265	89%	47.8	39.3

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Figure 28. Divide Creek: Average Height and Width of Whitebark Pine Seedlings, 2010 – 2020.



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ii. Hole-in-the-Wall

A total of 830 whitebark pine seedlings were planted in the Hole-in-the-Wall campground area and in the cirque area above the campground in the fall of 2010. This was the first whitebark pine planting site that has not been burned, so was somewhat experimental in nature. Areas of vegetation were “scalped” surrounding planting sites to reduce competition.

Five monitoring plots were established near the Hole-in-the-Wall Campground between August 23 and 25, 2010 (Figure 29). Plots contained 172 seedlings, monitoring 21% of planted trees.

Trees at this site were much less successful than at other ten-year-old sites (Table 11). Survival is only 22%, and surviving trees remain very small (Table 14). The lower than average overall survival at Hole-in-the-Wall suggests that non-burned sites may not be as ideal of planting sites as burned sites. Not only did this site not receive the added nutrient boost and reduced competition after fire, but seedlings were also not inoculated with mycorrhizae. This planting also took place at the end of August, so perhaps seedlings experienced high levels of temperature stress and temporary drought stress before becoming dormant for winter.

Table 14. Hole-in-the-Wall: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in 2010.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2010	159	159	100%	10.9	9.4
2012	79	172	46%	8.6	9.2
2015	49	172	28%	11.9	11.1
2020	35	162	22%	18.1	16.7

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c. Five-Year-old Plantings

i. Numa Lookout (Fall)

On September 24, 2015, the area north of the lookout on the flank of Numa Peak was planted with 222 whitebark pine seedlings. This site is the furthest north that seedlings have been planted in the area. Plantings took place in short stature open forested areas that have not burned. The understory was relatively thick. Two monitoring plots were installed on the same day, encompassing 64 trees or 29% of planted seedlings (Figure 30).

Following the trend of low survival in unburned sites, only 14% of seedlings remained alive five years after planting (Table 15). Survival plummeted after three years, and now appears to have stabilized. Seedlings remained small at this site as well, barely taller than at the time of planting, and on average have actually become smaller in width. Post-planting weather was not favorable, as the summers of 2017 and 2018 were extremely hot and dry. Unsheltered seedlings especially seemed to fare poorly.

Table 15. Numa Lookout: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2015.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>Survival</i>	<i>Average Height (cm)</i>	<i>Average Width (cm)</i>
2015	64	64	100%	11.6	12.1
2016	57	66	86%	11.8	11.4
2018	10	66	15%	9.0	8.9
2020	9	66	14%	11.9	9.4

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Figure 29. Hole-in-the-Wall: Whitebark Pine Seedling Monitoring Plots, Planted in the Fall of 2015.

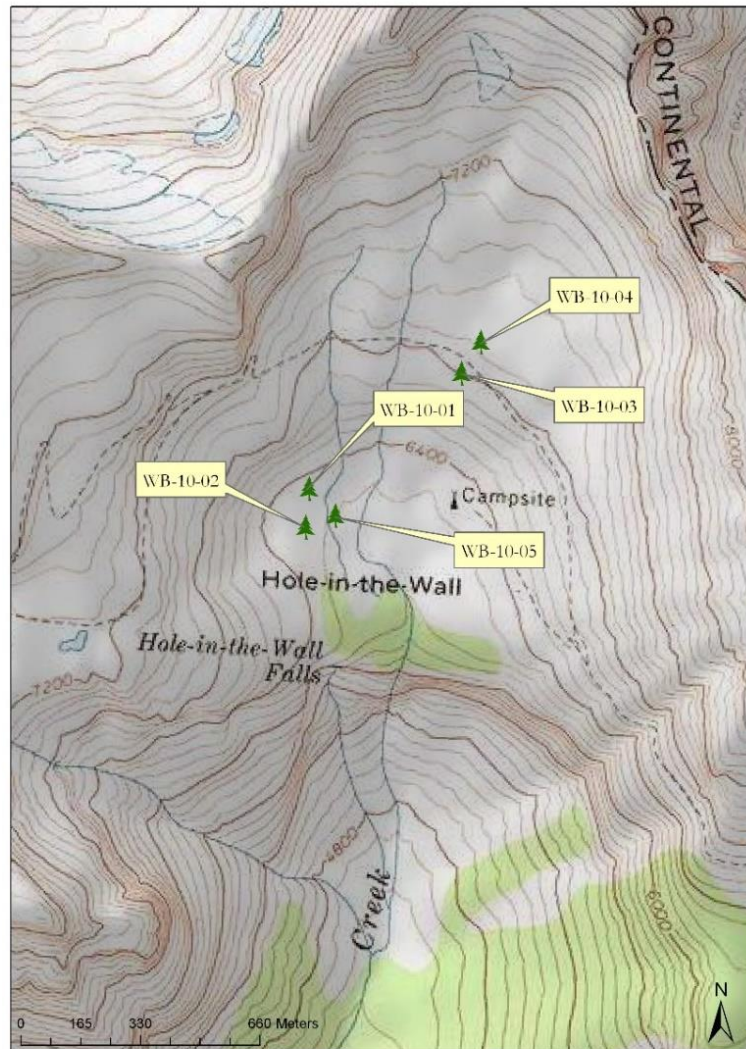
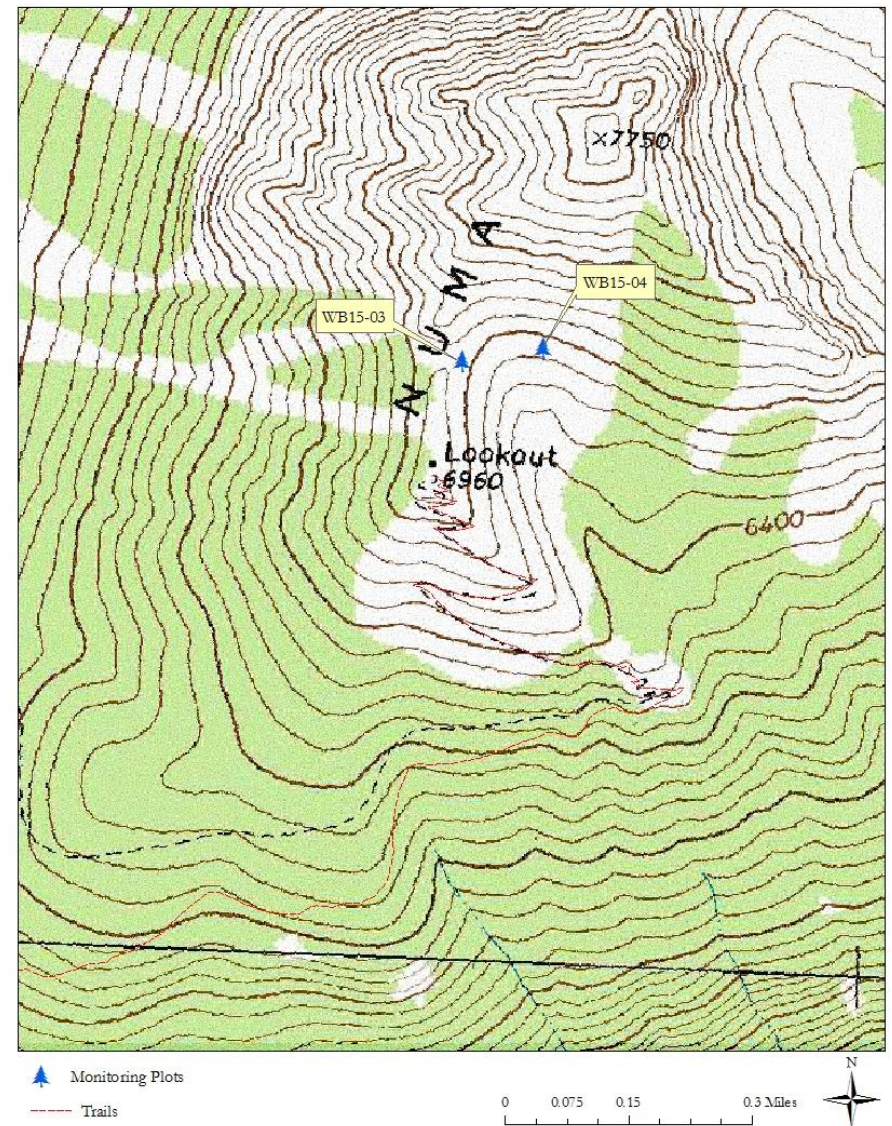


Figure 30. Numa Lookout: Whitebark Pine Seedling Monitoring Plots, Planted in 2010.



ii. Scenic Point Upper

The Scenic Point planting site is located southeast and downslope from Scenic Point proper (Figure 31). Historically, this area supported one of the larger whitebark pine stands in the Park. It remains one of the Park's healthiest stands with a fair amount of live trees and documented Plus Trees, despite substantial blister rust present on all age classes. There is also notable natural regeneration of whitebark pine here. This area has not been burned.

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

It was expected from the beginning that these trees will struggle, mostly due to heat stress. Five years after planting, 31% of seedlings remain alive at this site (Table 16). However, survival at this site is higher than several other unburned sites and has remained relatively level over the past two years. Parkwide five-year survival averages 34% for whitebark pine, so survival in this planting is only slightly lower than average.

Consistent with the observed trend to date, plantings in non-burned areas appear not to fare as well as seedlings planted within a burn perimeter. The surviving trees have grown only slightly in height, on average, and remain smaller in width than at the time of planting. If the remaining trees are established and adapted to the site, perhaps survival will remain relatively stable, however.

Table 16. Scenic Point: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2015.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>Survival</i>	<i>Average Height (cm)</i>	<i>Average Width (cm)</i>
2015	68	68	100%	10.8	12.1
2016	66	68	97%	8.7	12.3
2018	22	68	32%	10.6	10.2
2020	21	68	31%	11.2	11.6

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d. Two-Year-old Plantings ***i. Mount Brown***

Whitebark pine seedlings were planted near Mt. Brown Lookout in the fall of 2018, 2019 and 2020 (Figure 32). All plantings were within the burn perimeter of the Sprague Fire of 2017. All monitoring plots were read in 2020 and results will be discussed below under each year's plantings. In the past several years, five-needled pines have not been monitored the second year after planting, but these plots were monitored opportunistically while reading one-year-old plots nearby.

In 2018, 443 seedlings were planted near the lookout at Mount Brown. The seedlings had been kept in the nursery for different amounts of time and therefore were of different ages; 189 of them were two years old, while 254 were three to four years old. Monitoring plots were established shortly after planting. Plots ranged from 7,450 feet to 6,785 feet, and a total of 25% of planted seedlings were captured in monitoring plots. Seedlings were not inoculated with ectomycorrhizal slurry.

Two years after planting, survival had dropped to 76%. Perhaps the heavy snow year in the alpine at least partly contributed to the decline. Several of the unhealthy and dead seedlings were snow matted and had been infected with brown felt blight, a fungus that can develop on branches that are buried in snow. A few trees had been buried by rodents. Surviving trees had begun to put on good growth, however, in both height and width (Table 17).

Table 17. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2018.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2018	110	110	100%	15.1	11.0
2019	101	110	92%	14.2	11.2
2020	84	110	76%	16.3	14.2

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Figure 31. Scenic Point: Whitebark Pine Seedling Monitoring Plots, Planted in the Fall of 2015.

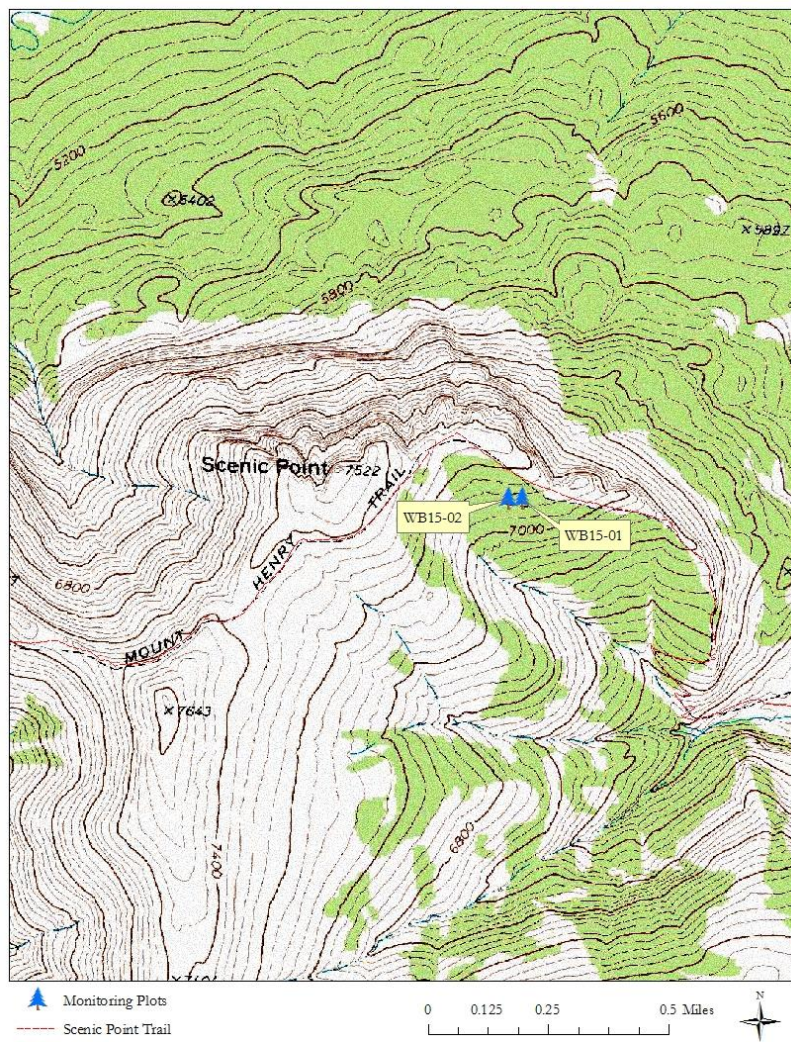
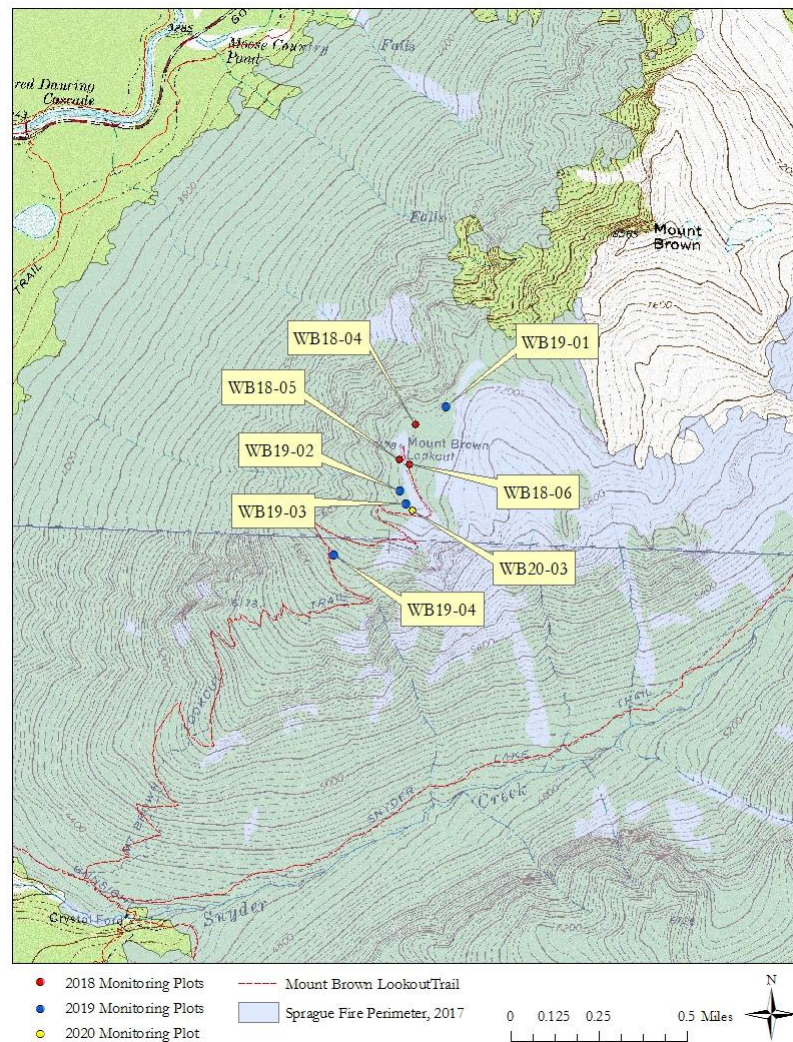


Figure 32. Mount Brown: Whitebark Pine Seedling Monitoring Plots, Planted in 2018, 2019 and 2020.



c. One-Year-old Plantings

i. Mount Brown

In the fall of 2019, a total of 580 seedlings were planted near the Mount Brown Lookout (Figure 32). A wider range of elevations for planting sites was utilized in 2019 than in 2018, this year ranging from 7,460 to 7,420 feet. 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.

Monitoring plots were established shortly after planting at. 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 18). No whitebark pine seedlings planted in 2019 were inoculated with ectomycorrhizal slurry.

First year survival is lower than that for the two-year-old planting, at 69% (Table 18). Snow matting and infection with brown felt blight also affected trees in these plots, perhaps to a higher degree than in the 2018 planting. Quite a few seedlings were rated as “almost dead” from this planting, so likely the death rate will increase by the next monitoring event. Other environmental factors were favorable, so it was unfortunate that snow blight affected these trees so heavily. As seen in most plantings, seedlings were smaller one year out than at the time of planting. Often this is due to shedding of long nursery-grown needles and replacement by shorter needles.

Table 18. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2019.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2019	97	117	100%	9.0	10.2
2020	81	117	69%	7.9	9.9

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f. New Plantings

i. Mount Brown

On September 28, 2020, 210 seedlings were planted near the Mount Brown Lookout, near the 2019 planting site (Figure 32), within the perimeter of the 2017 Sprague Fire. Planting conditions were favorable, since there were several days of ample rain prior to planting, and the soil remained moist. Revegetation has been slow in the area, and the planting site remained largely unvegetated. One plot was installed the same day as planting, at 7,325 feet, encompassing 44 seedlings (21% of planted trees). No whitebark pine seedlings planted in 2020 were inoculated with ectomycorrhizal slurry.

At the time of planting, 100% of all monitored seedlings were rated as “good” in all plots (Table 19). Seedlings averaged 11.1 cm tall and 10.1 cm wide. Plots are scheduled for revisiting in 2021.

Table 19. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2020.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2020	44	44	100%	11.1	10.1

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ii. Otokomi Knob

On September 21 and 22, 2020, 290 whitebark pine seedlings were planted on the nose of a slope adjacent to the Otokomi Lake Trail, approximately three miles from the trail head (Figure 33). Plantings took place near the edge of the perimeter of the 2015 Reynolds Creek Fire, adjacent to a mosaic of unburned and

burned vegetation. Just to the east of the highest plot are is an unburned island containing several live and dead whitebark pine trees. Regenerating whitebark pine seedlings were also observed nearby.

It is uncertain where the parent trees supplying seed for these seedlings originated. One of three trees are candidates: Firebrand 11-06, Old Man 07-33 or Rising Wolf 07-39.

Two monitoring plots were installed the second day of planting, containing 67 trees, encompassing 20% of the planting. As in 2019, planting conditions were favorable, since there were several days of good rain prior to planting. Experienced planters made great use of existing microsites and seedlings were watered in after planting by an MCC crew. Although it had been five years since the Reynolds Creek Fire burned this area, natural regeneration was occurring very slowly in the area, leaving plenty of open space with limited competition. It will be interesting to surmise whether post-fire effects are still beneficial to seedling success five years post-fire.

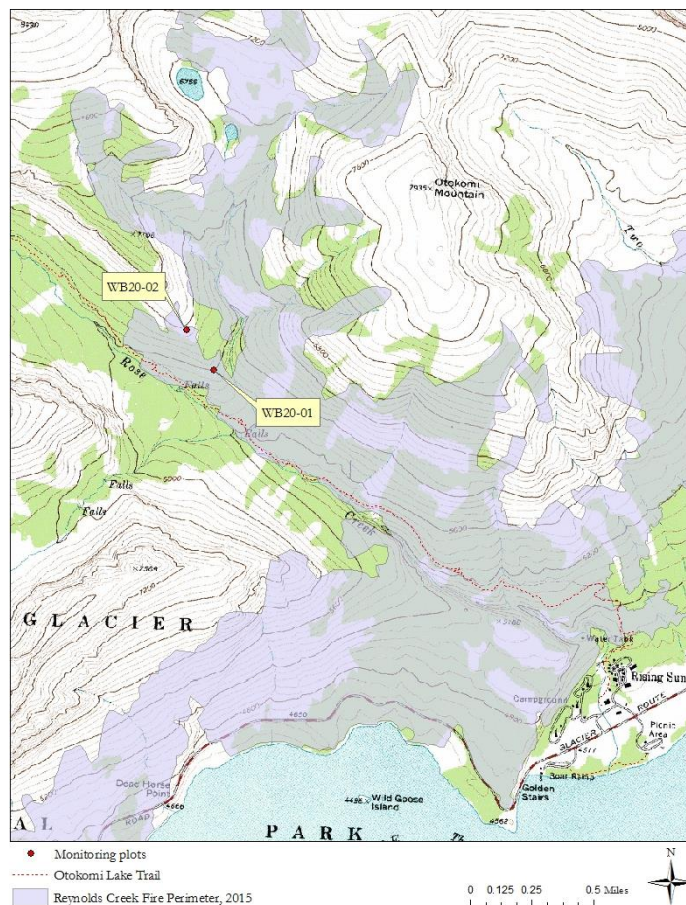
At the time of planting, 65 trees were rated a 5 (good), one tree was rated a 5 -, and one tree was rated a 4 (fair). Seedlings averaged 12.9 cm in height and 13.1 cm in width (Table 20). Plots are scheduled for revisiting in 2021.

Table 20. Otokomi Knob: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2020.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2020	67	67	100%	12.9	13.1

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Figure 33. Otokomi Knob: Whitebark Pine Seedling Monitoring Plots, Planted in 2020.



iii. Other small plantings in 2020

Whitebark pine seedlings were planted at a few other sites in small numbers, including at Sperry Chalet, and a first planting at Mount Brown. No monitoring plots were installed at these sites, due to the small planting numbers, but it may be worth noting that at Sperry Chalet, the seedlings originated from seed from Preston Park trees. At the initial Mount Brown planting, parent trees were from Scenic Point.

D. CONCLUSIONS AND RECOMMENDATIONS

1. *Limber Pine*

Overall survival of all monitored limber pine seedlings to date in the Park is 17%. 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.

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 limber pine sites are located, there was considerably low precipitation and higher temperatures in 2002, 2003, 2015, 2018 and 2020. 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.

The relatively recent fires in suitable limber pine habitat appears to be a large factor in increased success of more recent plantings. Continued hot and dry summers have taken its toll on seedlings in these open areas, however.

2. *Whitebark Pine*

Overall survival of all monitored whitebark pine seedlings to date in Glacier National Park is 48%. Traditionally, revegetation of whitebark pine seedlings has shown better progress than limber pine restoration. More of the whitebark pine plantings have been able to take advantage of burned areas, which may at least partly contribute to the increased success in whitebark pine.

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). While several of Glacier's plantings are below these averages, many of our plantings are on par with or exceeding these survival rates (Table 11). 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.

Both Whitebark and limber 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.

In recent years, Glacier staff has been more critical about choosing sites that are appropriate for 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 2021, both limber pine and whitebark pine monitoring have a much heavier schedule (Table 21). Seven total limber pine planting sites are scheduled for monitoring. One 15-year-old site, Baring Creek (with only three surviving trees) is scheduled to be revisited. Six 5-year-old sites are also due for monitoring: Dead Horse Point, Turnout #6 on the GTSR, Golden Staircase, Otokimi, Baring Creek and Lost Lake.

Eleven total Whitebark pine sites are scheduled for monitoring. Two 20-year-old whitebark pine sites are due to be read. Dutch Creek, which was originally accessed by helicopter after the Moose Fire of 2001, may or may not be monitored. It is very remote and has never been re-visited. Two plantings at Flattop Mountain, however, are planned to be monitored at years 19 and 20. One 15-year-old planting at Caper Peak is scheduled to be monitored, along with two 10-year-old plantings at Cobalt Lake and Grinnell Picnic Area. Four 5-year-old whitebark pine planting sites are on the schedule: Dead Horse Point, Goat Mountain Slope, Golden Staircase, and Otokomi, and two one-year-old plantings, at Mount Brown Lookout and Otokomi Knob, will be monitored.

In 2021, if climate cooperates, plans are to plant 500 whitebark pine seedlings. 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 21: Whitebark and Limber Pine Monitoring Schedule, 2020 to 2026. (Black text = completed, blue text = scheduled, red text = all trees in plot are dead)

Plot(s)	Species	Location	Year Planted	2020	2021	2022	2023	2024	2025	2026
DC01-01 to -04	Whitebark pine	Dutch Creek	2001		X (year 20)					X (year 25)
GP00-01 to -07 (-05)	Whitebark pine	Grinnell Point	2000	X (year 20)					X (year 25)	
FT01-01 to -27	Whitebark pine	Flattop	2001		X (year 20)					X (year 25)
FT02-01 to -11	Whitebark pine	Flattop	2002		X (year 19)					X (year 24)
LP02-24	Limber pine	Firebrand Pass Trail	2002			X (year 20) 1 TREE LEFT				
LP03-01	Limber pine	Two Med Camp Store	2003				X (year 20)			
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004					X (year 20)		
LP05-01 to -06	Limber pine	Scenic Point	2005	X (year 15)					X (year 20)	
LP06-02	Limber pine	Baring Creek	2006		X (year 15)					X (year 20)
WB06-01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006		X (year 15)					X (year 20)
WB07-01 to -07 (-08 & -09)	Whitebark pine	Red Eagle (trees)	2007			X (year 15)				
WBS07-04 & -05	Whitebark pine	Red Eagle (seeds)	2007			X (year 15)				
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010	X (year 10)					X (year 15)	
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010	X (year 10)					X (year 15)	
GP00-01 to -07	Whitebark pine	Grinnell Picnic Area	2011		X (year 10)					X (year 15)
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011		X (year 10)					X (year 15)
WB12-01 to -04	Whitebark pine	Divide Mountain	2012			X (year 10)				
LP12-01 to -02	Limber pine	Cutbank	2012			X (year 10)				
LP12-03 and -11	Limber pine	Apikuni Flats	2012			X (year 10)				
LP12-04 to -05	Limber pine	Rising Sun CG	2012			X (year 10)				
LP12-06 to -09	Limber pine	Scenic Point	2012			X (year 10)				
LP12-10	Limber pine	Many Glacier Well Area	2012			X (year 10)				
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013				X (year 10)			
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013				X (year 10)			
WB13-05 to -07	Whitebark pine	Numa Ridge	2013				X (year 10)			
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013				X (year 10)			
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014					X (year 10)		
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014					X (year 10)		
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014					X (year 10)		
WB14-06, -06A -07, -08, -09	Whitebark pine	Numa Ridge (fall)	2014					X (year 10)		
WB14-10 to -12	Whitebark pine	Divide Creek upper (fall)	2014					X (year 10)		
WB14-13 -14 -15	Whitebark pine	Firebrand Pass upper (fall)	2014					X (year 10)		
WB14-16 to -17	Whitebark pine	White Calf (fall)	2014					X (year 10)		
WB15-01 to -02	Whitebark pine	Scenic Point upper (fall)	2015	X (year 5)					X (year 10)	
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015	X (year 5)					X (year 10)	
LP16-01	Limber pine	Dead Horse Point (lower)	2016		X (year 5)					X (year 10)
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016		X (year 5)					X (year 10)
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016		X (year 5)					X (year 10)
LP16-06	Limber pine	Dead Horse Point (upper)	2016		X (year 5)					X (year 10)
LP16-07	Limber pine	Otokomi (lower bench)	2016		X (year 5)					X (year 10)
LP16-08	Limber pine	Baring Creek	2016		X (year 5)					X (year 10)
LP16-09 to -10	Limber pine	Lost Lake	2016		X (year 5)					X (year 10)
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016		X (year 5)					X (year 10)
WB16-03	Whitebark pine	Otokomi (upper)	2016		X (year 5)					X (year 10)
WB16-04	Whitebark pine	Goat Mountain Slope	2016		X (year 5)					X (year 10)
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016		X (year 5)					X (year 10)
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016		X (year 5)					X (year 10)
WB18-01 to -03	Whitebark pine	Sperry Chalet	2108		X (year 3)		X (year 5)			
WB18-04 to -06	Whitebark pine	Mt. Brown Lookout	2108	X (year 2)	X (year 3)	X (year 4)	X (year 5)			
WB19-01 to -04	Whitebark pine	Mt. Brown Lookout	2019	X (year 1)	X (year 2)	X (year 3)	X (year 4)		X (year 6)	
WB20-01 to -02	Whitebark pine	Otokomi Knob	2020	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB20-03	Whitebark pine	Mt. Brown Lookout	2020	X (year 0)	X (year 1)		X (year 3)		X (year 5)	

VIII. WHITEBARK AND LIMBER PINE PLUS TREE CONE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicanlis*) 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*). 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).

Glacier National Park undertook a 5-needle pine restoration program in 1997 to help perpetuate these species. Taking advantage of natural blister rust resistance currently may be the most effective strategy for restoration of whitebark and limber pine, since efforts such as removing secondary hosts have failed in the past. Glacier has been attempting to utilize naturally resistant trees in its restoration program for over 20 years. Since 1997, the Park has been collecting cones from suspected blister rust resistant whitebark pine trees, using phenotypic indicators of resistance. Subsequently, in 2009, Glacier National Park took part in the ongoing U.S. Forest Service's study to determine the genetic basis of resistance in some of these healthy-looking trees. Results from these genetic resistance tests will continue to direct cone collection within the Park.

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 2012, efforts have focused on attaching verbenone packets to healthy-looking trees to protect them from further damage from pine beetle infection. At that time, cone counts also taken place, and if time permits, a blister rust assessment of the tree is performed. Since blister rust data has not been consistently recorded for all trees in all years, this report focuses on cone counts.

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 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 127 whitebark pine trees that are being monitored in the plus tree pool at 16 different locations. Cone information was only collected on 102 trees in 2020 due to time constraints and COVID-19 travel restrictions on the Blackfoot Reservation (3 trees at Cobalt, 11 trees at White Calf, 5 trees at Grinnell Glacier, and 2 trees at Lee Ridge) (Figure 34; Table 22).

Currently, there are 33 limber pine trees at 8 different locations present in the plus tree monitoring pool (Figure 35; Table 23). Seven new trees at Rising Sun were added to pool. Cone information was collected on all trees except for three at White Calf due to COVID-19 travel restrictions on the Blackfoot Reservation.

In 2020, the primary data taken on whitebark and limber pine plus trees were cone counts. This is similar to data collected from 2012 through 2019. A renewed attempt is being made to collect more detailed data on blister rust status, cardinal direction of rust on the tree, blister rust height on the tree, canopy kill, bark chewing, pollen cones, and Clark’s Nutcracker observations (auditory, cone foraging, seed caching, flyover). This effort will need to be standardized and consistent before data can be utilized. 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 22. Numbers of Whitebark Pine Plus Trees Monitored from 2007-2020.

Year	# of Trees Added	Plus Trees that Died	Total # of Trees in Pool	# of Trees Monitored	Trees not Monitored	# Trees Not Monitored that are Potential Trees
2007	57 (7 Numa, 7 OM, 6 OL, 20 PP, 6 RW, 7 SP, 3 SB)	0	56	56	0	
2008	4 (TD)	0	60	41	19	
2009	13 (5 SP, 5 Numa, 3 PP)	0	73	53	20	
2010	9 (1 PP, 1 SP, 7 WC)	0	82	61	21	
2011	18 (4 WC, 2 TD, 3 FB, 9 OM**)	0	100	91	9	
2012		0	100	94	6	6 OM
2013	4 (2 SP***, 1 Spot, 1 FB)	1 (Numa)	103	97	6	6 OM
2014		1 (TD - avalanche)	102	92	10	6 (4 OM; 2 SP)
2015	11 (8 KM, 3 TM)		113	104	9	6 (4 OM; 2 SP)
2016	3 (1 Numa, 1 KM, 1 TM)		116	110	6	5 (3 OM; 2 SP)
2017	4 (KM***)		120	115	5	5 (3 OM; 2 SP)
2018	11 (1 OL; 3 CB; 5 GG; 2 LR)		131	107	24	9 (3 OM; 2 SP; 4 KM)
2019	1 (OL)					
2020			127	106	21	

**6 of these were potential plus trees

*** potential trees

DHP = Dead Horse Point

FB = Firebrand Pass Tr

GG = Grinnell Glacier Tr

KM = Kupunkamint Mtn.

LR = Lee Ridge

MG = Many Glacier

OL = Otokomi Lake

CL = Cobalt Lake

OM = Old Man Lake Tr

PP = Preston Park

RW = Rising Wolf

SB = Siyeh Bend

SP = Scenic Point

TD = Triple Divide Trail

TM = Two Medicine

WC = Whitecalf

Table 23. Numbers of Limber Pine Plus Trees Monitored from 2007-2020.

Year	# of Trees Added	Plus Trees that Died	Total # of Trees in Pool	# of Trees Monitored	Trees not Monitored
2007	2 (1 DHP, 1 SP)	0	2	2	0
2008	0	0	2	2	0
2009	0	0	2	1	1
2010	2 (1 DHP, 1 WC)	0	4	4	0
2011			4	2	2
2012	1 (WC)		5	4	1
2013			5	4	1
2014			5	3	2
2015	18 (8 MG; 6 Spot; 3 KM; 1 SP)	1 (DHP)	22	22	0
2016	2 (1 WC; 1 KM)		24	23	1
2017			24	23	1
2018	2 (OM)		24	23	1
2019			26	23	3
2020	7 (RS)		33	30	3

DHP = Dead Horse Point

SP = Scenic Point

WC = Whitecalf

RS= Rising Sun

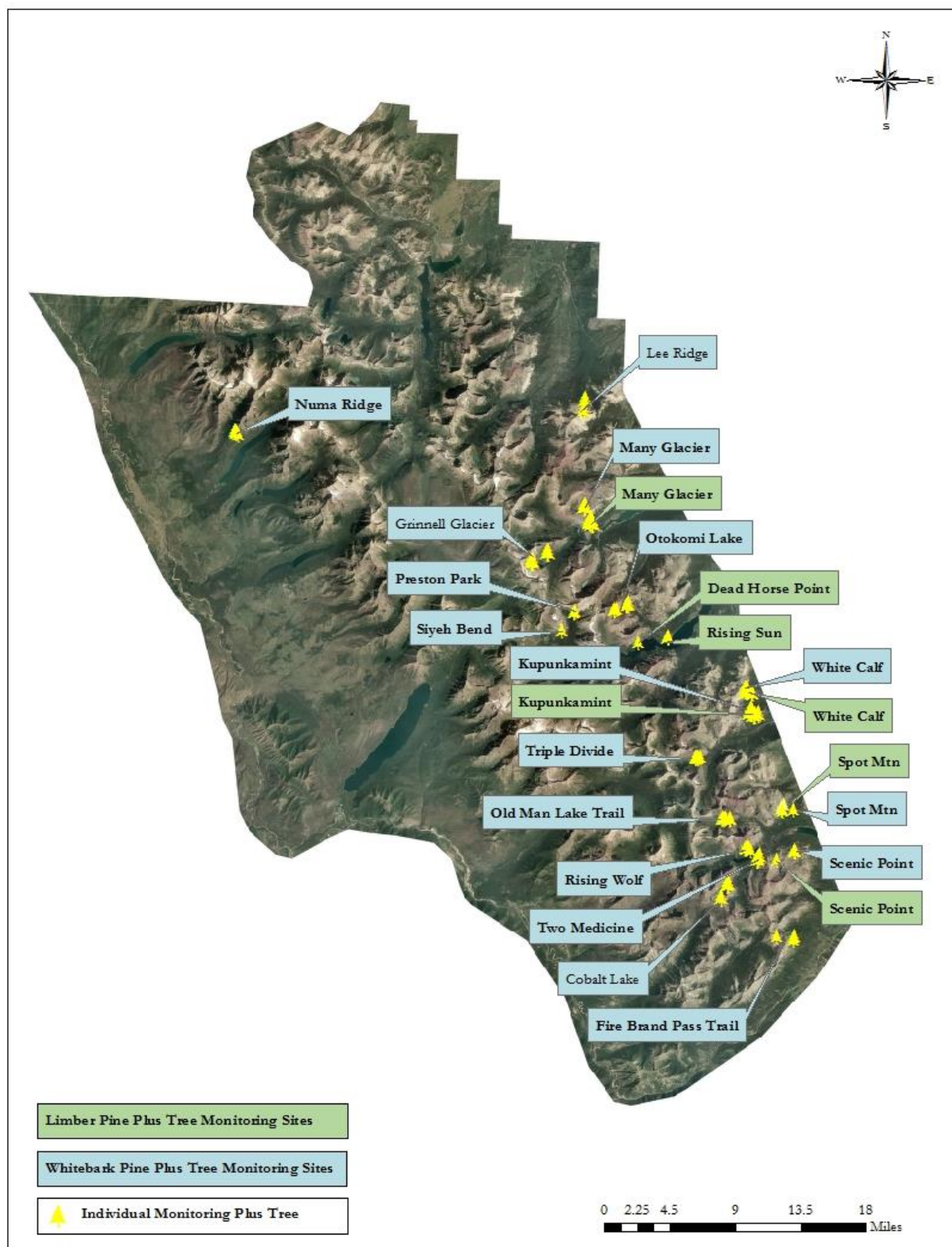
Spot = Spot Mt.

MG = Many Glacier

KM = Kupunkamint Mtn.

OM = Old Man Lake Tr

Figure 34. Location of Whitebark and Limber Pine Plus Trees.



C. RESULTS

In 2020, 106 of the existing 127 whitebark pine plus trees were monitored for cone production. Overall, 2020 had a slightly above average number of trees with cones, at 83% (Figure 35; Tables 24, 25). The average number of cones was 22 per tree. After a banner whitebark pine cone year in 2018 and then a dramatic drop in 2019, 2020 cone production rebounded to average rates.

Across the 16 different stands, the average number of cones per tree was quite variable this year. Cones were present in 12 of the 12 stands monitored, and the average number of cones per tree ranged from 7.0 cones to 64.4 cones (Table 24). Within a stand, cone production also varied from tree to tree. Some trees within a stand produced no cones while others in the same stand produced more than 50 cones. In the past several years, trees at Kupunkamint have been the most reliable in terms of a good cone crop, and again averaged the highest average number of cones per tree in 2020, at 64.4 (Table 24). Plus trees at Rising Wolf had good cone production with an average of 38.0 cones, with Old Man Lake Trail averaging 35.8 cones per tree.

For limber pine, 30 out of 33 trees in the pool were monitored in 2020. Seven limber pine trees were added to the pool in 2020 at a new location, Rising Sun. Twenty-eight trees (85%) produced cones in 2020 (Figure 35; Table 26, 27). The average number of cones was 51 per tree.

Limber cone production, averaging 51 cones per tree, was below the 14-year average (66 cones per tree). While 2018 was a mast year that was followed by a crash in 2019, the numbers are, at least, on the rebound. Some individual trees had strong cone production, with 5 trees having 100 or more cones. The lone tree at Deadhorse Point had 111 observed cones. The 7 new trees at Rising Sun averaged 70 cones per tree. On the low end, only 1 of 3 trees at Old Man produced cones, for an average of 6 cones per tree at that stand.

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 of 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 fourteen years of data.

D. CONCLUSIONS AND RECOMMENDATIONS

Monitoring data is beginning to document the cyclic nature of cone production in whitebark pine trees. 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 35). Environmental conditions, such as extreme weather patterns, may alter or accentuate this pattern. 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 14 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, 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.

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.

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 35).

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 6 years, GNP has added 30 trees to the whitebark pine plus tree monitoring pool and 29 trees to the limber pine plus tree monitoring pool (Tables 22, 23). 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, Granite Park, Firebrand Pass Trail, and Spot Mountain. 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 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, limited data on the health of plus trees was taken this year. Health data should be collected in a standardized manner in order 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.

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 plus trees that are in that program. 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 criterion. 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 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 2021 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.
- Determine if mapping whitebark and limber pine with each stand is a necessary effort for management and protection of these trees.

Table 24. Whitebark Pine Cone Production by Stand, 2020.

<i>Site</i>	<i>Year</i>	<i># of Trees in Pool</i>	<i># of Trees Monitored</i>	<i># With Cones</i>	<i>Total # of Cones</i>	<i>Average Cones per Tree</i>
Cobalt Lake	2020	3	0	0	n/a	n/a
Firebrand Pass Trail	2020	4	4	4	68	17.0
Grinnell Glacier Trail	2020	5	0	0	n/a	n/a
Kupunkamint	2020	12	12	12	773	64.4
Lee Ridge	2020	2	0	0	n/a	n/a
Numa Lookout	2020	12	12	10	101	8.4
Old Man Lake Trail	2020	15	15	14	537	35.8
Otokomi Lake	2020	7	7	5	111	15.9
Preston Park	2020	24	24	20	215	9.0
Rising Wolf	2020	6	6	5	230	38.3
Scenic Point	2020	13	13	10	93	7.2
Siyeh Bend	2020	3	3	1	25	8.3
Spot Mountain	2020	1	1	1	87	87.0
Triple Divide	2020	5	5	5	64	12.8
Two Medicine	2020	4	4	1	13	3.3
White Calf	2020	11	0	0	n/a	n/a
TOTAL		127	106	88	2317	22

Table 25. Whitebark Pine Cone Production by Year, 2007-2020.

<i>Year</i>	<i># of Trees in Pool</i>	<i># of Trees Monitored</i>	<i># With Cones</i>	<i>Total # of Cones</i>	<i>Average Cones per Tree</i>	<i>% With Cones</i>
2007	56	56	42	1395	25	75%
2008	60	41	23	195	5	56%
2009	73	53	35	517	10	66%
2010	82	61	47	1584	26	77%
2011	100	91	85	5507	61	93%
2012	100	94	73	1144	12	78%
2013	101	95	80	1631	18	84%
2014	100	92	78	2220	24	85%
2015	111	104	75	1754	17	72%
2016	114	110	95	3766	34	86%
2017	118	115	100	3655	32	87%
2018	129	107	106	5797	54	99%
2019	128	105	28	178	1	27%
2020	127	106	88	2317	22	83%

Figure 35. Trends in Whitebark Pine Cone Production 2007-2020.

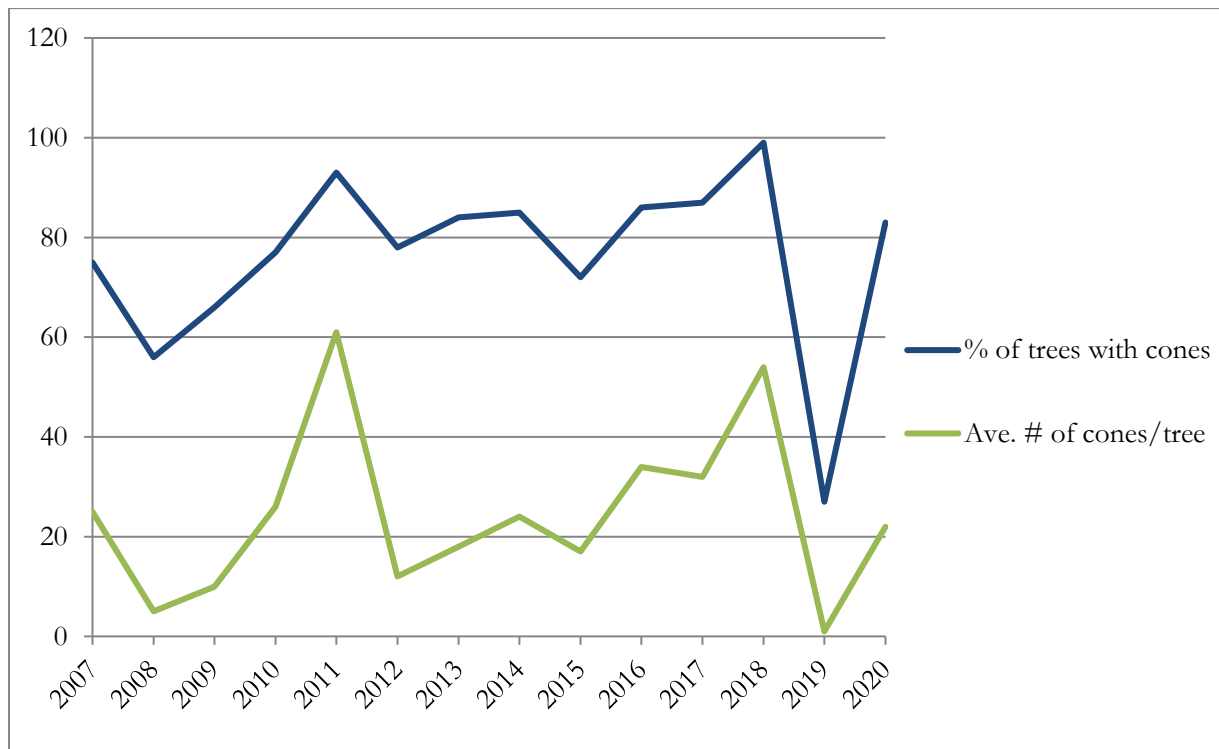


Table 26. Limber Pine Cone Production by Stand, 2020.

<i>Site</i>	<i>Date</i>	<i># trees in pool</i>	<i># of Trees Monitored</i>	<i># With Cones</i>	<i># of Cones</i>	<i>Avg Cones per tree</i>
Dead Horse Point	2020	1	1	1	111	111
Scenic Point	2020	2	2	2	38	19
White Calf	2020	3	0	0	0	n/a
Spot	2020	5	5	5	249	50
Many Glacier	2020	8	8	8	404	51
Kupunkamint	2020	4	4	4	217	54
Old Man	2020	3	3	1	19	6
Rising Sun	2020	7	7	7	493	70
TOTAL		33	30	28	1531	51

Table 27. Limber Pine Cone Production by Year, 2007-2020.

<i>Year</i>	<i># of Trees in Pool</i>	<i># of Trees Monitored</i>	<i># With Cones</i>	<i>% With Cones</i>	<i>Total # of Cones</i>	<i>Average Cones per Tree</i>
2007	2	2	2	100%	110	55
2008	2	2	2	100%	70	35
2009	2	2	1	50%	200	100
2010	3	3	3	100%	136	34
2011	4	2	2	100%	155	78
2012	5	4	4	100%	329	82
2013	5	4	3	75%	180	45
2014	5	3	3	100%	264	88
2015	22	22	22	100%	1996	91
2016	24	23	23	100%	1811	79
2017	24	23	23	91%	925	40
2018	24	23	23	100%	3108	135
2019	26	23	11	48%	189	8
2020	33	30	28	93%	1531	51

Figure 36. Trends in Limber Pine Cone Production 2007-2020.



IX. 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 being experimented with in the nursery. Given their common presence in a number of plant communities, however, these species should be salvaged whenever possible.

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

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

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

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

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

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

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

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

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

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

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

<u>Trees</u>	<u>Shrubs</u>	<u>Forbs/Ferns</u>	<u>Grasses</u>
<i>Larix occidentalis</i>	<i>Acer glabrum</i>	<i>Arnica cordifolia</i>	<i>Calamagrostis rubescens</i>
<i>Pinus contorta</i>	<i>Amelanchier alnifolia</i>	<i>Chamerion angustifolium</i>	<i>Carex concinnoides</i>
<i>Pseudotsuga menziesii</i>	<i>Linnaea borealis*</i>	<i>Chimaphila umbellata*</i>	<i>Carex geyeri</i>
<u>Subcanopy:</u>	<i>Mahonia repens</i>	<i>Clintonia uniflora*</i>	<i>Oryzopsis asperifolia</i>
<i>Abies lasiocarpa</i>	<i>Rosa woodsii</i>	<i>Eurybia conspicua</i>	
<i>Pseudotsuga menziesii</i>	<i>Rubus parviflorus</i>	<i>Pteridium aquilinum</i>	
<i>Thuja plicata</i>	<i>Spiraea betulifolia</i>	<i>Symphotrichum laeve var. laeve</i>	
<i>Tsuga heterophylla</i>	<i>Symphoricarpos albus</i>	<i>Xerophyllum tenax*</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 sulphurescens
Heterotheca villosa
Heuchera cylindrica
Lithospermum ruderales
Lomatium triternatum
Lupinus sericeus
Penstemon confertus
Potentilla glandulosa
Potentilla gracilis
Sedum lanceolatum

Grasses

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

Subalpine meadow (subalpine – east and west):

Trees

Abies lasiocarpa

Shrubs

Dasiphora floribunda

Salix arctica

*Vaccinium caespitosum**

*Vaccinium scoparium**

Forbs/Ferns

Achillea millefolium

Agoseris glauca

Anemone occidentalis

Antennaria alpina/umbrinella

Arenaria capillaris

Arnica diversifolia/ mollis

*Castilleja spp.**

Chamerion angustifolium

Epilobium anagallidifolium

Erigeron compositus

Erigeron peregrinus

Eriogonum flavum

Galium boreale

Hedysarum sulphurescens

Heracleum sphondylium

Hypericum scouleri

Oxyria digyna

Pedicularis bracteosa

Phacelia hastata

Polygonum bistortoides

Potentilla diversifolia

Senecio cymbalarioides

Sibbaldia procumbens

Solidago multiradiata

Symphyotrichum foliaceum var. *foliaceum*

Symphyotrichum laeve var. *laeve*

Valeriana sitchensis

Veratrum viride

Veronica wormskjoldii

*Xerophyllum tenax**

Zigadenus elegans

Grasses

Agrostis variabilis

Carex haydeniana

Carex nigricans

Carex paysonis

Carex phaeocephala

Carex spectabilis

Deschampsia atropurpurea

Juncus drummondii

Juncus mertensianus

Juncus parryi

Luzula glabrata / spicata

Phleum alpinum

Poa alpina

Poa secunda

Trisetum spicatum

Road sides (montane – east and west):

Trees

varies by site

Shrubs

Arctostaphylos uva-ursi

Juniperus communis

*Linnaea borealis**

Mahonia repens

Rosa woodsii

Spiraea betulifolia

Symphoricarpos albus

Forbs/Ferns

Achillea millefolium

Anaphalis margaritacea

Antennaria howellii

Antennaria rosea

*Aralia nudicaulis**

Arnica cordifolia/ latifolia

Chamerion angustifolium

Eurybia conspicua

Fragaria virginiana/ vesca

Geranium viscosissimum

Geum macrophyllum

Heracleum sphondylium

Maianthemum stellatum

*Osmorhiza berteroi**

Solidago canadensis

Symphyotrichum laeve var. *laeve*

*Xerophyllum tenax**

Grasses

Bromus carinatus

Bromus vulgaris

Calamagrostis rubescens

Carex concinnoides

Carex geyeri

Carex microptera

Carex rossii

Deschampsia elongata

Elymus glaucus

Elymus trachycaulus v.

trachycaulus

Festuca occidentalis

Festuca subulata

Oryzopsis asperifolia

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

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

<i>Achillea millefolium</i>	<i>Fragaria virginiana/vesca</i>
<i>Anaphalis margaritacea</i>	<i>Rosa spp</i>
<i>Antennaria howellii</i>	<i>Symphoricarpos albus/occidentalis</i>
<i>Arctostaphylos uva-ursi</i>	<i>Symphytotrichum laeve var. laeve</i>
<i>Eurybia conspicua</i>	

Species to continue experimenting with in the nursery:

<i>Angelica arguta*</i>	<i>Juniperus communis/horizontalis</i>	<i>Phacelia hastata</i>
<i>Aralia nudicaulis*</i>	<i>Linnaea borealis*</i>	<i>Shepherdia canadensis</i>
<i>Carex geyeri</i>	<i>Lupinus sericeus</i>	<i>Vaccinium spp.*</i>
<i>Castilleja spp.*</i>	<i>Maianthemum racemosum*</i>	<i>Veratrum viride</i>
<i>Chimaphila umbellata*</i>	<i>Menziesia ferruginea</i>	<i>Viola canadensis*</i>
<i>Clintonia uniflora*</i>	<i>Orthilia secunda*</i>	<i>Viola orbiculata*</i>
<i>Disporum hookeri/trachycarpum*</i>	<i>Oryzopsis asperifolia</i>	<i>Xerophyllum tenax</i>
<i>Erythronium grandiflorum*</i>	<i>Osmorhiza berteroi*</i>	
<i>Hieracium biflorum</i>	<i>Osmorhiza occidentalis*</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) setting goals and objectives for revegetation projects; (2) road shoulder revegetation strategies (3) evaluation of monitoring techniques; (4) seed bank analysis and its impact on revegetation; (5) salvaging plants for restoration; (6) supplemental watering of 0-2 year old restoration plantings; (7) thorough weeding of any nursery stock or salvage material; (8) whitebark and limber pine plus-tree health (9) seeding and planting density; and (10) research ideas for the field and for the nursery.

X. 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 Reveg. (year 1 after spraying)
- Camas Creek Overlook Weed Reveg. (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 Reveg. (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): NOT MONITORED: NO 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)

XI. RESOURCES AND REFERENCES

- Arno, S. and R. Hoff. 1990. *Pinus albicanlis* 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. 1993-2019. *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.
- Dow Agrosciences. Milestone Specialty Herbicide Family of Products Grass Planting Guidelines: https://www.rrsi.com/wp-content/uploads/Milestone_Grass_Planting_Guidelines.pdf
- Dow Agrosciences, 2012. Native Forb and Shrub Tolerance to Milestone® Herbicide.
- 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 Yellow-stone 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.
- NRCS, 2015. Soil Quality Indicators. Physical, Chemical, and Biological Indicators for Soil Quality Assessment and Management.
<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=stelprdb1237387>
- 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.
- Rice, P. M., J. C. Toney, D. J. Bedunah, and C. E. Carlson. 1997. *Plant community diversity and growth form responses to herbicide applications for control of Centaurea maculosa*. J. Appl. Ecol. 34: 1397-1412.
- 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.
- Thorpe, A S., Thelen, G. and Diaconu, A. 2009. *Root exudate is allelopathic in invaded community but not in native community: field evidence for the novel weapons hypothesis*. Journal of Ecology (2009) 97 (4): 641-645.
- 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. 2004. *Roadside Revegetation in Glacier National Park, U.S.A.: Effects of Herbicide and Seeding Treatments*. Restoration Ecology (2004) 6(2):197–206.
- 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.nrmssc.usgs.gov/research/blister.htm>
- Weir, T.L., Bais, H.P. and Stull, V.J. 2006. *Oxalate contributes to the resistance of Gaillardia grandiflora and Lupinus sericeus to a phytotoxin produced by Centaurea maculosa*. Planta (2006) 223 (4): 785-795

APPENDIX A. TEMPERATURE AND PRECIPITATION DATA *

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

WEST GLACIER

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1948-2019	41.5	50.8	57.5	63	61.8	52.4	41.7	30.9
1995	41.1	51.4	56.2	63.1	58.5	54	40.2	32.6
1996	42	46.3	58.5	65	61.5	51	40.2	26.4
1997	36	51.5	57.4	63.1	63.5	54.5	42.5	31.8
1998	44	54.9	56.4	68.4	64.5	59.4	42.3	36
1999	41.5	49.3	55.2	60.5	65.7	51.8	42.8	37.7
2000	43	50.2	56.7	63.4	63	51	42.8	28.3
2001	40	52.4	55.4	62.8	64.8	57.6	42.7	35.5
2002	39.7	47.8	57.4	67	60.3	54.1	37.5	33.2
2003	43.1	50.9	59.7	68.7	67.9	56.8	46	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	53.4	60	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	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	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	65.8	54.9	49.1	31.6
2016	49.1	52.2	60.4	63.8	63.8	53.1	43	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	31.8
2019	42.0	52.3	58.8	63.5	64.4	55.0	37.5	30.8
2020	41.3	52.0	61.4	66.9	68.3	61.5	45.0	38.6
Precipitation (inches)								
1948-2019	2.0	2.6	3.4	1.6	1.5	2.0	2.5	3.1
1995	1.7	1.2	6.9	3.4	2.1	1.4	5.2	7.5
1996	3	6.1	1.9	1.2	1.9	3.1	4.1	4.4
1997	2	1.8	3	1.5	1.4	3	3	1.6
1998	2	4.6	4.9	2.6	1.2	1.7	1	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	1	0.4	3.2	0.9	0.7
2001	3	1.3	4	0.6	0.1	1.2	3.8	2.3
2002	2.4	2.7	3	1.5	0.7	1.7	0.5	2.5
2003	1.4	1.9	1.8	0.04	0.1	2	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
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	3.2	0.9	1.9	1.5	1.4	3.2
2009	1	4	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	0.4	1.8	3.9	0.6	4.3
2014	2.5	1.2	5.3	1.2	2.4	1	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	1.3	2.3	2.5	10.6	2.7
2017	4.8	1.3	3.9	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	2.8	2.0	1.7
2020	1.2	3.5	4.3	1.3	0.4	1.3	4.5	4.3

SAINT MARY

	April	May	June	July	August	September	October	November
Mean Temperature (degrees F) **								
1982-2019	39.0	47.9	55.5	62.3	61.3	52.7	42.7	31.1
1994	42.1	52	56.9	62.8	63.1	58.9	43	27.6
1995	38.8	46.4	54.3	61.9	59.8	53.9	40.4	32.5
1996	43.2	45	56.6	64.7	64	50.2	42	21
1997	35.8	47.9	56.2	62.5	62.6	58.3	45.1	34.8
1998	42.1	53.8	53	67.8	62.3	58.5	45.8	33.1
1999	39.7	46.9	53.7	59.2	65.7	52.1	43	40.1
2000	43.7	50.1	65.3	65.7	65.5	52.6	43.9	28
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	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	57.2	49.3	42.4	33.6
2006	40.5	48.7	55.8	65.8	59.2	52.5	39	26.4
2007	39.1	49.4	56.9	69	60.2	52.1	44.5	32.5
2008	35.4	46.5	53	61.2	60.7	50.6	44.4	37.2
2009	34.8	47.2	52.2	62	58.8	57.2	34.7	35
2010	36	38.7	48.3	56.6	53	46.3	45.8	15.4
2011	29.6	42.2	52.3	60	61.1	54.9	41.4	28.6
2012	40.6	44.3	52.7	62.3	60.2	52	36.1	32.7
2013	32.1	48.1	54.2	62	62.1	52.5	38.4	30.2
2014	38.8	47.3	51.9	64.1	60.2	50.4	48	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	49.6	56.6	67	62.5	53	41	30.5
2018	34.7	52.4	54.7	62.5	61	47.8	34.4	31.8
2019	36.8	44.4	52.9	58.3	58.5	49.6	33.8	28.4
2020	33.7	45.7	53.6	58.9	61	53.6	37.5	34.1
Precipitation (inches)								
1982-2019	1.9	2.6	3.5	1.5	1.5	1.9	2.2	2.6
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	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	0.2	4.9
1999	1.5	1.5	1.8	0.9	2.2	1.7	3.1	4.1
2000	2	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	5.1	0.6	1.5	2.3	1	0.2
2003	1.5	1.2	1.6	0.1	0	1	1	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	3.8	2	2
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	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	4.4	4.7	1.3	1.9	2.4	0.1	2.1
2011	4	3.1	2.5	0.6	0.7	0.9	3.1	2.5
2012	1.1	1	3.9	0.7	0.6	1.2	3.1	2.7
2013	2.6	2.1	2.8	0.3	1.6	3	0.5	1.7
2014	2.2	1.2	7.2	1	2.4	1.5	1.7	3.8
2015	1.4	2.3	1.7	1.4	1	1.7	1.2	2
2016	0.4	3.8	0.9	1.1	2	3	3.9	1.8
2017	1.8	1.9	1.7	0.1	0.3	0.4	1.7	3
2018	1.1	1.9	3.1	1.0	0.7	0.9	3.4	1.1
2019	3.3	5.6	2.1	0.7	1.4	4.0	2.7	2.3
2020	2.3	2.1	5.3	0.6	0.2	1.7	3.4	4.6

Appendix B. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimates (not in micropLOTS).

	GRAS-99-029		GRAS-00-003		GRAS-00-008		GRAS-00-025		GRAS-00-026		GRAS-00-029		GRAS-00-042		GRAS-00-048		GRAS-01-003		GRAS-01-007		GRAS-01-010		GRAS-01-014		Plot			
	St. Mary		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Cut Bank		Two Medicine		Two Medicine		St. Mary		Frequency			
	Visitor's Center		Horse Corrals N		Red Mtn East		Pray Lake		East Spot Mtn		Avalanche Chute		Mad Wolf N		Old Bison Siding		Boundary		SS Moose Ponds		Lower TM Lake		Sleepy Lagoons		1999-			
	1999	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2001	2020	2001	2020	2001	2020	2001	2020	2001	2020		
Ground Cover																										0	0	
Bare soil	0.11	1.07	0.07	0.43	1.29	2.07		2.14	0.93	2.0			3.29	3.86			0.29	3.79		0.08	0.46	28.43	0.71	1.0			8	10
Basal vegetation	5.93	6.50	5.14	5.50	4.36	4.64	3.21	7.21	4.64	7.64	7.29	7.14	7.71	7.21	8.43	5.07	7.43	6.86	7.64	6.79	6.64	5.86	3.93	4.21			12	12
Gravel			0.04	2.07	18.21	10.96	4.11	5.44	4.04	4.14		0.07	1.07	1		3.86	0.21	2.72	1.86	15.51	0.11	4.14	0.43	0.07			9	11
Lichen	0.07		0.75	0.43	0.75	1.58	0.71	6.79	0.29	2.01		0.29			0.29	9.57	0.68	11.79	0.21	6.15	0.04		0.43	0.14			10	9
Litter	86.21	90.71	73.29	76.79	67.14	73.44	69.36	40.00	88.71	76.92	91.43	83.29	84.36	86.71	84.21	67.64	88.14	70.67	89.07	64.18	89.93	55.21	74.64	75.89			12	12
Moss	5.57	1.50	18.00	13.07	0.07	0.44	0.00	31.65		2.14		0.36	2.0	0.79	4.93	12.29	2.79	0.74	0.71	5.09	1.93	3.51	11.36	17.71			10	12
Rock			0.07	0.68	5.14	3.36	0.64	0.93	0.43	0.71	0.79	1.71	0.21	0.14			0.07	1.07	0.29	0.93	0.04	2.21	2.07	0.86			10	10
Wood			0.14		0.39		0.04				0.57	0.86	0.14		1.57				0.04		0.64	0.36					8	2
Other	2.36			1.0	0.93				0.04				1.32		0.57				0.07		0.14		5.18				8	1
Selaginella			2.79		1.89	3.5	22.0	5.21	1.07	4.43								0.14	0.25	1.29	0.18	0.29	1.32	0.21			7	7
Domestic scat										0.5						1.57		2.21						1.0			0	4
Wild scat		0.21				0.29				0.01		0.51		0.29										0.18			0	6
Tree	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	1.21	23.29	0	0			
Pinus contorta																						6.07					0	1
Populus tremuloides																1					1.21	17.21					1	2
Pseudotsuga menziesii										0.14																	0	1
# of tree species	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	2	0	0				
Shrub	0	0	0.10	0	34.75	45.71	0	0.10	12.43	15.65	33.36	34.07	19.57	41.79	3.79	22.71	3.21	5.22	0	0	9.00	14.57	1.71	3.86				
Amelanchier alnifolia			0.01		7.61	13.08					1.64	3.07									2.14	3.64		0.1			4	4
Arctostaphylos uva-ursi					25.61	27.93			8.57	9.00	30.71	30.64	9.64	11.07			3.07	4.29			1.57	4.43		0.5			6	7
Juniperus communis					0.86	5.79		0.1						0.1													1	3
Mahonia repens			0.1																		4.07	6.57					2	1
Pentstemon floribunda									0.57	0.71			4.21	13.71	3.79	22.71	0.14	0.93	0.1	1.0			0.21	1.71			6	6
Prunus virginiana														0.5													0	1
Rosa acicularis					0.29				3.29		0.36		1.86														4	0
Rosa woodsii																						0.29		0.64			0	2
Rosa sp.				0.1		0.86				5.94		0.29		3.21				0.01			1.29		1.43	1.93			2	7
Salix brachycarpa													3.89	13.43													1	1
Shepherdia canadensis														0.36													0	1
Spiraea betulifolia					0.43	0.43					0.64	0.23															2	2
Symphoricarpos albus												0.1										0.1	0.07	0.67			1	3
# of shrub species	0	0	2	1	5	5	0	1	3	3	4	5	4	7	1	1	2	3	1	1	4	5	3	6				
Native Grass	17.14	45.64	18.71	25.64	7.57	11.80	13.50	18.07	20.21	37.48	24.71	37.94	18.07	21.84	34.57	19.43	13.64	32.69	15.86	28.57	20.93	13.44	19.57	37.61				
Agrostis scabra							0.1																				1	0
Bromus carinatus	0.36	0.14												0.6								0.1	0.1				1	4
Bromus pumellianus									1.14	0.36			2.57														2	1
Calamagrostis purpurascens														0.29													0	1
Carex obtusata	0.71	0.1	1.75	1.86			1.46	0.1	1.39	1.21			0.32	0.07	0.64	2.21		0.07	0.11	0.14	0.25	0.07	2.93	0.29			9	10
Carex filifolia	0.14	0.21																0.21						1.58			1	3
Carex geyerii					0.75	1.07					1.25	9.29			0.50						4.07	3.87					4	3
Carex petasata			0.54	2.44	0.1	0.64	0.11	0.10	0.21	0.89		0.1	0.5		0.43	3.9	0.5	0.87	0.07	0.1	0.68	0.79	0.1				9	10
Carex raynoldsii																											0	0
Carex rossii																		2.86									0	1
Carex scirpoidea													0.1	1.07													1	1
Carex spp.		1.44	0.36			0.14		3.71		0.86				0.01			0.29	0.36		0.59		0.87		1.65			2	9
Danthonia intermedia			0.21	0.37	0.1	0.01	5	2.93		0.1	0.89	0.44			2.43	0.07	0.89	1.21	1.21	1.34	1.25	0.37	0.14				9	9
Elymus lanceolatus		4.51												1.15									0.57	9.07			1	3
Elymus smithii	0.86												1.07										3.00				3	0
Elymus spicatus					0.86	0.71			1.14	1.43	3.14	4.36							0.04	0.07	1.36	0.36	0.1	0.21			6	6

Appendix B, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimate

	GRAS-99-029		GRAS-00-003		GRAS-00-008		GRAS-00-025		GRAS-00-026		GRAS-00-029		GRAS-00-042		GRAS-00-048		GRAS-01-003		GRAS-01-007		GRAS-01-010		GRAS-01-014		Plot		
	St. Mary		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Cut Bank		Two Medicine		Two Medicine		St. Mary		Frequency		
	Visitor's Center		Horse Corrals N		Red Mtn East		Pray Lake		East Spot Mtn		Avalanche Chute		Mad Wolf N		Old Bison Siding		Boundary		SS Moose Ponds		Lower TM Lake		Sleepy Lagoons		1999-2020		
	1999	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2001	2020	2001	2020	2001	2020	2001	2020	2001	2020	
<i>Elymus trachycaulus</i> ssp. <i>subsecundus</i>	0.71	0.29												0.86		0.1										3	1
<i>Elymus trachycaulus</i> ssp. <i>trachycaulus</i>														0.68				0.1								0	2
<i>Festuca campestris</i>	11.64	34.71	10.25	12.50	3.32	7.36	1.32	1.71	10.64	26.29	19.36	25.00	3.32	2.43	23.11	0.36	8.50	21.71	10.64	22.71	12.57	3.08	2.29	6.86		12	12
<i>Festuca idahoensis</i>	1.14	2.46	5.71	8.50	1.93	1.55	3.00	6.29	4.64	6.07	0.14	0.09	6.50	15.21	7.39	13.29	3.29	8.07	3.86	6.21	1.36	0.86	7.36	17.04		12	12
<i>Helictotrichon hookeri</i>		0.01		0.93					0.29	0.07			0.18	0.1												2	4
<i>Juncus balticus</i>	1.93	3.69											0.64	0.82			0.04	0.04								3	3
<i>Koeleria macrantha</i>	0.11	0.29						0.29	0.29	0.07			0.46	0.76	0.14	0.22	0.21	0.29			0.07	0.15	2.14	0.44		7	8
<i>Lagula spicata</i>							2.21	1.24		0.11																1	2
<i>Melica spectabilis</i>																						0.08				0	1
<i>Muhlenbergia richardsonis</i>									0.14					1.75									0.86	0.21		3	1
<i>Oryzopsis exigua</i>					0.21	0.32																				1	1
<i>Phleum alpinum</i>																				0.07						0	1
<i>Poa alpina</i>									0.1	0.1				0.1												1	2
<i>Poa cusickii</i>										1.08																0	1
<i>Poa interior</i>														0.51												0	1
<i>Poa secunda</i>								0.36																0.01		0	2
<i>Poa</i> sp.		0.21																								0	1
<i>Stipa nelsonii</i>					0.39	0.08												0.01					0.57	1.21		2	3
<i>Stipa richardsonii</i>																	0.04	0.1								1	1
<i>Trisetum spicatum</i>					0.32	0.29	1.18	2.79					0.1													3	2
<i>Trisetum vulfii</i>									0.43																	1	0
# of grass species	9	12	6	6	9	10	8	10	11	13	5	6	13	14	8	6	8	13	6	8	8	11	10	13		12	12
Native Forb	16.93	31.39	26.00	53.79	12.79	16.34	36.79	28.93	26.64	40.14	13.14	40.51	30.71	41.71	18.00	35.39	23.50	40.52	27.93	49.08	25.36	55.43	15.00	9.26			
<i>Achillea millefolium</i>	2.07	1.04	2.64	9.79	1.18	1.25	2.14	1.79	1.14	3.18	2.25	9.64	3.07	3.65	1.75	2.07	1.54	8.00	3.64	6.21	4.07	9.44				11	11
<i>Agoseris glauca</i>			0.25	1.08	0.07				0.96	1.79	0.18		1.21	0.86	0.32	4.22	0.61	3.29	2.00	3.43	1.43	1.08				9	7
<i>Allium cernuum</i>		0.04			0.04	0.1					0.11	0.07	1.11	0.15							0.29	0.29		0.1		4	6
<i>Allium textile</i>										0.1																0	1
<i>Androsace chamaejasme</i>													0.46	0.58												1	1
<i>Androsace septentrionalis</i>					0.04	0.03																				1	1
<i>Anemone multifida</i>	0.11	0.21			0.04				0.86				0.39	0.57			0.04						0.1			6	2
<i>Anemone patens</i>					0.1	0.14			0.36	3.14							0.36	0.21								3	3
<i>Antennaria anaphaloides</i>											0.1				0.32	1.39	0.61	0.50			0.29	0.14				3	4
<i>Antennaria racemosa</i>																										0	0
<i>Antennaria rosea</i>			0.1	1.14	0.11	1.21	2.86	1.43			0.43	0.64							1.04	2.36	0.39	0.07				6	6
<i>Antennaria umbrinella</i>	0.1	0.1	0.21		0.21			5.43	3.57	6.71		1.29					0.1									5	4
<i>Antennaria</i> sp.					0.14																		0.1			2	0
<i>Aquilegia flavescens</i>													1.71	2.94												1	1
<i>Arabis divericarpa</i>										0.10			0.14													1	1
<i>Arabis drummondii</i>														0.14								0.29				0	2
<i>Arabis glabra</i>																	0.1	0.07								1	1
<i>Arabis hirsuta</i>			0.1																							1	0
<i>Arabis bolboellii</i>						0.1																				0	1
<i>Arabis nuttallii</i>					0.07				0.04								0.11		0.11				0.04			5	0
<i>Arabis</i> sp.																										0	0
<i>Arenaria capillaris</i>							3.57	1.66		0.1																1	2

Appendix B, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimate

	GRAS-99-029		GRAS-00-003		GRAS-00-008		GRAS-00-025		GRAS-00-026		GRAS-00-029		GRAS-00-042		GRAS-00-048		GRAS-01-003		GRAS-01-007		GRAS-01-010		GRAS-01-014		Plot	
	St. Mary		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Cut Bank		Two Medicine		Two Medicine		St. Mary		Frequency	
	Visitor's Center		Horse Corrals N		Red Mtn East		Pray Lake		East Spot Mtn		Avalanche Chute		Mad Wolf N		Old Bison Siding		Boundary		SS Moose Ponds		Lower TM Lake		Sleepy Lagoons		1999-	
	1999	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2001	2020	2001	2020	2001	2020	2001	2020	2001	2020
<i>Arenaria sp.</i>					0.07																				1	0
<i>Arnica sororia</i>	0.14	0.07															0.29				0.1	0.89	0.1		3	3
<i>Aster conspicuus</i>													0.50												1	0
<i>Aster laevis</i>				1.57		0.11							0.93	0.1				0.01	0.07	0.86	0.1				3	5
<i>Aster sibiricus</i>													2.86												0	1
<i>Aster sp.</i>										0.24															0	1
<i>Artemisia ludoviciana</i>						0.14																			0	1
<i>Astragalus adsurgens</i>																									0	0
<i>Astragalus alpinus</i>																									0	0
<i>Astragalus agrestis</i>																									0	0
<i>Astragalus australis</i>																									0	0
<i>Astragalus robbinsii</i>																									0	0
<i>Astragalus tenellus</i>	0.21																						0.1		2	0
<i>Astragalus sp.</i>													0.14												0	1
<i>Balsamorhiza sagittata</i>																			0.36						0	1
<i>Besseyia wyomingensis</i>									0.46	1.61			0.71	0.75											2	2
<i>Botrychium lunaria</i>													0.07						0.11						2	0
<i>Botrychium paradoxum</i>																			0.01						0	1
<i>Botrychium sp.</i>													0.01				0.01								0	2
<i>Bupleurum americanum</i>					0.11	0.79			0.54	0.14			0.18	0.68											3	3
<i>Calochortus apiculatus</i>						0.01					0.11	0.26		0.04							0.11	1.01	0.04		3	4
<i>Camassia quamash</i>																	0.07	0.07			0.57	0.14			2	2
<i>Campanula rotundifolia</i>	0.04	0.08	0.18	1.08	0.32	0.24	0.39	1.22	0.36	0.36	0.43	0.38	0.50	0.76	0.25	2.36	0.54	1.65	0.54	1.90	1.11	1.24	0.07	0.07	12	12
<i>Castilleja cusickii</i>										0.14				0.55											0	2
<i>Castilleja lutescens</i>										0.11				0.14											0	2
<i>Castilleja sulphurea</i>									0.43																1	0
<i>Castilleja sp.</i>											0.1										0.18				2	0
<i>Cerastium arvense</i>	0.14	0.08	0.93	3.43	0.07	0.79	0.36	0.37	1.21	2.61	0.07	0.01	1.25	1.38	0.50	1.36	0.57	6.01	0.79	3.43	0.43	11.64	0.29	0.51	12	12
<i>Chamerion angustifolium</i>												0.1											0.1		1	1
<i>Cirsium bookerianum</i>																					0.1				1	0
<i>Clematis occidentalis</i>													0.1	0.57											1	1
<i>Collinsia parviflora</i>			0.04			0.01																			1	1
<i>Collomia linearis</i>																	0.78					1.16			0	2
<i>Comandra umbellata</i>																									0	0
<i>Cryptantha celosioides</i>																									0	0
<i>Delphinium bicolor</i>																	0.1	0.23							1	1
<i>Dodecatheon conjugens</i>			0.1						0.25	0.16			0.14	0.22	0.1	0.15	1.46	0.52	1.14	0.15	1.07	0.44			7	6
<i>Douglasia montana</i>										0.57			0.1												1	1
<i>Draba albertina</i>										0.17				0.17			0.1								0	3
<i>Draba aurea</i>													0.11												1	0
<i>Draba incerta</i>										0.1															0	1
<i>Draba nemorosa</i>						0.16				0.01									0.06						0	3
<i>Draba sp.</i>																	0.01				0.01				0	2
<i>Dryas octopetala</i>													0.86	0.71											1	1
<i>Epilobium brachycarpum</i>																									0	0
<i>Erigeron caespitosus</i>									0.1																1	0
<i>Erigeron compositus</i>							0.14			0.01															0	2
<i>Erigeron speciosus</i>				0.21					0.1			0.07					0.01		1.89		3.64				1	5
<i>Erigeron subtrinervis</i>											0.07										2.07				2	0
<i>Erigeron sp.</i>									0.07					0.57											0	2

Appendix B, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimate

	GRAS-99-029		GRAS-00-003		GRAS-00-008		GRAS-00-025		GRAS-00-026		GRAS-00-029		GRAS-00-042		GRAS-00-048		GRAS-01-003		GRAS-01-007		GRAS-01-010		GRAS-01-014		Plot	
	St. Mary		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Cut Bank		Two Medicine		Two Medicine		St. Mary		Frequency	
	Visitor's Center		Horse Corral N		Red Mtn East		Pray Lake		East Spot Mtn		Avalanche Chute		Mad Wolf N		Old Bison Siding		Boundary		SS Moose Ponds		Lower TM Lake		Sleepy Lagoons		1999-	
	1999	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2001	2020	2001	2020	2001	2020	2001	2020	2001	2020
<i>Eriogonum flavum</i>					0.1	0.1	3.68	11.15		0.57										0.43					2	4
<i>Eriogonum ovalifolium</i>					0.1						0.1														2	0
<i>Eriogonum umbellatum</i>			5.46	14.29	0.21		0.1	1.14	0.04	1.36	0.1	0.1			0.36	1.07	0.79	4.86	2.71	10.29	0.1	0.07	0.1		10	8
<i>Erysimum inconspicuum</i>						0.1																			0	1
<i>Fragaria virginiana</i>	1.86	5.29		0.43	0.1	0.1					2.64	7.07	3.36	4.07			0.1	1.5	2.14	3.50			0.29	1.07	7	8
<i>Gaillardia aristata</i>					0.1	0.1			0.57	1.51			1.32	1.69				0.1			0.14	0.36			4	5
<i>Galium boreale</i>	0.29	0.43	0.21	3.21	0.25	0.45			1.71	2.43	1.46	3.33	2.14	1.74	2.04	6.36	0.64	2.58	1.96	4.54	3.50	7.65	0.29	3.86	11	11
<i>Gentiana amarella</i>													0.04	0.13											1	1
<i>Geranium viscosissimum</i>	0.29	2.29											0.1	0.36					0.29	0.11	0.1				3	4
<i>Geum triflorum</i>	6.29	19.29											0.01								0.1	0.21	3.64	1.29	3	4
<i>Happelopappus carthamoides</i>																									0	0
<i>Hedysarum alpinum</i>																									0	0
<i>Hedysarum sulphurescens</i>								0.1	0.1				1.29	2.21											2	2
<i>Heracleum sphondylium</i>													0.21	0.36				0.21							1	2
<i>Heterotheca villosa</i>								0.1	0.1																1	1
<i>Heuchera cylindrica</i>		0.1	6.43	9.86	0.1		1.57	1.79	0.07	0.07	0.5						0.29	2.00	1.29	3.21	0.21	0.36	1.36		8	8
<i>Heuchera parvifolia</i>									0.1	0.15		0.29													1	2
<i>Hieracium scouleri</i> var. <i>albertinum</i>					3.07	2.01					0.86	3									0.21	0.14			3	3
<i>Hieracium umbellatum</i>																									0	0
<i>Lathyrus ochroleucus</i>																									0	0
<i>Linum lewisii</i>								0.11					0.14	0.01											2	1
<i>Lithospermum ruderale</i>	0.32	1.00																					1.82	0.57	2	2
<i>Lomatium macrocarpum</i>																									0	0
<i>Lomatium triternatum</i>		0.1		1.71					0.1	0.21	0.89					0.58	3.07	4.21	2.36	2.37	2.50	2.86			4	8
<i>Lupinus argenteus</i>													4.00												0	1
<i>Lupinus sericeus</i>				0.07	3.71	3.07			4.71	4.44	0.61	5.11	3.21		2.79	4.29	0.68	2.43			1.04	8.79	0.25	0.1	8	8
<i>Maianthemum stellatum</i>	3.21	1.54			0.1	0.1																			2	2
<i>Microseris nutans</i>																					0.14	3.79			1	1
<i>Microseris gracilis</i>			0.1	0.05											0.07	0.1	0.54					1.74			2	4
<i>Mimuartia obtusiloba</i>								1.89	2.43				0.01												1	2
<i>Mimuartia rubella</i>						0.14																			0	1
<i>Moebria lateriflora</i>													0.82	0.29			0.07								2	1
<i>Monarda fistulosa</i>																									0	0
<i>Orthocarpus luteus</i>																							0.07		1	0
<i>Orthocarpus tenuifolius</i>	0.1																								1	0
<i>Oxytropis campestris</i>					0.07				0.21	0.58			0.36	0.08			0.1								3	3
<i>Oxytropis sericea</i>																									0	0
<i>Oxytropis splendens</i>	0.1												0.07	0.57											2	1
<i>Packera cana</i>	0.1	0.1			0.1	0.14													0.25	0.07					3	3
<i>Pedicularis contorta</i>					0.43	0.36			0.64	0.43	4.14										0.5	0.65			4	3
<i>Penstemon albertinus</i>						0.29																			0	1
<i>Penstemon confertus</i>		0.1	2.86	2.57	0.18	1.79	0.86	0.44	0.29	0.21		10.07			7.43	13.43	7.14	5.21	6.07	10.50	1.75				8	9
<i>Penstemon procerus</i>					0.36																				1	0
<i>Perideridia gairdneri</i>																	0.29					0.79			0	2
<i>Phacelia sericea</i>					0.1	0.1																			1	1
<i>Phlox boottii</i>	0.14								0.54														1.93	0.14	3	1
<i>Polemonium pulcherrimum</i>	0.18										0.14														2	0

Appendix B, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimate

Appendix B, continued. Eastside Grasslands: Comparison of canopy cover by lifeform and species for 12 plots read in 2020. Red = Ocular cover estimate

	GRAS-99-029		GRAS-00-003		GRAS-00-008		GRAS-00-025		GRAS-00-026		GRAS-00-029		GRAS-00-042		GRAS-00-048		GRAS-01-003		GRAS-01-007		GRAS-01-010		GRAS-01-014		Plot	
	St. Mary		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Two Medicine		Cut Bank		Two Medicine		Two Medicine		St. Mary		Frequency	
	Visitor's Center		Horse Corrals N		Red Mtn East		Pray Lake		East Spot Mtn		Avalanche Chute		Mad Wolf N		Old Bison Siding		Boundary		SS Moose Ponds		Lower TM Lake		Sleepy Lagoons		1999-2020	
	1999	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2000	2020	2001	2020	2001	2020	2001	2020	2001	2020	2001	2020
Exotic Grass	1.0	10.94	1.61	0.44	0	0	0.10	0.46	0	0	0.04	0	0.14	0.11	1.68	6.72	1.00	3.04	0	0	1.82	9.01	0.07	6.79		
<i>Bromus inermis</i>																									0	0
<i>Phleum pratense</i>	0.1	0.1	1.14	0.44				0.01			0.04	0.1		0.11	1.14	2.01	1.00	2.53		0.07	1.43	0.94	0.07	0.1	7	10
<i>Poa compressa</i>	0.50	0.72					0.1	0.45									0.07	0.08	0.1					0.1	4	4
<i>Poa pratensis</i>	0.54	10.21	0.68	0.1									0.14	0.01	0.54	4.71		0.44			0.39	8.09	0.1	6.79	6	7
# of exotic grass species	3	3	2	2	0	0	1	2	0	0	1	1	1	2	2	2	2	3	1	1	2	2	2	3	12	12
Exotic Forb	0.04	0.01	0.21	0.21	0	0	0.21	0.29	0	0	0	0	0	0	0.10	0.29	0.14	0.68	0.43	0	0.43	0.51	1.82	2.20		
<i>Alyssum alyssoides</i>																									0	0
<i>Centaurea maculosa</i>	0.04	0.1																					1.82	1.84	2	2
<i>Erysimum cheiranthoides</i>																									0	0
<i>Medicago lupulina</i>																							0.07		1	0
<i>Melilotus officinalis</i>																								0.1	0	1
<i>Myosotis micrantha</i>								0.1																	0	1
<i>Rumex acetosella</i>			0.04				0.21	0.29																	2	1
<i>Taraxacum officinale</i>			0.18	0.21											0.1	1	0.14	0.43	0.43	0.1	0.43	0.14		0.07	5	6
<i>Tragopogon dubius</i>		0.01														0.29		0.46				0.37		0.29	0	5
# of exotic forb species	1	2	2	1	0	0	1	2	0	0	0	0	0	0	1	2	1	2	1	1	1	2	2	4	12	12