

Glacier National Park: Restoration Monitoring Report

2021

By: Jennifer Hintz Guse and Allison Dubenezic

Grasslands Crew: Nicolas Matallana-Mejia,
Keegan Herron and Marissa Ng

Division of Resource Management
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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, 2021
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, 2021
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. 303-B: LAKE MCDONALD SEGMENT OF GOING-TO-THE-SUN ROAD

A. BACKGROUND AND PURPOSE

The Lake McDonald segment of Going-To-The-Sun Road was revegetated in 1991. Over 10 miles of roadside were planted and seeded with native species, including 17 turnouts that were deleted. Six of the deleted turnouts serve as monitoring sites and have been monitored since 1992.

The initial purposes of monitoring 303-B were to determine:

- (1) establishment and growth of seeded species;
- (2) if seeding increased cover and diversity of native species and minimized cover of exotics;
- (3) the appropriateness of species selection and seeding rates;
- (4) the survival and growth of nursery stock; and
- (5) realistic, quantifiable goals for future projects.

B. METHODS

Five deleted turnouts (#s 14, 21, 22, 27, and 40) were selected as sites to assess the effectiveness of seeding native grasses and forbs on the cover and diversity of native species and its effect on reducing exotic species invasion. Turnouts were divided into two plots. One randomly selected plot was to be seeded with native grasses and forbs, while the other was to receive no seed treatment and serve as a control. Due to miscommunication, however, some of the plots were not seeded correctly. In addition, a single plot was established on turnout #12 as another seeded sample. The final treatment of each turnout is as follows:

<u>Plots</u>	<u>Seeded/Not seeded</u>
121	seeded
141	seeded
142	seeded
211	seeded
212	not seeded
221	not seeded
222	not seeded
271	seeded
272	not seeded
401	not seeded
402	seeded

In total, there were 11 plots, 6 seeded and 5 unseeded (Figure 1). Shrubs and trees were planted on all plots as described in the 303-B Completion Report (Lapp, 1992).

Three permanent transects were originally established on each plot and are marked on both ends with rebar. In most cases a baseline pin is also present and the distances from this pin are used to locate transect pins on the north end. Transects start on the north end, and are 20m long, except for plot 121, which is 30m long. Plots vary from 3 to 5 m wide. Transects are used for microplot locations for canopy cover determination, as well as for line-intercept measurements of shrubs and trees, both planted and not planted.

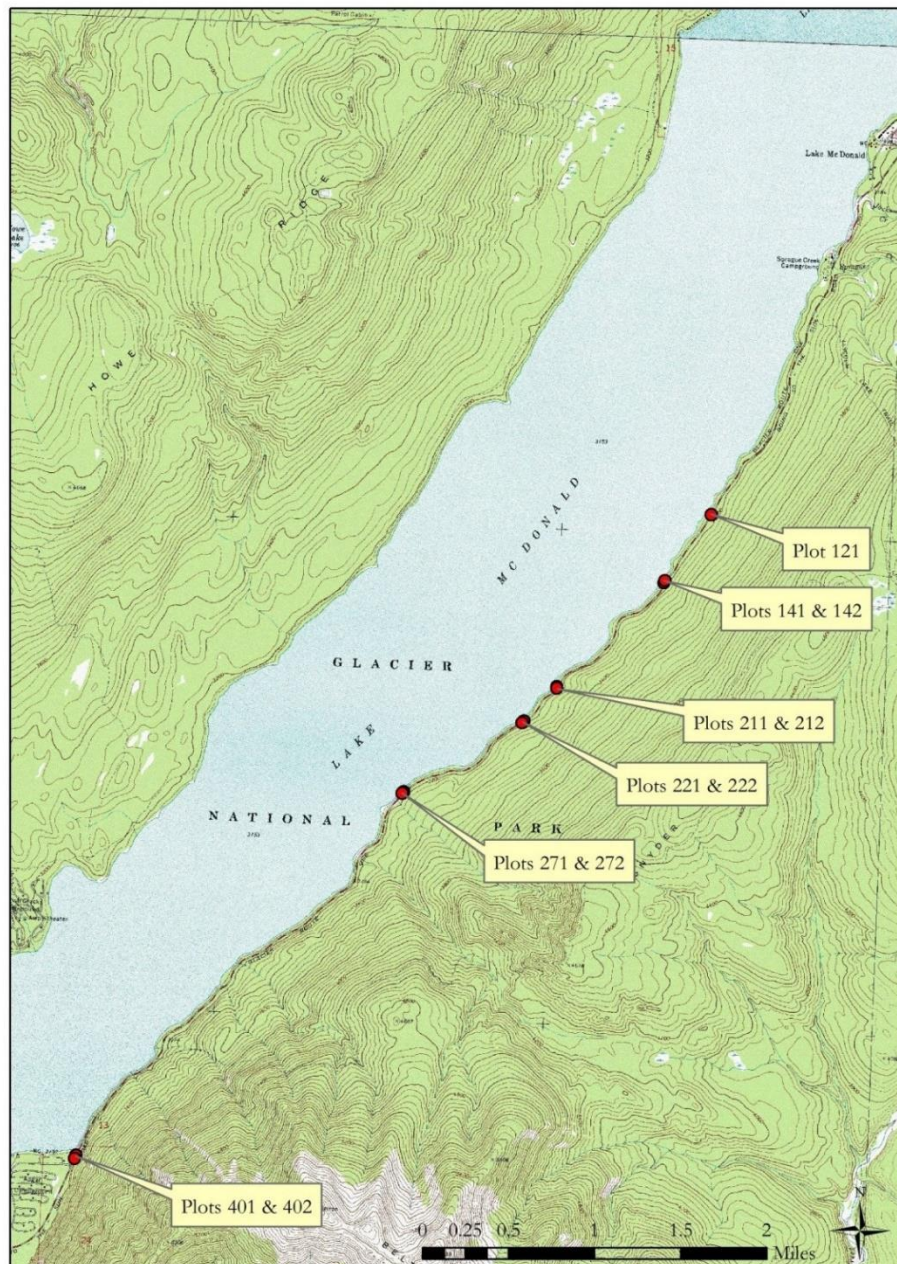
Canopy cover of all native and exotic plants and ground cover are measured in five 50cm x 20cm microplots along each transect. These microplots were originally randomly selected, and are permanently located for re-reads, resulting in paired samples year to year. Locations for the lower left corner of the microplots are on the left side of the tape, standing at the origin and are listed on the datasheets. Percent ocular cover is estimated

for all species within microplots, as well as each ground cover component. After reading all microplots, the plot is walked for estimated ocular cover of any species not captured in microplots.

Line intercept methodology is used to determine shrub and tree cover along the entire transect for each of the three transects. Using a pin or meter stick perpendicular to the tape, the beginning and ending number on the tape is recorded for the location on the tape where each species starts and ends, using whole centimeters. The total number of hits per species is calculated.

Monitoring took place on all plots in 1992, 1994, 1996, 2001, 2011 and 2021. Prior to 2011, statistics were utilized for data analysis. Lifeform and species cover was analyzed using Wilcoxin's signed rank test for paired samples (lifeform & species comparisons between years) and a Mann-Whitney U test for independent samples (seeded vs. unseeded plots within year). A McNemar's test was performed to determine differences of average species frequency between years. Statistics were not able to be performed in 2011 or 2021.

Figure 1. 303B: Location of Plots Along Lake McDonald Section of Going-To-The-Sun Road.



C. RESULTS AND DISCUSSION

1. Total Vegetation Cover (herbaceous and woody combined)

Monitoring data collected in 2021, thirty years after planting and seeding, revealed that mean overall vegetation increased substantially in unseeded plots over the past ten years, by nearly 20%. Mean overall vegetation in unseeded plots, however, remained relatively stable (Table 2).

Table 2. 303-B: Comparison of Mean Percent Cover for Total Vegetation, Native Vegetation and Exotic Vegetation on Seeded and Unseeded Plots, 1992-2021.

Year	Overall vegetation						Native vegetation						Exotic vegetation					
	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
Seeded	17	39	41	27	45	44	7	21	22	17	31	34	10	18	19	10	15	10
Unseeded	19	29	39	27	56	74	3	5	12	17	43	69	16	24	26	10	13	6

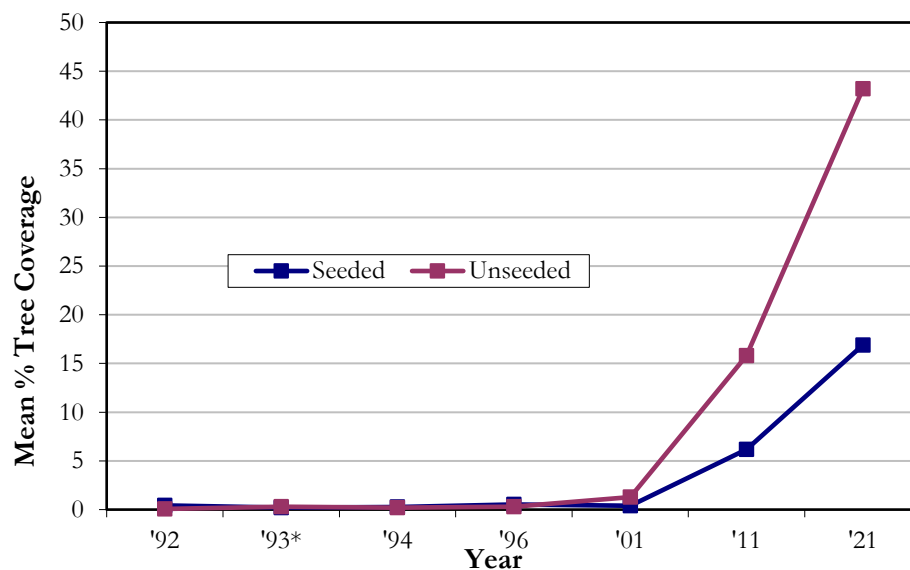
The increase of overall vegetation cover, as well as native cover, is almost totally due to a large increase of tree area, especially in unseeded plots (Table 2). Most other lifeforms decreased in cover over the past ten years. Average shrub cover increased very slightly in unseeded plots, but all other lifeforms declined. Increasing tree cover may shade out or outcompete other species, resulting in lower cover of almost all other lifeforms.

2. Woody Vegetation

2a. Trees

Tree cover increased substantially under both seed treatments between 2011 and 2021 (Table 3, Figure 2). In seeded plots, estimated ocular tree cover rose almost 11%, and in unseeded plots, it rose by over 27% over the past ten years.

Figure 2. Average Tree Cover for 303B plots, 1992-2021; Estimated Ocular Cover in Microplots



*some plots not surveyed in 1993 due to high exotic forb cover

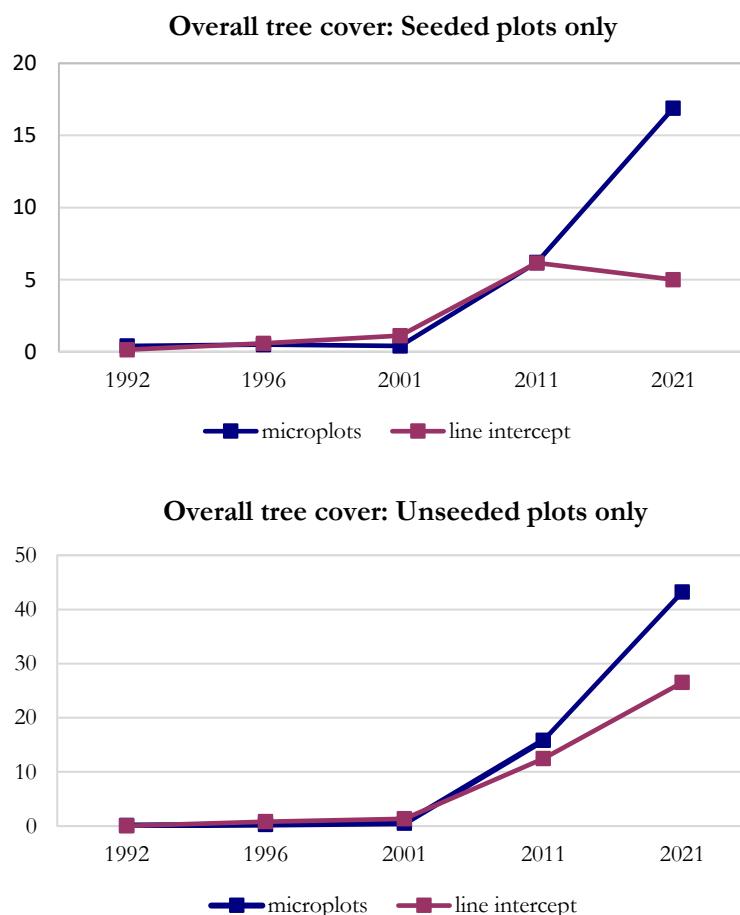
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Slightly different results were found using point-intercept methodology (Figure 3). Unseeded plots were found to have a substantial increase in tree cover using this method, but to a lesser degree, with a 14% increase. Seeded plots showed a slight decline in cover, however, by 1%, using the line intercept method. One reason may be differences in interpretation of methodology between the years, particularly in plot 402, a seeded plot. In 2021, *Pseudotsuga menziesii* was not included in line intercept sampling, as it was interpreted to be a well-established mature tree species on the forest edge of the plot, and not planted in revegetation efforts. It appears that it was included in point intercept sampling in that plot in previous years. All other plots appear to have been sampled similarly.

Several tree species showed large increases in cover in many plots under point intercept methodology. *P. menziesii* increased substantially, by 8% to 20% in several plots (Table 3). *Larix occidentalis* increased from 9 to 36% cover in plot 401. Many plots had massive growth in trees near the forested edge of the plot, and in a few cases, throughout the plot, as in plots 401 and 402, closest to Apgar. Other plots experienced more road disturbance. Trees have been mowed and even cut within several of the plots, especially closer to the road edge.

Tree cover has been dynamic within this project. Although many of the original trees planted for this project died, numerous conifer seedlings began to establish on 303-B plots between 1996 and 2001. Over time, *Pseudotsuga menziesii* has increased on both seeded and unseeded plots, contributing the most to overall tree cover. Other tree species have recruited, including *Pinus contorta* and *Pinus monticola*. Although persistent mowing of the road corridor keeps many species from establishing, in areas that are more protected, tree cover is flourishing and is the most successful life form across the project.

Figure 3. Average Tree Cover for 303B plots, 1992-2021; Ocular Cover vs. Point Intercept Methodology

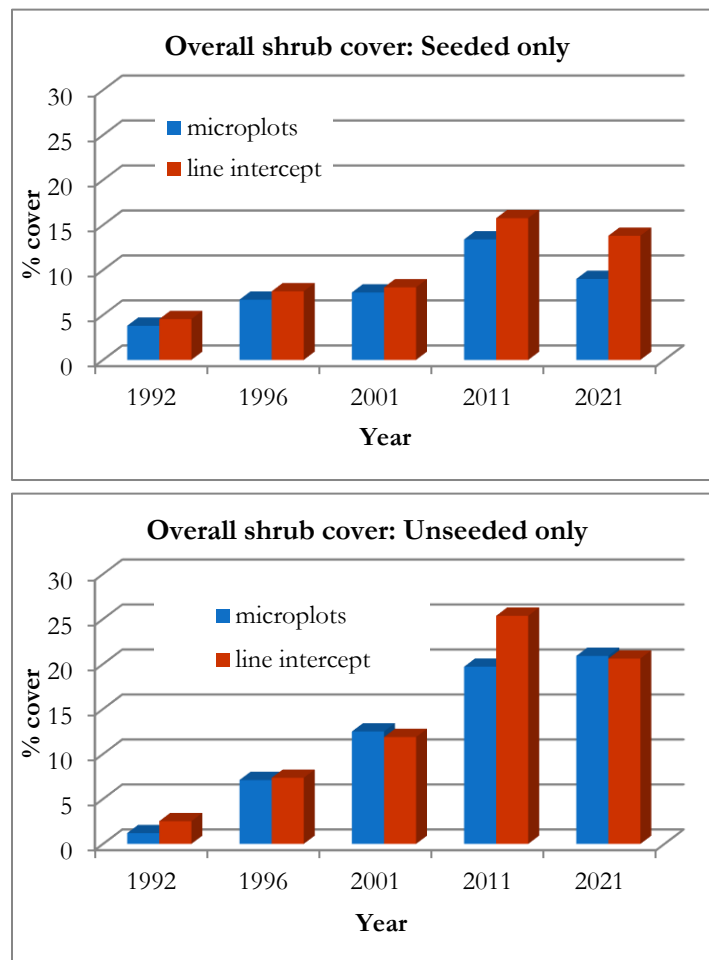


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2b. Shrubs

Canopy cover estimates for shrubs and trees were also obtained using line intercept and microplot estimates. Both methodologies showed similar but slightly different trends. Using microplot cover estimations, Unseeded plots showed a very slight increase in cover over the past ten years, while seeded plots showed a decrease in cover. Using point intercept, both seeded and unseeded plots showed a decrease in cover (Figure 4). In this case, line intercept sampling may be more accurate, due to the higher sample size and more quantitative data.

Figure 4. Average Shrub Cover for 303B plots, 1992-2021.



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The most notable species that declined was *Arctostaphylos uva-ursi*, which decreased in many plots sampled by microplot and line intercept. Overall average cover was reduced over the past ten years in microplots by almost 2% in seeded plots and by 4% in unseeded plots. Using point intercept, *A. uva-ursi* declined by 2% in seeded plots and by over 7% in unseeded plots. This low-growing sub-shrub is thriving in some areas of this study, especially in areas of low disturbance. However, other areas closer to the road are scoured and inundated with gravel, proving inhospitable to many plant species, which likely contributed to its decline. Additionally, the increase in tree cover could be out shading or outcompeting this species.

Another shrub species that showed a modest decline in several plots was *Rosa woodsii*. Under microplot sampling, this shrub species declined by 1% in seeded plots and by over 2% in unseeded plots, on average. Using line intercept, *R. woodsii* decreased very slightly in seeded plots, but declined by 3% in unseeded plots. Many other species had mixed results, declining substantially in some plots, but increasing slightly in others, including *Shepherdia canadensis*, *Symphoricarpos albus* and *Spiraea betulifolia*. This could be due to differences in

location. Plots closer to the road experienced more woody species decline due to mowing and scouring. Additionally, shrubs in several plots were experiencing defoliation from a myriad of insects observed eating the leaves. Some plants were almost skeletonized, while others were not affected at all, or barely infested. Given the severe heat and dry conditions of the summer of 2021, damage from insects may have been exacerbated, and may have contributed to lower covers of certain shrub species.

It had been noted in earlier reports that shrub cover was increasing faster on unseeded plots in comparison to seeded plots (Asebrook et al. 1996, 2001). Asebrook et al (1996) suggested that competition for light and water from tall herbaceous plants might inhibit some shrub growth on seeded plots. To date, shrub cover remains higher on unseeded plots. At this point, it is difficult to determine whether seeding or not seeding has any effect on current vegetative composition, but it may have set the stage for subsequent success and survival of certain lifeforms and species. The early success and current higher canopy cover of shrubs on unseeded plots, however, indicates that initial seeding may inhibit woody plant establishment and growth. Perhaps in areas where high woody cover is the goal, seeding should not occur in areas underneath or near planted woody species.

2. Herbaceous Vegetation

2a. Native Grasses

Native grass cover on seeded plots has experienced a continuous decline since 1994 (Table 3, Figure 5). Many species decreased in cover slightly, adding up to an overall decline in this lifeform.

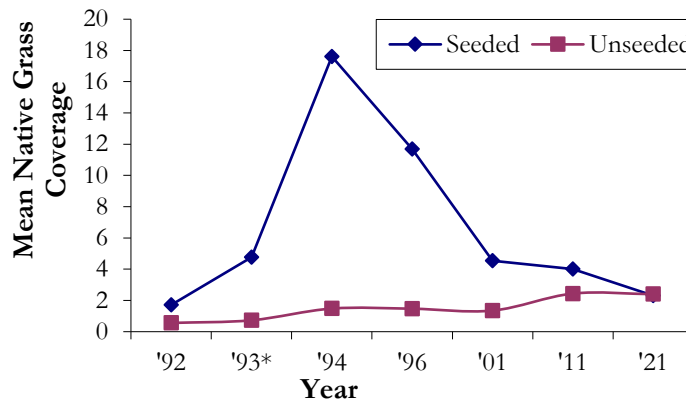
In seeded plots, overall native grass cover decreased by almost 2% in the past 10 years, averaging just over 2%. *Elymus glaucus*, a seeded nurse grass, peaked at an average of 10% in 1996 and has slowly dropped to less than 1% by 2021 (Table 3). As seen on other restoration projects, this grass can rapidly establish and increase when there is little other vegetative competition, but often declines dramatically after three to four years (Hassell, 1983). *Bromus carinatus*, another seeded nurse grass, returned to seeded plots after previously disappearing, potentially from remnant seed in the seed bank. However, this species had very low overall cover, at less than 1%. Several other native grass species declined, including *Danthonia* and *Carex* species. Although these species never had large covers, they are all now less than 1%. While most native grasses decreased in cover, a very slight increase was found in *Calamagrostis rubescens*, also seeded, which optimistically could become a persistent later seral native grasses across the project.

In unseeded plots, overall native grass cover remained stable from 2011 to 2021, at 2.4% (Table 3). *E. glaucus* cover increased slightly on average across plots. Very small increases (less than 1%) were also seen in several other native grass species, such as *Danthonia intermedia*, *Festuca occidentalis* and *Poa palustris*. These species most likely recruited from nearby forested areas. Several of the later seral grasses decreased, however, in unseeded plots, such as *C. rubescens* and *Elymus trachycaulus*. Sedges also experienced a slight decrease in cover across unseeded plots, when looking at all sedge species lumped together, and continue to provide very low overall on this project.

Seeded and unseeded plots now have essentially equal average native grass cover. Thirty years after revegetation, the effects of seeding and not seeding have likely become diminished. In the first years after seeding, native grass cover in seeded plots showed promise, steadily increasing. After ten years, however, they began to decline. Under ideal conditions, initial establishment by nurse grasses would have been followed by increases in later seral species as well as recruiting native grass species, and differences in native grass cover between seeded and unseeded plots may have persisted. With continued disturbance along the road corridor, however, these differences have become muddled.

Figure 5. Average Native Grass Cover for 303B plots, 1992-2021.

*some plots not surveyed in 1993 due to high exotic forb cover



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2b. Native Forbs

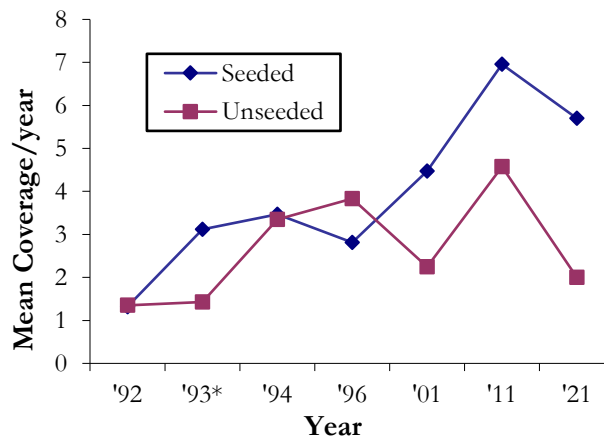
After a relatively steady increase in overall cover of native forbs since from 1992 to 2011 in both seeded and unseeded plots, native forbs have decreased markedly under both seeding treatments over the past ten years (Table 3, Figure 6).

In seeded plots, almost all species that had developed substantial cover have declined since 2011. The exception to this rule was *Xerophyllum tenax*, which was seeded, and has been slowly increasing over time. In several plots, seeded *X. tenax* plants are thriving, with some individuals approaching a half meter wide. None were observed having flowered yet, however.

In unseeded plots, there was a slight change in cover in many species, but some of the largest declines were found in the *Fragaria* species. Both species of strawberry had promise to provide good ground cover, with their stoloniferous growth form, but may not have been able to survive the disturbance and/or shading by tree overstory. Several species are recruiting to these areas, however, in small amounts, including *X. tenax*. A few species reappeared after previously disappearing from unseeded plots, including *Anaphalis margaritacea* and *Penstemon confertus*. A few of these areas had been inadvertently seeded or received some seeded material inadvertently from adjacent seeded areas. There may have been some residual seed in the seed bank that resulted in resprouting in some areas.

Figure 6. Average Native Forb Cover for 303B plots, 1992-2021.

*some plots not surveyed in 1993 due to high exotic forb cover



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Table 3. 303-B: Comparison of Mean Canopy Cover (%) Estimates Between Seeded and Unseeded Plots for Lifeform, Seeded Species, and Select Exotic and Native Species.

Bold red font or **green fill** cells indicate that there is a significant difference (95% confidence) between consecutive years for seeded or unseeded plots.

Cells that have a double blue outline indicate that there is a significant difference (95% confidence level) between 2001 and 1992 for seeded and unseeded plots.

Statistics were not performed in 2011 or 2021.

* Indicates that there is a significant difference between seeded and unseeded plots for that year

+ Seeded species

	Seed Rate (seeds/m ²)	Seeded					Unseeded				
		1992	1996	2001	2011	2021	1992	1996	2001	2011	2021
LIFEFORM											
Tree		0.4	0.5	0.4	6.2	16.9	*0.1	*0.3	0.5	15.8	43.2
Shrub		*3.8	6.7	7.5	13.4	9.0	*1.2	*7.1	12.5	19.7	20.9
Native grass		*1.7	*11.7	*4.6	4.0	2.3	*0.6	*1.2	*1.5	2.4	2.4
Native forb		1.3	2.8	*4.5	7.0	5.7	*1.4	*3.8	*2.3	4.6	2.0
Exotic grass		*0.9	*2.6	*4.5	8.0	6.7	*0.72	*2.4	4	6.3	3.9
Exotic forb		*8.8	*16.4	*5.6	6.7	3.0	*14.7	*23.9	*5.8	7.0	1.9
NATIVE GRASSES											
+ <i>Bromus carinatus</i>	43.0	*0.4	0	0	0	0.3	*0.0	0	0	0.3	0.1
<i>Carex</i> spp.		*1.0	*1.4	0.7	0.3	0.1	*0.6	*0.9	0.7	0.1	0.2
<i>Carex aurea</i>					0.3	0.1				0.2	0.003
<i>Carex microptera</i>					0.01	0				0	0.02
<i>Carex pachystachya</i>					0	0				0.1	0
<i>Carex rossii</i>					0.04	0				0.01	0.01
+ <i>Calamagrostis rubescens</i>	161.4	0	*0.9	0.3	0.4	0.5	0	*0.2	0.2	0.6	0.4
<i>Danthonia intermedia</i>					0.8	0.1				0.2	0.4
<i>Danthonia spicata</i>		0	0	0.1	0.8	0	0	0	0.5	0	0
+ <i>Elymus glaucus</i>	161.4	*0.8	*10.0	*3.4	1.4	0.7	*0.0	*0.1	*0.4	0.7	0.9
+ <i>Elymus trachycaulus</i>	32.3	0	0	0	0	0	0	0	0.1	0.5	0.1
<i>Festuca occidentalis</i>				0	0.1	0.1			0.01	0.1	0.2
<i>Poa palustris</i>		0	0.1	0.2	0	0	0	0.1	0	0	0.05
SELECT NATIVE FORBS											
+ <i>Achillea millefolium</i>	32.3	*0.3	*0.5	*0.3	0.3	0.1	*0	*0	*0.1	0	0
+ <i>Anaphalis margaritacea</i>	32.3	*0.1	0.5	*	0	0	*0	0	*0.2	0	0.02
+ <i>Antennaria bonellii</i>	21.5	0	0	0.1	0.7	0.2	0	0	0	0.1	0.1
+ <i>Aster laevis</i>	53.8	*0.2	*0.5	*1.5	2.3	1.6	*0.1	*0.5	*0.8	1.6	1.6
<i>Fragaria vesca</i>		0	0	0.2	0.5	0	0	0.2	0.4	1.4	0.03
<i>Fragaria virginiana</i>		0	*0.1	*0.1	0.4	0.1	0	*1.2	*0.5	0.6	0.02
+ <i>Penstemon</i> spp.	64.6	0	*0.1	*0.2	1.1	0.5	0	*0.0	*0	0	0.1
+ <i>Solidago canadensis</i>	53.8	0	0.5	0.7	0.5	0.3	0	0.4	0.3	0.3	0.03
+ <i>Xerophyllum tenax</i>	107.6	0	*0.1	*0.2	1.0	2.6	0	*0	*0	0	0.1

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Table 3, continued

		Seeded					Unseeded				
SELECT NATIVE TREES		1992	1996	2001	2011	2021	1992	1996	2001	2011	2021
<i>Betula papyrifera</i>				0	0	4.3			0	0.03	9.2
<i>Larix occidentalis</i>				0	0	0			0	0.7	4.7
<i>Pinus contorta</i>				0	0	1.0			0.08	0.6	3.4
<i>Picea engelmannii</i>				0.04	1.6	1.2			0.07	1.9	0.8
<i>Populus balsamifera</i>				0.01	0.2	0.1			0.02	0.4	0.02
<i>Pseudotsuga menziesii</i>				0.39	4.3	8.8			0.19	9.7	20.7
SELECT NATIVE SHRUBS											
<i>Acer glabrum</i>				0	0.04	0.70			0.01	1.3	4.32
<i>Alnus viridis</i>						0					0.7
<i>Amelanchier alnifolia</i>				0.8	0.45	0.70			0.57	0.01	0.8
<i>Arctostaphylos uva-ursi</i>		0.3	* 0.5	*1.1	5.6	4.0	0.3	*3.1	*7.9	10.7	6.3
<i>Linnaea borealis</i>				0	0.1	0.1			0.8	1.1	0.7
<i>Paxistima myrsinites</i>				0.2	0.6	0.3			0	0.1	0.4
<i>Rosa woodsii</i>		1.1	2.4	*2.0	1.4	0.4	0.7	2.7	*2.9	2.9	0.7
<i>Shepherdia canadensis</i>		0	0.1	*0.0	2.0	1.3	0	1	*1.0	3.3	4.0
<i>Spiraea betulifolia</i>				0	0.1	1.5			0.1	0.6	0.2
<i>Symphoricarpos albus</i>		*1.6	*1.5	*3.6	2.0	0.6	* 0	*0	*0.3	0.7	1.7
SELECT EXOTIC GRASSES											
<i>Agrostis stolonifera</i>		0	0.9	1.8	1.9	0.4	0	1	1.6	1.3	0.8
<i>Elymus repens</i>		0	0.1	0.1	0.1	0.1	0	0	0	0	0
<i>Dactylis glomerata</i>		0	*0.3	0.8	4.5	4.9	0	*0.1	0.5	3.3	2.5
<i>Pbleum pratense</i>		0.1	* 0.2	0.4	0.2	0	0	* 0	0.2	0.3	0.1
<i>Poa compressa</i>		0.1	0.5	0.5	0.4	0.1	0.2	0.5	0.7	0.5	0.1
<i>Poa pratensis</i>		0	0.83	*1.2	0.9	0.1	0	1.1	*0.6	0.4	0.2
<i>Bromus inermis</i>				0.01	0.1	0.8			0.1	0.6	0.3
SELECT EXOTIC FORBS											
<i>Centaurea maculosa</i>		0.2	0.2	0.4	0.5	0.4	0.1	0.4	0.4	0.2	0.04
<i>Chrysanthemum leucanthemum</i>		1.1	2.8	1.3	0.6	0.2	2.6	2.6	0.9	0.4	0.3
<i>Hypericum perforatum</i>		0	* 0.2	*0.1	0.4	0.1	0	* 0.0	*0.0	0	0
<i>Linaria vulgaris</i>		0	0	0	0	0	0	0.2	0	0	0.04
<i>Medicago lupulina</i>		* 1.9	5.9	0.3	0.7	0.2	* 2.1	9.6	0.4	1.0	0.04
<i>Melilotus</i> spp.		4.2	*3.4	0.1	0.1	0	6.5	*5.1	0	0.2	0.02
<i>Prunella vulgaris</i>		0	* 0.8	*1.3	1.1	0.5	0	* 1.1	*1.6	0.6	0.4
<i>Taraxacum officinale</i>		0.2	* 0.9	0.5	0.5	0.1	0.8	*1.1	0.6	0.7	0.1
<i>Trifolium agrarium</i>		0	2	0.1	2.0	0.1	0	1.6	0	2.4	0.03
<i>Trifolium</i> spp.		* 1.7	0.9	0.5	0	0.02	* 1.2	1.8	0.5	0	0.02
<i>Veronica officinalis</i>		0	* 0.2	*1.1	1.0	1.5	0	* 0.5	*1.7	1.1	1.0
<i>Verbascum thapsus</i>		0.2	0.1	0	0	0	0.7	0	0	0	0

Table 4. 303-B: Number of Native and Exotic Species by Plot, 1992-2021.

Plot Number	Year	# Natives	# Exotics	Total
121	1992	17	8	25
Seeded	1993	19	16	35
	1994	27	15	42
	1996	24	18	42
	2001	19	17	36
	2011	24	13	37
	2021	31	6	37
141	1992	13	9	22
Seeded	1993	25	19	44
	1994	23	21	44
	1996	18	19	37
	2001	17	14	31
	2011	23	13	36
	2021	28	12	40
142	1992	13	9	22
Seeded	1993	21	17	38
	1994	29	19	48
	1996	27	20	47
	2001	23	14	37
	2011	27	17	44
	2021	34	14	48
211	1992	12	9	21
Seeded	1993	18	20	38
	1994	23	14	37
	1996	23	18	41
	2001	26	15	41
	2011	28	13	41
	2021	25	7	32
212	1992	11	8	19
Unseeded	1993	17	18	35
	1994	20	15	35
	1996	23	16	39
	2001	23	14	37
	2011	22	13	35
	2021	38	8	46
221	1992	10	13	23
Unseeded	1993	NM	NM	NM
	1994	22	15	37
	1996	21	17	38
	2001	17	14	31
	2011	16	16	32
	2021	30	10	40
222	1992	11	7	18
Unseeded	1993	NM	NM	NM
	1994	13	14	27
	1996	17	18	35
	2001	12	12	24
	2011	17	14	31
	2021	28	13	41

Plot Number	Year	# Natives	# Exotics	Total
271	1992	14	11	25
Seeded	1993	NM	NM	NM
	1994	16	15	31
	1996	14	17	31
	2001	18	13	31
	2011	16	15	31
	2021	27	11	38
272	1992	9	12	21
Unseeded	1993	NM	NM	NM
	1994	12	17	30
	1996	19	19	38
	2001	16	13	29
	2011	15	16	31
	2021	23	9	32
401	1992	9	9	18
Unseeded	1993	12	15	27
	1994	16	14	30
	1996	15	14	29
	2001	15	16	31
	2011	21	15	36
	2021	32	14	46
402	1992	10	11	21
Seeded	1993	17	16	33
	1994	21	17	38
	1996	10	16	26
	2001	14	13	27
	2011	16	15	31
	2021	28	21	49

Treatment	Year	# Natives	# Exotics	Total
Seeded	1992	79	57	136
Unseeded		50	49	99
Seeded	1994	139	101	240
Unseeded		83	75	158
Seeded	1996	116	108	224
Unseeded		95	84	179
Seeded	2001	117	86	203
Unseeded		83	69	152
Seeded	2011	134	86	220
Unseeded		91	74	165
Seeded	2021	64	26	90
Unseeded		69	26	95

Table 5. 303-B: Lifeform Canopy Cover (%) and Ground Cover by Plot for Years 1992 -2021.

Red text indicates that there is a significant difference between consecutive years at the 95% confidence level.

Cells that have a double blue outline indicate that there is a significant difference between 2001 and 1994 or 1992 values at the 95% confidence level.

No statistics were performed in 2011 or 2021.

	121 seeded						141 seeded						142 seeded					
	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
LIFEFORM CANOPY COVER (%)																		
Tree	0.1	0.2	0.2	0	6	25	0.1	0.3	0.3	0	0	4	0	0.7	1	0	5	24
Shrub	5.3	6.9	8.8	8.2	11	0.5	2.9	3.5	6.3	3.2	8	8	7.9	13.5	15.1	23.6	21	17
Native grass	3.2	22.6	15.7	3.4	3	3	1.1	28.5	12	4.8	1	1	1.1	9.4	6.7	2.8	2	0.4
Native forb	1.8	3.2	1.8	4.3	10	11	1.5	5.4	4	6.8	8	3.5	2.6	4.6	6.1	4.7	7	7
Exotic grass	1	2.9	4.1	6.5	5	3	0.3	1.9	2	4.7	5	14	1.4	2.3	2.2	1.6	5	3
Exotic forb	7.7	8.3	12.2	3.6	4	1	1.9	15.3	14.3	7	7	5	2.3	15	16	2.6	4	2
GROUND COVER (%)																		
Basal vegetation	1	1	1	<1	1	1	1	2	1	1	1	1	2	1	2	<1	2	1
Litter	13	41	59	57	62	69	9	49	77	43	56	56	13	44	37	36	40	56
Moss	2	7	5	4.8	28	22	2	5	6	8	22	32	1	5	7	7.1	25	32
Bare soil	40	2	1	0	0	0	37	5	< 1	4	0	0.6	45	9	2	<1	0	0.6
Gravel	38	35	25	35	8	6	41	33	8	44	20	8	31	29	42	54	32	7.6
Rock	4	13	7	2.6	1	0.3	3	9	5	2	1	0.5	6	12	7	2.4	2	0.5
Wood	< 1	< 1	< 1	<1	0	2	2	< 1	< 1	0	0	0.5	1	< 1	0	0	0	0.5
Other (asphalt)	0	< 1	0	<1	0	0.8	< 1	0	< 1	0	0	2	1	< 1	0	<1	0	1.5

	211 seeded						212 not seeded						221 not seeded					
	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
LIFEFORM CANOPY COVER (%)																		
Tree	0	0.3	0.4	0.1	0	0.01	0.1	0.41	0.21	0.2	3	39	0.1	0.2	0.2	1.2	26	13
Shrub	0.4	2.1	2.3	1.7	1	2	0.3	3.3	2.6	9.5	13	21	0.9	6.9	10.7	26.3	30	10
Native grass	0.7	6.9	4.4	3.6	8	4	*0.4	1.7	1	1	2	4	0.9	2.1	1.2	0.8	1	1
Native forb	0.8	4.3	2.4	8.2	15	12	0.8	3.4	4.5	5.8	15	5	2	6.6	7.4	4	4	3
Exotic grass	0.7	6	2.5	3.6	4	1	0.8	2.6	1.9	2.9	4	2	1.5	1.6	1.8	1.1	5	4
Exotic forb	6.9	24.3	11.7	10.1	5	0.4	3.9	25.2	12.8	11.4	5	1	12	23.3	25	8.6	5	2
GROUND COVER (%)																		
Basal vegetation	1	1	2	1	1	1	1	1	1	1	1	1	2	1	2	1	1	2
Litter	3	19	35	24	6	20	19	20	44	44	47	53	15	30	54	33	51	65
Moss	1	10	8	11	53	63	< 1	5	9	9	22	26	< 1	5	5	4	12	11
Bare soil	43	5	2	<1	0	0.1	29	5	< 1	0	3	0.4	43	4	1	<1	1	2
Gravel	47	48	41	60	37	14	47	55	41	45	25	15	31	44	29	59	34	17
Rock	5	16	12	5	2	0.3	4	12	8	2	0	0.4	5	12	10	3	2	1
Wood	< 1	< 1	< 1	0	0	0	< 1	1	< 1	0	1	0.5	< 1	< 1	0	0	0	3
Other (asphalt/lichen)	0	1	< 1	<1	0	1.4	< 1	< 1	0	0	0	3	2	3	2	1	0	0

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Table 5, continued. 303-B: Lifeform Canopy Cover (%) $\pm$ Standard Error and Ground Cover by Plot for Years 1992 - 2021.

	222						271						272					
	not seeded						seeded						not seeded					
	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
LIFEFORM CANOPY COVER (%)																		
Tree	0.1	0.1	0.1	0.3	11	25	0.3	0.1	0.1	0.3	5	7	0.1	0.2	0.2	0	15	76
Shrub	1.3	5	4	14	17	16	6.1	6.6	5.9	4.1	15	6	2.5	4.9	9.7	5	19	37
Native grass	0.3	1	0.7	0.6	1	2	2.9	31.7	28.3	11.1	6	3	0.5	0.9	1.1	2.2	2	1
Native forb	2.8	5.6	5.2	0.9	2	0.2	0.6	0.7	1	2	0	1	1	0.2	1.7	0.5	1	0.5
Exotic grass	0.5	2.4	2.1	4.3	1	3	1.6	2.9	3.7	4.9	20	13	0.7	3.1	5.7	10	12	5
Exotic forb	16.3	23.3	38.7	3.4	3	3	20.8	10.1	14.3	5.1	4	0.4	31.7	19.9	17.7	3.5	3	1
GROUND COVER (%)																		
Basal vegetation	2	1	1	1	1	1	2	2	2	1	2	2	2	1	2	<1	1	1
Litter	32	48	62	48	91	90	35	63	69	71	77	89	32	50	69	78	86	96
Moss	< 1	2	3	1	1	3	1	5	6	7	15	6	< 1	6	4	1	2	2
Bare soil	28	3	1	0.2	0	0.4	32	2	0	1	0	0.1	34	9	6	0	0	0
Gravel	32	37	27	48	6	4	24	17	18	20	5	2.4	26	23	13	18	3	0.1
Rock	3	7	6	2	1	1	4	9	5	2	0	0	4	7	5	2	1	0.3
Wood	< 1	< 1	0	0	0	0.5	1	1	< 1	0	0	0.1	0	0	0	0	1	0
Other (asphalt)	< 1	1	< 1	0	0	0.1	< 1	1	< 1	0	0	1	0	< 1	< 1	< 1	0	0

	401						402					
	not seeded						seeded					
	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
LIFEFORM CANOPY COVER (%)												
Tree	0.1	0.1	0.7	0.5	25	63	2.2	0.1	1.4	2	22	42
Shrub	1.3	5.2	8.5	8	20	19	0.1	0.5	1.8	4	24	22
Native grass	0.7	1.8	1.8	2.3	7	4	1.2	6.5	3.1	1.6	4	3
Native forb	0.1	0.9	0.4	0.1	1	2	0.7	2.7	1.6	0.8	0	1
Exotic grass	0.2	1.5	0.4	1.9	10	5	0.3	1.4	0.9	5.7	11	6
Exotic forb	9.7	15.5	25.3	2	20	3	13.1	19.7	29.7	4.9	15	10
GROUND COVER (%)												
Basal vegetation	1	1	1	1	2	0.6	1	1	2	1	2	2
Litter	1	11	34	53	63	92	3	32	63	77	53	88
Moss	0	9	15	25	35	7	< 1	19	11	11	42	9
Bare soil	37	12	3	<1	0	0.4	52	7	4	3.7	0	0
Gravel	57	59	37	16	0	0	37	35	9	6.1	2	0
Rock	3	9	7	5	1	0.1	2	6	6	1.7	1	0
Wood	0	< 1	0	<1	0	0	1	1	1	0.3	0	0.3
Other (asphalt)	< 1	< 1	< 1	1	0	0	< 1	< 1	< 1	0	0	1

See 1993, 1994 or 1996 Revegetation Monitoring Report for 1993 data
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Seeding *Xerophyllum tenax* in the Park has been experimental over the years, with some fairly unsuccessful results in the past when it is seeded with several other species. Although overall average cover of *X. tenax* was only 1.5% after thirty years, this species had the highest cover of all native forb species across the project. The largest cover recorded for *X. tenax* in a microplot was 45% in 2021; in 2011 the highest cover in a microplot was 35%. This illustrates that early establishment and growth under low vegetation competition are important when this species is seeded and that it takes over 20 years for it to have a significant presence within restoration areas.

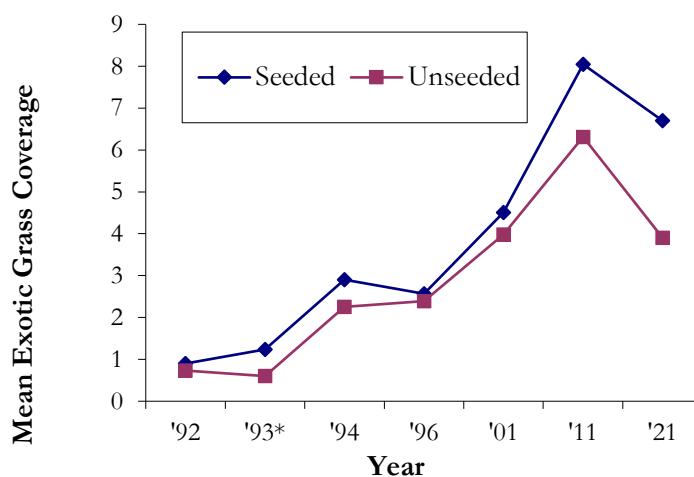
2c. Exotic grasses

After a steady increase in cover of exotic grasses since the inception of the project, overall exotic grass cover decreased in both seed treatments over the course of the past ten years (Table 3, Figure 7). *Dactylis glomerata* had been primarily responsible for increases of exotic grass cover in the past. While it is still the most dominant exotic grass species in the project, it only increased slightly in seeded plots, and decreased in unseeded plots, since 2011. It remains the non-woody species with the highest average cover across the project, however (at 4%), and only three woody species have higher average cover; *Pseudotsuga menziesii* (14%), *Betula papyrifera* (7%) and *Arctostaphylos uva-ursi* (5%).

Most other species of non-native grass decreased in cover in the past decade, under both seed treatments, including *Agrostis stolonifera*, *Phleum pratense*, *Poa pratensis* and *P. compressa*. In seeded plots, *Bromus inermis* also decreased, but it increased in seeded plots. It is uncertain why some aggressive, rhizomatous grasses such as *A. stolonifera* and *P. pratensis* declined while *B. inermis* was able to increase in cover. It is possible that it was better able to survive the dry roadside conditions, since the other two species thrive under more moist conditions and grow best on moist sites where the climate is cool and humid (FEIS 2021). Additionally, shrubs and trees may be outcompeting exotic grasses, especially in shaded areas. The lack of full sun in this project zone could also be detrimental to these species. While *Poa pratensis* is deemed an aggressive competitor, it grows best in full sunlight and only tolerates light shading (FEIS 2021).

Figure 7. Average Exotic Grass Cover for 303B plots, 1992-2021.

*some plots not surveyed in 1993 due to high exotic forb cover



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2d. Exotic forbs

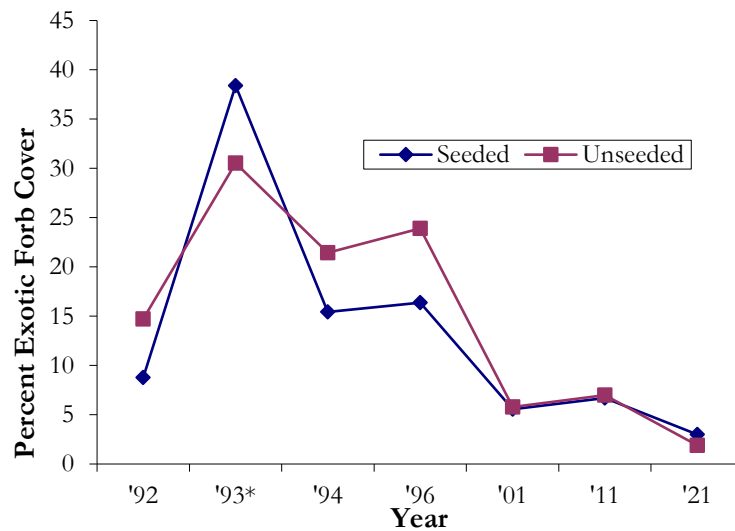
While there has been a bit of a roller coaster in cover of exotic forbs over time, the overall trend has been downward (Table 3, Figure 8). Over the past ten years, exotic forb cover has declined in both seed treatments, and in almost all species. *Veronica officinalis* is the only species that has shown much of an increase over the past decade, rising from 1% to 1.5% in seeded plots. This low-growing species is one of the few weeds in Glacier that can survive in shady conditions. It may be our only exotic that invades under a closed canopy

(Lesica 2002), and therefore one of the few species that can survive and thrive under increasing tree and shrub cover in this project. *Prunella vulgaris* also decreased in cover and frequency in both seeded and unseeded areas. This species can spread aggressively via stolons, but perhaps it is being outcompeted, is being shaded out by overstory in this project or is being affected by herbicide treatment.

Noxious weed species are mostly under control in this project. All have decreased in cover since 2011, except for *Linaria vulgaris*, which returned to unseeded plots in very low cover. *Cirsium arvense* has disappeared from the project since 1996. Other noxious weed species present throughout the project have declined in cover, including *Chrysanthemum leucanthemum*, *Centaurea maculosa* and *Hypericum perforatum*. These reductions are likely due, at least in part, to herbicide application.

Figure 8. Average Exotic Forb Cover for 303B plots, 1992-2021.

*some plots not surveyed in 1993 due to high exotic forb cover



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Table 6. 303-B: Mean % Cover of Shrubs and Trees by Plot for Seeded Plots Based on Line Intercept Data, 1992-2021.

	121 (seeded)							141 (seeded)							142 (seeded)						
Species	1992	1993	1994	1996	2001	2011	2021	1992	1993	1994	1996	2001	2011	2021	1992	1993	1994	2001	1996	2011	2021
<i>Acer glabrum</i>							0.03						1.1	3.5							
<i>Amelanchier alnifolia</i>												< 0.1	0.7	1.4	2	1.2	2.8	6.5	4.1	3.4	4.6
<i>Arctostaphylos uva-ursi</i>	0.4	1.1	1.1	1	1.3	2	0.9		0.1	0.03	0.3		0.2		0.4	1	0.4	1.7	0.9	6.6	9.3
<i>Betula papyrifera</i>						0.1															
<i>Cornus sericea</i>	0.3	0.8	0.8	0.5											0.03						0.3
<i>Larix occidentalis</i>	0.04																				
<i>Linnaea borealis</i>														0.9						0.2	1.0
<i>Mahonia repens</i>															0.3	0.2	0.2	0.1	0.1	0.2	
<i>Paxistima myrsinites</i>	0.4	0.03	0.5	0.5	0.2	0.3	0.3	0.1	0.4	0.5	0.2	0.1	0.4	0.1	0.2	0.4	0.5	0.9	0.3	0.9	0.4
<i>Picea engelmannii</i>																		0.7		0.5	1.2
<i>Pinus contorta</i>																					
<i>Populus tremuloides</i>																					
<i>Populus balsamifera ssp. trichocarpa</i>																		0.1		0.2	2.6
<i>Prunus virginiana</i>	0.2	0.2	0.2	0.1		0.3	0.1														
<i>Pseudotsuga menziesii</i>					< 0.1	2.8	8.8					< 0.1	0.5	8.4				0.2	0.6	0.1	2.6
<i>Rosa woodsii</i>	5.6	6.8	5.8	4.2	2.8	1.4	0.6	2.1	2.9	2.1	2.5	0.8	2.1	2.7	0.4	1.5	1.4	1.2	2.2	2.5	0.6
<i>Rosa spp.</i>																					
<i>Rubus parviflorus</i>								0.3	0.4	0.6		0.9	0.3		0.2	0.2	0.2	0.6	0.4	0.4	
<i>Salix scouleriana</i>						0.8	0.02													0.4	0.5
<i>Salix sp.</i>					0.5													0.4			
<i>Shepherdia canadensis</i>	0.7	0.9	1.2	1	0.3	2.9	0.7		0.1	0.2	0.2	1.3	8	6.4				0.2	0.2	0.8	2.1
<i>Sorbus scopulina</i>														0.2							
<i>Spiraea betulifolia</i>			0.02	0.1	0.1	0.1	0.3														
<i>Symphoricarpos albus</i>	1.8	3	2.9	2.3	2.3	1.8	1.3	1.3	5.1	3.9	3.7	5.1	11	6.8	3.7	6.6	6	6.7	6.8	7.4	3.4
<i>Thuja plicata</i>																		0.3		0.2	0.7
<i>Tsuga heterophylla</i>																				2	
<i>Vaccinium membranaceum</i>																		0.2		0.3	0.1

Table 6, continued. Mean % Cover of Shrubs and Trees by Plot for Seeded Plots Based on Line Intercept Data, 1992-2021.

	211 (seeded)							271 (seeded)						402 (seeded)						
Species	1992	1993	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1993	1994	1996	2001	2011	2021
<i>Acer glabrum</i>	0.1	0.4	0.3	0.4	0.2	0.2	0.2		0.03				0.1						0.1	1.1
<i>Amelanchier alnifolia</i>																				0.5
<i>Arctostaphylos uva-ursi</i>						0.2	0.3	0.3	0.2	0.6	1	4.3	2.5	1.7	0.6	2.2	2.6	4	20.7	13.3
<i>Betula papyrifera</i>																				
<i>Cornus sericea</i>																				
<i>Larix occidentalis</i>																				1.5
<i>Linnaea borealis</i>				0.03		1.5	0.1					0.1								
<i>Mahonia repens</i>																				
<i>Paxistima myrsinites</i>	0.2	0.3	0.4	0.4	0.9	1	0.8							0.2		0.2	0.1	0.6	0.4	0.2
<i>Picea engelmannii</i>												0.2								1.1
<i>Pinus contorta</i>							0.02												0.4	2.2
<i>Populus tremuloides</i>														0.2		0.2				
<i>Populus balsamifera ssp. trichocarpa</i>														0.4	0.5	0.03	0.5	0.2	0.6	0.1
<i>Prunus virginiana</i>																				
<i>Pseudotsuga menziesii</i>					1.1	0.9	0.7					4.3		0.3	0.5	0.8	2.5	4	24.2	*
<i>Rosa woodsii</i>	0.5	2.4	2	3.3	3.3	1.1	0.1	2	3.7	3	1.5	2.8	4.6							
<i>Rosa spp.</i>												0.8								
<i>Rubus parviflorus</i>									0.03	0.1										
<i>Salix scouleriana</i>	0.3	1.2	1.4	2																
<i>Salix sp.</i>					0.8									0.6	0.2	0.4	0.4	0.2		
<i>Shepherdia canadensis</i>						0.1	0.1												1	3.7
<i>Sorbus scopulina</i>																				
<i>Spiraea betulifolia</i>		0.5	0.3	0.1		0.1												0.1	0.4	1.9
<i>Symphoricarpos albus</i>			0.03			0.1		1.2	1.3	1.4	2	3.4	3.9						0.1	0.8
<i>Thuja plicata</i>																				
<i>Tsuga heterophylla</i>																				
<i>Vaccinium membranaceum</i>											0.2									

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Table 7. 303-B: Mean % Cover of Shrubs and Trees by Plot for Unseeded Plots Based on Line Intercept Data, 1992-2021.

	221 (unseeded)						222 (unseeded)						272 (unseeded)					
Species	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021	1992	1994	1996	2001	2011	2021
<i>Abies lasiocarpa</i>										0.3		1.9						
<i>Acer glabrum</i>													0.6	1.4	2.3	< 0.1	1.3	0.9
<i>Alnus incana</i>					2.5	5.5												
<i>Alnus viridus</i>				0.7														
<i>Amelanchier alnifolia</i>					0.8	0.8				< 0.1	0.5	0.7						0.7
<i>Apocynum androsaemifolium</i>														0.1	0.3			
<i>Arctostaphylos uva-ursi</i>	0.3	1.3	2.5	13.2	20.2	6.8	0.1	0.5	1.5	9.2	20.5	6.1	1.2	0.9	2	0.1	8.2	8.4
<i>Betula papyrifera</i>				0.2														
<i>Cornus sericea</i>								0.1	0.03	0.2	0.1	0.2						
<i>Crataegus douglasii</i>						0.03												
<i>Larix occidentalis</i>				0.1	0.5	0.8												
<i>Linnaea borealis</i>																		
<i>Lonicera utahensis</i>						0.2												
<i>Mahonia repens</i>	0.02						0.1		0.1		0.2	0.4	0.2	0.1	0.3	0.3		0.1
<i>Paxistima myrsinites</i>	0.2	0.2		0.1	0.4	0.5	0.02	0.2	0.3	0.2	0.4	0.4						
<i>Picea engelmannii</i>				0.2	0.8	0.3					1	0.8						
<i>Pinus contorta</i>	0.1	0.1	0.3	1	1.5	4.1						0.2					0.3	
<i>Pinus monticola</i>						0.7					0.9	3.6			1.2			
<i>Populus tremuloides</i>																		
<i>Populus balsamifera ssp. trichocarpa</i>									0.1	0.1								
<i>Prunus virginiana</i>																		
<i>Pseudotsuga menziesii</i>			0.2	0.8	9.8	13.1			0.1	0.5	9.2	5.3		0.2	0.2	1	7.8	20.0
<i>Rosa acicularis</i>																	1.3	
<i>Rosa woodsii</i>	0.8	2.6	4.6	10.4	11.1	1.7	0.4	4.2	4.3	2.9	2.6	0.4	3.5	4.1	4.7	0.5	0.5	1.4
<i>Rosa spp.</i>																	0.1	
<i>Rubus idaeus</i>															0.1			
<i>Rubus parviflorus</i>					0.4	0.4									0.1		0	0.2
<i>Salix scouleriana</i>																		
<i>Salix spp.</i>																		
<i>Shepherdia canadensis</i>	0.02			0.7	3.9	4.7			0.02	0.3	3.02	5.6			0.02	1.3	1.23	2.5
<i>Sorbus scopulina</i>																		
<i>Spiraea betulifolia</i>																		0.1
<i>Symphoricarpos albus</i>													1.2	1.6	2.5	3.2	7.6	10.0
<i>Thuja plicata</i>																	0.6	0.2
<i>Tsuga heterophylla</i>													2.0					
<i>Vaccinium membranaceum</i>													0.3					

Table 7, continued. Mean % Cover of Shrubs and Trees by Plot for Unseeded Plots Based on Line Intercept Data, 1992-2021.

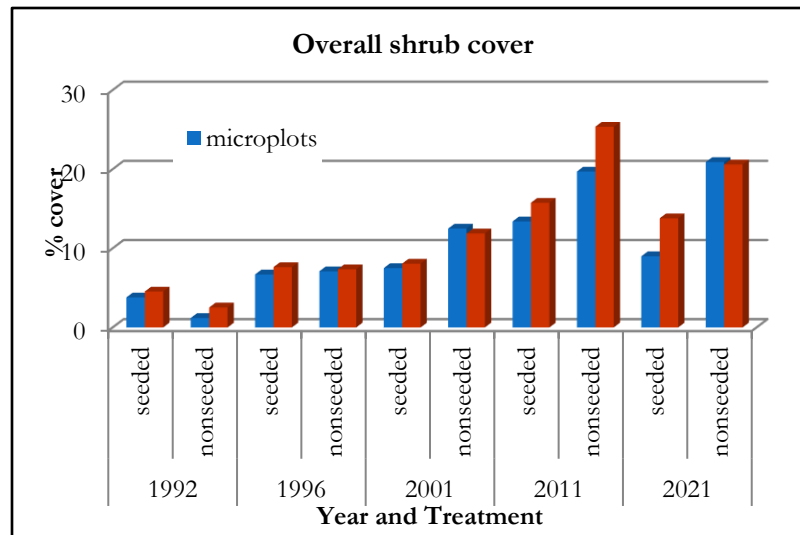
Species	401 (unseeded)							212 (unseeded)						
	1992	1993	1994	1996	2001	2011	2021	1992	1993	1994	1996	2001	2011	2021
<i>Abies lasiocarpa</i>														
<i>Acer glabrum</i>						0.1	4.7				0.2	0.2	0.9	1.0
<i>Alnus incana</i>														
<i>Alnus viridis</i>														
<i>Amelanchier alnifolia</i>														0.5
<i>Apocynum androsaemifolium</i>														
<i>Arctostaphylos uva-ursi</i>	0.4	1	1.4	3.1	5.8	12.9	4.1	1.2	2.5	3.2	2.4	3.5	3.9	2.7
<i>Betula papyrifera</i>			0.1	0.1		0.4							0.5	0.4
<i>Cornus sericea</i>					0.1		0.1	0.6	0.2	0.4	0.4	0.4	0.7	1.0
<i>Crataegus douglasii</i>														
<i>Larix occidentalis</i>						8.9	36.8							
<i>Linnaea borealis</i>							0.1	0.3	1	0.5	0.4	< 0.1	5.5	4.9
<i>Lonicera utahensis</i>													0.1	0.3
<i>Mahonia repens</i>							0.2	0.1	0.2	0.1	0.1	0.2	0.4	0.2
<i>Paxistima myrsinites</i>	0.8	0.2	0.2	0.1		0.2	2.6	0.2		0.3	0.4	0.3	0.2	0.2
<i>Picea engelmannii</i>					< 0.1	3.6	8.9							
<i>Pinus contorta</i>						3.1	2.7				0.1	0.1	0.1	0.2
<i>Pinus monticola</i>													0	
<i>Populus tremuloides</i>	0.1	0.4	0.5	0.2										
<i>Populus balsamifera ssp. trichocarpa</i>		0.2	0.1	1.4	0.1	0.3	0.1				0.2			
<i>Prunus virginiana</i>														
<i>Pseudotsuga menziesii</i>				0.2	2.8	10.5	31.7						0.3	0.1
<i>Rosa acicularis</i>														
<i>Rosa woodsii</i>								0.7	2.4	4.1	3.4	4.4	1.9	1.9
<i>Rosa spp.</i>														
<i>Rubus idaeus</i>														
<i>Rubus parviflorus</i>														
<i>Salix scouleriana</i>														
<i>Salix spp.</i>												0.1		
<i>Shepherdia canadensis</i>		0.2	0.2	0.7	0.5	6.3	12.9			0.03	0.4	0.7	6.2	4.4
<i>Sorbus scopulina</i>														
<i>Spiraea betulifolia</i>		0.2	0.1		0.2	0.9	1.3						0.1	
<i>Symphoricarpos albus</i>							0.7							0.3
<i>Thuja plicata</i>							0.3						2.4	
<i>Tsuga heterophylla</i>														0.2
<i>Vaccinium membranaceum</i>														

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3c. Comparison of methods for assessing cover of trees and shrubs

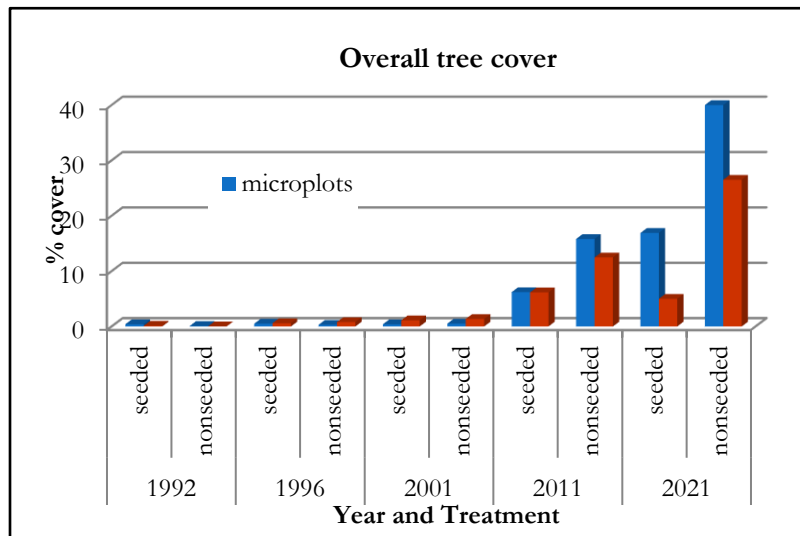
Overall, the two methods to assess cover of woody plants within this project, microplots and line intercept, have generally provided somewhat similar trends. Line intercept data had higher estimates of overall shrub cover and lower estimates of tree cover, however (Figures 9 and 10).

Figure 9. 303-B: Comparison of overall shrub cover by treatment using microplot and line intercept methods, 1992-2021.



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Figure 10. 303-B: Comparison of overall tree cover by treatment using microplot and line intercept methods, 1992-2021.



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Using line intercept methods for monitoring woody plants has a few advantages. First, this method is more objective than estimating cover within microplots, reducing observer error over time. Second, the use of line intercept did prove to be better throughout the project at detecting small, infrequent or scattered plants, particularly at the start of the project. As these methods were able to detect infrequent or scattered woody plants sooner, line intercept methods consistently captured monitoring data on more species each year. As trees and shrubs grow to greater than several meters tall, however, this method becomes quite tedious and difficult, and may be less accurate.

III. EASTSIDE GRASSLAND MONITORING: 2018-2021

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: 2018-2021

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: 2018-2021

Monitoring methods remained the same for repeat surveys in 2018, 2019, 2020 and 2021. 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, 12 plots were re-read in 2020, and 38 plots were re-read in 2021. 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. In 2021, sampling was distributed across the eastern side of the park. 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 at each corner to assist in finding the plot and documenting the overall condition of the meadow.

In 2021, data collection was fully migrated onto handheld tablets, which we tested in 2020. Data collection was streamlined as the tablets served as GPS devices, camera, and for data collection. We downloaded a detailed topographic map of the park, along with the GPS locations of the grassland plots, onto the Avenza Pro app on each tablet, and collected data in custom data sheets in Microsoft Excel. While some issues occurred with opening excel in the field, overall, the tablets proved to be effective and reliable tools for field collection.

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. Additionally, the park hopes to continue revisiting a subset of grassland plots as part of a long-term study of the condition of the Park's grasslands.

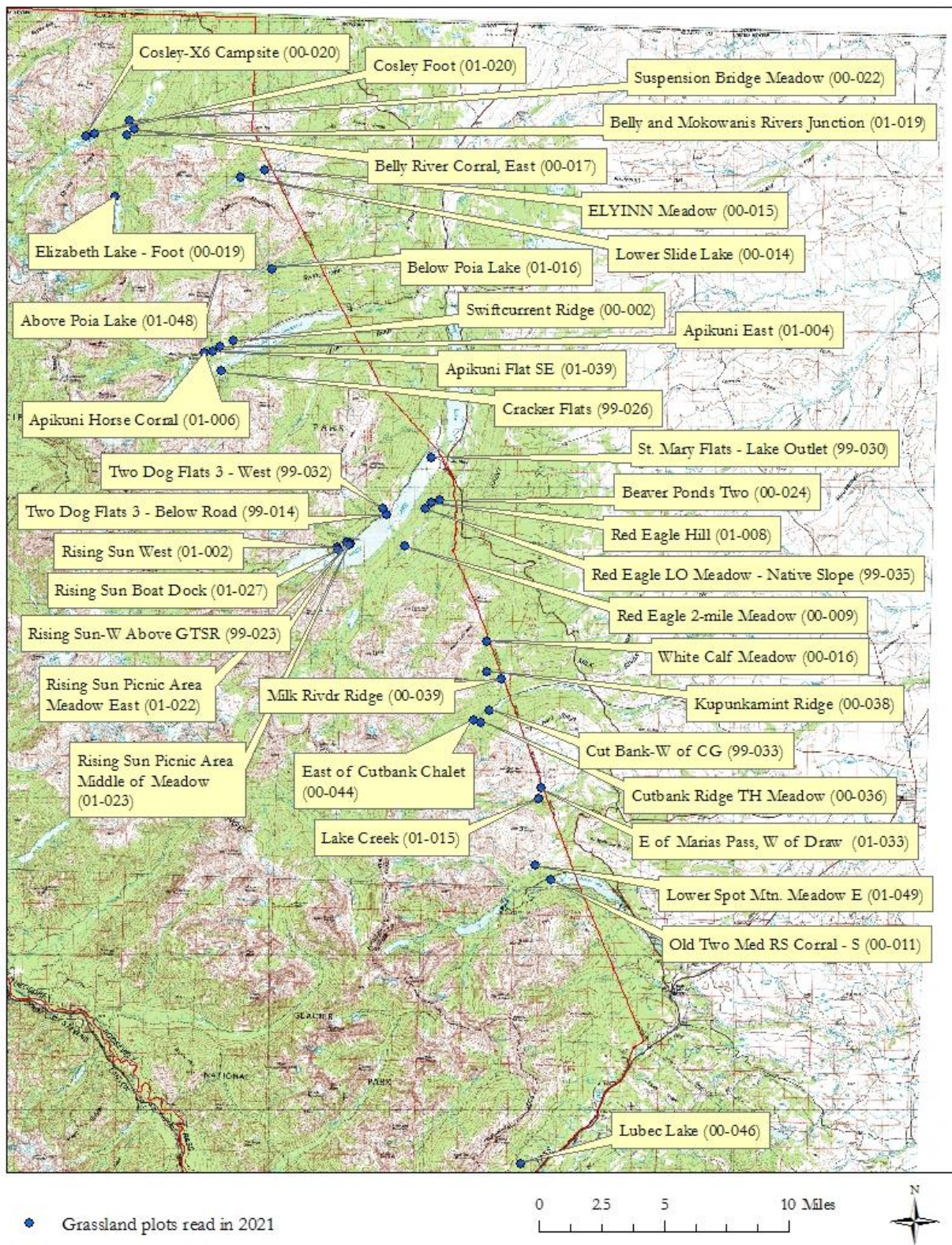
C. Progress Report

The following progress report pertains to grassland monitoring plots that were re-read in 2021. For full results from 2018, 2019 and 2020, please refer to the Glacier National Park Vegetation Monitoring Reports from these years (Asebrook and Hintz, 2018, 2019; Hintz, Dubenezic and Matallana-Mejia, 2020).

Thirty-eight plots were re-surveyed in 2021 (Figure 11). Thirty-five of these plots were re-surveyed for the first time, while three plots were re-surveyed for a second time (i.e. surveyed 20 years ago, again in the last three years and again this year) as part of a pilot study to quantify year-to-year variation at grassland plots. In total, 70 plots have now been re-surveyed once between 2018 and 2021, which is at the upper end of our initial goal of 50 – 75.

Nico Matallana, botany technician at Glacier Park and graduate student at Colorado State University, led the data collection effort this summer and is now analyzing the data with assistance from his advisor and graduate committee at CSU. He has performed large scale quality control on the data and is preparing to perform a series of statistical tests to understand how the grasslands are changing. As part of his graduate work, Nico hopes to assess the overall change in community composition and structure, and determine which drivers best explain this change. Specifically, he aims to answer the following questions: 1) Does proximity to human disturbance, time since last fire, elevation, aspect, slope or a combination of these predictors best explain changes in community composition and structure? 2) How has palatability of grasslands changed in terms of dominant species? And 3) In terms of palatability, how will grassland communities respond to bison reintroduction? Results will be published in following Glacier National Park Vegetation Monitoring Reports and in a peer-reviewed journal. He would like to thank Glacier National Park, the Glacier Park Conservancy, the Colorado State University's Graduate Degree Program in Ecology and his graduate advisor Dr. Melinda Smith for providing resources and support for this work.

Figure 11. Location of Eastside Grassland Plots Monitored in 2021.



IV. BOWMAN LAKE ACCESS ROAD REVEGETATION MONITORING: 2021

A. INTRODUCTION

As park visitation increases, the North Fork district has experienced a parallel trend in crowded roads, parking, lake access, and campgrounds. At Bowman, the road to the lake passed through the popular campground and day-use parking areas. To alleviate congestion, this access road was re-routed through the picnic area to the east. The road construction for this re-route took place in August 2019. Prior to construction, native plants were salvaged in the swath of forest and open picnic area that lay within the new roadbed corridor. These plants were dug up in “clumps” and staged nearby until they could be re-planted a few weeks later along the old roadbed. Approximately 690 ft² of native plant material was salvaged. The old roadbed was converted into a walking path with both sides also 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 shrub, forb, and grass species. Social trails have become well established between the campground, parking areas, and lake. Some sections 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. 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. 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-tenth of a percent. For our reference, two percent was equivalent to one ¼ m² plot frame. Exotic forbs and exotic grasses were identified and assigned canopy cover. Photos were taken from the north and south ends of the plots for reference and qualitative documentation. Plots were read for a second time in September 2021.

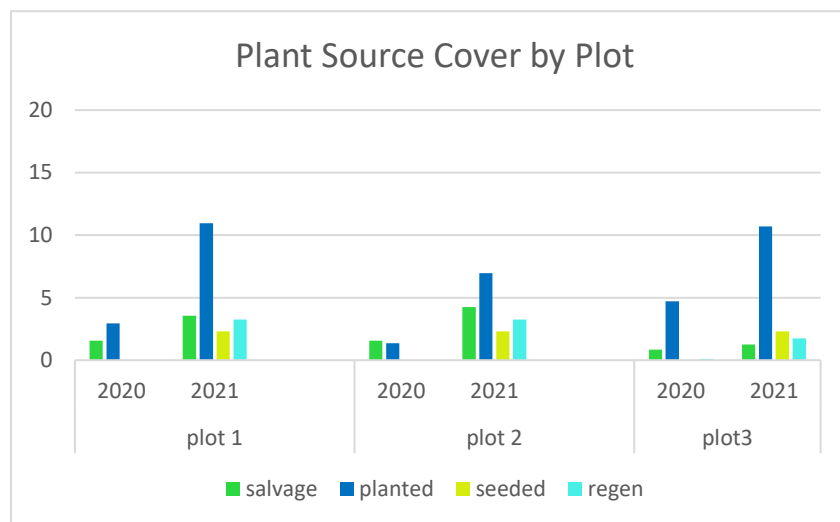
The revegetation site is slightly more open on the southern end next to the campground with a *Vaccinium caespitosum* and *Arctostaphylos uva-ursi* understory. Towards the lake, species such as *Picea engelmannii*, *Juniperus communis*, and *Mahonia repens* close the surrounding understory in a bit more.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

C. RESULTS

In 2021, salvaged, planted, seeded, and natural regeneration all showed an increase in cover across plots. Overall cover of native species increased from 2.9 percent in 2020 to 17.8 percent in 2021. Non-native species cover increased as well, from 0.3 percent to 1.25 percent.

Planted material provided the highest cover in 2021, with an average of 9.5 percent across plots. Salvaged material contributed an average cover of 3 percent. Natural regeneration and seeded material followed, at 2.75 percent and 2.3 percent, respectively. In a few cases, salvaged and planted material were lumped together when it was too difficult to distinguish between sources. Salvaged clumps were typically diverse, with intertwined growth, whereas planted material was more spaced out. However, after two years, the lines are starting to blur.

Figure 12. Bowman Lake Road Revegetation Project: Plant Source Cover by Plot.



Salvaged

Overall cover of salvaged plants increased in all three plots, from 1.3 percent in 2020 to 3 percent in 2021. Of the 28 species that were salvaged, 26 species were captured in 2021 data. A *Juniperis communis* and some *Vaccinium scoparium* did not survive.

Trees and shrubs provided the most substantial salvage cover. *Abies lasiocarpa*, *Picea engelmannii*, *Linnaea borealis*, and *Vaccinium caespitosum* all provided 0.3 to 0.5 percent cover across plots. From the start, native grass has been a minimal component in the salvage mats; only a trace was captured in 2021 for *Calamagrostis rubescens* and *Carex concinnoides*. Native forbs play a minor role, with most being found in trace amounts. *Antennaria rosea*, *Fragaria virginiana*, *Penstemon confertus*, and *Potentilla gracilis* were salvaged from the picnic area and are slowly, but steadily, increasing in cover.

Planted

Of the 23 species that were planted, 15 were captured in 2021 monitoring. *Festuca occidentalis/rubra* is thriving, two years into this restoration project. As planted material, it has an overall average cover of 3.5 percent across plots. *Oryzopsis asperifolia* is enhancing native grass cover, at 1.25 percent.

Larix occidentalis represents the most cover for trees, averaging 3 percent. These larch were grown in 1-gallon containers and most were 2-3 feet tall when planted. While Larch Needle Cast (*Meria laricis*) was

observed on many trees in 2020, it was not observed in 2021. However, three dead larch trees were present in the monitoring plots. Cause of mortality is unknown, as animal disturbance could have been a factor.

Spiraea betulifolia and *Symphoricarpos albus* are providing low, but increasing, shrub cover in all three plots. Although 45 (1-gallon) *Mahonia repens* were planted, it is struggling a bit, with 0.125 percent cover across plots. Forty-two (1-gallon) *Rosa sp.* were planted, yet none were captured in monitoring.

Seeded

Of the 19 native species that were seeded, three were observed in plots in 2021. Seeding has resulted in the lowest cover of any revegetation source to date. *Festuca occidentalis/rubra* was observed in all three plots at 2.3 percent cover. *Amelanchier alnifolia* and *Solidago canadensis* were present in trace amounts.

Germination of some species, especially shrubs such as *Mahonia repens*, *Prunus virginiana*, and *Rosa woodsii*, may still occur over time. *Cornus canadensis* may also still emerge. Again, seed dormancy, the seedbed, seed age and viability, and environmental conditions such as rainfall may have affected germination rates, to date.

Natural Regeneration

Natural regeneration was evident, though still minimal, at 2.75 percent overall cover across plots. Seventeen native plant species were determined to be natural regeneration in origin. Native grass species are doing well in particular, with *Elymus glaucus* increasing to 2 percent cover across plots. *Danthonia intermedia*, *Calamagrostis rubescens*, *Deschampsia elongata*, and *Poa palustris* have also established in the project area.

As a pioneer species, *Chamerion angustifolium* has found its way into this disturbed landscape. *Larix occidentalis* and *Populus tremuloides* seedlings were detected in trace amounts. Sources of natural regeneration may have come from soil in the old roadbed, salvaged mats, or dispersed from the surrounding forest/wildlife.

Exotic Grasses and Forbs

Six exotic grass species and ten exotic forb species were detected in the plots. Overall cover of exotic species increased, but remained low, at 1.25 percent across plots. Some species that were present in 2020, such as *Cirsium arvense* and *Agrostis stolonifera*, were not detected in 2021. *Cerastium fontanum*, *Medicago lupulina*, *Ranunculus repens*, *Trifolium arvense*, and *Poa annua* were detected for the first time in 2021. Most exotic species were found in trace amounts; no single species was found in cover above 0.75 percent in any one plot.

Figure 13. Bowman Lake Road Revegetation Project: Lifeform Cover, 2020-2021.

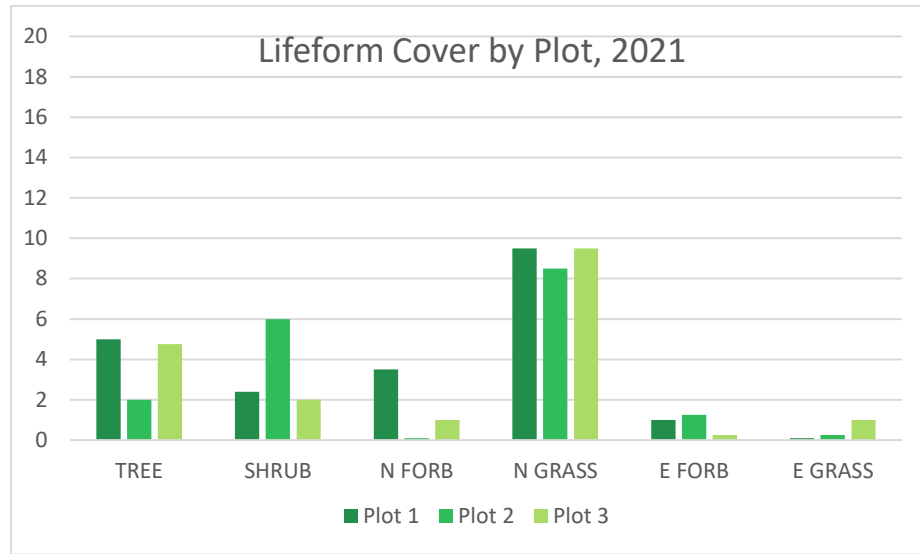


Table 8. Bowman Lake Road Revegetation Project: Lifeform Cover, 2020-2021.

		L side of road (first plot)		R side of road		L side of road (middle plot)	
		NF-20-01		NF-20-02		NF-20-03	
		2020	2021	2020	2021	2020	2021
	source*	0.125m ² =1%					
TREE		2.75	5	1	2	3.3	4.75
<i>Abies lasiocarpa</i>	(sal)	0.15	0.5 (dying)	T	0.25		0.25
<i>Larix occidentalis</i>	(p)	2.5	4.5 (1 tree dead)	0.6	1.25	3	3.5 (2 trees dead)
<i>Larix occidentalis</i>	(r)		T				
<i>Picea engelmannii</i>	(sal)	T		0.2	0.5	0.3	1
<i>Pinus contorta</i>	(sal)	T	T				
<i>Populus tremuloids</i>	(r)				T		
SHRUB		1	2.4	1	3.5	1	1.75
<i>Amelanchier alnifolia</i>	(s & sal)			T	T	T	T
<i>Arctostaphylos uva-ursi</i>	(p & sal)	0.25	0.5		T	T	0.25
<i>Juniperus communis</i>	(sal)			0.1 (dead)			
<i>Linnaea borealis</i>	(sal)	T	0.25	T	0.75	0.2	T
<i>Mahonia repens</i>	(p & sal)	T	0.25	T	T	T	T
<i>Rhamnus alnifolia</i>	(sal)	T	T				
<i>Ribes sp.</i>	(r)		T				
<i>Rosa woodsii</i>	(sal)			T	T	T	T
<i>Rosa woodsii</i>	(r)		T				

<i>Rubus pubescens</i>	(sal)	T	0.25				
<i>Shepherdia canadensis</i>	(p)					T	
<i>Spiraea betulifolia</i>	(p & sal)	0.25	0.5	T	0.75	0.25	1
<i>Symphoricarpos albus</i>	(p & sal)	T	0.25	T	1.25	0.3	0.5
<i>Vaccinium caespitosum</i>	(sal)	0.35	0.4	0.75	0.75	0.25	T
<i>Vaccinium membranaceum</i>	(sal)			T	T		T
<i>Vaccinium scoparium</i>	(r)			T	T		
<i>Vaccinium scoparium</i>	(sal)	T				T	
NATIVE FORB		T	3.6	0.5	3	T	0.5
<i>Achillea millefolium</i>	(r & sal)	T	T	T	T		
<i>Anemone multifida</i>	(r)		T				
<i>Antennaria bonellii/ racemosa</i>	(p)	T	1.25			T	T
<i>Antennaria rosea</i>	(sal)	T	0.15	T	T	T	T
<i>Arnica cordifolia</i>	(p '20)	T	T	T	T	T	T
<i>Cardamine pensylvanica</i>	(*)					T	T
<i>Chamerion angustifolium</i>	(r)	T	T				T
<i>Chamerion angustifolium</i>	(sal)			T	T		
<i>Cornus canadensis</i>	(sal)	T	T	T			
<i>Eurybia conspicua</i>	(p)	T					
<i>Fragaria vesca</i>					T		
<i>Fragaria virginiana</i>	(p & sal)	T	0.25	0.5	2	T	0.25
<i>Fragaria virginiana</i>	(s)						
<i>Galium boreale</i>	(sal)		T	T	T		
<i>Galium triflorum</i>	(r)				T		T
<i>Geum macrophyllum</i>	(sal)					T	T
<i>Geum macrophyllum</i>	(p)	T	0.5				

		NF_20-01		NF-20-02		NF-20-03	
	source*	2020	2021	2020	2021	2020	2021
NATIVE FORB, con't							
<i>Heuchera cylindrica</i>	(p)			0.25	1		
<i>Hieracium albiflorum</i>	(r)						T
<i>Penstemon confertus</i>	(sal)	T	0.5			T	
<i>Potentilla glandulosa (?)</i>	(s)	T					
<i>Potentilla gracilis</i>	(sal)	0.8	1	T	T		T
<i>Senecio pseudolaureus</i>	(sal)			T	T		
<i>Solidago canadensis</i>	(s)	T	T				
<i>Solidago canadensis</i>	(p)					0.25	0.25
<i>Symphotrichum laeve</i>	(s & sal)		T			T	T

<i>Tiarella trifoliata</i>	(p & r)		T	T	T	0.1	T
<i>Viola sp.</i>	(r)						T
NATIVE GRASS		0.25	9	0.5	8.5	1	9.5
<i>Agrsotis scabra</i>			0.25		T		0.25
<i>Calamagrostis rubescens</i>	(r)				1	T	T
<i>Calamagrostis rubescens</i>	(sal)	T	T			0.1	
<i>Carex concinnoides</i>	(sal)	T			T		
<i>Carex rossii</i>	(p & r)		0.25		0.25	0.1	
<i>Carex sp.</i>	(p)	T				0.2	0.5
<i>Carex sp.</i>	(sal)			T			
<i>Danthonia intermedia</i>	(r)		T				
<i>Deschampsia elongata</i>	(r)		T				
<i>Elymus glaucus</i>	(r)		3		1.5	0.1	1.5
<i>Festuca occidentalis/ rubra</i>	(p & r)	T	5	T	3.5	T	5.5
<i>Juncus sp.</i>	(r)						
<i>Oryzopsis asperifolia</i>	(p)	0.2	0.75	0.5	1.5	0.5	1.5
<i>Poa palustris</i>	(r)		T		0.5		0.25
<i>Trifolium spicatum</i>			T		0.25		
<i>Unknown grass</i>	(r)			T			

		NF_20-01		NF-20-02		NF-20-03	
	source*	2020	2021	2020	2021	2020	2021
EXOTIC FORB		0.25	1	T	1.25	T	0.25
<i>Cerastium fontanum</i>			0.5		T		
<i>Cirsium arvense</i>		T					
<i>Cirsium vulgare</i>							
<i>Hieracium sp.</i>				T			
<i>Leucanthemum vulgare</i>						T (pulled)	
<i>Medicago lupulina</i>					0.75		
<i>Melilotus sp.</i>		T		T	T	T	T
<i>Plantago major</i>		T			T		T
<i>Prunella vulgaris</i>		T			T	T	T
<i>Ranunculus repens</i>			T		T		T
<i>Rumex sp.</i>					T		
<i>Taraxacum officinale</i>		T			T		T
<i>Trifolium sp.</i>					T		T
<i>Veronica officinalis</i>		T		T			
<i>Veronica serpyllifolia</i>			0.5		0.25		
EXOTIC GRASS		0.25	T	0.25	0.25	0.2	1
<i>Agrostis stolonifera</i>		T		T			
<i>Dactylis glomerata</i>		T			0.25		T

<i>Elymus repens</i>		T		0.1	T	0.1	0.5
<i>Phleum pratense</i>		T			T		T
<i>Poa annua</i>			T		T		T
<i>Poa compressa</i>				T	T		
<i>Poa pratensis</i>		T		0.1	T	0.1	0.75

(p) = planted

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

(s) = seeded

(*) = came in on nursery stock

(r) = regen

D. DISCUSSION AND RECOMMENDATIONS

With four different sources of plant material at play in this revegetation site, it will take time for success to come into focus. This monitoring has already shown that salvaging can be a powerful revegetation tool but that, ultimately, an assortment of plant sources can work together to provide quick and long-term native cover that is diverse and resilient.

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 presence that discourages trampling feet. Simply providing this vegetation 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. In this project, salvaged forest mats included a substantial *Vaccinium spp.* component that was not represented in planted form. So far, these rhizomatous plants have survived and help this project blend with the surrounding plant communities.

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 for a few summers seems prudent when July and August precipitation is low. Fencing was never installed at this site, yet foot traffic does not appear to be affecting the restoration site at this point in time.

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 litter will provide some organic matter to this revegetation site.

Monitoring should continue in 2022 since revegetation success and survival take time to play out. This revegetation site receives heavy visitation. Litter and bare soil cover are not being assessed at this time, but if concerns arise about trampling, survival, soil moisture, or natural recruitment, these components could be captured in future monitoring events.

V. TWO DOG FLATS HERBICIDE ASSESSMENT PILOT PROJECT

A. INTRODUCTION

The Two Dog Flats grasslands lie in the St. Mary Valley on the eastern edge of Glacier National Park. This fescue-type 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 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, ground squirrels, birds, and pollinators 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 has 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 (Milestone®) 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 possibly 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 plots to determine effectiveness of herbicide treatments on 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 and Nitrogen, total Phosphate, pesticide residue, and 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 suspected during seed collection in Two Dog Flats. *Gaillardia* and *Lupinus*, 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. Are these plants truly declining?

Where herbicide has been applied with a truck sprayer near the road, the abundance of mosses, lichens, and *Selaginella* 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? This study may provide insightful data for these concerns.

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 his plots, alongside the road, will not be re-read, this research serves as a valuable reference. In herbicide-treated plots, he found that 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 in restoration that could provide heavier canopy cover against non-native grasses.

B. METHODS

During a reconnaissance trip on September 29, 2020, the furthest east meadow of the Two Dog Flats complex was assessed for overall condition and spotted knapweed abundance and distribution. It was determined that the upper northwestern edge of this meadow would be an advantageous area for this project, with the strategy of eventually 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. This spot contains high spotted knapweed cover, but maintains 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 the opened niches will be less likely to be rapidly colonized by non-native grasses prior to seeding and/or planting efforts. Additionally, existing native plants may have the opportunity to expand into these open spaces, and native seeds may be more likely to present in the seed bank.

Five treatments were chosen to evaluate knapweed control and the use of native seed for restoration. The treatments are as follows:

1. Herbicide + seed
2. Hand pull + seed
3. Herbicide + no seed
4. Hand pull + no seed
5. Control

Three parallel 55-meter transects, with 10 plots each, were installed on May 19, 2021. Each treatment was randomly replicated twice on each transect, for a total of 30 plots (Figure 14). GPS points were taken at the northeast and southwest ends of each transect. Nails were installed at these points and photos were taken. Along each of the transects, a $\frac{1}{4}$ -m² plot was read on the northwest side of the transect line at every five meters. A 1-m² plot frame was used to center the smaller plot frame within a buffer zone (Figure 15). Plots were read on June 29-30, 2021. In each transect, all species were identified and given an estimated ocular percent cover. Ground cover was also assessed, with special attention given to biocrust components, such as moss, lichen and *Selaginella*.

Additionally, three composite soil cores (four samples per transect) were collected for chemical analysis. An additional sample was collected on each transect for bulk density analysis. An attempt was made to collect 15cm cores per sample but the soil here was quite rocky and dense. The actual core length was recorded, and samples were placed in Whirl-Pak bags.

On July 8, knapweed treatments were implemented. The plots for treatments 1 and 3 were sprayed with Milestone®, an aminopyralid herbicide. A 1-m² area was sprayed, so that the plots had a treatment buffer zone around them. Treatments 2 and 4 were hand pulled for knapweed, using the same buffer zone. Knapweed was bolting, but not flowering at the time of treatment. Rosettes and bolting plants were both treated.

On October 12, treatments 1 and 2 were seeded. The seed mix was based on the highest covers of native grass species in the plots. Six native grass species were used, with *Festuca idahoensis* comprising 66 percent of the mix. While *Carex petasata* and *Carex obtusata* had the highest cover in plots, their seed was not available to use in the mix. As a low elevation site, 80 seeds/1ft² was used for the mix (Table 9). Again, a buffer was used when seeding these 12 plots. The plots were lightly raked, and the mix was broadcast seeded with 1.03 grams of seed per plot. This raking created some minor disturbance to moss cover in plots, but it helped to create a seedbed that better protects seed from the wind.

Figure 14. Two Dog Flats Restoration: 2021 Treatments.

1. Herbicide + seed	T1: 5 m 5	T2: 5m 3	T3: 5m 3
2. Hand Pull + seed	10 m 3	10m 1	10m 4
3. Herbicide + no seed	15m 2	15m 2	15m 2
4. Hand Pull + no seed	20m 4	20m 4	20m 1
5. Control	25m 1	25m 5	25m 5
	30m 3	30m 2	30m 5
	35m 2	35m 1	35m 4
	40m 5	40m 5	40m 3
	45m 1	45m 3	45m 2
	50m 4	50m 4	50m 1

Figure 15. Two-Dog Flats Restoration: Transect and plot layout.

□ = 1/4m² plots

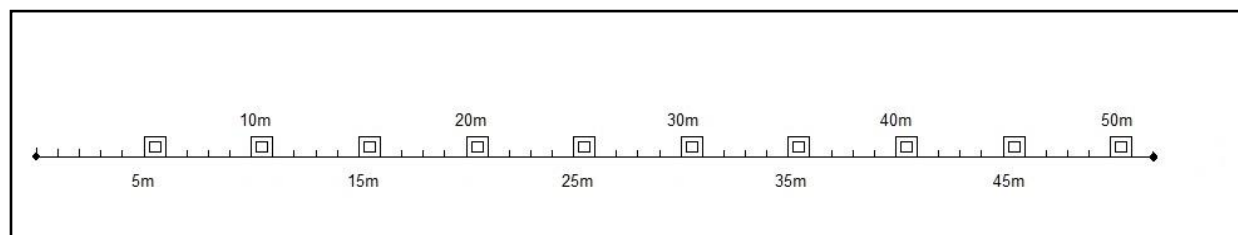


Table 9. Two-Dog Flats Restoration: Native Grass Seed Mix.

Species	% of Mix	Seeds/ ft ²	Grams Requested
<i>Achnatherum nelsonii</i>	1	0.8	0.17
<i>Achnatherum richardsonii</i>	3	2.4	0.67
<i>Festuca campestris</i>	22	17.6	4.24
<i>Festuca idahoensis</i>	66	52.8	6.5
<i>Koeleria macrantha</i>	6	4.8	0.12
<i>Pseudoroegneria spicatum</i>	2	1.6	0.76
	100%	80 seeds/ft ²	12.46g

Figure 16. Two-Dog Flats Restoration: Location of Study Area.



Figure 17. Two-Dog Flats Restoration: Transect Locations.



C. RESULTS

Data collected in 2021 provides a baseline for the condition of this grassland study area prior to the controlled treatment and restoration effort. All three transects had a similar composition of species, cover, and distribution, which is to be expected due to their proximity to one another. Averages for ocular cover were calculated from the 10 plots within a transect or all 30 plots in the study area.

1. Spotted Knapweed

All 30 plots had spotted knapweed. On all three transects, knapweed had the second highest cover, after native forbs. Cover in individual plots ranged from 0.5 percent to 60 percent. In only five individual plots, knapweed cover exceeded native forb cover. Knapweed cover was low (below 10 percent) on all transects at the 45 and 50-meter plots. On these plots, native grass cover was above 7 percent.

2. Exotic Grass

Phleum pratense and *Poa pratensis* were the two exotic grass species observed in plots. Both occurred in similar cover and distribution. Exotic grass cover in all three transects ranged from 2.7 to 6.0 percent. Cover exceeded 10 percent in four individual plots. Three plots had no exotic grass cover. The highest exotic grass cover in any individual plot was 18 percent. Exotic grass cover was highest on the northern end of transects 1 and 3, attributed to both *Phleum* and *Poa*. In this same area, native grass cover was higher than average and knapweed cover was low.

3. Native grass

Carex petasata and *Carex obtusata* made up the bulk (over two-thirds) of the native grass cover along all three transects. In fact, *Carex* was detected in all plots except one. Native grass cover ranged from 4.9 to 7.7 percent across all transects. Other grasses that provided cover are *Festuca idahoensis*, *Festuca campestris*, *Koeleria macrantha*, *Pseudoroegneria spicata*, *Stipa nelsonii*, and *Stipa richardsonii*. *Calamagrostis rubescens* was present on the northern end of all three transects.

4. Native forbs

Native forb cover was diverse and high in cover, averaging 45 percent across the three transects. No individual plot had less than 23 percent cover or above 75 percent cover. The five species with highest cover were *Lomatium triternatum*, *Penstemon confertus*, *Fragaria virginiana*, *Cerastium arvense*, and *Lupinus sericeus*. In all plots that had a native forb cover above 50 percent, knapweed cover was below 20 percent.

5. Moss/lichen

Moss and lichen cover was variable along transects, with a range from 2 to 9.5 percent. Lichen was minimal in plots and was lumped together with moss cover for this discussion. Moss and lichen cover exceeded 10 percent in six plots. Nine plots had no moss or lichen cover. On transect 3, closest to the aspen grove, cover was the lowest, averaging 2 percent. *Selaginella* was not detected on any transects.

6. Bare soil

Bare soil ranged from 2.8 percent to 10.5 percent across transects. On transect 2 at 15 meters, bare soil was 58 percent. This was certainly an outlier in this cover type. Quite a bit of elk scat was evident in October, so wildlife use in this corner of the grasslands may contribute to areas of bare soil.

7. Shrub/Tree encroachment

All three transects had a shrub cover below 5 percent. Shrubs consisted of *Rosa woodsii*, *Symphoricarpos albus*, and *Mabonia repens*.

Tree cover was very low. Overall tree cover ranged from 0 to 0.8 percent. Two *Pseudotsuga menziesii* seedlings were observed on two transects. *Pseudotsuga* and *Populus tremuloides* trees distantly surround the transects on three sides, yet tree recruitment within plots remains low.

Table 10. Two-Dog Flats Restoration: Average Cover by Transect.

Cover	T1	T2	T3
bare soil	5.9	10.5	2.8
moss/lichen	9.5	6.1	2.05
TREE	0.8	0.05	0
SHRUB	4.8	3.6	4.2
NATIVE GRASS	7.7	4.9	5.1
NATIVE FORB	42.1	45.9	47.9
EXOTIC GRASS	5.4	2.7	6
knapweed	16.9	24.1	19.22

Figure 18. Two-Dog Flats Restoration: Ocular Cover, by Transect and Plot, 2021.



D. DISCUSSION

Only native grass species were used in the initial seeding treatment since forbs tend to be susceptible to detrimental effects of herbicide. Grasses may act as placeholders for niches vacated by exotic forbs killed by spraying. Pre-existing native forbs may also fill in after spraying. In subsequent years, if time and funding permit, additional native forbs may be added for diversity. Idaho and rough fescue (*Festuca idahoensis* and *F. campestris*) are good components in the restoration mixes as these meadows are generally characterized as fescue grasslands. Both these grasses are bunchgrasses that should establish well and commandeer space. In summer 2022, if *Carex petasata* and *Carex obtusata* are collected by the nursery staff, these could be added to a future seeding mix. Although they are not as large in stature as the bunchgrasses, they provided the most cover for native grasses/graminoids and should be represented in restoration efforts, if possible.

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. Knapweed treatments should continue as prescribed in each 1m² area and plots should be re-read annually as time and funding permit.

Although attempts were made to collect soil samples with a soil core, consistent samples were difficult to obtain due to rocky and hard conditions. Samples that were collected have been stored for potential future analysis. Soil collection and analysis could be re-visited in 2022 if time and funding allow. Again, since studies have shown that herbicides and knapweed can affect soil functions, obtaining this baseline data for a key component of grassland health would be valuable for park management decisions.

VI. 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 22 sites, 18 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 (Tables 11, 13 & Figure 19). 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 2021. 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.

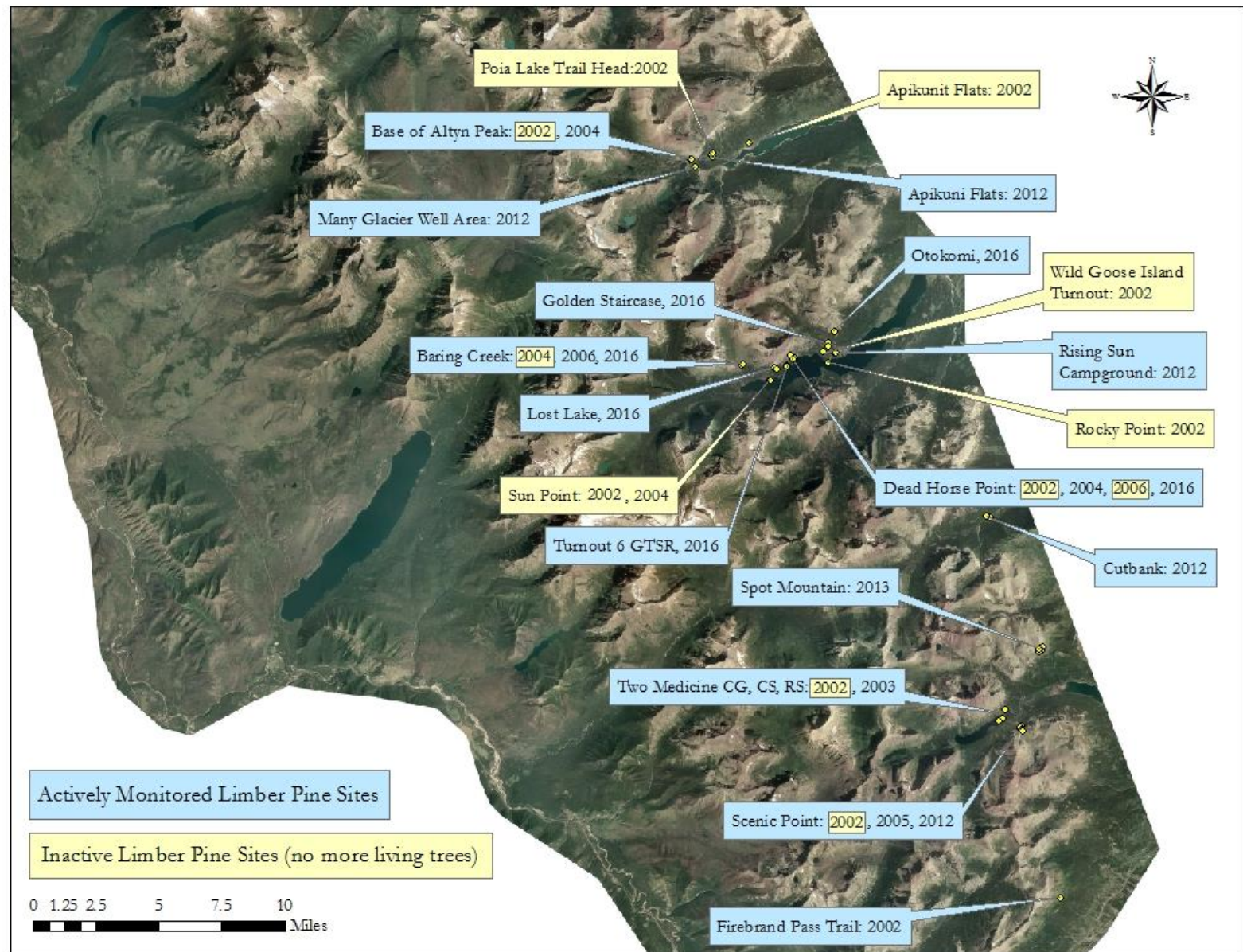
Several planting techniques to enhance health and survival have been utilized and refined over the 19 years of 5-needle pine restoration in Glacier. The use of microsites, either existing or constructed, is now almost universal in all plantings. Care is taken to plant during favorable weather conditions 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 11. Limber Pine Monitoring Plot Establishment to Date.

Site	Year	# of Plots Established	# of Cones Planted	Multiplier*	# of Trees Planted Overall	Total # Trees Captured	% Trees Monitored
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 19. Limber Pine Seedling Monitoring Sites.



2. *Whitebark Pine Restoration*

Whitebark pine seedlings have been planted at 25 sites between 2000 and 2021, all of which continue to support live trees (Figure 20; Table 12 and 16). A total of 25,476 seedlings have been planted in the park between 2000 and 2021. 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, in 2020 at Sperry Chalet, and in 2021, 15 trees were planted at Reuter Ridge. Additionally, small plantings have taken place over the years during general revegetation projects and memorial tree plantings in areas such as Old Man Lake Campground.

Monitoring plots have captured 21% of total planted whitebark pine seedlings (Table 12). The number of plots created at each site was dependent on planting densities and number of seedlings planted at the site. Data on the survival and health of individuals were collected during each monitoring event.

As with limber pine restoration, collecting and planting techniques to enhance health and survival have been refined over the 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 (Figure 20). This strategy has been moderately successful in Waterton Lakes National Park and a few other areas, prompting experiments in Glacier.

Figure 20. Whitebark Pine Seedling and Seed Monitoring Sites.

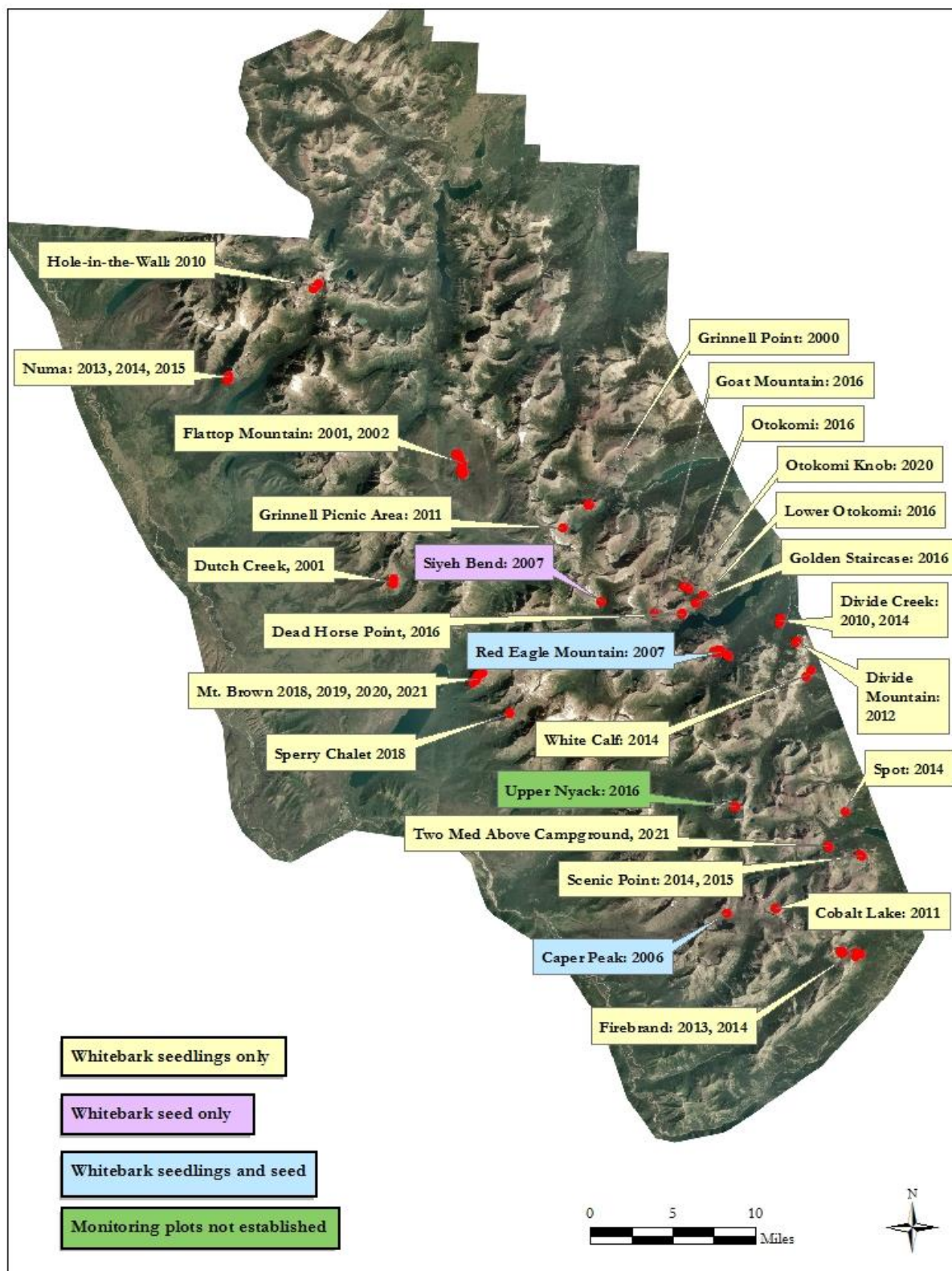


Table 12. Whitebark Pine Seedling Monitoring Plot Establishment to Date.

<i>Site</i>	<i>Year Established</i>	<i># of Plots Established</i>	<i># of Cones Planted</i>	<i>Multiplier</i>	<i># of Trees Planted</i>	<i># of Trees Monitored</i>	<i>% Trees Monitored</i>
Caper Peak	2006 (fall)	2			139	139	100%
Cobalt Lake	2011 (late summer)	3	250	2.04	510	108	21%
Dead Horse Point (Upper)	2016 (spring)	2	171	1.3	227	52	23%
Divide Creek	2010 (fall)	5			1,126	263	23%
	2014 (fall)	3	933	1.1	1,026	216	21%
Divide Mountain	2012 (fall)	4	686	2	1,283	216	17%
Dutch Creek	2001 (fall)	4	100	1	100	100	100%
Firebrand	2013 (spring)	4	516	2	1,032	208	20%
	2013 (fall)	5	1,175	2	2,350	375	16%
	2014 (spring)	2	238	1.9	452	102	23%
	2014 (fall)	3	517	1.1	569	133	23%
Flattop Mtn.	2001 (spring)	16			1,500	285	19%
	2001 (fall)	11			1,438	350	24%
	2002 (fall)	11			2,222	292	13%
Goat Mountain	2016 (spring)	1	104	1.4	145	34	23%
Golden Staircase	2016 (spring)	2	196	1.5	294	59	20%
Grinnell Glacier Picnic	2011 (late summer)	2	150	2	300	98	33%
Grinnell Point	2000 (fall)	7			96	96	100%
Hole-in-the-Wall	2010 (fall)	5	222		830	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%
	2021 (fall)	4	500	1	500	156	31%
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%
Two Medicine Above CG	2021 (fall)	2	135	1	135	74	55%
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		140			25,476	5,439	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 19). Table 13 is a summary of all the limber plantings to date indicating the number of trees that have survived, 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.

Eight limber pine planting sites were monitored in 2021; seven 5-year-old plantings, that were planted in 2016, and one 15-year-old planting, that was planted in 2006. The 5-year-old plantings that were monitored were: Baring Creek, Dead Horse Point Upper and Lower, Golden Staircase, Lost Lake, Otokomi Bench and Turnout #6 on the Going to the Sun Road. The 15-year-old planting monitored was at Baring Creek. No limber pine seedlings were planted in 2021.

Table 13. Parkwide: Survival, Height and Width of Remaining Live Limber Pine Seedlings as of Latest Monitoring Event, 2002 – 2021.

Site	Year Planted	Season Planted	Last Year Monitored	# of Trees Monitored	# of Trees Survived	% Survival	Monitoring Year	Average	
								Height	Width
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
Baring Creek	2006	spring	2021	69	2	3%	10	27.0	42.5
Sum/Average Year 15				523	14	3%		47.7	68.2
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
Baring Creek	2016	spring	2021	28	14	50%	5	18.2	24.1
Dead Horse Point (lower)	2016	spring	2021	64	4	6%	5	17.5	21.8
Dead Horse Point (upper)	2016	spring	2021	66	4	6%	5	17.3	24.8
Golden Staircase	2016	spring	2021	41	4	10%	5	19.3	21.3
Lost Lake	2016	fall	2021	64	40	63%	5	22.4	24.7
Otokomi (lower bench)	2016	spring	2021	52	16	31%	5	16.6	18.6
Turnout 6 (GTSR, St. Mary)	2016	spring	2021	44	12	27%	5	22.7	23.3
Sum/Average Year 5				1473	414	28%		15.2	15.9
Dead Horse Point	2006	spring	2009	20	0	0%	3	N/A	N/A
Sum/Average Year 3				20	0	0%		N/A	N/A
Various	2002	fall	2004	547	0	0%	2	N/A	N/A
Sum/Average Year 2				547	0	0%		N/A	N/A
Average Survival to Date				2563	428	17%			

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a. Fifteen-Year-Old Plantings

Two sites were planted with limber pine seedlings in 2006, Dead Horse Point and Baring Creek. In the spring of 2006, 262 seedlings were planted just above the road at Dead Horse Point (Figure 21). One monitoring plot was established with 20 trees, encompassing 8% of seedlings. By 2007, one year after planting, all trees had died in this plot. This planting site is an exposed, hot slope that is also prone to regular avalanche activity, experiencing some level of disturbance on a nearly yearly basis and large-scale disturbance on a fairly regular basis. As seen with other plantings in this area, this site has not proven to be particularly amenable to supporting limber pine seedlings.

In the spring of 2006, 250 seedlings were planted on the slopes above the Baring Creek drainage (Figure 22). Shortly after planting, three monitoring plots were established encompassing 71 seedlings, or 28%, of planted trees.

Seedlings at Baring Creek declined quickly, prior to the Reynolds Creek fire burning through this area in 2015. By one year after planting, only 17% of planted seedlings had survived. By three years after planting, survival had dipped to 4%, or three remaining live trees. These three trees continued to survive after the fire, which spared the plot site, since it burned in a mosaic pattern. Survivorship remained at 4% through ten years post-planting. Between ten and fifteen years after planting, another seedling died. In 2021, two trees continue to survive (3%). The high original mortality may have been due to this site being open and exposed with little shelter. The two surviving seedlings are tucked under shrubs, which shade them, but has also kept them fairly stunted. The remaining seedlings are much smaller than average 15-year-old seedlings in the Park (Table 13 and 14). One had a dead top and was rated a 4 -, so its fate is uncertain.

Figure 21. Dead Horse Point: Limber Pine Seedling Monitoring Monitoring Plots, Planted in 2006.

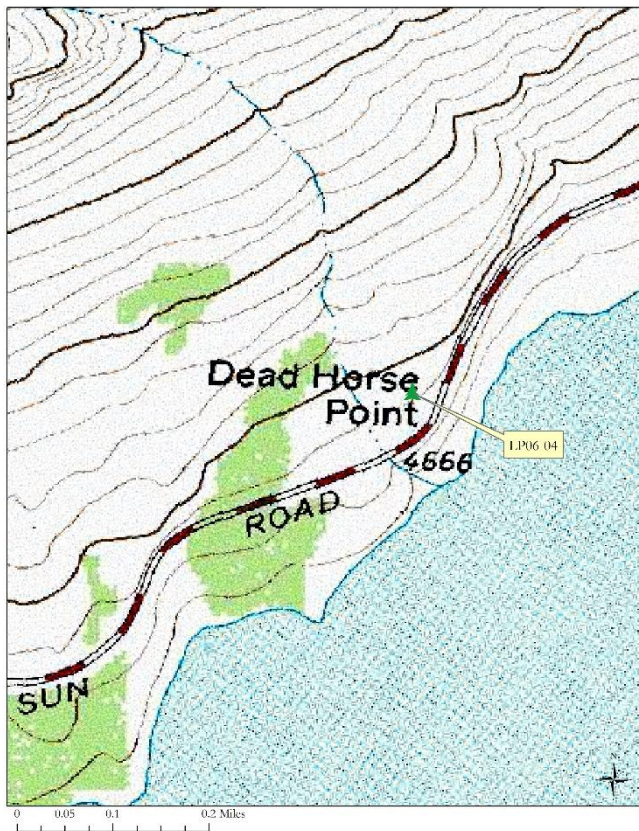


Figure 22. Baring Creek: Limber Pine Seedling Plots, Planted in 2006.

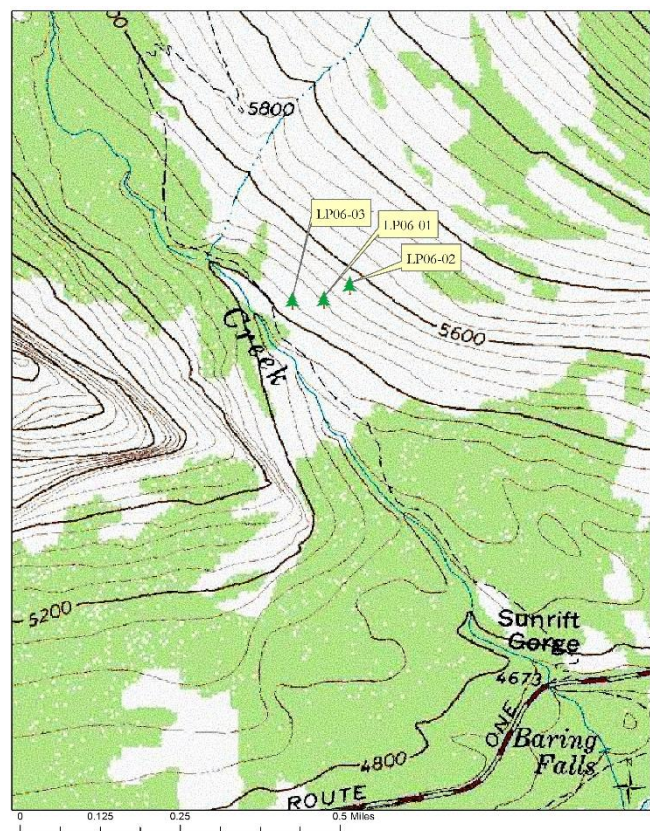


Table 14. Baring Creek and Dead Horse Point: Survival, Height and Width of Limber Pine Seedlings.

<i>Site</i>	<i>Monitoring Year</i>	<i>Years Post Planting</i>	<i>Total # Trees Monitored</i>	<i># Trees Survived</i>	<i>% of Trees Survived</i>	<i>Average Height</i>	<i>Average Width</i>
Baring Creek	2006	0	71	71	100%		
	2007	1	71	12	17%		
	2008	2	71	3	4%		
	2009	3	71	3	4%		
	2011	5	71	3	4%	20.33	9.67
	2016	10	71	3	4%	24.33	22.33
	2021	15	69	2	3%	27	42.5
Dead Horse Point	2006	0	20	20	0%		
	2007	1	20	0	0%		
Total 15 Year Survival	2021	15	89	2	2%	27	42.5

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b. Five-Year-Old Plantings

Limber pine seedlings were planted at six different sites in 2016 (Figure 23): Baring Creek, Dead Horse Point (lower and upper), Golden Staircase (lower), Lost Lake, Otokomi Mountain. (bench on lower slope), and Turnout #6 along the GTSR (below the road between Sun Point and Dead Horse Point). A total of 1,039 limber pine seedlings were planted. All but the Lost Lake planting took place in the spring and all plantings were within the burn perimeter of the Reynolds Creek Fire of 2015. This is the first time that burned habitat had been available for limber pine planting since the inception of the restoration program in the Park. Extra care was taken to find suitable planting sites within the burn that previously supported limber pine populations and that provided protection, good soil, microsites, and good planting conditions. A total of 35% of planted limber pine seedlings from 2016 are captured in monitoring plots.

Five-year overall survival for all limber pine planting sites planted in 2016 was 26%. Initial survival was promising across all plots planted in 2016, with first year survival averaging 86%. Three years after planting, survival across all monitoring sites dipped substantially, however, averaging only 30%. Survival did not drop much in the subsequent two years (Table 15). The range of survival at five years varied widely across sites, however, from 63% at Lost Lake to 3% at Dead Horse Point.

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

i. Baring Creek

In the spring of 2016, 104 seedlings were planted in the Baring Creek area, approximately 0.7 miles up the trail, in the first opening (Figure 23). Twenty-eight percent of trees were captured in a single monitoring plot (Table 11). All trees were alive and in good condition at the time of planting.

First year survival at Baring Creek was 90%. A large decrease was seen three years after planting, when 48% of seedlings were alive. Given the extreme hot, dry nature of the summers of 2017 and 2018, a drop in survival rates was not unexpected. Between years three and five, survival remained stable. One less tree was monitored in 2021, so five-year survival percentage was actually a notch higher than three-year survival, at 50% (Table 15). Trees at this site are shorter, but wider, than average for this planting cohort.

ii. Dead Horse Point

Limber pine seedlings were planted at two sites in the Dead Horse Point area in 2016; one on the bench just above the road, which was planted by Browning High School students and revegetation crew, and one about 475 feet higher on an upper bench (Figure 23). Both areas were planted in the spring. The lower plot captured 64 of 98 planted trees (65%), and the upper plot captured 65 of 147 planted trees (44%, Table 11).

At five years post-planting, seedlings at both Dead Horse Point sites had the lowest survival rates of all limber pine seedlings planted in 2016, with just 3% survival at both sites. Survivorship had declined sharply by year three in both Dead Horse Point Plots, at just 6% at the lower site and 12% at the upper site (Table 15). This was a substantial decline from one-year post planting, when 95% and 97% of seedlings survived in the lower and upper plots,

respectively. The lower bench area has not historically seen success in previous plantings, partially due to low elevation, perhaps, or other site-specific characteristics. It is not recommended to plant there in the future, as it is also a common snow slide area. The upper site is one of the higher elevation planting areas of 2016, so elevation probably played less of a role at that site. It is unknown why that planting experienced such low survival, but climate likely played a role. Trees in both plots were shorter than average compared to all limber pine seedlings planted in 2016. Seedlings also averaged smaller in width in the lower plot, but in the upper plot, seedlings were wider than average (Table 15).

i. Golden Staircase

In the spring of 2016, 98 seedlings were planted on a bench in the lower Golden Staircase area (Figure 23). Two monitoring plots were established in this planting in the spring, encompassing 42 seedlings, or 43% of planted trees (Table 11). Most trees (83%) were in good condition at the time of planting. The rest were considered in fair health.

Seedlings at this site also performed below average for the 2016 plantings, with only 10% survival after five years (Table 15). Again, there was a substantial decline three years after planting, where survival dropped to 17% from first year survival of 83%. A considerable amount of these surviving trees were only rated as fair (26%) or almost dead (9%) at that time as well. Seedlings at Golden Staircase were slightly smaller than average at five years. These plots are near average elevation but are on a bench in a relatively exposed area, which may be proving detrimental. Whitebark pine seedlings that were planted about 1,200 m higher up on this slope had a 63% survival rate five years after planting. There may be a general trend in which there is better survival at higher elevations where conditions are likely to be slightly cooler, with a shorter summer season, but it tends to be highly site specific.

ii. Lost Lake

Lost Lake, located east of Sun Point, on the north side of the road (Figure 23) was the only site planted in the fall of 2016. All other sites were planted in the spring. The highest number of seedlings was also planted here, with 312 trees. Monitoring plots encompassed 63 trees, or 20% of planted seedlings at this site (Table 11). Most trees were in good condition (94%) at the first monitoring event shortly after planting.

At Lost Lake, fifth-year survival was the highest of all 2016 plantings, at 63% (Table 15). This was only a 3% decrease from third year survival. Although there was a considerable decline in survival at Lost Lake from year one, where survival was 98%, the rate of loss seems to have stabilized. The elevation at Lost Lake is on the lower end of the range for the 2016 planting cohort, but seedlings were planted in late fall (early October) just prior to dormancy, which may have been an advantage over the other spring-planted trees. Seedlings at this site are now larger than average, after being some of the smallest of limber pine seedlings planted in 2016. Being planted in late fall may have provided a late start, but after five years, their growth rate has soared, and they now average the largest seedlings of this planting cohort.

iii. Otokomi Bench

In the spring of 2016, 179 seedlings were planted on a bench on lower Otokomi Mountain (Figure 23). Monitoring plots were established shortly thereafter, and 53 trees (29% of planted seedlings), were included in monitoring plots (Table 11). Most trees were considered in good condition at first monitoring.

Survival was 31% at this site three years after planting (Table 15). This is a 7% decline from third year survival, which dropped considerably from first year survival of 71%. Otokomi Bench had the lowest year one survival of all sites in this planting, but at five years after planting, average survival is above average. These seedlings are the smallest seedlings on average after five years of out-planting, but they were also some of the smallest seedlings planted. Perhaps some of the recent relative success at Otokomi Bench is due to it being the highest elevation site of all limber pine plantings from 2016.

iv. Turnout #6

Seedlings were planted in an area termed Turnout 6, west of Dead Horse Point on the south side of the Going-to-the-Sun Road (Figure 23). This is the lowest elevation limber pine planting of 2016. Turnout #6 was one of the earliest plantings in the spring of 2016, encompassing 101 seedlings. Monitoring plots incorporated 44 trees (44% of planted trees, Table 11).

Fifth year survival at Turnout #6 was 27%, slightly above average for limber pine seedlings planted in 2016. Third year survival at this site had been 31%, and, like the rest of the 2016 plantings, it had dropped considerably from 73% survival at one year after planting (Table 15). These seedlings are slightly bigger than average for this cohort five years after planting.

Figure 23. Limber Pine Monitoring Plots Installed and Planted in 2016.

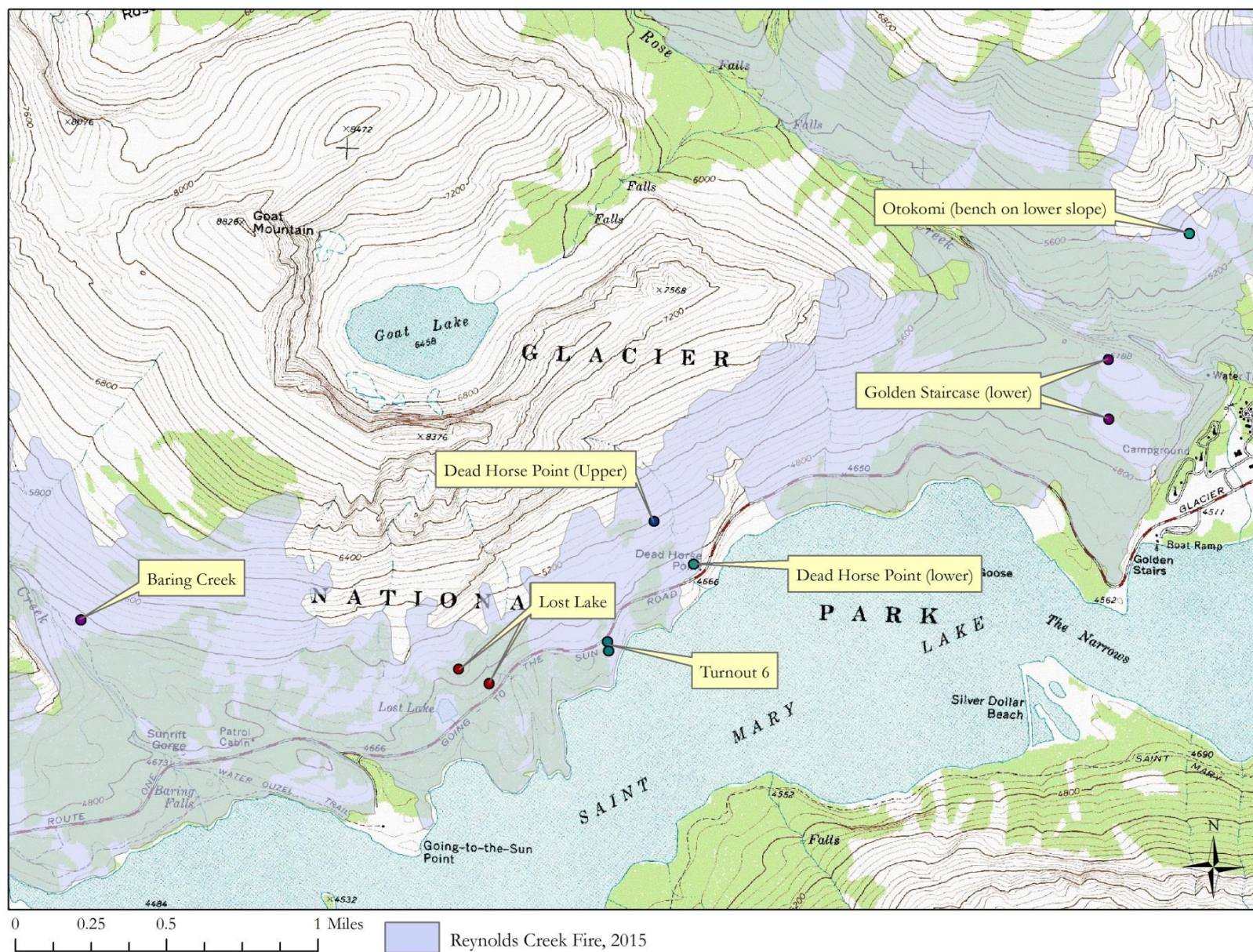


Table 15. Limber Pine Seedlings Planted in 2016: Survival and Average Height and Width.

<i>Site</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
Baring Creek	spring	2016	0	0	0	29	29	29	100%	8.3	10.0
		2017	3	0	3	23	26	29	90%	9.6	12.1
		2019	15	0	1	13	14	29	48%	14.0	16.6
		2021	14	0	0	14	14	28	50%	18.2	24.1
Dead Horse Point (lower)	spring	2016	0	0	0	64	64	64	100%	8.5	8.7
		2017	7	0	7	50	57	64	89%	10.2	13.4
		2019	60	0	2	2	4	64	6%	12.8	14.5
		2021	60	0	0	4	4	64	6%	17.5	21.8
Dead Horse Point (upper)	spring	2016	0	0	2	63	65	65	100%	8.5	10.6
		2017	4	0	7	55	62	66	94%	9.7	11.9
		2019	58	0	2	6	8	66	12%	11.9	15.5
		2021	62	0	0	4	4	66	6%	17.3	24.8
Golden Staircase (lower)	spring	2016	0	0	7	35	42	42	100%	8.6	10.0
		2007	7	3	9	23	35	42	83%	9.6	11.0
		2019	35	0	0	7	7	42	17%	13.7	14.9
		2021	37	0	0	4	4	41	10%	19.3	21.3
Lost Lake	fall	2016	0	0	4	59	63	63	100%	7.5	9.5
		2017	1	1	5	57	63	64	98%	8.2	10.1
		2019	22	0	6	36	42	64	66%	12.5	14.3
		2021	24	0	1	39	40	64	63%	22.4	24.7
Otokomi (bench on lower slope)	spring	2016	0	0	2	50	52	52	100%	8.0	10.6
		2017	15	2	6	29	37	52	71%	8.9	9.2
		2019	32	1	10	9	20	52	38%	11.8	14.8
		2021	36	1	2	13	16	52	31%	16.6	18.6
Turnout #6	spring	2016	0	0	3	41	44	44	100%	7.8	10.2
		2017	12	2	4	27	33	45	73%	10.4	12.6
		2019	31	0	1	13	14	45	31%	13.9	15.5
		2021	32	0	1	11	12	44	27%	22.7	23.3
Total Year 0 Survival							359	359	100%		
Total Year 1 Survival							313	362	86%		
Total Year 3 Survival							109	362	30%		
Total Year 5 Survival							94	359	26%		
Average Year 0 Height/Width										8.17	9.92
Average Year 1 Height/Width										9.50	11.47
Average Year 3 Height/Width										12.94	15.16
Average Year 5 Height/Width										19.14	22.66

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2. *Whitebark Pine Seedling Results*

Whitebark pine seedlings have been planted at 25 sites between 2000 and 2020, all of which continue to support live trees (Figure 20, Table 12). All whitebark plantings to date, the number of trees that have survived, percent survival and average sizes of seedlings at each site is summarized in Table 16. Overall survival for monitored whitebark pine seedlings planted in the park is 48%, based on the most recent monitoring event at each site.

Eleven Whitebark Pine planting sites were due for monitoring in 2021: Caper Peak, Cobalt Lake, Dead Horse Point, Flattop Mountain, Goat Mountain Slope, Golden Staircase, Grinnell Picnic Area, Mount Brown Lookout, Otokomi Slope, Otokomi Knob and Sperry Chalet. New whitebark pine seedlings were planted at Mount Brown and above the Two Medicine Campground in 2021. The 2001 planting at Dutch Creek was due for monitoring in 2021, for 20-year survival, but was not monitored, due to the time and effort required. If time permits, these trees will be monitored in 2022. As one of the first plantings in the park, this would be interesting information to obtain about some of our oldest seedlings. However, the remoteness of this site and lack of follow-up monitoring may make these plots and trees difficult to find.

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

Table 16. Parkwide: Survival and Average Height & Width for Whitebark Pine Seedlings from the Most Recent Monitoring Year

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Last Year Monitored</i>	<i># of Trees Monitored</i>	<i># of Trees Survived</i>	<i>% Survival</i>	<i>Monitoring Year</i>	<i>Average</i>	
								<i>Height</i>	<i>Width</i>
Grinnell Point	2000	fall	2020	95	54	57%	20	62.9	76.1
Flattop Mtn. Spring 2001	2001	spring	2021	634	162	26%	20	118.7	78.4
Sum/Average 20 year-old-trees				729	216	30%		111.4	77.8
Flattop Mtn. Fall 2001	2001	fall	2021	295	107	36%	19	105.7	87.3
Sum/Average* 19 year-old-trees				295	107	36%		105.7	87.3
Caper Peak	2006	fall	2021	140	26	19%	15	51.0	48.7
Sum/Average* 15 year-old-trees				140	26	19%		113.2	79.7
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
Grinnell Picnic Area	2011	late summer	2021	105	40	38%	10	31.3	32.4
Sum/Average* 10 year-old-trees				890	497	56%		50.5	46.3
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
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
Spot Mountain	2014	spring	2019	36	2	6%	5	10.5	11.5
Whitetail	2014	fall	2019	152	16	11%	5	9.8	10.5
Numa Lookout	2015	fall	2020	66	9	14%	5	11.9	9.4
Dead Horse Point (upper)	2016	spring	2021	54	21	39%	5	22.2	23.0
Goat Mountain Slope	2016	spring	2021	34	21	62%	5	26.6	28.5
Golden Staircase (upper)	2016	spring	2021	59	37	63%	5	25.6	23.5
Otokomi (lower)	2016	spring	2021	101	73	72%	5	26.1	24.8
Otokomi (upper)	2016	spring	2021	65	52	80%	5	34.1	26.8
Sum/Average* 5 year-old-trees				2474	1094	44%		14.9	14.3
Scenic Point (upper)	2015	fall	2020	68	21	31%	3	11.2	11.6
Sperry Chalet	2018	fall	2021	122	75	61%	3	16.3	14.8
Mount Brown Lookout	2018	fall	2021	110	77	70%	3	18.3	16.7
Sum/Average* 3 year-old-trees				300	173	58%		15.9	14.7
Red Eagle - lower	2007	fall	2008	55	55	100%	1	8.8	8.8
Mount Brown Lookout	2019	fall	2020	117	81	69%	1	7.9	9.9
Otokomi Knob	2020	fall	2021	67	65	97%	1	11.5	12.2
Mount Brown Lookout	2020	fall	2021	47	43	91%	1	11.1	12.1
Sum/Average* 1 year-old-trees				286	244	85%		9.4	10.6
Mount Brown Lookout	2021	fall	2021	156	156	100%	0	12.9	12.3
Above Two Med Campground	2021	fall	2021	74	74	100%	0	8.7	7.9
Sum/Average* 0 year-old-trees				230	230	100%		11.5	10.9
Overall Sum/Average Survival				5344	2587	48%			

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

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a. Nineteen and Twenty-Year-old Plantings
i. Flattop Mountain

A total of 5,160 trees were planted on Flattop Mountain between 2001 and 2002, at elevations between 6,300 and 6,800 feet. Monitoring plots included 927 trees, capturing 18% of planted seedlings (Table 12). Seedlings at this site were planted in July 2001, September 2001 and September 2002, and were planted within the perimeter of the McDonald Creek Fire of 1998 (Figure 24). All 38 plots established on Flattop Mountain were revisited in September 2021, which marks the nineteenth and twentieth year of monitoring.

The overall survival rate for seedlings planted on Flattop Mountain, currently at 29%, remained relatively stable over the past 5 years (Table 17). That represents only a 2% decline since 2016. Survival rates were quite variable across individual plots at Flattop and ranged from 7% to 88%. Most of the surviving seedlings were in good condition with 23% of all trees monitored rated as good and 6% rated as fair. Only one tree was considered almost dead. Many of the trees rated in fair condition had evidence of blister rust, however, and may not survive.

Survival rate varied slightly between planting cohorts. Twenty-year survival was 23% for seedlings planted in the spring of 2001 and 30% for seedlings planted in the fall of 2001 (Table 17). Nineteen-year survival was 36%, for seedlings planted in the fall of 2002.

The 20-year survival rate for the 2001 fall planting was right at the 30% average for all projects in the Park that have reached twenty years old (Table 18). The 2001 spring planting survival rate was slightly lower than the twenty year average. However, only one other project, Grinnell Point, has reached this age. Planted in 2000, whitebark seedlings at Grinnell Point had a 57% survival rate at twenty years. The Trees at Grinnell Point were planted immediately following the Grinnell Point Fire of 2000, which may have provided more nutrients to developing seedlings. The Flattop site, located on a long bench with gentle undulations, is much more protected than Grinnell Point, which is located on a high wind-swept slope. Trees were planted at Flattop three and four years after the McDonald Creek Fire of 1998 however, and it is possible that after three years soil nutrients had become less bio-available. As other projects reach this milestone, further comparisons can be made.

Survival rates were somewhat higher for the 19-year-old seedlings, which were planted at the far north end of the project (Figure 24). This area is at a slightly higher elevation and experienced more intense burn severity, resulting in less competition from other species. Cooler temperatures and higher precipitation near the time of planting may also have played a role in seedling survival and prevented the desiccation of newly planted seedlings (Appendix A). These conditions occurred in August 2002, whereas warmer and drier conditions existed in July and August of 2001 when the other whitebark pine seedlings were planted to the south. However, more blister rust was found in this planting, so future survival may wane.

In general, most trees at Flattop Mountain have been vigorous in both health and survival since the last monitoring event. Survival rates declined by only 2 to 3% in each of the three plantings over the past five years. The surviving trees grew substantially over the past five years (Table 19; Figure 25). Average height is now 114 cm and average width is 82 cm. The tallest tree monitored is 2.45 meters tall 20 years after planting, even after a tree fell on it and it grew around it. Unfortunately, this tree also had a branch with active blister rust, so it may not survive. The widest tree was 2.08 meters wide and looked healthy.

While growth in trees at Flattop have continued an upward trajectory, the rate of growth has slightly decreased over the past five years (Table 19, Figure 25). The growth rate ranged from 6.6 to 7.1 cm per year in height for all three plantings over the past five years. Growth rate peaked between years five to ten after planting, averaging 7.4 to 7.9 cm in height per year. Prior to this, the growth rate in height only averaged 3 to 6 cm per year across plantings at Flattop. Growth rate in width also decreased slightly over the past five years. Seedlings grew an average of 4.1 to 5.2 cm per year in width over the past five years. Growth rate in width also peaked between years five to ten after planting, averaging 4.3 to 6.0 cm per year. Previously it was only between 2.7 and 4.5 cm per year. While survival was lower at Flattop than at Grinnell Point, the only other project to reach 20 years of age in the Park, trees averaged much taller at Flattop. Flattop seedlings averaged 50 cm taller than seedlings from Grinnell Point at 20 years old. Grinnell trees, however, were 6cm wider on average. This reflects the fact that Grinnell Point is a much more wind-swept site.

The greatest mortality at Flattop occurred within the first three or four years after planting and has diminished over time. From the 2001 and 2002 plantings, mortality averaged about 50% through 2005. Between 2005 and 2011, monitoring events suggested that mortality was about 1% per year for the 2001 planting and 2% per year for the 2002 planting (Table 17). Mortality has slowed in the subsequent ten-year period to around a half a percent per year.

Among the remaining live trees that were not considered totally healthy, most field comments cited mechanical damage of an unknown cause. A few seedlings still suffered from competition from neighboring vegetation, but most

trees are now large enough to have outgrown the surrounding vegetation. Few naturally regenerating trees exist in the planting areas to compete with planted seedlings. Bark sloughing from snags in the area has become much less common, but many more snags are beginning to fall and sometimes squash planted trees. Quite a few trees have had a snag fall on top of them, but most grow around the fallen snag with no long-lasting detrimental effects.

ii. Blister Rust Infection in Planted Seedlings

An increasing number of seedlings at Flattop have been found to be infected with blister rust within the monitoring project (Table 19). In 2011, one seedling was determined to be infected with blister rust, the first planted seedling ever to be detected with the fungus. After removing the infected limb on that tree in 2011, it was found alive five years later with a good health rating. Unfortunately, that tree was found dead in 2021. In 2016, three additional trees were discovered that had been infected with blister rust, all from the 2001 planting, and distributed throughout the planting area. One tree was found dead and the other two were rated as fair, with active blister rust on the bole, which is generally considered to be a precursor to death of the tree. One of the two surviving trees was dead in 2021, and one was still alive with active blister rust. Four other trees were considered “suspicious” for blister rust presence in 2016.

In 2021, 40 trees were found with evidence of blister rust, 24 from the 2001 planting and 16 from the 2002 planting (Table 19). Additionally, 14 trees had suspicious characteristics, which were not definitive enough to be certain that it was blister rust. In several cases where evidence of blister rust was found on the planted tree, the rest of the tree looked quite healthy, or even appeared to be thriving. All trees with definitive blister rust were rated as “fair”, however, since their health was compromised. Several other trees were rated in fair condition with one or more dead branches, although it could not be determined to be caused by blister rust. A total of 40 trees have been identified with blister rust infections of the 659 whitebark pine seedlings that are currently being monitored at Flattop, which is 6% of the monitored population. Although this seems low, if the infection rate continues to increase, it could threaten this population in the future.

The first planted seedling ever to be found with blister rust infection was found at Flattop Mountain in 2011. Since then, blister rust has also been found in planted whitebark pine seedlings at Red Eagle in 2017, ten years after planting. At that time, 14 trees were found with active blister rust (4%), two trees were found with inactive blister rust (0.6%), and seven with potential blister rust (2%). Blister rust has also been found at three other whitebark pine planting sites: Grinnell Point, Divide Creek and Grinnell Picnic Area (Table 20). At Grinnell Point, three trees were found with active blister rust 20 years after planting. Two trees had only one canker, but one had more than ten 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. At Divide Creek, blister rust evidence was found on 13 trees (5%) in 2020, ten years after planting. All plots contained trees that were infected. Several other dead trees or trees with a dead leader may have been infected by blister rust, but it was not definitive. At Grinnell Picnic Area, eight trees (8%) were found with evidence of blister rust in 2021, ten years after planting. One additional tree had potential evidence of blister rust. It appears that blister rust first begins to show up in planted seedlings somewhere between five and ten years after planting. Since we do not monitor sites between years five and ten it is unknown the earliest timeframe when blister rust has been detected in planted seedlings. Extra diligence to look for evidence of blister rust infection must be taken when monitoring seedlings that have been planted for ten years. Crews should be trained in identification of blister rust sign since it can be difficult to assess.

Since parent trees have not been tied to our older outplanted seedlings, at this point it is not possible to link diseased seedlings to a specific parent tree to make inferences about genetic resistance to blister rust. In more recent plantings, individual seedlings are linked to parent trees in hopes of beginning to track blister rust vulnerability in the field. In older plantings, seedlings were grown from seed from parent trees which presumably had some level of genetic resistance, but this was only based on visual reference of trees that phenotypically appear healthy within a stand of mostly sick and dead trees. Results of genetic testing on plus trees within the Park are now guiding our selection of seedlings to grow and plant.

Subsequent monitoring should track blister rust infection closely. Since removal of infected limbs appears to aid in longer-term survival in whitebark pine, sawing off infected limbs in the future should be considered.

Figure 24. Flattop Mountain: Location of Whitebark Pine Seedling Plots, Established in 2001 and 2002.

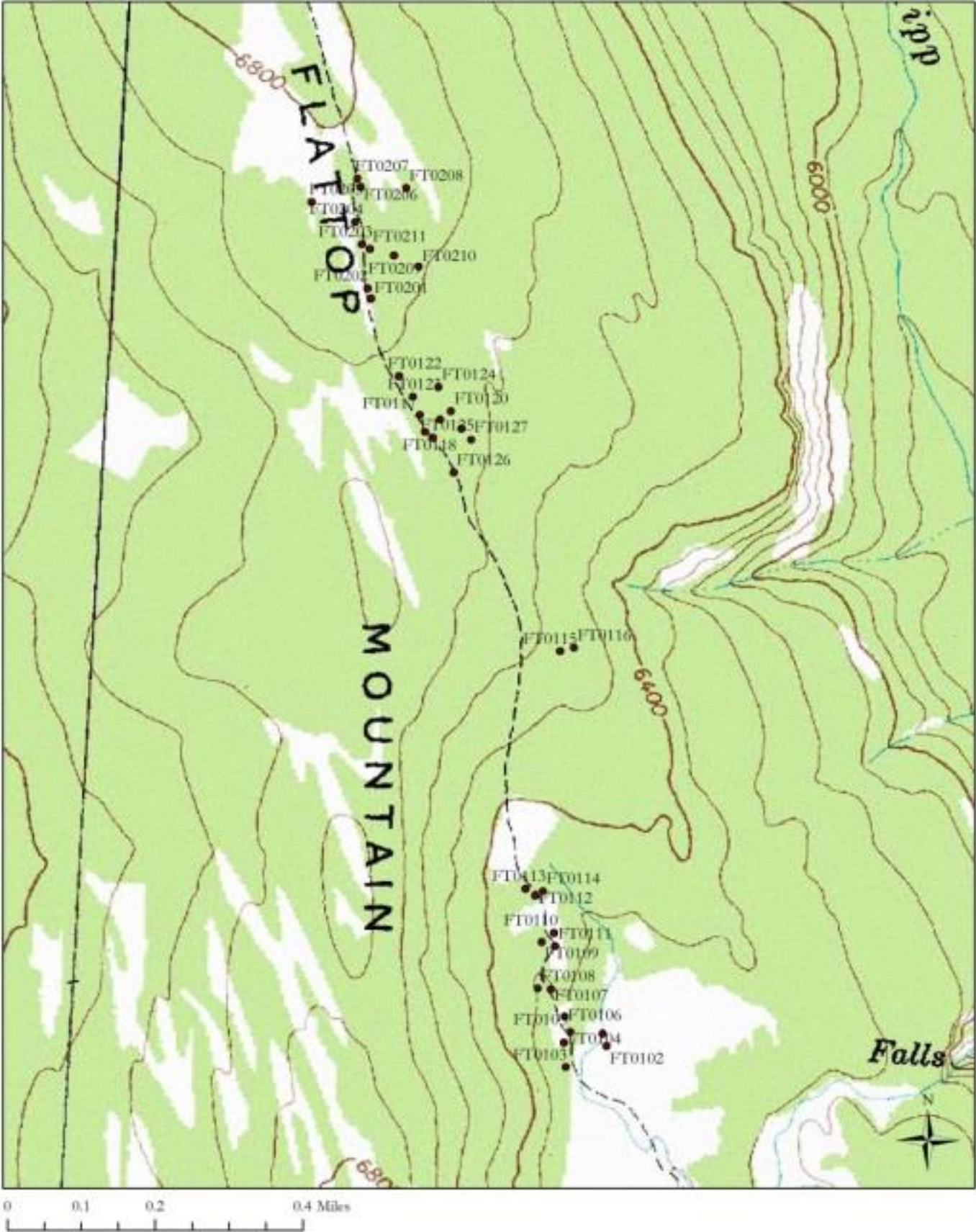


Table 17. Flattop Mountain: Health and Survival of Whitebark Pine Seedlings Monitored, 2001-2021.

<i>Site</i>	<i>Monitoring Year</i>	<i>Years Post Planting</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># of Trees Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>
Spring 2001	Spring 2001	0	0	1	11	325	337	337	100%
	Fall 2001	0	8	17	6	39	62	70	89%
	2002	1	171	5	6	155	166	337	49%
	2005	4	133	1	8	124	133	382	35%
	2006	5	258	2	19	104	125	383	33%
	2009	8	273	0	16	94	110	383	29%
	2011	10	277	0	14	93	107	384	28%
	2016	15	286	1	9	85	95	381	25%
	2021	20	296	1	10	76	87	383	23%
Fall 2001	2001	0	19	1	36	187	224	243	92%
	2002	1	15	1	4	31	36	51	71%
	2005	4	157	1	9	80	90	247	36%
	2006	5	159	1	14	75	90	249	36%
	2009	8	163	0	14	74	88	251	35%
	2011	10	166	1	4	84	89	255	35%
	2016	15	170	0	3	79	82	252	33%
	2021	20	176	0	21	54	75	251	30%
Fall 2002	2002	0	0	0	1	278	279	279	100%
	2005	3	145	0	18	119	137	282	49%
	2006	4	151	0	18	113	131	282	46%
	2009	7	169	0	12	106	118	287	41%
	2011	9	171	0	19	102	121	292	41%
	2016	14	182	0	7	103	110	292	38%
	2021	19	187	0	21	86	107	294	36%
Overall	2002	0 or 1	186	6	11	464	481	667	72%
	2005	3 or 4	435	2	35	323	360	911	40%
	2006	4 or 5	568	3	51	292	346	914	38%
	2009	7 or 8	605	0	42	274	316	921	34%
	2011	9 or 10	614	1	37	279	317	931	34%
	2016	14 or 15	638	1	19	267	287	925	31%
	2021	19 or 20	659	1	52	216	269	928	29%

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Table 18. Survival, Height and Width of All Whitebark Pine Seedlings Monitored in GNP Twenty Years After Planting.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i># of Trees Monitored</i>	<i># of Trees Survived</i>	<i>% Survival</i>	<i>Average</i>	
							<i>Height</i>	<i>Width</i>
Grinnell Point WBP	2000	fall	2020	95	54	57%	62.9	76.1
Flattop Mtn. WBP Spring 2001	2001	spring	2021	383	87	23%	117.9	71.1
Flattop Mtn.WBP Fall 2001	2001	fall	2021	251	75	30%	119.6	87.0
Average 20 year-old-trees				729	216	30%	100.14	78.08

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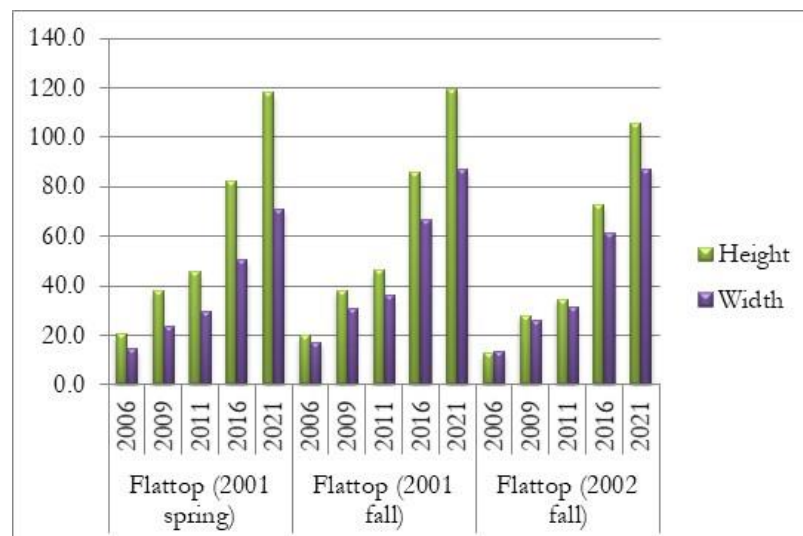
Table 19. Flattop Mountain: Size of Whitebark Pine Seedlings and Occurrence of Blister Rust, 2006-2021.

<i>Site</i>	<i>Monitoring Year</i>	<i>Average Height (cm)</i>	<i>Average Width (cm)</i>	<i># Trees w/ Blister Rust</i>	<i># Trees w/ Potential Blister Rust</i>
Flattop (2001 spring)	2001	*	*	0	0
	2002	*	*	0	0
	2005	*	*	0	0
	2006	20.3	14.5	0	0
	2009	37.7	23.6	0	0
	2011	45.4	29.4	1	0
	2016	82.5	50.7	4	4
	2021	117.9	71.1	8	6
Flattop (2001 fall)	2001	*	*	0	0
	2002	*	*	0	0
	2005	*	*	0	0
	2006	19.9	17.3	0	0
	2009	38.2	30.7	0	0
	2011	46.1	36.0	0	0
	2016	85.7	66.5	0	0
	2021	119.6	87.0	16	5
Flattop (2002 fall)	2002	*	*	0	0
	2005	*	*	0	0
	2006	12.8	13.5	0	0
	2009	28.0	25.8	0	0
	2011	34.5	31.5	0	0
	2016	72.6	61.4	0	0
	2021	105.7	87.3	16	3
Average/Total	2001	*	*	0	0
	2002	*	*	0	0
	2005	*	*	0	0
	2006	17.6	15.1	0	0
	2009	34.6	26.7	0	0
	2011	42.0	32.3	1	0
	2016	80.3	59.5	4	4
	2021	114.4	81.8	40	14

* Height and width were not measured prior to 2006

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Figure 25. Flattop Mountain: Height and Width of Whitebark Pine Seedlings, 2006-2021.



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Table 20. Parkwide: Blister Rust Found on Planted Seedlings.

<i>Site</i>	<i>Monitoring Year</i>	<i># of Years After Planting</i>	<i># Trees w/ Blister Rust</i>	<i>% of Trees w/ Blister Rust</i>	<i># Trees w/ Potential BR</i>	<i>% of Trees w/ Potential BR</i>
Flattop	2011	9/10	1	0.1%	0	0%
	2016	14/15	4	0.4%	4	0.4%
	2021	19/20	40	4%	14	2%
Red Eagle	2017	10	16	4%	7	2%
Grinnell Point	2020	20	3	3%	*	*
Divide Creek	2020	10	13	5%	*	*
Grinnell Picnic Area	2021	10	7	7%	1	1%

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iii. Fifteen-Year-old Planting (Caper Peak)

In the fall of 2006, 140 whitebark pine seedlings were planted on the flank of Caper Peak above Lake Isabel. Two monitoring plots were installed just following planting but were set up differently than other limber and whitebark seedling plots. Direct seeding took place within the same plots as seedlings were planted, and seeds were interspersed among the seedlings. Transects were set up from the center of the circular plot, and at haphazard distances along each transect, groups of seedlings or caches of seeds were planted. Each planting site contained multiple trees or seeds, varying from two to five seedlings in each location, and from three to five seeds in each location. Monitoring plots included all planted seedlings and seed (Figure 26).

This site is located on a small bench of an exposed south facing slope next to an avalanche chute. Extreme weather events and moderate to high avalanche activity are common in this area, but the planting site is surrounded by a rock barrier providing the trees with some shelter. The Rampage Fire burned the area in 2003, providing good planting habitat, which was utilized three years after the burn.

Although this site has not been visited on a regular schedule due to its remoteness, it was monitored at the milestone ten- and fifteen-years post planting. By the second year after planting, survival had dipped to 46%. In the subsequent eight years, survival only decreased slightly. Ten years after planting, in 2016, the survival rate had dipped to 34%, and continued to decline to 19% by fifteen years after planting (Table 21).

The Flattop spring and fall plantings and Grinnell Point planting are the only other whitebark pine projects that have been monitored at 15 years after planting. Survival at 15 years for all sites averaged 30% (Table 22). The Caper Peak site is behind the overall average, at 19%.

These trees are also substantially smaller than the average height for fifteen-year-old whitebark pine seedlings. Caper Peak seedlings average over 24 cm shorter and 11cm less wide than the other 15-year-old plantings. This may reflect the harshness of the site. However, they did show steady growth over the past five years. To date, all whitebark plantings that have reached 15 years old have been planted in burns, which should aid health and survival.

No seed was found to have germinated in the Caper Peak plots after fifteen years. A total of seven whitebark pine seed plots have been installed park-wide to date to monitor the establishment of whitebark pine seedlings from seed planted directly into the ground. In addition to the seed plots established at Caper Peak, two seed transects were installed in the Red Eagle area and three transects were installed at Siyeh Bend in 2007. No germination has been found at any site to date. Likely no germination will take place in direct seedings in the future, but if time permits, it may be worthwhile to continue to monitor seeded whitebark pine.

Table 21. Health, Survival and Average Height and Width of Whitebark Pine Seedlings Planted at Caper Peak in 2006.

<i>Monitoring Year</i>	<i>Years Post Planting</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i># of Trees Monitored</i>	<i># of Trees Survived</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2006	0	0	0	0	139	139	139	100%	*	*
2008	2	75	1	6	57	139	64	46%	13.6	11.8
2016	10	93	3	4	40	140	47	34%	35.7	32.7
2021	15	114	1	3	22	140	26	19%	51.0	48.7

* Height and Width not recorded prior to 2008

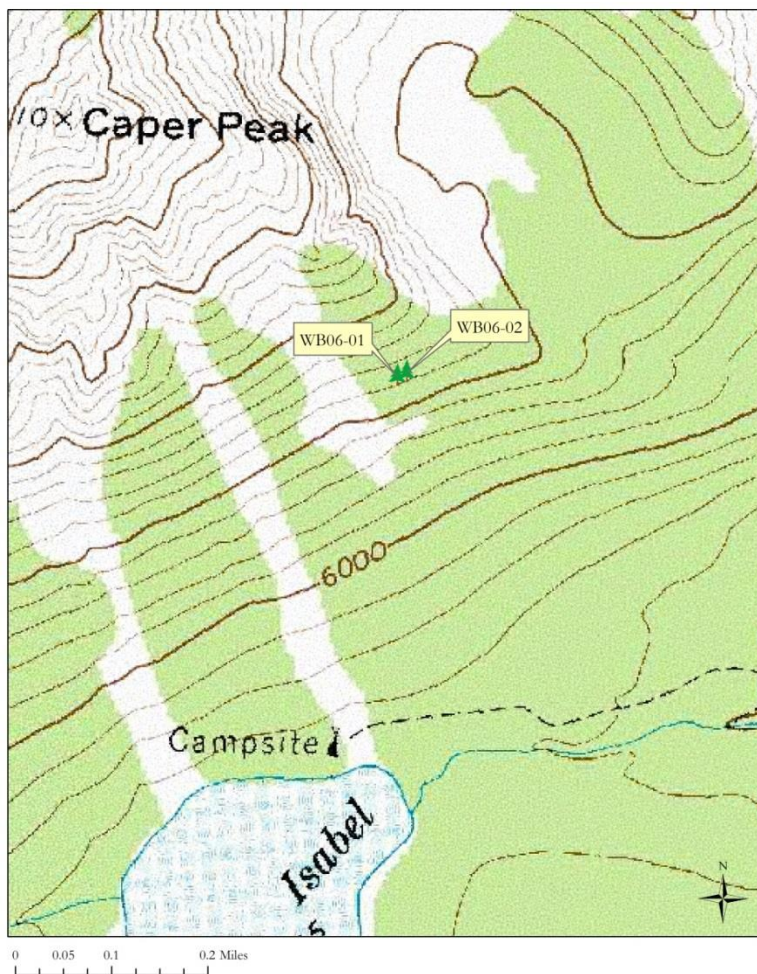
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Table 22. Parkwide: Survival, Height and Width of 15-Year-Old Trees.

Site	Year Planted	Season Planted	Year Monitored	Age of Planting	# of Trees Monitored	# of Trees Survived	% Survival	Average	
								Height	Width
Grinnell Point WBP	2000	fall	2015	15	96	62	65%	53.8	66.7
Flattop Mtn. WBP Spring 2001	2001	spring	2016	15	381	95	25%	85.7	66.5
Flattop Mtn.WBP Fall 2001	2001	fall	2016	15	252	82	33%	82.5	50.7
Caper Peak WBP Fall	2006	fall	2021	15	140	26	19%	51.0	48.7
Average 15 year-old-trees					869	265	30%	75.7	59.9

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

Figure 26. Caper Peak: Location of Whitebark Pine Seedling Plots, Established in 2006.



iv. Ten-Year-old Plantings

a. Grinnell Picnic Area

In August, 2011, a total of 146 whitebark pine seedlings were planted in relatively flat areas near the Grinnell Glacier Picnic Area (Figure 27). This area was not within a burn, but does contain sparsely vegetated, open areas and areas with denuded soil (from social trails) under trees. Seedlings were typically planted together in groupings of two or three trees per hole throughout the revegetation site. Two monitoring plots were installed in 2011 tracking 98 seedlings. In 2012, supplemental planting took place in this area and five seedlings were added to plots. Monitoring plots captured 67% of planted seedlings.

Ten years after planting, 19% of seedlings were still alive (Table 23). This represents more than a 20% decline in the past five years. Survival rate decreased most in the first year after planting, where it dropped to 49%. It declined another 3% at three years after planting, and then remained stable through five years post-planting. Although the ten-year survival at this site is relatively low, it has seen more success than at the Cobalt Lake site that was also planted at about the same time in 2011. Only two trees remain living at the Cobalt Lake planting. Unlike Cobalt Lake, seedlings at Grinnell Glacier have grown continuously in both height and width since the time of planting and showed a substantial boost in size over the past five years, increasing in both height and width by around 30cm, although they grew faster in height (Table 23).

High early mortality at this site has been attributed to early season planting, transplantation in the nursery, and inadequate microsites. These seedlings were planted at the end of August when temperatures remained high and rainfall was low (Appendix A). Although seedlings were well watered in when planted, the results of this project may again indicate how important weather is to survival in whitebark pine seedlings. Planting during late summer appears to be too hot and dry for prime survival rates. Later planting dates should be targeted for cooler temperatures and more reliable precipitation. Additionally, these seedlings came as bare root plants from the Coeur d'Alene Nursery and needed to be put back into containers prior to planting. This is a high amount of handling for tree seedlings and many of them did not look healthy upon planting. Many of the surviving seedlings, however, appear to be thriving now that they are established, suggesting that this environment is more favorable for whitebark than previously suspected.

Future survival is threatened by blister rust infection at this site, however. As has been seen in several ten-year plantings, blister rust was found in 2021 for the first time in this monitoring area. Seven trees (7%) were identified with definitive or likely blister rust evidence (Table 24). One tree appeared suspicious for blister rust. All blister rust infected trees were found in plot WB11-01, the more exposed site, further from the picnic area. Further monitoring should track this closely, and perhaps infected limbs should be removed.

Table 23. Grinnell Picnic Area: Health, Survival and Average Height and Width of Whitebark Pine Seedlings, 2011-2021.

Year	Dead/ Missing	Almost Dead	Fair	Good	# Survived	# of Trees Monitored	% Survival	Average Height (cm)	Average Width (cm)
2011	6	27	13	52	92	98	94%	9.4	10.0
2012	53	3	4	43	50	103	49%	10.5	11.8
2014	62	0	3	39	42	104	40%	12.8	15.8
2016	63	0	0	42	42	105	40%	18.6	21.6
2021	114	1	3	22	26	140	19%	51.0	48.4

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Table 24. Grinnell Picnic Area: Number of Trees With Blister Rust Evidence in Planted Whitebark Pine Seedlings, 2021.

Year	Active BR	Inactive BR	Likely BR	Possibly BR	Total
2021	1	1	5	1	8

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b. Cobalt Lake

In August 2011, a total of 250 whitebark pine seedlings were planted in open, flat areas to the north of the Cobalt Lake Campground (Figure 28). This area is not located within a burn, which required that vegetation was ‘scalped’ around the planted whitebark seedlings to reduce competition. Seedlings were planted in forest openings near existing whitebark pine trees and typically planted together in groupings of two to three trees per planting hole. Three monitoring plots were established, encompassing 108 trees or 21% of planted seedlings.

Seedlings at Cobalt Lake were monitored in 2021 for the fourth time since planting. Only 2% (2 trees) of seedlings are surviving at this site ten years after planting (Table 25). Both trees were rated in “fair” condition. Survival at this site has never been high, dropping to 31% the first year after planting and then dipping to 10% three years post-planting. Poor initial survival was likely due, at least in part, to a late August planting date, followed by hot and dry weather. These conditions have proven to be challenging for initial survival. Almost half (49%) of seedlings were in fair condition or worse one month after planting. Subsequent poor performance at this site is likely due to lack of shelter

and adequate resources. The Cobalt Lake Campground area did not provide many microsites, as this site is located in open, very rocky terrain where soil is not ideal for planting. Small microsites were improvised but, in general, these microsites are not providing the protection and shade that these seedlings often require. Additionally, soil requirements may not have been met at this site. Since this area has not burned, the soil may lack nutrients for developing seedlings. It is also unknown whether mycorrhizal fungi exist in the soil at this site to form beneficial mutualistic relationships with the trees. Furthermore, these seedlings endured a high amount of handling and many of them did not look healthy upon planting. Trees came as bare root plants from the Coeur d'Alene nursery and needed to be put back into containers prior to planting. Surviving seedlings continue to be small at this site, averaging only 16 cm tall and 6.5 cm wide at 10 years old (Table 25).

Table 25. Cobalt Lake: Health, Survival and Average Height and Width of Whitebark Pine Seedlings, 2011-2021.

Year	Dead/ Missing	Almost Dead	Fair	Good	# Survived	# of Trees Monitored	% Survival	Average Height (cm)	Average Width (cm)
2011	1	16	36	55	107	108	99%	9.5	10.6
2012	75	10	5	18	33	108	31%	10.2	12.0
2014	97	4	4	3	11	108	10%	13.0	11.3
2016	102	0	2	4	6	108	6%	14.8	11.0
2021	106	0	2	0	2	108	2%	16.0	6.5

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

ii. *Five-Year-old Plantings*

Whitebark pine seedlings were planted at six sites in 2016: Dead Horse Point, Goat Mountain, Golden Staircase, Upper Otokomi, Lower Otokomi and Upper Nyack (Figure 29). In total, 1,750 trees were planted, including 907 trees in the spring and 1,156 trees in the fall.

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

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

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

Five years after planting, survival across all monitoring areas averaged 65% (Tables 26, 27). The range of survival was 39% to 80%. At all sites but Dead Horse Point, survival was higher than average for all five-year-old whitebark pine plantings in the park (Table 28). Overall survival in this cohort remained relatively stable over the past two years, only dropping 4%. There was a notable decrease from first year to third-year survival rates, however, when it dropped from 96% to 69% (Table 27). First year monitoring took place before the extreme heat waves and “flash droughts” of both 2017 and 2018. Unfortunately, this extreme weather likely took its toll on newly establishing seedlings. Surviving seedlings, however, were larger than average five-year-old planted whitebark pine seedlings across the park (Table 28).

Figure 27. Whitebark Pine Seedling Monitoring Plots Established at Grinnell Glacier Picnic Area, Planted in 2011.

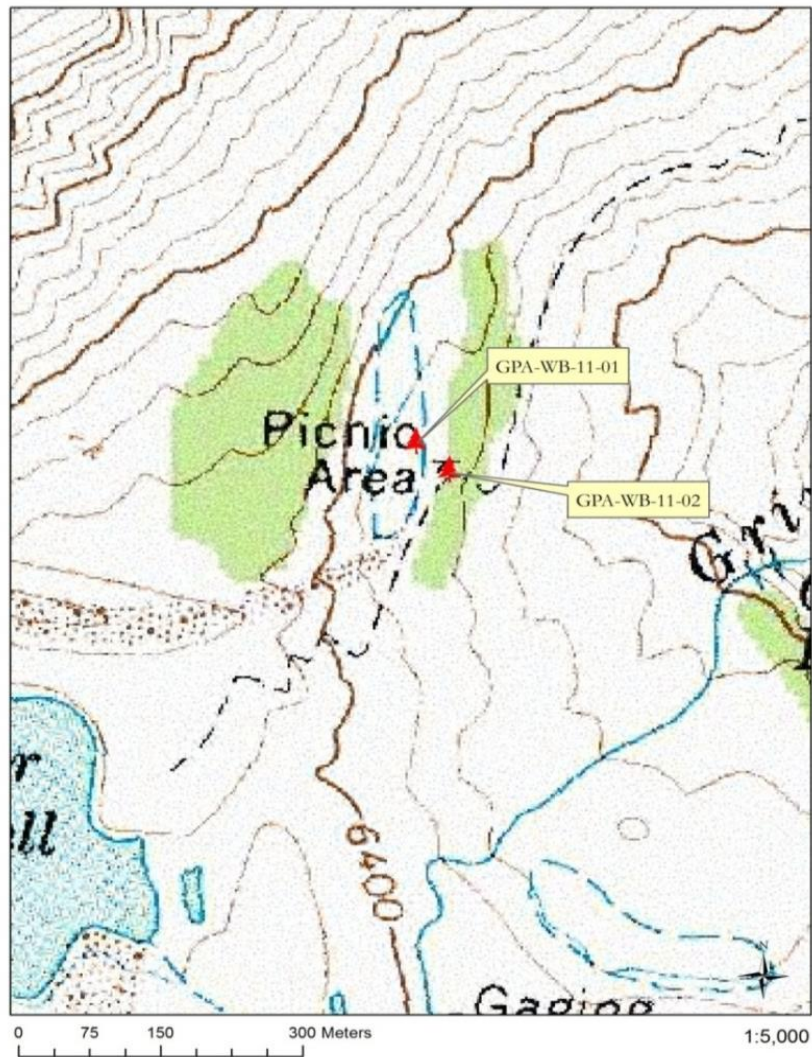


Figure 28. Cobalt Lake: Location of Whitebark Pine Seedling Plots, Established in 2011.

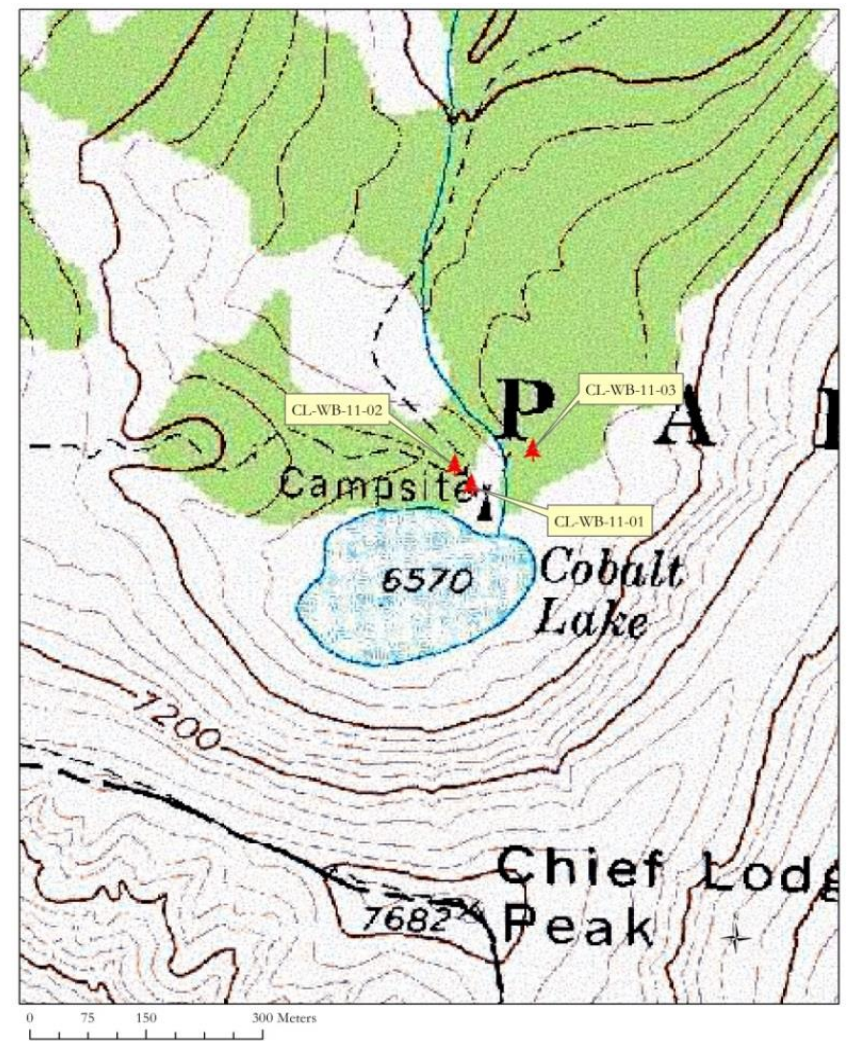


Table 26. Whitebark Pine Seedlings Planted in 2016: Five-Year Health, Survival and Average Height and Width, 2021.

<i>Site</i>	<i>Season Planted</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
Dead Horse Point (Upper)	spring	33	2	0	19	21	54	39%	22.2	23.0
Goat Mountain Slope	spring	13	0	0	21	21	34	62%	26.6	28.5
Golden Staircase (High)	spring	22	0	0	37	37	59	63%	25.6	23.5
Otokomi (Upper)	spring	13	0	3	49	52	65	80%	34.1	26.8
Otokomi (Lower)	fall	28	0	7	66	73	101	72%	26.1	24.8
Total/Weighted Average		109	2	10	192	204	313	65%	27.0	25.5

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a. Dead Horse Point

In the spring of 2016, an estimated 227 seedlings were planted on an upper bench of the Dead Horse Point area (Figure 29). Fifty-two trees, 23% of planted seedlings, were captured in two monitoring plots. All trees were alive and most (80%) were in good condition at the time of planting; 20% were in fair condition.

Five years after planting, survival had dropped to 39%, the lowest of all 2016 plantings. This site also had the lowest survival one year and three years after planting, at 89% and 43%, respectively. Surviving seedlings, are also smaller than average, and are the smallest trees of this cohort (Table 27).

This is the lowest elevation whitebark pine planting site in the Park (Table 12), which may induce environmental conditions that are less favorable than other higher, potentially cooler sites. While there are standing snags for shade and protection at this site, they are widely spaced, and open scree dominates the understory, perhaps creating hotter and drier conditions than favorable, especially at this low-elevation location.

b. Goat Mountain

An estimated 145 seedlings were planted in the spring of 2016 on the slope of Goat Mountain, at the edge of a mosaicked burn that did not seem to have burned excessively hot (Figure 29). Unburned areas surround the planting site. One monitoring plot was established here, encompassing 34 trees (23% of planted seedlings). All trees were in good condition at the time of planting.

Five years after planting, 62% of seedlings have survived, slightly below average (65%) for the 2016 plantings. No trees were lost in this plot since the last monitoring event in 2019. There was a fairly large drop from the 94% survival one year after planting, but survival has stabilized over the past two years. Seedlings were about average in height, but are the largest, on average, in width. These trees were the largest all around, on average, in 2017 (Table 27). Several factors may benefit seedlings planted in this area, such as soil that did not burn excessively hot and surrounding islands of live trees for protection, so it is unknown why trees are not faring as well as at some other sites planted in 2016.

c. Golden Staircase (Upper)

In the spring of 2016, an estimated 294 whitebark pine seedlings were planted on an upper bench of the Golden Staircase area (Figure 29). Parts of this section of the fire perimeter appeared to burn relatively severely, but the planting site is located within a mosaic, and is surrounded by small areas that have not burned. Soil seemed light and dry. Two monitoring plots were established shortly after planting, including 59 trees, or 20% of planted seedlings. All trees were alive at initial monitoring, and all but two trees were in good condition.

Five years after planting, 63% of seedlings were alive, slightly below average for the sites planted in 2016 (Tables 26, 27). This represents an 8% decline over the past two years. There was great initial survival at this site, with 100% survival the first year after planting, which then dropped to 71% three years post-planting.

Seedlings remained smaller than average at Golden Staircase, which may reflect that this is the highest elevation site from that planting year, perhaps providing fewer optimal growing days. The higher elevation of this site, compared to other whitebark planting sites, as well as the limber pine planting site lower on the same slope, may prove beneficial in the long run, with slightly cooler temperatures. Standing snags at this site were small and dispersed, which did not seem to offer a lot of protection to developing seedlings.

d. Otokomi Mountain (Upper & Lower)

Whitebark pine seedlings were planted in two widely separated areas of Otokomi Mountain in 2016 (Figure 29). In the spring, an estimated 241 seedlings were planted within burned forest on a relatively flat slope. It should be noted that although this site is termed “lower” Otokomi, the elevation of planting sites is nearly as high as the upper site, but is accessed lower on the Otokomi trail, before an off-trail hike. Shortly after planting, three monitoring plots were established at the “lower” site, encompassing 98 trees, 24% of planted seedlings. All were alive and healthy at the time of initial monitoring.

In the fall of 2016, an estimated 406 seedlings were planted at the “upper” site, accessed from the upper part of the Otokomi Lake trail, on the edge of a burn. This planting area was on a steeper slope within a burned forest, at the edge of a fire mosaic. One monitoring plot was installed, including 65 trees, 27% of fall-planted seedlings in the area. All trees were alive and healthy at the time of initial monitoring.

Five years after planting, both sites have high survival, at 72% and 80%, for the lower and upper sites, respectively (Tables 26, 27). This represents only a 3% and 5% decline at these sites over the past two years. One year after planting, survival was very high, at 97% and 95% in these plots, respectively. More trees were in poor health at the “lower” site at that time. The small difference in survival between these sites may be due to environmental differences. The “lower” site encompasses three plots, with aspects south to southwest. The “upper” site, a single plot with a southwest aspect, seems to have a little less exposure.

The the “upper” planting, planted in the spring, supports the largest trees of all whitebark pine seedlings planted in 2016, while trees in the fall-planted “lower” site continue to be smaller than average for this cohort.

Table 27. Whitebark Pine Seedlings Planted in 2016: Health, Survival and Size, 2016-2021.

<i>Site</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
Dead Horse Point (Upper)	spring	2016	0	0	5	20	25	25	100%	10.6	10.9
		2017	6	0	5	43	48	54	89%	11.7	12.3
		2019	31	0	1	22	23	54	43%	15.1	18.8
		2021	33	2	0	19	21	54	39%	22.2	23.0
Goat Mountain Slope	spring	2016	0	0	0	34	34	34	100%	10.4	11.3
		2017	2	0	0	32	32	34	94%	13.5	14.1
		2019	13	0	5	16	21	34	62%	17.3	18.1
		2021	13	0	0	21	21	34	62%	26.6	28.5
Golden Staircase (High)	spring	2016	0	0	2	57	59	59	100%	10.0	10.5
		2017	0	1	8	50	59	59	100%	11.9	12.9
		2019	17	0	1	41	42	59	71%	15.5	16.8
		2021	22	0	0	37	37	59	63%	25.6	23.5
Otokomi (Upper)	spring	2016	0	0	0	64	64	64	100%	10.5	10.5
		2017	3	2	1	59	62	65	95%	12.8	12.5
		2019	10	0	7	48	55	65	85%	21.2	19.7
		2021	13	0	3	49	52	65	80%	34.1	26.8
Otokomi (Lower)	fall	2016	0	0	0	98	98	98	100%	11.4	11.3
		2017	3	7	13	77	97	100	97%	11.6	12.5
		2019	25	2	7	67	76	101	75%	16.6	18.0
		2021	28	0	7	66	73	101	72%	26.1	24.8
Total Year 0			0	0	7	273	280	280	100%		
Total Year 1			14	10	27	261	298	312	96%		
Total Year 3			96	2	21	194	217	313	69%		
Total Year 5			109	2	10	192	204	313	65%		
Average Year 0 Height/Width										10.6	10.9
Average Year 1 Height/Width										12.3	12.9
Average Year 3 Height/Width										17.2	18.3
Average Year 5 Height/Width										26.9	25.3

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Figure 29. Whitebark Pine Monitoring Plots Installed and Planted in 2016.

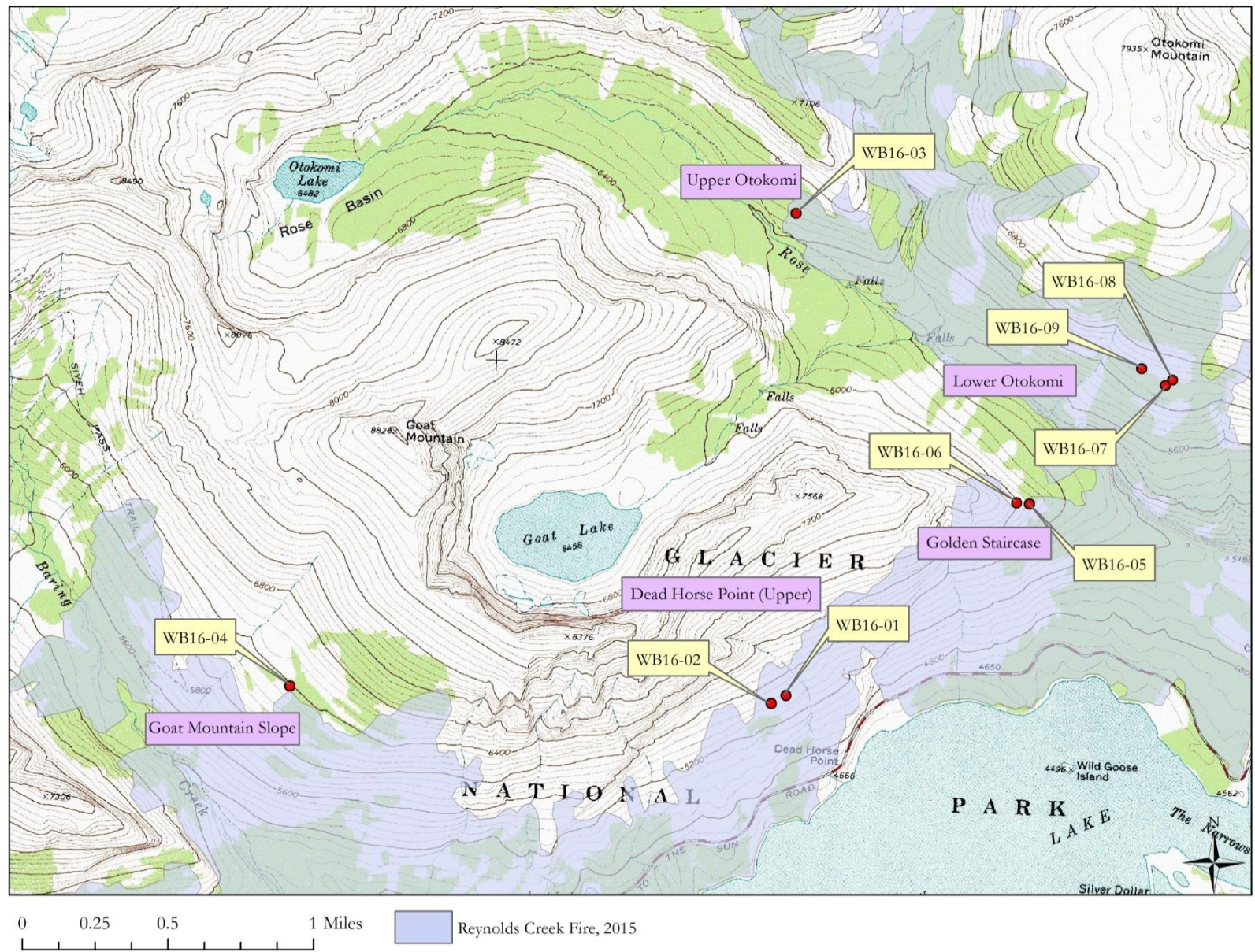


Table 28. Parkwide: Survival, Average Height and Width of all Whitebark Pine Seedlings Planted in the Park, Five Years After Planting.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i># of Trees Monitored</i>	<i># of Trees Survived</i>	<i>% Survival</i>	<i>Year 5</i>	
							<i>Height</i>	<i>Width</i>
Flattop Mtn. Spring 2001	2001	spring	2006	282	131	46%	12.8	13.5
Flattop Mtn. Fall 2001	2001	fall	2006	632	215	34%	12.8	13.5
Red Eagle - upper	2007	fall	2012	358	196	55%	27.8	26.9
Red Eagle - lower	2007	fall	2012	55	0	0%		
Hole-in-the-Wall	2010	fall	2015	172	49	28%	11.9	11.1
Divide Creek - lower	2010	fall	2015	265	249	94%	19.4	20.7
Cobalt Lake	2011	late summer	2016	108	6	6%	14.8	11.0
Grinnell Picnic Area	2011	late summer	2016	105	42	40%	18.6	21.6
Divide Mountain	2012	fall	2017	226	125	55%	11.2	12.4
Firebrand Upper	2013	spring	2018	209	154	74%	13.8	14.0
Firebrand Lower	2013	fall	2018	387	207	53%	11.2	12.7
Numa	2013	fall	2018	179	64	36%	14.5	10.7
Divide Creek	2014	fall	2019	222	157	71%	19.7	17.3
Firebrand (lower)	2014	spring	2019	108	63	58%	16.5	16.9
Firebrand (upper)	2014	fall	2019	159	4	3%	11.5	13.3
Numa	2014	fall	2019	120	41	34%	14.1	10.8
Scenic Point (upper)	2014	spring	2019	189	42	22%	11.9	10.6
Spot	2014	spring	2019	36	2	6%	10.5	11.5
Whitetail	2014	fall	2019	152	16	11%	9.8	10.5
Numa	2015	fall	2020	66	9	14%	11.9	9.4
Dead Horse Point (upper)	2016	spring	2021	54	21	39%	22.2	23.0
Golden Staircase (high)	2016	spring	2021	59	37	63%	25.6	23.5
Goat Mountain Slope	2016	spring	2021	34	21	62%	26.6	28.5
Otokomi (upper)	2016	spring	2021	65	52	80%	34.1	26.8
Otokomi (lower)	2016	fall	2021	101	73	72%	26.1	24.8
Average 5- year-old-trees				4343	1976	45%	15.6	17.1

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

iii. Three-Year-old Plantings

Whitebark pine seedlings were planted at two sites in 2018: Sperry Chalet and Mount Brown Lookout (Figures 30, 31). In total, 1,007 trees were planted, all in the fall.

All plantings were within the burn perimeter of the Sprague Fire of 2017. Care was taken to find suitable planting sites within the burn that previously supported whitebark pine populations and were suitable planting sites. Planting sites were established in areas that provided protection, good soil, microsites, and good planting conditions. No whitebark pine seedlings planted in 2018 were inoculated with an ectomycorrhizal slurry.

Parent tree populations for planted seedlings differed for each site and plot and was noted (Tables 29, 30). In some cases, an individual plus tree was identified as the seed source, so, in these cases, survival may be able to be traced to individual parent tree. The age of seedlings planted also differed. Normally, seedlings are two years old at the time of planting, but because planting conditions were poor in 2016-2017, with extreme heat and drought, the trees slated to be planted in the fall of 2016, and all trees slated to be planted during 2017, were held over in the nursery in Glacier for one or two years. Another crop of seedlings arrived from the nursery in Coeur d'Alene to be planted in 2018. All these seedlings were planted in 2018. This generally resulted in older seedlings being larger than younger seedlings at the time of planting.

i. Mount Brown

Whitebark pine seedlings were planted near Mt. Brown Lookout in the fall of 2018, 2019, 2020 and 2021 (Figure 30). All plantings were within the burn perimeter of the Sprague Fire of 2017. Monitoring plots planted in 2018, 2020 and 2021 were read in 2021, at years 3 and 1 after planting, and at the time of planting, respectively. Results will be discussed below under each year's plantings.

In 2018, 443 seedlings were planted near the lookout at Mount Brown the year after the Sprague fire burned the area. Since the seedlings had been kept in the nursery for different amounts of time, trees were of different ages; 189 of them were two years old, while 254 were three to four years old. Monitoring plots were installed shortly after planting and elevations ranged from 7,450 feet to 6,785 feet. A total of 25% 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.

The three-year-old planting is the oldest planting at Mount Brown and was monitored for the fourth time in 2021. Normally, plots are not monitored the second year after planting, but these plots were monitored opportunistically at year two, while monitoring other plots. This lends an opportunity to observe yearly progress for this planting which is not typical due to time constraints given the number of plantings that have accumulated.

Survival has dropped slightly each year, but the largest decrease was seen between years one and two after planting. From years zero to one, survival dropped 8%, from years one to two survival dropped 16%, and from years two to three survival dropped 6%. Three years after planting, overall survival is 70%, which is above average for third-year plantings, and was fairly consistent across plots (Table 29). Average survival at three years post-planting for all monitored seedlings in the Park is 60% (Table 31). Seedlings were also larger than average three-year-old seedlings, averaging almost 6 cm taller and almost 4 cm wider (Tables 29 and 31). This may reflect that many of the seedlings were older when planted. There is great disparity in height among plots, again, likely reflecting different ages. Trees in plot 6 (from Numa parent trees) were almost three times taller than those from plot 4 (from Triple Divide parent trees). Trees from plot 5 (from an individual Numa and an individual Siyeh plus tree) were also on the taller side. Now that planted seedlings are beginning to be tied to parent tree populations, and even individual parent trees, trends in survival and size may potentially be correlated with genetics.

In 2020, it was noted that 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. Some of these trees subsequently died, but some also recovered and gained health.

ii. Sperry Chalet

Whitebark pine seedlings were planted near Sperry Chalet in the fall of 2018, in a rocky, benchy area within the burn perimeter of the Sprague Fire of 2017 (Figure 31). Three monitoring plots were established the day of planting at elevations from 6645 to 6690 feet. A total of 21% of planted seedlings were captured in monitoring plots. Due to retaining seedlings in the nursery while planting conditions improved, outplanted seedlings in 2018 were of differing ages and therefore sizes. At the Sperry Chalet area, 190 of the planted seedlings were two years old, while 374 of the seedlings were three to four years old. At the time of planting, 100% of all monitored seedlings were rated as "good" (Table 30).

Seedlings fared extraordinarily well one year after planting, with 99% survival (Table 30). This is much higher than the parkwide average of 75% for all first-year plantings (Table 34). The growing season of 2019, which was cooler and supplied intermittent rain, provided better conditions for establishing seedlings than has been experienced the past two summers, which were exceptionally hot and dry (Appendix A). Quite a few trees were rated fair and a few were rated almost dead at each site, however. By 2021, three years after planting, survival had dropped to 61%, which is near average for three-year plantings, however. Survival varied wildly between plots. Plot 2, with seedlings from Numa parent trees, had only 39% survival. Plot 1, from a Rising Wolf parent plus tree, showed moderate success at 67% survival, and plot 3, from a Siyeh Bend parent plus tree, boasted 72% survival. Overall survival for these plots is on par with average for three-year-old plantings in the park, at 60% (Table 31).

As in the three-year-old Mount Brown planting, sizes also varied widely between plots. Plot 1, from the Rising Wolf parent tree, contained the shortest trees at three years, but they were also the widest. Plot 3, with the Siyeh Bend parent tree, averaged the tallest trees by over 7 cm. This may reflect age at planting more than other environmental factors, however.

Both the Sperry Chalet and Mount Brown plantings from 2018 are scheduled to be monitored next in 2023, at five years post-planting. This monitoring event may capture how well seedlings fared throughout the extreme heat of 2021.

Table 29. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2018.

<i>Plot</i>	<i>Parent Tree</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
WB18-04	Triple Divide	2018	0	0	0	25	25	25	100%	6.4	7.04
WB18-05	Numa (1502), Siyeh 831	2018	0	0	0	43	43	43	100%	15.1	10.8
WB18-06	Numa *	2018	0	0	0	42	42	42	100%	20.2	13.5
WB18-04	Triple Divide	2019	3	1	5	16	22	25	88%	6.4	6.5
WB18-05	Numa (1502), Siyeh 831	2019	2	1	8	32	41	43	95%	14.5	10.0
WB18-06	Numa *	2019	4	0	18	20	38	42	90%	18.3	15.3
WB18-04	Triple Divide	2020	8	1	7	9	17	25	68%	7.9	8.1
WB18-05	Numa (1502), Siyeh 831	2020	8	1	11	23	35	43	81%	16.4	13.3
WB18-06	Numa *	2020	10	1	8	23	32	42	76%	20.9	18.5
WB18-04	Triple Divide	2021	8	0	4	13	17	25	68%	8.4	9.5
WB18-05	Numa (1502), Siyeh 831	2021	12	0	4	27	31	43	72%	19.5	16.5
WB18-06	Numa *	2021	13	1	2	26	29	42	69%	22.9	21.0
Total/Average 2018			0	0	0	110	110	110	100%	15.1	11.0
Total/Average 2019			9	2	31	68	101	110	92%	14.2	11.2
Total/Average 2020			26	3	26	55	84	110	76%	16.3	14.2
Total/Average 2021			33	1	10	66	77	110	70%	18.3	16.7

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

Table 30. Sperry Chalet: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2018.

<i>Plot</i>	<i>Parent Tree/Population</i>	<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
WB18-01	Rising Wolf (1409)	2018	0	0	0	68	68	68	100%	11.1	10.30
WB18-02	Numa	2018	0	0	0	28	28	28	100%	14.4	11.10
WB18-03	Siyeh (831)	2018	0	0	0	25	25	25	100%	18.1	11.60
WB18-01	Rising Wolf (1409)	2019	0	3	6	60	69	69	100%	10.4	12.8
WB18-02	Numa	2019	1	0	4	23	27	28	96%	13.4	12.8
WB18-03	Siyeh (831)	2019	0	1	1	23	25	25	100%	17.3	11.6
WB18-01	Rising Wolf (1409)	2021	23	3	10	33	46	69	67%	13.7	15.9
WB18-02	Numa	2021	17	1	5	5	11	28	39%	15.9	12.6
WB18-03	Siyeh (831)	2021	7	1	6	11	18	25	72%	23.3	13.6
Total/Average 2018			0	0	0	121	121	121	100%	13.3	10.8
Total/Average 2019			1	4	11	106	121	122	99%	12.5	12.6
Total/Average 2021			47	5	21	49	75	122	61%	16.3	14.8

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

Figure 30. Mount Brown: Whitebark Pine Seedling Monitoring Plots, Plots, Planted in the Fall of 2018, 2019, 2020 and 2021.

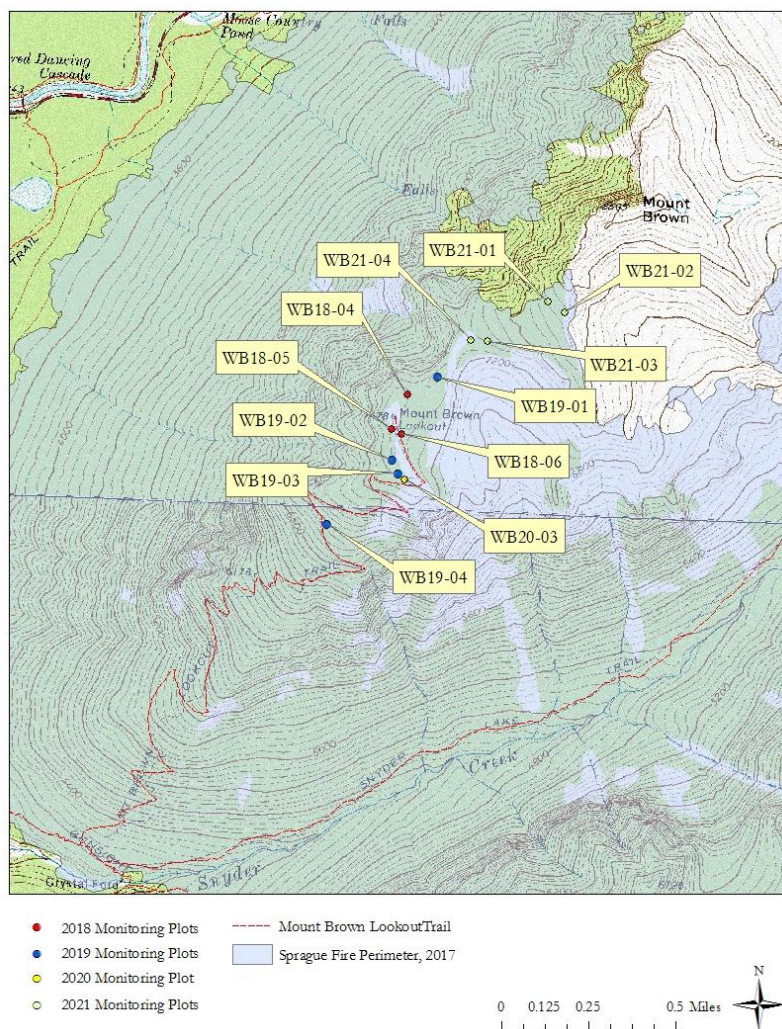


Figure 31. Sperry Chalet: Whitebark Pine Seedling Monitoring Plots, Planted in 2018.

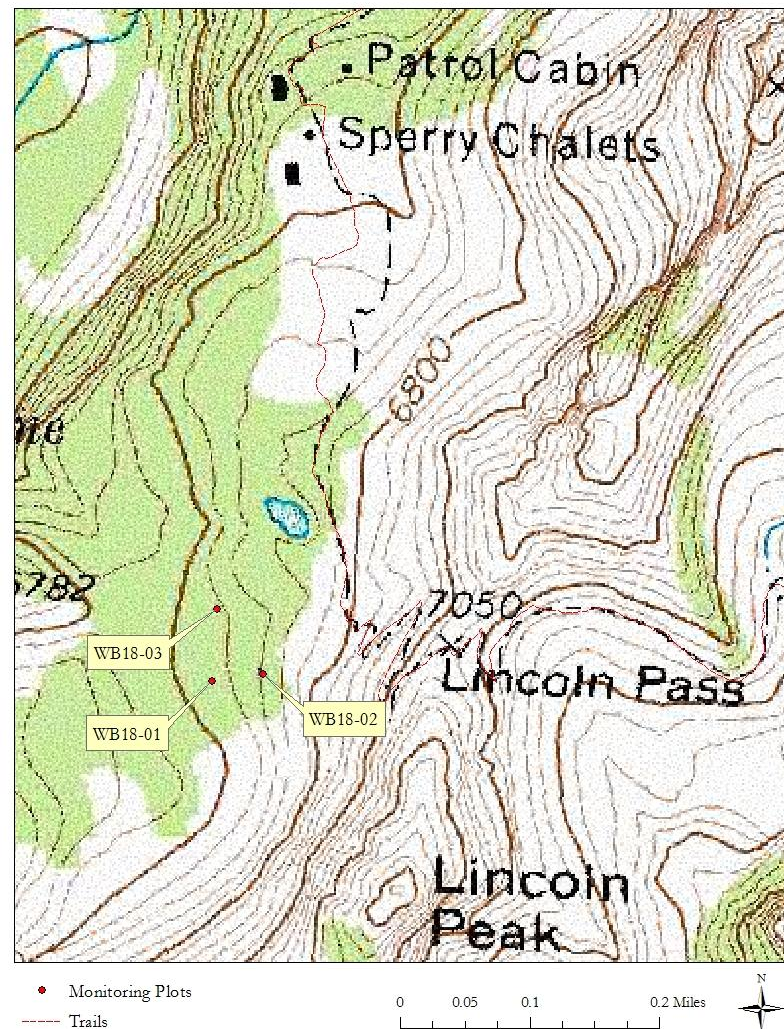


Table 31. Parkwide: Survival, Height and Width for Three-Year-Old Whitebark Pine Trees at All Monitoring Sites.

<i>Site</i>	<i>Year Planted</i>	<i>Season Planted</i>	<i>Year Monitored</i>	<i># of Trees Monitored</i>	<i># of Trees Survived</i>	<i>% Survival</i>	<i>Year 3</i>	
							<i>Height</i>	<i>Width</i>
Flattop Mtn. Fall 2002	2002	fall	2005	282	137	49%	*	*
Red Eagle - upper	2007	fall	2010	359	192	54%	15.9	17.6
Divide Creek - lower	2010	fall	2013	265	249	94%	12.4	14.5
Grinnell Picnic Area	2011	late summer	2014	104	42	40%	12.8	15.8
Cobalt Lake	2011	late summer	2014	108	11	10%	13.0	11.3
Divide Mountain	2012	fall	2015	226	134	59%	10.0	10.5
Firebrand (upper)	2013	spring	2016	209	169	81%	10.6	10.4
Firebrand (lower)	2013	fall	2016	387	236	61%	9.0	9.4
Numa	2013	fall	2016	179	156	87%	12.2	9.4
Divide Creek	2014	fall	2017	222	167	75%	14.6	14.6
Firebrand (lower)	2014	spring	2017	106	70	66%	12.9	13.4
Firebrand (upper)	2014	fall	2017	159	4	3%	9.3	10.0
Numa	2014	fall	2017	120	61	51%	12.8	10.1
Scenic Point (upper)	2014	spring	2017	189	100	53%	9.6	9.9
Spot	2014	spring	2017	36	12	33%	9.5	9.6
Whitetail	2014	fall	2017	152	47	31%	9.7	9.5
Numa	2015	fall	2018	10	66	15%	9.0	8.9
Scenic Point (upper)	2015	fall	2018	68	22	32%	10.6	10.2
Dead Horse Point (upper)	2016	spring	2019	54	23	43%	15.1	18.8
Goat Mountain Slope	2016	spring	2019	34	21	62%	17.3	18.1
Golden Staircase (high)	2016	spring	2019	59	42	71%	15.5	16.8
Otokomi (upper)	2016	spring	2019	65	55	85%	21.2	19.7
Otokomi (lower)	2016	fall	2019	101	76	75%	16.6	18.0
Mount Brown Lookout	2018	fall	2021	110	77	70%	18.3	16.7
Sperry Chalet	2018	fall	2021	122	75	61%	16.3	14.8
Average 3- year-old-trees				3726	2244	60%	12.6*	13*
Average spring only				752	492	65%	11.8**	13.1**
Average fall only				2762	1699	62%	11.4**	11.3**

* Weighted average

**Non-weighted average

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

iv. One-Year-old Plantings

a. Mount Brown

On September 28, 2020, 210 seedlings were planted near the Mount Brown Lookout, near the 2019 planting site (Figure 30), 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 monitoring 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. One year post-planting, survival was still high, at 91%, which is higher than the parkwide one-year survival average of 75% (Tables 32, 34). Seedlings did not grow at all in height, on average, but grew an average of 2 cm in width, which made them larger than average for all first year plantings tracked in the park.

Table 32. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2020.

<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
2020	0	0	0	0	44	44	100%	11.1	10.1
2021	4	1	4	38	43	47	91%	11.1	12.1

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

b. 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 32). 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 stands an unburned island containing several live and dead whitebark pine trees. Regenerating whitebark pine seedlings were also observed nearby.

It is uncertain from 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 determine over time whether post-fire effects are still beneficial to seedling success five years post-fire.

One year after planting, survival remained very high, at 97% (Table 33). As is often seen in Glacier, seedlings shrunk, on average, the year after planting. This is often because longer, nursery-grown needles are shed, and are replaced by shorter, more compact needles in the field. Seedlings were almost 1.5 cm shorter and 1 cm less wide one year post-planting (Table 33).

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

<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
2020	0	0	1	66	67	67	100%	12.9	13.1
2021	2	16	4	45	65	67	97%	11.5	12.2

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

Figure 32. Otokomi Knob Whitebark Pine Seedling Monitoring Plots, Planted in 2020.

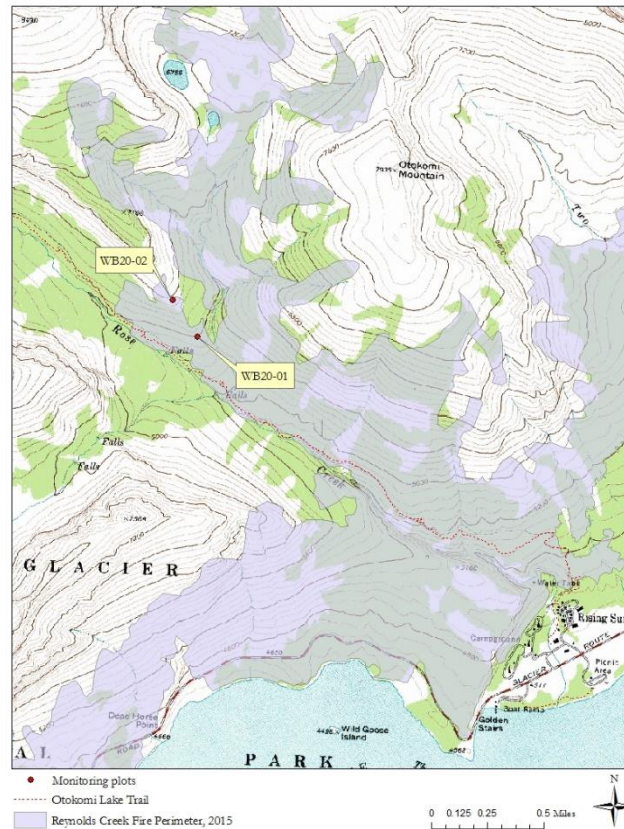


Table 34. Parkwide: Survival, Average Height and Width of all Whitebark Pine Seedlings Planted in the Park, One Year After Planting.

Site	Year Planted	Season Planted	Year Monitored	% Survival		Year 1	
						Height	Width
Flattop Mtn. Spring 2001	2001	spring	2002	43%		*	*
Red Eagle - upper	2007	fall	2008	77%		8.96	9.72
Red Eagle - lower	2007	fall	2008	90%		8.79	8.82
Divide Creek - lower	2010	fall	2011	95%		9.83	10.96
Grinnell Picnic Area	2011	late summer	2012	48%		10.52	11.84
Cobalt Lake	2011	late summer	2012	31%		10.15	12.00
Firebrand - upper 2013	2013	spring	2014	93%		8.82	8.31
Firebrand - lower 2013	2013	fall	2014	95%		7.96	8.05
Numa 2013	2013	fall	2014	99%		9.11	9.55
Spot	2014	spring	2015	75%		9.04	8.59
Firebrand - lower 2014	2014	spring	2015	91%		8.44	8.86
Scenic Point 2014	2014	spring	2015	77%		8.97	9.17
Numa 2014	2014	fall	2015	65%		11.19	9.23
Divide Creek - upper	2014	fall	2015	87%		10.4	9.69
Firebrand - upper 2014	2014	fall	2015	30%		7.36	8.89
Whitecalf	2014	fall	2015	62%		9.39	9.55
Numa 2015	2015	fall	2016	86%		11.82	11.39
Scenic Point 2015	2015	fall	2016	97%		8.71	12.29
Average 1-year-old-trees				75%		9.38	9.82

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

v. New Plantings
a. Mount Brown

On September 21, 2021, 500 whitebark pine seedlings were planted on the slope to Mount Brown Peak, past the Lookout (Figure 30). This planting took place near the edge of the burn perimeter of the Sprague Fire of 2017.

Two monitoring plots were installed the day after planting, containing 156 trees, capturing 31% of the planted seedlings. Planting conditions were favorable, since there were a few inches of snow accumulation from the day before. The soil was very moist, and did not require watering, but some trees were watered in anyway. The rest of September and through mid-October was warm and dry.

Parent trees for plots WB21-01, -03 and -04 came from Rising Wolf Plus Tree 07-39. Parent trees for plot WB21-01 came from Scenic Point Plus Tree 10-09.

At the time of planting, all trees were rated a 5 (good). Seedlings averaged 12.9 cm in height and 12.3 cm in width (Table 35). Plots are scheduled for first year monitoring in 2022.

Table 35. Mount Brown: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2021.

<i>Year</i>	<i># Survived</i>	<i># of Trees Monitored</i>	<i>% Survival</i>	<i>Average Height</i>	<i>Average Width</i>
2021	156	156	100%	12.9	12.3

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

b. Bench Above Two Medicine Campground

On September 23, 2021, 135 whitebark pine seedlings were planted on a bench above the Two Medicine Campground (Figure 33). This planting did not take place in a burned area and is only one of a handful of sites that whitebark pine has been planted outside of a burn perimeter.

Two monitoring plots were installed the same day as planting, containing 74 trees, capturing 55% of the planting. Conditions were favorable, since there was a day of rain prior to planting, but the rest of September and through mid-October was warm and dry. Parent trees for plot WB21-05 came from Scenic Point. The parent trees for plot WB21-06 was Rising Wolf Plus Tree 07-39. These seedlings were grown by Glacier personnel in the Columbia Falls Nursery the previous winter.

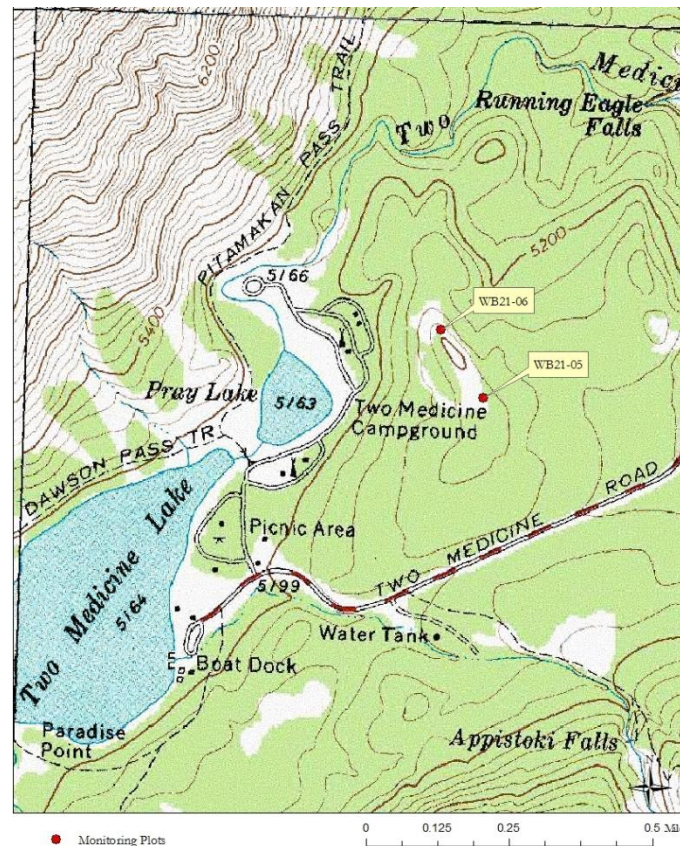
At the time of planting, 71 trees were rated 5 (good), and three trees were rated 4 (fair). Seedlings averaged 18.6 cm in height and 7.9 cm in width (Table 36). Plots are scheduled for first year monitoring in 2022.

Table 36. Knob Above Two Medicine Campground: Survival, Height and Width of Planted Whitebark Pine Seedlings, Planted in Fall of 2021.

<i>Year Monitored</i>	<i>Dead/ Missing</i>	<i>Almost Dead</i>	<i>Fair</i>	<i>Good</i>	<i>Number Survived</i>	<i>Total # Trees Mon.</i>	<i>% Survival</i>	<i>Height</i>	<i>Width</i>
2021	0	0	3	71	74	74	100%	8.6	7.9

S:\VegUnit\Whitebark & Limber Pine\Whitebark and Limber Pine report tables.xls (Above Two Med CG tab)

Figure 33. Two Medicine Bench Above Campground: Whitebark Pine Seedling Monitoring Plots, Planted in 2020.



c. Other small plantings in 2020

Whitebark pine seedlings were planted at a few other sites in small numbers, including 15 trees at Reuter Ridge, and several small memorial tree plantings. No monitoring plots were installed at these sites, due to the small planting numbers.

D. Future Monitoring

In 2022, six total limber pine planting sites are scheduled for monitoring. One 20-year-old site, Firebrand Pass Trail (with only one surviving tree) is scheduled to be revisited (Table 37). Five 10-year-old sites are also due for monitoring: Cutbank, Apikuni Flats, Rising Sun Campground, Scenic Point, and Many Glacier Well area. Since these monitoring plots are in the age range associated with the first detection of blister rust, it is especially important to look for evidence of infection at these sites. Blister rust has not yet been detected in planted limber pines in Glacier National Park.

Five total Whitebark pine sites are scheduled for monitoring. The Dutch Creek planting, which was originally accessed by helicopter after the Moose Fire of 2001, was not monitored at 20 years in 2021, but if time allows, it will be monitored in 2022. One 15-year-old whitebark pine site, Red Eagle, and one 10-year-old site, Divide Mountain, are scheduled for monitoring. Monitoring plots planted in 2019 and 2021 at Mount Brown Lookout are also scheduled for monitoring, at three years, and one year post-planting. Also at one year post-planting, the bench above Two Medicine Campground is also scheduled for monitoring in 2022.

In 2022, if climate cooperates, plans are to plant 500 whitebark pine seedlings and 300 limber pine seedlings. Monitoring plots should be installed at planting areas to capture a targeted 20% of seedlings.

Table 37: 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	2021	2022	2023	2024	2025	2026	2027
DC01-01 to -04	Whitebark pine	Dutch Creek	2001	X (year 20)	X (year 21)				X (year 25)	
GP00-01 to -07 (-05)	Whitebark pine	Grinnell Point	2000					X (year 25)		
FT01-01 to -27	Whitebark pine	Flattop	2001	X (year 20)					X (year 25)	
FT02-01 to -11	Whitebark pine	Flattop	2002	X (year 19)					X (year 24)	
LP02-01 to -25	Limber pine	Various	2002							
LP02-05	Limber pine	Many Glacier Hotel Slope	2002							
LP02-22	Limber pine	Sun Point	2002							
LP02-24	Limber pine	Firebrand Pass Trail	2002		X (year 20) 1 TREE LEFT					X (year 25) 1 TREE LEFT
LP03-01	Limber pine	Two Med Camp Store	2003			X (year 20)				
LP04-01 to -05	Limber pine	Baring Creek	2004				X (year 20)? All dead or missing 1 year			
LP04-06 to -07	Limber pine	Many Glacier Hotel Slope	2004				X (year 20)			
LP04-08	Limber pine	Sun Point	2004							
LP04-09	Limber pine	Sun Point	2004				X (year 20)? 1 missing tree left			
LP04-10	Limber pine	Dead Horse Point	2004							
LP04-11	Limber pine	Dead Horse Point	2004							
LP05-01 to -06	Limber pine	Scenic Point	2005					X (year 20)		
LP06-02	Limber pine	Baring Creek	2006	X (year 15)					X (year 20)	
LP06-01 & -03	Limber pine	Baring Creek	2006							
LP06-04	Limber pine	Dead Horse Point	2006							
WB06-01 to -02	Whitebark pine	Caper Peak (seeds + trees)	2006	X (year 15)					X (year 20) Seedlings only	
WB07-01 to -07 (-08 & -09)	Whitebark pine	Red Eagle (trees)	2007		X (year 15)					X (year 20)
WBS07-04 & -05	Whitebark pine	Red Eagle (seeds)	2007		X (year 15)					X (year 20)
WBS07-01 to -03	Whitebark pine	Siyeh Bend (seeds)	2007							
WB10-01 to -05	Whitebark pine	Hole-in-the-Wall	2010					X (year 15)		
WB10-06 to -10	Whitebark pine	Divide Creek lower	2010					X (year 15)		
GPA-WB-11-01 to -02	Whitebark pine	Grinnell Picnic Area	2011	X (year 10)					X (year 15)	
CL-WB-11-01 to -03	Whitebark pine	Cobalt Lake	2011	X (year 10)					X (year 15)	
WB12-01 to -04	Whitebark pine	Divide Mountain	2012		X (year 10)					X (year 15)
LP12-01 to -02	Limber pine	Cutbank	2012		X (year 10)					X (year 15)
LP12-03 and -11	Limber pine	Apikuni Flats	2012		X (year 10)					X (year 15)
LP12-04 to -05	Limber pine	Rising Sun CG	2012		X (year 10)					X (year 15)
LP12-06 to -09	Limber pine	Scenic Point	2012		X (year 10)					X (year 15)
LP12-10	Limber pine	Many Glacier Well Area	2012		X (year 10)					X (year 15)
WB13-01 to -04	Whitebark pine	Firebrand Pass upper (spring)	2013			X (year 10)				
WB13-08 to -12	Whitebark pine	Firebrand Pass lower (fall)	2013			X (year 10)				
WB13-05 to -07	Whitebark pine	Numa Ridge	2013			X (year 10)				
LP13-01 to -07	Limber pine	Spot Mtn. (spring & fall)	2013			X (year 10)				
WB14-01	Whitebark pine	Spot Mtn. (spring)	2014				X (year 10)			
WB14-02 to -03	Whitebark pine	Firebrand Pass lower (spring)	2014				X (year 10)			
WB14-04 to -05	Whitebark pine	Scenic Point upper (spring)	2014				X (year 10)			
WB14-06, -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 10)		
WB15-03 to -04	Whitebark pine	Numa Ridge (fall)	2015					X (year 10)		
LP16-01	Limber pine	Dead Horse Point (lower)	2016	X (year 5)					X (year 10)	
LP16-02 to -03	Limber pine	Turnout #6, GTSR, St. Mary	2016	X (year 5)					X (year 10)	
LP16-04 to -05	Limber pine	Golden Staircase (lower)	2016	X (year 5)					X (year 10)	
LP16-06	Limber pine	Dead Horse Point (upper)	2016	X (year 5)					X (year 10)	
LP16-07	Limber pine	Otokomi (lower bench)	2016	X (year 5)					X (year 10)	
LP16-08	Limber pine	Baring Creek	2016	X (year 5)					X (year 10)	
LP16-09 to -10	Limber pine	Lost Lake	2016	X (year 5)					X (year 10)	
WB16-01 to -02	Whitebark pine	Dead Horse Point (upper)	2016	X (year 5)					X (year 10)	
WB16-03	Whitebark pine	Otokomi (upper)	2016	X (year 5)					X (year 10)	
WB16-04	Whitebark pine	Goat Mountain Slope	2016	X (year 5)					X (year 10)	
WB16-05 to -06	Whitebark pine	Golden Staircase (high)	2016	X (year 5)					X (year 10)	
WB16-07 to -09	Whitebark pine	Otokomi (lower slope)	2016	X (year 5)					X (year 10)	
WB18-01 to -03	Whitebark pine	Sperry Chalet	2108	X (year 3)		X (year 5)				
WB18-04 to -06	Whitebark pine	Mt. Brown Lookout	2108	X (year 3)		X (year 5)				
WB19-01 to -04	Whitebark pine	Mt. Brown Lookout	2019		X (year 3)	X (year 4)		X (year 6)		
WB20-01 to -02	Whitebark pine	Otokomi Knob	2020	X (year 1)		X (year 3)		X (year 5)		
WB20-03	Whitebark pine	Mt. Brown Lookout	2020	X (year 1)		X (year 3)		X (year 5)		
WB21-01 to -04	Whitebark pine	Mt. Brown Lookout	2021	X (year 0)	X (year 1)		X (year 3)		X (year 5)	
WB21-05 & -06	Whitebark pine	Above Two Medicine CG	2021	X (year 0)	X (year 1)		X (year 3)		X (year 5)	

VII. WHITEBARK AND LIMBER PINE PLUS TREE CONE MONITORING

A. INTRODUCTION

Whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*) populations have declined dramatically in Glacier National Park, largely due to the introduction of a non-native fungus, white pine blister rust (*Cronartium ribicola*). 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 take 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. 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 138 whitebark pine trees that are being monitored at 17 different locations (Figure 34; Table 38). Cone information was collected on 129 trees in 2021. Two trees were removed from the pool and not monitored due to poor health (Otokomi Lake-1 and Preston Park-1). Seven other trees were not monitored due to logistics or deep snow at the site. Eleven trees were added to the pool this year. A new site for whitebark pine plus trees was discovered at Haystack Butte, adjacent to the Highline Trail on the west side of the Continental Divide. Seven trees were added to the pool here; cone counts may have been underestimated since these trees were not discovered until August when cones had already been eaten. Three trees were added at Cobalt Lake and one tree was added at Two Medicine.

Currently, there are 33 limber pine trees at 8 different locations present in the plus tree monitoring pool (Figure 34; Table 39). No trees were added or removed from the pool. Cone information was collected on all trees in 2021.

The primary data taken on whitebark and limber pine plus trees in 2021 were cone counts. This is similar to data collected from 2012 through 2020. A renewed attempt is being made to collect more detailed data on blister rust status, blister rust location on the tree, flagging, bark chewing, swelling, pollen cones, and Clark’s Nutcracker observations (auditory, cone foraging, seed caching, and 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 38. Numbers of Whitebark Pine Plus Trees Monitored from 2007-2021.

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	
2021	11 (7 HB; 1 CL; 1 TM)	2 (OL; PP)	138	129	9	

**6 of these were potential plus trees

*** potential trees

CL = Cobalt Lake

FB = Firebrand Pass Tr.

GG = Grinnell Glacier Tr.

HB = Haystack Butte

KM = Kupunkamint Mtn.

LR = Lee Ridge

OL = Otokomi Lake

OM = Old Man Lake Tr.

PP = Preston Park

RW = Rising Wolf

SB = Siyeh Bend

SP = Scenic Point

TD = Triple Divide Tr.

TM = Two Medicine

WC = White Calf

Table 39. Numbers of Limber Pine Plus Trees Monitored from 2007-2021.

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		0	4	2	2
2012	1 (WC)	0	5	4	1
2013		0	5	4	1
2014		0	5	3	2
2015	18 (8 MG; 6 Spot; 3 KM; 1 SP)	1 (DHP)	22	22	
2016	2 (1 WC; 1 KM)	0	24	23	1
2017		0	24	23	1
2018	2 (OM)	0	24	23	1
2019		0	26		
2020	7 (RS)	0	33	30	3
2021		0	33	33	0

DHP = Dead Horse Point

MG = Many Glacier

RS= Rising Sun

Spot = Spot Mt.

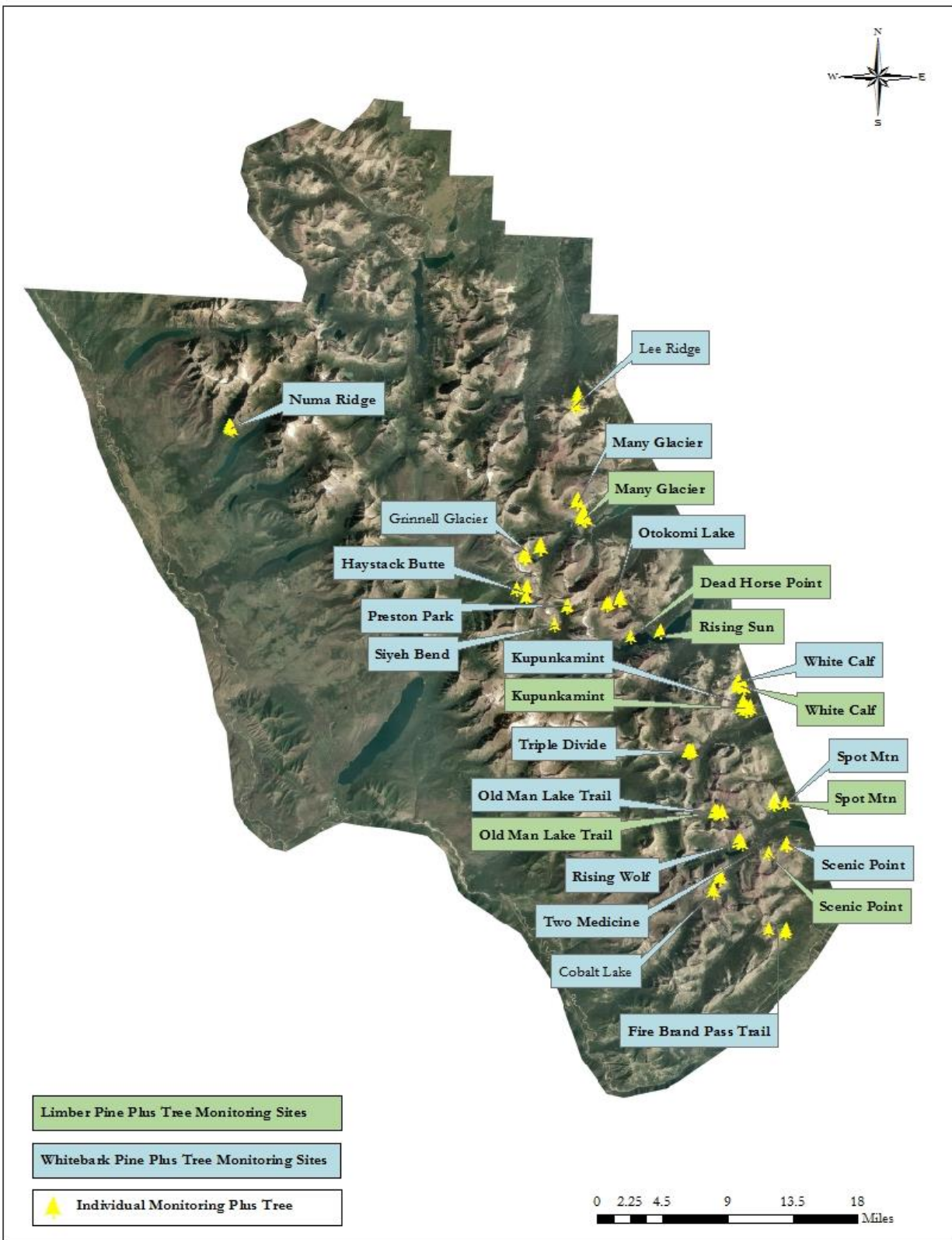
WC = Whitecalf

OM = Old Man Lake Trail

SP = Scenic Point

KM = Kupunkamint Mtn.

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



C. RESULTS

For whitebark pine, 129 of the existing 138 plus trees were monitored for cone production in 2021. Overall, the number of trees that produced cones in 2021 was 91 percent, well above the 15-year average of 77 percent (Figure 35; Table 41). In 2021, the average number of cones was 36 per tree. In comparison to data collected since 2007, this was also well above the average of 25 cones per tree. After a banner whitebark pine cone year in 2018 and then a dramatic drop in 2019, 2020 rebounded to average rates. In 2021, this upward trend has continued. The revegetation crew reported that cone size, of those caged and collected, appeared to be on the smaller side this year. It will be interesting to see if this cone size correlates to seed viability at Coeur d'Alene Nursery.

Cones were present in 17 of the 17 whitebark pine stands monitored. The average number of cones per tree, across stands, ranged from 8 cones to 83 cones (Table 40). Within a stand, cone production varied from tree to tree. Some trees within a stand produced no cones while others in the same stand produced more than 100 cones. In the past several years, trees at Kupunkamint Mountain have been the most reliable in terms of a good cone crop, and again averaged the highest average number of cones per tree in 2021, at 83 cones (Table 40). Trees at White Calf and Preston Park had good cone production, with an average of 46 cones and 42 cones, respectively. Rising Wolf was on the low end of the spectrum, with an average of 8 cones per tree.

For limber pine, 33 out of 33 trees in the pool were monitored in 2021. Twenty-eight trees (85%) produced cones (Figure 36; Table 43). Limber cone production, averaging 70 cones per tree, was just above the 15-year average (66 cones per tree). Whitecalf averaged the highest number of cones per tree, at 136. In 2020, the seven trees at Rising Sun averaged 70 cones per tree. This year, they averaged 19 cones per tree (Table 42).

Some individual trees had strong cone production, with nine trees having 100 or more cones. Two trees had 242 and 275 observed cones. Every tree that was monitored had some cones; 7-8 cones per tree was the low end of the range.

While 2018 was a mast year that was followed by a crash in 2019, the numbers have, collectively, been on the upswing. 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 fifteen 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 (Tables 40, 41, 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 15 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 two to four 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 in the plus tree pool, 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 (Table 43, Figure 36).

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 five years, GNP has added 27 trees to the whitebark pine plus tree monitoring pool and nine trees to the limber pine plus tree monitoring pool (Tables 38, 39). 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. As of March 2022, seven of Glacier's plus trees have been rated in the upper 25th percentile of all tested trees based on four resistance traits. Seed is being collected from these trees for gene conservation and the CCE Sow and Grow Project.

Also based on tree data from GNP and many other locations throughout Montana and the Pacific Northwest, the USFS is recommending that seed should only be collected from trees that have $\geq 20\%$ rust resistance (Maholovich pers. comm.). At least 11 of GNP's whitebark pine plus trees meet this criterion. While we are following this tree selection criterion for seed and scion collection for the current High Five seed program, GNP resource staff is also collecting seed from the remaining plus trees for operational use during mast years. As many of these trees are alive and appear relatively healthy, GNP will continue to protect all plus trees with Verbenone to prevent potential mountain pine beetle invasion.

Additional whitebark and limber pine trees are being added to the genetics study for more information on new five-needle pine stands in the park, as the required 1,800 seeds per tree are collected. On-going information from this study will continue to provide us with guidance for whitebark seed collection in the future and protection of our plus tree pool. As both physical tree and genetics monitoring continue, 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 to 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 2022 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 work on 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 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 40. Whitebark Pine Cone Production by Stand, 2021.

<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	2021	6	6	5	91	15.1
Firebrand Pass Trail	2021	4	4	4	96	24.0
Grinnell Glacier Trail	2021	5	2	1	25	12.5
Haystack Butte	2021	7	7	6	234	33.4
Kupunkamint	2021	13	13	11	1074	82.6
Lee Ridge	2021	2	0			
Numa Lookout	2021	12	12	11	185	15.4
Old Man Lake Trail	2021	15	15	15	471	31.4
Otokomi Lake	2021	7	6	5	227	37.8
Preston Park	2021	24	23	22	974	42.3
Rising Wolf	2021	5	5	2	38	7.6
Scenic Point	2021	13	12	12	406	33.8
Siyeh Bend	2021	3	3	3	49	16.3
Spot Mountain	2021	1	1	1	35	35.0
Triple Divide	2021	5	5	5	163	32.6
Two Medicine	2021	5	5	5	117	23.4
White Calf	2021	11	10	10	461	46.1
TOTAL		138	129	118	4646	36

Table 41. Whitebark Pine Cone Production by Year, 2007-2021.

<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%
2021	138	129	118	4646	36	91%

Figure 35. Trends in Whitebark Pine Cone Production 2007-2021.

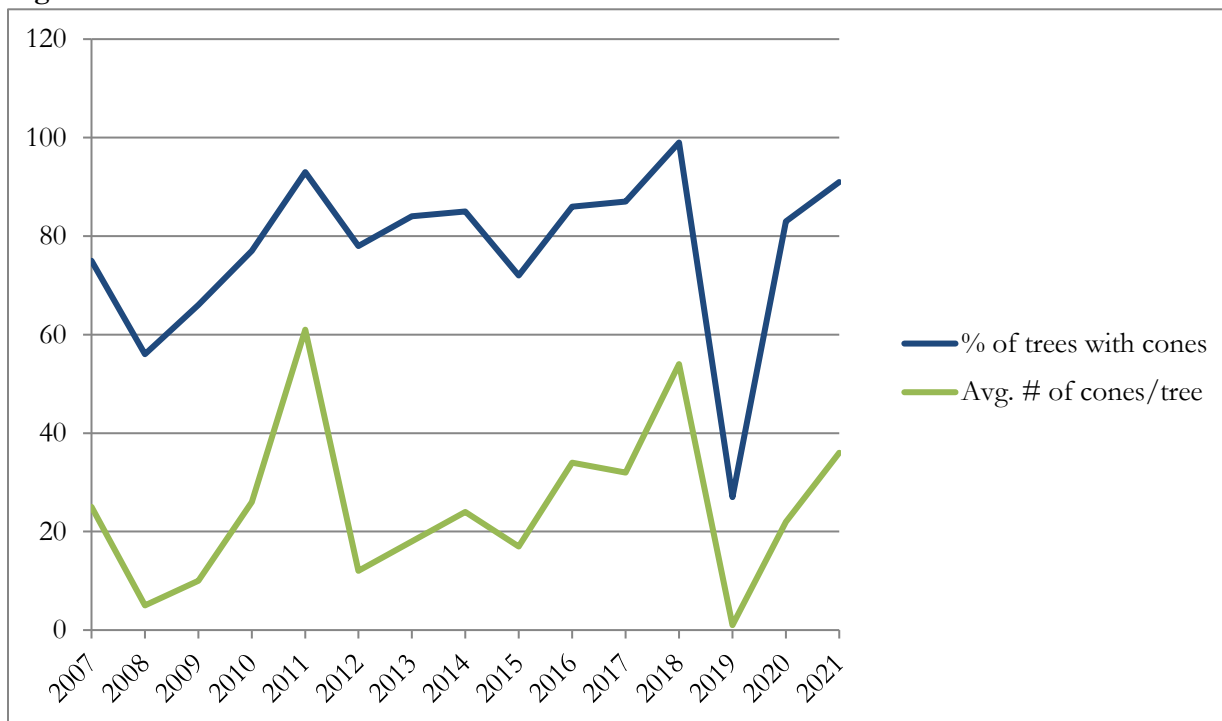


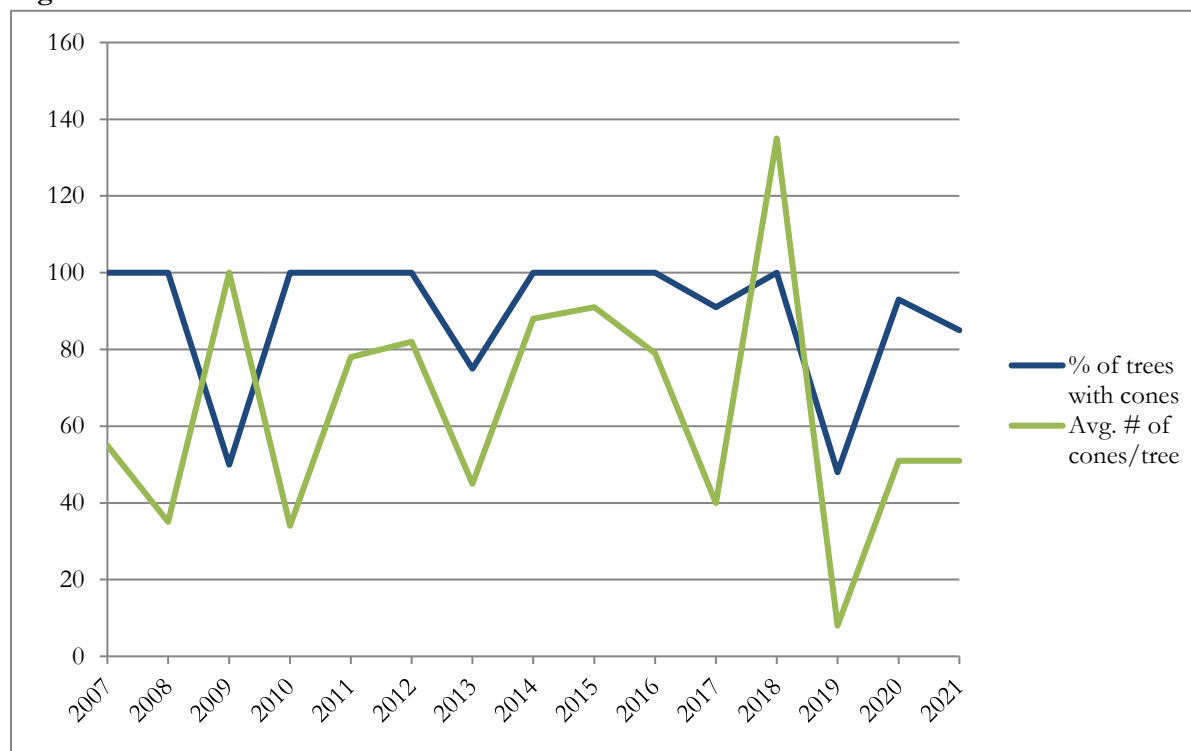
Table 42. Limber Pine Cone Production by Stand, 2021.

<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	2021	1	1	1	51	51
Scenic Point	2021	2	2	2	62	31
White Calf	2021	3	3	0	474	158
Spot	2021	5	5	5	374	75
Many Glacier	2021	8	8	8	552	69
Kupunkamint	2021	4	4	4	544	136
Old Man	2021	3	3	1	108	36
Rising Sun	2021	7	7	7	134	19
TOTAL		33	33	28	2299	70

Table 43. Limber Pine Cone Production by Year, 2007-2021.

<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
2021	33	33	28	85%	2299	70

Figure 36. Trends in Limber Pine Cone Production 2007-2021.



VIII. 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):Trees

Abies lasiocarpa
Picea engelmannii
Pinus contorta

Shrubs

Alnus viridis
Arctostaphylos uva-ursi
Menziesia ferruginea
Paxistima myrsinites
Ribes lacustre
Rubus parviflorus
Sorbus scopulina
Spiraea betulifolia
*Vaccinium membranaceum**
*Vaccinium myrtillus**
*Vaccinium scoparium**

Forbs/Ferns

Arnica cordifolia/ latifolia
Erigeron peregrinus
*Erythronium grandiflorum**
Eucephalus engelmannii
Luzula glabrata var. hitchcockii
*Mitella breweri**
Pedicularis bracteosa
*Thalictrum occidentale**
Valeriana sitchensis
Veratrum viride
*Viola orbiculata**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri

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

Abies lasiocarpa
Larix occidentalis
Pinus contorta
Pseudotsuga menziesii

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Lonicera utahensis
Mahonia repens
Menziesia ferruginea (higher)
Paxistima myrsinites
Rosa woodsii
Rubus parviflorus
Shepherdia canadensis

Forbs/Ferns

Achillea millefolium
Arnica cordifolia
*Clintonia uniflora**
Eurybia conspicua
*Goodyera oblongifolia**
*Orthilia secunda**
*Thalictrum occidentale**
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex geyeri
Carex rossii
Festuca occidentalis

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

Pinus ponderosa

Shrubs

Arctostaphylos uva-ursi
Dasiphora floribunda
Juniperus communis
*Vaccinium caespitosum**

Forbs/Ferns

Antennaria rosea
Heuchera cylindrica
Penstemon confertus
Potentilla gracilis

Grasses

Festuca campestris
Danthonia intermedia
Pseudoroegneria spicata

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

Larix occidentalis
Pinus contorta
Pseudotsuga menziesii

Subcanopy:

Abies lasiocarpa
Pseudotsuga menziesii
Thuja plicata
Tsuga heterophylla

Shrubs

Acer glabrum
Amelanchier alnifolia
*Linnaea borealis**
Mahonia repens
Rosa woodsii
Rubus parviflorus
Spiraea betulifolia
Symphoricarpos albus
*Vaccinium caespitosum**
*Vaccinium membranaceum**
*Vaccinium myrtillus**

Forbs/Ferns

Arnica cordifolia
Chamerion angustifolium
*Chimaphila umbellata**
*Clintonia uniflora**
Eurybia conspicua
Pteridium aquilinum
Symphytotrichum laeve var. laeve
*Xerophyllum tenax**

Grasses

Calamagrostis rubescens
Carex concinnoides
Carex geyeri
Oryzopsis asperifolia

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 albiflorum</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.

IX. MONITORING SCHEDULE: 1992 - 2026

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)
- Bowman Lake Reveg (year 1)
- Two Dog Flats Weed/Reveg (year 0)
- GTSR – Phase XI: Lunch Creek (year 10) - discontinued
- GTSR – Phase VIIb: West tunnel to Avalanche (year 10) - discontinued
- GTSR – Phase XII: Siyeh Bend to Rising Sun (year 5) - discontinued

2022

- Two Dog Flats Weed/Reveg (year 1)
- Christian Damm/George Malansen Alpine Plots (Year 10)
- Two Dog Flats Weed/Reveg (year 1)
- Bowman Lake Reveg (year 2)

2023

- 303-C (St. Mary GTSR) - Level II, photomonitor (year 30)
- Two Dog Flats Weed/Reveg (year 2)
- Bowman Lake Reveg (year 3)

2024

- 303-D (Rising Sun GTSR) - Level III, photomonitor (year 30)
- Two Dog Flats Weed/Reveg (year 3)
- GLORIA monitoring (year 20)

- Apgar-Headquarters Bike Path – Level II (year 20)
- Camas Road Hydromulch – Level II (year 20)

2025

- Peter Lesica's tundra monitoring plots (year 35)
- Peter Lesica's wetland monitoring plots (year 20)

2026

- 303E (Logan Pass and Oberlin Bend) - Level IV, photomonitor (year 30)

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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