Cameron Peak Reforestation Group

Annual Monitoring Report (2023)

The Cameron Peak Reforestation Group (CPRG) formed in response to the Cameron Peak fire, the largest fire in Colorado history. It burned more than 200,000 acres in northern Colorado in 2020, and more than half of that area burned at high severity.

The CPRG works collaboratively to bring resources to help landowners recover and reforest following the Cameron Peak and High Park fires. This collaboration includes:

- Big Thompson Watershed Coalition
- Coalition for the Poudre River Watershed
- Colorado Forest Restoration Institute at Colorado State University
- Larimer County Conservation Corps
- The Nature Conservancy Colorado Chapter
- Trees, Water & People
- Wildlands Restoration Volunteers
- Tree nurseries

The CPRG collaborates to raise funding for purchasing trees, planning, and hiring tree-planting crews. We integrate the best-available science into planning and monitoring for an adaptive approach tounderstand where to focus our efforts, measure the impacts of our projects, and adjust our approach over time.

April 2024
The Nature Conservancy's Colorado Field Office
2424 Spruce Street Boulder, CO 80302.

Photo credit: The Nature Conservancy Colorado

INTRODUCTION

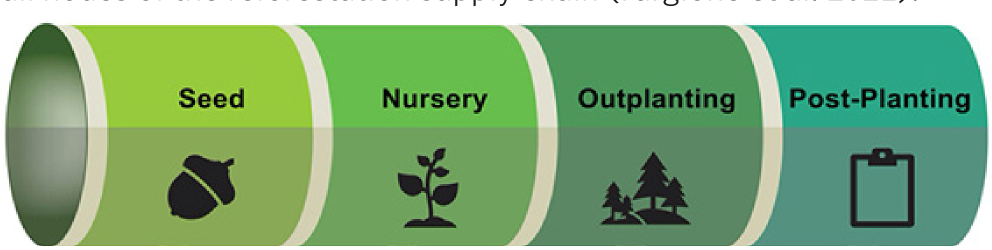
The Cameron Peak Reforestation Group ("CPRG"), a coalition of non-profits and local government actors, works collaboratively to reforest Larimer County burn scars with native conifers, including the Cameron Peak (2020) and High Park (2012) wildfires. Following these fires and in the absence of a planting, thousands of acres of low-elevation ponderosa pine forest are at risk of losing their native forest cover. The CPRG engages private landowners in ecological restoration of burned areas. Post-planting, the CPRG monitors seedling survival and growth to assess the impact of climate conditions and microsite selection on survival. Using this real-time feedback, the CPRG aims to adapt future planting projects to incorporate lessons learned and adjust practices to local weather, topographic and post-fire conditions.

Post-planting survival of ponderosa pine in burn scars varies widely across the dry forest types of the southwestern United States. Natural regeneration as well as the survival of outplanted seedlings are increasingly influenced by a long-term warming and drying trends (Davis et al. 2023). A study in Arizona reported survival of planted ponderosa pine seedlings varied from 0-70% with an average of 25% at year five following fire; these results are similar to recent work in New Mexico with a reported 20% survival rate at the end of year three (Ouzts et al. 2015, Marsh et al. 2022a). In contrast, a high-elevation site in northern Colorado at 8,300 feet reported a 61% survival rate for ponderosa pine at the end of the third growing season (Marshall et al. 2023). The development of reforestation plans to meet desired restoration goals, such as post-planting density and layout, is difficult given the wide range of reported seedling survival rates in Southwestern burn scars.

Many factors – climatic, topographic, and biotic -- influence seedling survival post-planting, some of which can be ameliorated by enhanced macro-site selection and micro-siting techniques to take advantage of cooler, wetter growing environments within a given site (North et al. 2019). Surface temperatures in a burn scar can be particularly hot, with little shade or moisture normally provided by vegetation (Marsh et al. 2022b). In addition, periodic drought has increased throughout the 21st century as compared to the 20th century (1985-1999 period) and further contributes to unfavorable growing conditions for seedling trees (Stevens-Rumann et al. 2018). The shallow, developing root systems are less able to survive prolonged exposure to high temperatures and water stress that adult trees can tolerate (Dobrowski et al. 2015). In the face of this underlying drying trend, planters can select sites based on aspect and the presence of shade objects, both of which are shown to increase rates of survival and growth (Crockett and Hurteau 2022, Marsh et al. 2023). To ameliorate prolonged exposure to high temperatures, recent work in Colorado has shown that seedlings planted on north aspects had a 37% greater survival and achieved greater seedling height than those on south aspects (Marshall et al. 2023). This same study found that selecting micro-sites on the north to northeast side of a shade object resulted in 20% greater likelihood of survival (Marshall et al. 2023). Other factors such as climate (e.g., years with above-average moisture), and site and soil productivity, are important to seedling survival but less easily manipulated (Rother and Veblen 2017, Stevens-Rumann et al. 2018).

Here we focus on outplanting survival and growth, but we recognize that every decision along the reforestation pipeline from seed to post-planting may further influence survivorship. Here we report on our approach to planting (Fig 1.).

Figure 1: To meet reforestation goals, we must increase the quality and quantity of production and operations along all nodes of the reforestation supply chain (Fargione et al. 2021).



SEED

We provided nurseries with local seed collected in 2019 during a mast seeding year (collected and planted in U.S. Forest Service seed zone 491, collected at 7,559 feet above sea level). The U.S. Forest Service defines geographic zones and seed transfer guidelines to limit the geographic and climatic distance that a given population moves. The CPRG uses the U.S. Forest Service seed zones and transfer guidelines for ponderosa pine.

NURSERY

We contracted professional nurseries to grow ponderosa pine seedlings in 10 cm3 containers. Nurseries hardened off seedlings prior to outplanting.

OUTPLANTING

To help these new seedlings adapt to Colorado's current and future climate, we made three critical adjustments to traditional tree planting: (i) targeting planting sites in areas with no surviving conifers and cone-bearing trees ("prioritization"), (ii) selecting planting sites with current and future predicted climatic suitability ("climate suitability"), and (iii) planting seedlings at low density and in small tree islands to allow for future management with prescribed fire and to safeguard against future damage from wildfire ("increased resilience"). We explain these three approaches below.

Prioritization

We predicted the location of surviving trees, also termed conifer refugia, using remotely sensed images and targeted our work to area without surviving conifers and 150 feet or more from surviving trees (Chambers et al. 2016, Chapman et al. 2020). These seed-source limited areas are unlikely to recover without planting.

Climate Suitability

We use downscaled climate models to select climatically suitable niches for reforestation. Specifically, we used climate water deficit, an indicator of drought-stress that measures the difference between potential and actual evapotranspiration, to identify sites with lower climate water deficit, which is strongly associated with successful ponderosa pine regeneration. We used spatially explicit maps of 30-year average climate water deficit (1981-2010) and predicted climate water deficit over the next century, using averaged downscaled climate model RCP 4.5, a moderate emissions scenario, and RCP 8.5, a high-emissions scenario, to select sites with the lowest climate-water deficit (Figure 1). This research and mapping products developed by Kyle Rodman (2020) found that climate water deficit below 400 predicts high regeneration potential for ponderosa pine, while average regeneration potential is found in areas with a climate water deficit centered on 600.

Planting Design for Increased Resilience

Trained volunteers and local conservation corps planted seedlings at variable densities within planting units varying from 1-44 acres in size. Desired density is 150-175 trees/acre, but this density depends on site conditions and can be much lower. We encourage planters to plant seedlings on the north to northeast side of shade objects (such as dead trees, stumps, or rocks) and to create micro-topographic depressions to catch run-off during rainfall events using excess backfill to create a small ring around the tree. In addition, we instruct planters to avoid areas with already established seedlings, also known as natural regeneration. A lack of shade objects or existing natural regeneration impact planting density. We outplanted in both the spring and fall planting windows.

The strategy driving decisions surrounding unit size, density and clustered planting across the larger landscape are made site-by-site and in close collaboration with landowners, but also include the development of small founder stands in areas distant from an existing seed source (North et al. 2019).

POST-PLANTING

With limited understanding of survival rates, we developed a simple framework to monitor success of planting done by the CPRG in the Cameron Peak and High Park burn scars. The CPRG installed variable-length transects in planting units with more than 400 trees to measure survivorship and growth of planted ponderosa pine seedlings. We install new monitoring transects twice annually following each planting campaign.

Transect locations are randomly selected within the planting unit to minimize bias. At the starting point, we mark the first 25 seedlings along the transect within 5 meters on either side of the transect for monitoring. We monitor survival at the end of the growing season during year 0, 1, 2, and 3. Year 0 monitoring occurs 1-4 weeks post-planting at the time of transect installation. During transect installation, we measure macro- and micro-site characteristics: aspect, presence of a shade object (which would shade the base of the seedling during the hottest portion of the day), and location in/out of a micro-topographic depression. During installation, we also establish survivorship or mortality and seedling size (as described below). After installation, regular monitoring occurs at the end of each growing season. For example, year 1 monitoring occurs at the end of the first growing season in late fall, such that for fall plantings, it is measured 12 months after planting, while for spring planting is measured ~6 months post-planting. During each monitoring campaign, we assess survivorship or mortality and seedling growth, measured as height to apical bud and diameter at root collar.

As of December 2023, the CPRG has planted 434 acres on private land in the Cameron Peak and High Park burn scars with native ponderosa pine seedlings during spring and fall planting windows (Table 1). The CPRG planted seedlings between 6,669 - 8,916 feet. The CPRG installed 12 transects and monitored 300 seedlings. Because planting occurred over multiple years, we analyze first growing season growth and survival data and include notes where second-year data exists.

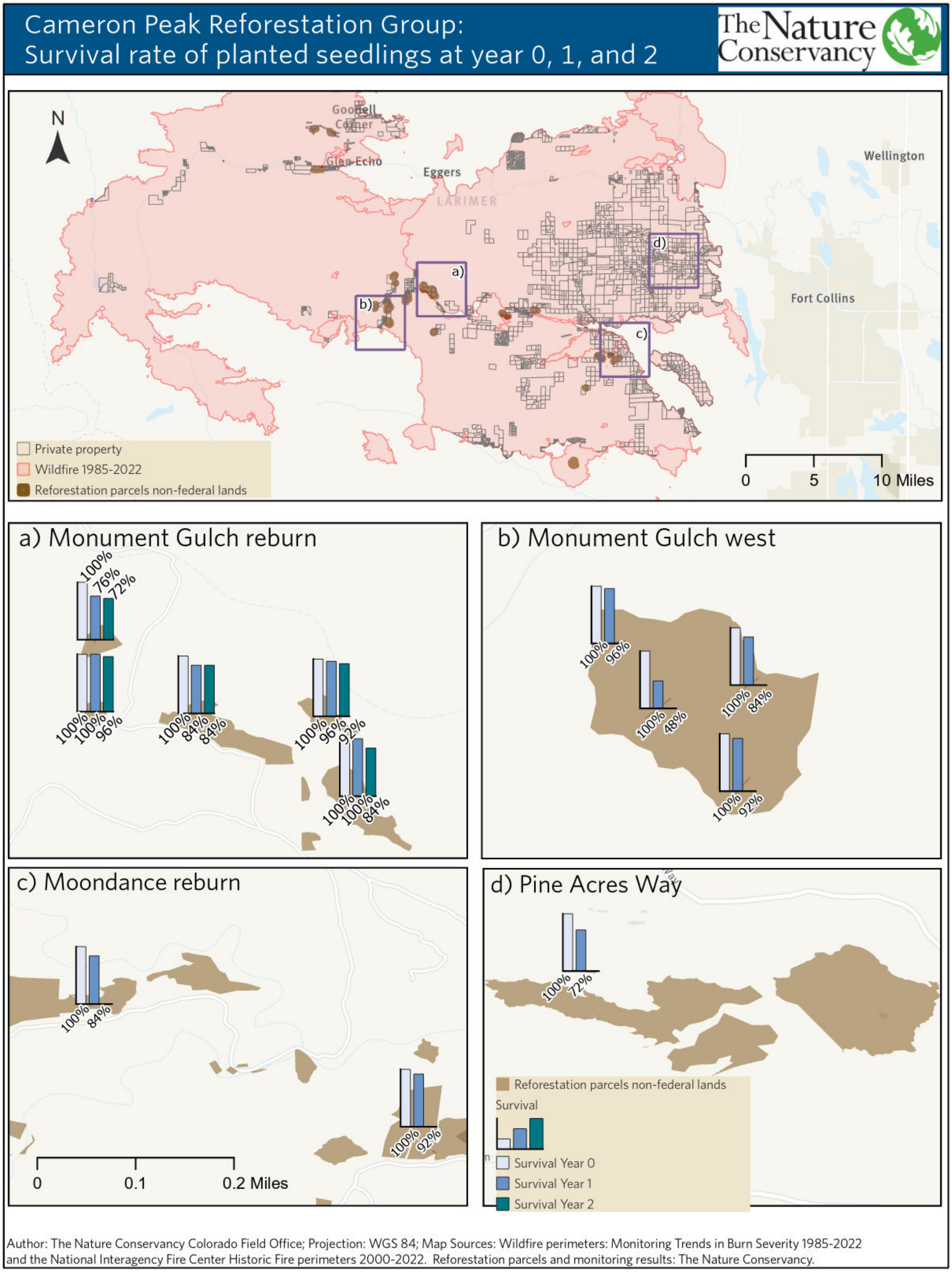
Table 1: The Cameron Peak Reforestation Group has planted a total of 434 acres on private land, gaining knowledge and momentum since its work initiated in 2021.

Year	Acres Planted
2021	98
2022	132
2023	204
Total	434

RESULTS

Survival is 84% after the first growing season across 12 transects (range: 48-100%; Figure 1). Anecdotal observations are that survival is lower on sites with low pre-fire productivity, evidenced by short, small diameter trees and/or rocky soils.

Figure 1: Map of survival by year and plot. Survival after two growing seasons is available at Monument Gulch reburn and reported below but are not otherwise analyzed as part of this report.



The difference in height and diameter reflects increases and decreases due to dieback and moose and elk trampling of surviving seedlings (Figure 2 and 3). Dead seedlings have been removed from the data set.

Figure 2: A series of boxplots shows the difference in height after first growing season measured from ground to apical bud demonstrates growth and dieback due to browse and moisture stress. a) the difference in height of all surviving individuals (n=256) with a mean of 23.46 mm; b) height increase only (n=211) with a mean of 32.06 mm; and c) height decrease only (n=45) with a mean of -16.88 mm.

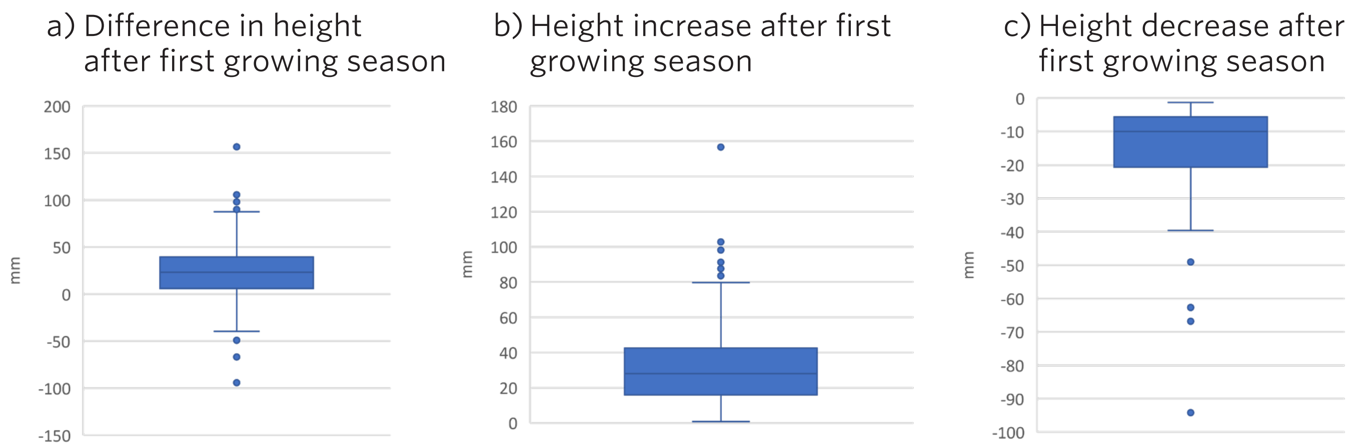
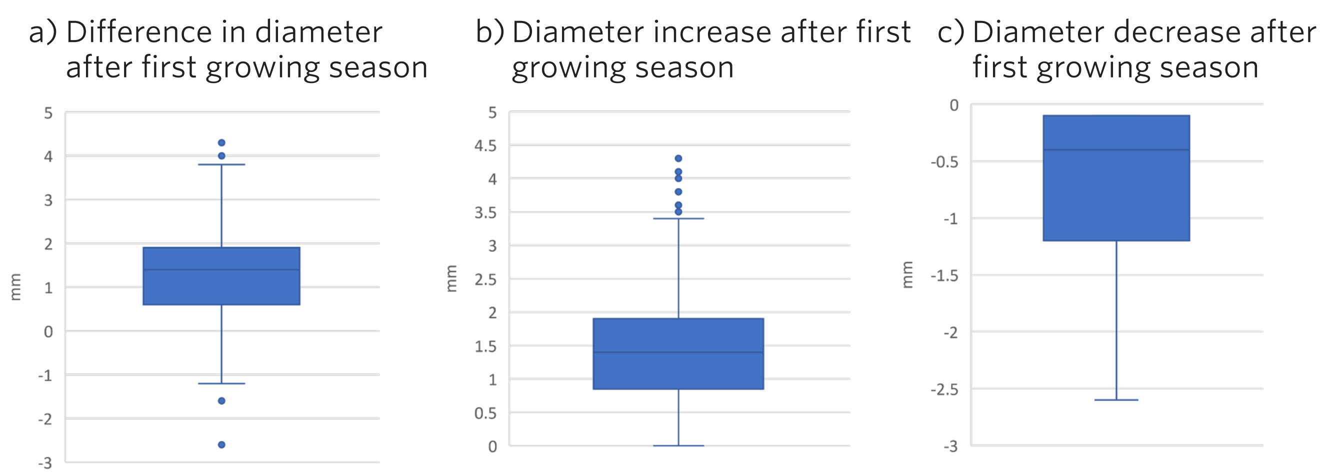


Figure 3: A series of boxplot shows the difference in diameter after first growing season as measured at root collar and demonstrates total difference in growth, growth only, and decreases only. a) the difference in diameter of all surviving individuals (n=256) with a mean of 1.33 mm; b) diameter growth (n=237) with a mean of 1.49 mm; and c) reduction in diameter (n=19) with a mean of -0.69 mm.



We used a binomial logistic regression with no random effects to examine if aspect, presence of a shade object, location in a topographic depression, or site (all categorical variables) predict survival at the end of the first growing season. We found that the interaction between shade and aspect is marginally significant (0.056). This potentially suggests that seedlings planted in a north-facing slope under shade have a higher probability of survival compared to the ones that did not (Figure 4); more data are needed to corroborate this effect (Table 2). Shade could have an effect on survival (0.088), evidenced by one site where shade had a highly significant effect on survival of trees planted there (PAG4, 0.005).

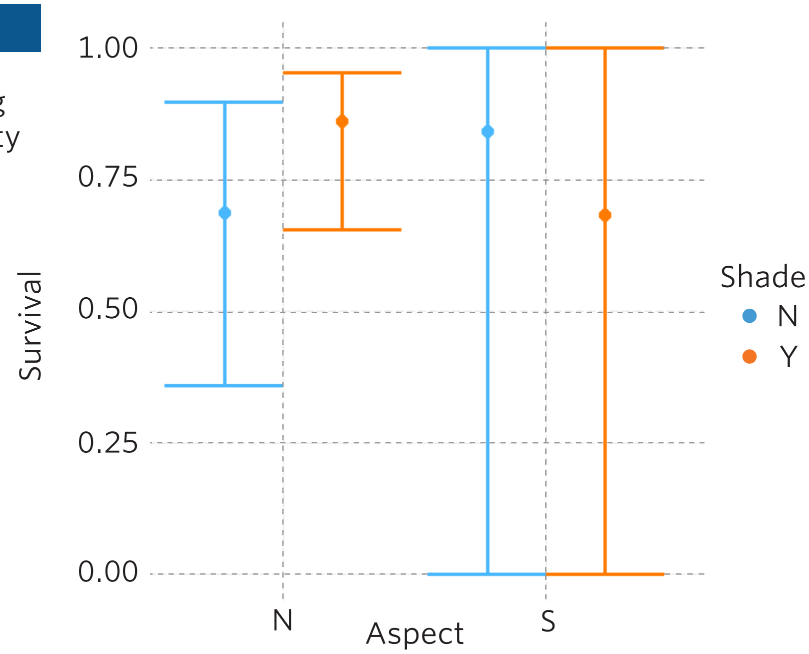


Figure 4: Seedlings planted in a north-facing aspect under shade have a higher probability of survival.

Table 2: Percentage of the 300 observations per categorical variable. "In" indicates where the seedling is located on the north to northeast side of a shade object, in a microtopographic depression and on a north-facing slope; "out" indicates no shade object, not in a topographic depression, and on a south, west, or east aspect.

	In	Out
Shade	74%	26%
Topographic Depression	35%	65%
North Aspect	71%	29%

DISCUSSION AND IMPLICATIONS FOR ADAPTIVE MANAGEMENT

Although we found a slight influence of aspect and shade on survival, we hypothesize this is due to the small data set with replicates across climatically suitable sites on northern aspects and lacking replicates on other aspects, for example. Other studies with a greater number of replicates across all conditions find that aspect, nurse object and depressions significantly impact survival of ponderosa pine and Douglas-fir seedlings (Marshall et al. 2023). As such, we recommend no changes to existing protocols and urge attention to assure good site selection to enhance survival.

We expect additional mortality to occur between years 2-5 post-planting, when the seedlings are smallest, and their root systems are most susceptible to hot and dry summer temperatures. Survival of 84% following the first growing season is very good, considering the extensive learning that has occurred throughout the past two years. The CPRG plans to continue to monitor survival and growth over the first 3 growing seasons post-planting and expects that additional monitoring would provide further insights on factors affecting the survival of planted seedlings.

Reburns are areas with compound disturbances, in this case two fires within the past decade. These areas are seed-source limited and likely to transition to grass or shrubland without planting, but they are extremely difficult planting areas that are hot and dry due to the lack downed trees or coarse wood debris to provide shade. We are surprised to see such high rates of survival in the two reburned areas. This may be explained by the selection of climatically suitable sites.

ACKNOWLEDGEMENTS

We thank the private landowners who have generously allowed us to access their properties, install monitoring plots, and return each year to measure growth and survival. Thank you to volunteers Paul Acker and Amy Williams for the numerous hours spent on hands and knees measuring the growth of small trees. Thank you to Laura Marshall of Colorado State University for support in the design of the monitoring plots. We are grateful to The Nature Conservancy for providing funding for monitoring.

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