MINISTRY OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT

Rock Creek Wildfire Report:

Vegetation Monitoring and Invasive Plant Management

2015-2020

HABITAT CONSERVATION TRUST FOUNDATION

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Report Prepared by:

Cora Skaien, PhD.

Barb Stewart, RP Bio, P. Ag

Lisa Tedesco, RP Bio

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Executive Summary

Once frequent across the landscape from natural ignition sources or Indigenous burning, wildland fires have decreased in frequency since the arrival of colonial settlers.. The loss of fire on the landscape has had largely negative impacts on vegetation, wildlife and biodiversity. In some areas of the province the reintroduction of fire using prescribed burning is being pursued. The responses of vegetation and wildlife to prescribed burning and wildfire can be variable and inconsistent. The response of vegetation to prescribed burns versus wildfires can differ due to differences in fire intensity and seasonal timing. Responses can also change depending on whether a site was harvested prior to or following the fire event. Additionally, few studies have investigated the influence of wildfire on insects intentionally released to be used for biocontrol.

Here, we investigated the influence of wildfire on vegetation groups in a study site that experienced a catastrophic stand replacing fire north of Rock Creek, BC in August of 2015. The first part of this report assesses vegetation change in the Kettle East study site between 2014 and 2020, using a nearby site, Rexin, as a control. The second section of the report summarizes the outcome of the invasive plant management treatments completed, funding challenges and effectiveness of the management.

Four 10-year targets were established for vegetation recovery objectives in the original Kettle East project (Tedesco 2020). By 2020, year 5 of monitoring, two of the four objectives are potentially satsifed for the open forest plots. The canopy cover of trees in the A layer is dramatically reduced post-fire in all open forest plots, indicating that stem density and layer distribution has indeed been reduced. Herbaceous and forb species percent cover, particularly of perennial species, has increased dramatically post-fire, particularly if the plot was not harvested (salvaged) subsequently. However, much of this increase is likely due to one species: fireweed (*Epilobium angustifolium*). Targets relating to increased grass and shrub cover remain unmet 5 years after fire in open forest plots. Both of these groups decreased initially after fire and have not yet returned to pre-fire levels however increasing trends post-fire that suggest that these groups may soon reach or exceed pre-fire levels. Overall, wildfire resulted in decreases in percent cover for native grass species, shrubs in the B layer, and trees in the A layer. Wildfire increased the percent cover of native herbaceous and forb species, with values up to 14-times greater, and increased the percent cover of coniferous and deciduous trees in the B Layer. There was a short-term increase in exotic species after fire, which then declined in non-harvested plots.

A coordinated approach to post-fire invasive plant management was implemented across all jurisdictions within the wildfire perimeter from 2016 to 2020. The approach included monitoring of priority invasive plants species sites, monitoring to assess the survival of biological control insects, and completing herbicide treatments to suppress invasive plants for a few years after the fire to give the natural plant communities time to recover. Annual monitoring of the highest priority invasive plants found no increase; however, only a portion of moderate to low priority species identified were monitored in more than one year. Invasive plant herbicide treatments occurred over five years, with the majority completed in year 1 and 2. The scope of management recommended in the plan was achieved on some but not on all jurisdictions.

Fire guard monitoring in 2017 and 2020 did not find any new invasive plant species where introduction could be attributed directly to guard construction or crews; however, resources were not sufficient to complete the scope of surveys recommended. Invasive plants previously recorded in areas were still present post fire. The establishment of low persistence grass seed mixes used on fire guards and newly

constructed harvest roads was not assessed. A new species to the region, North Africa grass (*Ventenata dubia*), was found along some roads and may have been a fire related introduction. It may have been introduced during post-fire fence construction or the sites may have been a result of expansion from a site within the fire that was not discovered until 2020.

Many biocontrol insects perished in the fire; however, many of the species are highly mobile and quickly re-established from nearby unburned areas and were detected at low levels in June 2016. Analysis of the monitoring of biocontrol insect presence post-fire was unable to detect differences in the occurrence of biocontrol insect species between patches that were burned in the 2015 wildfire compared to those that were not burned. The presence of some root feeding insect larvae in the spring following the fire indicated some larvae survived the fire in the roots of diffuse knapweed (*Centaurea diffusa*). Overall, this monitoring found that all the biocontrol insect species suspected to be present before the fire were still present at low levels the following year where host plants survived. The monitoring found presence at sites across the landscape, so if historical dispersal patterns occur the insects should re-populate all sites within the fire area. Monitoring during summer of 2021 is recommended to assess the status of the population recovery.

Report Terms of Reference

1. Analyze the vegetation monitoring data from the Kettle East and Rexin restoration sites to assess vegetation changes in response to wildfire and harvesting.
2. Assess the results of the vegetation monitoring and identify where else within the fire the information can be applied.
3. Assess whether the objectives of the Rock Creek Fire Invasive Plant Management Plan were met.
4. Assess invasive plant status in response to herbicide treatment work completed on public land and other jurisdictions within the fire perimeter and buffer zone around the fire perimeter as recommended in the invasive plant management plan.
5. Provide an overview on the status of invasive plant biocontrol re-colonization since the fire using available data.
6. Summarize locations of grass seeding post-fire to enable future establishment monitoring.
7. Provide recommendations for future invasive plant management within the Rock Creek wildlife area.

Background

Wildland fire is a historically natural occurrence throughout much of British Columbia, whether from natural ignition sources or Indigenous burning. Indigenous burning ceased on the landscape with the arrival of colonial settlers and for nearly a century, fire suppression has been the primary management approach to addressing wildfire on the landscape. The impacts, largely negative, of the loss of fire on the landscape for vegetation, wildlife and biodiversity across ecosystems and habitats is well documented (Zager et al. 1983; Chang 1996; Keane et al. 2002; Keane and Parsons 2010). However, the response of different vegetation groups, such as grasses, herbaceous and forb species, shrubs and trees, have had variable and inconsistent responses to prescribed burns (e.g., Metlen et al. 2004; Wayman and North 2007; Halpern et al. 2012; Newman et al. 2012; Willms et al. 2017), and vegetation response can differ between prescribed burns and wildfire due to differences in burn intensity and season of occurrence (Pidgen and Mallik 2013; Alba et al. 2015). The impacts of burning on vegetation groups can be further altered with harvesting before or after burns, with responses being hard to predict (e.g., Dodson et al. 2007; Wayman and North 2007; Dodson and Peterson 2010). Additionally, both harvesting and fire individually and synergystically have frequently been shown to increase exotic species abundance, at least in the short-term (Collins et al. 2007; Dodson et al. 2008; Nelson et al. 2008; Stoddard et al. 2011). Although some studies have demonstrated that prescribed burns can decrease the abundance of insect species considered pests (Schmid and Parker 1990; McNichol et al. 2019; Ray et al. 2019), few studies have investigated the influence of wildfire or prescribed fire on insects intentionally released to be used for biocontrol. Biological responses can often be site specific, with generalities sought to best inform land management practices. Here, we investigate the influence of wildfire on vegetation groups (e.g., native grasses and herbaceous species, shrubs, trees, exotic and invasive species).

Over 80 years of fire suppression had produced extensive fuel loading along the valley bottom and lower slopes of the Kettle River resulting in a stand replacing fire north of Rock Creek, BC in August of 2015. Prior to the fire, an area within the fire perimeter had been identified for ecosystem restoration treatments and had existing baseline vegetation surveys, providing a unique opportunity to assess vegetation changes resulting from the wildfire and post-fire harvesting. Many native plants were expected to recover and re-colonize the area if they were not outcompeted by introduced invasive plants that often increase following wildlife (Alba and others 2015). Invasive plants usually thrive in open areas and since the tree canopy will take many decades to re-establish, a much larger area of open grassland susceptible to dense populations of invasive plants had been created. The disturbance associated with fire suppression activities, infrastructure replacement, and salvage harvesting created new opportunities for invasive plant species to be introduced and to thrive. Post-fire rehabilitation work has often led to new introductions of invasive plants (Keeley 2005). To mitigate the potential negative impacts of invasive plant expansion in this high value area, a five year plan for invasive plant management was developed and implemented from 2016-2020 (Stewart 2016).

This report assesses the effectiveness of the five-year invasive plant management plan implemented across the entire fire area and delves into the site specific vegetation responses observed within the restoration study site. The first portion of the report addresses activities and outcomes in the Kettle East study site between 2014 and 2020, using Rexin as a nearby control site for the vegetation monitoring portion of this report. For detailed results of operations during the first nine years of the larger restoration and enhancement program regarding burning in this region see Boundary Restoration and Enhancement Program (BREP) 2012-2015 (Tedesco 2016) and BREP 2015-2020 (Tedesco 2020). The second section of the report summarizes the outcome of the invasive plant management treatments completed, funding challenges and effectiveness of the management that was implemented.

Vegetation Monitoring: Before-After Control-Impact (BACI) Analyses Investigating Impacts of Wildfire and Harvesting (2014-2020)

Background

The loss of fire on the landscape has largely negatively impacted vegetation, wildlife and biodiversity (Zager et al. 1983; Chang 1996; Keane et al. 2002; Keane and Parsons 2010). Additionally, suppression of fire on the landscape can increase fuel loads, leading to less frequent but higher severity fires. The response of vegetation to prescribed burns and wildfire in dry mixed forest ecosystems is highly variable and specific to vegetation grouping, including native grasses, native herbaceous and forb species, shrub species, tree species and exotic species. For example, some studies observe decreases in cover or richness of vegetation groups (e.g., Metlen et al. 2004; Wayman and North 2007; Willms et al. 2017), others observe increases (e.g., Halpern et al. 2012), and others observe a delayed response with an initial decrease, followed by an increase 4-6 years after intervention (e.g., Newman et al. 2012). Additionally, burning and harvesting frequently affect percent cover and species richness synergistically, with responses of either intervention on its own being weaker or in a different direction than when both impact the landscape together (e.g., Dodson et al. 2007; Wayman and North 2007; Dodson and Peterson 2010).

This section of the report investigates the effects of wildfire and subsequent salvage (harvesting) on plant communities in the Kettle drainage north of Rock Creek, BC (Figure 1). A human-caused wildfire occurred at the Kettle East site in 2015 after baseline surveys were performed in 2014 and shortly before planned treatments (i.e., harvest, understory slashing, prescribed burn) could be implemented. The neighbouring Rexin site was unaffected by the wildfire, resulting in an opportunity for a Before-After Control-Impact (BACI) study to assess the impacts of fire and subsequent salvage in these open forest (OF) and open range (OR) plots.

Objective

One of the broad objectives of the BREP is to reduce the extent of ecosystem degradation by completing high quality restoration activities targeting sites that are characterized as open range and open forest fire-maintained ecosystems (Tedesco 2020). Specific objectives of the monitoring of plant communities at the Kettle East and Rexin sites is to be able to detect changes and trends in species cover and richness over time. Vegetation objectives included:

- reducing conifer stem densities and layer distribution to prescription targets;
- increasing grass cover by 10% or more over ten years;
- increasing herb/forb cover by 10% or more over ten years; and
- increasing shrub cover by 15% or more over ten years.

Presently, Kettle East is at year 5 post-fire and Rexin has been monitored to year 2 post-harvest with year 5 monitoring occurring in the summer of 2021.

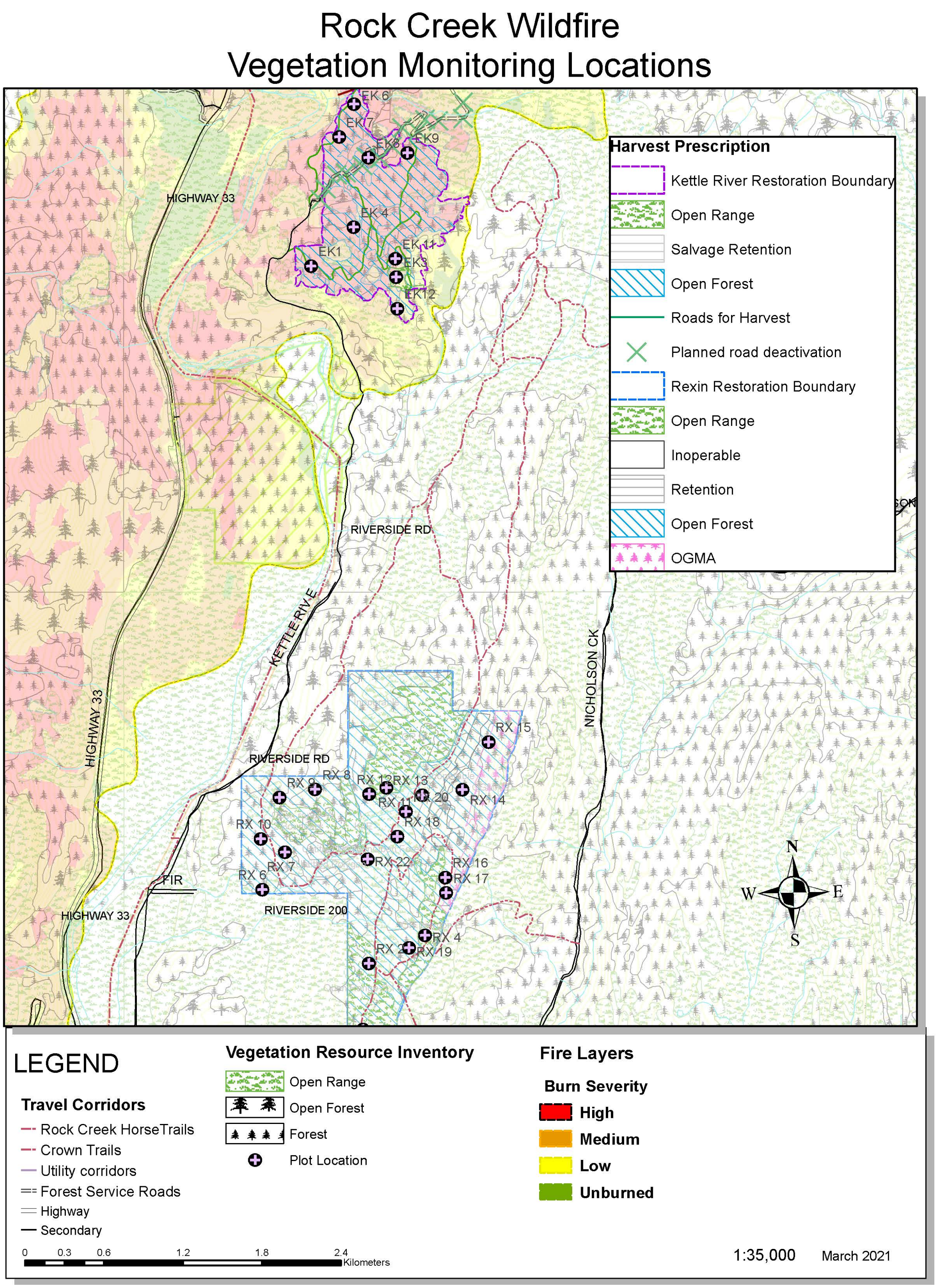

Figure 1. Map showing the location of Kettle East and Rexin within the Kettle drainage basin.

Study Sites

This report covers assessment of the impacts of wildfire on the Kettle East site, which experienced a wildfire on August 13, 2015 after one year of vegetation monitoring had occurred (Figure 1). After the wildfire, salvage (harvesting) activities occurred in some of the Kettle East plots. For specifics on 'site selection', location of plots and harvesting methods, see Boundary Enhancement and Restoration Program 2015-2020 (Tedesco 2020).

The nearby Rexin restoration site has similar plant communities and acts as an unburned control site for assessing changes in vegetation over time, which allows us to partition influences over time that are likely due to wildfire versus natural variation in vegetative communities. Both of these sites are a subset from a larger monitoring program (Tedesco 2016, 2020). Both Kettle East and Rexin were surveyed with the same methodology, and both sites have plots that were harvested and others that were not harvested.

Kettle East

The Kettle East site is a mosaic of ecosystems ranging from non-forested rock outcrops to subhygric swales, depressions and gullies. Four larger (>0.2ha) open range (OR) areas have been mapped totalling 2.8ha. These open range ecosystems either belong to the rock outcrop site series (IDFxh4/72) or the deep soil grassland type (IDFxh4/82). This site ranges in elevation from 665-980 m.

The open forest (OF) plots dominate the Kettle East site and are classified as IDFxh4/01 (Douglas fir – Ponderosa pine / Pinegrass). The terrain is predominantly moderately sloping (15-40% slopes) with small areas (< 1 ha) where slopes are steeper than 45%. There are small areas (about 5% of open forest, OF) that belong to the IDFxh4/02 (Douglas fir – Ponderosa pine / Pinegrass – Penstemon); these are usually adjacent to non-forested openings. As well, there are occasional small (<0.2ha) unmappable non-forested openings within the open forest type. There are also small areas (<10%, circa 4 ha total) of subhgric/seepage ecosystems found within the Open Forest type; these are found in swales, gullies and depressions. These ecosystems belong primarily to the IDFxh4/03 site series. They are generally easily identifiable on the ground due to topography and the presence of the deciduous trees paper birch and trembling aspen and/or Douglas maple.

Wildfire Burn Severity

The intended restoration site was burned in its entirety during the 2015 Rock Creek wildfire, prior to implementation of any site treatments as initially planned. The fire ignited on Thursday, August 13 under hot and windy conditions (Table 1).

Table 1. Recorded weather conditions and calculated Fire Weather Index (FWI) codes and indices for the BCWS Rock Creek weather station from August 12 to August 15, 2015. Actual date of ignition is highlighted in yellow.

Date	Temp (°c)	RH	Wind (km/h)	Precip (mm)	FFMC	DMC	DC	ISI	BUI	FWI
2015-08-12	35.7	13	69	0	97.4	186	913	14.9	247	51.1
2015-08-13	37.1	11	54	0	98.1	193	923	17.8	254	56.9
2015-08-14	29.4	26	no data	0	95.9	198	931	12.9	259	46.7
2015-08-15	24.5	29	12	0	94.3	202	939	11.4	262	43.1

RH=relative humidity; FFMC=fine fuel moisture code; DMC=duff moisture code; DC=drought code; ISI=initial spread index; BUI=build-up index; FWI=fire weather index

Burned area reflectance classification (BARC) mapping was completed for the wildfire area in November 2015. BARC is derived from landsat imagery and then field verified to determine soil burn severity (Parson et al. 2010). Most of the fire at the Kettle East site was identified as high burn severity with some small patches of low burn severity.

Salvage After Wildfire

Lisa Tedesco, Habitat Biologist, was contacted by the Selkirk Resource District in November 2015 to provide input and advice on proposed salvage harvest within the Rock Creek fire area that would include the Kettle East prescription area. Values that were incorporated into the salvage prescription included stem densities to promote habitat suitability for Lewis's woodpecker, retention of all remaining unburned or low severity burn patches, retention of largest trees onsite and protection of wetland features and deciduous patches. Note, there were initially open forest and open range prescription targets set for this site prior to the wildlife, and details can be found in Tedesco (2020). After the wildfire, the salvage prescription included: (1) keeping leave trees of Douglas fir, Ponderosa Pine and western larch with dbh > 50 cm; (2) 100% of all live deciduous stems were to be reserved from harvest; and (3) a minimum of 8 - 12 stems or trees/ha, each being a minimum of 3 m in length and >20 cm in diameter at one end, of any species and/or stubs of any species may be retained for wildlife where available.

Following the wildfire, vegetation monitoring plots were revisited. Nine of twelve plots were able to be relocated. Reserve areas were established that allowed for three of the vegetation monitoring plots to be excluded from harvest (2 open forest and 1 open range) with the remaining six plots impacted by salvage activities. Salvage harvest occurred in spring and early summer 2016. Road deactivation and rehabilitation work was completed in 2017. The main FSR had standard deactivation works completed (ditching and water bars) while new in-block roads from harvesting were rehabilitated completely with recontouring and seeding.

Surveyed Plots

There were 12 total plots initially surveyed, with three that were not relocated post-fire. The nine re-located plots were surveyed across the Kettle East site before (2014) and after (2016, 2017, 2020) the 2015 wildfire, with five open forest (OF) plots harvested after wildfire (salvaged; EK01, EK04, EK08, EK09 and EK11) and three not harvested (not salvaged; EK06, EK07 and EK12) after wildfire (*Figure 2*). These eight open forest plots, and the one open range plot (EK03), were assessed in this report. There were three additional open forest plots that were only surveyed in 2014 (EK02, EK05, EK10) and were thus not included in analyses for this report.

Kettle East Restoration
Vegetation Monitoring Locations

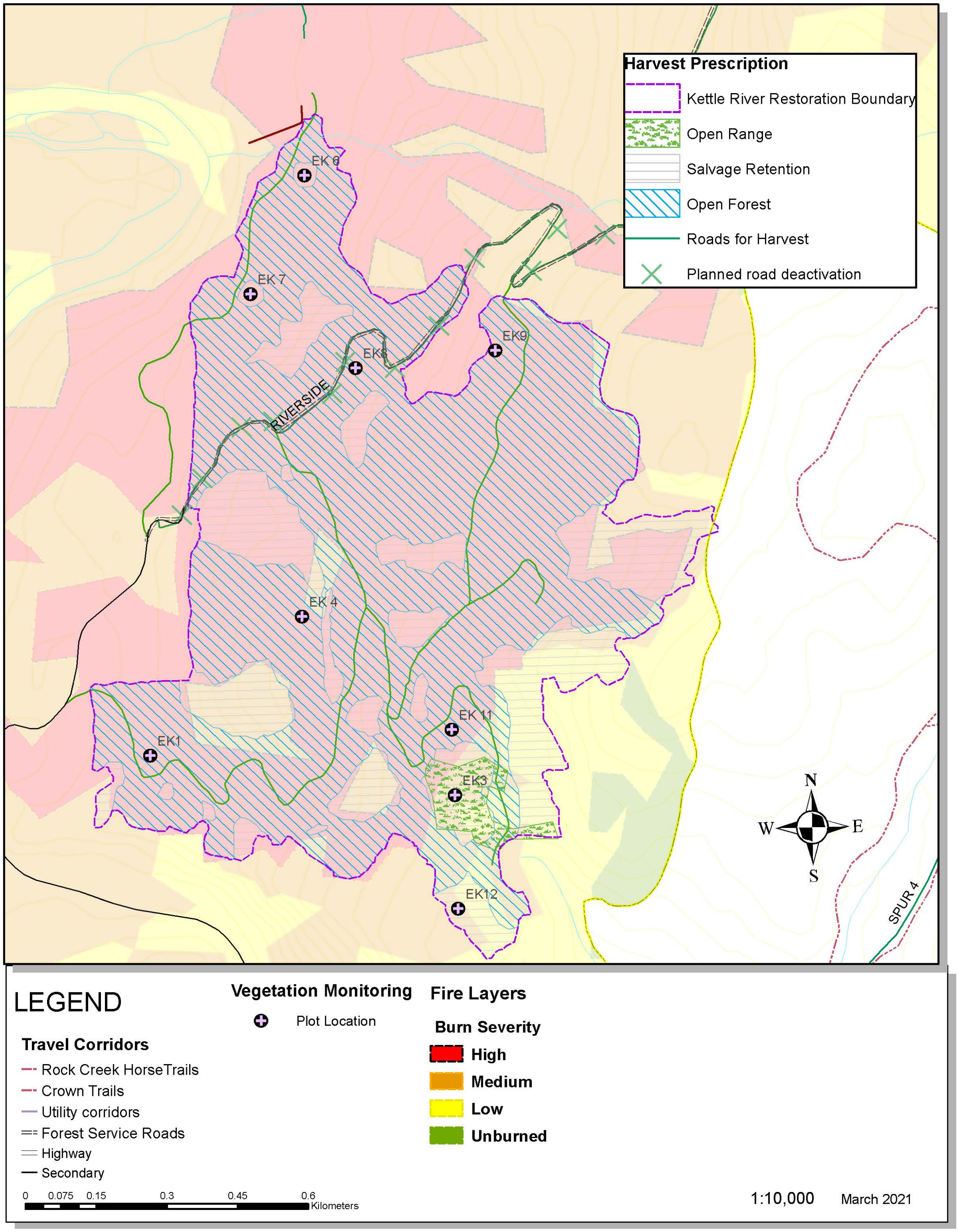

Figure 2. Ecosystem restoration treatment plan map for Kettle East. Only open forest plots EK01, EK04, EK06, EK07, EK08, EK09, EK11 and EK12, and open range plots EK03, are assessed in this report.

Rexin

The Rexin site is entirely within the IDFxh4 Boundary very dry hot interior Douglas-fir variant. This site ranges in elevation from 640-1120 meters.

The OR units have a high level of variability including rock outcroppings, grassland expanses and both sparsely and densely forested areas. The prescription has identified the open range units for management as IDFxh4/01 and 02, Douglas fir – Ponderosa pine / Pinegrass and Douglas fir – Ponderosa pine / Pinegrass – Penstemon respectively, however site series 82 was also prevalent. There was very low shrub cover in many plots with moderate cover of bluebunch wheatgrass (*Pseudoroegneria spicata*) (30-35%), variable presence of fescues (*Festuca spp*) (2-20% cover) and a diversity of native forbs and herbs. Tree density ranged from 140 to 640 stems/ha. Areas of denser Douglas fir (*Pseudotsuga menziesii)* near roads were identified for harvest removal. No other treatment will occur in these areas until the intended prescribed burn is completed. The end target is an average of 20 stems/ha with a range of 0-75 stems/ha.

The OF units are both being managed as IDFxh4/01 but unlike the OR units, they are predominantly forests. Grass cover is primarily pinegrass *(Calamagrostis rubescens)* and shrub cover are much higher at 5-50%. Forest cover in some areas is dominated by ponderosa pine *(Pinus ponderosa*) with lesser components of Douglas fir and western larch (*Larix occidentalis)*. Other areas have equal parts mature Douglas fir and western larch with scattered ponderosa pine, with the latter species distributed based on soil moisture. Stem densities for all species ranged from and average of 640 stems/ha to 1000 stems/ha. The target in both habitats is retention of 250 stems/ha.

Harvest and Slashing

Harvest of this site started in late winter 2017 and continued into early spring at which time operations were halted due to site conditions. Harvest and hauling of logs resumed in October 2017 and was completed in the same month. This is the first site where we have allowed harvest to occur outside of winter operating conditions (i.e. snow cover and frozen ground).

No understory slashing was completed on this site. Flammulated owl *(Psiloscops flammeolus)* is one of the species associated with this ecosystem and they require thickets of regenerating trees for cover. The scattered thickets on site were retained to support habitat needs for this species.

Scheduled Prescribed Burn

Burn plan development will begin in spring 2020 with earliest possible ignitions being spring 2021. Currently, there has been no burning on the Rexin site since monitoring has begun.

Surveyed Plots

There are 15 OF and 6 OR plots currently surveyed in the Rexin site (2016, 2017, 2018 and scheduled for 2021). Only 11 OF plots, RX06, RX09, RX12, RX13, RX14, RX15, RX16, RX17, RX18, RX19, and RX22, and one OR plot RX11, are assessed in this report as controls for the Kettle East plots because they were the most similar to the burned Kettle East plots in terms of BEC classification, tree cover and species, and understory composition (Figure 3). Of the 11 re-surveyed OF plots, 8 were harvested (RX12, RX13, RX14, RX16, RX17, RX18, RX19 and RX22) and 3 were not harvested (RX06, RX09 and RX15). Four plots (RX03, RX05, RX21 and RX23) were only surveyed in 2016, all of which were OR plots, and thus could not be included in the Before-After Control-Impact (BACI) analyses conducted.

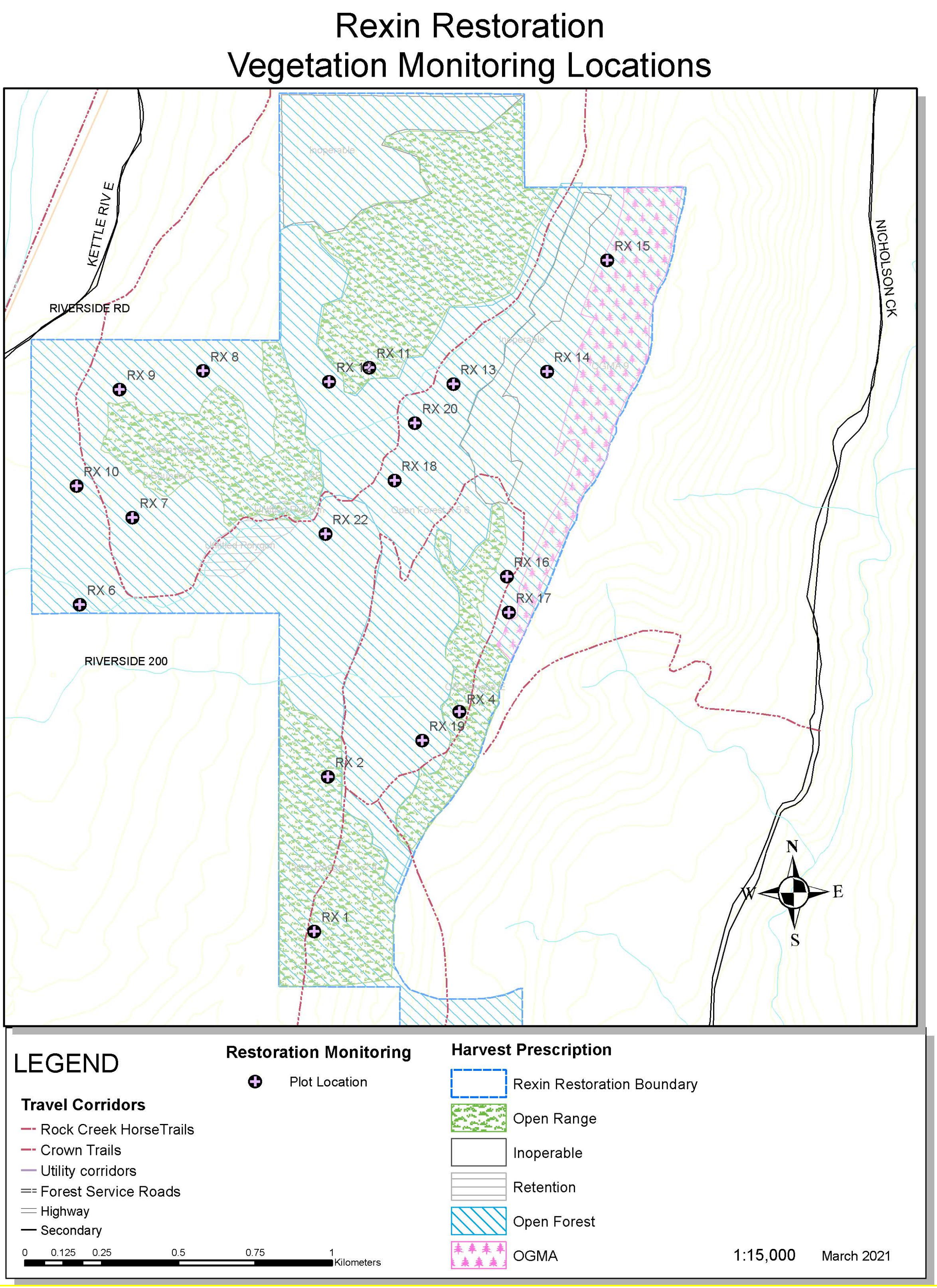

Figure 3. Ecosystem restoration treatment plan map for Rexin. Only open forest plots RX06, RX09, RX12, RX13, RX14, RX15, RX16, RX17, RX18, RX19, and RX22, and open range plot RX11, are assessed in this report as controls for the Kettle East plots.

Vegetation Monitoring Methodology

Vegetation monitoring consists of permanent vegetation and photo monitoring plots. These methods have been developed collaboratively for the Selkirk District. Pre-treatment vegetation monitoring plots are set up at the time of prescription development by the prescription author and field team. All post-treatment vegetation monitoring and pre-treatment monitoring at Rexin were completed by local consultant Barb Stewart, Kettle Ecological, while the baseline pre-treatment surveys at Kettle East site were completed by consultant T. Braumandl, Ecora Consulting.

Permanent vegetation plots were located to be representative of the conditions and expected treatments within the standards unit. Re-monitoring post-treatment is scheduled for 1, 2, 5, 7, and 10 years post-treatment. The Biogeoclimatic Ecosystem Classification (BEC) System Land Management Handbook 25 (MoFR and MoE 2010) and associated Ecosystem Field Form is the basis for the monitoring system. At each permanent plot the following information is collected:

- One FS882 parts 1 (site description), 2 (soil description) and 3 (vegetation; recorded to nearest percent or decimal if <1%)
- One FS882 part 4 (mensuration form; not used here)
- One FS1225 Photo plot record

During vegetation monitoring, percent cover by species is recorded under the BEC layer system of A (tree layers), B (conifer regeneration and shrub layers), C (grass, herb and forb layer) and D (mosses and lichens). For analysis of changes in cover and species richness over time, species were grouped by layer and lifeform (*Table* 2). The exotic species grouping includes non-native grasses, forbs and herbs whether considered invasive or not. All 'A' layer trees are grouped, including both coniferous and deciduous trees. Conifer and deciduous cover, in part from regeneration, recorded in the B layer has been grouped separately from shrubs in the B layer.

The photo plot record is collected standing at the plot centre looking out in each of the four cardinal directions. All data collected is entered into VPro, the provincial vegetation database.

Table 2. Species groupings used in analyses by BEC layer and lifeform classification.

Group Name	Layer	Layer #	Lifeform
Trees > 10 m	A	1, 2, 3	1, 2 (conifer, deciduous)
Trees < 10 m	B	4, 5	1, 2 (conifer, deciduous)
Shrubs	B	0, 4, 5	3, 4 (low and tall)
Grasses	C	6	6 (native)
Forbs and Herbs	C	0*, 6	7, 8, 12 (native)
Exotic Species	C	6	6, 7, 8 (non-native)
Mosses and Lichens	D	7	Not reported on

* Lifeform 0 applied to shrubs except for one occurrence of herb/forb.

Statistical Analysis

The influences of burning via wildfire and harvesting (i.e., salvage) on the percent cover and species richness were assessed for five species grouping of interest, following BEC classification, which included native grass species, native herbaceous and forb species (three categories: annuals and biennials, perennials and all species together), exotic species (grass, herbaceous and forb species pooled together), shrub species in the B layer, coniferous and deciduous trees in the B Layer and coniferous and deciduous trees in the A Layer. We performed two analyses for each species grouping: one comparing Before-After, Control-Impact (BACI design) of harvesting and burning using Kettle East as the impacted site and Rexin as the control site, and another BACI analysis using just the Kettle East plots to determine changes in vegetation over time since wildfire, relative to harvesting or not harvesting post-fire (i.e., salvaging). The BACI framework allows for a comparison of the treatments by assessing differences in plots that are measured both before and after a treatment or intervention is applied (e.g., same plots measured before and after a fire; before-after), relative to control plots that did not receive a treatment or intervention (e.g., plots that were not burned in the wildfire; control-impact). The control plots allow for natural variation that may have occurred without intervention to be accounted for, that may otherwise confound results.

Statistical analyses were conducted using the lme function in the nlme package (Pinheiro et al. 2020) in the R Statistical Package (R Core Team). Percent cover and species richness was log transformed when necessary so that models met ANOVA assumptions of normality and equal variance of residuals. Model assumptions were met unless stated otherwise in results. All data depicted is the mean and standard error of the raw data.

In each BACI model using both Kettle East and Rexin sites (i.e., the "full model"), we investigated impacts of burning via wildfire and/or harvesting on the percent cover and species richness of our five groups of interest using two explanatory variables, including an interaction between these two categorical variables. These two variables were: (1) whether the survey date is before (year -1) or after harvesting and burning (years 1, 2 and 5 treated as equals in this category; 2 levels); and (2) the experimental condition (i.e., "intervention", 4 levels), which includes plots that were burned by the 2015 wildfire and harvested (Kettle East; n = 6), burned and not harvested (Kettle East; n = 2), harvested but not burned (Rexin; n = 8), and not harvested nor burned (Rexin; n = 3). The term of most interest is the interaction term which informs us of whether the wildfire and harvesting had different influences on our response variables relative to control plots without the intervention (control-impact), comparing values before and after the intervention (before-after). Random effects in each model included the PlotID to account for repeated measures, and the survey year to account for annual environmental variation. These models will be referred to as the full model.

In each BACI model using only the Kettle East site (i.e., the "Kettle East model", we investigated the percent cover and species richness of the five groups of interest before and after wildfire relative to whether the plots were harvested or not, and the number of years that passed since fire, using two explanatory variables and an interaction between these variables. These variables were: (1) The "experimental year" in which the data was collected (-1 for the year before burn, and years 1, 2 and 5 after burn; 4 levels); and (2) the experimental condition (i.e., "intervention"; 2 levels), which included plots that were burned in the 2015 wildfire and harvested (n = 6) and burned but not harvested (n = 2). Here, we were interested in both the interaction term (i.e., did the response differ for burned plots relative to whether they were harvested or not?), and the experimental year (i.e., how different was the percent cover and species richness in the year before fire, compared to 1, 2 and 5 years post-fire?). Random effects in each model included the PlotID to account for repeated measures. These models will be referred to as the Kettle East models.

Results

Environmental Variability: Precipitation

Precipitation data was recorded from the Rock Creek BC Weather Station. Kettle East plots were monitored between 2014 to 2020, and Rexin plots were monitored from 2016 to 2018 (with monitoring scheduled for 2021 at Rexin). Not all plots were monitored in the same year between sites, and thus it is important to assess annual environmental variability in the region.

Weather conditions varied annually and during the growing season. Average annual precipitation was 365 mm, with the driest year in 2015 (283 mm) and the wettest year in 2016 (456 mm; Figure 4). The average annual growing season (May to September) precipitation was 141 mm, with the driest summers being 2015 (78.2 mm) and 2017 (78.8 mm) and the wettest summers being 2019 (191.6 mm) and 2020 (194.6 mm).

Annual growing season precipitation was similarly high at the Rock Creek station in both 2014 and 2016 (~176 mm), which corresponds to the first year of monitoring for the Kettle East and Rexin sites, respectively. Both 2015 and 2017, the subsequent years, were also similarly dry. Therefore, conditions were similar prior to intervention at both sites, supporting the use of Rexin as a control site for Kettle East.

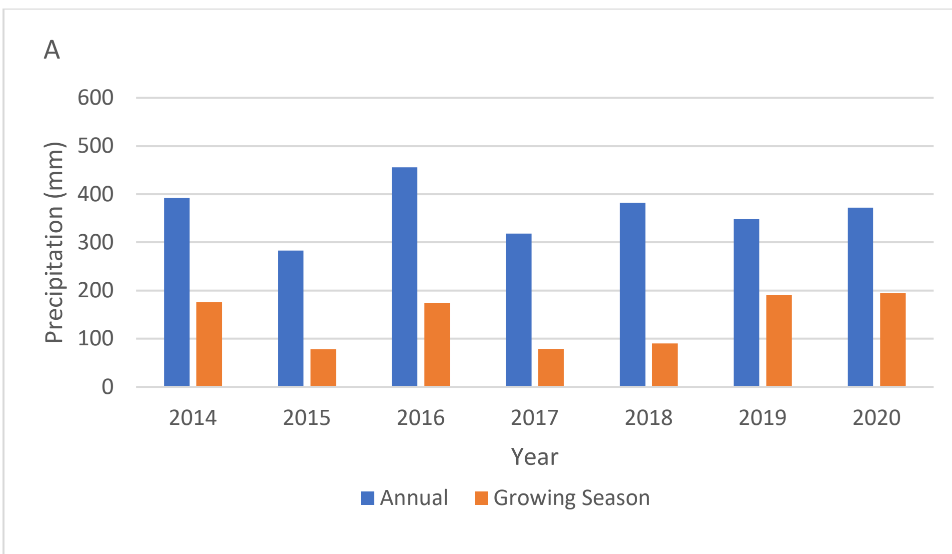

Figure 4. Annual and growing season (May to September inclusive) precipitation in mm at the Rock Creek BC Wildfire Service weather station from 2014 to 2020.

Open Forest Plots

These analyses represent the results from repeated measures within 19 Open Forest (OF) plots across 2 sites (Kettle East and Rexin) between 2014 and 2020. Of these 19 plots, 8 were burned in the 2015 wildfire (Kettle East) and 11 were unburned (Rexin). Additionally, 5 of the 8 burned plots were salvaged after fire (harvested), and 8 of the 11 unburned plots were harvested. In most instances, the percent cover and species richness in the first survey of each site (2014 for Kettle East and 2016 for Rexin) were similar before any intervention (i.e., harvesting post-fire and/or burning), making Rexin a good control site for the Kettle East fire. The 'full model' uses data from the wildfire in Kettle East, as well as the lack of fire in the Rexin control site, assessing only values 'before' versus 'after' interventions of burning and harvesting. The 'Kettle East model" assesses only the Kettle East site and looks at individual differences for each year surveyed (one year before fire, and years 1, 2 and 5 after fire).

OF Native Grass Species

Wildfire significantly decreased the percent cover of native grass species from ~22% to ~3-15%, depending on year, with post-fire harvesting (salvaging) causing this decrease to be more severe (~3-9%; significant BACI interaction in full model, p = 0.001; significant BACI interaction in Kettle East model, p = 0.004 Figure 5a). Although the percent cover of native grasses in harvested and not harveated Kettle East plots increased from year 1 (3-10%) to year 5 (9-15%) after wildfire, the percent cover of native grasses did not recover to pre-fire levels of ~22% by 2020 (experimental year in Kettle East model, p < 0.001).

Similarly, wildfire reduced species richness from ~3-5 species to~2-3 species, approximately a two-fold decrease, with no changes in percent cover when plots were salvaged/harvested (significant BACI interaction in full model, p < 0.0001; non-significant difference in harvesting in Kettle East model, p = 0.30; Figure 5b). Species richness values post-fire were substantially less than those before wildfire, and did not recover to pre-fire levels (experimental year in Kettle East model, p < 0.0001).

Overall, wildfire reduced both percent cover and species richness of native grass species, with a trend for both values increasing from years 1 to 5 post-fire, but not recovering to pre-fire values. Harvesting (salvaging) post fire made the decrease in percent cover more severe and with a slower recovery.

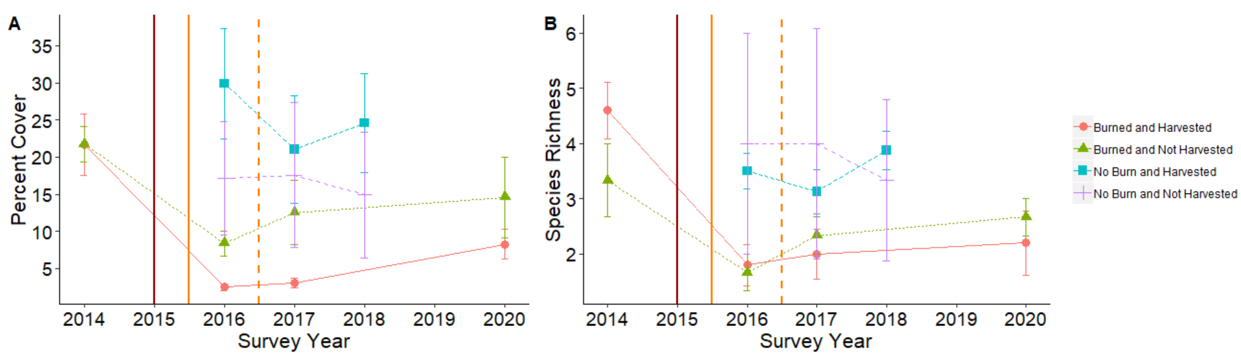

Figure 5. The percent cover (A) and species richness (B) of native grass species in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

OF Native Herbaceous and Forb Species

Wildfire increased percent cover of native herbaceous and forb species from ~4-10% to ~35-55%, and burning without subsequent harvesting led to the highest percent cover (~55%; significant BACI interaction in full model, p < 0.0001; Figure 6a). Further, year relative to wildfire significantly impacted percent cover in Kettle East plots (Kettle East model, p < 0.0001), with percent cover being greatest one year after wildfire (~32-52%) compared to pre-fire values (~4%). There was, however, a decrease in percent cover by year 5 post-burn (~15%) compared to year 1 (~35%) in plots that were both burned and harvested (salvaged). The increase in percent cover was greatest in plots that were burned but not harvested, which had percent cover about 10-times greater in year 5 (~45%) than pre-fire values. This initial increase was likely due to a high abundance of fireweed (*Epilobium angustifolium)*, which is common in areas after moderate to high intensity wildfires, but less common after low intensity prescribed burns.

Despite a significant interaction (significant BACI interaction in full model, p = 0.02; Figure 6b), species richness of native forbs and herbaceous species do not appear to have been influenced by wildfire or harvesting, although harvesting without wildfire may have increased species richness in Rexin plots. Within Kettle East plots, fire did not influence the species richness in plots, with values consistently around 5-6 species each surveyed year (BACI interaction, p = 0.60; time since fire, p = 0.96 in Kettle East fire model).

Overall, wildfire resulted in an initial increase in the percent cover of native herbaceous and forb species cover when all annuals, biennials and perennials are assessed together. This initial increase was followed by a decrease by year 5 post-fire, with year 5 values still greater than pre-fire values. The greatest percent cover by year 5 was achieved in plots that were burned but not harvested. This may be because of the additional soil disturbance that occurs with harvesting and salvaging. Conversely, little descernable impact of wildfire and harvesting was observed on species richness.

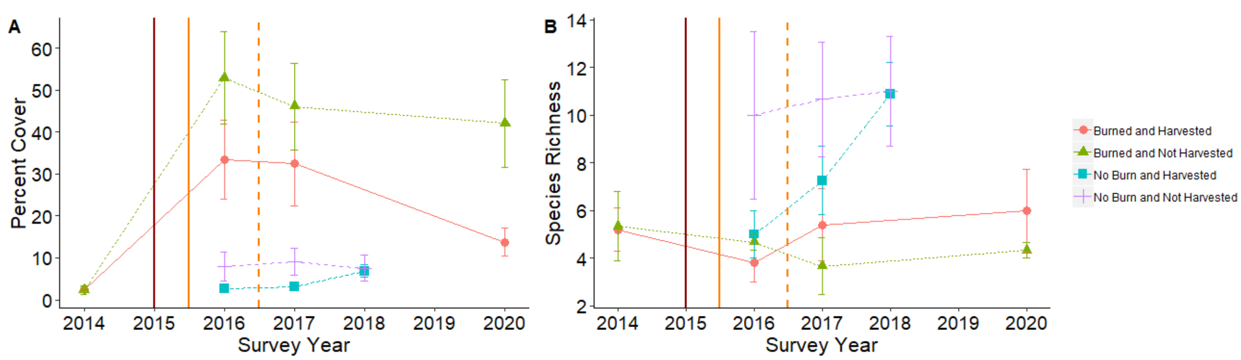

Figure 6. The percent cover (A) and species richness (B) of native herbaceous and forb species (annuals, biennials and perennials grouped together) in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

Native herbacecous and forb species with an annual or biennial life cycle occurred at low cover regardless of year (typically < 1%), with no significant differences detected by intervention in the full model despite a minor trend for an increase in cover with harvesting in both burned and unburned plots (non-significant BACI interaction in full model, p =0.68; Figure 7a). In the model assessing only Kettle East plots, time since wildfire significantly increased the percent cover of native herbaceous and forb species with an annual life cycle in plots that were also harvested (salvaged), with little variation in plots that were not harvested (significant BACI interaction in Kettle East model, $p = 0.04$). Model assumptions were not met for these analyses, however, suggesting that these statistical results may be biased and unreliable. However, when assessing the observed patterns, it is clear that annuals and bienniels performed best in harvested and salvaged sites. This is likely because annual species tend to thrive in disturbed soils, such as those caused by the harvesting process.

Species richness varied with time, but not intervention (non-significant BACI interaction in full model, $p = 0.33$; time since intervention, $p = 0.04$; Figure 7b), with time since wildfire significantly increasing the species richness of native herbaceous and forb species with an annual life cycle (time since intervention, $p < 0.0001$). Model assumption were not met for these analyses.

Overall, there was very low percent cover and species richness of native herbaceous and forb species with an annual or biennial life cycle, making assessment difficult. Despite this, there does appear to be a minor increase in these species after wildfire at very low coverage, and there is a potential that harvesting may also result in minor increases in cover and richness of these species.

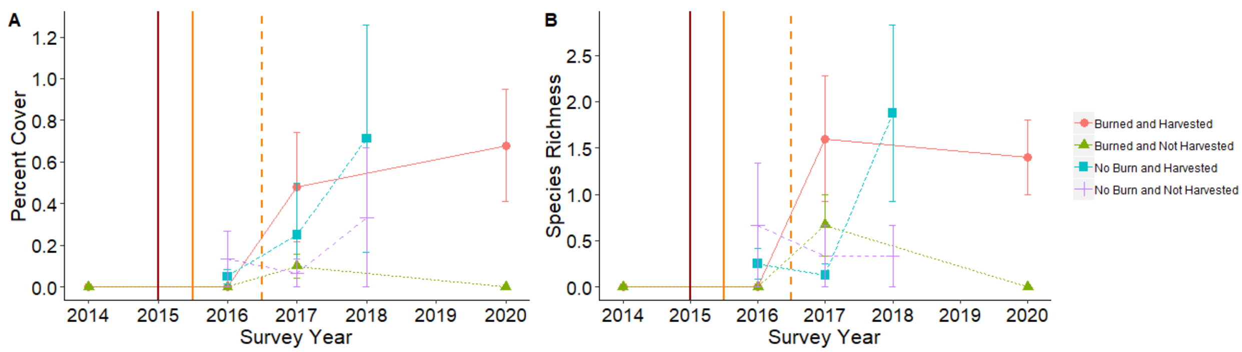

Figure 7. The percent cover (A) and species richness (B) of native herbaceous and forb species with an annual or biennial life cycle in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

Wildfire increased percent cover of native herbaceous and forb species with a perennial life cycle, and wildfire without subsequent harvesting led to the highest percent cover (significant BACI interaction in full model, $p < 0.0001$; Figure 8a). Further, year relative to wildfire significantly impacted percent cover in Kettle East plots ($p < 0.0001$), with percent cover being up to 14-times higher post-fire (years 1, 2 and 5 post-burn) compared to pre-fire values. Percent cover decreased by year 5 post-fire compared to year 1 post-fire in plots that were burned and harvested (salvaged), but not necessarily so for plots that were burned but not harvested.

Wildfire slightly decreased species richness of native herbaceous and forb species, and harvesting without fire led to a slight increase in species richness relative other interventions, but results were overall inconsistent (significant BACI interaction in full model, $p = 0.0008$; Figure 8b). When assessing only Kettle East plots, there were no differences for species richness with time ($p = 0.25$) or intervention ($p = 0.93$).

Because most of the native herbaceous and forb species were perennial, the conclusions for all native native herbaceous and forb species apply again here. Specifically, wildfire resulted in an initial increase in percent cover, with values decreasing again by year 5 post-fire. However, these values remain greater at 5 years post-fire than values pre-fire. The group with the highest percent cover 5 years after fire were plots that were burned but not harvested. Conversely, little descernable impact of wildfire and harvesting was observed on species richness.

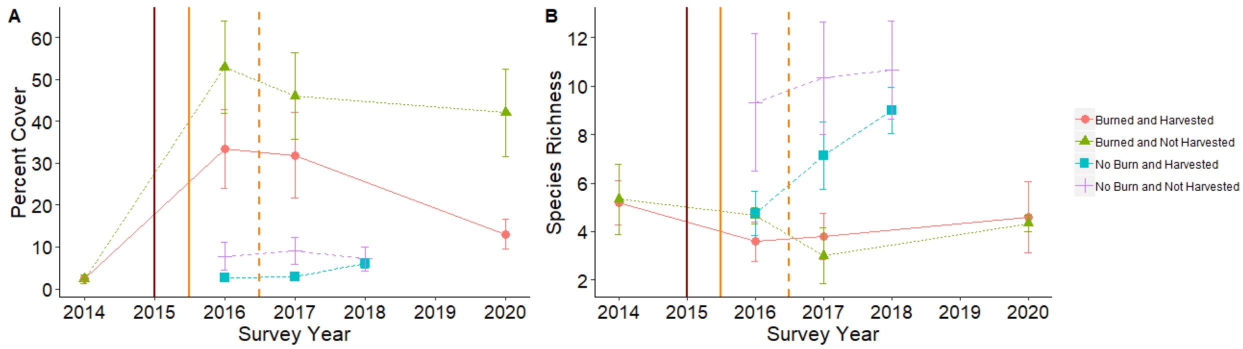

Figure 8. The percent cover (A) and species richness (B) of native herbaceous and forb species with a perennial life cycle in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

OF Exotic Grass, Herbaceous and Forb Species

BACI analyses of the full model suggest that wildfire and harvesting (salvaging) had no influence on the percent cover of exotic species when comparing values before intervention to values after intervention (non-significant interaction, $p = 0.67$; Figure 9a). A significant interaction analysing the Kettle East data ($p = 0.0006$), however, indicates that there is an initial increase in exotic species cover one year after wildfire in plots that were not harvested, with these values dropping back to 0 by years 2 and 5. Conversely, exotic species cover increased in plots that were both burned and harvested (salvaged) by years 2 and 5 after fire (~1.7%) compared to pre-fire levels (~0.4%).

Similarly, species richness was not different in burned and harvested plots before or after intervention relative to controls (non-significant BACI interaction in full model, $p = 0.13$; Figure 9b). A significant interaction analysing the Kettle East data ($p = 0.04$) indicates that wildfire initially increased the species richness of exotic species from <1 species to ~2-4 species for both harvested (salvaged) and unharvested plots, but that this increase was short-lived in unharvested plots, returning to 0 by year 2. The increased species richness of exotic species remained high in plots that were burned and harvested (~4 species five years after intervention).

Overall, the percent cover (<2%) and species richness (0-4 species) of exotic species is low for Kettle East and Rexin plots. Harvesting increased the percent cover and richness of exotic species in both burned and unburned plots. This is likely in large part due to the fact that most of the exotic species observed within monitored plots were annual species, which thrive on disturbed soils such as those from harvesting and salvaging practices. Wildfire resulted in an initial increase in exotic species cover and richness one year after burn, but then these values returned to similarly low levels as observed prior to burning in plots that were not harvested. Although invasive species management occurred in both Rexin and Kettle East, none of the plots monitored over time were influenced directly by invasive species management.

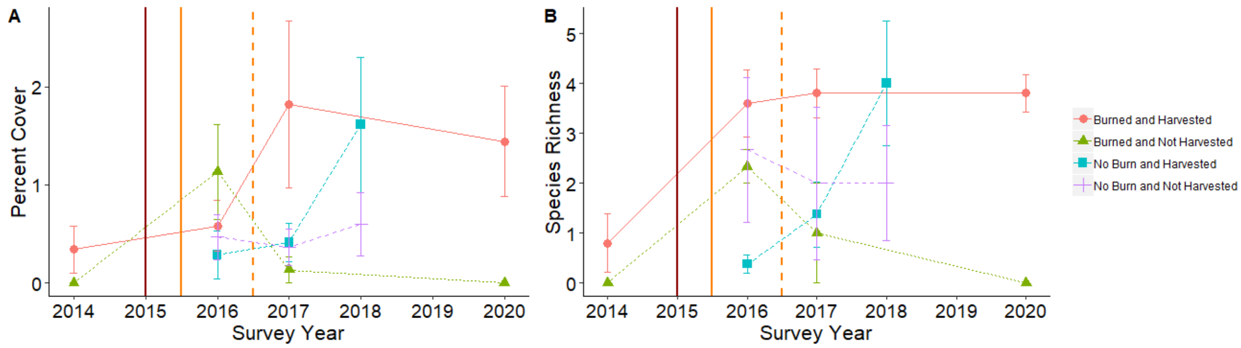

Figure 9. The percent cover (A) and species richness (B) of exotic species (grass, herbaceous and forb species combined) in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

OF Native Shrub Species in the B Layer

Percent cover of native shrubs species decreased after wildfire from ~12-13% to ~2-5% in year 1, with the decrease most severe in plots that were burned and not harvested (significant BACI interaction in full model, $p = 0.0008$; Figure 10a). In the Kettle East model, no differences were detected over time ($p = 0.06$) or with or without harvesting (salvaging; $p = 0.99$), despite a trend for plots that were both burned and harvested to have less of a decline in cover over time.

Species richness remained unchanged before and after wildfire whether harvested (salvaged) or not (~3-4 species at all survey times), whereas unburned control plots had higher species richness over time regardless of whether plots were harvested (from ~3 to ~5 species; significant BACI interaction in full model, $p < 0.0001$; Figure 10b). This finding suggests that wildfire suppressed the increase in species richness of the B layer shrubs that may otherwise have been expected without burning. In the Kettle East model, no differences were detected over time ($p = 0.18$) or with or without harvesting ($p = 0.96$).

Overall, wildfire decreased percent cover and species richness of shrub species in the B layer compared to control plots, but this layer was able to recover to close to values pre-fire relatively quickly (i.e., 5 years after fire for percent cover, 2 years after fire for species richness). Analyses suggest that harvesting had very little influence, if any, on percent cover or species richness of shrub species.

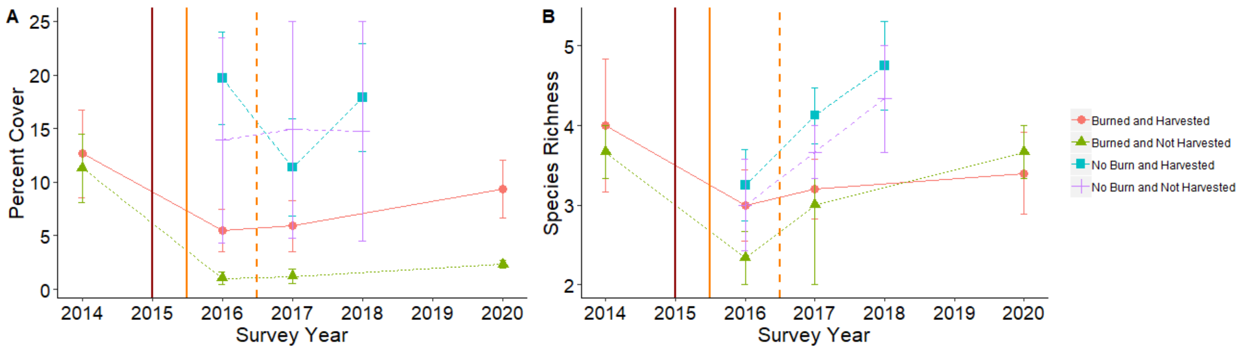

Figure 10. The percent cover (A) and species richness (B) of native shrubs species of the B Layer in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

OF Trees in the B Layer

Wildfire increased the percent cover of coniferous and deciduous trees in the B Layer from ~1% to ~2% (significant BACI interaction in full model, $p = 0.003$; Figure 11a). This pattern did not differ by whether the plot was harvested or not within the Kettle East plots (Kettle East model, $p = 0.26$). Years 1 and 2 after fire had similar levels to pre-fire values, but values doubled by year 5 (Kettle East model, $p = 0.0005$). In contrast, no changes occurred in the Rexin control plots over time.

Wildfire increased the species richness of coniferous and deciduous trees in the B Layer from < 1 species to up to 3 species (significant BACI interaction in full model, $p = 0.004$; Figure 11b). This pattern did not differ between plots that were harvested (salvaged) or not in the Kettle East site (Kettle East model, $p = 0.79$). Species richness in Kettle East plots already doubled by years 1 and 2 after the fire compared to pre-fire levels, and became even greater by year 5 after fire (Kettle East model, $p = 0.001$). In contrast, no significant changes occurred in the Rexin control plots over time.

Overall, wildfire increased both the percent cover and species richness of coniferous and deciduous trees in the B Layer, with the greatest values occurring five years after wildfire. Conifer planting did occur in three of the six burned and harvested Kettle East plots, but at very low levels. Additionally, natural regeneration was observed in 2017, with even more visible in 2020. This natural regeneration was often at much greater levels than that from planting within these specific plots.

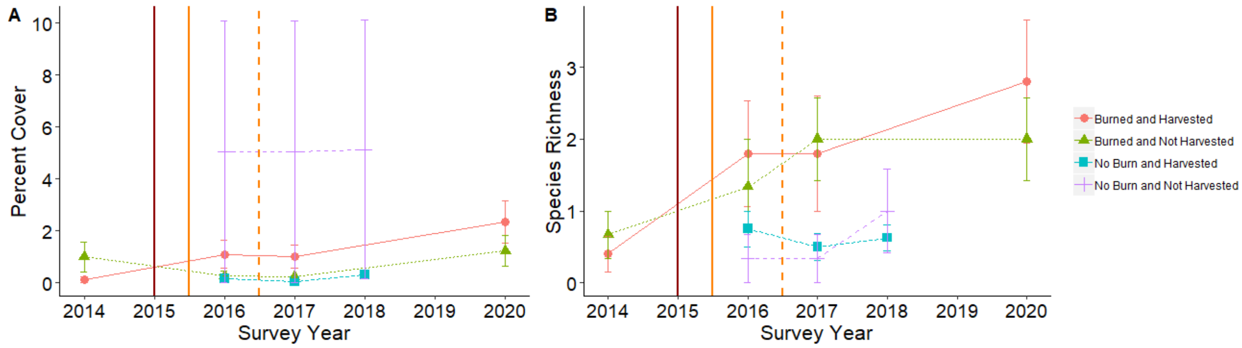

Figure 11. The percent cover (A) and species richness (B) of conifeorus and deciduous tree species in the B Layer in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

OF Trees in the A Layer

Wildfire dramatically reduced percent cover of deciduous and conifeorus trees of the A Layer regardless of harvesting (salvaging) in Kettle East plots from ~50% to ~5% (significant BACI interaction in full model, $p < 0.0001$; Figure 12a). Harvesting alone at the Rexin site also reduced percent cover of the A layer from ~38% to ~18%. Within the Kettle East model, time relative to intervention (i.e., wildfire or wildfire plus salvage) influenced cover ($p < 0.0001$), but values did not differ in years 1, 2 or 5 post-fire, with all values being significantly lower than pre-fire levels at <5%.

Wildfire and harvesting (salvaging) both reduced the species richness of trees in the A Layer within plots, particularly if both interventions occurred (significant BACI interaction in full model, $p = 0.0003$; Figure 12b). For Kettle East plots, time relative to intervention influenced cover ($p < 0.0001$). Despite lack of statistical significance, there is a trend for wildfire and harvesting to result in an immediate decrease in species richness of the A Layer, whereas plots that were not harvested after wildfire did not exhibit the same timeline for severity in decrease in species richness but instead gradually decreased with time (non-significant BACI interaction in Kettle East model, $p = 0.19$; Figure 8b). This gradual decrease was likely a direct result of scorched trees dying over time.

Overall, both wildfire and harvesting reduced the percent cover and species richness of the A layer, which is not suprising given that both interventions actively remove this layer. It takes many years for species to germinate and grow to be large enough to become part of the A layer again, and thus it is also not surprising that values have not recovered by five years after fire or harvesting.

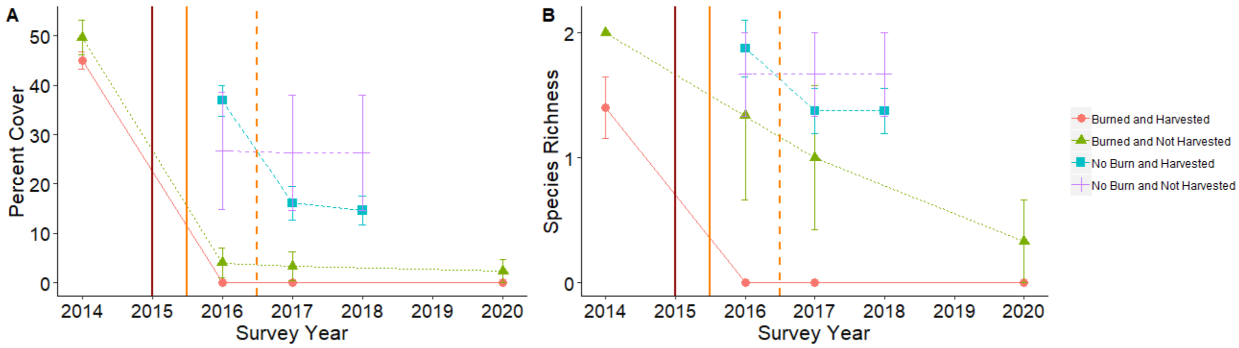

Figure 12. The percent cover (A) and species richness (B) of mature coniferous and deciduous tree species in the A Layer in Open Forest plots in Rexin plots that were harvested and not burned (blue), Rexin plots not harvested and not burned (purple), Kettle East plots that were burned oin the 2015 wildfire and subsequently harvested (red) and Kettle East plots that were burned in the wildfire but not harvested (green). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The solid orange line represents when harvest occurred in Kettle East for the 5 of 8 plots harvested. The dashed orange line represents when 8 of 11 plots were harvested in Rexin.

Open Range Plots

There was only one Open Range (OR) plot within the Kettle East site which experienced wildife, and one OR plot assessed as a control in the Rexin site. Both plots had thin, shallow soil on a steep rocky outcrop. Because there were only two plots, one per experimental treatment, no statistical analyses were performed on these plots. Instead, raw values of percent cover and species richness were only visually depicted and trends cautiously commented on.

OR Native Grass Species

Trends suggest that wildfire on open range plots caused an initial increase in the percent cover of native grass species from 20% pre-fire to 26% and 33% in years 1 and 2 after burning, but that there may be a dramatic decrease to 12% by year 5 (Figure 13a). In contrast, the unburned control plot varied much less annually from 20-24% (Figure 13a). This decrease in 2017 and 2018, however, may be strongly linked to drought since these were dry years (Figure 4). Additionally, grazing by cattle in 2017 to 2020 may have contributed to the decline by year 5 after wildfire (2020), given that cattle grazing began in the area again in 2017 at low density, with increased cattle grazing by 2020.

The increase in species richness from 3 to 4 species may be a result of wildfire, or may be by chance, given that the contol plot also varied annually in species richness from 1 to 2 species (Figure 13b).

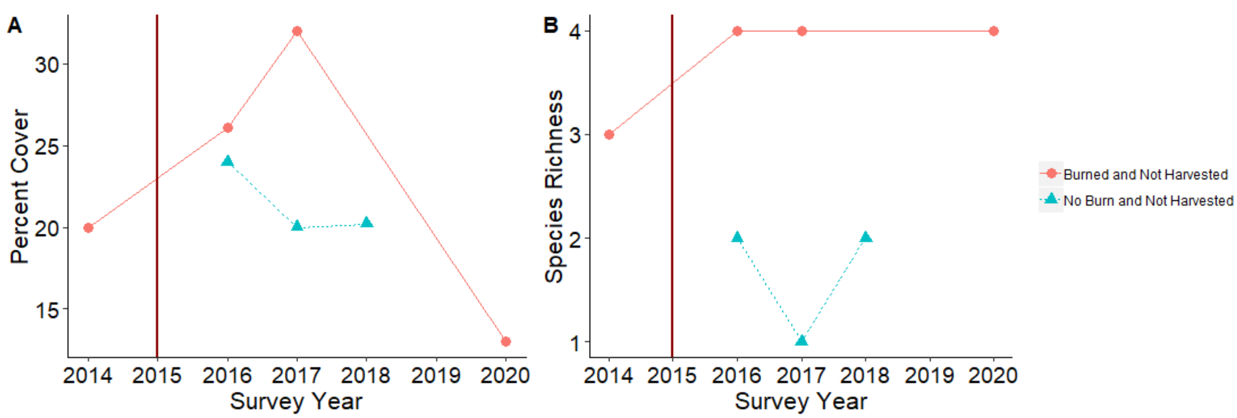

Figure 13. The percent cover (A) and species richness (B) of native grass species in Open Range plots in Rexin plots that were not burned nor harvested (blue) and Kettle East plots that were burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

OR Native Herbaceous and Forb Species

Percent cover of native herbaceous and forb species changed little from before wildfire compared to any year after wildfire (8-11%; Figure 14a). The slight variation in percent cover after wildfire of all native herbaceous and forb species observed in the open range plot at Kettle East is more likely a result of annual variation than fire given that annual variation was also observed in the unaltered control plot, but at higher values (16-20%; Figure 14a). There was greater percent cover in the control plot during the first surveyed year (20%) compared to the first survey conducted in the burned plot (8%). We observed a 2.5-fold increase in species richness after burning from 7 to 18 species, but a 2-fold increase over time is also observed in the unburned Rexin plot from 6 to 12 species, suggesting that an increase over time may have occurred regardless of wildfire, but perhaps to a lesser extent (Figure 14b).

Percent cover of native herbaceous and forb species with an annual life cycle varied minimally before wildfire compared to years surveyed after wildfire (0-1.8%; Figure 15a). Further, the percent cover and species richness of this group increased dramatically in unaltered control plots (1% to 6% and 1 to 5 species, respectively), suggesting that wildfire may have hindered an increase in percent cover for species with an annual life cycle (Figure 15a). Additionally, the observed increased in species richness after fire from 1 to 5 species was likely due to annual variation given the similar trajectory in the unaltered control plot (Figure 15b).

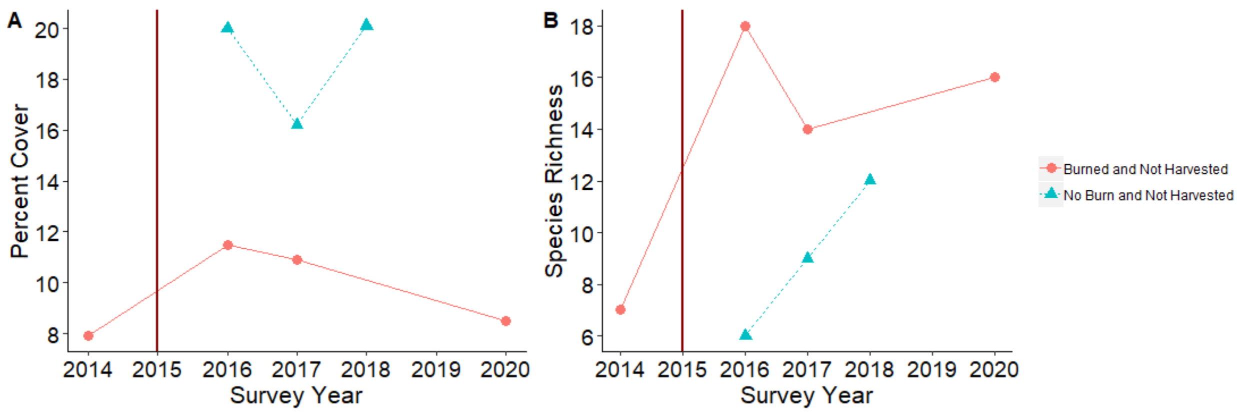

Figure 14. The percent cover (A) and species richness (B) of native herbaceous and forb species in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plots that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

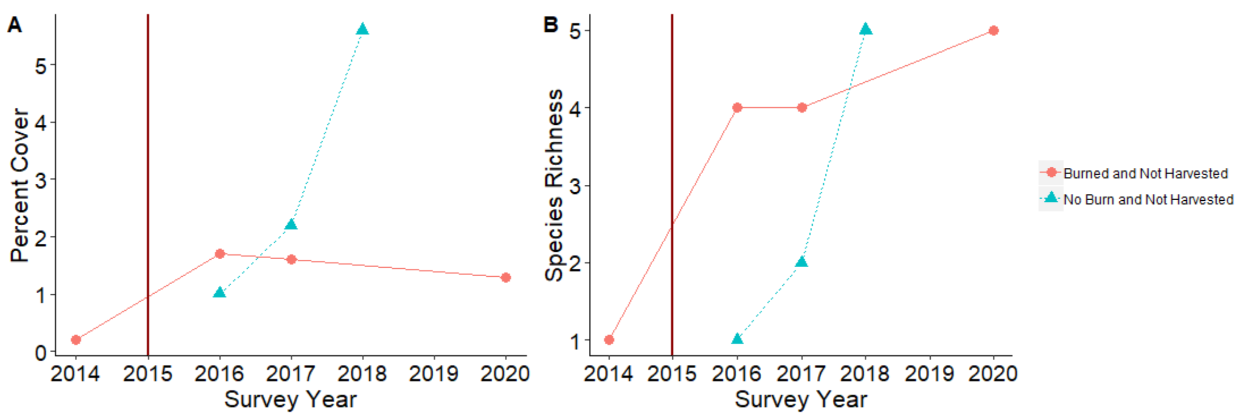

Figure 15. The percent cover (A) and species richness (B) of native herbaceous and forb species with an annual or bienniel life cycle in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plot that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

The percent cover of native herbaceous and forb species with a perennial life cycle also varied little from before wildfire compared to any year after wildfire (~8-10%; Figure 16a). In contrast, the unaltered control plot had a decrease in percent cover over time from ~20% to ~14%, and had overall higher cover during all years surveyed (Figure 16a). Annual variation exists in species richness for this group in both the burned and control plots, but the increase is far more dramatic in the burned plot in which there was an increase from 6 to 14 species, compared to an increase of 5 to 7 species in control. Thus, wildfire may have increased the species richness of native herbaceous and forb species with a perennial life cycle, particularly one year after fire (Figure 16b). This result may also be related to surveyer bias given that baseline plots for these plots was conducted by a different individual than subsequent plots.

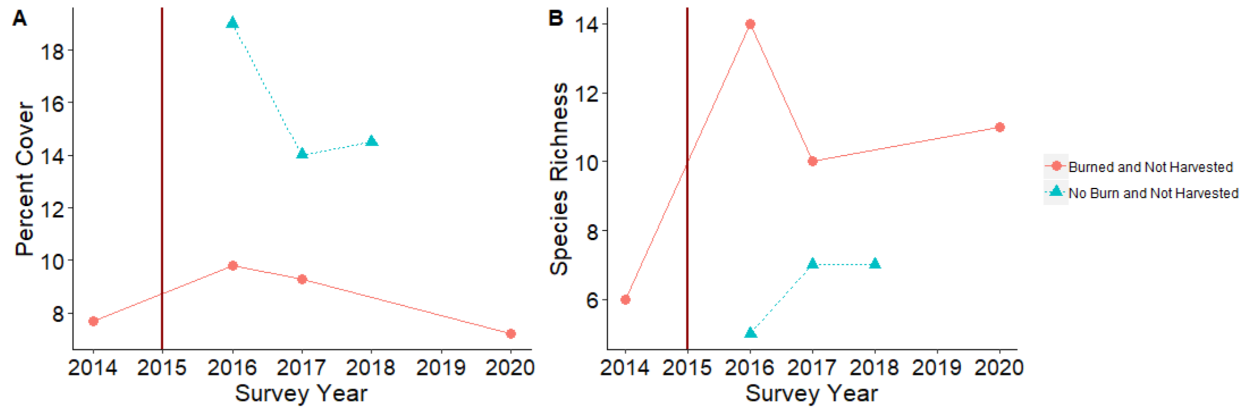

Figure 16. The percent cover (A) and species richness (B) of native herbaceous and forb species with a perenniel life cycle in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plots that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

OR Exotic Grass, Herbaceous and Forb Species

The percent cover of exotic grass, herbaceous and forb species was low in all surveyed years (~1-4%), but it also decreased after wildfire to about half the level it was before wildfire (Figure 17a). In contrast, the unaltered control plot had a higher percent cover of exotic species (~4-8%) in all years, with much annual variation. The species richness of exotic species appears to likely have varied annually with environmental condtiions given similar annual values in both burned and control plots, despite an appearance of an increase in exotic species after fire otherwise (Figure 17b). Additionally, the wildfire may have resulted in removal of the seed bank, resulting in a need for more dispersal events for exotic species.

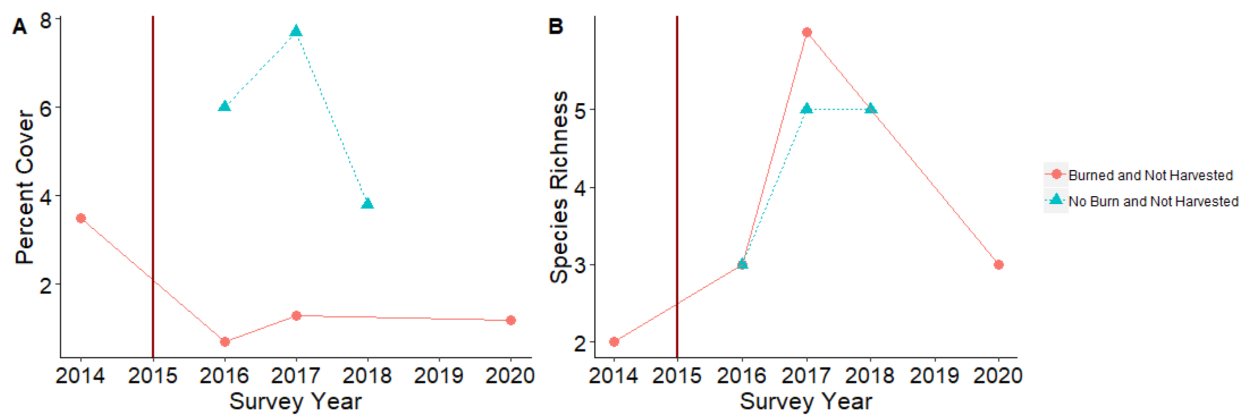

Figure 17. The percent cover (A) and species richness (B) of exotic grass, herbaceous and forb species in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plot that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

OR Native Shrub Species in the B Layer

There were no shrub species found in the open range plot at the Rexin site, making comparions impossible for differences over time compared to the burned plot (Figure 18). Percent cover was very low in the burned plot (1-1.8%), as was species richness (2-4 species; Figure 18). Overall, there is a trend for both percent cover and species richness to decrease after wildfire, with species richness being reduce to half the value observed before fire (Figure 18). These sites had very thin soil, and it is possible that the loss of cryptogamic crust (an important biotic crust layer that stabalizes soil and retains moisture) may have resulted in suboptimal conditions for shrub species to thrive after wildfire.

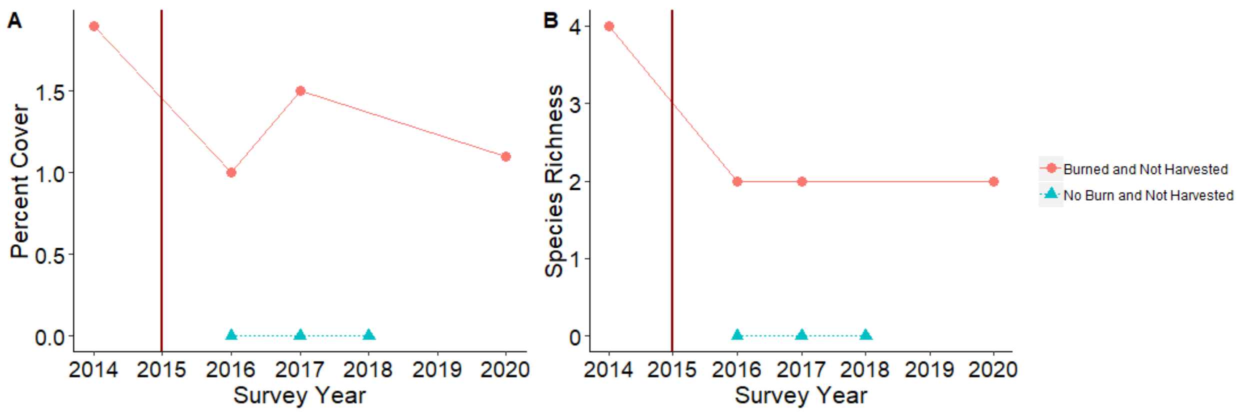

Figure 18. The percent cover (A) and species richness (B) of native shrub species in the B Layer in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plot that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

OR Trees in the B Layer

There was very low cover of coniferous and deciduous trees in the B Layer within the Kettle East open range plot before wildfire (0.5%), and this increased to 1% post-fire (Figure 19a). Species richness showed no change over time, holding a consistent species richness of 1 before and after wildfire (Figure 19b). The control Rexin plot had no tree species in the B Layer in any surveyed year.

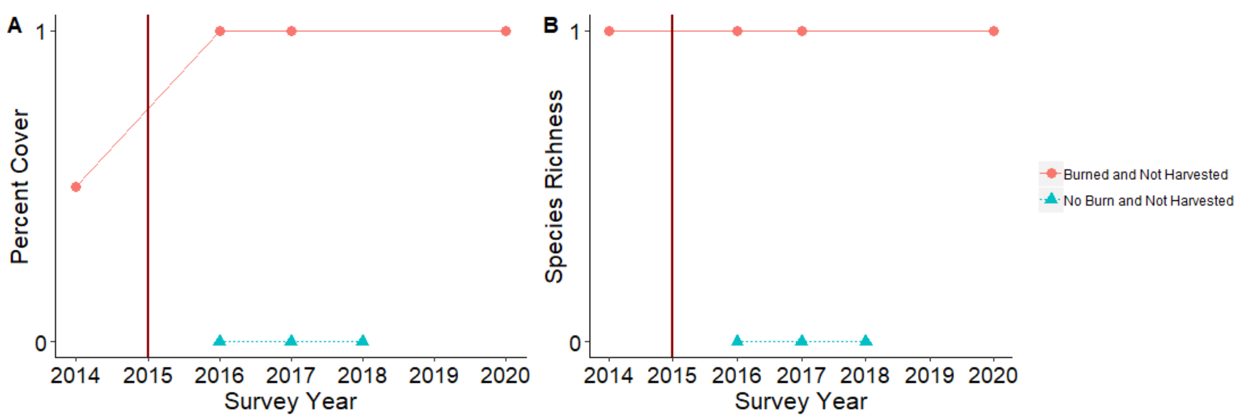

Figure 19. The percent cover (A) and species richness (B) of coniferous and deciduous tree species in the B Layer in Open Range plots in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plot that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

OR Trees in the A Layer

There were very few coniferous and deciduous trees in the Kettle East open range plot before wildfire (2%), and this diminished to 0% post fire (Figure 20a). Similarly, species richness decreased from 1 before wildfire to 0 after wildfire (Figure 20b). The control Rexin plot had no tree species in the A Layer in any surveyed year.

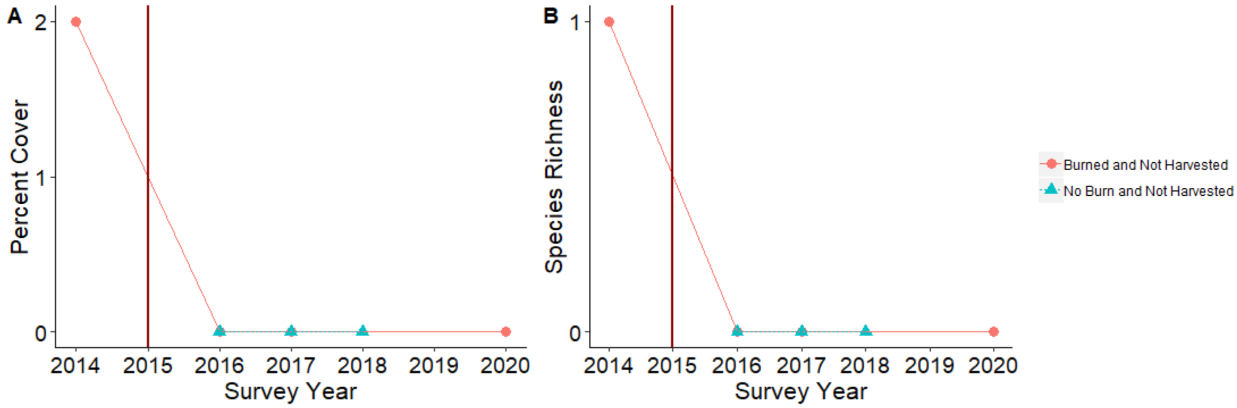

Figure 20. The percent cover (A) and species richness (B) of coniferous and deciduous tree species in Open Range plots in the A Layer in the Rexin plot that was not burned nor harvested (blue) and the Kettle East plot that was burned and not harvested (red). The vertical solid red line represent when a wildfire impacted the entire Kettle East site. The Rexin site was unaffected by fire.

Discussion

Impacts of Wildfire on Vegetation in Open Forest Plots

The impact of both wildfire and harvesting (salvaging at Kettle East sites) varied by species grouping and metric measured (i.e., percent cover or species richness) for the open forest plots (Figures 5-12). We will attempt to discuss the influences of wildfire and harvesting separately here, but it is important to remember that these two factors often do not work in isolation and that both burning and harvesting together frequently influence percent cover and species richness (Dodson et al. 2007; Wayman and North 2007; Dodson and Peterson 2010). As a result, harvesting is also often discussed alongside burning in this section when appropriate.

Of the five groups of interest, wildfire resulted in decreases in percent cover for native grass species (Figure 5), shrubs in the B layer (Figure 10), and trees in the A layer (Figure 12). Decreases in shrub cover within the first 5 years following a fire are consistent with findings in many other studies (Metlen et al. 2004; Wayman and North 2007; Willms et al. 2017), as were decreases in grass cover (Dodson et al. 2008). However, both native grass species and shrub species had percent cover values that increased annually post-fire, with trajectories suggesting levels should at least reach values similar to those pre-fire, if not exceed them, in the coming years. This assertion is supported by a study in the East Kootenays which has found that there was a 2-4 year lag in increase in grass species post-fire and post-harvest, with increases observed 5 or 6 years after intervention (Newman et al. 2012). Further, Abella and Springer (2015) found that total understory plant abundance frequently declined within 4 years of fire, but increased when studies evaluated the same plots greater than 5 years after fire. Moore et al. (2006) observed that in ponderosa pine forests of Arizona, that grass species cover continued to increase over time after fire and harvest. Thus, more time may be needed to see increases in percent cover in the Kettle East site since intervention. Lastly, assessing changes in the A Layer will take more time since seedlings will not have had sufficient time to recruit into the A Layer.

Despite decreases in percent cover in many of the groups of interest, wildfire increased the percent cover of native herbaceous and forb species, with values up to 14-times greater (all species pooled together or those with a perenniel life cycle) than values pre-fire (Figures 6-8). Similar findings were observed in a 6-year study in the east Kootenay in which herbaceous biomass nearly doubled after fire given the increased sunlight reaching the forest floor after canopy cover declined (Newman et al. 2012). The current patterns, however, show a trend for the initial increase in native herbaceous and forb species to slowly decline with time, but remain much higher than pre-fire levels at year 5 (Figures 3-5), matching findings of Halpern et al. (2012). The observed pattern here is likely a result of an initial spike in the abundance of fireweed immediately after the moderate to high intensity fire, with a subsequent decline; fireweed is not expected at such abundance after prescribed burns of low fire intensity, however. Assessing these data at the 7 and 10 year timeframe will reveal whether levels remain high (e.g., Newman et al. 2012), or return to pre-fire levels (e.g., Kerns and Day 2018). Further, when combined with harvesting, the increase in cover of native herbaceous and forb species after fire was lower than the increase observed with just wildfire, similar to findings that demonstrate that harvesting can reduce the percent cover of forb species (Metlen et al. 2004). Burning alone did not influence native herbaceous and forb species with an annual life cycle, despite such findings in other dry, fire-adapted forests (Rossman et al. 2018). However, burning and harvesting (salvaging in this case) combined did increase the species richness of native herbaceous and forb species with an annual or bienniel life cycle (Figure 5), matching findings of other studies in which burning or harvesting increased cover or richness of species only when both were present (Wayman and

North 2007; Dodson and Peterson 2010). Most of these studies, however, assess the impacts of harvesting before presribed burn, as opposed to salvaging after wildfire. Overall, the percent cover (<1%) and species richness (<2 species) of native herbaceous and forb species with an annual or bienniel life cycle (Figure 4) was substantially lower than those with with a perenniel life cycle (percent cover <5% pre-fire and 15-55% post-fire; species richness ~4-11 species; Figure 8). As fireweed declines, there may be more opportunity for species with an annual or bienniel life cycle to thrive.

Wildfire also resulted in an increase in the percent cover of coniferous and deciduous trees in the B Layer (Figure 11). Part of this increase may be due to planting in three of the plots observed; however, natural regeneration was noted in many plots in 2017 and 2020, suggesting that much of this pattern is from natural processes.

There was no influence of fire on the percent cover of exotic species in the full model, but the Kettle East model revealed that there was a short-term increase in exotic species after fire, which then declined in non-harvested plots (Figure 9). This increase was at low abundance, with pre-fire values being <1% and post-fire values being ~2% (Figure 9), similar to other studies that have found that exotic species cover is overall low in dry, fire-adapted forests (e.g., Dodson et al. 2008; Abella and Springer 2014; Rossman et al. 2018). Initial increases in exotic species cover following fire and thinning has been observed in other studies (Collins et al. 2007; Dodson et al. 2008; Nelson et al. 2008; Stoddard et al. 2011), but similar to our findings, these increases were often short-lived with values decreasing again by 6 years post-fire. Contrary to these findings, however, exotic species cover remained relatively high after 5 years of intervention in plots that were both burned and harvested (salvaged) despite their short-lived increase in plots that were only burned. This pattern may be caused by the fact that harvesting (salvaging) occurred after wildfire, as opposed to most studies which investigate harvesting followed by prescribed burns. Harvesting causes soil disturbance that allows exotic species to thrive, and the Kettle East salvage occurred in the spring and early summer, which resulted in abundant soil disturbance to promote exotic species occurrence and persistence.

For species richness, burning resulted in decreases for native grass species (Figure 5) and trees in the A layer (Figure 12). There was also a short-term increase in exotic species richness after fire, which subsequently declined (Figure 9). Burning had no effect on species richness for native herbaceous and forb species with a perennial life cycle (Figure 8) or for shrub species (Figure 10). These findings are in contrast to many other studies that observe an increase in species richness or diversity following fire and/or thinning (e.g., Dodson et al. 2007; Wayman and North 2007), suggesting that these sites may have had the seed bank removed during fire, be dispersal limited, or that the site may have overall low Beta diversity.

Native grass, forb, herbaceous and shrub species all aproached similar percent cover and species richness levels by year 5 compared to pre-fire conditions, except in some instances where harvesting increased their cover initially (e.g., percent cover of native herbaceous and forb species; Figures 6-8, 9). Thus, burning may result in short-term declines in key vegetation groups, but these decreases appear to be short-lived. Kerns and Day (2018) observed that native perenniel plant functional groups within Malheur National Forest of Oregon were able to resist or recover from burning and thinning within 5 years, but did not necessarily strongly respond. Similarly, Dodson et al. (2008) observed that thinning and burning treatments in dry confierous forests of Central Washington had mostly neutral to minor beneficial effects on understory vegetation, with only minor increases in exotic species. Other studies have found that there is an initial lag before understory species increase in cover compared to pre-fire levels until after ~5 years post-fire (e.g., Moore et al. 2006; Newman et al. 2012). For the Kettle East site, more time is needed to determine if values can increase relative to pre-fire levels.

Impacts of Harvesting on Vegetation in Open Forest Plots

Harvesting also had variable impacts across the species groupings and metric measured for open forest plots. These impacts were sometimes observed in combination with wildfire, but other times, the impacts were only observed in Rexin plots that were harvested and not burned. When differences were observed based on whether a plot was harvested or not for each species grouping, these changes tended to remain 5 years post-fire and post-harvest as opposed to returning back to pre-harvest levels. This is in contrast to the response to burning, in which cover and richness values approached levels close to pre-fire levels by 5-years post-fire for most vegetation groups.

Harvesting (salvaging) after burning decreased the percent cover of native grass species over time more severely than burning without harvesting, but had no influence on species richness (Figure 5). This reduction is likely largely due to a change in species dominance from an ecosystem dominated by pinegrass pre-fire, to one mostly dominated by bunchgrasses and early seral species (e.g., *Achnatherum species*, Sandbergs bluegrass (*Poa secunda*), Junegrass *(Koeleria macrantha*)), which often occur at lower densities. This dramatic reduction may also be in part due to soil disturbance from salvaging after wildfire, with more time needed before grass can establish. Harvesting alone had little influence on native herbaceous and forb species with a perenniel life cycle (Figures 6, 8). However, harvesting after wildfire reduced the magnitude of the observed increase experienced with wildfire compared to values before intervention (Figures 6, 8). This is consistent with findings that have demonstrated a decrease in forb cover in treatments that included harvesting (Metlen et al. 2004), but is in contrast to studies that have observed fire plus harvesting typically work together to increase cover and richness of many herbaceous species (Dodson and Peterson 2010). However, most studies have looked at the impacts of harvesting before prescribed burn, as opposed to salvaging after wildfire, such as occurred at the Kettle East site, which may be the cause of the different patterns observed.

Harvesting resulted in an increase in the percent cover and species richness of native herbaceous and forb species with an annual or biennial life cycle (Figure 7) and of exotic species (Figure 9). Such increases in species richness post-fire in species with an annual life cycle have been observed in other dry, fire-adapted forests, but these prior findings also observed this increase to be enhanced with fire (Rossman et al. 2018), in contrast to our current findings in which fire had no influence on this group (Figure 7). The increase in exotic species observed within 5 years of harvesting is consistent with findings in other studies (Nelson et al. 2008; Willms et al. 2017), and the overall low cover and richness of exotic species relative to other vegetation groups is also consistent with other findings (e.g., Nelson et al. 2008). In our study, harvesting was more likely than fire to increase exotic species cover and richness, and this may be due to differences in the nature of the disturbances (harvesting vs. fire), or from exotic species seeds being brought in on forestry equipment. However, most of the exotic species observed in these vegetation plots were annuals. Elsewhere in the burned region, many perennial invasive species, such as St. John's wort (*Hypericum perforatum*)*,* increased substantially in reponse to wildfire. Thus, these vegetaion plots do not capture all aspects of vegetation response within the Kettle East fire.

Shrub species experienced a more severe decline in percent cover when plots were burned but not harvested compared to those that were burned and harvested, with no influence on species richness

(Figure 10). This finding matches those found by others in which both burning and harvesting combined increased shrub cover (Dodson et al. 2008), but in contrast to other studies that have found harvesting to decrease shrub cover and harvesting with burning to have no influence on shrub cover (e.g., Collins et al. 2007). In the Kettle East site, shrub species were not targetted in the harvest, and this increased light penetration would lead us to expect this group to increase in harvested sites.

Harvesting dramatically decreased the percent cover of coniferous and deciduous trees in the A layer, as would be expected given the removal of large trees by harvesting and insufficient time for recruitment of seedlings into the A Layer (Figure 12). In contrast, hearvesting had no influence on the percent cover or species richness of coniferous and deciduous trees in the B Layer (Figure 11).

Although we have selected Rexin as a control site for Kettle East, harvesting methodology at Rexin was much different than harvesting at Kettle East. In the Kettle East site, all trees that might have survived the wildfire were left for retention while others were removed. As a result, Kettle East had very little canopy remaining, whereas Rexin had only a small decline in canopy with harvesting. This difference in response is seen in Figure 12, and may impact the response observed for all other vegetation groups.

Assessment of Open Range Plots

It is hard to make definitive claims about the influence of wildfire on the open range plots because there was no replication of treatments (i.e., plots that experienced wildfire compared to those that did not with similar environmental conditions otherwise). However, there were trends in the Kettle East burned plot relative to unburned Rexin plot. Specifically, wildfire potentially led to an increase in percent cover and species richness of native grass species, but with a dramatic decrease in percent cover 5 years after fire compared to pre-fire values (Figure 13). Variation over time for native herbaceous and forb species (Figures 14-16), and for exotic species (Figure 17), were similar in both burned and control plots, resulting in no detectable differences with fire. Both shrub species (Figure 18) and tree species in the A Layer (Figure 20) decreased after fire, but unaltered control plots did not have any shrub or tree species in any survey year, making this a difficult comparison. There was little to no change in the cover and richness of tree species in the B Layer (Figure 19). Neither open range plot was harvested due to low tree coverage, and thus no conclusions can be made about the effects of harvesting on open range plots.

Prescribed Burn Versus Wildfire

The 2015 burn in the Kettle East site was a wildfire, despite plans for a prescribed burn on the site for the subsequent year. Although prescribed burns are intended to mimic the ecological effects of wildfires and reduce fuel load, many studies have found that species may respond differently to prescribed burns compared to wildfire. For example, Pidgen and Mallik (2013) found that clearcutting plus prescribed burns created different vegetation communities than did wildfires or sites that were only clearcut. In another example, Alba et al. (2015) observed that prescribed burns had short-term influences on both native and exotic species, whereas wildfire tended to have minimal long-term effects on native species but promoted the occurrence and abundance of exotic species. In contrast to much of the cited literature in this report, Kettle East experienced an unplanned wildfire with subsequent salvaging, reversing the order of the harvest relative to the burn. In unharvested and burned plots in the Kettle East site, we luckily observe a decline in exotic species following the initial increase in exotic species cover; however, in the plots that were also harvested (salvaged) following wildfire, exotic species cover remains greater than before fire but at low levels overall (Figure 9).

One reason for the difference in responses for vegetation groups is that prescribed fires occur in the spring or fall, whereas wildfires tend to occur in the summer. Even within prescribed burns, late season burning has been shown to have greater impacts on reducing native species cover than early season burns (Knapp et al. 2007). The life stage of plants determined the impact of wildfire and prescribed burns. Thus, often late summer or fall burns can have a lower impact on many plant species which have completed growth and reproduction for the season, whereas spring burns may disrupt growth and reproduction in many plant species. More research is needed in comparisons of early versus late season burns, and in how fire severity at these different times can impact vegetation.

The intensity of the burn also varies between prescribed burns and wildfires, with prescribed burns more often burning at lower intensities than wildfires. The wildfire at the Kettle East site was indeed mostly deemed a high-intensity fire. High intensity fires have been shown to reduce soil organic matter, reduce water infiltration rates, and alter soil physical properties by increasing pH and modifying nutrients (e.g., Kennard and Gholz 2001). These changes may impair growth of vegetation (e.g., Giovannini et al., 1990); however, the increased nutrients conversely may promote growth (e.g., Hungerford et al., 1990). We do indeed see patterns that differ from prescribed burns in other sites within the Boundary Restoration Project (Tedesco 2020). For example, these other sites mostly exhibited a sharp decline in herbaceous and forb species after prescribed burns, whereas after the Kettle East wildfire, we observed an increase in native herbaceous and forb species after wildfire (Figures 6, 8). This increase in largely a result of the high abundance of fireweed, however, which thrives after moderate to high severity fires, and is not expected after low intensity prescribed burns. Overall, each site within the BREP often had its own unique trajectory (Tedesco 2020), suggesting that vegetation response to fire can be quite variable, regardless of whether the fire is from wildfire or a prescribed burn.

Evaluating Targets

Of the initial four 10-year targets outlined for this project (Tedesco 2020), two of the four objectives are potentially satsifed by year 5 for the open forest plots (Table 3). Open range targets are not assessed here due to low sample size. Specifically, the canopy cover of trees in the A layer is dramatically reduced post-fire in all OF plots, indicating that stem density and layer distribution has indeed been altered (although these specific metrics are not assessed here). Herbaceous and forb species percent cover, particularly of perennial species, has increased dramatically post-fire, particularly if the OF plot was not harvested (salvaged) subsequently. However, much of this increase is likely due to one species: fireweed. Targets relating to increased grass and shrub cover remain unmet 5 years after fire in OF plots. Both of these groups decreased initially after fire and have not yet returned to pre-fire levels despite increasing trends post-fire that suggest that these groups may soon reach or exceed pre-fire levels. The success of reaching these targets will need to be assessed at the 10-year mark post-fire, with many studies suggesting that in similar ecosystems, increases in cover or richness for these vegetation groups were observed after 5 or 6 years after intervention but not earlier (e.g., Moore et al. 2006; Newman et al. 2012). Additionally, in the global analysis of the 2015-2020 assessment of the Boundary Restoration Project (Tedesco 2020), grass species initially decline after fire, but began increasing to above pre-fire levels 5 years after fire.

Table 3. The 10-year target outlined for the vegetation monitoring project for open forest plots and the current 5-year outcome.

Target	Result	Target Satisfied?
Reduced conifer stem density and layer distribution to prescription targets	Results do not comment on stem density, but canopy was dramatically reduced in both open range and open forest plots, over-achieving on this target.	Potentially yes
Increase grass cover by 10% or more over ten years	Grass levels decreased to 50% by year 5 post-fire compared to pre-fire levels for open forest. Open range levels increased in years 1 and 2, but plummeted by year 5.	Not by year 5
increasing herb/forb cover by 10% or more over ten years	In open forest plots, percent cover increased from 4% to 18% in burned and harvested (salvaged) plots, and from 4% to 55% in burned and not harvested plots. However, these values were higher in years 1 and 2 after fire, and most of this increase was due to one species (firweed).	Target met by year 1, 2 and 5; but caution given mostly due to one plant species (fireweed)
increasing shrub cover by 15% or more over ten years	In open forest plots, percent cover of shrub species decreased and neared pre-fire levels by year 5, and species richness unchanged was unchanged by fire.	Not by year 5

Reducing conifer stem densities and layer distribution to prescription targets (OF)

Our analyses did not look at the actual reduction of crown closure or canopy cover from the wildfire and harvesting (salvaging). Although percent cover is presented here, anecdotally we can report that stem density actually over-achieved and was below 250 stems/hectare after wildfire. The dramatic reduction in the percent cover of coniferous and deciduous trees in the A Layer (Figure 12) is not unexpected. Harvest treatments result in a notable reduction in stems/ha on site so logically percent cover should decrease. Additionally, decreases in percent cover may occur in initial years following burning as scorching, where it occurs, can reduce crown vigor. Such cover may increase again over time if the crowns of the remaining trees flush in response to increased light and space.

Analyses of multiple sites in the BREP demonstrated no reduction in percent cover or species richness of the A Layer (Tedesco 2020). In contrast, we observe dramatic reductions in percent cover and species richness of the A Layer in the Kettle East site. This difference may exist because of the overall high burn severity of the wildfire as a result of a hot, dry summer and heavy fuel loads, which killed more trees than a typical prescribed burn would. The salvage prescription included stem densities that would promote habitat suitability for Lewis's woodpecker and retention of largest trees onsite. However, it is possible that the specific plots monitored here may have been in areas where fewer trees were retained than the surrounding area during harvest for plots that experienced harvesting (salvaging), or that the burn severity may have been greater compared to the surrounding area.

Increasing native grass cover (OF)

As of five years post-fire, grass cover and richness remain reduced compared to pre-fire values in Kettle East (Figure 5). This reduction in cover is likely in large part due from a shift in community composition from one dominated by pine grass, to one dominated by bunchgrasses and early seral species that occur at lower densities. However, there is additionally a trend for cover to increase from years 1 to 2 to 5 post-fire, with the potential for a continued increase by year 10. Although some studies have observed that grass species cover can increase as early as 2 years after fire (Moore et al. 2006), others have found that understory regeneration broadly can experience a lag of 4-6 years before increases are observed (e.g., Abella and Springer 2015). Many of these trajectories are species-specific, and we suspect that the observed delay in grass recovery is due to soil disturbance, particularly after salvaging, and the major shift in dominant grass species. We predict that the grass cover will start to increase now that the pinegrass has root systems and that the bunch grasses are germinating in areas that were salvaged. Whether values return to or exceed pre-fire values remains to be seen.

Increasing native herbaceous and forb cover (OF)

We observed an immediate increase in native herbaceous and forb species following wildfire at the Kettle East site, with a subsequent decline over time (Figure 6), matching findings of Halpern et al. (2012). However, much of this increase is due to one species alone: fireweed. Fireweed is already declining in these plots and we predict that the ecosystem may become more grass dominated once the plant community stabilized. Although values at year 5 post-fire remain higher than pre-fire values, the trajectory does suggest that the values may continue to decline over time.

Because previous studies have suggested that lumping annuals and perennial species together can mask patterns, we separated them here. For example, Rossman et al. (2018) observed annual herbaceous vegetation responded more rapidly to burning than perennial in the short term (2-3 years) and that this trend continued into the long-term (10-13 years) at different spatial scales. However, annual species were at very low cover (<2%), and thus did not influence the broad patterns for all herbaceous and forb species combined for the Kettle East site. Annual species demonstrated an increase in cover and richness with harvesting but did not show any response to wildfire. Part of this lack of response in species with an annual and biennial life cycle may be associated with the dominance of fireweed in the years following the wildfire. By year 10, there may well be a very different pattern for annuals and biennials.

Increasing shrub cover (OF)

Despite the target for increased shrub cover, there was a decrease in shrub species cover detected with wildfire for Kettle East, with values nearly recovering to pre-fire values by year 5 post-burn (Figure 10). Willms et al. (2017) noted a consistent response in their meta-analysis of a reduction in shrub cover following burns, although these studies primarily focused on the effects of prescribed burning as opposed to wildfire. The trajectory from years 1 to 2 to 5 post-fire suggest that shrub cover is increasing over time. Many studies have demonstrated an initial lag before understory species increase in cover compared to pre-fire levels until after ~5 years post-fire (e.g., Moore et al. 2006; Newman et al. 2012). Thus, it is possible that this trend may continue with values increasing by year 10. However, shrub cover may also return to pre-fire levels and not meet our 10-year target, or transition into a completely different community given the lack of a mature canopy post-fire at Kettle East. It is possible that shrub species may increase further, but subsequently decline as they are replaced with grass species, in part due to browsing. There may be a subsequent increase in shrub cover with even more time, however, as canopy cover increases with successful recrutiment of tree species. The Kettle East area broadly is typically grass dominated when there is no canopy cover, and shrub dominated when there is mature canopy. Because of the dramatic reduction in canopy, shrub cover may not meet the targets initially established prior to wildfire by year 10.

Post-Fire Invasive Plant Management

Extensive fuel loading along the valley bottom and lower slopes of the Kettle River, combined with what was described as the perfect triangle of high temperatures, high wind and tinder dry grass, resulted in a stand replacing fire north of Rock Creek, BC in August of 2015. The disturbance associated with fire suppression activities, infrastructure replacement (e.g. range fencing and power pole replacement), and salvage harvesting created new opportunities for invasive plant species to be introduced or to expand their range. The valley bottom and lower valley slopes had a history of many invasive plant species being well-established, and local land managers recognized the need to implement an aggressive post-fire treatment program to prevent further expansion into recently burned areas. To mitigate the potential negative impacts of invasive plant expansion in this high value areas, a five-year plan for invasive plant management was developed (2016) and implemented from 2016-2020.

The plan recommended management actions focused in locations with invasive plant species identified as priority according to the species priority list within the *Operational Plan for Invasive Plant Management in the Boundary* (Boundary Invasive Species Society 2016), monitoring to assess the survival of invasive plants and biological control insects post-fire, and utilizing herbicide treatments to suppress seed production post wildfire to give the natural plant communities time to recover.

Prior to the wildfire in 2015, many historical invasive plant sites had not been monitored, resulting in the lack of an accurate inventory of presence and abundance records for species. Surveys were conducted in summer 2016 to assess priority invasive plants sites as identified in the five-year management plant.

Invasive plant occurrence and treatment information for the project area is contained in a provincial database referred to as the Invasive Alien Plant (IAP) database. Within this database each occurrence record for a species has a unique site identification number (site ID) enabling tracking changes in invasive plant density and distribution over time. All monitoring and treatment information for this report was downloaded from the IAP database. The monitoring work was completed by staff of the Boundary Invasive Species Society (BISS) while the herbicide treatment work was completed by contractors hired by the Regional District of Kootenay Boundary (RDKB) and funded through various agreements with agencies and industry.

Overview of Invasive Plant Monitoring

Post Fire Invasive Plant Response

The post fire invasive plant management plan had made assumptions based on the literature available through the Fire Effects Information System (FEIS)[1] about likely species response (survival, timing of flowering) post-wildfire. The information available for local invasive plant species had many gaps, so monitoring was done to assess the accuracy of the assumptions about expected response. As predicted, many invasive plants survived the fire, and some were delayed in producing flowers by 1-2 months depending on soil burn severity while others showed no difference in timing of flowering. Overall, the expectations for survival and recovery as laid out in the plan were observed.

Low Soil Burn Severity

In low burn severity areas, bluebunch wheatgrass, rough fescue (*Festuca campestris),* and other bunchgrass species survived with litter remaining on the soil in some locations (Figure 21). The native and invasive plants recovered quickly (Figure 22), with very little observable difference in cover or flowering

[1] FEIS database available at https://www.feis-crs.org/feis/

period when making a visual comparison to unburned areas. Sulphur cinquefoil (*Potentilla recta*), dalmatian toadflax *(Linaria dalmatica*) and diffuse knapweed (*Centaurea diffusa*) were observed growing soon after snow melt in the spring of 2016. Native bunchgrasses had green shoots in March. This rapid recovery mainly occurred on the south end of the fire in the open grasslands, along roadsides, and in areas with sparse trees.

Figure 21. Regrowth of surviving rough fescue (Festuca campestris) plant with evidence of leaf litter remaining post-fire. Rock Creek, October 29, 2015.

Figure 22. Regrowth of surviving St John's wort, dalmatian toadflax and diffuse knapweed (left to right) the following spring. South of Kettle River Recreation Area, March 29, 2016.

Moderate Soil Burn Severity

In moderate burn severity areas where a crown fire had occurred, there was little to no litter layer remaining on the soil; however, the soil was still present. Surface growth of plants had been completely removed, but roots of perennial species survived. Native bunchgrasses greened up in early spring along with perennial invasive plants including sulphur cinquefoil, diffuse knapweed, St John's wort and dalmatian toadflax. Annual species were delayed in growth but were visible in some areas later in the season.

Many common native species, including arnica *(Arnica cordifolia*), silky lupin (*Lupinus sericeus*), and thread leaved phacelia (*Phacelia linearis*), were thriving by June 2016 (Figure 23). By August, open forest areas had diverse native plant communities in flower (Figure 24, Figure 25). Previously forested areas had a flush of pinegrass that produced seed in 2016 in response to the open canopy (Figure 26). In highly disturbed harvest areas, new annual weedy species started showing up in 2017 including a visible increase in sweet clover (*Melilotus alba*), mullein (*Verbascum thapsus*), pricky lettuce *(Lactuca seriola)* and other low priority exotic species. These transitory weedy species appeared to decline by 2020 based on observations. This recovery pattern occurred mostly in the open forest areas on the south half of the fire although there were some pockets of moderate soil burns severity as well in the north with similar plant recovery pattern.

Figure 23. Regrowth of surviving bluebunch wheatgrass and new growth of thread leaved phacelia. Kettle River East Road, June 15, 2016.

Figure 24. Recovery of arnica, silky lupin, fireweed with annual weedy species growing. Riverside Road, June 24, 2016.

Figure 25. Kettle River Recreation Area with dense fireweed and many native species. August 3, 2016.

Figure 26. Fireweed flowering and pinegrass producing seed in response to increased light. August 17, 2016.

High Burn Severity in Forested Areas

Many of the forested areas with high soil burn severity experienced loss of duff and surface soil, exposing mineral soil and rock (Figure 27); however, in some locations, this was quite patchy and limited to areas with heavy fuel loads pre-fire (Figure 28). No invasive plants were observed growing in these areas immediately after fire. Instead, early colonizer species including liverworts (*Marchantia polymorpha*) and fireweed were commonly found. By late summer and fall, fluffy fireweed seed covered the ground (Figure 29). As a result, there was a dense flush of fireweed from 2017 to 2019, which was the expected recovery process after a burn. Slowly, native species are returning to these areas. Most areas with this level of vegetation removal occurred in heavily forested areas pre-fire.

Figure 25. Bare ground exposing rocks with no vegetation (right). March 2016. Picture 10. Patches of high intensity burn with only fireweed growing (lower). June 24, 2016.

Figure 26. Patches of high severity burn with only fireweed growing (lower). June 24, 2016.

Figure *27*. Suckering of willows from surviving roots with an understory of liverworts growing and fireweed seed covering ground at Kettle East site. August 17, 2016.

Invasive Plant Surveys Completed

Invasive plant monitoring in 2016 and 2017 focused on completing surveys at previously known sites of priority species and completing surveys along roadside corridors to assess scope of herbicide treatment required. Many areas within the fire perimeter had not been monitored or surveyed for many years prior to the fire, so accurate inventory information was required to direct treatment contractors. Monitoring of biocontrol insects is included in a separate section of the report. Monitoring was completed by staff of BISS using the Collector app (2018-2020) and GIS Pro app (2016-2017) installed on either an iPad, iPhone, or tablet with built in GPS. All the records collected were then uploaded into the IAP database.

A map showing the location of surveys is included in the Appendix 1. There was insufficient staff capacity to survey all sites recommended in the plan. Locations were prioritized with the first tier as category 1 and 2 species, then roadsides for all species, then other strategic control sites as time allowed. In 2020, there was not enough resources or staff capacity to re-monitor sites, which would have given a more accurate picture of the current invasive plant status in the fire area. Based on the surveys completed, Tables 4 and 5 show summaries of area infested, number of sites, and number of sites treated by invasive plant for high priority species within regional priority category 1 and 2.

Roadside inventories were completed post-fire and prior to herbicide treatment work being completed. Some fire guards were monitored in 2017 and 2020; however, resources were insufficient to complete the scope of surveys recommended (i.e., monitoring in years 1, 2, 3, 5). The surveys that were completed did not find any new invasive plant species, but on some sites, there were occurrences of invasive plants previously known in the area. The establishment of the grass seed mix used was not assessed; however, in some areas, the natives re-established and spread very quickly, particularly in open grasslands where only the surface soil was disturbed by fireguard construction. Staff reported more weedy species where fire guards were cut through forested areas. This is likely because in the grassland sites, the equipment building the guards only scuff the surface to expose soil, whereas through forested areas, it involves deeper soil disturbance (pushing over trees or cutting a trail across a sloped hillside), except where crews were following old skid trails.

Monitoring of all category 1 species sites was not achieved in 2016, however was by 2017 (Table 4). There was no increase in category 1 species so the work to suppress populations post-fire was successful. However, a new species North Africa grass *(Ventenata dubia*), which was likely present before the fire on a private property, did spread along one road network. This spread was not directly related to the wildfire, but certainly was related to recreation traffic, fence construction, and likely disturbance from post-fire harvesting. There was speculation that this species was introduced to Hwy 33 by post-fire fence construction; however after the large private land site was located nearby the introduction source is unclear.

Table 4. Area infested by year of invasive plant, total sites and # sites treated by invasive plant species for Category 1 – Eradication or annual control.

Estimated Area (ha) of Species by Category	2016	2017	2018	2019	2020	Total Sites	Sites with no plants	# Sites Treated
1 - Eradication or annual control	**0.021**	**0.0331**	**0.138**	**0.026**	**0.002**			
Longspine sandbur (CENC LON)		0.0021	0.02	0.01	0.001	1	0	1
Plumeless thistle (CARD ACA)		0	0	0	0	1	1	0
Russian knapweed (ACRO REP)	0.001	0	0.018	0	0	2	2	1
Scotch thistle (ONOP ACA)	0.02	0.011	0.1	0.016	0.0005	2	0	2
Teasel (DIPS FUL)		0.02	0	0	0.0005	1	0	1
EDRR				**0.0198**	**15.5726**			
North africa grass (VENT DUB)				0.0198	15.5726	17	0	**4**
Total	**0.021**	**0.0331**	**0.138**	**0.0458**	**15.5746**	**24**	**3**	**9**

Monitoring of all category 2 invasive plant species was not achieved in 2016 or 2017 (Table 5). All sites scheduled for treatment were monitored, however some sites never received treatment and thus were not monitored. Insufficient resources and BISS staff capacity were the main reason why this monitoring was not achieved. Hoary alyssum (*Berteroa incana*) changed category in 2019 to strategic control; however, for the purposes of this report, was left in the control and contain category to enable assessment based on actions proposed. This table only includes surveys completed and not all sites were surveys each year.

Table 5. Area infested for Category 2– control and contain invasive plant species, total sites and # sites treated by survey year.

Species By Category	2016	2017	2018	2019	2020	Total Sites	# Site with no plants by 2020	# Sites Treated
2- Control and contain	**105.98**	**97.13**	**104.82**	**28.57**	**17.46**			
Baby's breath (GYPS PAN)	0.17	0.27	0.32	0.55	0.00	18	1	11
Blueweed (ECHI VUL)			0.01	0.03	0.00	2	0	1
Common bugloss (ANCH OFF)	100.03	89.13	99.67	15.27	12.41	72	11	58
Common tansy (TANA VUL)	0.89	0.01	0.44	0.77	1.19	34	5	22
Heart-podded hoary cress (CARD DRA)	0.03	0.05	0.01		0.00	3	0	1
Hoary alyssum (BERT INC)	4.81	7.59	3.55	9.67	3.67	88	1	65
Leafy spurge (EUPH ESU)	0.06	0.09	0.82	2.31	0.18	20	5	20
Total Area all species (ha)	**105.98**	**97.13**	**104.82**	**28.57**	**17.46**	**171**	**23**	**137**

For category 3- strategic control species, the plan objectives were to only monitor some sites, and focus time to assess which species survived in different burn intensities. Post-fire monitoring found the invasive yellow hawkweed species *(Pilosella species*), nodding thistle (*Carduus nutans*), scentless chamomile (*Tripleurospermum inodorum*), spotted knapweed (*Centaurea biebersteinii)*, sulphur cinquefoil, and wormwood (*Artemesia absinthium*) still present post-fire at previously known sites. All the sites checked were along roadsides with low fuel loading so would be considered low or moderate soil burn severity. No surveys were done on sites for burdock, chicory, or bachelors buttons. It is likely that all species were killed at sites with high ground fuel loads within the high soil burn severity area since no invasive plants were found growing.

Overview of Herbicide Treatment Completed by Jurisdiction

During the planning stages for herbicide treatment, treatment sites were selected based on regional priority and proximity to a travel corridor (roads and trails) within 5 km buffer around the fire. Category 1 (eradicate or annual control), category 2 (control and contain) and category 3 (strategic control) were included, and other species were only included on a site-specific basis. Management was limited by the financial resources available; some jurisdictions were able to address all sites while others were not. The Ministry of Transportation and Infrastructure committed an additional $8,000 towards their 2016 operating budget for treatment of Highway 33 through the fire area. Most land managers addressed Rock Creek fire treatment costs by reallocating funds usually dedicated to other areas or priorities, therefor doing less outside the fire area. Appendix 2 shows the locations of treatment by year from 2016 to 2020. Most of the treatment work occurred in 2016 and 2017, with a significant decline in resources and corresponding sites treated from 2018-2020. All sites with category 1 invasive plants were treated by 2017. The majority of selected priority sites were treated but it was difficult to compare to pre-fire data because of limitations in how data was recorded. Specifically, some treatments were recorded on one expanded site instead of several smaller sites, making it appear as if many sites were not treated, when they were. There were several resource roads connecting from the north and east that remained untreated (e.g., Fiva, Riverside and Nicholson) due to insufficient resources. The road deactivation completed in the Kettle East area reduced recreation traffic through the area, but it also limited invasive plant treatment crew ability to access some priority sites.

The costs associated with the treatment work by the different jurisdictions and funding partners were not tracked in a way that would allow for reporting total value invested within the fire area only over the five-year period. The following sections summarize activities and contributions by jurisdiction and partner where the information was available.

BC Parks

Salvage harvesting was completed by BC Parks within Kettle River Recreation Area (KRRA) in 2016 and the harvest prescription included measure to minimize soil disturbance. The revenue from stumpage was used to fund invasive plant treatment work from 2016-2020.

Invasive plant treatment work began in 2016, with previously known patches of St John's wort and diffuse knapweed being treated around the campground area and main access road into the KRRA. Table 6 shows the area treated by category and year. The goal for species with biocontrol available was to suppress invasive plant populations and to allow the biological control insects time to rebuild populations. The benches south of the access road were treated up to the surviving tree line to suppress large patches of St Johns' wort. During 2016, Milestone Herbicide, which has low impact on some native broadleaf plants but provides control for 3-4 years, was used. This herbicide has low impact on some native forbs and trees species. However, it did not achieve satisfactory control of St. John's wort, so Clearview Herbicide was used for future treatments. This herbicide has a greater impact on native broadleaf plants but was more effective in controlling St. John's wort. The expectation was that after three years the sensitive native broadleaf forbs should start to return as the herbicide residual control declines. In 2017, as more invasive plant sites became visible, treatment expanded to include hoary alyssum and leafy spurge (*Euphorbia esula*), and treatment of the Park operations yard. Some additional work was done on St. John's wort in dense patches in the north end of the Park. In 2018, a second pass was done in the operations yard area and more work was completed on St John's wort and diffuse knapweed to suppress the dense infestations. In 2019, funds were not available for treatment, so only the leafy spurge sites were treated, with costs being covered by other partner funds. By 2020, the residual control from 2017 treatments had started to decline resulting in St John's wort increase, so an extensive herbicide treatment was done in the high use areas in the north end of KRRA including the access roads, playground, camp sites and group site. The inventory completed in fall 2020 found pockets of *Chrysolina spp,* a biocontrol agent for St John's wort, now present but only in the south end. A new patch of leafy spurge and some sulphur cinquefoil was found and treated. The hoary alyssum patches along the south boundary were much smaller than in previous years and were re-treated with herbicide.

Table 6. Area of invasive plant treated (ha) by BC Parks by category and year.

BC Parks	2016	2017	2018	2019	2020
Kettle River Recreation Area					
2- Control and contain		**1.2444**	**0.1**	**0.0222**	**0.0954**
Hoary alyssum (BERT INC)		1.2194	0.1		0.0854
Leafy spurge (EUPH ESU)		0.025		0.0222	0.01
3 - Strategic control					**0.4507**
Nodding thistle (CARD NUT)					0.0439
Spotted knapweed (CENT BIE)					0.3793
Sulphur cinquefoil (POTE REC)					0.0275
3 - Biocontrol	**6.1333**	**1.9056**	**2.5332**		**3.5524**
Canada thistle (CIRS ARV)					0.2012
Dalmatian toadflax (LINA DAL)	0.05				
Diffuse knapweed (CENT DIF)	2.5833		0.1422		0.7085
St. John's wort (HYPE PER)	3.5	1.9056	2.391		2.6427
Total Area Treated (ha) by Year	**6.1333**	**3.15**	**2.6332**	**0.0222**	**4.0985**

Biocontrol insect monitoring in 2016 and 2017 showed some insect presence post-fire but at very low levels. Ten biocontrol insect releases were completed for Canada thistle, diffuse knapweed and St. John's wort during 2016 and 2017 to augment populations and speed up suppression of the target invasive plant. Details on biocontrol insect species released can be found in the biocontrol section of this report. Monitoring in 2020 found diffuse knapweed insects widespread, some biocontrol insect species present on St John's wort in the south end of the park, and suppression of Canada thistle evident.

Overall, the native plant communities seem to be recovering well and the objectives of the invasive plant management plan were met.

Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD)

FLNRORD - Range Branch

The Range Branch was not able to provide new funds, so work was shifted from other areas to enable using existing operational budgets to complete herbicide treatments as outlined in the plan. As a result, very little work was completed on roads outside of the fire area in 2016 and 2017. The resources were sufficient to address the majority of category 1 and 2 sites and some category 3 strategic control sites on crown roads leading into the fire except the roads in the Fiva/Riverside and from Nicholson Creek over to the BC Hydro powerline corridor.

Table 7 shows the area treated by year for each priority category. No work was done off the roadsides, despite large patches of St John's wort developing along the steep slopes in the Riverside area (north of Kettle East site). During 2018-2020, significant resources were spent controlling common bugloss (*Anchusa officinalis*) within the 5 km buffer on the Rock Creek horse trails with very few roads treated within the fire area itself. Some funds were received from the Habitat Section from the Land Based Investment Fund for work within the Kettle East/Riverside area, but these have been reported in the ecosystem program section. There were many spur roads and a few resource roads that were not treated due to insufficient funds to address the scope of the problem.

Table 7. Area of invasive plant treated (ha) by FLNRORD – Range Branch by category and year.

FLNRORD- Range Branch	**2016**	**2017**	**2018**	**2019**	**2020**
Regional Priority Species	14.15	15.70	19.17	11.11	14.77
1 - Eradication or annual control			**0.07**	**0.02**	**0.00**
Scotch thistle (ONOP ACA)			0.07	0.02	
Teasel (DIPS FUL)					**0.00**
2- Control and contain	**4.35**	**3.75**	**16.68**	**6.21**	**9.41**
Common bugloss (ANCH OFF)	4.07	2.77	14.49	2.79	4.68
Common tansy (TANA VUL)	0.02			0.00	
Hoary alyssum (BERT INC)	0.21	0.76	1.84	3.24	3.87
Leafy spurge (EUPH ESU)	0.04	0.22	0.34	0.18	0.86
3 - Strategic control	**8.11**	**5.60**	**0.80**	**3.38**	**3.11**
Nodding thistle (CARD NUT)	1.93	0.98	0.66	2.21	0.35
Orange hawkweed (HIER AUR)	0.01	0.22	0.02		
Spotted knapweed (CENT BIE)	2.88	1.59		0.50	1.43
Sulphur cinquefoil (POTE REC)	0.77	0.27	0.07		0.60
Wormwood (ARTE ABS)		0.97	0.04	0.48	0.47
Yellow devil hawkweed (HIER GLO)	1.39	0.38		0.19	
Yellow hawkweed species (HIER SPP)	1.14	1.20			0.27
3 - Biocontrol	**1.69**	**6.35**	**1.62**	**1.50**	**2.25**
Canada thistle (CIRS ARV)					0.04
Dalmatian toadflax (LINA DAL)		0.20			0.29
Diffuse knapweed (CENT DIF)	1.69	1.17	0.44	1.02	0.51
Hound's-tongue (CYNO OFF)				0.02	
St. John's wort (HYPE PER)		4.98	1.18	0.46	1.41
Total Area Treated (ha) By Year	**14.15**	**15.70**	**19.17**	**11.11**	**14.77**

FLNRORD - Ecosystem Section

Treatment work was done on the ecosystem restoration site within the Kettle East site experiencing wildfire, using funds received from the Land Based Investment Fund ($5000/year for 2016 and 2017). There was also work from 2017-2020 on the Rexin Restoration site, which is located within the 5 km buffer around the fire, through annual funding provided by the Land Based Investment Fund and the Habitat Conservation Trust Fund.

The work on the Kettle East site in 2016 and 2017 was focussed on treating road corridors in advance of the planned road deactivation that was completed in 2017. After deactivation it was difficult to get a treatment crew into the area, which certainly reduced recreation traffic as well. BISS staff hiked some of the roads in 2020 looking for North Africa grass and noted good control of invasive plants along the roads through the deactivated areas. However, dense infestations of wormwood and St John's wort were present on many of the slopes beyond the restoration site. The treatment in Rexin restoration site was focussed on roads used for harvesting during 2017-2018 and expanded off roads in 2019-2020. This treatment work included all species since the site is scheduled for prescribed fire in 2022. Table 8 shows the area treated of invasive plants each year.

Table 8. Area of invasive plant treated (ha) by FLNRORD – Ecosystem Section by category and year.

FLNRORD Ecosystem Restoration Sites	2016	2017	2018	2019	2020
Regional Priority Species					
2- Control and contain		**0.01**	**0.17**	**0.22**	**0.04**
Common bugloss (ANCH OFF)		0.01			0.01
Hoary alyssum (BERT INC)			0.17	0.17	0.03
Leafy spurge (EUPH ESU)				0.05	
3 - Strategic control	**1.75**	**2.27**	**0.69**	**0.13**	**0.19**
Burdock species (ARCT SPP)		0.44			
Nodding thistle (CARD NUT)	0.01	0.95	0.64	0.05	0.02
Orange hawkweed (HIER AUR)				0.01	0.01
Spotted knapweed (CENT BIE)	1.00				
Sulphur cinquefoil (POTE REC)	0.12	0.21		0.06	0.08
Wormwood (ARTE ABS)	0.60	0.38			0.07
Yellow devil hawkweed (HIER GLO)			0.04	0.01	0.03
Yellow hawkweed species (HIER SPP)	0.03	0.30		0.01	
3 - Biocontrol	**4.48**	**4.41**	**1.10**	**0.67**	**0.77**
Canada thistle (CIRS ARV)					0.10
Diffuse knapweed (CENT DIF)	0.88	1.10	0.61	0.18	0.17
St. John's wort (HYPE PER)	3.60	3.31	0.49	0.49	0.51
Total Area Treated (ha) By Year	**6.23**	**6.69**	**1.96**	**1.02**	**1.00**

FLNRORD - Recreation Sites and Trails BC

Recreation Sites and Trails BC is responsible for management of the Kettle Valley Rail Trail. In 2016, the funds from their annual invasive plant management budget were directed to work on to the trail within the fire boundaries. All invasive plant species present in 2016 were treated on the trail through the highest value areas including KRRA and the cattle ranch north of the park. No funds were allocated in 2017-2020. The leafy spurge site on the rail trail was treated using Range Branch funds in 2016, 2017 and 2020. One site south of James creek and a site at parking area in Westbridge was treated in 2019 and 2020 using Range Branch funds. More sites should have been done south of Westbridge; however, resources were not provided by Recreation Sites and Trails program. Table 9 shows the area of invasive plant treated each year.

Prior to the wildfire, the trail had dense trees and shrubs in some areas and the fire removed the trees, thus opening up the canopy and creating more habitat for invasive plants to grow in the future.

Table 9. Area of invasive plants treated (ha) by FLNRORD – Recreation Sites and Trails BC by category and year.

Recreation Sites and Trails BC	2016	2019	2020
Regional Priority Species	**2.42**	**0.4623**	**0.1333**
2- Control and contain		**0.3556**	**0.1**
Baby's breath (GYPS PAN)		0.1067	
Common tansy (TANA VUL)			0.0333
Hoary alyssum (BERT INC)		0.2489	0.0667
3 - Strategic control		**0.1067**	**0.0333**
Nodding thistle (CARD NUT)		0.0711	
Sulphur cinquefoil (POTE REC)		0.0356	0.0333
3 - Biocontrol	**2.42**		
Dalmatian toadflax (LINA DAL)	0.732		
Diffuse knapweed (CENT DIF)	1.44		
St. John's wort (HYPE PER)	0.248		
Total Area Treated (ha) All Years	**2.42**	**0.4623**	**0.1333**

Ministry of Transportation and Infrastructure (MOTI)

MOTI provided an additional $8,000 in funding in 2016 to control all invasive plants on highways 33 and 3 within the fire perimeter. Some regular program funding was used and 2016 to treat high priority species on secondary roads within the 5 km buffer, while in 2017-2020, regular budget funds were used for all work.

The work in 2016 focussed on Highway 33 treating all invasive plant species and Highway 3 priority species. In 2017, Highway 33 was re-treated and priority species were treated on Highway 3 within the 5 km buffer. Priority sites on secondary roads including Kettle River East, Kettle Valley South and Hulme Creek roads were treated. The total amount invested is not available, however the resources were sufficient to address all priority sites within the plan area on this jurisdiction. Over the five-year period a total of 37 IAP sites were treated, some multiple times to gain control resulting in 8.77 ha to 11.4 ha treated per year on roadsides and in gravel pits (Table 10).

The burned areas experienced higher than normal runoff levels resulting in a small mud slide on Highway 33 that was seeded. There was no information available on whether the disturbance associated with the power pole replacement was seeded or not, but it did revegetate well. The disturbance associated with fence replacement was seeded immediately after construction. In most areas, the backslopes recovered quickly since the burn intensity was very low in the absence of woody fuels. Some of the fire killed trees that were felled along the road were hauled to Johnstone Creek Pit for disposal while the rest were left long the roadside. This pit was also used for storage of waste material from a slump resulting from increased underground water west of Rock Creek that was repaired. This pit was monitored and treated multiple times.

In 2018 surveys were completed looking for north Africa grass at the post-fire fence replacement sites along the highway and three sites were found. This was presumably introduced by the fence construction crew who had done some work in the Gilpin area immediately prior to starting fence construction on Highway 33 in 2016. However, when a large site of North Africa grass was found off Riverside Rd in 2020, the evidence suggested that the introduction may have been from this location rather than Gilpin. Further surveys done in 2019-2020 did not located any new sites on highways or secondary roads in the fire. In 2020 other patches were found on a resource road in the Zamora area, at a parking area for the Kettle Valley rail trail and on a private property just outside the fire perimeter. The survey map shows the locations of North Africa grass under the EDRR category (Early Detection Rapid Response) included in the appendix of this report.

Table 10. Area of invasive plants treated (ha) Ministry of Transportation and Infrastructure by category and year.

Ministry of Transportation and Infrastructure	2016	2017	2018	2019	2020
Regional Priority and Species	**9.02**	**11.44**	**11.21**	**10.33**	**8.77**
1 - Eradication or annual control			**0.04**		
Russian knapweed (ACRO REP)			0.04		
2- Control and contain	**5.17**	**5.18**	**7.96**	**4.55**	**5.52**
Baby's breath (GYPS PAN)		0.17	0.20	0.20	
Blueweed (ECHI VUL)			0.01	0.03	
Common bugloss (ANCH OFF)	1.12	1.73	3.45	1.39	2.21
Common tansy (TANA VUL)	0.11		0.43		
Hoary alyssum (BERT INC)	0.55	3.10	2.44	2.53	2.80
Leafy spurge (EUPH ESU)	3.39	0.18	1.43	0.40	0.50
3 - Strategic control	**0.80**	**4.44**	**1.78**	**2.09**	**2.00**
Chicory (CICH INT)		0.04			
Nodding thistle (CARD NUT)	0.01	2.63	0.75	1.22	1.10
Scentless chamomile (MATR PER)			0.02		
Spotted knapweed (CENT BIE)	0.79	1.31	0.69	0.24	0.74
Sulphur cinquefoil (POTE REC)		0.47	0.22	0.39	0.16
Yellow devil hawkweed (HIER GLO)				0.22	
Yellow hawkweed species (HIER SPP)			0.11	0.01	
3 - Biocontrol	**3.05**	**1.82**	**1.43**	**3.69**	**1.25**
Canada thistle (CIRS ARV)	0.40		0.18		0.01
Dalmatian toadflax (LINA DAL)	1.36	0.04	0.12	0.27	0.32
Diffuse knapweed (CENT DIF)	1.30	1.25	0.80	2.73	0.82
St. John's wort (HYPE PER)		0.52	0.34	0.69	0.10
Total Area Treated (ha) By Year	**9.02**	**11.44**	**11.21**	**10.33**	**8.77**

BC Hydro Rights-of-way

BC Hydro redirected funds from their regular program for 2016 and 2017 to complete work within the fire area. The treatment work included the powerline Rights-of-Way (RoW) and access roads immediately adjacent to the powerline. Due to topography, the RoW is mainly on the sides of the valley. The Riverside area (east side) had fire guards along many of the access roads and in some areas the RoW itself was used as a guard. The machine guards constructed in this area revegetated quickly with native species (Figure 30) and no invasive plants were found during surveys in 2017 or portions of the area surveyed in 2020. During 2017 monitoring, large areas of pinegrass in seed were visible from access roads. The east side access roads were retreated in 2017 and treatment expanded farther down roads to prevent movement of invasive hawkweeds into highly disturbed areas. The RoW on the west side of the valley was just beyond the fire perimeter. Extensive broadcast herbicide treatment work targeting all invasive plant species was completed on the RoW to increase livestock forage in the short term since the range unit had been heavily impacted in some areas by fire. Prior to the fire, the RoW had moderate infestation of diffuse knapweed with healthy populations of biocontrol insects present, with some spotted knapweed and hoary alyssum showing up along access roads. Hawkweeds were spreading down into the area from the west, so new sites located in 2017 were treated to prevent spreading into the salvage harvest south of the RoW. No funds were available during 2018-2019 since resources were shifted to other areas. In 2020, work was completed on the west side since the residual control was declining and knapweed was on the increase again. As this work was done, many new infestations of hoary alyssum and hawkweed were found, presumably resulting from recreation traffic (e.g. mushroom pickers, hunters) and harvest activity. Additional work will be needed in 2021 to re-treat hoary alyssum and hawkweeds to prevent further expansion, but this work will need to be coordinated with FLNRORD since sites occur beyond the RoW. Table 11 shows the areas treated by category of invasive plant species.

Figure 28. Recovery of natural plant community near BC Hydro power line accessed off Riverside Rd. June 24, 2016.

Table 11. Area of invasive plants treated (ha) by BC Hydro by category and year.

BC HYDRO	2016	2017	2020
3 - Strategic control	**3.18**	**2.02**	**2.28**
Orange hawkweed (HIER AUR)		0.03	
Spotted knapweed (CENT BIE)	1.89	1.08	1.28
Sulphur cinquefoil (POTE REC)	1.18	0.16	
Yellow devil hawkweed (HIER GLO)		0.12	
Yellow hawkweed species (HIER SPP)	0.11	0.63	1.00
3 - Biocontrol	**3.18**	**1.70**	**0.92**
Diffuse knapweed (CENT DIF)	1.25	0.51	
St. John's wort (HYPE PER)	1.93	1.19	0.92
Total Area Treated (ha) by Year	**6.35**	**3.72**	**3.20**

Regional District of Kootenay Boundary – Private Land

The RDKB new invaders program offered treatment on private land up to 5 acres to control category 1 and 2 species. Prior to the fire, this program had been completing treatment of many properties that fell within the selection criteria of being along a road within 5 km of the fire perimeter. The treatment totals in Table 12 include some of the work done in an average year, since the program normally targets priority species. Some of the normal annual work within the 5 km buffer was removed from the data, primarily common bugloss sites in the lower Nicholson creek area which have little connection to the fire but were still selected due to proximity to roads within 5 km. From 2016 to 2018, the new invaders program was expanded to include treatment of all invasvie plant species on properties within the fire perimeter. This was done to support overall invasive plant management objectives within the larger fire recovery area. The cost of the work completed within the fire perimeter were not tracked in a way that would allow for separating the typical annual costs from the additional costs resulting from the temporary program expansion.

Table 12. Area of invasive plants treated (ha) by RDKB programs by category and year.

RDKB New Invaders Program	2016	2017	2018	2019	2020
2- Control and contain	**15.45**	**6.90**	**7.36**	**13.79**	**8.51**
Baby's breath (GYPS PAN)		0.09	0.49	0.17	
Common bugloss (ANCH OFF)	9.55	1.09	4.51	6.55	6.68
Common tansy (TANA VUL)	0.88		0.31	0.71	0.16
Heart-podded hoary cress (CARD DRA)	0.03				
Hoary alyssum (BERT INC)	3.77	5.68	1.29	3.68	1.58
Leafy spurge (EUPH ESU)	1.23	0.04	0.77	2.67	0.09
3 - Biocontrol	**11.70**	**0.31**	**0.30**	**3.48**	**3.65**
Dalmatian toadflax (LINA DAL)				0.92	0.04
Diffuse knapweed (CENT DIF)	4.90	0.31		1.83	2.54
St. John's wort (HYPE PER)	6.80		0.30	0.74	1.06
3 - Strategic control	**1.65**	**0.26**		**2.45**	**1.53**
Nodding thistle (CARD NUT)				0.68	0.60
Spotted knapweed (CENT BIE)	1.58				0.51
Sulphur cinquefoil (POTE REC)	0.08	0.21		1.42	0.43
Wormwood (ARTE ABS)		0.05			
Yellow hawkweed species (HIER SPP)				0.36	
Total Area Treated (ha) All Years	**28.80**	**7.48**	**7.66**	**19.73**	**13.69**

Invasive Plan Biocontrol Monitoring and Re-colonization

Background

Biological control insects are the primary control method for several invasive plant species occurring within the fire area. Over time, the insects have continued to provide some level of control across the region and their population numbers appear to be cycling up and down based on host plant availability. Most historical biocontrol releases had not been monitored prior to the fire; however, we know from observations that most of the insect species were widespread in the area prior to the fire. No literature was found related to the survival and recolonization of biocontrol insects being used in the area. Monitoring was needed to see which insects were still present after the fire and to track re-colonization. Information on life history of the insects was sources from the BC government biocontrol matrix[2] and insects were grouped based on life-stage present at the time of the fire. Depending on the life stage of the insect, some species would have had the ability to move out of the fire region or may have been protected inside the root of the host plant, so may have experienced little impact. Other species were potentially highly impacted because the host plants with larvae present were burned. FLNRORD biocontrol program staff assisted with completing some presence/absence monitoring for some sites within different soil burn severity during June of 2016. The results of this monitoring have not yet been analysed by ministry staff. The data is available in IAP, so for this report the presence/absence monitoring data from BISS staff and the Ministry data were pooled to identify trends. This does not represent insect survival

[2] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/invasive-species/management/plants/biological-control

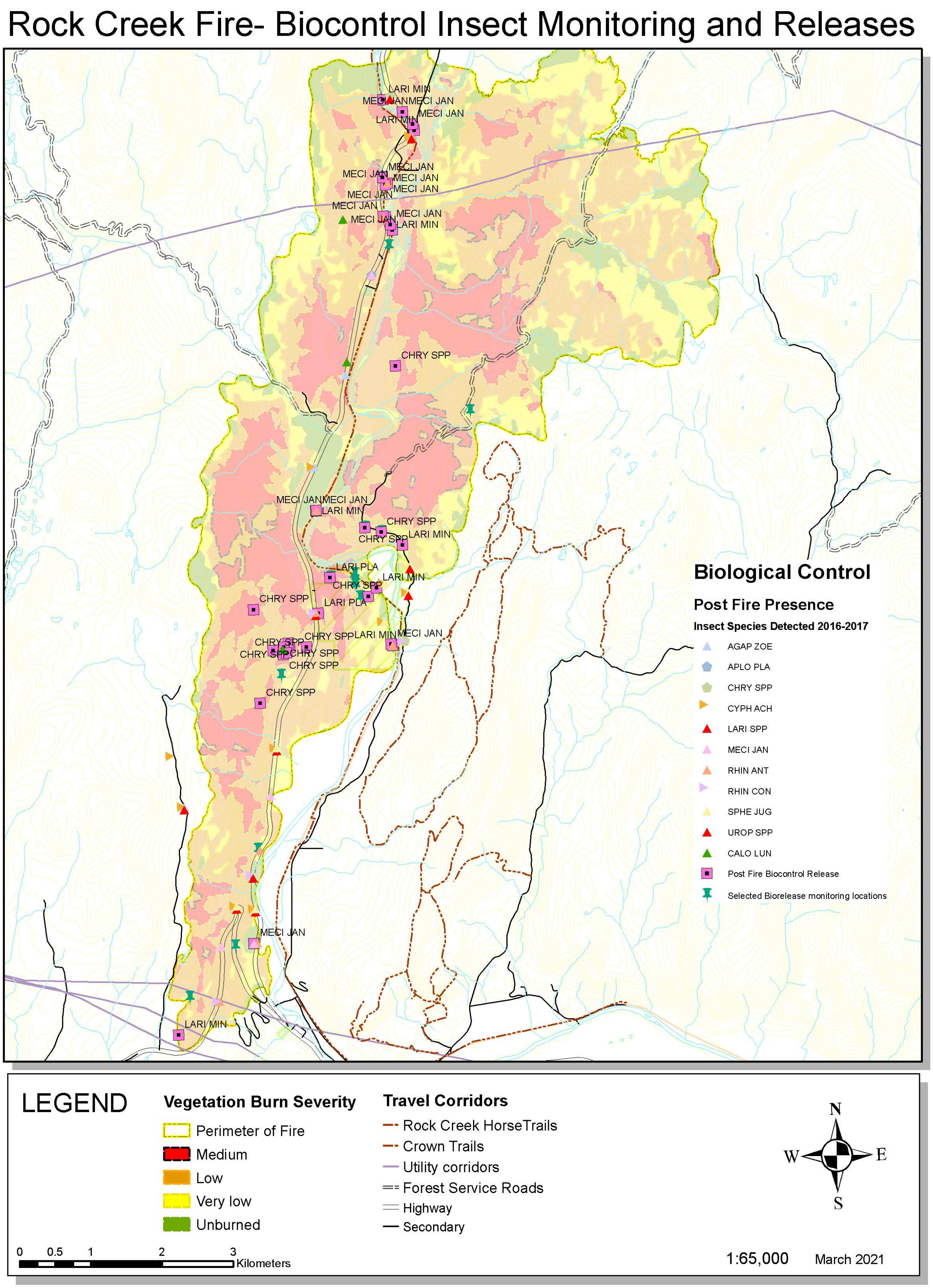

Figure 29. Map of biocontrol insect monitoring and release locations within the Rock Creek wildfire.

except for possibly a few root boring species where, if they were detected in the root in June 2016, they must have survived the fire as a larvae in the plant root. Many of the species are strong fliers and could easily have re-colonized from the edges of the fire perimeter by the time the monitoring was done in spring 2016. The fire was a long linear fire with some unburned areas in the middle, resulting in potential for significant re-colonization from nearby areas. A map showing the locations of presence absence monitoring (dispersal records) and new insect release locations is contained in Figure 31. The soil burn severity polygons are coarse scale and created based on imagery and soil conditions. In many areas, small pockets of low or moderate burn severity exist within the high severity polygons. The degree of damage to the plant species was highly dependant on the ground fuels present at the time of the fire. Across the fire, all high burn severity forested areas with high pre-fire fuel loads did not have any invasive plants present post fire as the fire burned down into the soil, completely removing the growing plants and the seed bank as well. Most open forest areas with lesser fuel loads had the surface litter layer removed and many perennial plants survived and regrew from roots. During the biocontrol monitoring, surveyors were limited to only surveying locations with host plants present. The sites included in the moderate burn severity were small pockets where the litter layer was removed but the soil remained, allowing for the root system of perennial plants to survive and regrow.

Analyses for Presence/Absence for Biocontrol Insects

All locations assessed for host plant species within the Rock Creek wildfire area had biocontrol insects present. There were three biocontrol insect species groupings in which we feel confident that the presence/absence records represent true presence and absences on certain invasive plant species. These three biocontrol insect species occurred on three different invasive plant species: (1) *Larinus spp* and *Larinus minutus* (LARI SPP), a seed-eating insect (above-ground feeder) that feeds on diffuse knapweed; (2) *Mecinus janthiniformis* (MECI JAN), an above-ground feeder that feeds on dalmatian toadflax; and (3) *Chrysolina spp* (CHRY SPP), a seed-feeding insect that would have had adults buried beneath the soil at the time of fire (below-ground occurrence) and feeds on St. John's wort. All other insect species have true presence records, but incomplete absence records and thus analyses could not be conducted in the same way for all biocontrol insect species. We only assessed the presence and absence of these species in 2016, the year after the fire, in an attempt to capture the short-term effects of wildfire on biocontrol insect presence via either survival or short-distance dispersal.

Statistical Analyses

To assess the probability of the presence or absence of a biocontrol insect species on invasive plant species, we used logistic regression in the glmmADMB package (Fournier 2012) in the R Statistical Package (R Core Team). We conducted four different analyses: (1) a full model assessing the presence/absence of all three biocontrol insect species grouped together on all three invasive plant species; (2) a model assessing the presence/absence of LARI SPP on diffuse knapweed; (3) a model assessing the presence/absence of MECI JAN on dalmatian toadfax; and (4) a model assessing the presence/absence of CHRY SPP on St. John's wort. Significance was assessed with Type 3 sum of squares.

The fixed-effects explanatory variables included in the full model included: (1) whether a patch was burned or not (categorical, 2 levels); (2) whether the insect species was above-ground or below-ground (categorical, 2 levels); (3) the density of the invasive plant species (treated as a continuous covariate); and (4) the distribution of the invasive plant species (treated as a categorical covariate, with up to 8 possible levels and not all levels present for each invasive plant species; Table 13). For each of the remaining three models for each invasive plant species, the same explanatory variables were included except whether the species was above or below ground during the fire because each plant species only had one insect species, and thus only an above or a below ground insect. Additionally, the distribution of invasive plant species was treated as a continuous variable in these three models, on a scale from 1 to 8 representing increasing abundance of plants. In some cases, only one covariate could be included in the model to get model convergence. In such cases, two models were run, each with one covariate, and the results of both models are presented.

Table 13. Area of invasive plants treated (ha) by RDKB programs by category and year.

Code Number	Plant Distribution Description
1	1 | rare individual, a single occurrence
2	2 | few sporadically occurring individuals
3	3 | single patch or clump of a species
4	4 | several sporadically occurring individuals
5	5 | a few patches or clumps of a species
6	6 | several well-spaced patches or clumps
7	7 | continuous uniform occurrence of well-spaced individuals
8	8 | continuous occurrence of a species with a few gaps in the distribution

Presence/Absence of Biocontrol Species for All Invasive Plant Species Grouped Together

There was no difference in detection of biocontrol insect species between whether a patch was affected by wildfire or not (p = 0.33), by the density of invasive plant species (p = 0.75) or by the distribution of invasive plant species (p = 0.76). Of the 29 records for above-ground insects, 86% of records (25 of 29) had insects present (Figure 32). Of the 16 records for possible below-ground insects, 94% (15 of 16) had insects present (Figure 32). The probability of detecting a below ground insect one year after wildfire was significantly lower than the probability of detecting an above-ground insect (p = 0.004).

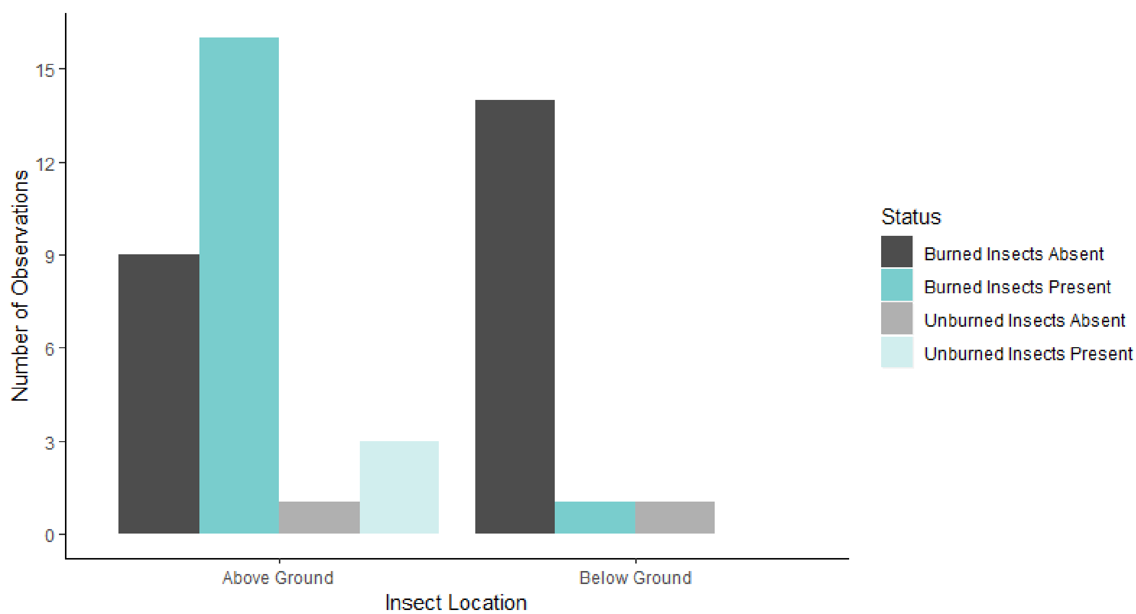

Figure 30. The number of observations where biocontrol insects were present (blues) or absent (greys) for above and below ground insect species (n = 45).

Presence/Absence of Biocontrol Species for Diffuse Knapweed

There were no differences in detection of LARI SPP between patches of diffuse knapweed that were affected by wildfire compared to those that were not (p = 0.16). Of the 12 occurrences of diffuse knapweed that were in patches that experienced wildfire, 42% (5 of 12) had LARI SPP detected (Figure 33). Three areas with diffuse knapweed were not burned, and 66% (2 of 3) had LARI SPP detected. Invasive plant density (p = 0.21) and distribution (p = 0.20) also did not influence probability of occurrence.

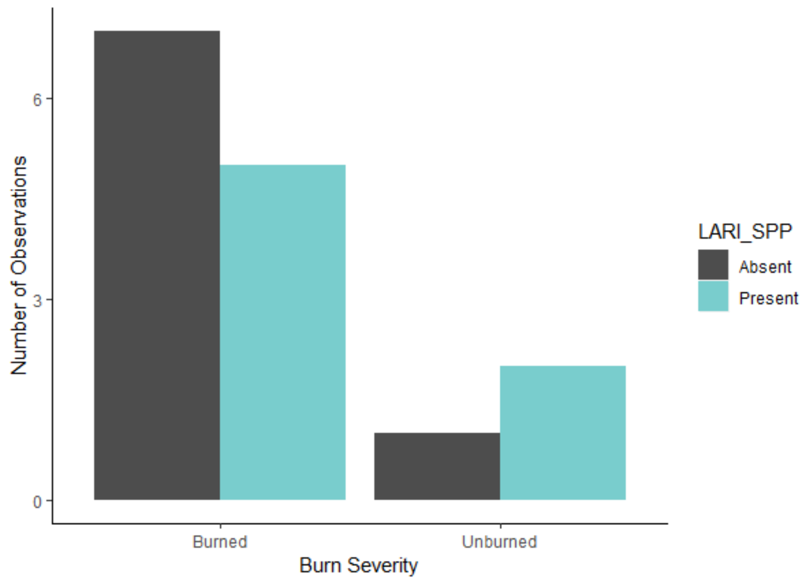

Figure 31. The number of observations in 2016 where LARI SPP were present or absent on diffuse knapweed in the East Kettle site after the 2015 Rock Creek wildfire (n = 15).

Presence/Absence of Biocontrol Species for Dalmatian Toadflax

There were no differences in detection of MECI JAN between patches of dalmatian toadflax that were burned compared to those that were not burned in the wildfire (p = 0.99). Of the 14 observations of dalmatian toadflax, only one occurred in an unburned patch in which MECI JAN was detected (Figure 34). In the remaining 13 patches that were burned, 85% (11 of 13) had MECI JAN detected. Invasive plant density (p = 0.64) and distribution (p = 0.88) also did not influence probability of occurrence.

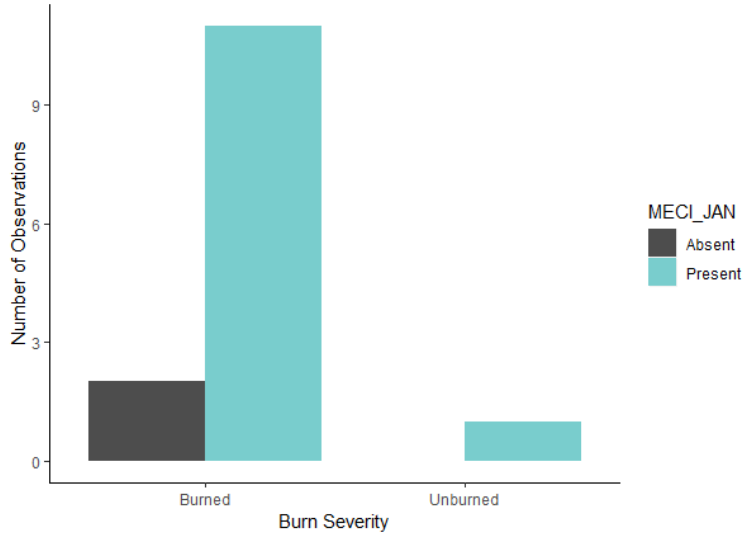

Figure 32. The number of observations in 2016 where MECI JAN were present or absent on dalmatian toadflax in the East Kettle site after the 2015 Rock Creek wildfire (n = 14).

Presence/Absence of Biocontrol Species for St. John's Wort

There were no differences in detection of CHRY SPP between patches of St. John's wort that were burned compared to those that were not burned in the wildfire (p = 0.99 in model with density; p = 0.95 in model with distribution). Of the 16 plots with St. John's wort, only 1 occurred in an unburned patch and no CHRY SPP were detected there (Figure 35). Of the remaining 15 that were burned in the 2015 wildfire, only 7% (1 of 15) had CHRY SPP detected. Invasive plant density (p = 0.98) and distribution (p = 0.70) also did not influence probability of occurrence.

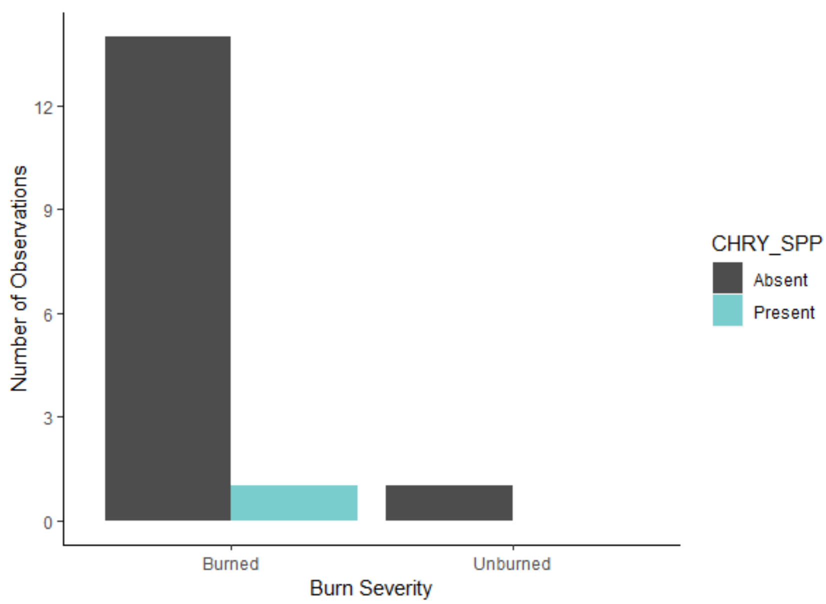

Figure 33. The number of observations in 2016 where CHRY SPP were present or absent on St. John's wort in the East Kettle site after the 2015 Rock Creek wildfire (n = 16).

Conclusions for Presence/Absence of Biocontrol Species Relative to Wildfire

We were unable to detect any differences in the occurrence of biocontrol insect species between patches that were burned in the 2015 Rock Creek wildfire compared to those that were not burned, suggesting dispersal from nearby areas occurs rapidly. The fire was long and narrow facilitating dispersal from nearby areas, the results may be different for a larger geographic area burned. Of the three biocontrol insect species assessed for presence/absence above, MECI JAN were by far the most frequently detected and CHRY SPP the least frequently detected species. MECI JAN was widespread prior to the fire so there were likely many potential nearby unburned patches to disperse from. LARI SPP are considered widespread however have been so effective at suppressing host plants that the diffuse knapweed populations were low resulting in low levels of LAMI SPP. CHRY SPP had low population levels in the valley prior to the fire so the pre-fire populations levels impacted the post-fire dispersal. The CHRY SPP was the only below-ground insect investigated, and this explains why the global analysis suggests that above ground insects were more frequently detected. CHRY SPP had low population levels in the valley prior to the fire so the pre-fire populations levels may have affected the results.

Analyses for Species Richness for Biocontrol Insects

The impacts of wildfire on species richness of biocontrol insect species was assessed for each of the four invasive plant species separately. These four invasive plant species were diffuse knapweed, dalmatian toadflax, Canada thistle and St. John's wort. Each is discussed separately below.

Statistical Analyses

To determine if wildfire influenced the species richness of insect species, we performed linear models in the R statistical package (R Core Team) for each invasive plant species independently. The fixed effects explanatory variables included in the model were: (1) whether a patch was burned or not (categorical, 2 levels); (2) the density of the invasive plant species (categorical covariate, up to 3 levels); and (3) the distribution of the invasive plant species (categorical covariate, up to 8 possible levels; Table 13). Type 3 sum of squares were used to assess significance. Means and standard deviations are presented (Figure 36).

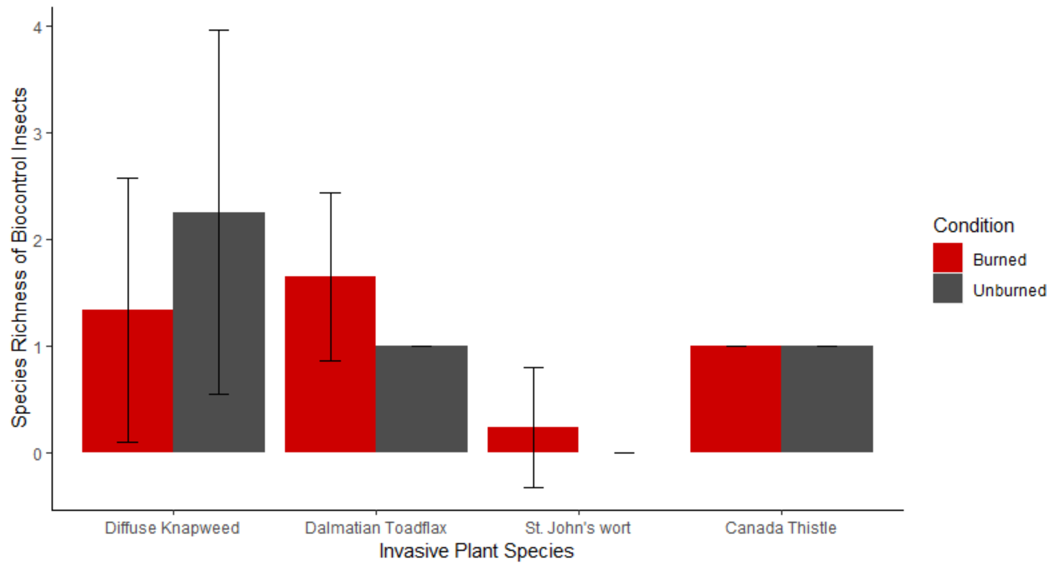

Figure 34. The species richness of biocontrol insects on the four invasive plant species observed in the assessed area. Species richness is shown for both areas that were burned (red, n = 51) and areas that were not burned (grey, n = 7). Values represent mean and standard deviation.

Species Richness for Biocontrol Insect Species on Diffuse Knapweed

There were five different insect species detected on diffuse knapweed during the 2016 post-fire monitoring, including three root-feeding insects and two seed-feeding insects (Table 14). There did not appear to be any influence of wildfire on insect species richness on diffuse knapweed (p = 0.09; Figure 36), and all species were detected across the range of vegetation burn severity. Site monitoring found a range of insects at sites with values from 0 to 4 species detected across all burn severity classes. Root boring insects *Agapeta zoegana* (AGAP ZOE), *Cyphocleonus achates* (CYPH ACH), and/or *Sphenoptera jugoslavica* (SPHE JUG) were detected at 9 of the 19 locations monitored that had some knapweed plants present. Seed eating insects *Larinus* species (pooled records from *Larinus spp* and *Larinus minutus* (LARI SPP)) and/or *Urophora spp* (UROP SPP) were found at 10 of the 19 locations monitored. These two groups of species are strong fliers and were expected to disperse quickly back into the area. There were 7 sites where no insects were detected during surveys and several of these had very few plants. Despite this, the analysis did not detect any influence of plant density (p = 0.30) or distribution (p = 0.12) on the species richness of biocontrol insect species on diffuse knapweed. It is, however, possible that some insects were present but not detected in June as detections depend highly on skills of surveyor, time of day, and can vary by site conditions.

Table 14. Diffuse knapweed biocontrol insect detections by site monitored.

IAPP Site_ID	Density of Plants	Distribution of Plants	Estimated Area of Plants (ha)	Root Insects			Seed Feeding Insects		Total Species Present
				AGAP ZOE	CYPH ACH	SPHE JUG	LARI SPP	UROP SPP	
Diffuse knapweed (CENT DIF)									
Moderate Burn Severity									
114968	2	**3**	0.01		1				1
315161	2	**5**	0.008		1	1	1		3
315175	1	**4**	0.01				1		1
315216	1	**7**	0.02	1					1
315217	2	**5**	0.02						0
315219	1	**1**	0.001						0
315227	1	**4**	0.02				1	1	2
Low Burn Severity									
316224		**2**	0.001				1		1
315170	2	**3**	0.003						0
315172	1	**5**	0.9	1	1	1	1		4
315243	2	**5**	0.02			1		1	2
315187	1	**4**	0.02		1				1
315228	2	**6**	0.02						0
315229	2	**5**	0.02		1			1	2
315230	1	**2**	0.01					1	1
Unburned									
315166	2	**3**	0.004	1	1	1	1		4
315169	2	**3**	0.0005				1	1	2
315171	1	**1**	0.0001						0
315183	2	**5**	0.02	1	1	1			3
Total Detections				4	7	5	7	5	

Species Richness for Biocontrol Insect Species on Dalmatian Toadflax

Species richness of biocontrol insect species on dalmatian toadflax was not significantly influenced by fire ($p = 0.47$; Figure 36), invasive plant density ($p = 0.63$), nor invasive plant distribution ($p = 0.77$). Two of three insect species were found on dalmatian toadflax: *Rhinusa antirrhini* (RHIN ANT) and *Mecinus janthinformis* (MECI JAN). Both insects were likely present throughout the area prior to the fire since they are both widespread within the valley and typically rapidly disperse. *Rhinusa antirrhini* (RHIN ANT) was present at almost all monitoring sites in 2016 post-fire monitoring (Table 15). This insect normally disperses quickly and likely moved into some burned areas from nearby unburned patches early in the spring. *Mecinus janthinformis* (MECI JAN) was found in 12 of 17 locations with dalmatian toadflax monitored, and since the larvae would have been killed by the fire, they likely dispersed onto sites from nearby areas. The occurrence of dalmatian toadflax was relatively low before the fire. Pre-fire, it mainly occurred on roadsides and trails in small pockets. The populations of both insects was expected to rapidly increase on sites and are now likely present at all dalmatian toadflax patches.

Table 15. Dalmatian toadflax biocontrol insect detections by site monitored.

IAPP Site ID	Density of plants	Distribution of plants	Estimated Area of plant (ha)	CALO LUN	MECI JAN	RHIN ANT	Total Species by Site
Dalmatian toadflax (LINA DAL)							
Moderate Burn Severity							
315159	1	1	0.0001		1	1	2
315160	2	3	0.0003		1		1
315161	2	6	0.12		1		1
315174	2	6	0.2	1		1	2
315175	2	4	0.02		1	1	2
112527	1	7	0.2		1	1	2
315217	2	5	0.02	1		1	2
315219	2	5	0.02		1		1
315747	1	7	0.2		1	1	2
315748	2	5	1.3		1	1	2
Low Burn Severity							
315165	2	6	0.2			1	1
316224	2	5	0.05		1		1
315170	3	5	0.03		1	1	2
217788	1	4	0.1		1	1	2
315187	1	4	0.02				0
315228	2	6	0.02	1		1	2
315229	3	8	0.02			1	1
Unburned							
315171	1	1	0.0001		1		1
Total Sites with Detections by Each Insect				**3**	**12**	**12**	

Species Richness for Biocontrol Insect Species on St. John's Wort

Species richness of biocontrol insect species on St. John's wort was not significantly influenced by fire ($p = 0.41$; Figure 36), invasive plant density ($p = 0.49$), nor invasive plant distribution ($p = 0.95$). As expected, after the fire, the St John's wort expanded as the crown closure was reduced and very few locations with St John's wort had *Chrysolina spp* present with only 2 of 19 occurrences of St John's wort having this biocontrol species present (Table 16). Some of the sites checked were historical insect release locations. There was one site with plants present in the moderate burn severity, but it must have had lower ground fuel loads since some plants survived. *Aplocera* was present at one location, but for some records, the surveyor did not have the skill to detect the species so it is listed as not checked at some monitoring points. Based on monitoring results, the priority was to release more *Chysolina* spp to attempt to get populations to build. In 2019 and 2020, there were reports of *Chrysolin*a spp populations starting to increase in the valley bottom, but so far this species is only being found in small pockets on the south end of Kettle River Recreation Area, and north of Rock Creek in the Rexin restoration site. There are likely more locations in the south end of the valley experiencing a population increase of *Chrysolina spp*. A landowner southwest of the park called in spring 2020 to report high populations of *Chrysolina spp* on their property. If the populations of *Chrysolina spp*. do increase, there are extensive areas within the fire with dense infestations of St John's wort to support higher insect populations.

Table 16. St Johns wort biocontrol species detections by site monitored.

IAPP Site ID	Density of Plants	Distribution of Plants	Estimated Area of Plants (ha)	APLO PLA	CHRY SPP	Total Species by Site
St. John's wort (HYPE PER)						
High Burn Severity						
315174	2	6	0.2			0
Moderate Burn Severity						
114968	1	1	0.001	not checked		0
278460	1	7	1	not checked		0
315161	2	5	0.24			0
315175	2	7	0.08			0
315219	2	6	0.02	1		1
315227	1	4	0.02			0
315747	1	1	0.001	not checked		0
315748	1	1	0.001	not checked		0
Low Burn Severity						
113397	2	5	0.003	not checked	1	1
217788	1	1	0.1	not checked		0
315172	1	5	0.9			0
315187	1	4	0.02			0
315228	2	6	0.02			0
315229	2	5	0.02			0
315230	2	5	0.01		1	1
315243	2	5	0.02			0
Unburned						
315183	2	5	0.02			0
Total Detections				**1**	**2**	**3**

Species Richness for Biocontrol Insect Species on Canada Thistle

There were two biocontrol species found in total on three Canada thistle plants, with each plant containing only one of these two insect species (Figure 36). One of these plants contained *Larinus carlinae* (LARI PLA), and the other two each had *Rhinocyllus conicus* (RHIN CON). The LARI PLA was found on a Canada Thistle in a patch that was burned by wildfire. One of the plants with RHIN CON was in a patch that was burned by the wildfire, and the other was not. Because there were only 3 records, no statistical analyses were performed for the species richness of biocontrol insect species on Canada thistle.

Biocontrol Releases Completed 2016-2018

In 2016 and 2017, releases were completed to augment or re-establish populations as insects became available from FLNRORD or local collections. In some locations, if an insect was detected at very low levels, a new release was still done to speed up population recovery. Table 17 has a list of releases by species and jurisdiction completed within the fire perimeter. Post release monitoring found that the releases of *Chrysolina spp* did not to appear to build populations, and monitoring in 2018 at two locations only found low levels of the insect. Monitoring in 2019 and 2020 found population increases of *Chrysolina spp* at some release sites. The releases of *Mecinus janthiniformis, Larinus minutus* and *Larinus carlinae* established well after release so no further releases were needed.

Table 17. Biocontrol Insect Releases completed by Jurisdiction 2016-2018.

	2016				2017			2018		
Land Jurisdiction	**CHRY SPP**	**LARI MIN**	**LARI PLA**	**MECI JAN**	**CHRY SPP**	**LARI MIN**	**MECI JAN**	**CHRY SPP**	**MECI JAN**	**Total Releases**
FLNRORD	**2**							**1**		**3**
St. John's wort (HYPE PER)	2							1		3
MOTI HWY33				**1**		**1**	**3**		**1**	**6**
Dalmatian toadflax (LINA DAL)				1			3		1	5
Diffuse knapweed (CENT DIF)						1				1
MOTI SEC		**1**								**1**
Diffuse knapweed (CENT DIF)		1								1
PARKS	**1**	**1**	**2**	**1**		**1**				**6**
Canada thistle (CIRS ARV)			2							2
Dalmatian toadflax (LINA DAL)				1						1
Diffuse knapweed (CENT DIF)		1				1				2
St. John's wort (HYPE PER)	1									1
Private	**4**	**1**		**5**	**5**	**2**	**2**	**2**	**1**	**22**
Dalmatian toadflax (LINA DAL)				5			2		1	8
Diffuse knapweed (CENT DIF)		1				2				3
St. John's wort (HYPE PER)	4				5			2		11
TRAILS						**2**	**2**			**4**
Dalmatian toadflax (LINA DAL)							2			2
Diffuse knapweed (CENT DIF)						2				2
Total Releases	**7**	**3**	**2**	**7**	**5**	**6**	**7**	**3**	**2**	**42**

Projection Invasive Plant Response across the Fire based on Vegetation Monitoring Results

After the wildfire, there were many areas where trees were salvage harvested, both on crown and private land. Completing intensive surveys to assess post-fire invasive plant response over such a large area was beyond the resources available to the project. The pre- and post-fire vegetation monitoring results provided an opportunity to look at expected invasive changes in specific pre-fire plant communities resulting from the burn followed by disturbance associated with harvesting. Invasive plants are typically found at low density or absent from sites with high crown closure since most invasive plant species in the fire area are shade intolerant (Roche et al. 1999). The pre-fire plot surveys on Kettle East with crown closure >35% only had trace amounts of invasive plants pre-fire, despite many invasive plant species being present in nearby open forest or grassland areas surrounding the Kettle East site. The vegetation response analysis indicated that in pre-fire forested plots there was an initial increase in exotic species cover one year after wildfire in plots that were not harvested, with these values dropping back to 0 by years 2 and 5. Conversely, exotic species cover increased in plots that were both burned and harvested (salvaged) by years 2 and 5 after fire (~1.7%) compared to pre-fire levels (~0.4%). These results can be applied to the larger fire area where similar plant conditions and disturbance patterns occurred to predict potential short-term plant community change. The vegetation analysis results for open range areas had too small of a sample size to consider using it as a predictor for other areas within the fire. To identify similar forested areas ESRI ArcMap was used to do a spatial analysis of existing vegetation description layers to identify locations within the wildfire perimeter that had similar pre-fire conditions of IDFdm1 forest with crown closure >35% that were either harvested or not harvested.

To identify similar plant communities, the Vegetation Resource Inventory (VRI) from 2009 (VEG_R1_PLY), available through dataBC was used to identify polygons inside the fire perimeter that are within the IDFdm1 and had a crown closure of 35% or higher before the fire. This layer was then used to select polygons with high burn severity similar to what occurred at Kettle East. A spatial layer with the harvest boundaries for the crown land within the West Boundary Community Forest (WBCF) was used and rough boundaries were created spatially for the larger harvested areas on private land, Parks, and woodlots that did not have spatial data available. This did not capture the smaller private harvestsites or harvest that only included open forest types. The harvested and unharvested areas in the IDF with crown closure >35% were selected to identify areas where we would likely see similar invasive plant response. The overall area harvested after the fire was estimated at 518 ha and 338 ha were in areas with pre-fire canopy closure >35% (Table 18).

Table 18. *Area of Pre-fire Crown Closure >35% harvested and unharvested in the IDFdm1 within the Fire Perimeter .*

IDFdm1 within the Fire Perimeter	**Total Area (ha) within perimeter**	**Area (ha) Harvested**	**Area (ha) Not Harvested**	**% of Total Fire Area**
Total Area of Crown Closure >35%	1139	338.4	800.6	26.3%
Area of Crown Closure >35% by Soil Burn Severity				
High Burn Severity	587	290	297	13.6%
Moderate Burn Severity	305	43	262	7.1%
Low Burn Severity	165	5.4	159.5	3.8%
Unburned	81	0	81	1.9%

Areas with Similar Crown Closure Prior to the Rock Creek Fire with Similar Expected Invasive Plant Response as Plot Sites

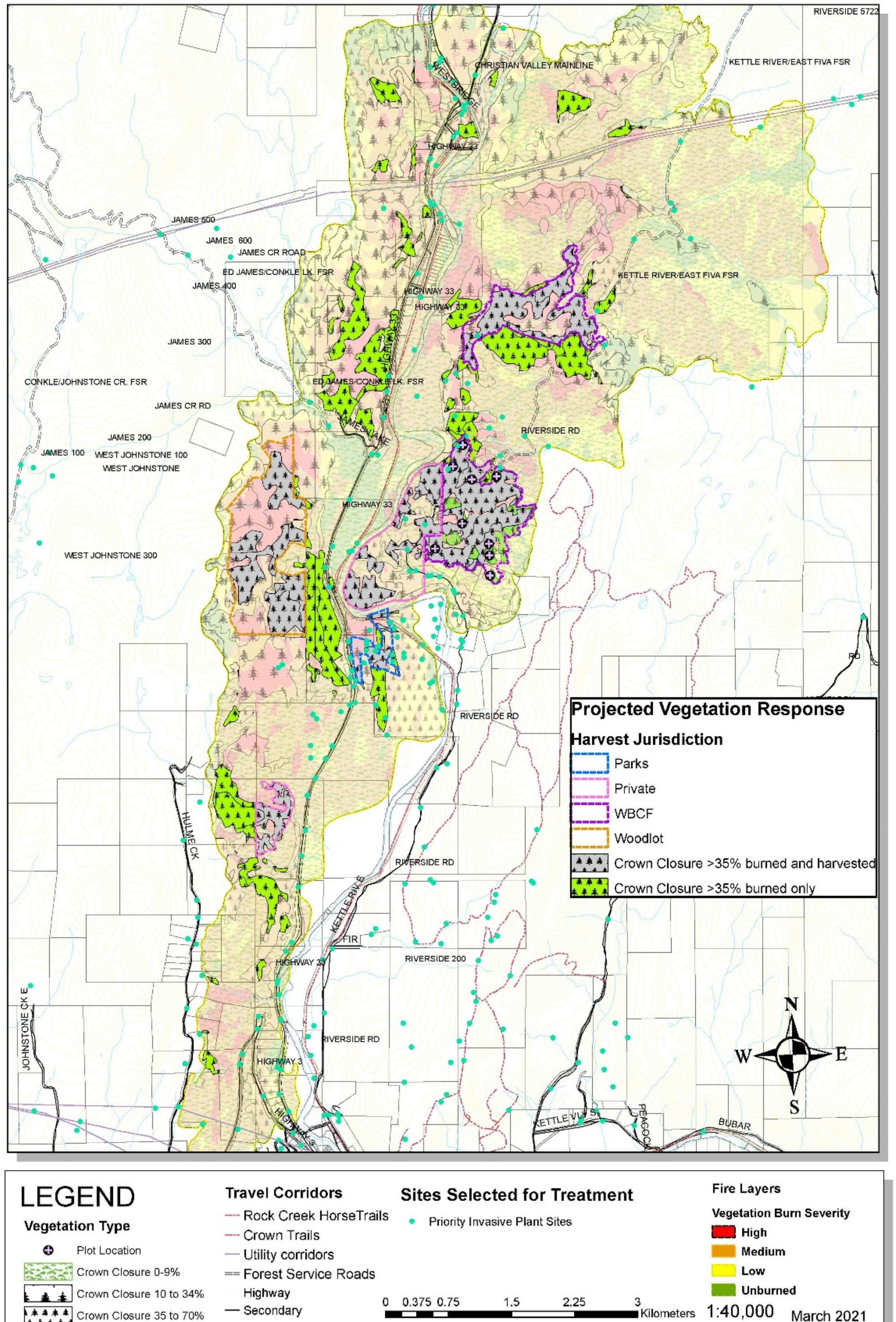

Figure 35. Selection harvest in pre-fire locations with >35% canopy cover in the IDFdm1 within the Rock Creek wildfire perimeter.

Across both crown and private lands harvest used a selection method, leaving trees that had potential to survive. Local observation suggests that most of the leave trees died within 2 years. Figure 37 shows the location of harvested areas in relation to original plant communtiy and burn severity. Of the 587 ha of high burn severity area, 290 ha were harvested and willl likely have a small increase in exotic species in the short-term. There was 297 ha in the high burn severity that were not harvested and would likely have a short-term increase in year 1, followed by decline as observed in Kettle East. The long-term trajectory for harvested sites is likely a slow increase in perennial invasive plants over time since they will compete strongly with the native plant species in the open canopy condition. Fortunately, some of the invasive plant species (diffuse knapweed, st. John's wort, and dalmatian toadflax) have potentially effective biocontrol insects present, so the degree of increase will likely be limited by the effectiveness of the insects. Unfortunately sulphur cinquefoil has no biocontrol options available so is more likely to increase in disturbed areas over time. It is likely that the IDFdm1 with >35% canopy closure that experienced moderate burn severity would experience similar short-term response as the high severity burn category since most trees in this category were also killed creating similar low canopy closure conditions that will likely last over 30 years as tree recruitment takes time. The remaining areas with >35% canopy closure in the low or unburned areas are likely to see little change in invasive plants since the canopy cover would be similar post-fire and continue to provide enough shade to suppress invasive plant species. The total area with >35% canopy cover was 26% of the fire area (1139 ha).

Open range (<10% canopy cover of trees) areas with similar sites conditions (aspect, slope, soil depth) to the plot at Kettle East are likely to see a similar response to the OR plot at Kettle East; however, this has not been projected across the fire. With only one plot representing a steep slope, thin soil grassland, there was not enough variation to capture the range of open range sites (deep soils, level or east aspect) that occurred across the fire. Water availability is a major limiting factor for growth on this thin soil type site and water availability was likely already suppressing invasive plants growth since the native species had a competitive edge. This is likely why the OR plot only had low levels of exotic plants, mostly annual species, prior to the fire. Other open range areas with deeper soils and more moisture retention, which are far more common across the fire, are likely to support far more potential invasive plant growth post fire than the plot site conditions.

Post Fire Grass Seeding

After the wildfire, government staff recognized a need to provide recommendations on grass seed mixes to use for crown and private land post-fire. After research and discussion amongst local experts, a decision was made to only encourage seeding in areas where post-fire disturbance occurred, including logging, property cleanup, fence construction, or other activities that disturbed the soil. A post-fire seeding handout with four different mixes was produced and shared out to all land managers and the public (copy in Appendix 3). The mixes were designed to have low persistence agronomic species to provide competition for invasive plants and increase forage for livestock in the short-term while allowing for native plants to move in while the short-lived agronomic species declined. The team worked with local seed suppliers to get a large shipment of seed brought in. The Red Cross purchased some seed for private land, while the Selkirk Forest District purchased some seed for use on range or private undeveloped land. An additional low growing grass mix (Orchard Star) was purchased specifically for private land use in yards. The Boundary Invasive Species Society staff facilitated distribution of the seed to landowners within the fire perimeter. The RDKB through Grant in Aid provided resources for BISS staff to do sixteen site visits to affected landowners and provide recommendations on revegetation of their property post fire. Selkirk Forest District provided seed to one range tenure holder to use on the disturbance created by woodlot salvage harvesting. In total, 18 bags of seed were distributed to 13 landowners during the early spring of 2016. All seed was spread by the landowners themselves. The seed analysis results for the mix used on the crown portions of the fire after November 2015 is included in Appendix 3 of the report.

There had been plans to monitor the seed mix establishment in 2017; however, the severe drought experienced resulted in delaying the monitoring. Unfortunately, BISS staff and District Range staff were unable to monitor the seed mix establishment in 2019 (high fire risk Aug/Sept) or 2020 but will attempt to do monitoring in 2021.

Tree Planting and Natural Regeneration

Post-fire tree planting was completed on Kettle East site along with the Riverside harvest and James Creek woodlot. Some monitoring was completed on the Kettle East site through FLNRO Selkirk District. Monitoring results for planted trees were not available at the time of writing this report. Planted trees were recorded on three of the vegetation plots so there may be an opportunity to track future survival of planted and natural regeneration on the plots. Overall wildlife increased both percent cover and species richness of coniferous and deciduous trees in the B Layer (Figure 11). Natural Ponderosa pine and black cottonwood (*Populus trichocarpa*) regeneration was visible by year 2 on vegetation monitoring sites. Pre-fire mixed conifer and deciduous stands were not sampled. Surveyor observations while traversing between plot locations observed dense natural recovery of shrubs and trees in previously mixed stands by year 5. In some locations, shrub density was so high, it was difficult to walk through the draws. These areas are likely to quickly re-establish dense canopy cover that will suppress invasive plant growth. For more information on natural regeneration, see the initial Vegetation Monitoring section of this report.

Report Summary

This report (1) evaluated the progress of vegetation monitoring 5-years post-wildfire in the Kettle East site, (2) assessed the progress of invasive plant management, and (3) summarized the biocontrol insect monitoring completed post-wildfire.

Vegetation Monitoring

The Kettle East and Rexin (used as a control site) sites are a subset of sites being monitored at regular intervals as part of a larger BREP (Tedesco 2016, 2020). Below, we discuss the current results for different subsets of ecological monitoring for Kettle East and Rexin sites.

The impact of both wildfire and harvesting varied by species grouping and metric measured (i.e., percent cover or species richness), with no consistent increase or decrease for all species groupings. For example, burning decreased percent cover of native grass species (Figure 5), shrubs in the B layer (Figure 10), and trees in the A layer (Figure 12) at Kettle East, but increased the percent cover of exotic species (shot-term increase; Figure 9) and native herbaceous and forb species (Figures 6-8). Additionally, the immediate influences of wildfire on vegetation were often mediated over 5 years, with values becoming more similar to pre-fire levels in most groups. In contrast, when harvesting or salvaging occurred, these changes often stayed after 5 years, in large part due to the impacts that soil disturbance has on different specues.

Burning and harvesting often do not work in isolation, but rather they frequently influence the percent cover and species richness of vegetation groups synergystically (e.g., Bewley Wayman and North 2007; Dodson et al. 2007; Dodson and Peterson 2010). Most studies have investigated the influence of harvesting prior to prescribed burn; however, our study investigates the influences of wildfire and subsequent salvaging. Although we find many parallels between our study and the findings of many others that investigate prescribed burns, we also note some key differences. For example, fireweed often dominated our plots at Kettle East, a species that might not be present at such high abundance after a low-intensity prescribed burn, thus dramatically altering the response for the C layer (BEC system) in our sites compared to published literature investigating prescribed burns.

By year 5 post-fire, 2 of the 4 targets set for the vegetation monitoring program for open forest sites by year 10 were met (i.e., increased cover of native herbaceous and forb species, and decreased canopy), with trajectories for native grass and shrub species suggesting that the other two targets may be achieved by year 10. Native grass, forb, herbaceous and shrub species all aproached similar percent cover and species richness levels by year 5 compared to pre-fire conditions, except in some instances where harvesting increased their cover initially and cover remained high even 5 years after intervention (e.g., percent cover of native herbaceous and forb species; Figures 6-8). Further, grass and shrub species cover are on an upward tajectory from year 1 to year 5 post-fire. Thus, although burning resulted in short-term declines in key vegetation groups, these decreases may be short-lived. Many studies have observed that there is a delay of 5+ years before increases in vegetation groups are observed post-fire (e.g., Moore et al. 2006; Newman et al. 2012), whereas others have observed that little change occurs from pre-fire values compared to 5+ years after fire (Dodson et al. 2008; Kerns and Day 2018). However, much of the herbaceous layer was dominated by one species (fireweed), and we suspect that grass species will begin to dominate once fireweed continues to decline in abundance. As a result, both the shrub and herbaceous layers may decline by year 10 due to low canopy cover, and grass cover will likely exceed pre-fire levels. Ultimately, for the Kettle East site, more time is needed to determine if percent cover of grass and shrub species can increase relative to pre-fire levels which can be assessed at the 7 and 10 year mark. Evaluation at the 7 and 10 year mark will also reveal whether native herbaceous and forb species cover remains higher than pre-fire levels, returns to pre-fire levels, or becomes lower than pre-fire levels.

Post-Fire Invasive Plant Monitoring and Treatment

The valley bottom and lower valley slopes had a history of many invasive plant species and local land managers recognized the need to implement an aggressive post-fire treatment program to prevent further expansion into recently burned areas. The disturbance associated with fire suppression activities, infrastructure replacement, and salvage harvesting created new opportunities for invasive plant species to be introduced or expand. To mitigate the potential negative impacts of invasive plant expansion in this high value areas, a five-year plan for invasive plant management was developed and implemented from 2016-2020. The plan included focusing management actions for locations with priority invasive plant, monitoring to assess the survival of invasive plants and biological control insects, combined with herbicide treatments to prevent species from going to seed in the first few years after the fire to give the natural plant communities time to recover.

The monitoring actions recommended in the plan were completed for category 1 invasive plants. There was no increase in category 1 invasive plants, so the work to suppress populations of the highest priority species post fire was successful. However, only a portion of the category 2 and 3 sites identified were monitored and treated. Road networks identified for treatment were completed except for a couple roads connecting in from the northeast corner of the fire area. Post treatment surveys were not completed, so further surveys should be completed in 2021 to assess the longer-term control achieved. Resources for treatment on public forest land and trails limited the scope of treatment work completed.

Some fire guards were monitored in 2017 and 2020; however, resources were not sufficient to complete the scope of surveys recommended (Year 1, 2, 3, 5). The surveys that were completed did not find any new invasive plant species likely introduced directly by fire fighting activities. On some sites there were invasive plants growing that were previously known to exist in the area. North Africa grass was found along some newly built fences along Highway 33 in 2018, possibly introduced during post-fire fence construction; however, a large patch was found on a private lot in 2020 and may have been the introduction source. It is unclear whether the introduction was directly fire related, although it did increase with the fire related activity and disturbance.

The establishment of the grass seed mixes used were not assessed; however, in some areas, the native plant community filled back in very quickly, particularly in open grasslands where only the surface soil was disturbed by fireguard construction. Surveyors reported more annual weedy species where fire guards were cut through forested areas than through grassland areas.

Biocontrol Monitoring in 2016

The monitoring of biocontrol insect presence post-fire was completed by regional biocontrol staff from FLNRORD and BISS staff. During analysis of the data, we were unable to detect differences in the occurrence of biocontrol insect species between patches that were burned in the 2015 wildfire compared to those that were not burned. Of the three biocontrol insect species assessed for presence/absence above, MECI JAN were by far the most frequently detected and CHRY SPP the least frequently detected species (Figures 32-35). It is likely that many biocontrol insect individuals perished in the fire; however, many of the insects are highly mobile and quickly re-established from nearby unburned areas and were detected at low levels in June 2016. The presence of some root boring insect larvae in the spring following the fire indicated some larvae survived the fire in the roots of diffuse knapweed. These species were only detected in the low to moderate burn severity areas where the invasive plant itself survived and regrew from roots. In the high burn severity areas, there were some areas where invasive plants were completely removed by the fire and other locations where there was root survival, presumably a result of differing ground fuel loading.

Overall, this monitoring found that all the biocontrol insect species suspected to be present before the fire were still present the following year in some pockets where host plants remained. The monitoring found presence across the landscape, so if historical dispersal patterns occur the insects should re-populate all sites within the fire area eventually. It is likely that monitoring in 2021 (6 years post-fire) would find population recovery across the area. This is supported by incidental monitoring in 2020 in KRRA that found knapweed insects at all locations with host plants and healthy *Chysolina spp* populations in the south end of the Park. A landowner southwest of the park called in spring 2020 to report high populations of *Chrysolina spp* on their property. Monitoring during summer of 2021 is recommended to assess if more sites have presence and to assess the population levels.

Recommendations:

This report provides valuable information regarding the effects of wildfire on vegetation communities and biocontrol insects. The wildfire provided this framework opportunistically. For future experimental design and data analysis, we have the following recommendations.

- The vegetation analysis completed focussed on groups of species based on growth form and we suggest expanding to include species composition during future analysis.
- The vegetation analysis was limited by available data. Increasing the number of plots and synchronizing monitoring between the treatment and control plots would improve the analysis.
- Complete a ten-year post fire vegetation analysis to assess plant community change since few studies track long-term plant community changes.
- Assess the establishment of the grass seed mix used on fire guards and newly constructed harvest roads on public land harvest areas.
- Secure resources to complete monitoring of all category 2 and 3 invasive plant sites treated during project to assess current infestations levels post-treatment.
- Re-survey invasive species along roads through moderate to high soil burn severity areas and complete herbicide treatments to prevent expansion of invasive plants into the adjacent recovering plant communities.
- Monitor biocontrol insect presence and population levels within the fire perimeter in 2021 to assess population expansion/recovery since the 2016 monitoring.
- Sample harvested areas in upper Riverside to assess invasive plant infestation levels and whether a similar plant community response occurred as was observed in Kettle East.

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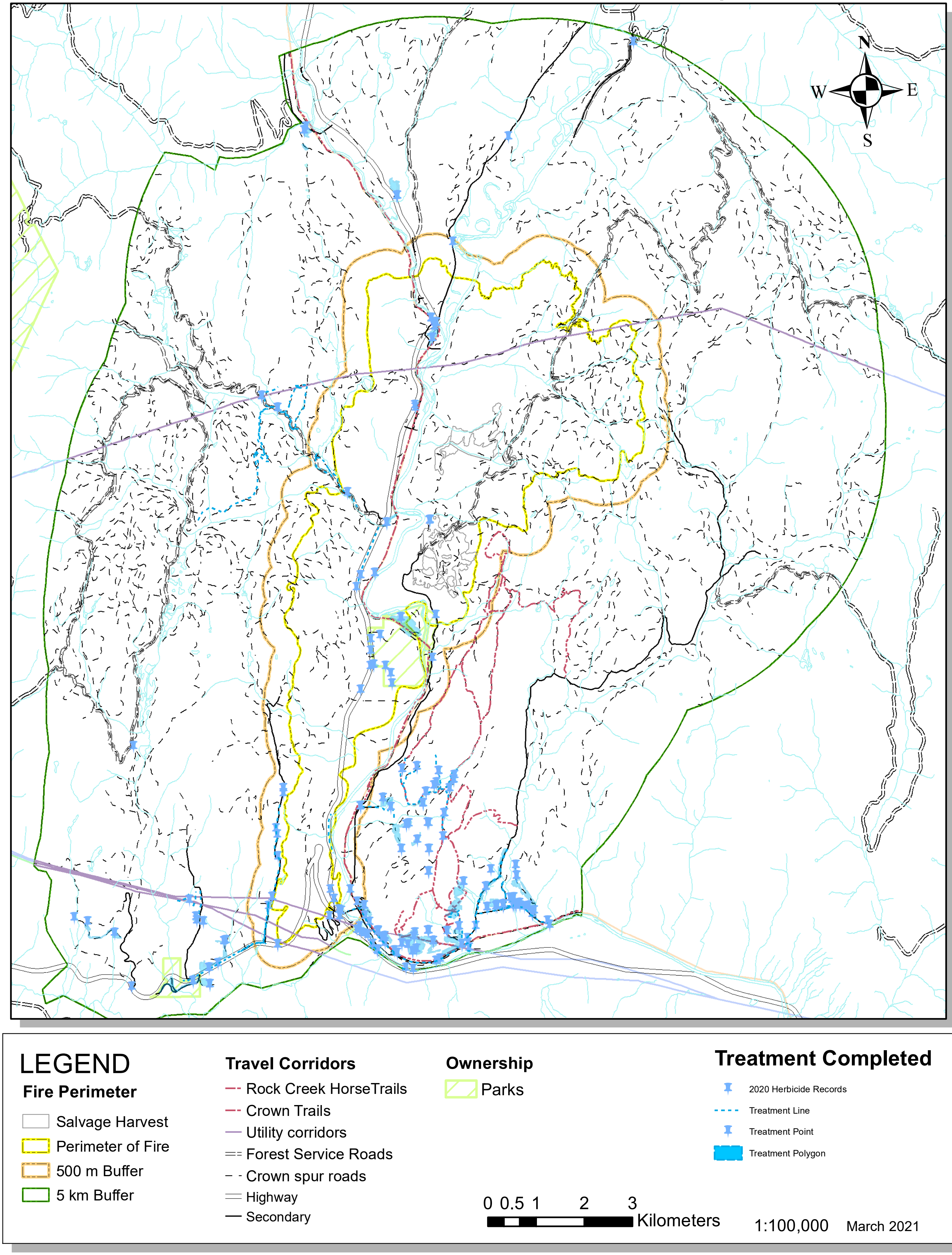
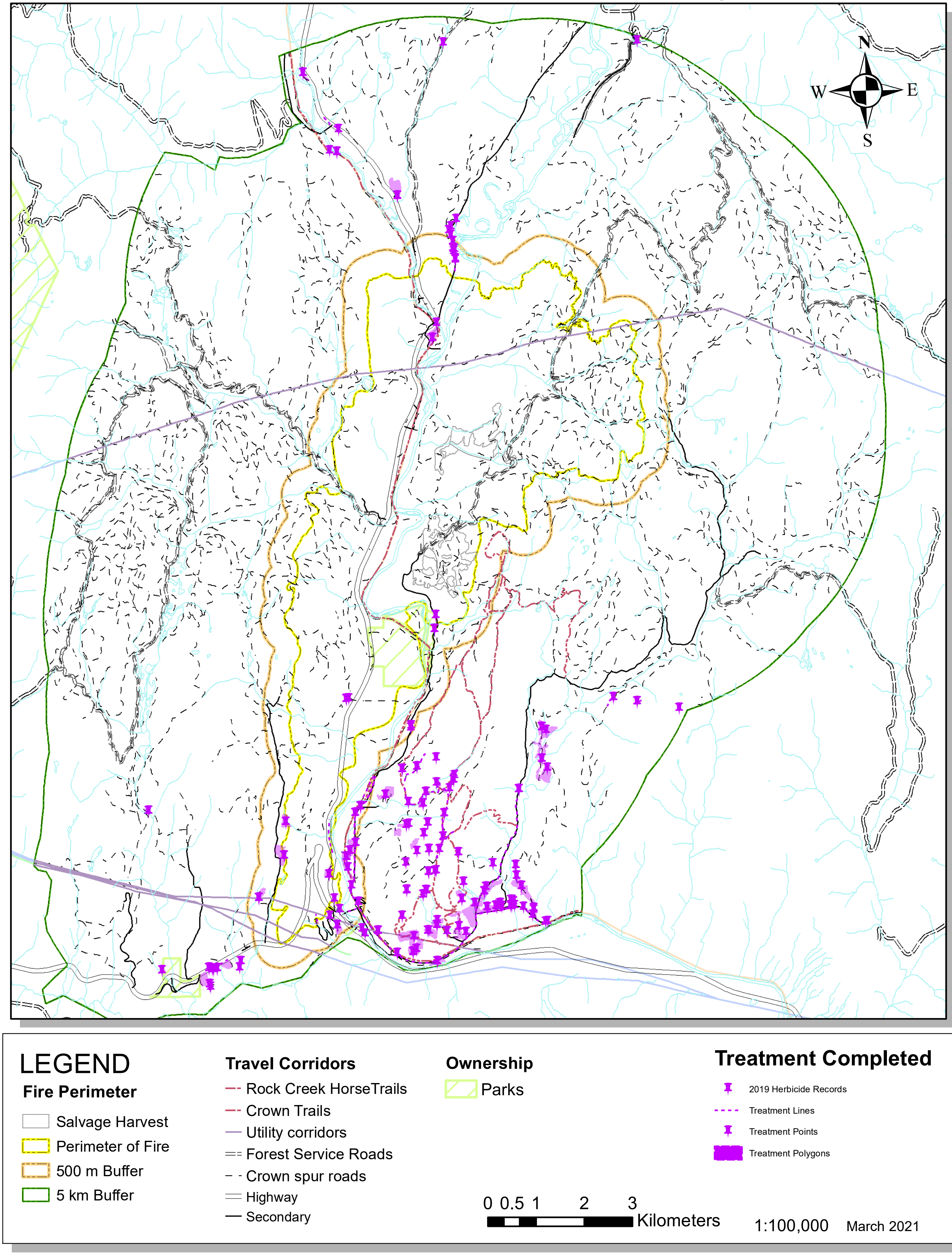
Appendix 1. Invasive plant survey locations from 2016 to 2020

Rock Creek Fire
Herbicide and Mechanical Treatment Completed 2020

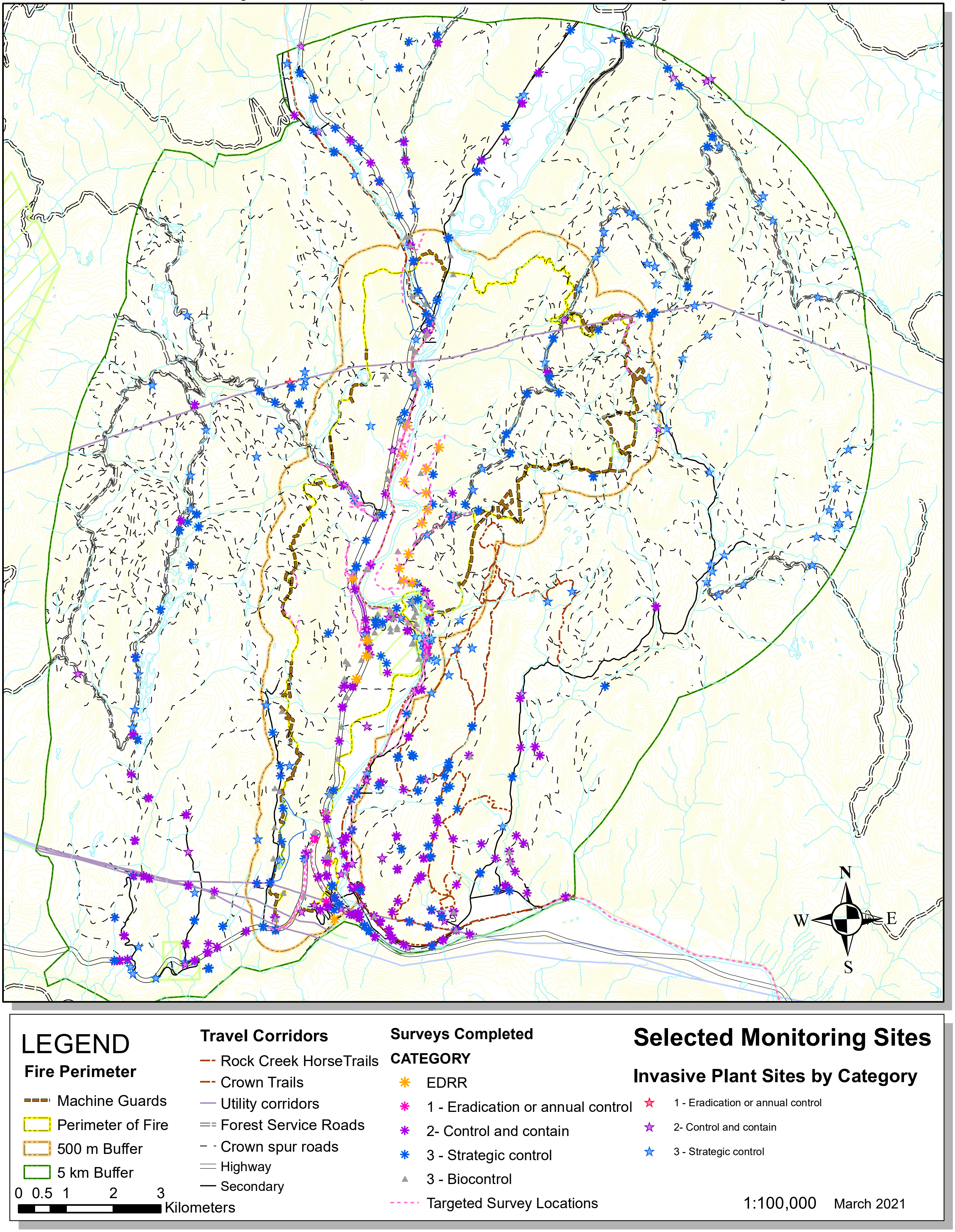


Appendix 2. Rock Creek fire invasive plant herbicide and mechanical treatments completed 2016-2020

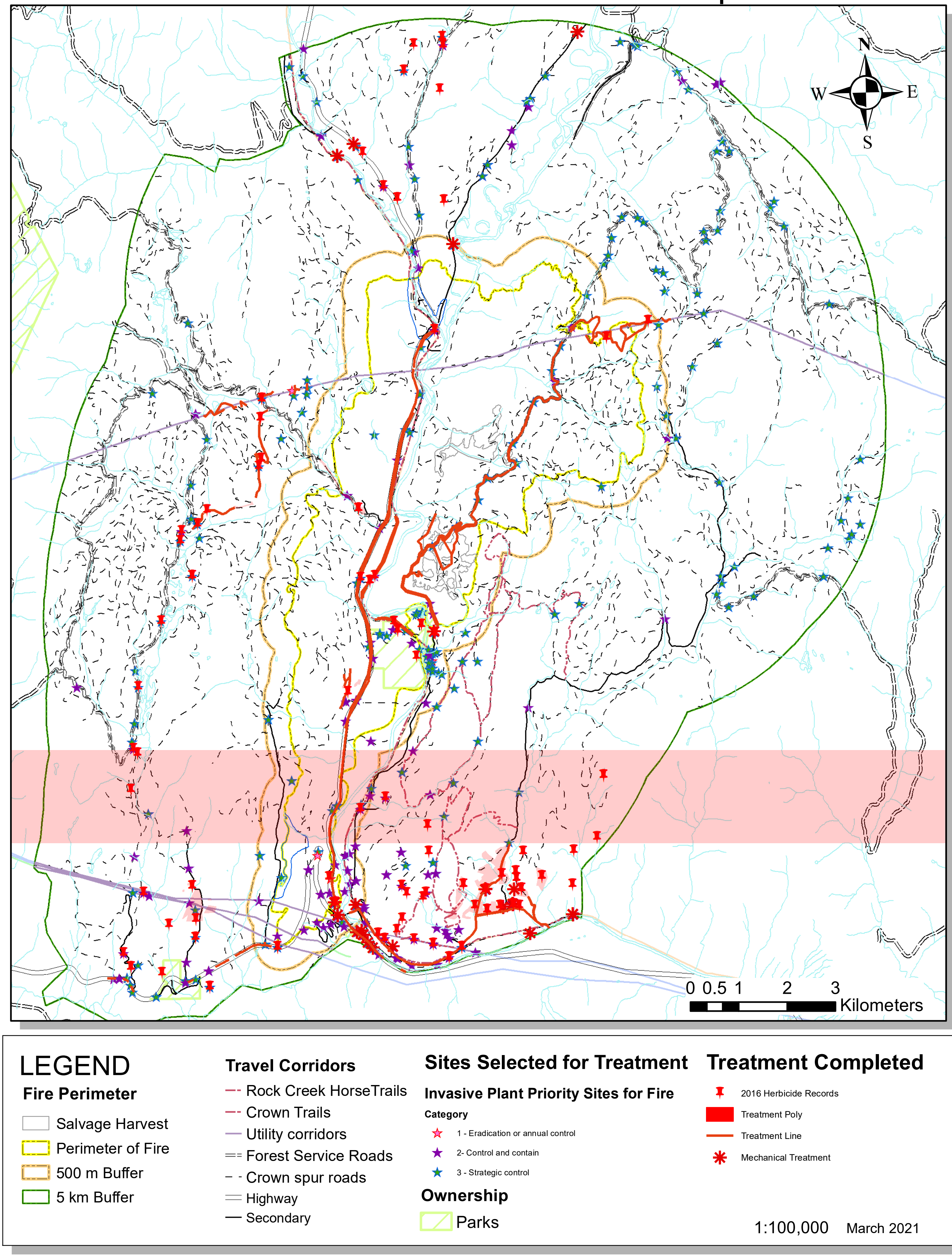
Rock Creek Fire
Herbicide and Mechanical Treatment Completed 2019



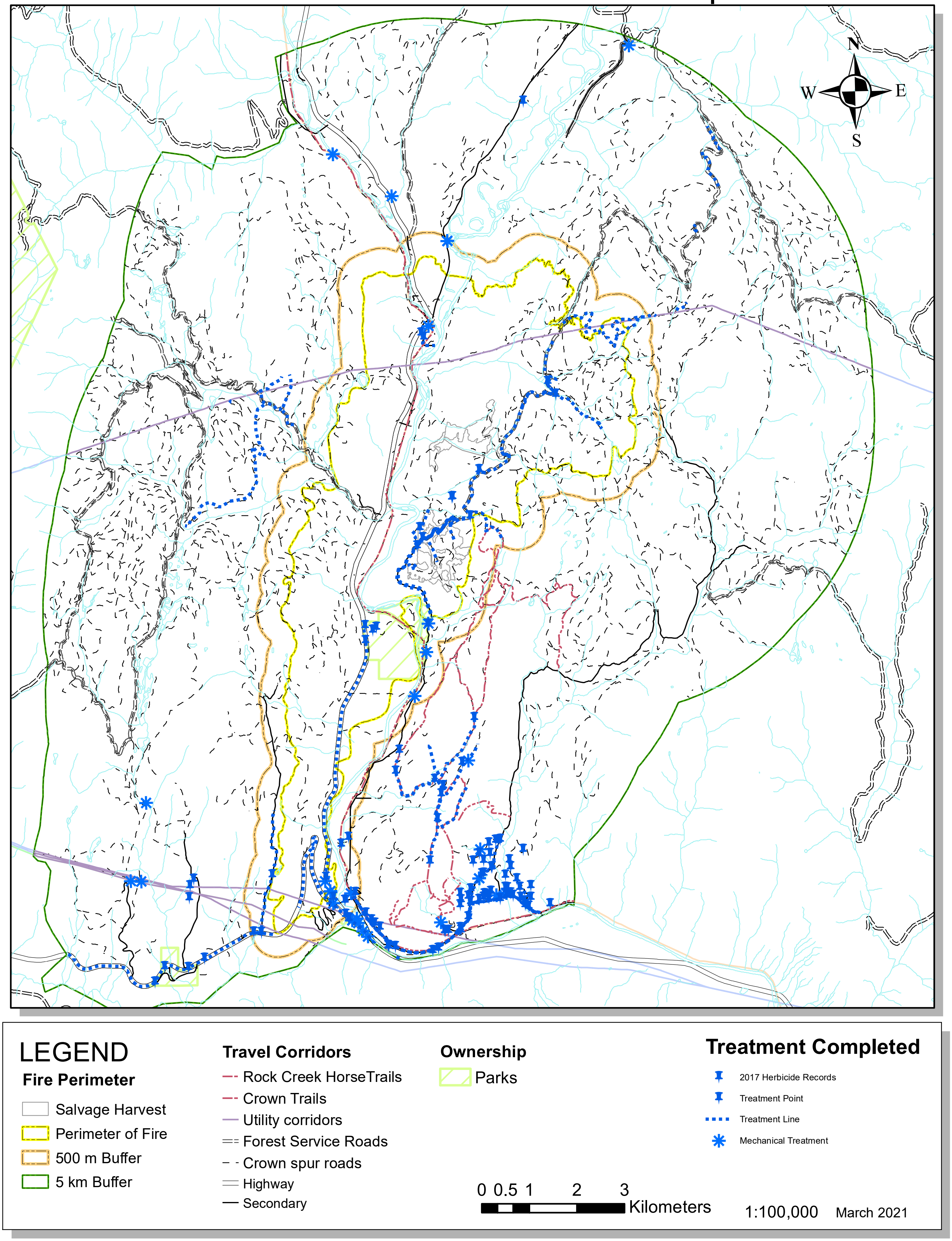
Rock Creek Fire
Surveys Completed 2016-2020 by Priority



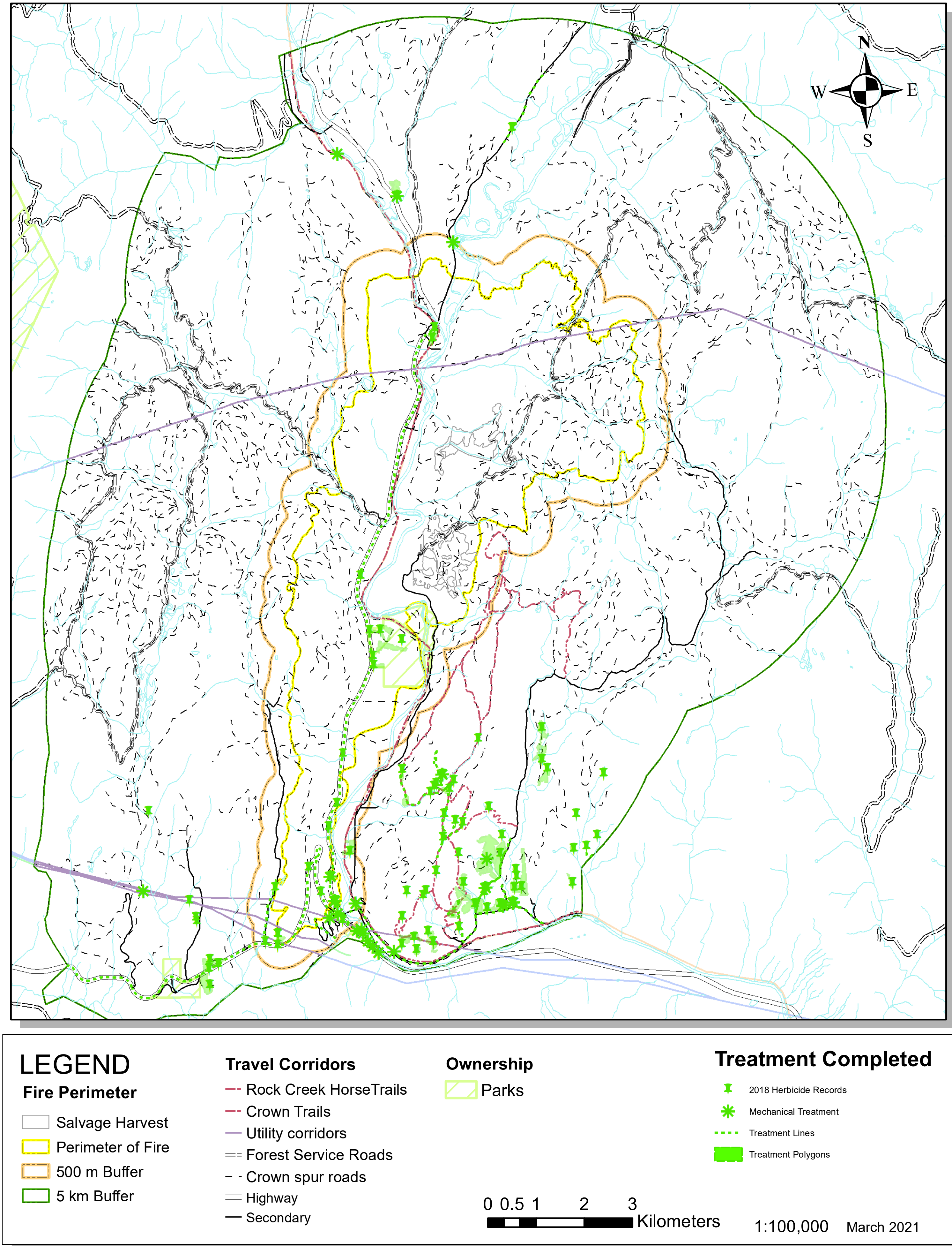
Rock Creek Fire
Herbicide and Mechanical Treatment Completed 2016



Rock Creek Fire
Herbicide and Mechanical Treatment Completed 2017



Rock Creek Fire
Herbicide and Mechanical Treatment Completed 2018



Appendix 3. Grass seed mixes developed and seed analysis results for seed lots used

Seeding of Rangelands Burned by Wildfires
Boundary Region, BC

Overview

Broad scale seeding of all burned areas is unnecessary and inappropriate within the context of managing for a natural landscape.

Many areas in the Boundary contain fire maintained ecosystems which are well adapted to fire and have plant communities that are highly resilient to low and moderate severity burns. A balance of values will be achieved if seeding is used to gain specific benefits while allowing most areas to regrow to a natural condition.

Following a burn some areas may benefit from seeding to address weed control, erosion control, or can be seeded for forage replacement and to take advantage of an opportunity to improve livestock distribution and provide forage enhancement. Thoughtful use of seeding will reduce the on-site and off-site effects of fireguards and staging areas. Seeding can also take advantage of the seedbed created by the fire to improve livestock distribution and forage production for livestock and wildlife.

Any seeding of Crown range must be done with the written permission of the District Manager and must be identified and planned in conjunction with the Range Program.

Seed Analysis Certificates and Weed Content

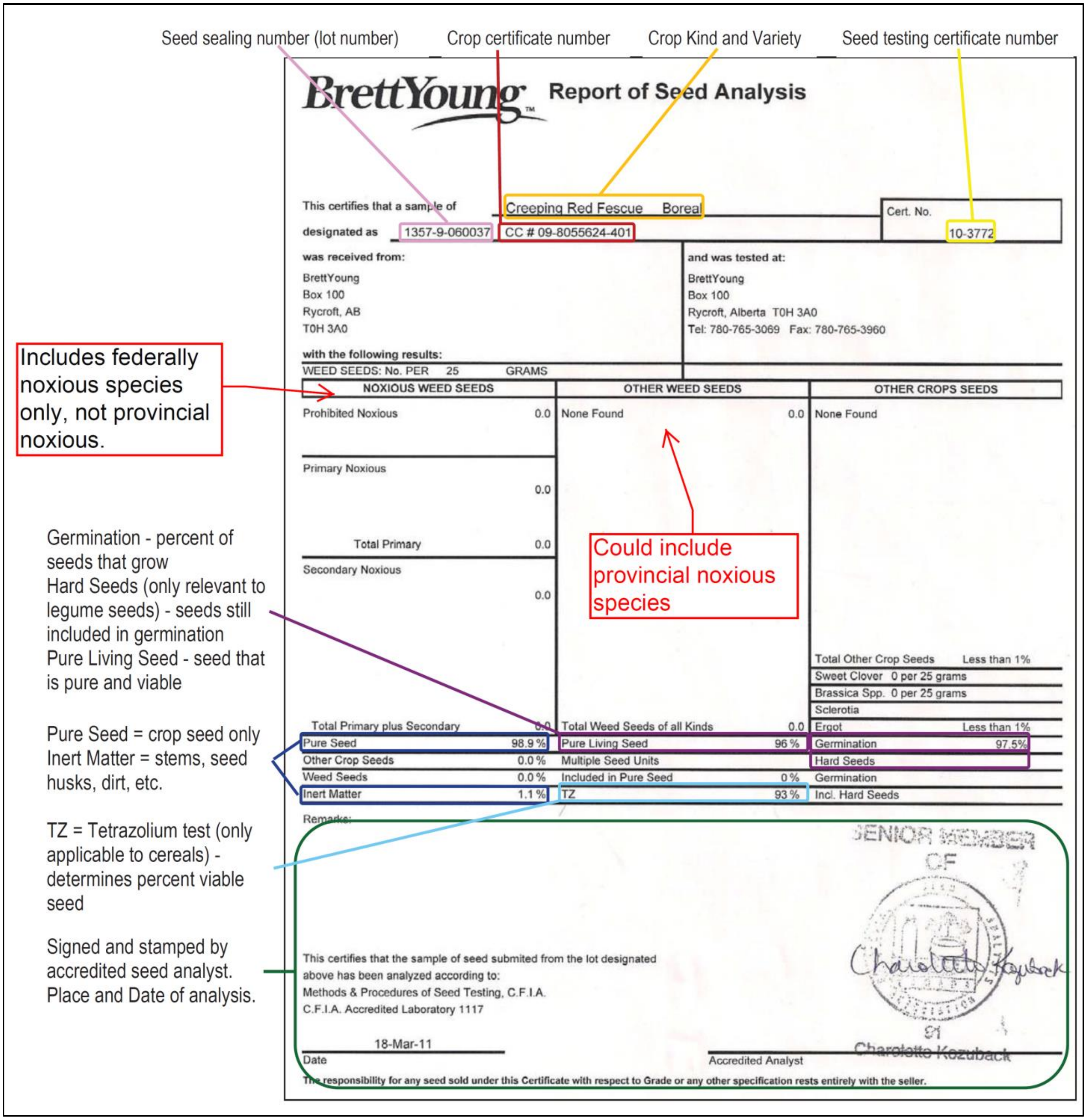
Before purchasing and applying a seed mixture it is important to obtain a copy of and review the seed lot's Seed Analysis Certificate (Figure 1) to learn of any invasive plant species that are present in, or adjacent to, the seed lot. Under the Canada Seeds Act, all seed that is offered for sale must be graded and labelled before it can be sold and seed suppliers are required to provide a copy of the seed analysis certificate when requested by a customer. A seed analysis certificate documents three primary pieces of information:

1. Noxious Weeds Seed – This list will show presence of any federally listed noxious weeds. This will not include provincially or regionally listed noxious weeds.
2. Other Weed Seeds – This list will show presence of any other weeds seeds including provincially and regionally listed species.
3. Other Crop Seeds – This list will show presence of other seeds not supposed to be in the mix but that are not considered noxious or weeds (e.g. agronomic grasses).

When ordering seed, it is important to specify that the individual species in each mix must grade **Common No. 1** or better, and that the blended mixture must meet the grade requirements for **Common No. 1 Forage Mixture**. Accepting seed mixtures with a lower grade specification, such as Common No. 2 forage mixture or Canada No. 1 ground cover, may increase the likelihood of contamination by noxious weeds. It is important to note that under the Canada Seed Act there is no minimum standard for native seed and no grade designation for mixtures composed of native species. Exercise caution when interpreting seed certificates for native species.

With respect to weed seed content, buyers can specify weed species they do not want in their seed mixes. This is useful when tendering for seed supplies.

To obtain a list of provincially and regionally listed noxious weeds go to:
www.agf.gov.bc.ca/cropprot/weedguid/weedguid.htm



BrettYoung **Report of Seed Analysis**

This certifies that a sample of Creeping Red Fescue Boreal

designated as 1357-9-060037 CC # 09-8055624-401

Cert. No. 10-3772

was received from:
BrettYoung
Box 100
Rycroft, AB
T0H 3A0

and was tested at:
BrettYoung
Box 100
Rycroft, Alberta T0H 3A0
Tel: 780-765-3069 Fax: 780-765-3960

with the following results:
WEED SEEDS: No. PER 25 GRAMS

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROPS SEEDS	
Prohibited Noxious	0.0	None Found	0.0	None Found	
Primary Noxious	0.0				
Total Primary	0.0				
Secondary Noxious	0.0				
				Total Other Crop Seeds	Less than 1%
				Sweet Clover 0 per 25 grams	
				Brassica Spp. 0 per 25 grams	
				Sclerotia	
Total Primary plus Secondary	0.0	Total Weed Seeds of all Kinds	0.0	Ergot	Less than 1%
Pure Seed	98.9 %	Pure Living Seed	96 %	Germination	97.5%
Other Crop Seeds	0.0 %	Multiple Seed Units		Hard Seeds	
Weed Seeds	0.0 %	Included in Pure Seed	0 %	Germination	
Inert Matter	1.1 %	TZ	93 %	Incl. Hard Seeds	

Remarks:

This certifies that the sample of seed submited from the lot designated above has been analyzed according to:
Methods & Procedures of Seed Testing, C.F.I.A.
C.F.I.A. Accredited Laboratory 1117

18-Mar-11
Date

SENIOR MEMBER OF
Charlotte Kozuback
Accredited Analyst

The responsibility for any seed sold under this Certificate with respect to Grade or any other specification rests entirely with the seller.

Figure 1. Example Seed Analysis Certificate. Actual layout may vary.

Seeding of Rangelands Burned by Wildfires
Boundary Region, BC

Use of non-native seed

There is concern about the introduction of non-native plant species through seeding of domestic forage species. Consider site sensitivity, invasiveness of the seeded species, and persistence of the seeded species and availability of native species when making your decisions. Short-lived, non-invasive domestic species will have the least long-term impact on a site while persistent invasive species will have the greatest.

There does not appear to be any native species available that can achieve a weed resistant cover in the short-term needed to control the establishment of invasive weeds. Furthermore, British Columbia cultivars of native grass species can be difficult or costly to obtain.

Annual grasses are an option as long as they can maintain sufficient cover in successive years to resist weeds. In very dry conditions, annual grasses may not set seed and therefore may not maintain the needed cover. Reseeding would then be needed.

Hard Fescue is persistent but not invasive on very dry sites and appears to be one of the only options available.

On moister sites, that will succeed to forests, very few of the domestic forages will be persistent. However, known invasive species such as smooth brome should be avoided.

When to seed

Plants need sufficient growth prior to freeze-up in order to survive the winter. The best times to seed are (in order of preference):

1. Immediately after the fire until the end of August.
2. If unable to seed prior to the end of August, seeding in October/November just prior to snowfall (<2.5cm or 1" of snow on the ground) or waiting until snowmelt in early spring may be the best option.
3. September seeding may be successful under ideal conditions (if the grass does not germinate until the following spring) but legumes will likely not survive. Seeding onto snow (>5cm or >2") has the same results.

Most sites will have the bladed material pulled back onto fireguards. Seeding can be done before or after this work.

If an area is scheduled for salvage logging then seeding should be done after the logging (to cover new disturbances), and can be done either before or after site preparation.

Seeding of Rangelands Burned by Wildfires
Boundary Region, BC

Objectives for Seeding

Weed control

The following sites may benefit from seeding to achieve a weed resistant plant cover within one growing season. The purpose is to ensure that these areas do not become vectors for weed spread.

- Fireguards, staging areas and other mineral soils exposed by fire suppression activities
- Moderate and high severity burned areas (see appendix 1) where the area is at risk to weed invasion (e.g. on or near a transportation corridor, in close proximity to existing invasive plant sites).

For information on invasive plant locations go to the Map Display module of the Invasive Alien Plant Program at *www.for.gov.bc.ca/hra/Plants/application.htm*

For local support on identifying invasive plants, your risk and treatment or management options contact the Boundary Invasive Species Society at *boundaryinvasives@gmail.com*

Erosion control

The following sites may benefit from seeding to achieve an erosion resistant plant cover within one growing season. The purpose is to minimize erosion during rain events and snow melt:

- Fireguards, staging areas and other mineral soils exposed by fire suppression activities that are on steep slopes, in gullies or draws.
- Moderate and high severity burned areas (see appendix 1) where native understory vegetation is killed and the areas is considered at risk to erosion (e.g. steep slopes, gullies and draws)

Livestock distribution

Forage seeding can be used as an attractant to lure livestock from sensitive sites such as riparian zones. Ridge tops and areas far from water that have burned hot and have exposed soils are candidates for this treatment, and site selection would be at the discretion of local range staff.

Forage replacement

If large areas burned hot enough to kill understory vegetation, then forage replacement by seeding may be needed. Care must be taken to not attract livestock into sensitive sites with this forage.

Areas that burned hot enough to create a seedbed, but not kill the understory vegetation, may produce slightly less forage during the spring following the fire because of the reduction in live tillers and the loss of moisture holding mulch. In many cases this reduced production will be compensated by an increase in areas accessible to grazing, and an increase in production due to the removal of forest canopy. Where this compensation is not anticipated, then forage seeding may be required to fill the time-gap until stressed plants fully recover.

Use low seeding rates and non-persistent species to minimize effects on the succession of these sites to a native plant community.

Forage Enhancement

In some cases, large areas have burned sufficiently to create a seedbed but not kill native understory. This may create an opportunity to enhance forage quality and quantity by introducing palatable and productive domestic forage. Care should be taken to select species that are not persistent or invasive. This treatment can create livestock management and utilization problems where remaining native plants have a lower tolerance to heavy grazing pressure.

Seed mixes and application rates

The following mixes provide a range of options for dry and moist sites to address erosion, weed control and livestock use. These mixes deliver approximately the same number of seeds per species and include recommended application rates.

Grasslands, rangelands, Ponderosa Pine and dry Douglas fir forests

1. Sensitive areas where we need to discourage livestock use

- Seeding rate 10kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
*Annual ryegrass,	35	Low	Low (1 yr)	High
Slender wheatgrass	40	Moderate	Moderate	Moderate
Chewings fescue	15	Low	High (+30 yr)	High
Hard fescue	10	Low	High	High

*If you are fall planting use fall Rye, if you are spring planting use spring varieties

2. Areas where livestock use is appropriate

- Seeding rate 10kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
*Annual ryegrass	25	Low	Low (1 yr)	High
Slender wheatgrass	20	Moderate	Moderate	Moderate
Orchardgrass	20	Low	Moderate	Moderate
Hard fescue	10	Low	High	High
White Clover	25	Moderate	Moderate	Moderate

*If you are fall planting use fall Rye, if you are spring planting use spring varieties

Seeding of Rangelands Burned by Wildfires
Boundary Region, BC

3. Enhancing livestock distribution, and forage production

- Seed at 4kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
*Annual ryegrass	30	Low	Low (1 yr)	High
Slender wheatgrass	25	Moderate	Moderate	Moderate
Orchardgrass	25	Low	Moderate	Moderate
White Clover	20	Moderate	Moderate	Moderate

*If you are fall planting use fall Rye, if you are spring planting use spring varieties

Wetter parts of Douglas fir forests and lodge pole pine and spruce forests

1. Sensitive areas where we need to discourage livestock use

- Seed at 10kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
Annual ryegrass	50	Low	Low (1 yr)	High
Chewings fescue	25	Low	High	High
Hard fescue	25	Low	High	High

2. Areas where livestock use is appropriate

- Seed at 10kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
Annual ryegrass,	55	Low	Low (1 yr)	High
Orchardgrass	30	Low	Moderate	Moderate
White clover	15	Moderate	Moderate	Moderate

3. Enhancing livestock distribution, and forage production

- Seed at4kg/ha

Species	% by weight	Invasiveness	Persistence	Weed resistance
Orchardgrass	70	Low	Moderate	Moderate
White clover	30	Moderate	Moderate	Moderate

Appendix 1. Burn severity coding matrix (USDI National Parks Service 2003

Table 28. Burn severity coding matrix.

	Forests		Shrublands		Grasslands	
	Substrate (S)	Vegetation (V)	Substrate (S)	Vegetation (V)	Substrate (S)	Vegetation (V)
Unburned (5)	not burned	not burned	not burned	not burned	not burned	not burned
Scorched (4)	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; leaf structures unchanged	foliage scorched
Lightly Burned (3)	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned	foliage and smaller twigs partially to completely consumed; branches mostly intact	litter charred to partially consumed, some leaf structure undamaged; surface is predominately black; some gray ash may be present immediately postburn; charring may extend slightly into soil surface where litter is sparse, otherwise soil is not altered	foliage and smaller twigs partially to completely consumed; branches mostly intact; less than 60% of the shrub canopy is commonly consumed	litter charred to partially consumed, but some plant parts are still discernible; charring may extend slightly into soil surface, but soil is not visibly altered; surface appears black (this soon becomes inconspicuous); burns may be spotty to uniform depending on the grass continuity	grasses with approximately two inches of stubble; foliage and smaller twigs of associated species partially to completely consumed; some plant parts may still be standing; bases of plants are not deeply burned and are still recognizable
Moderately Burned (2)	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches still present	leaf litter consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches (>.6–1 cm in diameter) (0.25–0.50 in) still present; 40–80% of the shrub canopy is commonly consumed.	leaf litter consumed, leaving coarse, light gray or white colored ash immediately after the burn; ash soon disappears leaving bare mineral soil; charring may extend slightly into soil surface	unburned grass stubble usually less than two inches tall, and mostly confined to an outer ring; for other species, foliage completely consumed, plant bases are burned to ground level and obscured in ash immediately after burning; burns tend to be uniform
Heavily Burned (1)	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred	leaf litter completely consumed, leaving a fluffy fine white ash; all organic material is consumed in mineral soil to a depth of 1–2.5 cm (0.5–1 in), this is underlain by a zone of black organic material; colloidal structure of the surface mineral soil may be altered	all plant parts consumed leaving only stubs greater than 1 cm (0.5 in) in diameter	leaf litter completely consumed, leaving a fluffy fine white ash, this soon disappears leaving bare mineral soil; charring extends to a depth of 1 cm (0.5 in) into the soil; this severity class is usually limited to situations where heavy fuel load on mesic sites has burned under dry conditions and low wind	no unburned grasses above the root crown; for other species, all plant parts consumed leaving some or no major stems or trunks, any left are deeply charred; this severity class is uncommon due to the short burnout time of grasses
Not Applicable (0)	inorganic preburn	none present preburn	inorganic preburn	none present preburn	inorganic preburn	none present preburn

Report of Seed Analysis
CFIA Accredited Laboratory No. 1215

SEEDCHECK TECHNOLOGIES INC.

101, 5906-50 Street
Leduc, Alberta T9E 0R6
Phone: (780) 980-8324
Fax: (780) 980-8375
www.seedcheck.net

LAB#: 15-67988

Customer: Premier Pacific Seeds Ltd.
#203, 19315 - 96 Avenue
Surrey, B.C. V4N 4C4

Sender Information:

SeedType:	Annual Ryegrass
Scientific Name:	(Lolium multiflorum)
Lot#:	L99-15-8

Analyzed According to Canadian Methods & Procedures for Testing Seed

Tests: Germination , Canadian Purity,

Total Grams Analyzed: 50.10	Per 25g
Prohibited Noxious:	0
Primary Noxious:	
Total Primary	**0**
Secondary Noxious:	
Total Primary & Secondary Noxious	**0**
Other Weed Seeds:	
Total Noxious & Other Weed Seeds	**0**

Date Received: Oct 22, 2015 Purity Date: Oct 23, 2015	Per 25g
Other Crop Seeds:	
Total Other Crop Seeds	**0%**
Sweet Clover (Melilotus sp.)	0
Brassica spp.	0
Ergot Bodies	0%
Percentage Test:	2.011g
Pure seed %	99.5
Other crop %	0.0
Weed Seed %	0.0
Inert matter%	0.5
Ergot (included in inert)%	0.0
Date of Germination	11/5/15
% GERMINATION	98
Abnormal Seedlings%	0
Dead Seed%	2
Fresh Seed%	0
Pure Living Seed%	97

Advisory Tests & Remarks:

SENIOR MEMBER
OF

COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC.

124
Lisa Greenan

From:AG VISION SEEDS To:Premier Pacific Seed 09/03/2015 00:36 #848 P.001/005

AG SEED LAB

P.O. BOX 998, CARROT RIVER, SK, CANADA S0E 0L0
PHONE: (306) 768-3335 FAX: (306) 768-2169
EMAIL: agseedlab@sasktel.net WEB: www.agvision.ca

Certificate of Seed Analysis #: AG14-541 *CFIA Accreditation No. 1207*

From: *Date: 13-Mar-15*

Ag-Vision Seeds Ltd.
Box 550
Carrot River Sk S0E 0L0
CANADA

Kind/Type: Slender wheatgrass
Designation:
Lot#: 14-0234

Number Per: 25 grams

Prohibited Noxious	*Value*	*Other Weed Seeds*	*Value*	*Other Crop Seeds*	*Value*
	0		0	Barley	
Primary Noxious	0				
Total Primary:	0				
Secondary Noxious	0				
				Total Other Crop Seeds:	
Total Primary + Secondary:	0	*Total Weed Seeds of All Kinds:*	0	*Less than* 2% *by mass*	

PURITY		*GERMINATION*		*OTHER DETERMINATIONS*	
% Pure Seed:	98.1	*% Germination:*	92	*Sweet Clover:*	0/25g
% Other Crops	0.0	*% Hard Seeds:*	-	*Brassica Spp:*	0/25g
% Weed Seed:	0.0	*GERMINATION INCLUDING*		*Sclerotia Bodies:*	-
% Inert:	1.9	*% Hard Seed:*	-		
% Pure Living Seed:	90.0			*Ergot:*	<1%

Number of Grams Tested: 50

Remarks:

Dormancy Breaking Treatment - 3 days Prechill at 5C

SENIOR MEMBER
OF
COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA, INC.
159
Loretta Buhler

This certifies that the sample submitted from the lot designated above has been analysed according to:

1) X Canadian Methods and Procedures for Testing Seed, C.F.I.A.
2) ____ Rules for Testing Seeds, A.O.S.A.
3) ____ International Rules for Testing Seeds, I.S.T.A.
4) ____ As Specified by Contract 5) ____ Other

The responsibility for any seed sold and advertised for sale under this certificate with respect to grade or any other specifications rests entirely with Seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

SEEDCHECK TECHNOLOGIES INC.

101, 5906-50 Street
Leduc, Alberta T9E 0R6
Phone: (780) 980-8324
Fax: (780) 980-8375
www.seedcheck.net

Report of Seed Analysis
CFIA Accredited Laboratory No. 1215

LAB#: 16-71429

Customer: Premier Pacific Seeds Ltd.
#203, 19315 - 96 Avenue
Surrey, B.C. V4N 4C4

Sender Information:

SeedType:	Orchardgrass
Scientific Name:	(Dactylis glomerata)
Lot#:	Y22-15-757

Analyzed According to Canadian Methods & Procedures for Testing Seed

Tests: Germination , Canadian Purity,

Total Grams Analyzed: 25.29	Per 25g	Date Received: Feb 29, 2016 Purity Date: Feb 29, 2016	Per 25g
Prohibited Noxious:	0	**Other Crop Seeds:**	
		(Lolium spp.) Ryegrass	
Primary Noxious:			
Total Primary	**0**		
Secondary Noxious:		**Total Other Crop Seeds**	**<2%**
		Sweet Clover (Melilotus sp.)	0
		Brassica spp.	0
		Ergot Bodies	0%
Total Primary & Secondary Noxious	**0**		
Other Weed Seeds:		**Percentage Test:**	3.059g
		Pure seed %	90.0
		Other crop %	1.8
		Weed Seed %	0.0
		Inert matter%	8.2
		Multiple Seed Units%	14.2
		Date of Germination	3/14/16
		% GERMINATION	97
		Abnormal Seedlings%	3
		Dead Seed%	0
		Fresh Seed%	0
Total Noxious & Other Weed Seeds	**0**	Pure Living Seed%	87

Advisory Tests & Remarks:

SENIOR MEMBER
OF
COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC.
124
Lisa Greenan

SEEDCHECK TECHNOLOGIES INC.

Report of Seed Analysis
CFIA Accredited Laboratory No. 1215

LAB#: 15-68000

101, 5906-50 Street
Leduc, Alberta T9E 0R6
Phone: (780) 980-8324
Fax: (780) 980-8375
www.seedcheck.net

Customer: Premier Pacific Seeds Ltd.
#203, 19315 - 96 Avenue
Surrey, B.C. V4N 4C4

Sender Information:

SeedType:	Hard Fescue
Scientific Name:	(Festuca brevipila)
Variety:	Eureka 2
Crop Cert#:	U21-15-35SK6-1
Lot#:	U21-15-35SK6-1

Analyzed According to Canadian Methods & Procedures for Testing Seed

Tests: Germination , Canadian Purity,

Total Grams Analyzed: 25.03	Per 25g
Prohibited Noxious:	0
Primary Noxious:	
Total Primary	**0**
Secondary Noxious:	
Total Primary & Secondary Noxious	**0**
Other Weed Seeds:	
(Vulpia myuros) Rattail fescue	12
Total Noxious & Other Weed Seeds	**12**

Date Received: Oct 22, 2015 Purity Date: Oct 23, 2015	Per 25g
Other Crop Seeds:	
(Lolium spp.) Ryegrass	
Total Other Crop Seeds	**<1%**
Sweet Clover (Melilotus sp.)	0
Brassica spp.	0
Ergot Bodies	<1%
Percentage Test:	1.006g
Pure seed %	97.8
Other crop %	0.2
Weed Seed %	0.2
Inert matter%	1.8
Ergot (included in inert)%	0.1
Date of Germination	11/12/15
% GERMINATION	92
Abnormal Seedlings%	2
Dead Seed%	6
Fresh Seed%	0
Pure Living Seed%	90

Advisory Tests & Remarks:

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC.

98
Morgan Webb

AG SEED LAB

P.O. BOX 998, CARROT RIVER, SASKATCHEWAN, CANADA S0E 0L0
PHONE: 306-768-3335 FAX: 306-768-2169 EMAIL: agseedlab@sasktel.net WEB: www.agvision.ca

Certificate of Seed Analysis #: AG15-205 ***CFIA Accreditation No. 1207***

Date: ***06-Jan-16***

From:
Ag-Vision Seeds Ltd.
Box 550
Carrot River Sk S0E 0L0
CANADA

Kind/Type: White clover
Designation:
Lot#: 15-0086

Number Per: 2 grams

Prohibited Noxious	*Value*	*Other Weed Seeds*	*Value*	*Other Crop Seeds*	*Value*
	0	Panicgrass	2		0
				Total Other Crop Seeds:	0
Total Noxious:	0	*Total Weed Seeds of All Kinds:*	2		

PURITY		***GERMINATION***		***OTHER DETERMINATIONS***
% Pure Seed:	99.97	*% Germination:*	83	
% Other Crop:	0.00	*% Hard Seeds:*	9	
% Weed Seed:	0.03	***GERMINATION INCLUDING***		
% Inert:	0.00	*% Hard Seed:*	92	
% Pure Living Seed:	-			

Number of Grams Tested: 20

Remarks: Test is free of U.S.A. Federal Noxious Weed Seeds.
CT Iowa State Noxious Weed check in 20 grams analyzed
-None Found-

SENIOR MEMBER
OF
COMMERCIAL SEED ANALYSTS ASSOCIATION CANADA INC.
159
Loretta Buhler

This certifies that the sample submitted from the lot designated above has been analysed according to:
1). _____Canadian Methods and Procedures for Testing Seed, C.F.I.A.
2). __X__ Rules for Testing Seeds, A.O.S.A.
3). _____International Rules for Testing Seeds, I.S.T.A.
4). _____As Specified by Contract 5). ____Other
The responsibility for any seed sold and advertised for sale under this certificate with respect to grade or any other specifications rests entirely with Seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

AG SEED LAB

P.O. BOX 998, CARROT RIVER, SASKATCHEWAN, CANADA S0E 0L0
PHONE: 306-768-3335 FAX: 306-768-2169 EMAIL: agseedlab@sasktel.net WEB: www.agvision.ca

Certificate of Seed Analysis #: AG15-008 ***CFIA Accreditation No. 1207***

From: ***Date: 08-Sep-15***

Ag-Vision Seeds Ltd.
Box 550
Carrot River Sk S0E 0L0
CANADA

Kind/Type: Hard fescue
Designation:
Lot#: 15-0007

Number Per:

Prohibited Noxious	***Value***	***Other Weed Seeds***	***Value***	***Other Crop Seeds***	***Value***
	0	Narrowleaf hawksbeard	4	Fowl bluegrass	
Primary Noxious		Sedge	4		
	0				
Total Primary:	0				
Secondary Noxious					
	0			***Total Other Crop Seeds:***	
Total Primary + Secondary:	0	***Total Weed Seeds of All Kinds:***	8	***Less than*** 2% ***by mass***	

PURITY		***GERMINATION***		***OTHER DETERMINATIONS***	
% Pure Seed:	96.3	***% Germination:***	85	***Sweet Clover:***	0/25g
% Other Crops	0.0	***% Hard Seeds:***	-	***Brassica Spp:***	0/25g
% Weed Seed:	0.0	***GERMINATION INCLUDING***		***Sclerotia Bodies:***	-
% Inert:	3.7	***% Hard Seed:***	-	***Ergot:***	0%
% Pure Living Seed:	82.0				

Number of Grams Tested:

Remarks:

ASSOCIATE MEMBER
OF
SEED COMMERCIAL ANALYSTS ASSOCIATION CANADA INC
A-50
Liza Perkins

This certifies that the sample submitted from the lot designated above has been analysed according to:

1). _X_ Canadian Methods and Procedures for Testing Seed, C.F.I.A.
2). _____Rules for Testing Seeds, A.O.S.A.
3). _____International Rules for Testing Seeds, I.S.T.A.
4). _____As Specified by Contract 5). ____Other

The responsibility for any seed sold and advertised for sale under this certificate with respect to grade or any other specifications rests entirely with Seller.
Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

Precision SEED TESTING
...certified technicians produce accurate results

REPORT OF SEED ANALYSIS

CFIA ACCREDITED* LABORATORY #1175
Box 210, Beaverlodge, Alberta, Canada T0H 0C0
Ph: (780) 354-2259 1-800-379-4804 Fax: (780) 354-8955
precisionseed@xplornet.com

*Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

FROM
Fosters Seed & Feed
Box 210
Beaverlodge, Alberta
T0H 0C0

KIND: Tall Fescue

VARIETY:

CERTIFICATE NUMBER: 15-34144

DESIGNATION (LOT NUMBER): 41625

NUMBER PER 25. GRAMS

NOXIOUS WEED SEEDS		OTHER WEED SEEDS		OTHER CROP SEEDS	
PROHIBITED	0.0	Wild barley	1.0	Sheep fescue	
		Mannagrass	1.0	Timothy	
PRIMARY					
TOTAL	0.0				
SECONDARY					
TOTAL	0.0	TOTAL	2.0	TOTAL	Less than 2%

TOTAL PRIMARY + SECONDARY NOXIOUS WEED SEEDS	0.0	TOTAL WEED SEEDS ALL KINDS	2.0	SWEET CLOVER	0
PURE SEED	99.3 %	GERMINATION	98. %	BRASSICA CROP	0
OTHER CROP	0.3 %	HARD SEEDS	- %	ERGOT	0.0%
WEED SEEDS	0.0 %	GERMINATION (+HARD SEEDS)	- %		
INERT MATTER	0.4 %				
PURE LIVING SEED	97.0 %	NUMBER OF GRAMS TESTED	50.	SCLEROTIA BODIES	-

REMARKS (Data provided for information purposes only)

SENIOR MEMBER OF SEED ANALYSTS SOCIETY OF CANADA

Date Sep 19, 2015

This certifies that the sample of seed submitted from the lot designated above has been analyzed according to:

(1) X Canadian Methods and Procedures for Testing Seed, C.F.I.A

(2) ____ Rules for Testing Seeds, A.O.S.A.

(3) ____ International Rules for Seed Testing, I.S.T.A.

(4) ____ As specified on Contract

The responsibility of any seed sold, offered or advertised for sale under this certificate with respect to grade or any other specifications rests entirely with the seller. Varietal information supplied by sender.

Precision
SEED TESTING
...certified technicians produce accurate results

REPORT OF SEED ANALYSIS

CFIA ACCREDITED* LABORATORY #1175
Box 210, Beaverlodge, Alberta, Canada T0H 0C0
Ph: (780) 354-2259 1-800-379-4804 Fax: (780) 354-8955
precisionseed@xplornet.com

*Accredited by CFIA to conduct tests in accordance with the laboratory's scope of accreditation and the Canadian Methods and Procedures for Testing Seed.

FROM

Fosters Seed & Feed
Box 210
Beaverlodge, Alberta
T0H 0C0

KIND Creeping Red Fescue

VARIETY Oracle

15-8065981-401

DESIGNATION (LOT NUMBER) 0187-9-41675

CERTIFICATE NUMBER 15-34171

NUMBER PER 25. **GRAMS**

NOXIOUS WEED SEEDS	OTHER WEED SEEDS	OTHER CROP SEEDS
PROHIBITED 0.0		
PRIMARY TOTAL 0.0		
SECONDARY TOTAL 0.0	TOTAL 0	TOTAL 0

TOTAL PRIMARY + SECONDARY NOXIOUS WEED SEEDS	0.0	TOTAL WEED SEEDS ALL KINDS	0.0	SWEET CLOVER	0
PURE SEED	97.1 %	GERMINATION	94.25 %	BRASSICA CROP	0
OTHER CROP	0.0 %	HARD SEEDS	- %	ERGOT	~~0.0%~~
WEED SEEDS	0.0 %	GERMINATION (+HARD SEEDS)	- %		
INERT MATTER	2.9 %				
PURE LIVING SEED	92.0 %	NUMBER OF GRAMS TESTED	25.	SCLEROTIA BODIES	-

REMARKS (Data provided for information purposes only)

SENIOR MEMBER OF

COMMERCIAL SEED ANALYSTS ASSOCIATION OF CANADA INC.

Date Oct 13, 2015

This certifies that the sample of seed submitted from the lot designated above has been analyzed according to:

(1) _X_ Canadian Methods and Procedures for Testing Seed, C.F.I.A

(2) _____ Rules for Testing Seeds, A.O.S.A.

(3) _____ International Rules for Seed Testing, I.S.T.A.

(4) _____ As specified on Contract

The responsibility of any seed sold, offered or advertised for sale under this certificate with respect to grade or any other specifications rests entirely with the seller. Varietal information supplied by sender.

ISTA

ORANGE INTERNATIONAL SEED LOT CERTIFICATE
BULLETIN INTERNATIONAL ORANGE DE LOT DE SEMENCES
INTERNATIONALER ORANGE-BERICHT ÜBER EINE SAATGUTPARTIE

(See back - Voir au verso - Rückseite beachten)

INTERNATIONAL SEED TESTING ASSOCIATION - UNIFORMITY - SEED TESTING

Stamp of Laboratory / Cachet du Laboratoire / Stempel der Prüfstelle: PALMERSTON NORTH NZ01

STATED BY APPLICANT – INFORMATIONS DU REQUÉRANT – ANGABEN DES ANTRAGSTELLERS
Without responsibility of the laboratory - Sans responsabilité du laboratoire - Ohne Verantwortung der Prüfstelle

AQ:401556/F

Name of applicant / Nom du requérant / Name des Antragstellers	**PGG/Wrightson Seeds Ltd** **PO Box 939** **Christchurch 8140**
Species, cultivar, category, weight of lot etc. / Espèce, cultivar, catégorie, poids du lot, etc. / Art, Sorte, Kategorie, Gewicht der Partie usw.	**Perennial Ryegrass GRASSLANDS NUI** **First generation 10500 kg** **H15172A**

INFORMATION – INFORMATIONS – ANGABEN

Testing and issuing laboratory / Laboratoire d'essai qui délivre le bulletin / Untersuchende und berichtende Prüfstelle :	**AsureQuality Seed Laboratory NZ01** ~~P.O Box 609 Palmerston North 4440 New Zealand~~
Sampling by / Échantillonnage par / Probenahme durch :	**AsureQuality Seed Laboratory NZ01** ~~P.O Box 609 Palmerston North 4440 New Zealand~~
Marks of lot / Marques du lot / Kennzeichnung der Partie :	**201554933 : BD**
Seal of lot / Plomb du lot / Versiegelung der Partie :	**MPI Label Stitched through**

Status of Certificate / Nature du Bulletin / Status des Berichts: **ORIGINAL**

Number of containers / Nombre de contenants / Anzahl der Behälter	Date of sampling / Echantillonnage effectué le / Datum der Probeziehung	Date sample received / Echantillon reçu le / Eingangsdatum der Probe	Date test concluded / Analyse terminée le / Datum des Prüfungsabschlusses	Test number / No de l'analyse / Untersuchungs-Nr.
420	2015-09-24	2015-09-25	2015-10-08	93159-1

ANALYSIS RESULTS – RÉSULTATS DE L'ANALYSE – UNTERSUCHUNGSERGEBNISSE

SPECIES - ESPÈCE - ART (Scientific name - Nom scientifique - wissenschaftlicher Name): **~~Lolium sp.~~**

PURITY - PURETÉ - REINHEIT % Weight - % en poids - % Gewicht			*GERMINATION - KEIMFÄHIGKEIT*	% Number - % en nombre - % Anzahl					*MOISTURE CONTENT* (wet basis) *TENEUR EN EAU* (poids humide) *FEUCHTIGKEITSGEHALT* (Frischeinwaage) %
Pure seeds / Semences pures / Reine Samen	Inert matter / Matières inertes / Unschädliche Verunreinigungen	Other seeds / Semences d'autres plantes / Andere Samen	Number of days / Nombre de jours / Anzahl Tage	Normal seedlings / Germes normaux / Normale Keimlinge	Hard seeds / Graines dures / Harte Samen	Fresh seeds / Graines fraîches / Frische Samen	Abnormal seedlings / Germes anormaux / Anomale Keimlinge	Dead seeds / Semences mortes / Tote Samen	
99.7	0.1	0.2	6	96	N	0	3	1	N

Kind of inert matter - Nature des matières inertes - Art der unschädl. Verunreinigungen

Empty glumes, straw, chaffy matter.

Other seeds - Semences d'autres plantes - Andere Samen / Species (scientific names) - Espèces (noms scientifiques) - Arten (wissenschaftliche Namen)

Sherardia arvensis, Vulpia bromoides

OTHER DETERMINATIONS – AUTRES DÉTERMINATIONS – WEITERE UNTERSUCHUNGSERGEBNISSE

TP 20 deg C. Blotters soaked in 0.2% KNO_3 solution. Complete test. Weight examined 60.20g. Canadian Prohibited Seeds: None found. Primary and Secondary Noxious Weed Seeds: None found. Weed Seeds: 2 Anthriscus caucalis, 1 Poa annua, 34 Sherardia arvensis, 40 Vulpia bromoides. Other Crop Seeds: None found. Total Weeds 32 in 25.00g. Soil present 0.01%. Sample free from ergot. Minimum pure living seed 96%. Classification of Weeds and Crops according to Canadian Regulations. Complies Canadian Grade Certified Number 1 Seed.

(See also additional observations on back - Voir aussi observations complémentaires au verso - Siehe zusätzliche Bemerkungen auf der Rückseite)

Place and country - Localité et pays - Ort und Staat	Date - Datum	Signature - Unterschrift
Palmerston North, New Zealand	**2015-11-16**	D. Bell **Team Leader**

See declaration on back - Voir déclaration au verso - Siehe Erklärung auf der Rückseite

ISTA Reg. No. / Reg.-Nr. 01843892