Restoration of Ottertail Carrion Pit, Yoho National Park

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Submitted: December 14, 2021
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Abstract

In collaboration with the Parks Canada Invasive Plant Management Program of the Lake Louise, Kootenay and Yoho field unit, a project was completed in the summers of 2019 and 2020 to restore Ottertail landing area, a former test site for carrion disposal infrastructure including an electrified mat and fence. The goal of the project was to control invasive plants, focusing on meadow hawkweed (*Heiracium caespitosum*) and increase cover of native grasses, forbs, and shrubs. This plant invasion is of special concern as hawkweed (*Heiracium, spp.*) populations have been expanding in Yoho National Park in recent years, and have great potential to spread and decrease native plant populations and overall biodiversity in the alpine ecosystems of Yoho National Park. Ottertail landing area was identified as an area with high seed dispersal potential due to animal activity in the area and proximity to alpine ecosystems. In order to restore this site to pre-mat conditions, a site-specific restoration strategy was created, incorporating the testing of several non-chemical strategies including the use of hemp-matting, steaming, reducing compaction, and seeding with competitive native grasses. Data collected over the summers of 2019 and 2020 have shown that the strategies used were minimally effective at reducing non-native plant cover, but very effective in encouraging the growth of native species.

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Acknowledgments

I would like to thank the Kootenay/Yoho National Park Fire and Vegetation Manager, Martin Lafontaine, for allowing me the opportunity to pursue this project in Yoho National Park, helping with the design of the project, gathering materials, and implementing treatments. Thank you to the LLYK Vegetation Crew: Megan Kinley, Brittany Boyd, and Persia Khan, for the long days spent driving to and from the site, identifying plants, and carrying out steam treatments. Also, I would like to thank my parents, who hiked to the site in the summer of 2020 to collect results and take pictures while I was unable to travel due to restrictions.

1.0 INTRODUCTION

The Lake Louise, Yoho and Kootenay (LLYK) field unit of Parks Canada currently uses an integrated approach to control invasive vegetation, considering a variety of factors when developing management strategies. The LLYK Integrated Invasive Management Plan (2017) was recently updated in an effort to shift the focus from managing individual species or infestations, to management of ecosystems as a whole, where infestations are minimized by managing strategic areas, and mitigating the underlying causes of invasions.

While prevention of new infestations is considered the most economical and effective method of limiting the impacts of invasive vegetation, this is not always possible. The Ottertail landing area in Yoho National Park was previously used as the test site for an electrified mat and carrion (animal carcass) disposal pit, and was decommissioned in 2017. The area was then identified in the summer of 2018 as a site requiring restoration by the LLYK vegetation crew. After the removal of infrastructure, the site was left infested with invasive species and extremely compacted. The species of the most concern at Ottertail landing area is meadow hawkweed (*Heiracium caespitosum*). This generalist species has high seed dispersal rate, and readily establishes in open areas with little canopy cover (Stone, 2011). Though the LLYK field unit only lists meadow hawkweed as a 'high priority' (as opposed to 'very high', or 'extreme'), the proximity of Ottertail landing area to sensitive alpine environments, and the high likelihood of seed dispersal due to animal traffic in the area makes this a priority area for management activities (Parks Canada, 2017).

The following control methods are commonly utilized by the LLYK field unit where invasive vegetation has established: (1) Mechanical control – physical treatment or removal; (2) Chemical control – use of herbicides; (3) Cultural control – use of restoration or ecosystem management practices; and (4) Bio-control – use of host-specific predators (Parks Canada, 2017). Often, effective control or eradication of infestation requires a combination of these methods, and other innovative, site specific and adaptive treatment methods.

A variety of treatment methods were considered in the restoration of Ottertail landing area, and it was decided in consultation with LLYK management that this area would serve as a site to test new and innovative non-chemical methods to restore invaded and compacted areas such as this. Several methods were considered in the development of a site-specific strategy, and those chosen included hemp matting, weed steaming and loosening compacted soil. This paper will report on the observed efficacy of these methods, as well as examine possible strategies to incorporate in future management plans of this and other similar areas.

1.1 Objectives

1. Develop a site-specific restoration strategy with the goal of reducing non-native plant cover on the site, focusing on especially vigorous species such as *H. caespitosum*, and increasing native species cover.
2. Demonstrate the efficacy of hemp matting and steam treatment to eradicate *H. caespitosum*.
3. Create a recommended strategy for future management of Ottertail landing area.

1.2 Benefit to Parks Canada

The completion of this project will facilitate the recolonization of the Ottertail landing with native plants, and the establishment of an ecosystem more resilient to invasion by vigorous invasive plants. In addition, the results of steaming and hemp matting to suppress hawkweeds (*Heiracium, spp.*) could provide Parks Canada staff with alternatives to herbicide use when treating various hawkweeds, both at Ottertail landing and elsewhere.

1.3 Contribution to the Field of Restoration

This project contributes to the field of restoration, as it:

1. Explores alternative techniques for controlling invasive plants in areas with a high dispersion risk.
2. Incorporates an innovative, site specific integrated treatment method while testing new methods of treating hawkweeds (*Heiracium spp.*).

Description of Meadow hawkweed (*Heiracium caespitosum*)

Establishment

H. caespitosum is one of eight species of non-native hawkweeds introduced to the Pacific Northwest from Europe approximately 50 years ago. The first record of meadow hawkweed in the area occurred in 1969, and the range of this plant is estimated to grow at a rate of 16% per year (Wilson and Callihan, 1999). This rapid spread has led to detrimental ecological effects including loss of biodiversity, wildlife habitat, and the degradation of cropland (Wallace et al., 2010)

Biology

Hawkweeds are fibrous-rooted perennial forbs, have star-shaped (ligulate) flowers, and milky latex in the stems and leaves. All hawkweeds belong to the Family Asteraceae and the genus Heiracium, which is divided into 3 subgenera. H. caespitosum is part of the subgenus Pilosella, which are all invasive varieties of hawkweeds distinguished by few stem leaves, toothed basal leaves, and the presence of stolons (above-ground runners). A single hawkweed rosette is capable of producing up to 30 flowering stems, each stem of H. caespitosum has yellow flowers, many heads, and measures 20 - 70 cm. tall (Wilson, 2006).

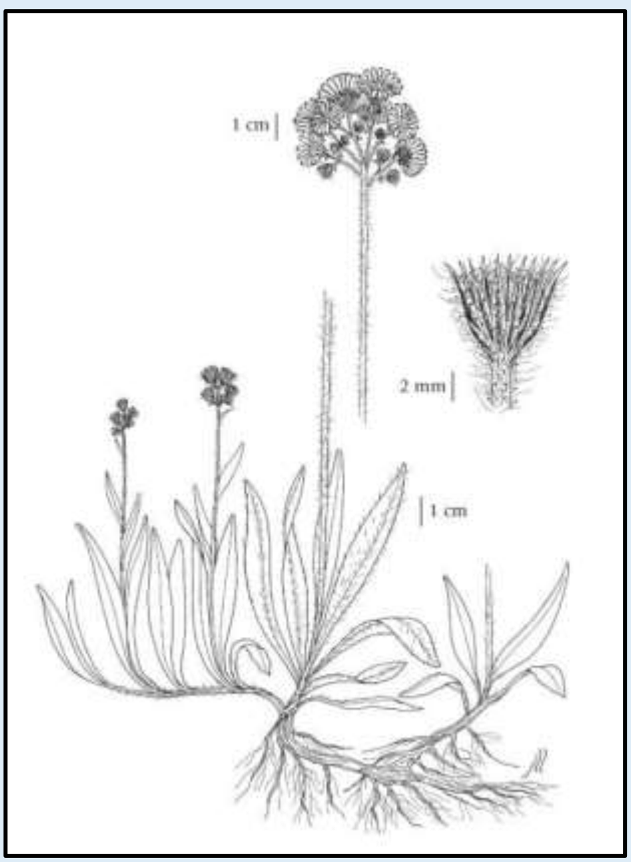


Figure 4. Illustration of *H. caespitosum* (Wilson, 2006)

Hawkweeds reproduce both sexually and asexually by seeds and vegetatively by stolons, rhizomes, and adventitious root buds. Many non-native hawkweeds possess characteristics that allow a species to easily become invasive: high seed production, high germinability, long-distance seed dispersal, as well as the ability to spread and regenerate from small fibrous root fragments (Wilson, 2006).

Hawkweeds (*Heiracium, spp*.) are able to capture nitrogen in nutrient-poor soils, limiting nutrient availability to competing plants. This allows them to easily outcompete native flora in disturbed areas to prevent shading, as the rosettes are shade intolerant, enabling this species to form dense populations and spread rapidly in the absence of competition.

Habitat

Invasive hawkweeds are well adapted to many habitats in the pacific, inland, and intermountain west. These herbaceous plants are found predominantly in open fields, meadows, and clearings in forests. H. caespitosum also often invades sites which are modified or disturbed, where the soil is well-drained, coarse textured, and moderately low in organic matter. This species is able to thrive from 725m in elevation, to over 1700m (Wilson, 2006), and is also commonly found on high alpine hillsides and in mountain meadows.

Figure 1. Text box, description of *H. caespitosum*

2.0 METHODS

2.1 Site Details

Ottertail landing site is located northwest of the Trans-Canada Highway, approximately 7km south of Field, B.C., between the Ottertail River and the Boulder Creek Parks Canada Compound in Yoho National Park (Figure 1). There is a maintenance road off the highway that leads past the active gravel pit to a decommissioned landing site. This site is the area under active restoration, as it is no longer in use. The 200m road to the restoration area from the gravel pit is restricted to avoid transporting additional seeds of invasive plants from the gravel pit to the restoration area.

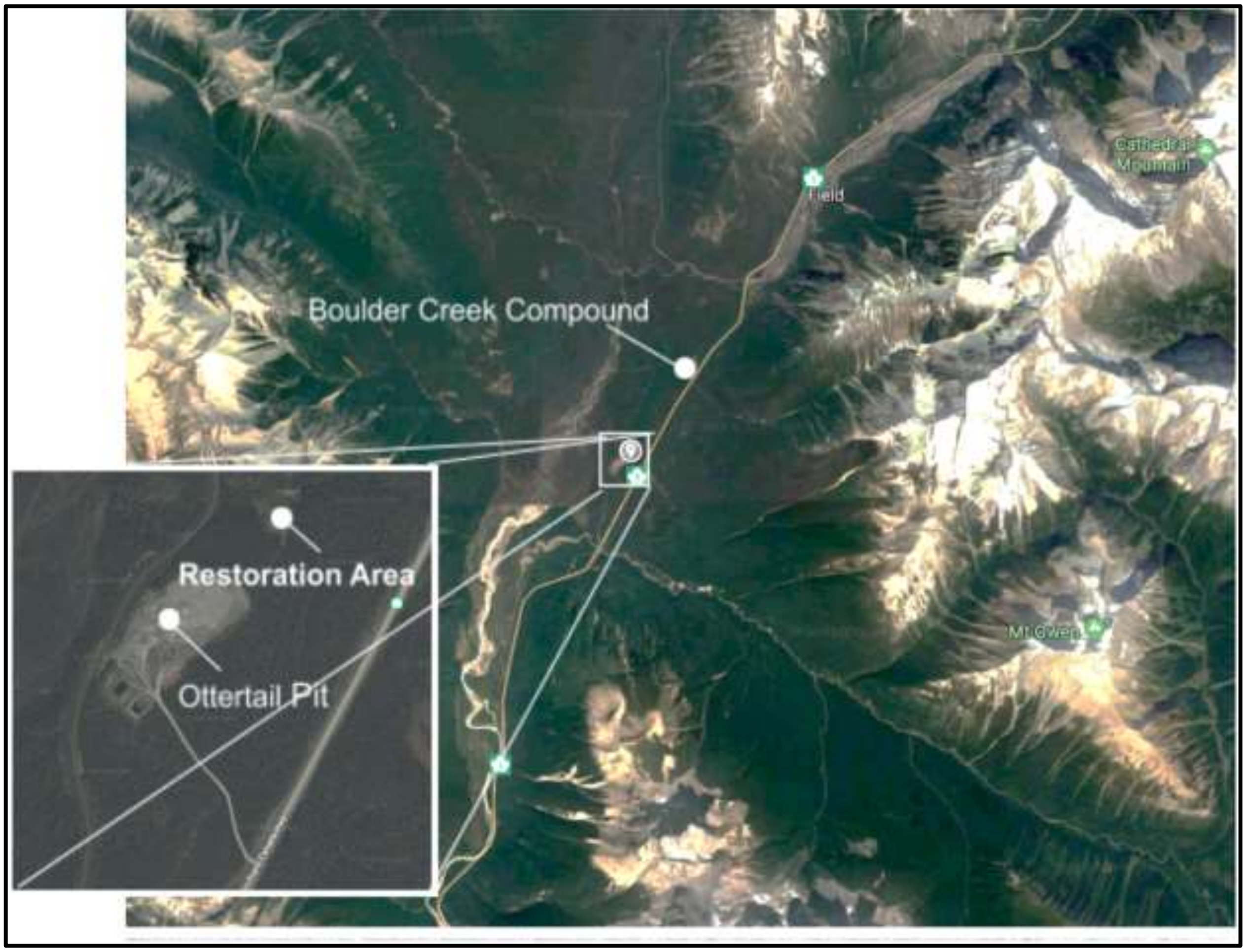


Figure 2. Map of Ottertail landing site location

Ottertail landing area falls in the Montane Cordillera Ecoregion, and the dry, cool subzone of the Montane Spruce biogeoclimatic zone (MSdk). This zone occurs in high plateaus in central and southern interior BC, and its canopies are dominated by Douglas-fir (*Pseudotsuga menziesii*) and trembling aspen (*Populus tremuloides*) (Centre for Forest Conservation Genetics, 2002).

Site history

Parks Canada's Wildlife department previously used the Ottertail landing site as a test site for an electrified mat exclosure. This was a pilot project for managing the disposal of carrion in the park, and was eventually ruled out, partially due to the infrastructure's inability to deter predators (Figure 3).

Figure 3. Electrified mat test site with grizzly bear (November 13, 2013) (Kuyer, 2018*).*

The testing equipment and large infrastructure was removed prior to August 2018. During the summer of 2018, the Vegetation Manager for the LLYK Field Unit was contacted by a Parks Canada Wildlife Ecologist to have the Vegetation Crew restore the site to conditions comparable to that of pre-electrified mat installation. The entire landing was to be controlled for invasive plants before being seeded with a Parks Canada approved native grass seed mix (M. Lafontaine, personal communication, July 19, 2019).

In September 2018, the previous vegetation crew treated the area with steam during precipitation events, and Milestone broad-leaf specific herbicide when weather was dry. No steam control was done after herbicide was applied to avoid risk of exposure to applicator(s) from vaporized herbicide residue (Kuyer, 2018).

After control work was completed, the footprint of the testing area was raked and the entire site was seeded with native grass seed mix. The technician noted that, "the raking was challenging since the ground was highly compacted or composed of coarse gravel, but there was evidence that some loosening of the surface soils was achieved" (Kuyer, 2018). The technician then dispersed approximately 3kg of grass seed mix across the restoration area using a hand-crank seed-disperser.

Kuyer (2018) recommended monitoring the establishment of grasses in the 2019 field season, as native grasses in this site are considered desirable, and conduct future control work using an adaptive management model.

Typical vegetation

Vegetation at Ottertail landing is characterized by herbaceous plant cover, both invasive and native, with sparse trembling aspen seedlings (*Populus tremuloides*), and small willows (*Salix spp.*), which seem to be colonizing near the edges of the site from the surrounding forest. See Appendix B for a full list of plants found at the site.

The center of the site, where the electrified mat infrastructure was previously installed, is extremely compacted, and is mostly still rocky, bare ground. The vegetation in this area includes invasive plants such as thistles (*Cirsium vulgare, Cirsium arvense*) and dandelions (*Taraxacum officinale*). There are also very sparse native grasses in this area from the seed mix spread in 2018 by previous vegetation crew members.

Surrounding the site is a mature stand forest. The canopy is dominated by Douglas-fir (*Pseudotsuga menziesii)*, subalpine fir *(Abies lasiocarpa)*, and trembling aspen *(Populus tremuloides*). See Appendix D for a full plant inventory of the mature-stand forest surrounding the site.

Physical description

The restoration site sits at 1217 m elevation, and is completely flat (0^o slope). The site was graded this way to accommodate the former carrion pit infrastructure and the road leading to the area. The area around most of the site is relatively flat as well, with the exception of the steep downward slope on the NW side of the site with a slope of 38^o and an aspect of 326° (NW).

The disturbed area covers 2260 m^2 (0.226 ha), and is made up of a compacted, rocky center (Figure 2), and an outer area vegetated primarily with non-native species, and small willows (*Salix spp.*) encroaching.

Figure 4. Compacted area, Ottertail landing site (July, 2019)

2.2 Site Assessment

The boundary of the treatment area was determined by marking the outer edges of the area that had been previously cleared and graded for the carrion pit and electrified fence infrastructure (Appendix A). This area was also delineated by the presence of invasive species, of which there were few outside the boundaries of the cleared area The exception to this was the very steep slope to the northwest of the study area that had a high density of hawkweeds. This area was determined by Parks Canada management too steep to treat manually, and would be re-evaluated at a later date to determine a management plan. The slope and aspect of the study area, as well as the slope to the northwest were determined using a clinometer and a compass.

Species lists

Identification of *H. caespitosum* was obtained through using a key to identification of hawkweeds (Wilson, 2006). The other invasive vegetation was identified in July 2019 to provide a baseline data prior to treatment (Appendix B).

A list of native species in the surrounding area was obtained through an interpretive walk around the perimeter of the site with a co-worker familiar with local native plants, as well as personal identification attempts using Plants of Southern Interior British Columbia (Parish et al., 1996). Separate plant lists were obtained for the outer 1m of the study area (Appendix C) and 5 meters outside of the boundary of the cleared area (Appendix D). These lists were separated to determine both possible pioneer species for the area, as well as a long-term target ecosystem.

2.3 Invasion by hawkweeds and other invasive plants

Ottertail landing area was subject to a great deal of continued disturbance, and was invaded by *H. caespitosum*, and other invasive plants. Parks Canada presently uses a mild selective herbicide, Milestone (0.25% spray solution), with the active ingredient aminopyralid, to manage existing infestations of hawkweeds and other invasive plants. Though aminopyralid has been proven to have a decreased risk of adversely affecting non-target species compared to the previously used clopyralid, adverse effects in non-target plants are still plausible, especially when broadcast sprayed (Durkin, 2007). In addition, rapid control methods such as the use of herbicide often cause a dramatic increase of bare ground, which increases erosion potential in the treated area, and increases the probability of re-invasion by undesirable invasive species.

Mechanical removal of *H. caespitosum* was considered, but it was decided that this would be extremely time-consuming, and the stolons and roots must be removed completely to avoid rosettes resprouting from root buds. Mowing was also considered, but removal of only the flowerheads will prevent seed production, but may encourage vegetative spread (Jacobs and Wiese, 2007). Grazing has a similar effect, as animals may eat flowerheads, but rosettes are not usually eaten. Additionally, the disturbance associated with grazing may disturb soil, helping to spread hawkweeds (Jacobs and Wiese, 2007).

Terrafibre weed suppressant is a non-woven hemp product that is 100% biodegradable. A significant amount of this hemp matting was donated to the LLYK field unit in the summer of 2018 to test its efficacy in suppressing various types of invasive plants in the park. Though there have not yet been any studies related to the efficacy of biodegradable matting in reducing invasive plant cover, the website states that it, “prevents soil erosion, suppresses weeds, preserves soil moisture [...], then fully biodegrades back into the soil, releasing important nutrients for providing a boost in plant growth (BioComposites Group, n.d.).

A large weed steamer was bought by the LLYK field unit in a previous summer, and though it had been used, the efficacy of steaming with this machine had not been internally documented. Steaming invasive plants involves the use of very hot water at a high pressure sprayed onto the foliage of plants at a close range. This method is attractive due to increasing public concern for health and the environment, and unlike manually pulling plants this method does not bring buried seeds to the surface or further disturb the area. Scenecsed plant biomass is also left on the soil surface, protecting the soil from erosion. The effects of steam treatments on plants vary greatly, and are influenced by several factors including temperature and exposure time (Ascard, et al., 2007).

Considering the above treatment options, chemical applications and large-scale mechanical removal were ruled out. The following methods were decided upon and carried out in an attempt to control invasive vegetation within Ottertail landing area.

Hand Pulling

A small patch of 36 wild caraway plants (*Carum carvi)* were hand pulled and bagged on June 25th. *C. carvi* is rated as a species of Very High concern in the LLYK Invasive Plant Management Plan (2017), and care was taken to remove all roots and plant material. These plants were not yet producing seed as it was early in the growing season, and no further patches of *C. carvi* were found.

Hemp Matting

The hemp matting used was Terrafibre Weed Suppressant Hemp Matting, donated by the Biocomposite Group to Parks Canada in the summer of 2018 to use in a different area of the park. In the summer of 2019, there were several sheets of matting leftover from the previous summer available to use at the Ottertail landing area. These mats were recommended by Parks Canada management as an alternative to herbicide use to treat hawkweeds and other invasive plants that form dense, uniform mats. The areas that had the highest density of hawkweeds were visually determined, and hemp matting was used to cover these areas on June 25, 2019. A map of the location of hemp matting can be seen in Appendix A. The matting was staked with wooden stakes on the outer edges, and weighted with rocks throughout.

Figure 5. Photo of hemp matting, staked and weighted with rocks

Steaming

The area surrounding the matting where hawkweeds were present was steamed using the ECO355 steamer (Appendix G). The steam was kept at an average of 115 degrees Celsius. One tank of water provided approximately 4 hours of steam treatment for 2 hoses. In this time, 2 rotating members of the vegetation crew were able to steam the areas of the site densely covered with hawkweed and other invasive plants. The timing of steam treatments can be seen in Table 1.

Table 1

Timing of steam treatments

Date	Steam treatment	Notes
June 29	Steamed 60% of *H. caespitosum* in treatment area	
July 4	Steamed remaining 40% of *H. caespitosum* in treatment area	Noted approximately 20% regrowth within previously steamed areas
July 16	Steamed 100% of regrowth	Noted approximately 35% regrowth in total steamed area

Figure 6. Photo of Parks Canada staff steam-treating hawkweeds

2.4 Soil Compaction

Soil compaction occurs when heavy machinery or repeated animal traffic compresses soil. During the installation, maintenance, and removal of the electrified mat infrastructure in Ottertail landing area, there was a high amount of machinery traffic in the area, as well as animal traffic, attracted by the carrion pit.

When pressure is applied to soil, this breaks the bonds of aggregating agents that hold the soil into aggregating units, reorienting the particles into a configuration with a higher mass per unit of volume (bulk density). The ability of most plant roots to penetrate soil is restricted as soil strength increases (Hamza and Anderson, 2005). In addition, soil compaction alters soil structure and hydrology, resulting in decreased aeration and water infiltration capacity, causing increased water runoff and erosion (Kozlowski, 1999). This decrease in porosity inhibits seed germination and growth of seedlings, which leads to slower regeneration of forest stands. This was identified as an issue of concern in the center of the treatment area, where much of the soil remained bare.

Shallow tillage (300 - 350 mm) has shown success in increasing seed germination rates in compacted soil (Spoor, 2006). Additionally, plant roots play a large part in creating and stabilizing useful structural features in soil, and plants which possess a deep taproot system are especially capable of penetrating compacted soils (Cochrane and Aylmore, 1994). Plant roots also constitute a major source of soil organic matter when decomposed, which retains soil water, helping the soil to resist and rebound from compaction (Hamza and Anderson, 2005).

The following methods were carried out in order to relieve some compaction in the area.

Loosening Compacted Soil

On July 4th 2019, a pick axe was used to manually loosen the top 3-5 inches of soil in the areas that were bare of plants to help in the establishment of grasses that would be seeded 2 weeks later, on July 18th.

Plants that had successfully established in the compacted area in 2019 were mostly vigorous species with taproots including Canada Thistle (*Cirsium arvense*), Bull Thistle (*Cirsium vulgare*), Dandelion (*Taraxacum officinale*), and native grasses that were seeded the previous summer (Kuyer, 2018). Though both species of thistles are rated as High priority in the Integrated Invasive Plant Management Plan for the LLYK Field Unit (2017), thistles are commonly viewed in the LLYK Field Unit as a successional species in disturbed areas, with little risk of colonizing undisturbed areas (Charlie MacLellan, personal communication, June 17, 2019). At this stage of the restoration of Ottertail landing, plants (both native and non-native) with deep taproot systems were seen as desirable, as they help to ease subsoil compaction (Hamza and Anderson, 2005). These species were not treated or removed at Ottertail for this reason.

In addition, the majority of the infrastructure was removed from the site when the electrified mat was decommissioned, but there were still remnants of infrastructure across the site including PVC pipe, coils of wire, plastic sheets, stakes, etc. These were removed in early July 2019.

Seeding

At the end of July 2019, all bare areas of the site, including areas where plant foliage was senesced due to steam exposure, were generously hand-seeded with a Parks Canada approved seed mix. The mix, from Grizzly Peak Revegetation Inc., consisted of:

40% Rocky Mountain Fescue (*Festuca saximontana*)
40% Fringed Brome (*Bromus ciliatus*)
20% Awned Wheatgrass (*Agropyron cristatum*)

2.5 Monitoring

Species cover

Polygons were created using GIS ArcCollector representing the total work area, the area to be covered with hemp matting, and the area to be steamed (Appendix A). In order to determine a ratio of native vs. non-native plant cover in the treatment site as a whole, ten random GPS points were generated, and 1x1m quadrats were completed at each of these points before any treatments were done in Summer 2019. The percent (%) cover of each species was recorded (Appendix E), to determine a total native versus non-native plant cover. This was meant to be duplicated, with 10 new randomly generated GPS points, in the summer of 2020 to determine the change in native versus non-native cover, and the establishment of seeded grass.

I was able to analyze photos of ten 1x1m quadrats in summer 2020 to determine species composition one year after treatments (Appendix G). My parents, who were able to reach the area to take pictures, did not have access to a GPS, so attempted to choose quadrats as randomly as possible.

2.6 Data analysis

Data analysis for this study was done through the interpretation of species composition data collected in polygons, as well as observed findings and repeat photography.

3.0 RESULTS

3.1 Steam Treatment Results

Regrowth of *H. caespitosum* after steam treatments is shown in Figure 7. Photo A (taken June 29, 2020) represents 10 minutes post treatment, and photos B and C were both taken 5 days post steam treatment (July 4, 2020). Photo A shows rosettes that are wilted, and dark green in colour, immediately after steam treatment, while 5 days later, rosettes become brown and crispy. It was noted that approximately 30% of rosettes showed regrowth after 5 days (Figure 7, photo C).

Figure 7. Comparative photos of meadow hawkweed *(H. caespitosum)* rosettes observed at Ottertail landing post-steam treatment

3.2 Hemp Matting Results

Photos taken 3 weeks after installing the hemp matting (Figure 8) show evidence of significant animal activity in this area. Deer, hare, and other animal prints were observed on the matting, and much of the trampling broke through the matting, creating holes.

Figure 8. Photo of animal footprints causing holes in the hemp matting (July 19, 2019)

Photos taken of hemp matting in 2019, and 2020 (Figure 9) show that the hemp matting continued to degrade from animal use, as well as weather over the winter. This allowed a high rate of light permeation and plant regeneration in the Spring of 2020.

Figure 9. Photos of hemp matting (left taken July 4, 2019, right taken August 30, 2020)

In the very few areas where the matting remained undisturbed, it proved effective at supressing plant material (Figure 10).

Figure 10. Photo of lifted hemp matting (August 30, 2020)

3.3 Loosening Soil and Seeding

The compacted area showed a significant increase of overall plant colonization in 2020 compared to 2019 (Figure 11). There was an increase of 23.1% in the total cover of grass species from both seeding and colonization (Table 2), which was mostly observed in the compacted centre of Ottertail landing.

Figure 11. Photos of compacted center of the treatment site (Left taken June 18, 2020, right taken August 30, 2020)

3.4 Plant Cover

The most notable change in overall plant cover values from 2019 to 2020 is the increase in native species and grass species (Table 2). This is attributed to loosening of the soil causing reduced compaction, as well as 2 consecutive years of seeding native grasses (in 2018 and 2019). There was also a small reduction in the overall cover of non-native species.

Table 2

Percent change in plant cover, before treatment to one year post treatment

	July 2019, before treatments	August 2020, one year after treatments	% Change
% cover of native species	48%	73.5%	+25.5%
% cover of non-native species	31%	25.6%	-5.4%
% cover of grass (desirable vegetation)	25.9%	49%	+23.1%

***H. caespitosum* regeneration**

Total regeneration rates of *H. caespitosum* were high from 2019 to 2020. Cover in 2019 was 14.5%, and 11.5% in 2020. This represents a 3% reduction in cover.

C. carvi

The small patch of *C. carvi* was investigated in August 2020, and only 8 plants were found. This represents a significant reduction from 36 plants in 2019. These plants were pulled and bagged while collecting results.

4.0 DISCUSSION

4.1 Weed Steaming Functionality

While planning any carrying out the steam treatment on the landing area, the following procedural limitations were noted:

- The treatment is spatially limited to 100 feet around the steamer trailer at all times due to hose length. The unit would not be a viable option in the back country or anywhere further from a road. In addition, driving the truck and steamer into disturbed areas could increase compaction and further disturb the site.
- The process is time-consuming. It takes approximately 16 person hours to steam the Ottertail landing area once (4 hours per tank x 2 people x 2 tanks)
- Consumption of fossil fuels is extremely high. This includes gas, diesel, and oil, as well as the additional truck fuel cost of hauling a heavy trailer to the site.

It is possible that multiple steam treatments of the area in the same summer would deplete energy stores in the roots of invasive plants, and each treatment would result in less regrowth. Hanson et al. (2004) found that 11-12 thermal treatments per growing season is necessary to keep weed cover below 1% in heavily infested areas. This would translate to treatment intervals of 1-2 weeks over the spring and summer months. Though the steam treatments appeared to reduce non-native herbaceous plant cover in the most heavily invaded areas, the limitations associated with using this type of technology were found to be cumbersome and costly. Unfortunately, the LLYK vegetation crew in the summer of 2019 had limited resources, and driving to and from the site was time-consuming. These limitations meant that steaming the area more than twice was not possible, which was a limiting factor in the use of this method.

4.2 Hemp Matting Functionality

BioComposites Group (www.biocompositesgroup.com, n.d.) describes TerrafibreHemp Weed Suppressant as being effective in, "establishing trees and shrubs, and suppressing invasive weeds in a variety of landscape situations." Based on the pictures and text on the website, it seems as though this matting is generally marketed towards urban landscaping projects. This type of hemp matting may have a higher chance of success if it was used in areas with less precipitation, and fewer animals.

These mats are 100% biodegradable, which is desirable for certain restoration projects, but high rates of precipitation in the park may have accelerated decomposition. In addition, animal traffic in the Ottertail landing site accelerated the rate of decomposition due to trampling on the mats creating holes which allowed light to penetrate through to the soil. In areas where the matting stayed intact, however, there was significant death of plant material, suggesting that the intact matting was effective at blocking light and suppressing the hawkweeds.

This type of matting was chosen both due to availability, and the desire to try a method different from the more traditional solarization method wherein thick transparent or black plastic is staked over large areas of uniform infestation, effectively heating the soil to scorch plant material and sterilize the seedbank. Though solarization has proven highly effective in a number of studies (Reemts, 2020; Cohen, et al., 2018), hemp matting was more readily available for this project, and there were concerns of high rates of animal trampling causing holes and shredding of the plastic material, which would be more damaging to the sensitive environment than biodegradable hemp.

The hemp matting was effective in the areas where it was left undisturbed, but it is unlikely that this type of treatment would prove durable enough to last the required amount of time to sterilize the seedbank in order to create space for desirable species. For this reason, it’s likely this matting would be effective in reducing infestations of invasive plants such as *H. caespitosum* if there were lower rates of animal traffic, in combination with other more rigorous management activities. For a relatively large area such as Ottertail, this treatment method was too time-consuming, costly to maintain, and delicate. Hemp matting would be a more suitable treatment for smaller infestations of invasive plants in highly accessible areas.

4.3 Lessons Learned

Data collection

In the early stages of this project, the slope to the northwest of the site was included in the project scope. It was determined in late July 2019 that this slope would be excluded from the boundaries of this project, and managed at a later date. Of the initial 10 quadrats completed in June 2019 as a baseline, 2 of them were on the slope that was later excluded from the project area. Though 8 quadrats was determined to be an acceptable representation of the plant composition of the area, 10 would have given a more accurate portrayal.

In addition, collecting data for each method of treatment (steaming, hemp matting, loosening soil) separately would allow restoration practitioners to better understand the efficacy of each treatment, and adapt future restoration activities accordingly.

Repeat photography

Repeat photography was used compare the success of loosening compacted soil as well as hemp matting functionality and durability. Unfortunately, photos were taken at different times of year (June 2019 and August 2020), which caused difficulties in plant identification, as well as determining the overall state of the site.

5.0 RECOMMENDATIONS

5.1 Methods

Invasive management

It is recommended that Ottertail landing site be monitored, and managed using an adaptive management design to continue to reduce invasive plant infestations, and increase the chance of native plant establishment. Neither steam-treatment nor hemp matting are a viable solution for the restoration of Ottertail landing area, and more cost-efficient and time-saving alternatives should be explored.

Due to the ability of *H. caespitosum* to limit nutrient availability to competing plants, treated areas are often left relatively bare, and fertilizers and soil amendments are commonly used to encourage growth of native plants and boost competition in recently controlled areas (Wilson, 2006). Applications of nitrogen, phosphorus and potassium fertilizer (300 pounds/acre 15:15:15) have been shown to reduce infestations by increasing competition in native plants when used in areas of low-productivity. These fertilizers will not increase growth and reproduction of hawkweeds, because hawkweeds are adapted to nutrient poor soils (Jacobs and Wiese, 2007). In general, boosting the quality of the soil in the affected area is an important part of integrated management of hawkweeds, and methods of improving soil quality should be investigated.

Historical control methods such as fertilizer and herbicide use can be costly as well as ecologically problematic in remote or protected areas. In response to this, the use of biocontrol agents has been promoted as a possible alternative to control invasive plant species including many varieties of hawkweeds (Grosskopf et al., 2007). This involves the introduction of an herbivore or pathogen from the invader's native range in order to control the invasive plant in its new range. Host specific testing has been conducted for five insect species, and currently only the hawkweed gall wasp (*Aulacidea subterminalis*) has tested sufficiently host-specific for field release to treat hawkweeds, but to date no biological control agents have been released to treat hawkweeds in North America (Jacobs and Wiese, 2007). The use of biocontrol agents could, in the future, prove to be an effective method of treatment for *Heiracium spp.*

The following should be investigated in the coming field seasons:

- The pros and cons of fertilizer use in the area, how all native and non-native plants would react to fertilizer or soil amendment use.
- Biocontrol options for *Heiracium spp.* It is possible that biocontrol agents such as the hawkweed gall wasp (*Aulacidea subterminalis*) be approved for release in the future in Western Canada. These options must be rigorously tested before release, and approved by the Government of Canada.

In addition, the use of broadleaf-specific herbicide was avoided in this project, but the use of herbicide alternatives, such as vinegar-based (acetic acid) sprays, herbicidal soaps, etc. should be investigated for use on *H. caespitosum*.

Loosening compacted soil

It is recommended to monitor the establishment of grasses, as well as species with a taproot to determine adaptive management strategies for the compacted section of the restoration area.

The use of a pick axe in 2019 to loosen compacted soil was more effective than the raking used in the summer of 2018 (Kuyer, 2018), but repeated use of the pick axe is physically demanding and it would be ideal to further loosen the soil to help with the establishment of the seeded grasses. It was estimated that this pickaxe loosened the top 3-5cm of soil in the compacted area. The compaction and quality of soil in the center area of the site will demand further treatment in the coming years.

Some small sections in the area may require the use of a rototiller to loosen the soil sufficiently for desirable plants to establish. The use of this type of equipment, as well as soil amendments should be balanced with possible damage and disturbance caused by tillage, which could encourage the establishment of opportunistic species such as *H. caespitosum*.

5.2 Monitoring

Ottertail landing site should be monitored in the coming years to document the effectiveness of ongoing restoration activities. Further to random GPS point quadrats, the area of each invasive species in Ottertail landing site should be recorded each year by creating polygons using ArcGIS software, which is new to Parks Canada. Layers of yearly data collection will allow technicians to discern the expansion or reduction of non-native plant populations, and ensure that non-native vegetation that is not currently worrisome (such as *Cirsium, spp.*) does not spread into the surrounding forest.

6.0 CONCLUSION

Infestations of hawkweeds, as well as other vigorous, persistent and easily spread species are a threat to the overall biodiversity of the parks in the LLYK field unit. During the summer of 2019, a restoration strategy was established to integrate the testing of new, non-chemical, restoration methods into the ongoing restoration of Ottertail landing. The combined use of hemp matting, steaming, loosening soil, and seeding were implemented with the goal of reducing invasive plant cover, focusing on meadow hawkweed, which has a very high potential of spread into the fragile alpine areas of Yoho National Park.

Hemp matting was used on areas heavily infested with *H. caespitosum*. This method had limited effectiveness due to excessive trampling by animals, combined with heavy precipitation, causing the mats to form holes and eventually shred. This allowed plant matter under the matting to largely persist. This method was very effective in areas of the mats which were left untouched, and appeared to cause death in 100% of the plant matter beneath the untouched matting. This method could therefore be extremely effective on small size infestations in isolated areas which are easy to access.

Steaming was used on the remainder of Ottertail landing site, yielding some death of above ground plant matter, and much resprouting from roots. Unfortunately, the logistics and cost of carrying out this method the 11-12 times per summer that may be necessary to significantly reduce the infestation is not feasible for a small field unit such as LLYK.

Though the above methods had limited efficacy, the soil in the centre of the landing area was much less compacted in 2020 due to soil loosening, and most of the observed vegetation in this area is desirable native grasses.

With continued persistence in the coming years, an adaptive management plan can be established for Ottertail landing area. The continued management of soil compaction, and strengthening of the ecosystem as a whole, along with new research and investigation into managing vigorous species such as *H. caespitosum* are promising avenues for the restoration of the site. However, even if the infestation of these species in Ottertail landing is reduced or eradicated, that is a small portion of the overall infestations of hawkweeds in Kootenay, Yoho, and Banff National Parks. In order to control the incredibly quick spread of many species of hawkweeds in protected areas, all concerned parties and stakeholders must collaborate to complete research, monitoring, and implementation of new and innovative solutions to strengthen degraded ecosystems, and control the spread of invasive species for these delicate montane ecosystems to flourish.

References

Ascard, J., Hatcher, P. E., Melander, B., & Upadhyaya, M. K. (2007). Thermal weed control. In K. Mahesk, M.K. Upadhyaya, and R. E. Blackshaw (Eds.), *Non-chemical weed management: Principles, concepts and technology*. (155-173). CABI. DOI: 10.1079/9781845932909.0155

BioComposites Group. (n.d). https://www.biocompositesgroup.com

Centre for Forest Conservation Genetics. (2002). Montane Spruce Zone. https://cfcg.forestry.ubc.ca/resources/cataloguing-in-situ-genetic-resources/ms-zone/

Cochrane, H. R. and Aylmore, L. A. G. (1994). The effects of plant roots on soil structure, in: *Proceedings of 3rd Triennial Conference Soils 94*, 207212.

Cohen, O., Gamliel, A., Katan, J., Kurzbaum, E., Riov, J., & Bar, P. (2018). Controlling the seed bank of the invasive plant *Acacia saligna*: Comparison of the efficacy of prescribed burning, soil solarization, and their combination. *Biol Invasions* 20, 2875–2887. DOI: https://doi.org/10.1007/s10530-018-1738-8

Durkin, P. R. (2007). Aminopyralid: Human health and ecological risk assessment. *US Forest Service and National Park Service*. https://www.fs.fed.us/foresthealth/pesticide/pdfs/062807_Aminopyralid.pdf

Grosskopf, G., Wilson, L., & Littlefield, J. (2008). Host-range investigations of potential biological control agents of alien invasive hawkweeds (Hieracium spp.) in the USA and Canada: an overview. In *Proceedings of the XII International Symposium on Biological Control of Weeds. Wallingford: Citeseer*. 552 (7). DOI: http://dx.doi.org/10.1079/9781845935061.0552

Hamza, M. A., and Anderson, W. K. (2005). Soil compaction in cropping systems: A review of the nature, causes and possible solutions. *Soil and Tillage Research*. 82(2) ,121-145. DOI: https://doi.org/10.1016/j.still.2004.08.009

Hansen, P. K., Kristoffersen, P. and Kristensen, K. (2004), Strategies for non-chemical weed control on public paved areas in Denmark. Pest. Manag. Sci., 60: 600-604. DOI: https://doi-org.ezproxy.library.uvic.ca/10.1002/ps.853

Kozlowski, T. T. (1999). Soil Compaction and growth of woody plants. *Scandinavian Journal of Forest Research*. 14(6), 596-619. DOI: 10.1080/02827589908540825

Kuyer, M. (2018). Ottertail pit restoration trials: Internal report, Parks Canada Agency.

Reemts, C. M., Neill, R. L., Neill, C. (2020). Forb cover increases after solarization and winter fire in a grassland invaded by yellow bluestem. *Rangeland Ecology & Management*, 73(6), 820-826. DOI: https://doi.org/10.1016/j.rama.2020.03.008.

Spoor, G. (2006). Alleviation of soil compaction: requirements equipment and techniques. *Soil Use and Management*, 22, 113-122. DOI: http://dx.doi.org/10.1111/j.1475-2743.2006.00015.x

Stone, K. R. (2011). Hieracium caespitosum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/plants/forb/hiecae/all.html

Wallace, J.M., Prather, T.S., and Wilson, L.M. (2010). Plant community response to integrated management of meadow hawkweed (*Hieracium caespitosum*) in the Pacific Northwest. *Invasive Plant Science and Management* 3(3), 268-275. DOI: https://doi.org/10.1614/IPSM-09-012.1

Parish, R., Coupe, R., and Lloyd, D. (1996). Plants of southern interior British Columbia. Lone Pine Press.

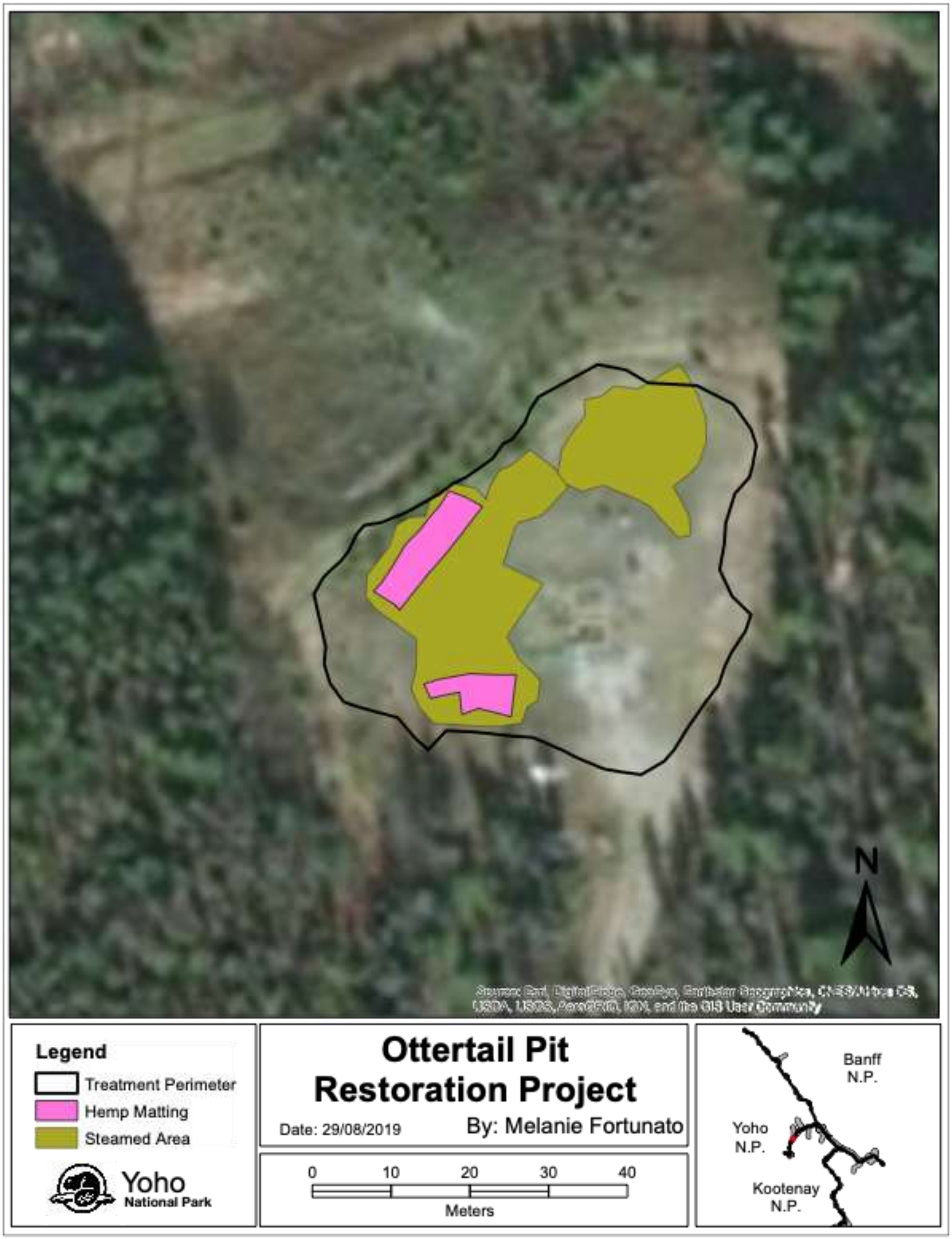
Parks Canada. (2017). Lake Louise, Yoho and Kootenay Field Unit: Integrated invasive plant management plan 2018-2022. Parks Canada Agency.

Wilson, L. M. (2006). Key to identification of invasive and native hawkweeds (*Hieracium* spp.) in the Pacific Northwest. B.C Ministry of Forests, Range Branch. Available: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/publications/key_to_identification_of_invasive_and_native_hawkweeds_in_the_pacific_northwest.pdf

Wilson, L and Callihan, R.H. (1999). Meadow and orange hawkweed. In R. Sheely and J. Petroff (Eds.), *Biology and management of noxious rangeland weeds* (238–248). Corvallis Oregon State University Press.

Appendices

Appendix A: Map of the treatment zones and perimeter of the treatment area



Appendix B: Plant inventory of the entirety of the treatment area (collected June 18, 2019)

Common Name	**Scientific Name**	**Notes**
*Wild Caraway	*Carum carvi*	All plants pulled June 25, 2019
American Vetch	*Vicia americana*	
*Yellow Hawkweed	*Hieracium caespitosum*	Primary target for treatment - Invasive species rated High in the LLYK vegetation management plan (2017)
*Dandelion	*Taraxacum officinale*	Deep taproot - desirable to loosen compacted soil
Grass	*Poa spp.*	Desirable vegetation. Approximately 30% cover of the area steamed in 2018 (previous year).
Yarrow	*Achillea millefolium*	Desirable
Fireweed	*Chamaenerion angustifolium*	Desirable
*Oxeye Daisy	*Leucanthemum vulgare*	Invasive species rated Moderate in the LLYK management plan (2017)
*Dandelion	*Taraxacum officinale*	Invasive species rated Low in the LLYK management plan (2017)
*Black Medic	*Medicago lupulina*	
*Buttercup	*Ranunculus acris*	
*Red clover	*Trifolium pratense*	
*Perennial Sowthistle	*Sonchus arvensis*	
*Bull Thistle	*Cirsium vulgare*	
*Canada Thistle	*Cirsium arvense*	
*Pennycress	*Thlaspi arvense*	Small area (10-20 small plants). Looks to have been treated with herbicide in

		2018.
Indian paintbrush	*Castilleja miniata*	
Trembling Aspen (seedlings)	*Populus tremuloides*	
Wild strawberry	*Fragaria vesca*	
Willow	*Salix spp.*	
Mountain avens	*Dryas octopetala*	
Timothy grass	*Phleum pratense*	

Appendix C: Plant inventory, 1 metre strip outside the site boundary in all directions

Common Name	**Scientific Name**
Showy Aster	*Eurybia spectabilis*
Willow	*Salix spp.*
Shrubby cinquefoil	*Dasiphora fruticosa*
Black twinberry	*Lonicera involucrata*
Spruce saplings	*Picea spp.*
Lodgepole pine saplings	*Pinus contorta*
Indian paintbrush	*Castilleja miniata*
Kinnikinnick	*Arctostaphylos uva-ursi*
Soapberry	*Shepherdia canadensis*
Rein bog orchid	*Platanthera dilatata*

Appendix D: Plant inventory, 5 metres outside of the site in all directions (excluding the very steep (>45 degrees) slope)

Common Name	**Scientific Name**
Wild strawberry	*Fragaria vesca*
Fireweed	*Chamerion angustifolium*
Saskatoon	*Amelanchier alnifolia*
Soapberry	*Shepherdia canadensis*
Birchleaf spirea	*Spiraea betulifolia*
Bunchberry	*Cornus canadensis*
Nootka rose	*Rosa nutkana*
Prickly rose	*Rosa acicularis*
Black twinberry	*Lonicera involucrata*
Showy aster	*Eurybia spectabilis*
Snowberry	*Symphoricarpos albus*
Bracted lousewort	*Pedicularis bracteosa*
Common juniper	*Juniperus communis*
Subalpine Fir	*Abies lasiocarpa*
Trembling Aspen	*Populus tremuloides*
Meadow horsetail	*Equisetum pratense*
Common horsetail	*Equisetum arvense*
Alpine forget-me-not	*Myosotis alpestris*
Northern bedstraw	*Galium boreale*
Trailing raspberry	*Rubus parvifolius*
*Red clover	*Trifolium pratense*
Highbush cranberry	*Viburnum trilobum*
Twinflower	*Linnaea borealis*

Moss	
Douglas-fir	*Pseudotsuga menziesii*
Rush-like sedge	*Carex scirpoidea*
Thimbleberry	*Rubus parviflorus*
Red-osier dogwood	*Cornus sericea*
*Dandelion	*Taraxacum officinale*
Wild raspberry	*Rubus occidentalis*
Lesser Wintergreen	*Pyrola minor*
American Vetch	*Vicia americana*

Appendix E. Randomly generated vegetation plots before treatments (June 25, 2019)

Plot #1 . UTM: 531731.62, 5688835.85

Percent Cover	Common Name	Scientific Name
40	Bare ground	N/A
15	Wild strawberry	*Fragaria virginiana*
10	Kinnikinnick	*Arctostaphylos uva-ursi*
10	*Meadow hawkweed	*Heiracium caespitosum*
5	Engelmann spruce (seedling)	*Picea engelmanii*
5	Yarrow	*Achillea millefolium*
3	Dandelion	*Taraxacum officinale*
2	Grass	*Poa spp.*
2	Willow	*Salix spp.*
1	Leafy aster	*Symphyotrichum foliaceum*

Plot #2. UTM: 531737.54, 5688828.38

Percent Cover	Common Name	Scientific Name
50	Mountain avens	*Dryas octopetala*
35	Moss	
10	Horsetail	*Equisetum arvense*
10	Willow	*Salix spp.*
10	Meadow hawkweed	*Heiracium caespitosum*
3	Engelmann spruce (seedling)	*Picea engelmanii*

Plot #3. UTM: 531758.74, 5688832.17

Percent Cover	Common Name	Scientific Name
25	Bare ground	N/A
20	Grass	*Poa spp.*

12	Dandelion	*Taraxacum officinale*
10	Moss	
5	Oxeye daisy	*Leucanthemum vulgare*
2	Plantain	*Plantago major*
1	Yarrow	*Achillea millefolium*

Plot #4. UTM: 531767.12, 5688841.04

Percent Cover	**Common Name**	**Scientific Name**
35	Grass	*Poa spp.*
25	Dandelion	*Taraxacum officinale*
10	Alsike clover	*Trifolium hybridum*
5	Oxeye daisy	*Leucanthemum vulgare*
3	Yarrow	*Achillea millefolium*
5	Meadow hawkweed	*Heiracium caespitosum*

Plot #5. UTM: 531775.29, 5688851.05

Percent Cover	**Common Name**	**Scientific Name**
80	Grass	*Poa spp.*
10	Oxeye daisy	*Leucanthemum vulgare*
5	American vetch	*Vicia americana*
5	Bare ground	N/A
4	Dandelion	*Taraxacum officinale*
3	Yarrow	*Achillea millefolium*

Plot #6. UTM: 531750.74, 5688871.52

Percent Cover	**Common Name**	**Scientific Name**

40	Bare ground	N/A
20	Yellow hawkweed	*Heiracium caespitosum*
10	Engelmann spruce	*Picea engelmanii*
5	American vetch	*Vicia americana*
5	Red clover	*Trifolium pratense*
4	Dandelion	*Taraxacum officinale*
2	Leafy aster	*Symphyotrichum foliaceum*
2	Yarrow	*Achillea millefolium*

Plot #7. UTM: 531742.26, 5688861.50

Percent Cover	**Common Name**	**Scientific Name**
70	Grass	*Poa spp.*
20	Meadow hawkweed	*Heiracium caespitosum*
10	Dandelion	*Taraxacum officinale*
5	Yarrow	*Achillea millefolium*
5	Red clover	*Trifolium pratense*
3	American vetch	*Vicia americana*
3	Wild strawberry	*Fragaria virginiana*
3	Oxeye daisy	*Leucanthemum vulgare*

Plot #8: UTM: 531748.12, 5688830.06

Percent Cover	**Common Name**	**Scientific Name**
80	Meadow hawkweed	*Heiracium caespitosum*
10	Bare ground	N/A
5	American vetch	*Vicia americana*

3	Willow	*Salix spp.*
2	Wild strawberry	*Fragaria virginiana*
2	Yarrow	*Achillea millefolium*
2	Indian paintbrush	*Castilleja coccinea*

Appendix F. Random vegetation plots, one year post-treatments (August 30, 2020)

Plot #1 . UTM: 531738.43, 5688838.36

Percent Cover	Common Name	Scientific Name
90	Grass	*Poa spp.*
10	Bare Ground	N/A

Plot #2. UTM: 531743.68, 5688845.12

Percent Cover	Common Name	Scientific Name
85	Grass	*Poa spp.*
15	Yarrow	*Achillea millefolium*
10	Clover	*Trifolium sp.*
5	Meadow hawkweed	*Heiracium caespitosum*
1	Strawberry	*Fragaria virginiana*
1	Oxeye daisy	*Leucanthemum vulgare*

Plot #3 . UTM: 531745.74, 5688860.12

Percent Cover	Common Name	Scientific Name
25	Grass	*Poa spp.*
15	American vetch	*Vicia americana*
15	Meadow hawkweed	*Heiracium caespitosum*
15	Moss	
10	Clover	*Trifolium sp.*
10	Oxeye daisy	*Leucanthemum vulgare*
10	Bare ground	N/A
5	Yarrow	*Achillea millefolium*
5	Creeping buttercup	*Ranuculus repens*
2	Plantain	*Plantago major*
1	Dandelion	*Taraxacum officinale*

1	Wild strawberry	*Fragaria virginiana*

Plot #4 . UTM: 531759.35, 5688871.14

Percent Cover	**Common Name**	**Scientific Name**
30	Meadow hawkweed	*Heiracium caespitosum*
30	Grass	*Poa spp.*
20	Bare Ground	N/A
15	Clover	*Trifolium sp.*
15	Wild strawberry	*Fragaria virginiana*
10	Dandelion	*Taraxacum officinale*
5	Moss	
5	Yarrow	*Achillea millefolium*
5	American vetch	*Vicia americana*

Plot #5 . UTM: 531770.23, 5688861.09

Percent Cover	**Common Name**	**Scientific Name**
25	Grass	*Poa spp.*
20	Clover	*Trifolium sp.*
15	Meadow hawkweed	*Heiracium caespitosum*
5	Dandelion	*Taraxacum officinale*
5	Yarrow	*Achillea millefolium*
5	American vetch	*Vicia americana*
2	Wild strawberry	*Fragaria virginiana*
2	Oxeye daisy	*Leucanthemum vulgare*
1	Bare Ground	N/A

Plot #6 . UTM: 531760.54, 5688850.03

Percent Cover	**Common Name**	**Scientific Name**

85	Grass	*Poa spp.*
20	Meadow hawkweed	*Heiracium caespitosum*
10	Clover	*Trifolium sp.*
5	Kinnikinnick	*Arctostaphylos uva-ursi*
5	Moss	

Plot #7 . UTM: 531769.80, 5688847.56

Percent Cover	Common Name	Scientific Name
50	Bare Ground	N/A
30	Grass	*Poa spp.*
15	Moss	
5	Meadow hawkweed	*Heiracium caespitosum*
1	Dandelion	*Taraxacum officinale*
1	Willow	*Salix sp.*
1	Plantain	*Plantago major*

Plot #8 . UTM: 531762.88, 5688848.34

Percent Cover	Common Name	Scientific Name
70	Grass	*Poa spp.*
30	Clover	*Trifolium sp.*
20	Yarrow	*Achillea millefolium*
5	Dandelion	*Taraxacum officinale*
5	Meadow hawkweed	*Heiracium caespitosum*
5	Canada thistle	*Cirsium arvense*

Plot #9 . UTM: 531766.48, 5688829.46

Percent Cover	Common Name	Scientific Name
40	Moss	

25	Mountain Avens	*Dryas octopetala*
20	Grass	*Poa spp.*
5	Meadow hawkweed	*Heiracium caespitosum*
5	Willow	*Salix sp.*
1	Oxeye daisy	*Leucanthemum vulgare*

Plot #10 . UTM: 531752.55, 5688829.37

Percent Cover	**Common Name**	**Scientific Name**
50	Bare ground	N/A
20	Grass	*Poa spp.*
20	Yarrow	*Achillea millefolium*
15	Meadow hawkweed	*Heiracium caespitosum*
10	Moss	
10	Clover	*Trifolium sp.*
2	Plantain	*Plantago major*

Appendix G: Steamer Guidelines (Operator Manual, ECO 355)

Step 1: Prior to leaving the compound, ensure adequate levels of gas (A), diesel (B), engine oil (using dipstick, C), pump oil (in viewer window, D), and a full tank of water. A full water tank should be sufficient for approximately 4 hours of steam treatment.

Step 2: Attach steamer wands to hoses upon arriving at the treatment site. Open the water valve at the base of the water tank and another at the hose junction for the use of both hoses.

Step 3: Insert key into engine (E), pull choke (F), and turn key to start engine. Note that once the engine has been started, water should be sprayed consistently from the steamer wands in order to avoid a pressure buildup in the machine.

Step 4: Spray cold water from the steamer wands for a few seconds in order to clear any stale water sitting in the hoses or elsewhere in the system. Once the water runs clear, attach steamer heads to the wands prior to turning on the burner (i.e. before the water is hot), ensuring that the spray mechanism is facing away from you. If utilizing both hoses, each person should use a 5L steamer head; otherwise, a 10L steamer head can be used if only one person is available for steaming.

Step 5: Turn on the burner switch (G) and watch the temperature gauge (H) as the water temperature increases. A temperature of approximately 115°C should be maintained for steaming, and water should be sprayed consistently from the wands until this temperature is reached. Make sure to keep an eye on the pressure gauge (I) as well, to ensure a constant pressure of approximately 1000kPa. Water temperature can be adjusted using the temperature dial (J), and water pressure can be adjusted using the hand dial (K) to increase or decrease the volume of water passing through the machine.

Step 6: Once the water has reached 115°C, steam treatment can begin. Aim to cover target plants entirely with the steamer heads and hold as near to the ground as possible for a few seconds or until plant material has wilted significantly. Be sure to check both the temperature gauge (H) and pressure gauge (I) sporadically to ensure optimal steam temperature and water pressure. Likewise, be sure to keep an eye on the water tank in order to avoid running out of water. (Note: some water is required during the cool-down process, so do not empty the tank entirely during steam treatment)

Step 7: When steam treatment is complete, or prior to using up the entire volume of water in the tank, turn off the burner switch (G). Continue to spray water consistently through the wands until the water temperature drops to below 40°C.

Step 8: Once the temperature gauge (H) has dropped to below 40°C, the machine can be turned off using the engine key (E). Make sure to remove the key from the engine for safe keeping during transport.

Step 9: Steamer heads and wands can now be removed from the hoses, and hoses should be wound up and locked into place for transport.