Tobacco Plains Invasive Plant Management

COL-F20-W-3057

Prepared For: Fish and Wildlife Compensation Program
Prepared By: Myra Juckers, BSc, PAg

June 29, 2020

Keefer Ecological Services Ltd
3816 Highland Rd.
Cranbrook BC V1C 6X7
(250) 489-4140
www.keefereco.com

Tobacco Plains Indian Band
3603 Hwy 93
Grasmere, BC V0B 1R0
(250) 887-3461

Acknowledgements

Keefer Ecological Services Ltd. (KES) and Tobacco Plains Indian Band (TPIB) would like to thank the Fish and Wildlife Compensation Program (FWCP) for their continued support of rangeland and open forest recovery efforts on Tobacco Plains Indian Reserve through invasive plant management. KES and TPIB would also like to thank the FWCP and the Columbia Basin Trust for supporting the sulphur cinquefoil (*Potentilla recta*) research study, which is examining best management practices to control sulphur cinquefoil on rangeland in the East Kootenay region.

KES and TPIB would like to thank the University of Saskatchewan for facilitating the sulphur cinquefoil research study. As well, to specifically acknowledge Dr. Katherine Stewart, Assistant Professor at the University of Saskatchewan, for overseeing the research study, and Marissa Delahey, Marc Roozendaal, Chelsea Voinorosky, and Lauren Reynolds for assisting with the fieldwork.

KES and TPIB would like to thank Cailey Chase of Vahana Nature Rehabilitation for conducting the targeted goat grazing with assistance from Dennis Wass and Jeff Tait. As well, KES and TPIB would like to thank Tracy Kaisner of West Fork Resource Management for facilitating herbicide application and Jeff Tait and Carter Phillips for assisting with these efforts.

KES would like to specifically thank Tom Phillips, Land and Resources Manager of TPIB, for his assistance in project management.

Executive Summary

Tobacco Plains Indian Reserve (TPIR), located within the southern Rocky Mountain Trench of British Columbia (BC), spans 5,261 ha, the majority of which is rangeland and open forest habitat. Fire-suppression practices and overgrazing have greatly reduced the health of these systems, making them susceptible to invasion by invasive plants. Since 2015, the Fish and Wildlife Compensation Program (FWCP) has supported efforts by Keefer Ecological Services Ltd. (KES) and Tobacco Plains Indian Band (TPIB) to conduct invasive plant management on TPIR, aiding in the recovery of rangeland and open forest habitats. With support from FWCP, as well as the Columbia Basin Trust, efforts continued in 2019, which included monitoring, herbicide application, and the initiation of a research study with the University of Saskatchewan.

Efforts continued to manage the leafy spurge (*Euphorbia esula*) infestation. The infestation size was estimated to be 1.9 ha, which was a 0.2 ha decrease from 2018. Since 2015, the distribution of leafy spurge has consistently been 5 (a few patches or clumps of a species) to 6 (several well-spaced patches or clumps) with a density of 3 (6 to 10 plants / m^2) to 4 (> 10 plants/m^2). In 2019, a notable change was observed, with the distribution determined as 4 (several sporadically occurring individuals) and 5, and density ranging from 1 (≤ 1 plant/m^2) to 4. Tordon 22K and glyphosate were sprayed in the area in late June to sustain the decline in the infestation size and the distribution and density of leafy spurge plants.

Over the years, treatment of orange hawkweed (*Hieracium aurantiacum*) with the herbicide Milestone has been met with moderate to high success. In 2019, approximately 2.8 ha of open forest and forest was sprayed with herbicide to control the spread and expansion of orange hawkweed infestations. However, new infestations of orange hawkweed continue to be found. Surveying for orange hawkweed in areas where it is commonly found, and continued application of Milestone, is needed to control its spread. Treatment of spotted knapweed (*Centaurea stoebe*) with Milestone in rangeland, open forests, and clearings has also been met with moderate to high success; however, re-emergence of spotted knapweed in areas sprayed in 2015 and 2016 was observed, highlighting the importance of monitoring to determine if re-treatment is necessary. Further, spread of spotted knapweed along roadsides throughout the reserve has been increasing. In 2019, approximately 6.78 km of roadside was sprayed with herbicide to control the spread of spotted knapweed throughout the reserve. Treating roadsides is critical to prevent the establishment of spotted knapweed in rangelands and open forests.

Blueweed (*Echium vulgare*) was identified at the TPIB sawmill. To manage its spread, the plant was manually removed and the area from which it was removed was sprayed with Milestone. New patches of scentless chamomile (*Tripleurospermum inodorum*) were identified at the sawmill; however, the area was not able to be treated. Scentless chamomile has not been identified at any other location on TPIR, highlighting the importance of managing this infestation to prevent its spread to other areas on the reserve. Yellow toadflax (*Linaria vulgaris*) was successfully managed; however, continued monitoring is critical to determine if the infestation re-emerges. A field bindweed (*Convolvulus arvensis*) infestation, treated with herbicide in 2015 and 2016, re-emerged in 2019. The patch was less than 0.25 m^2 in size and Milestone was sprayed on the patch to continue management efforts. Further, a 1.11 ha area in the southern reach of the reserve was treated with Milestone to manage infestations of Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), yellow hawkweed (*Hieracium spp.*) and hound's tongue

(*Cynoglossum officinale*), which emerged following forest thinning efforts in 2018.

In partnership with the University of Saskatchewan, a research study, examining best management practices to control the invasive plant sulphur cinquefoil (*Potentilla recta*) on rangeland in the East Kootenay region, was initiated in spring 2019. A component of the research is to examine the effectiveness of targeted goat grazing as a management strategy to control sulphur cinquefoil. Targeted goat grazing occurred on 8 ha of rangeland at two field sites, one located in the northern reach of TPIR and the other on private property near Wycliffe. Goat grazing treatments included grazing once and grazing twice per season, with grazing occurring over two field seasons (2019 and 2020). Preliminary results show targeted goat grazing conducted twice per season results in the greatest reduction in aboveground biomass and number of seed heads of sulphur cinquefoil. This suggests goats are affecting sulphur cinquefoil growth and reproduction, particularly under a higher grazing intensity. However, differences in the effects of grazing between sites was observed, suggesting site condition may influence the effectiveness of grazing treatments. Continued monitoring will provide important information for future sulphur cinquefoil management.

To continue moving forward with invasive plant management on TPIR, monitoring and further treatment of invasive plant infestations identified since 2015 is needed. This will maintain the momentum of management efforts and ensure infestations do not re-establish, expand, and spread. Treatment of roadsides and areas frequented by community members is also critical to control the spread of invasive plants throughout TPIR. Invasive plant management as a component of open forest treatments occurring on the reserve to recover open forest habitat is needed to control the emergence and establishment of invasive plants within these areas. Further, building awareness and educating community members on invasive plant identification and management supports prevention of invasive plant establishment and increases engagement in management efforts.

Table of Contents

List of Figures

List of Tables

Introduction

Invasive plants are defined by Catford et al. (2009) as plants that expand beyond their natural range and population density, adversely affecting native species, community dynamics, overall structure and function of ecosystems, and potentially the economy. To successfully invade an ecological community, invasive plants undergo six stages of invasion (Catford et al., 2009):

1) *Transport*: Movement of plants or propagules to a new location;
2) *Introduction*: Arrival of plant or plant propagules into a new location;
3) *Colonization*: Survival of introduced plants;
4) *Naturalization*: Survival and reproduction enabling pioneer population to be self-sustaining;
5) *Spread*: Dispersal of propagules and spread of populations outside of the area where they were first introduced; and
6) *Impact*: Harmful impact of species to ecology and economy.

The degree of impact of an invasive plant is influenced by the characteristics of the invasive plant and the ecological community it is invading. Invasive plants commonly exhibit high fecundity, greater tolerance to resource constraints, and better adaptation to changes in chemical status of the invaded site, enabling the plant to successfully invade an area (Masters and Sheley, 2001). As well, the absence of natural enemies and occupation of empty niches within an ecological community promotes establishment of invasive plants. Further, the degree of disturbance of an area is a large driver affecting successful invasion (Masters and Sheley, 2001).

Tobacco Plains Indian Reserve (TPIR), located within the southern Rocky Mountain Trench of British Columbia (BC), spans 5,261 ha, the majority of which is rangeland and open forest habitats. These habitats are critical for many species, providing winter range for mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), and elk (*Cervus canadensis*). As well, TPIR is home to several federally listed species at risk, including American badger (*Taxidea taxus*), Lewis's woodpecker (*Melanerpes lewis*), long-billed curlew (*Numenius americanus*), and the Spalding's campion (*Silene spaldingii*) plant. Fire-suppression practices since the 1930s and overgrazing from livestock and wildlife have greatly reduced the health of these systems, not only on TPIR, but also throughout the southern Rocky Mountain Trench (Forest Practices Board, 2016). This in turn has made these systems susceptible to invasion by invasive plants, further reducing their health. On TPIR, invasive plants such as leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stoebe*), orange hawkweed (*Hieracium aurantiacum*), and sulphur cinquefoil (*Potentilla recta*) are threatening rangelands and open forests.

In addition to forest thinning efforts to recover open forests on the reserve, the Fish and Wildlife Compensation Program (FWCP) has been supporting invasive plant management efforts on TPIR since 2015. Over the years, invasive plant management, conducted by Keefer Ecological Services Ltd. (KES) and Tobacco Plains Indian Band (TPIB), has involved:

In 2015-2016 (Juckers and Moody, 2016)

- Holding an invasive plant management workshop, led by the East Kootenay Invasive Species Council, at the TPIB office;
- Conducting an invasive plant survey of the reserve and developing an invasive plant

management report based on survey results; and
- Applying herbicide to various infestations on the reserve, including the 2.7 ha leafy spurge infestation identified in 2009, and small infestations (< 1 ha) of spotted knapweed, orange hawkweed, field bindweed (*Convolvulus arvensis*), and yellow hawkweed (*Hieracium* sp.).

In 2016-2017 (Juckers, 2017)

- Conducting a survey of orange hawkweed infestations throughout the reserve and mapping the extent of the infestations;
- Continued application of herbicide on the leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed, orange hawkweed, and field bindweed; and
- Conducting targeted goat grazing on 48 ha of rangeland infested with sulphur cinquefoil using approximately 300 goats.

In 2016-2017 (Juckers and Carignan, 2018)

- Conducting a survey of spotted knapweed infestations throughout the reserve and mapping the extent of the infestations;
- Monitoring invasive plant infestations sprayed in 2015 and 2016 to assess efficacy of herbicide application;
- Continued application of herbicide on the leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed and orange hawkweed;
- Conducting targeted goat grazing on 13 ha of rangeland infested with sulphur cinquefoil using approximately 50 goats; and
- Participating in the Ktunaxa Nation Annual General Assembly to bring awareness to ecosystem restoration initiatives occurring on TPIR.

In 2017-2018 (Juckers and Braumandl, 2019)

- Monitoring invasive plant infestations sprayed between 2015-2017 to assess efficacy of herbicide application;
- Continued application of herbicide on the leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed and orange hawkweed;
- Continued management of sulphur cinquefoil on 13 ha of rangeland using approximately 50 goats;
- Developing a research study design, in partnership with the University of Saskatchewan, to identify best management practices to control sulphur cinquefoil;
- Gathering baseline data to support the sulphur cinquefoil research study by conducting rangeland health assessments on three rangeland sites on TPIR and collecting soil samples to perform seedbank and soil nutrient analyses; and
- Participating in Aboriginal Day to bring awareness to community members of the sulphur cinquefoil research study that will be initiated on rangeland on TPIR in partnership with the University of Saskatchewan.

The following report describes the invasive plant management efforts conducted in 2019 to work towards the recovery of critical rangeland and open forest habitat on TPIR. These efforts align with the *Columbia Region: Upland and Dryland Action Plan* (FWCP, 2019). Specifically, Action #11, a Level 1 priority action under the habitat-based action type that focuses on the prevention and control of the spread and effects of high-priority invasive species; and Action #17, a Level 2 priority action under the monitoring and evaluation action type that focuses on ensuring invasive plant species distribution and abundance do not increase in response to treatments.

Goals and Objectives

The goal in 2019 was to continue efforts to recover critical rangeland and open forest habitat on TPIR (Figure 1) through invasive plant management. Objectives for 2019 included:

- Monitoring invasive plant infestations sprayed between 2015-2018 to assess efficacy of herbicide application;
- Continued application of herbicide on the leafy spurge infestation and small infestations (< 1 ha) of spotted knapweed and orange hawkweed;
- Implementing a research study, in partnership with the University of Saskatchewan, which is examining best management practices to control sulphur cinquefoil invasion on rangelands within the East Kootenay Region of BC;
- Engaging in outreach initiatives to bring awareness to the research study; and
- Providing recommendations to continue invasive plant management efforts on TPIR.

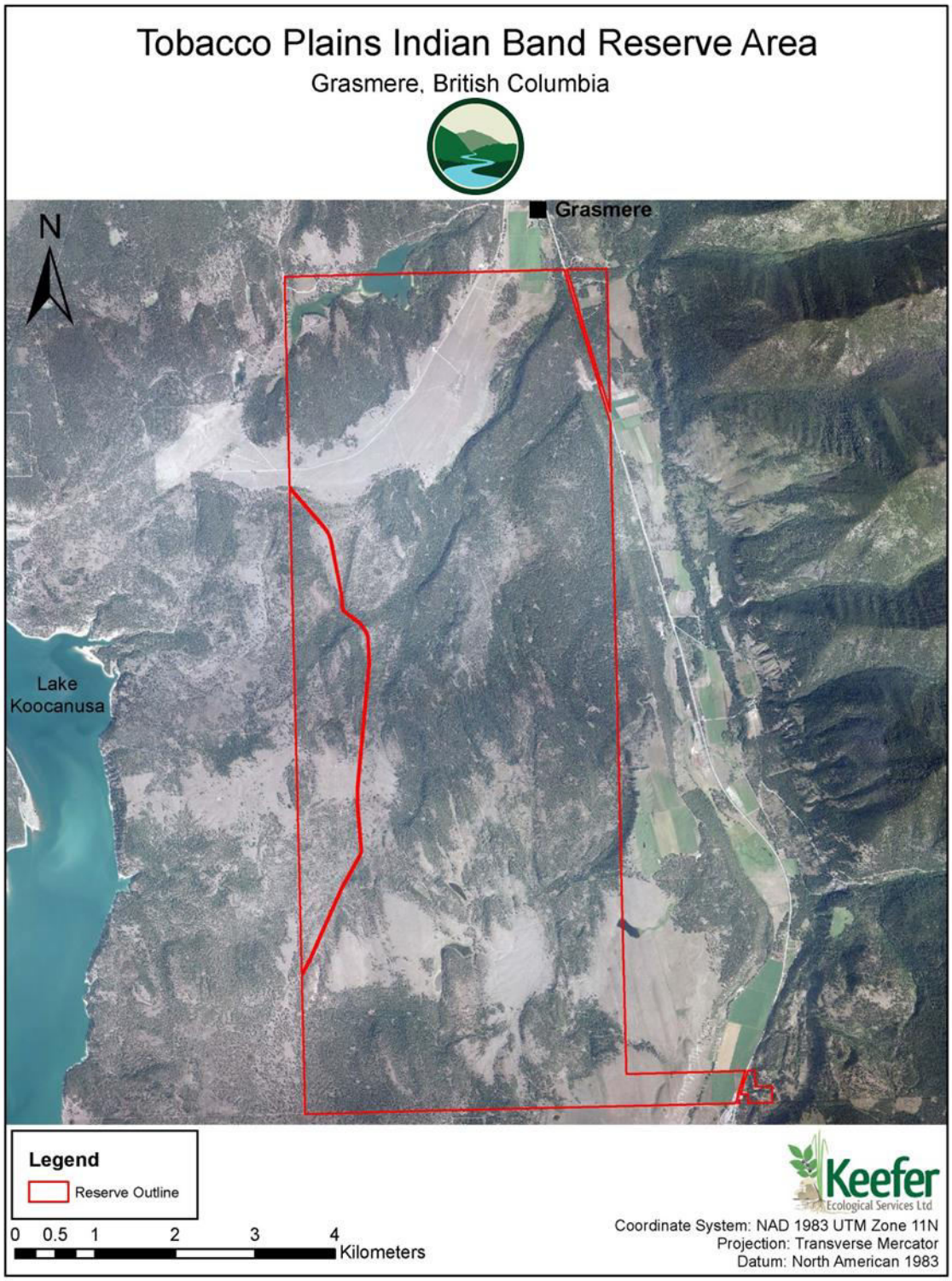

Figure 1: Map of Tobacco Plains Indian Reserve

Leafy Spurge (*Euphorbia esula*)

Leafy spurge was identified on TPIR in 2009 within a large sub-population of Spalding's campion (Keefer, 2009). It is a long-lived perennial forb that is considered one of the most unwanted invasive plants within BC (ISC BC, 2017). Leafy spurge forms dense stands, which displaces vegetation in rangeland, pasture, and native habitats (ISC BC, 2017). In 2015, management of the leafy spurge infestation, which spanned approximately 2.7 ha, was initiated. Management efforts have focused on working towards eradicating the noxious weed from the reserve through the application of herbicide.

From 2015-2017, the infestation area remained approximately 2.7 ha in size; however, in 2018, the area declined to 2.1 ha (Juckers and Braumandl, 2018) and in 2019, the decline continued, with the infestation area estimated to be 1.9 ha (Figure 2). Since 2015, the distribution of leafy spurge has consistently been 5 (a few patches or clumps of a species) to 6 (several well-spaced patches or clumps) with a density of 3 (6 to 10 plants / m^2) to 4 (> 10 plants/m^2). However, over the years declines in the leafy spurge infestation were observed, which was captured at the photo monitoring locations (Figure 3). In 2019, a notable change in the distribution and density of leafy spurge was finally observed, with the distribution determined as 4 (several sporadically occurring individuals) to 5, with a density ranging from 1 (≤ 1 plant/m^2) to 4. As well, as noted in 2018, the abundance of mature leafy spurge plants remained low. Patches of leafy spurge plants approximately 1 inch in height continued to be found throughout the infestation area; however, the patches were less abundant than that observed in 2018 (Juckers and Braumandl, 2018) and the density of leafy spurge plants within the patches was also lower.

Prior to the application of herbicide in 2019, the leafy spurge infestation area was surveyed for the endangered plant, Spalding's campion. As required under the Species at Risk Permit (SARA-PYR-2017-0379), a 5 m radius was established around Spalding's campion plants in close proximity to leafy spurge plants. Within the 5 m radius, glyphosate was applied onto leafy spurge plants rather than Tordon 22K. Glyphosate has moderate persistence in the soil with a soil field dissipation half-life averaging 44-60 days (Schuette, 1998), whereas Tordon 22K can remain in the soil for 5 years (Pachkowski and Thorton, 2011), presenting a higher risk to Spalding's campion. Three new plots, in addition to the eight plots established in 2017, were created in 2019 where glyphosate was applied (Figure 2).

Since 2015, herbicide has been applied to the leafy spurge infestation in late June and late August/early September. A second application was conducted to target plants that were missed or emerged since the initial herbicide application. In 2019, the decline in the distribution and density of leafy spurge was substantial enough to only apply herbicide in late June. Further, the efficacy of the herbicide application was determined to be 5 (50% to 59%; MFLNRO, 2010), which is an improvement from previous years (Juckers and Carignan, 2017; Juckers and Braumandl, 2019). However, invasion by *romus tectorum*) remains a concern as it is invading areas that were previously dense patches of leafy spurge.

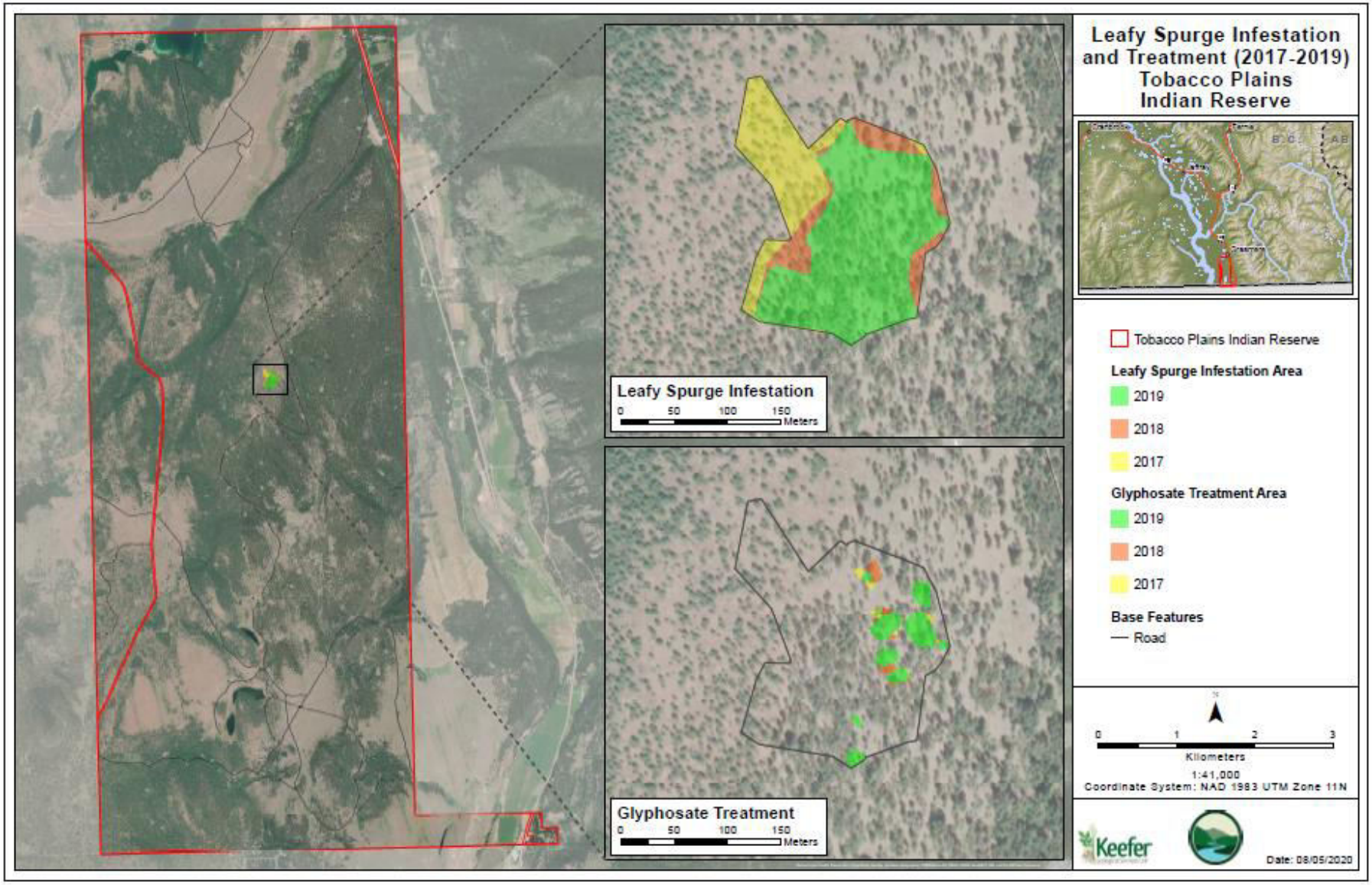

Figure 2: Leafy spurge (Euphorbia esula) treatment area on Tobacco Plains Indian Reserve.

A) Photo Point 1: 11U 639011E 5435159N, Bearing: 035°

Pre-treatment 2015

Photo of a leafy spurge patch within the leafy spurge infestation area taken on July 13, 2015 prior to the first application of herbicide

Pre-treatment 2016

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2016 prior to the first application of herbicide

Pre-treatment 2017

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 27, 2017 prior to the first application of herbicide

Pre-treatment 2018

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2018 prior to the first application of herbicide

Pre-treatment 2019

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 77, 2019 prior to the first application of herbicide

B) Photo Point 2: 11U 638999E 5435233 N, Bearing: 329°

Pre-treatment 2015

Photo of a leafy spurge patch within the leafy spurge infestation area taken on July 13, 2015 prior to the first application of herbicide

Pre-treatment 2016

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2016 prior to the first application of herbicide

Pre-treatment 2017

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 27, 2017 prior to the first application of herbicide

Pre-treatment 2018

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 13, 2018 prior to the first application of herbicide

Pre-treatment 2019

Photo of a leafy spurge patch within the leafy spurge infestation area taken on June 17, 2019 prior to the first application of herbicide

Figure 3: Photo documentation at Photo Point 1 (A) and 2 (B) of the leafy spurge infestation pre-treatment between 2015-2019 on Tobacco Plains Indian Reserve.

Orange hawkweed (*Hieracium aurantiacum*)

Orange hawkweed is identified as a regionally noxious weed in the East Kootenay Region under the BC *Weed Control Act*. Since 2015, orange hawkweed infestations have been managed on TPIR by applying Milestone, an herbicide known to effectively control the invasive plant (Henry, 2007). Efficacy of herbicide applications on orange hawkweed infestations have been moderate to high, ranging from 5 (50% to 59% efficacy) to 10 (100% efficacy) (Table 1). Patches sprayed in 2016 at the TPIB sawmill and Roosville cemetery have not re-emerged. However, a patch sprayed in 2015 on an old landing along the Proudfoot access road (Juckers and Braumandl, 2019) re-emerged in 2019, highlighting the importance of monitoring to determine if reapplication of herbicide is needed. In 2019, approximately 2.8 ha of forest and open forest were sprayed with Milestone to continue controlling the expansion of orange hawkweed infestations and the spread of the noxious weed throughout the reserve. Despite the success associated with the application of Milestone to control orange hawkweed, the invasive plant is becoming an increasingly larger problem throughout TPIR.

New infestations of orange hawkweed have been identified on the reserve each year since 2015 (Figure 4). New infestations are commonly found around the Edward's Lake area, in the southeastern region north and south of the Proudfoot access road, near the TPIB sawmill, in the Upper Gravelle community area, and within the east, northeast corner of the reserve in a forested area. Orange hawkweed is a highly successful invasive plant. High seed production and germination rates, asexual seed production, long distance seed dispersal, spread and regeneration from root fragments, root buds, rhizomes, and stolons, and rapid growth support its swift and widespread invasion (Wilson, 2007). Discovering new infestations throughout the reserve is not surprising based on the characteristics of orange hawkweed. Surveying for orange hawkweed in areas where it is commonly found and continued application of Milestone is needed to control its spread.

Table 1: Treatment efficacy of orange hawkweed (Hieracium aurantiacum) infestations sprayed with herbicide on Tobacco Plains Indian Reserve.

General Location	Monitoring Area	UTM	Year(s) Treated	Efficacy*	Comments
Stream feeding into SW end of Edwards Lake	0.85 ha	11U 636585E 5438572N	2016-2018	1	• OH infestation area is adjacent to a stream. • In 2018, sites within 1-10 m of the stream were treated with glyphosate and flower heads of OH found within 1 m of the stream were removed to prevent seed spread. • Monitoring conducted in 2019 to examine treatment efficacy found treatment success to be low. • Area was not treated in 2019 due to time constraints.
Edwards Lake area, side roads	8.82 ha + 0.35 km of roadside	11U 638139E 5439254N	2016-2019	6	• OH remains present in this monitoring area. • Several OH sites sprayed with Milestone in previous years did not reemerge; however, two notable OH sites are still present in the area (11U 638161E 5439087N; 11U 638203E 5439401N) and 4 new OH sites (< 1m^2) emerged (Figure 4). • Some OH patches are within 10 m of a stream and thus spraying with glyphosate is required to manage these patches. • Flowers heads of plants found within 1 m of the stream were removed to prevent seed spread. • OH infestations identified in 2019 were treated with Milestone.
Edwards Lake Rd S	8.13 ha + 0.38 km of roadside	11U 637898E 5438524N	2016-2019	7	• OH sprayed with Milestone in previous years has not reemerged; however, new plants/small infestations (≤ 1m^2) are emerging in the monitoring area. As such, an efficacy rating of 7 was given for this monitoring area. • OH infestations identified in 2019 were treated with Milestone.
NE corner of the reserve, Band Member Property	0.01 ha	11U 640101E 5439610N	2018	8	• OH emerged at the edge of the area sprayed in 2018. • The infestation is near a stream, which will influence treatment of OH as Milestone is not permitted to be sprayed within 10 m of a water body. • OH that emerged in 2019 was not treated due to time constraints.
TPIB Sawmill	15.20 ha	11U 640311E 5438295N	2016, 2019	10	• Area was sprayed with Milestone in 2016. In 2019, the area was monitored and OH had not reemerged. • 3 OH patches, less than 10m^2, were found at the outskirts of the sawmill beyond the area sprayed in 2016. These patches were sprayed with Milestone in 2019.
NEE corner of reserve in forested area	0.30 ha + 5 km of roadside	11U 640223E 5435328N	Area – 2015 Roadside – 2019	Area – 5 Roadside – NA	• The 0.30 ha area was sprayed in 2015. Monitoring in 2019 identified the emergence of three small patches (< 5m^2), two within the area sprayed in 2015 and one just outside the spray area. • Area was not sprayed in 2019 due to time constraints. • Roadside was sprayed in 2019.
Dorr Rd	2.00 ha	11U	2018-2019	8	• Infestation was identified in 2018. At this time, only 0.20 ha of the

General Location	Monitoring Area	UTM	Year(s) Treated	Efficacy*	Comments
		637616E 5434593N			infestation was sprayed. Efficacy associated with this herbicide application was 8. • In 2019, full extent of the infestation was determined to be 2.00 ha. • The 2.00 ha infestation was sprayed with Milestone in 2019.
NE of Indian Lake, old burn	0.58 ha	11U 639088E 5432585N	2016-2019	6	• Infestation has been sprayed each year since 2016. • Decline in OH has been notable. Since 2018, infestation declined by approximately 0.15 ha. • Milestone has effectively reduced the OH infestation; however, new patches continue to emerge each year requiring the site to be revisited and spraying efforts to continue.
Proudfoot Access Road	53.10 ha	11U 640346E 5429985N	2015-2019	7	• Monitoring area has been expanded from 15 ha to 53 ha to bring focus to a larger area needing to be surveyed/monitored for OH. • Although the monitoring area is large, OH patches are sporadic throughout the area and small, primarily less than 1 m^2. • Milestone has successfully managed OH infestations. Several OH sites sprayed in previous years have not re-emerged. • Efficacy of 7 was given because OH re-emerged at a site sprayed in 2015 (11U 640303E 5429883N) and OH was not completely controlled at a site sprayed in 2018 (11U 640464E 5430100N) • 7 new infestation sites were identified in 2019, 6 of which were less than 1m^2, the other was approximately 0.08 ha in size (Figure 4)
Rooseville Cemetery	0.05 ha	11U 642562E 5429278N	2016	10	• Area sprayed with Milestone in 2016. • OH has not re-emerged.

*Efficacy rating from MFLNRO (2010):
10–100% efficacy (complete control)
9–90% to 99% efficacy
8–80% to 89% efficacy (commercially acceptable control)
7–70% to 79% efficacy (may need additional passes)
6–60% to 69% efficacy
5–50% to 59% efficacy
4–40% to 49% efficacy
3–30% to 39% efficacy
2–20% to 29% efficacy
1–0% to 19% efficacy

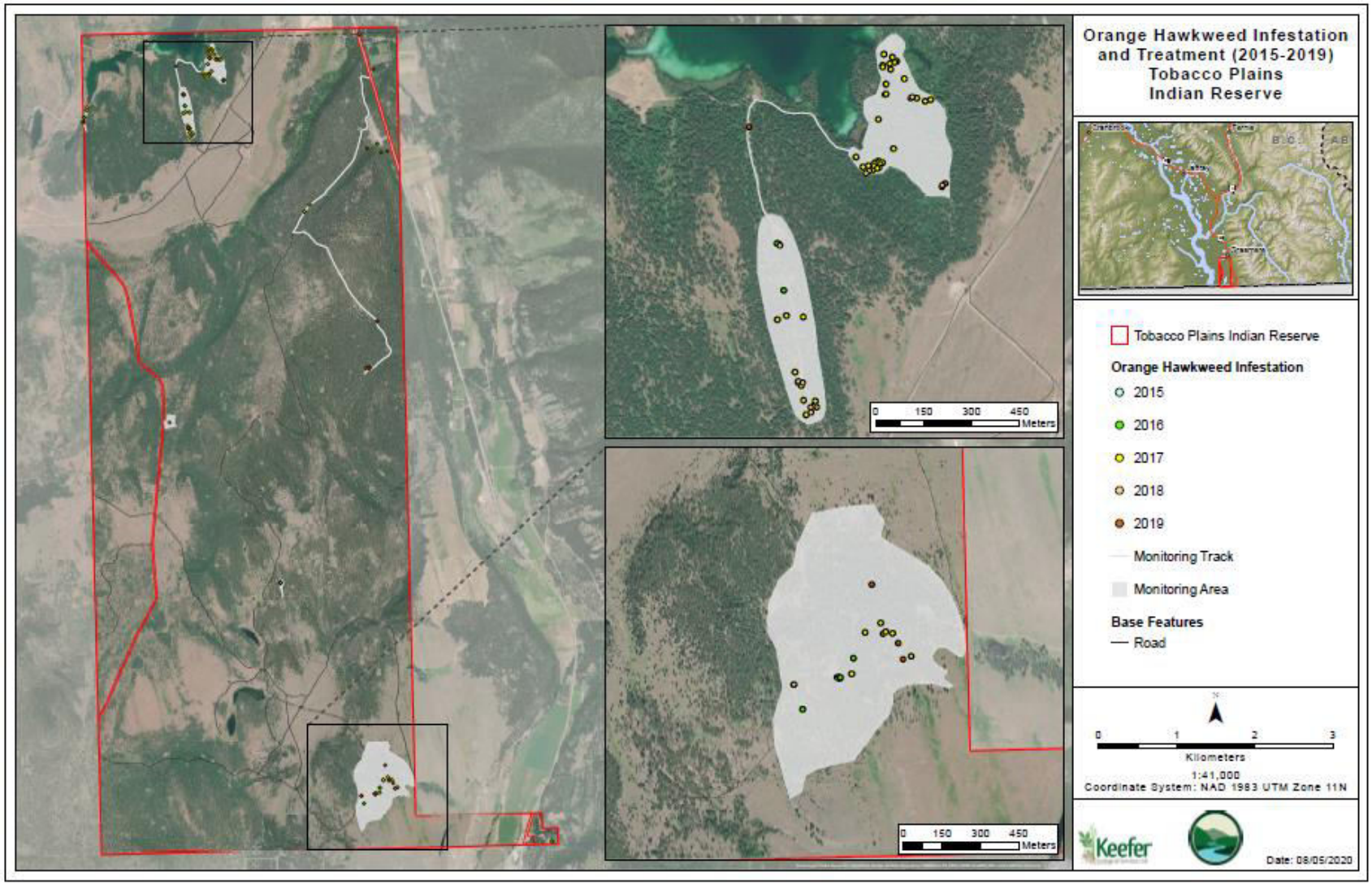

Figure 4: Orange hawkweed (Hieracium auranriacum) sites identified on Tobacco Plains Indian Reserve between 2015-2019 and specific areas to monitor.

Spotted knapweed (*Centaurea stoebe*)

Spotted knapweed is recognized as a provincially noxious weed under the BC *Weed Control Act*. The establishment and invasion of spotted knapweed is a concern shared by TPIB members. Spotted knapweed is challenging to manage when it becomes established because the roots release a chemical preventing root growth of other plants (AISC, 2014a). As well, a single plant can produce 140,000 seeds, which can remain viable in the soil for 5-10 years. On TPIR, large (greater than 1 ha) infestations of spotted knapweed have been located, including a forest clearing in the northeastern corner of the reserve by Upper Gravelle Road and within and around the Roosville cemetery (Figure 5). A large infestation is also located just outside the reserve in the southeastern corner along the Proudfoot access road. As control of large, established spotted knapweed infestations is challenging, management efforts on TPIR have focused on controlling the spread of this noxious weed.

Spotted knapweed treated with Milestone in rangelands, open forests, and clearings has been met with moderate to high success, with efficacy ratings of 6 (60% to 69% efficacy) and higher (Table 2). Spotted knapweed has re-emerged in areas treated in 2015 and 2016, highlighting the importance of continued monitoring to determine if reapplication of herbicide is needed. New infestations continue to be located in the southeastern region of the reserve north and south of the Proudfoot access road and within the sawmill area (Figure 5). As well, spotted knapweed has yet to be treated at the Edward's Lake Campground. The campground is seasonally used by band members and thus acts as an area that contributes to the spread of spotted knapweed throughout the reserve. Further, increasingly more infestations are located along roadsides.

Since 2017, more focus has been placed on surveying roadsides for spotted knapweed. The spread of spotted knapweed has been observed along roadsides with new infestations identified each year (Figure 5). Management of spotted knapweed along roadsides has been challenging, with efficacy rates low (Table 2). The low success is likely attributable to the soil structure and texture as the soil is coarse, which encourages the leaching of herbicide (Gover, 2008). Management of spotted knapweed along roadsides is critical to prevent its establishment into rangelands and open forests. In 2019, Milestone was applied to approximately 6.78 km of roadside to continue efforts to control the spread of spotted knapweed. An integrated approach, such as mechanical treatment followed by chemical treatment, may need to be considered if treatment success associated with herbicide application along roadsides remains low.

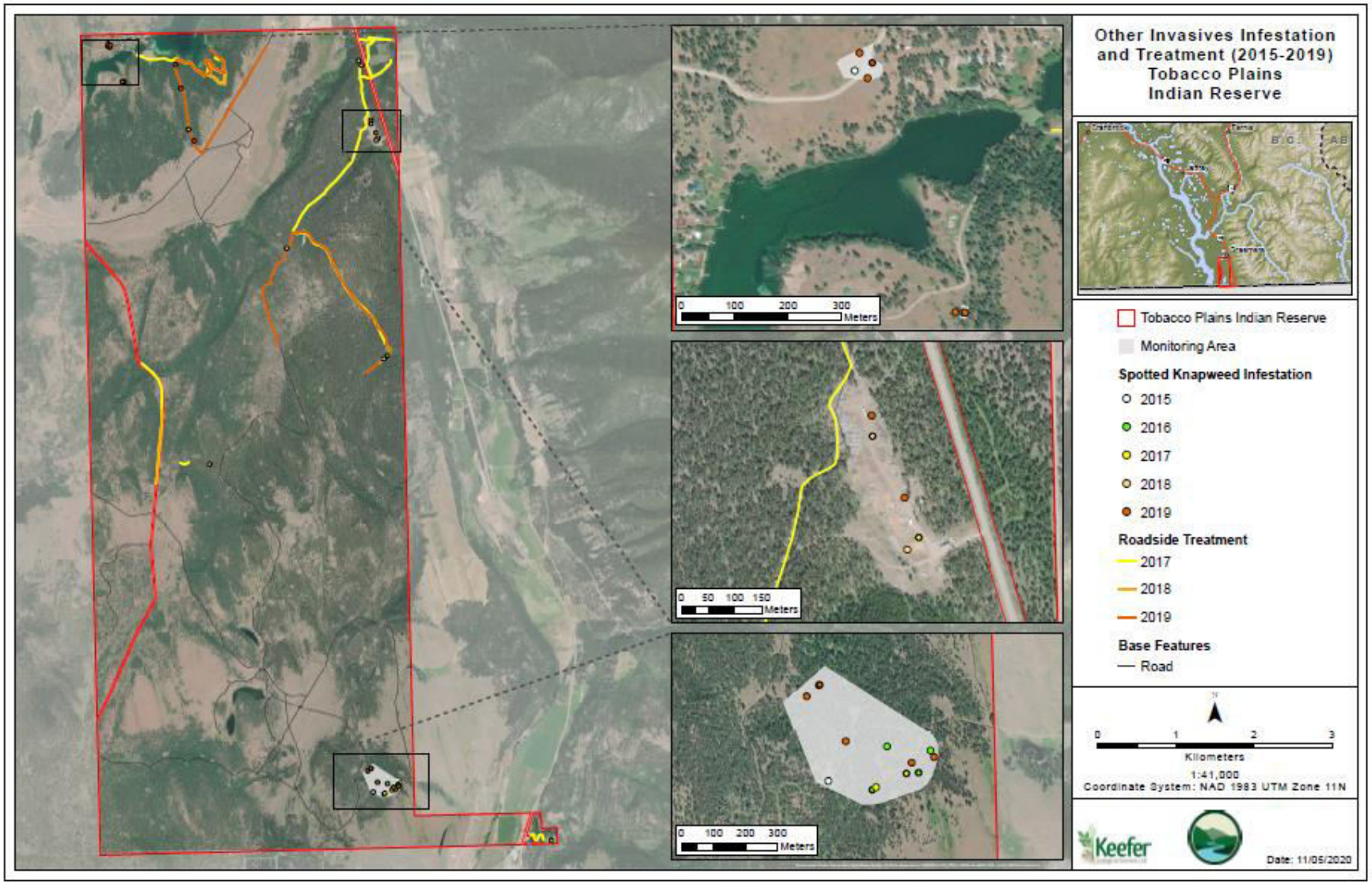

Figure 5: Spotted knapweed (Centaurea stoebe) sites identified on Tobacco Plains Indian Reserve between 2015-2019 and specific areas to monitor.

Table 2: Treatment efficacy of spotted knapweed (Centaurea stoebe) infestations sprayed with herbicide on Tobacco Plains Indian Reserve.

General Location	Monitoring Area	UTM	Year(s) Treated	Efficacy*	Comments
Near internet/cell tower, NW of Edwards Lake	0.33 ha	11U 636884E 5439442N	2015, 2018	6	• Area was sprayed in 2015 with Milestone. • SK did not re-emerge until 2018. Area was re-sprayed in 2018 to continue SK management. • In 2019, SK was found around the internet/cell tower and along the road. • Area was not sprayed in 2019 due to time constraints.
SE of the Arbour, Edwards Lake Area	0.03 ha	11U 637087E 5438989N	2015, 2018, 2019	8	• Area was sprayed with Milestone in 2015. • SK did not re-emerge until 2018. Area was re-sprayed in 2018 with Milestone to continue SK management. • 10 SK plants within a 2 m^2 area were identified in 2019 and hand-pulled.
Edwards Lake Rd S and side road	2.67 km + 0.02 ha	11U 638099E 5438090N	2017-2019	2	• SK was treated with Milestone in 2017 and 2018 along the roadside. • Monitoring conducted in 2019 found SK remained along the roadside. • SK was sprayed with Milestone in 2019 to continue efforts to control its spread.
Upper Gravelle Rd	0.81 km	11U 640094E 5439530N	2017	1	• SK was treated with Milestone in 2017 and has since re-emerged along the roadside. • In 2017, spot spraying was conducted. In future, continuous spraying, rather than spot spraying, should be considered to treat SK along the roadside. • SK was not sprayed in 2019 due to time constraints.
Upper Gravelle Rd, disturbed field	0.5 ha	11U 640250E 5439133N	2017	10	• SK was sprayed in 2017 with Milestone and SK has not re-emerged. • SK density is high in the surrounding area. Need to monitor for re-establishment of SK.
TPIB Sawmill	4.70 ha	11U 640344E 5438265N	2016, 2017	7	• Sites treated with Milestone in previous years have not re-emerged; however, new SK sites were identified at the sawmill in 2019 (Figure 5). • New SK sites in 2019 were not treated with Milestone due to time constraints.
Reserve roads west of Hwy 93	6.58 km + 0.16 ha	11U 640219E 5439133N	2017, 2019	1	• SK remains present along roadside. • Roadside was treated with Milestone in 2019.
Dorr Rd	1.08 km	11U 637319E 5435375N	2017, 2018	1	• SK remains present along roadside. • Roadside was not treated due to time constraints.
Side road off of Dorr Rd	0.1 km	11U 637810E 5434117N	2017, 2018	-	• Site was not monitored in 2019 due to time constraints.
Proudfoot Access Rd, forest thinned in 2014/15, open forest	12.74	11U 640512E 5429957N	2016-2019	7	• Monitoring has been expanded from 6.63 ha to 12.74 ha to bring focus to a larger area needing to be surveyed/monitored for SK. • Although the monitoring area is large, SK patches are sporadic throughout the area and small, primarily less than 10 m^2. • Several SK sites sprayed with Milestone in previous years have not re-emerged; however, at one SK site, which was a landing area (11U 640279E 5429916N), SK

General Location	Monitoring Area	UTM	Year(s) Treated	Efficacy*	Comments
					re-emerged in 2019 and was treated with Milestone. • 5 new SK sites were identified in 2019 and treated with Milestone.
Roosville Cemetery	2.00 ha	11U 642502E 5429275N	2016, 2017, 2019	4	• In 2016, approximately 0.4 ha within the monitoring area was treated with Milestone and no SK was observed in that area in 2017. In 2019, SK was observed in this area and was treated with Milestone. • In 2017, 0.1 ha was sprayed in the monitoring area, which included the roadside. In 2019, SK re-emerged along the roadside. SK was treated with Milestone.

*Efficacy rating from MFLNRO (2010):
10–100% efficacy (complete control)
9–90% to 99% efficacy
8–80% to 89% efficacy (commercially acceptable control)
7–70% to 79% efficacy (may need additional passes)
6–60% to 69% efficacy
5–50% to 59% efficacy
4–40% to 49% efficacy
3–30% to 39% efficacy
2–20% to 29% efficacy
1–0% to 19% efficacy

Sulphur Cinquefoil (*Potentilla recta*)

In 2019, KES and TPIB partnered with the University of Saskatchewan to initiate a research study examining best management practices to control sulphur cinquefoil invasion in rangelands within the East Kootenay region. A description of the study, implemented in spring/summer 2019, and results from the first field season are presented in Appendix A.

Other Invasive Plants

Blueweed (*Echium vulgare*)

Blueweed was identified in 2018 in a ditch adjacent to Highway 93 and a reserve road (Figure 6). As well, it was identified on a Band Member's property along Edwards Lake Road South (Juckers and Braumandl, 2019). In 2019, two blueweed plants were found within the TPIB sawmill (Figure 6). These plants were hand-pulled and Milestone was sprayed in the area from which they were pulled. Blueweed is a biennial or short-lived perennial plant that can produce 2,800 seeds, which remain viable for several years (AISC, 2014b). It is also recognized as a noxious weed in the East Kootenay region under the BC *Weed Control Act*. Continued monitoring and management of blueweed is critical to prevent its establishment into rangeland and open forest habitats on the reserve. As well, advising band members to remove blueweed from their properties will help prevent its spread throughout the reserve.

Canada Thistle (*Cirsium arvense*), Bull Thistle (*Cirsium vulgare*), Yellow Hawkweed (*Hieracium spp.*), and Hound's Tongue (*Cynoglossum officinale*)

Since 2014, open forest restoration efforts have occurred in the southern reach of the reserve. Efforts have primarily involved manually thinning trees; however, in early spring 2018, an eco-mulcher was used on approximately 2 ha to manage forest encroachment and recreate an open forest (Juckers and Braumandl, 2019). In response to the disturbance from the eco-mulcher, invasive plants quickly emerged in this area, including Canada thistle, bull thistle, yellow hawkweed, and hound's tongue. Canada thistle and hound's tongue are recognized as provincially noxious weeds under the BC *Weed Control Act* and yellow hawkweed and bull thistle are recognized as invasive plants of concern within the East Kootenay region. Canada thistle is an aggressive invasive plant that forms colonies (AISC, 2014c) and bull thistle is known to establish in clear-cuts and disturbed areas, becoming the dominant species for several years (BC Ministry of Agriculture, Food and Fisheries and Open Learning Agency, 2002). As well, yellow hawkweed forms a dense mat of rosettes, outcompeting native vegetation (ISC BC, 2014) and hound's tongue is an invasive plant known to do well in disturbed areas (AISC, 2014d). In 2019, approximately 1.11 ha of the eco-mulched area was treated with Milestone to manage the Canada thistle, bull thistle, yellow hawkweed, and hound's tongue infestations which emerged in this area (Figure 6).

Dalmatian Toadflax (*Linaria genistifolia*)

A Dalmatian toadflax patch, less than 0.001 ha, was found along Dorr Road in 2018 (Figure 6). Dalmatian toadflax is recognized as a provincially noxious weed under the BC *Weed Control Act*. It is a perennial plant that can produce up to 500,000 seeds, which can remain viable in the soil for 10 years

(AISC, 2014e; ISC BC, n.d.). The patch was not treated in 2018 and it was not monitored in 2019. Future monitoring and herbicide treatment is recommended to work towards eradicating the plant from the reserve, preventing its spread into disturbed rangelands.

Field Bindweed (*Convolvulus arvensis*)

A small infestation of field bindweed (< 0.01 ha) was identified on a wood stockpile within the southeastern reach of the reserve in 2015 (Figure 6). Field bindweed is a perennial vine that reproduces vegetatively and by seed, with seeds viable for up to 50 years (Ralph et al., 2014). It is recognized as an invasive plant of concern within BC. In 2015 and 2016, the infestation was sprayed with Milestone. In 2017, re-emergence of field bindweed was not observed; however, in 2019, field bindweed was identified. The patch was less than 0.25 m^2 in size and Milestone was sprayed on the patch to continue management efforts.

Scentless Chamomile (*Tripleurospermum inodorum*)

Scentless chamomile was identified on TPIR in 2017 at the TPIB sawmill (Juckers and Carignan, 2018). Scentless chamomile is a provincially noxious weed under the BC *Weed Control Act*. It is an annual, biennial, and occasionally perennial plant that only reproduces by seed; however, a large, mature plant is able to produce up to one million seeds, which can germinate throughout the growing season (AISC, 2014f). Milestone and Vantage XRT were used to treat the scentless chamomile infestation on TPIR in 2017. In 2018 and 2019, new patches of scentless chamomile were observed at the sawmill (Figure 6). In both years, time constraints prevented the treatment of these patches. However, scentless chamomile poses a threat to rangelands on the reserve and thus treatment of this invasive plant is critical to prevent its spread into this system.

Yellow Toadflax (*Linaria vulgaris*)

An infestation of yellow toadflax (< 0.001 ha) was identified on TPIR in 2017 within a clearing just off Edwards Lake Road South (Figure 6). Yellow toadflax is a perennial forb that primarily reproduces by sprouting from its creeping root system, which enables the plant to form large colonies (AISC, 2014g). The invasive plant is recognized as a provincially noxious weed under the BC *Weed Control Act*. The herbicide Tordon 22K was sprayed on the infestation in 2017. Re-application of Tordon 22K in 2018 was needed as a decline in infestation size and plant density was not observed. However, in 2019, yellow toadflax was not observed in this area and thus a treatment efficacy rating of 10 (100% efficacy) was given. Continued monitoring is necessary to identify if the infestation has re-emerged.

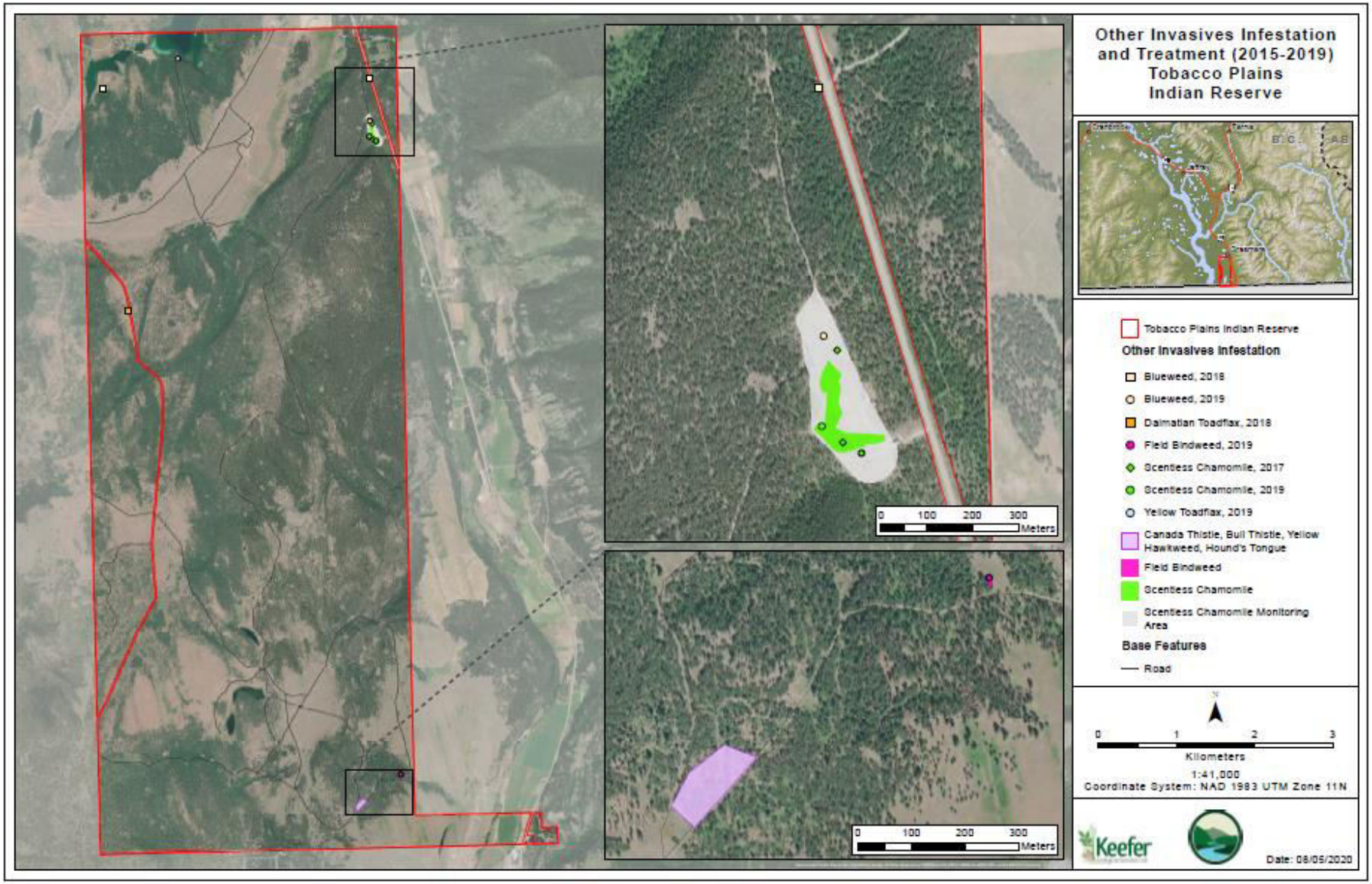

Figure 6: Other invasive plant infestation sites found on Tobacco Plains Indian Reserve.

Outreach

Various outreach activities were conducted to bring awareness to the sulphur cinquefoil research study. Three presentations were given, the first at the East Kootenay Invasive Species Council (EKISC) Annual General Meeting (AGM) on May 9th, 2019, in Cranbrook, BC; the second at the AGM of the Society of Ecological Restoration, Western Chapter on September 21st, 2019, in Saskatoon, SK; and the third at the 7th Native Prairie Restoration/Reclamation Workshop and 5th Transboundary Grasslands Partnership Workshop on February 27th, 2020, in Regina, SK. The presentation at the EKISC AGM focused on introducing the research initiative to EKISC members, with particular focus on targeted goat grazing as a management strategy being investigated to control sulphur cinquefoil. The other two presentations described the research initiative and presented results of the effects of targeted goat grazing on sulphur cinquefoil aboveground biomass and number of seed heads following the first field season of grazing. In addition to presentations, a radio interview was conducted through Summit 107 (now 2Day FM) in Cranbrook, BC, on June 27th, 2019. The interview focused on describing the research initiative and the use of targeted goat grazing as a strategy to manage invasive plants. As well, staff of the TPIB office hosted a community barbeque on July 8th, 2019, at TPIR to give community members the opportunity to meet the goats that were being used for the research study. Just over 30 people attended, which included youth, band members, and non-band members. Further, prior to the barbeque, a tour of the study site on TPIR was given, which was attended by four individuals, including three adults and one youth.

Invasive Plant Management Moving Forward

Monitoring and Continued Treatment

Since 2015, funding from FWCP has supported identification of invasive plant infestations throughout TPIR and subsequent management of these infestations. In addition to these efforts, time was allocated each year to revisit invasive plant sites that were treated to examine treatment success and determine if further treatment was needed. Monitoring is critical to examine changes in the size of the infestation as well as changes in the distribution and density of the invasive plant within the infestation area. This information guides management efforts by determining if the management approach was effective in controlling the invasive plant or if modifications are needed because treatment was ineffective. Further, monitoring can be used to identify new infestations.

Continued monitoring and treatment of infestations identified on TPIR since 2015 is critical to maintain the momentum of management efforts and ensure infestations do not re-establish, expand, and spread. Monitoring and continued treatment of spotted knapweed and orange hawkweed sites are needed to manage the spread of these noxious weeds throughout TPIR. In regards to spotted knapweed, herbicide treatment with Milestone has been met with success on rangeland and open forest sites; however, two to three years following herbicide application, spotted knapweed re-emerges, demonstrating the importance of continued monitoring and re-treatment of these sites. Management of orange hawkweed using Milestone has also been quite successful; however, new patches of orange

hawkweed continue to be found in treatment areas, demonstrating that monitoring helps identify new orange hawkweed infestations. Continued treatment of the leafy spurge infestation is critical to sustain the decline in the infestation size and reduce the distribution and density of leafy spurge in the infestation area. As well, this is the only location of leafy spurge found on the reserve and thus maintaining treatment efforts is needed to prevent the invasive plant from spreading to other locations. Similar to leafy spurge, a single infestation of Dalmatian toadflax, field bindweed, scentless chamomile, and yellow toadflax has been identified on TPIR. To prevent the expansion of these infestations and the spread of these invasive plants, monitoring and treatment are needed. Further, blueweed has been found at a small number of locations on TPIR and at each location, less than five plants were identified. Treating these locations is a priority to prevent the spread of blueweed on the reserve.

Roadsides

Roads are key habitats and corridors for invasive plants as they are typically well-drained, open habitats ideal for invasive plants to establish. As well, roadsides provide a starting point from which invasive plants move to adjacent rangeland, forests, and environmentally sensitive areas (ISC BC and MOTI, 2019). Over the years, the spread of spotted knapweed has been observed along roadsides throughout TPIR (Figure 5). Management of spotted knapweed along roadsides is critical to control its spread and prevent its establishment in rangeland and open forest habitats. As previously mentioned, the efficacy of spotted knapweed management along roadsides has been low. An integrated approach, which involves mowing prior to seed set, followed by herbicide application using Milestone, may improve management success. Movement of other invasive plants along roadsides, including orange hawkweed and blueweed, should be monitored as well to manage the spread of these noxious weeds throughout the reserve.

Areas Frequented by Community Members

The Roosville Cemetery, Edwards Lake Campground, and Upper Gravelle community area are areas that are frequented by community members but are also infested with spotted knapweed (Figure 5). Continued monitoring and treatment of spotted knapweed at the Roosville Cemetery is needed to sustain management efforts in this area and prevent the risk of spread by seed attaching onto people and vehicles. Management of spotted knapweed in the Upper Gravelle community area needs to be a priority as movement of community members from this area to other locations on the reserve increases the risk of spotted knapweed spread. Further, community members recreate at the Edwards Lake Campground during the summer. The occurrence of spotted knapweed in this area presents a high risk of spread by seed attaching onto people and vehicles. Treatment at the campground should be prioritized to control spotted knapweed movement.

Additional areas that are used by community members include a side road just southeast of Edwards Lake where a recreational site is present and the sawmill. Spotted knapweed and orange hawkweed are present along the side road southeast of Edwards Lake (Figure 4, Figure 5). Management in this area has been occurring since 2016; however, continued management of orange hawkweed and spotted knapweed is needed to prevent the spread of these noxious weeds by community members moving through the area. Further, the sawmill is home to numerous invasive plants, some of which include spotted knapweed, orange hawkweed, scentless chamomile, and blueweed (Figure 4, Figure 5,

Figure 6; Juckers and Keefer, 2016). The sawmill is not in operation; however, some community members still use the area, which poses the risk of spreading invasive plants present at this site to other areas of the reserve. Management of this area needs to be a high priority because it is a hotspot for invasive plants and therefore acts as a location where invasive plants establish and subsequently spread to other areas of the reserve.

Open Forest Treatment Areas

The TPIB, in partnership with KES, have been working to manage forest encroachment and increase open forest cover on the reserve since 2014. The TPIB Forestry Crew have worked in the southern reach of the reserve manually thinning Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). In April 2018 and January 2019, an eco-mulcher was used on 2 ha and 1.43 ha of land respectively, to remove Douglas fir and ponderosa pine ingrowth (Juckers and Braumandl, 2019). The eco-mulcher disturbs the soil surface and also releases mulch that covers the ground, burying plants underneath. Following treatment using the eco-mulcher, invasive plants were found to quickly emerge, some of which included Canada thistle, bull thistle, hound's tongue, and yellow hawkweed (Figure 7). Invasive plant management needs to be a component included in open forest treatments. The disturbance created from open forest treatment efforts creates an ideal environment for invasive plants to establish and form large infestations. Following thinning efforts, invasive plant treatment, such as herbicide application, needs to be conducted to control the emergence and establishment of invasive plants. As well, seeding with a native rangeland seed mix is highly recommended to reduce the risk of invasive plants establishing and becoming the dominant species within the thinned areas.

Figure 7: Patch of Canada thistle (Cirsium arvense) that emerged in the eco-mulched area on Tobacco Plains Indian Reserve in 2018.

Building Awareness and Education

Building awareness among the Tobacco Plains community on the identification and management of invasive plants on TPIR will support prevention of invasive plant establishment as well as increase engagement in management efforts. Invasive plant education can be presented to the community in a variety of ways, such as:

- Public presentations,
- Notices in newsletters and on Facebook,
- Posters in public spaces,
- Public awareness campaigns such as “Weed of the Month,”
- Roadside signs at invasive plant infestations,
- Workshops and field trips,
- Weed pulls with community groups (e.g., youth groups), and
- Employing community members to control weeds.

Collaborating with the East Kootenay Invasive Species Council (EKISC) also presents a great opportunity to build awareness and educate community members. EKISC can facilitate invasive plant identification workshops and workshops around various management strategies. As well, EKISC can teach members

how to use the "Report-A-Weed" app, which actively engages members in gathering information on the presence and distribution of invasive plants on the reserve. This in turn will help identify where to focus management efforts.

References

Alberta Invasive Species Council (AISC). 2014a. Spotted knapweed *Centaurea maculosa*. Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-SpottedKnapweed.pdf.

2014b. Blueweed *Echium vulgare* (aka Viper's bugloss). Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-Blueweed.pdf.

2014c. Canada Thistle *Cirsium arvense* (aka Creeping thistle). Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-CanadaThistle.pdf.

2014d. Hound's Tongue *Cynoglossum officinale*. Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-HoundsTongue.pdf.

2014e. Dalmatian Toadflax *Linaria dalmatica syn. Linaria genistifolia ssp. Dalmatica*. Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-DalmatianToadflax.pdf.

2014f. Scentless Chamomile *Tripleurospermum perforatum syn. T. inodorum*. Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-ScentlessChamomile.pdf

2014g. Yellow Toadflax *Linaria vulgaris* (Aka Common toadflax, Butter-and-Eggs, Spurred Snapdragon). Available at: https://abinvasives.ca/wp-content/uploads/2017/11/FS-CommonToadflax.pdf.

BC Ministry of Agriculture, Food and Fisheries and Open Learning Agency. 2002. A Guide to Weeds in British Columbia. Burnaby, BC: Open Learning Agency. pp. 16-19. Available at: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/guidance-resources/guidetoweeds.pdf.

Catford, J. A., Jansson, R. & Nilsson, C. 2009. Reducing redundancy in invasion ecology by integrating hypotheses into a single theoretical framework. *Diversity and Distributions,* 15: 22-40.

Fish and Wildlife Compensation Program (FWCP). 2019. Columbia Region: Upland & Dryland Action Plan. Available at: http://fwcp.ca/app/uploads/2019/08/Action-Plan-Columbia-Region-Upland-Dryland-Aug-21-2019.pdf.

Forest Practices Board. 2016. Restoring and maintaining rangelands in the East Kootenay. FPB/SR/53. Victoria, BC: Forest Practices Board.

Gover, A. 2008. Use and characteristics of herbicides for non-crop weed control. University Park, PA: Pennsylvania State University. Available at: https://plantscience.psu.edu/research/projects/wildland-weed-management/publications/other-publications/non-crop-herbicides.

Henry, C. 2007. Efficacy and application timing of Milestone® herbicide on hawkweeds. TechLine Invasive Plant News. Available at: https://static1.squarespace.com/static/50d37c2ce4b09ff030bc2f7b/t/5b153f1270a6ad083bf901a9/1528119060982/Hawkweeds.pdf.

Invasive Species Council of BC (ISC BC). 2014. Hawkweeds (*Hieracium spp*.). Available at: https://bcinvasives.ca/documents/Hawkweeds_TIPS_Final_08_06_2014.pdf.

Invasive Species Council of BC (ISC BC). 2017. Leafy Spurge *Euphorbia esula*. Factsheet. Available at: https://bcinvasives.ca/documents/Leafy_Spurge_TIPS_2017_WEB.pdf.

Invasive Species Council of BC (ISC BC). n.d. Dalmatian Toadflax. Available at: https://bcinvasives.ca/invasive-species/identify/invasive-plants/dalmatian-toadflax.

Invasive Species Council of BC (ISC BC) and the BC Ministry of Transportation and Infrastructure (MOTI). 2019. Best Practices for Managing Invasive Plants on Roadsides. A Pocket Guide for British Columbia's Maintenance Contractors. Available at: https://www.bcinvasives.ca/documents/Weeds_Roads_BMP_Guide-2019-web.pdf.

Juckers, M. 2017. Tobacco Plains Ecological Restoration. UKE-F17-W-1395. Keefer Ecological Services Ltd.: Cranbrook, BC.

Juckers, M. and T. Braumandl. 2019. Tobacco Plains Ecological Restoration. UKE-F19-W-2717. Keefer Ecological Services Ltd.: Cranbrook, BC.

Juckers, M. and G. Carignan. 2018. Tobacco Plains Ecological Restoration. UKE-F18-W-2404. Keefer Ecological Services Ltd.: Cranbrook, BC.

Juckers, M. and R. Moody. 2016. 2015-2016 Spalding's Campion Habitat Recovery: Tobacco Plains Indian Reserve. Keefer Ecological Services Ltd.: Cranbrook, BC.

Juckers, M. and M. Keefer. 2016. Invasive Plant Management on Tobacco Plains Indian Reserve. Keefer Ecological Services Ltd.: Cranbrook, BC.

Keefer, M. 2009. Spalding's Campion Presence/Absence Study on Tobacco Plains Indian Reserve, Grasmere, BC. Keefer Ecological Services Ltd., Cranbrook, BC.

Masters, R. A. & Sheley, R. L. 2001. Principles and Practices for Managing Rangeland Invasive Plants. *Journal of Range Management,* 54: 502-517.

Ministry of Forests, Lands & Natural Resource Operations (MFLNRO). 2010. The Invasive Alien Plant Program Reference Guide. Available at: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/iapp-resources/iapp_reference_guide_part_i.pdf.

Pachkowski, J. and J. Thorton. 2011. Integrated Pest Management (IPM): Leafy Spurge Prevention and Control. A Comprehensive Approach to Controlling Leafy Spurge for Landowners and Land Managers. Available at: https://www.brandonu.ca/rdi/files/2011/03/IPM_Leafy_Spurge_Manual.pdf.

Ralph, D., V. Miller, C. Hougen, and J. Leekie. 2017. Field guide to noxious weeds and other selected invasive plants of British Columbia. Eighth edition. Williams Lake, BC: Invasive Species Council of British Columbia. Available at: https://bcinvasives.ca/documents/Field_Guide_to_Noxious_Weeds_Final_WEB_09-25-2014.pdf.

Schuette, J. 1998. Environmental Fate of Glyphosate. Environmental Monitoring & Pest Management Department of Pesticide Regulation, Sacramento, CA.

Wilson, L.M. 2007. Key to identification of invasive and native hawkweeds (*Hieracium* spp.) in the Pacific Northwest. Revised March 2007. BC Ministry of Forests and Range, Forestry Practices Board: Kamloops, BC.

Appendix A

Summary report of the sulphur cinquefoil (*Potentilla recta)* research study

Targeted goat grazing reduces sulphur cinquefoil (*Potentilla recta*) aboveground biomass and number of seed heads in rangelands within the East Kootenay Region, British Columbia

Introduction

Rangelands within the East Kootenay Region of British Columbia (BC) are a valuable land resource, providing numerous services such as forage for livestock, biodiversity, and wildlife habitat; however, invasive plants are a major threat to the integrity of these rangelands (Phillips and Crowley, 2012). The forb, sulphur cinquefoil (*Potentilla recta*), is an invasive of particular concern as it is a dominante species in these rangelands. Sulphur cinquefoil is a perennial forb native to Eurasia that was introduced to North America prior to 1900 (Rice, 1999). It produces up to 6,000 seeds per plant (Dwire et al., 2006) and is known to live up to 10 years (Perkins et al., 2006). Sulphur cinquefoil is a particular threat to rangelands of the semi-arid intermountain region of the northwestern United States and southwestern Canada as it forms dense and continuous stands that dominate and outcompete native plants (Endress et al., 2008).

Target grazing, which is the application of livestock at a specific season, duration, and intensity, has been gaining in popularity as a strategy to manage invasive plants, such as sulphur cinquefoil (Frost and Launchbaugh, 2003). Sulphur cinquefoil is considered a plant avoided by foragers as it has low palatability, with a tannin content of 17 to 22% dry weight (DiTomaso et al., 2013). However, goats are able to efficiently process the high tannin content of sulphur cinquefoil and are known to reduce sulphur cinquefoil seed viability once seed passes through the digestive tract (Frost and Launchbaugh, 2003; Frost et al., 2013). The present study examined the application of targeted goat grazing as a strategy to manage sulphur cinquefoil in rangelands within the East Kootenay region of BC. The objective of the study was to assess the effects of targeted goat grazing applied once per season and twice per season on sulphur cinquefoil aboveground biomass and number of seed heads.

Methods

Study Sites

The study was conducted on degraded rangeland in the northern reach of Tobacco Plains First Nation community reserve (49° 4'18.65"N, 115° 7'9.66"W) and private property in Wycliffe (49°40'5.41"N, 115°52'55.01"W), located within the East Kootenay Region of the southern Rocky Mountain Trench in BC (Figure 1). The sites occurred within the Kootenay Very Dry Very Hot Interior Douglas-fir (IDFxx2) biogeoclimatic unit classified under the Biogeoclimatic Ecosystem Classification System of BC (MacKillop et al., 2018). The IDFxx2 unit is characterized by very dry conditions with growing-season moisture deficits commonly occurring. Grasslands are an important feature of this unit; however, over a century of overgrazing and anthropogenic disturbance has severely degraded the natural grassland plant community (MacKillop et al., 2018). The study sites occur on glaciofluvial deposits with silt loam to loamy sand textures and high coarse fragment content (MacKillop et al., 2018). The soil of the study sites was classified as orthic dark brown chernozem.

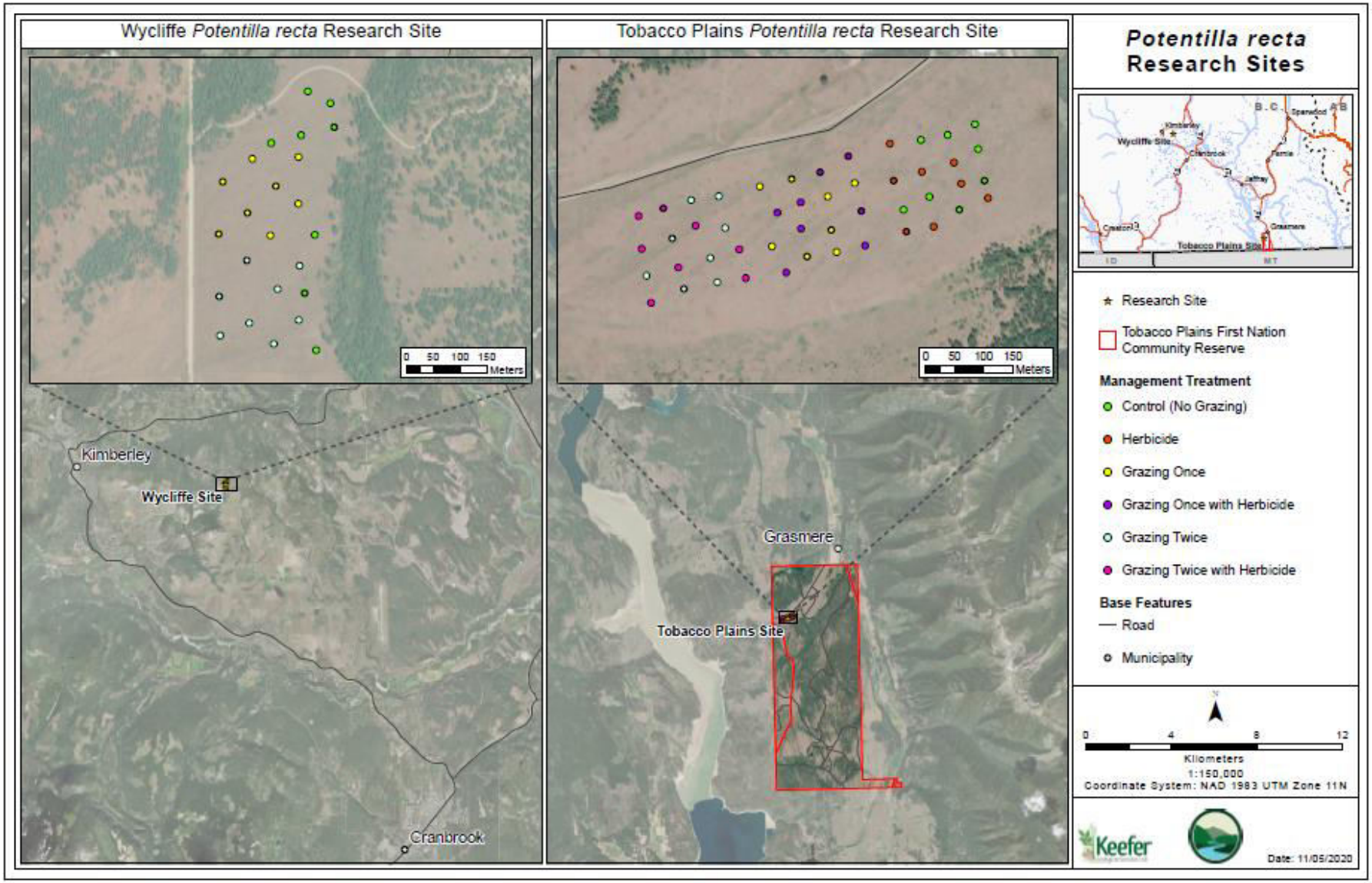

Figure 1: Sulphur cinquefoil (*Potentilla recta*) research study sites.

Study Design and Sample Collection

A nested, split-plot design was used for the study. Three 4 ha sections were delineated at each study site using Google Earth, with sections separated by approximately 25 m and 5 m at the Tobacco Plains and Wycliffe study sites, respectively. One section represented grazing once, another grazing twice, and the third section represented the control where no grazing occurred. Google Earth was used to identify eight plots nested within each section per study site that were systematically spaced by 50-100 m. Plot locations were uploaded onto a handheld GPS, which was used to locate plots. At the study sites, a 12 m radius was walked around each plot location to identify the densest sulphur cinquefoil patch within the 12 m radius. Once identified, a permanent 6 m x 6 m plot was established within the patch from which sample collection occurred.

A herd of 195 goats, consisting of 145 adults and 50 young of the year, was used to graze the study sites in late spring/summer 2019. The first grazing event occurred on two of the three 4 ha sections of rangeland from June 1-6 at Tobacco Plains and June 7-13 at Wycliffe, which was during the budding stage of sulphur cinquefoil. The second grazing event occurred on one of the three 4 ha sections of rangeland previously grazed from July 6-7 at Tobacco Plains and July 10-11 at Wycliffe, which was during the flowering and seed set stage of sulphur cinquefoil. Portable fencing and active goat herding was used to move the goats throughout the study area and separate the grazed and ungrazed areas as well as areas grazed once and twice.

Collection of sulphur cinquefoil aboveground biomass occurred at each site during the last week of May and July, before and after grazing treatment implementation. Aboveground biomass collection involved randomly tossing a 0.25 m x 0.5 m quadrat into the 6 m x 6 m plot and clipping sulphur cinquefoil plants just above the soil surface within the quadrat. Biomass samples were dried over 2 weeks at 40°C and subsequently weighed. The number of sulphur cinquefoil seed heads were counted during the last week of July prior to biomass collection from all plants in the 0.25 m x 0.5 m quadrat.

Statistical Analysis

Statistical analysis was conducted in R (R Core Team, 2019). General linear mixed models were used to analyze aboveground biomass and one-way ANOVA was used to analyze number of seed heads. Analyses were conducted on a per site basis. Aboveground biomass was log-transformed to meet model assumptions. Differences of least squares means was used to determine significant differences in aboveground biomass between grazing treatments and timing of sample collection (i.e., pre and post grazing treatment implementation) at each site. The Kruskal-Wallis test was used to determine significant differences in the number of seed heads between grazing treatments.

Results

In each grazing treatment, sulphur cinquefoil aboveground biomass was slightly greater at the Wycliffe study site than the Tobacco Plains study site (Figure 2). Aboveground biomass significantly increased in the no grazing treatment from late May to late July by an average of 55% and 54% at the Tobacco Plains and Wycliffe study sites, respectively. At the Tobacco Plains study site, aboveground biomass following a single graze was significantly lower than biomass present in the no grazing treatment in late May and late July, with an average reduction of 40% and 73%, respectively. At the

Wycliffe study site, aboveground biomass following a single graze was significantly lower than biomass present in late July in the no grazing treatment, with an average reduction of 63%. However, biomass following the single graze treatment did not significantly differ from biomass present in late May in the no grazing treatment. Aboveground biomass following two grazing events was significantly lower than biomass remaining following a single grazing event with an average reduction of 74% and 32% at the Tobacco Plains and Wycliffe study sites, respectively. Further, at the Tobacco Plains study site, biomass following two grazing events was lower than biomass present in late May and late July in the no grazing treatment, with a reduction of 85% and 93%, respectively. At the Wycliffe study site, biomass following two grazing events was, on average, 46% and 75% lower than biomass present in late May and late July in the no grazing treatment, respectively (Figure 2).

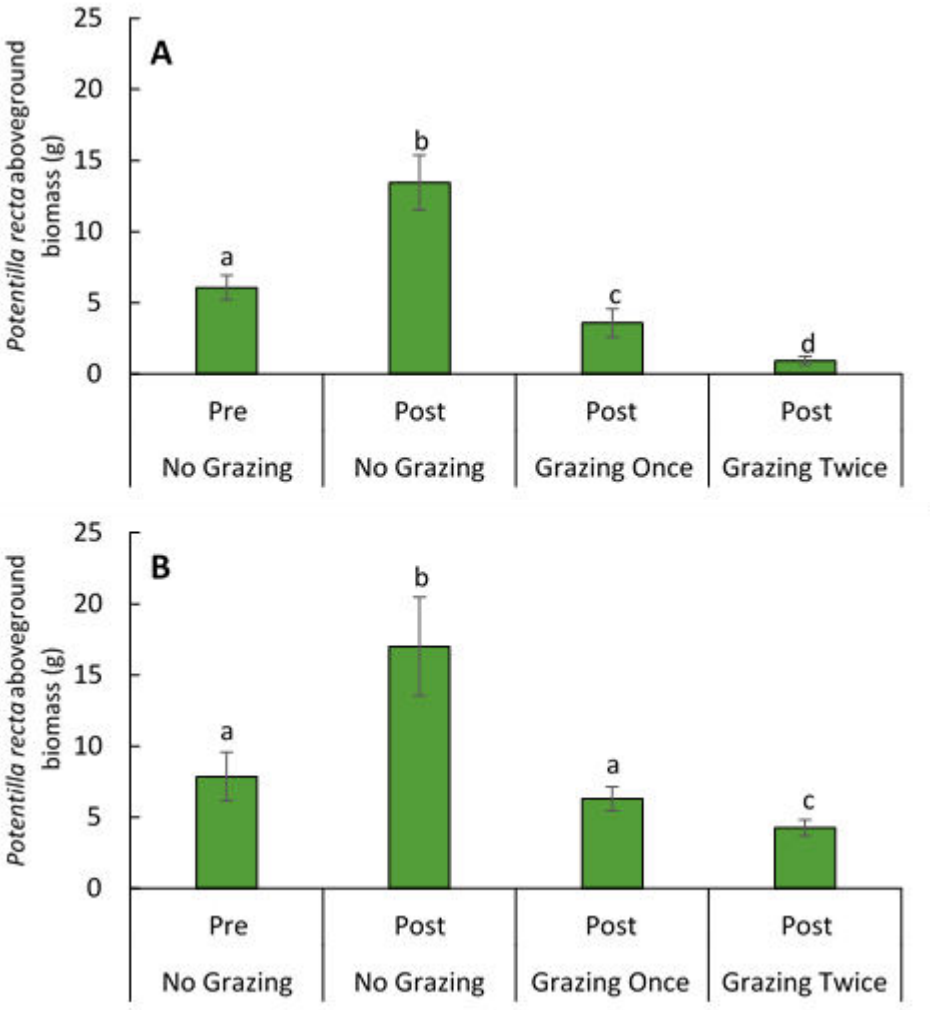

Figure 2: Mean sulphur cinquefoil (*Potentilla recta*) aboveground biomass (+/- standard error) pre (late May) and post (late July) grazing treatment implementation in the no grazing section and post grazing treatment implementation in the grazing once and grazing twice sections at the Tobacco Plains (A) and Wycliffe (B) study sties. Different letters indicate aboveground biomass significantly differs between treatments.

Number of sulphur cinquefoil seed heads in the no grazing and grazing once treatments was slightly higher at the Wycliffe study site than the Tobacco Plains study site (Figure 3). Following a single graze, the number of seed heads was significantly lower than the number present in the no grazing treatment, with an average reduction of 85% and 83% at the Tobacco Plains and Wycliffe study sites, respectively. At the Tobacco Plains study site, number of seed heads following two grazing events was significantly lower than the number present following a single graze and no grazing, with an average reduction of 91% and 99%, respectively. At the Wycliffe study site, a 100% reduction of number of seed heads was observed in the grazing twice treatment (Figure 3).

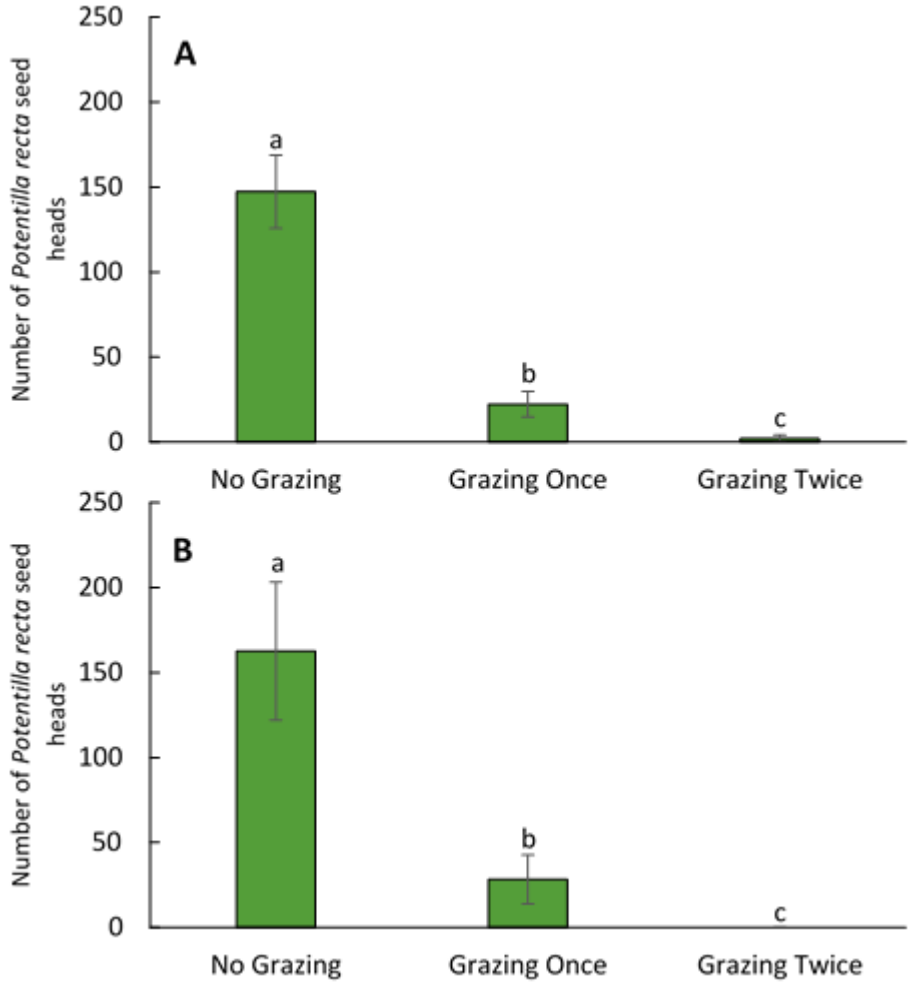

Figure 3: Mean number of sulphur cinquefoil (*Potentilla recta*) seed heads (+/- standard error) following grazing treatment implementation (late July) in the no grazing, grazing once, and grazing twice sections at the Tobacco Plains (A) and Wycliffe (B) study sties. Different letters indicate number of seed heads significantly differs between treatments.

Discussion

Reduction in sulphur cinquefoil aboveground biomass in response to targeted goat grazing follows results presented in other studies that examined grazing effects on sulphur cinquefoil within rangelands (Parks et al., 2008; Frost and Mosely, 2012). As well, the large reduction in the number of seed heads following grazing aligns with results presented by Mosely et al. (2017). Various grazing treatments, such as grazing at the preflower and flowering/seed set stage, have been shown to reduce sulphur cinquefoil aboveground biomass and seed production; however, reduction is greater with increased grazing intensity (Frost et al., 2012). This was shown through the present study as sulphur cinquefoil aboveground biomass and number of seed heads was lower following two grazing events in comparison to one grazing event.

Aboveground biomass of sulphur cinquefoil was greater at the Wycliffe study site than the Tobacco Plains study site. During late spring/summer 2019, the Wycliffe study site received more precipitation, which likely contributed to greater sulphur cinquefoil biomass. Targeted goat grazing significantly reduced sulphur cinquefoil aboveground biomass at Wycliffe; however, more biomass was remaining at the Wycliffe study site than the Tobacco Plains study site. Site condition is a factor that needs to be considered when implementing grazing treatments as conditions of the site may influence the effectiveness of grazing. However, the decreased aboveground biomass and seed production in response to targeted goat grazing at both study sites suggests grazing has potential to be an effective management strategy to suppress sulphur cinquefoil.

References

DiTomaso, J. M., Kyser, G. B., Oneto, S. R., Wilson, R. G., Orloff, S. B., Anderson, L. W., Wright, S. D., Roncoroni, J. A., Miller, T. L., Prather, T. S., Ransom, C., Beck, K. G., Duncan, C., Wilson, K. A. & Mann, J. J. 2013. *Weed Control in Natural Areas in the western United States*. Davis, CA: Weed Research and Information Center, University of California.

Dwire, K. A., Parks, C. G., McInnis, M. L. & Naylor, B. J. 2006. Seed Production and Dispersal of Sulfur Cinquefoil in Northeast Oregon. *Rangeland Ecology & Management,* 59: 63-72.

Endress, B. A., Parks, C. G., Naylor, B. J. & Radosevich, S. R. 2008. Herbicide and native grass seeding effects on sulfur cinquefoil (*Potentilla recta*) infested grasslands. *Invasive Plant Science and Management*, 1: 50-58.

Frost, R. A. & Launchbaugh, K. L. 2003. Prescription Grazing for Rangeland Weed Management: A New Look at an Old Tool. *Rangelands*, 25: 43-47.

Frost, R. A. & Mosley, J. C. 2012. Sulfur Cinquefoil (*Potentilla recta*) Response to Defoliation on Foothill Rangeland. *Invasive Plant Science and Management*, 5: 408-416.

Frost, R. A., Mosley, J. C. & Roeder, B. L. 2013. Recovery and Viability of Sulfur Cinquefoil Seeds From the Feces of Sheep and Goats. *Rangeland Ecology & Management,* 66: 51-55.

MacKillop, D. J., Ehman, A. J., Iverson, K. E. & McKenzie, E. B. 2018. *A field guide to site classification and*

identification for southeast British Columbia: the East Kootenay. Land Management Handbook 71. Victoria, BC: Province of BC.

Mosley, J. C., Frost, R. A., Roeder, B. L. & Kott, R. W. 2017. Targeted Sheep Grazing to Suppress Sulfur Cinquefoil (*Potentilla recta*) on Northwestern Montana Rangeland. *Rangeland Ecology & Management*, 70: 560-568.

Parks, C. G., Endress, B. A., Vavra, M., McInnis, M. L. & Naylor, B. J. 2008. Cattle, deer, and elk grazing of the invasive plant sulfur cinquefoil. *Natural Areas Journal*, 28: 404-409.

Perkins, D. L., Parks, C. G., Dwire, K. A., Endress, B. A. & Johnson, K. L. 2006. Age structure and age-related performance of sulfur cinquefoil (*Potentilla recta*). *Weed Science*, 54: 87-93.

Phillips, B. & Crowley, S. 2012. *Rocky Mountain Trench rangeland assessment project*. Cranbrook, BC: Environmental Stewardship Division, Ministry of Forest, Lands and Natural Resource Operations.

R Core Team. (2019) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rice, P. 1999. Sulfur cinquefoil. In R. L. Sheley & J. K. Petroff (Eds.), *Biology and management of rangeland weeds* (pp 382-388). Corvallis, OR: Oregon State University Press.