Bridge River Project Water Use Plan

BRGMON-2 Carpenter Reservoir Riparian Vegetation Monitoring

Implementation Year 7

Reference: BRGMON-2

Annual Report

Study Period: April 2019 – March 2020

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Executive Summary

For six years (2014-2019), riparian enhancement restoration treatments have been tested and applied to the drawdown zone of Carpenter Reservoir between 639 m and 650 m elevation, near the town of Gold bridge, BC. The BRGMON-2 monitoring program has been established under the Bridge Seton Water Use Plan to monitor the effectiveness of the treatments, in order to determine if treatments are having any beneficial effects on the quality and quantity of riparian habitat in the drawdown zone. Monitoring focused on comparing native vegetation colonization, establishment, cover and richness at a variety of treatment and control sites (including some reference sites).

Monitoring results indicate that, in most treatments, significant levels of change in vegetation cover do not occur swiftly. However, one treatment approach using Kellogg's sedge (*Carex kelloggii)* planting resulted in relative success in terms of establishment, cover and reproduction in 2019 and is also providing improved wildlife habitat. We investigated the inconsistent establishment of sedges throughout the study sites and conclude that successful establishment of sedge plugs at low elevation sites requires fine soils with minimum depth of 40 cm. Two years post-treatment of mounding and revegetation (performed in 2017), monitoring in 2019 noted increased species colonization and richness when mounding was paired with revegetation treatments. Combining revegetation with mounding was particularly important in the upper drawdown zone at Gun Creek Fan East, where richness of native species increased after planting, though overall vegetation cover remained very low. We expect total cover of native species from natural colonization combined with planting to slowly increase over time. On the other hand, exotic species are colonizing through natural dispersal and may prove to be limiting to native species, particularly for robust annuals and rhizomatous perennial species.

Recommendations derived from the cumulative riparian enhancement study (2013-2019) include:

1. finishing machine mounding treatments that were planned in 2019 but not constructed.
2. revegetation planting within areas treated with mounding in 2019 using native herb, shrub and tree species of local origin.
3. Conduct hand-seeding within mounded areas using native annual and perennial species collected locally mainly, meadow bird's-foot trefoil (*lotus denticulatus),* Kellogg's sedge
4. Conduct seeding of fall rye (*Secale cereale*) across the low mud flats working around areas that were planted with native perennials in 2019.
5. Plant patches of Kellogg's sedge throughout seeded areas to create a network of patches of perennial native vegetation across the low mud flat.
6. Mulch upper elevation tree and shrub species,
7. Water all planting treatments, irrigate plantings throughout growing season depending on weather and inundation.
8. Control any noxious weeds on mounding treatment sites through mechanical treatments (hand pulling before plants go to seed)

Management question	Summary of Key Monitoring Results
To determine if implementation of the chosen operating alternative have had negative, neutral or positive impacts on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area surrounding Carpenter Reservoir.	Final analysis will occur at the end of the study period, scheduled for 2022.
To determine if implementation of the chosen operating alternative have had negative, neutral or positive impacts on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area surrounding Carpenter Reservoir.	Final analysis will occur at the end of the study period, scheduled for 2022. Baseline vegetation data was collected from permanent plots established in 2013. No significant incursions into the buffer zone for over 56 days have occurred to date. Slight incursions in 2015 prompt a closer look into origin of Hypothesis
Does the implementation of a short term (7 year) intensive reservoir riparian enhancement program expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the drawdown zone of the Carpenter Lake Reservoir?	H_3: BRGWORKS-1 treatments have been diverse and monitoring time frames relatively short. We have seen for the first time in 2017 that one treatment, fall rye seeding appeared to increase colonization of Kellogg's sedge. It seems that some of the recruitment is enduring and that this treatment should be repeated. Kellogg's sedge plantings have developed mature plants that have self-seeded and resulted in increased colonization in the immediate area by this species. Seedlings have survived two years of inundations. We have also seen machine-work physical treatments, followed by seeding Kellogg's sedge, result in seedlings. Native species have colonized in mounded areas and some perennial native species have persisted for two growing seasons. Bluejoint reedgrass is establishing from plantings and individual plants have been observed expanding via rhizomes contributing to native plant vegetative colonization. In most treatments native species vegetation cover remains very low.

Management question	Summary of Key Monitoring Results
	H_{3A}: The introduction of native plants to treatment polygons directly affects native vegetation establishment. Planted and seeded vegetation has thus far proven the primary contribution to native vegetation diversity, cover, distribution and biomass. Control areas are dominated by exotic species. In the 4th year of monitoring, we have observed recruitment of seedlings that were self-seeded from originally planted plants and when seed was sown into machine-works treatment trials. These seedlings have survived two years of flooding. We have seen higher recruitment of Kellogg's sedge in fall rye seeding trials and recruitment of Kellogg's sedge, small winged sedge (*C. microptera)* and foxtail barley (*H. jubatum)* in mounding treatments. *Equisetum* sp. have regrown in mounded polygons where plants existed prior to treatment. Standing crop measurements have shown that in one treatment where Kellogg's sedge plugs have grown well that standing crop biomass can come close to the volumes of biomass found at the upstream reference ecosystem site (MMF04). Planting sedges has the potential for increasing biomass 10-fold over untreated control areas. More time and monitoring are required to form conclusions about long-term establishment of native species. H_{3B}: For many treatment sites, vegetation resulting from planting and seeding is not producing a significant amount of native vegetation cover. However, results vary from treatment to treatment and site to site. In the Low Mud Flat site we see a dramatic increase in native species cover due to planting Kellogg's sedge, particularly where fine silty soils are greater than 40cm in depth. Certain areas planted with bluejoint reedgrass show a dramatic increase in native species cover relative to control sites. Control polygons typically have very low native species cover and are dominated by exotic annuals. We hypothesize that over time established native perennial species will increase vegetation cover. H_{3D}: Treatments have directly affected species composition in a few cases primarily through planting Kellogg's sedge, Bluejoint reedgrass, Willow stakes for example. In mounding treatments, a greater number of species are colonizing from the combined natural establishment and revegetation treatments. Naturally colonizing species are both annual and perennial and some are exotic and native. Time is required to comment on long term patterns of vegetation composition.

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1. Introduction

The BRGMON-2 program arose from the Bridge-Seton Consultative Committee Report in 2003 (B.C. Hydro and Compass Resource Management, 2003), fulfilling the identified need to monitor riparian vegetation surrounding Carpenter Reservoir in relation to water management. The riparian vegetation monitoring for the drawdown zone of Carpenter Reservoir under BRGMON-2 has two specific goals as defined in the TOR (BC Hydro, 2017):

1. Monitor the effects of Carpenter Reservoir operating conditions on the (existing) riparian areas surrounding Carpenter Reservoir through monitoring carried out in Year 1 (2013) and Year 10 (2022).

Management question 1: Do reservoir operations have a negative, neutral or positive impact on the quality and quantity (species composition, biological productivity, spatial area) of the riparian vegetation surrounding Carpenter Reservoir?

2. Monitoring the effectiveness of the riparian enhancement program (BRGWORKS-1; the objective of riparian enhancement is to create conditions in the drawdown zone that encourage the establishment of native species using a combination of revegetation and physical works treatments) with respect to Carpenter Reservoir operating conditions. This component is implemented through a 7-year riparian enhancement program (BRGWORKS-1) and corresponds to Years 3 – 9 of BRGMON-2 (2014 to 2020).

Management question 2: Does the implementation of a short term (7 year) intensive riparian enhancement program expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the drawdown zone of the Carpenter Lake Reservoir.

This 2019 annual report addressed goal 2 and management question 2 with the null hypotheses:

H3: Implementation of a riparian enhancement program within the drawdown zone between the Gun Creek Fan and the Tyaughton Lake Road Junction will support the basis for continued natural re-colonization of native vegetation communities and species.

The sub-hypotheses are:

H3A: There is no significant difference in native vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.

H3B: There is no significant difference in the cover of native vegetation in control versus treatment locations.

H3C: There is no significant difference in native vegetation establishment and the cover of native vegetation communities (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

H3D: There is no significant difference in the species composition of naturally re-colonizing vegetation in treated versus control areas.

Year 2019 was the 7th year of the BRGMON-2 program and the 5th year of Component 2 monitoring. Year 2018 was a lag year for the BRGWORKS-1 program with no treatments, but riparian enhancement treatments were carried out again under BRGWORKS-1 in 2019. However, field monitoring for BRGMON-2 focused on sampling treatments performed under BRGWORKS-1 from 2014 through 2017 to inform the management question and null hypotheses.

As per the TOR (BC Hydro, 2017), this report contains:

9. Summary of annual reservoir inundation patterns including records from previous year and dates of BRGWORKS-1 treatments;
10. Highlights of annual treatment successes and failures;
11. Annual weather patterns, observational notes; and
12. Considerations and recommendations for adaptive management of riparian enhancement treatments and adjustments of treatments for BRGWORKS-1 for the next year (2020);

Given the lack of treatments performed in 2018, a summary of treatment methods employed in BRGWORKS-1 for 2018 is not included.

Observations of vegetation succession rates benefit from time passing; as there were no BRGWORKS-1 treatments in 2018 we looked at older treatments as well as some biomass analysis of the current (2019) BRGWORKS-1 seeding treatments. Further, we present data from dust storm monitoring and also include detailed recommendations for the implementation of the final planned year of treatments for BRGWORKS-1.

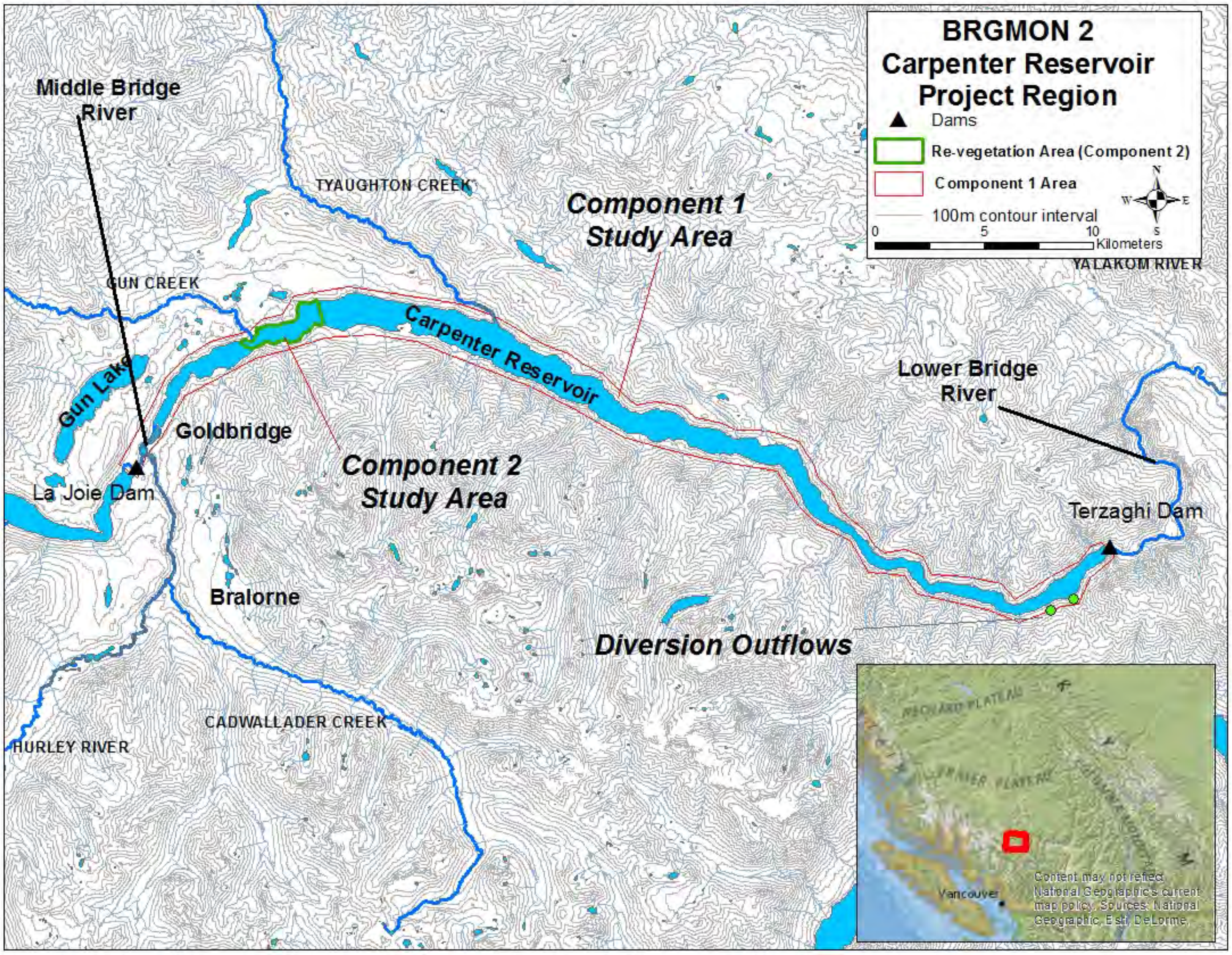
2. Background

Carpenter Reservoir is located 185 km north of Vancouver, 65km north west of Lillooet, British Columbia. Carpenter Reservoir was formed by Terazaghi Dam in the east, that floods 50 km (35%) of the total length of the Bridge River system. The study areas monitored by BRGMON-2 are shown on Map 1. The drawdown zone occupies the Interior Douglas-fir very dry cold (IDFxc) biogeoclimatic zone (formerly IDFxh2, BEC Data Base Changes version 6 2006) characterized by climax stand of Douglas-fir (*Pseudotsuga menziesii ssp. glauca*) and Ponderosa pine (*Pinus ponderosa*) on drier south facing slopes (BC Ministry of Forests, 1990).

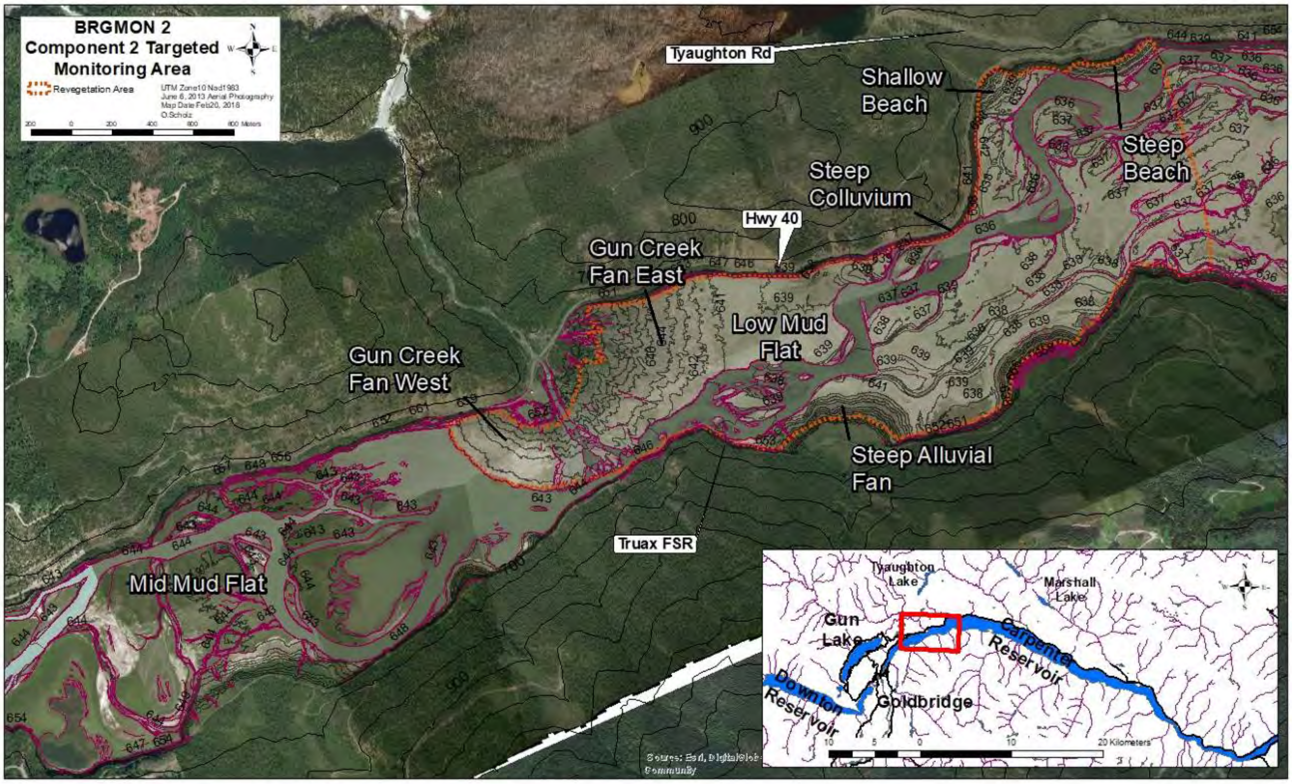
Terzaghi Dam was completed in 1960 to dam the Bridge River and form Carpenter Reservoir. The water storage levels in Carpenter Reservoir were managed to a full pool of

651.08 mASL (the absolute capacity of the reservoir) up until 2000, when water use planning committee was formed. Since 2000 water levels in Carpenter have been managed between a low of 606.55 m and a targeted maximum of 648.00 m (BC Hydro, 2011). Maintaining a 3 m zone between 648.00 m and 651.08 m was a key management target of the WUP program initiated in 2000. Any influx of water into the buffer zone is not to exceed eight weeks. Goal 1 of the BRGMON-2 program looks at the effects of maintaining the buffer zone on Carpenter Riparian vegetation. A survey in 2022 will compare data with the 2013 baseline.

The target area of BRGWORKS-1 and goal 2 of the BRGMON-2 program is located near the west end of Carpenter Reservoir (Map 2). The area within the inundation zone is comprised of shoreline and valley bottom or mud flat habitat. The mud flats extend east to Terazaghi dam and west to the edge of Gold Bridge their expanse dependant on reservoir levels at the time of year. The Gun Creek Fan, formed by historical alluvial deposits from flood events from Gun Creek, marks the western extent of the treatment area. The mud flats to the west rise from 644m just west of the Gun Creek Fan to peak full pool at Gold Bridge. The mud flats to the immediate west of the Gun Creek Fan were referred to as Mid Mud Flats terrain type (MMF) during the 2013 BRGMON-2 study (Scholz and Gibeau, 2014). MMF are fairly well vegetated by horsetails (*Equisetum* sp.), sedges (*Carex* sp.) and bluejoint reedgrass (*Calamagrostis canadensis*), as well as a mix of other herbaceous species. The area of riparian enhancement treatments extends to the junction of Tyaughton road with Hwy 40, 3.5km east of Gun Creek. The mud flats of the riparian enhancement treatment area (Low Mud Flats, LMF) are below 644 m and are sparsely vegetated by weedy annuals with much exposed mineral soil. The shoreline of the treatment area also includes a steep and shallow beach terrain on the north shore and an alluvial fan on the south shore. The 2014 report has detailed terrain type descriptions and associated vegetation assemblages (Scholz and Gibeau 2014).



Map 1. Targeted study areas for Components 1 and 2 of BRGMON-2 on the Carpenter Reservoir, British Columbia.



Map 2. Targeted monitoring area and associated terrain types on Carpenter Reservoir for Component 2 of BRGMON-2.

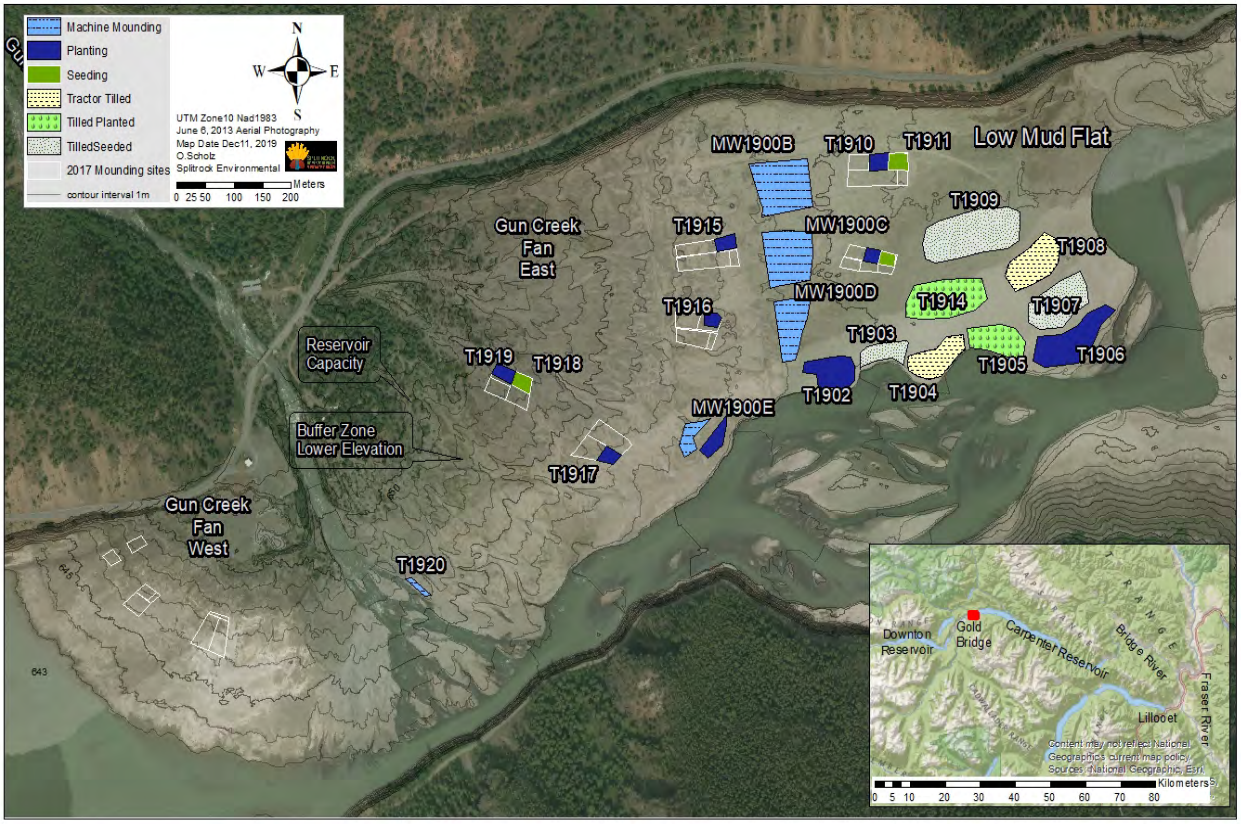
Since 2000, the pattern of the annual hydrograph for Carpenter Reservoir has seen water levels drawn down to their lowest by mid-late spring prior to freshet. Water levels then rise in late spring, and peak late summer/early fall. Water levels are then slowly drawn down over fall, winter, and early spring.

In an average year, elevations below 642 m are exposed to air for less than 50% of the growing season (Scholz and Gibeau, 2014). Based on analysis of historic drafting and inundation timing, we deem it highly unlikely that perennial native vegetation could survive below 640 m. Restoration treatments under BRGWORKS-1 have thus been completed within a 12m vertical range between 639 m and 651 m.

2.1 Update on BRGWORKS-1 Treatments

Riparian enhancement treatments for BRGWORKS-1 were implemented in 2014-2017 and 2019, and no treatments were carried out in 2018. The intention of the lag year was to allow time to assess the success of the 2017 treatments before making recommendations for the treatments under BRGWORKS-1 in 2019.

The recommendation for the 2019 treatments for BRGWORKS-1 were included in the BRGMON-2 mid-term comprehensive report (Scholz and Gibeau, 2019). Recommendations included expansion of machine-mounding treatments as well as seeding and planting. The mounding sites from 2017 had follow-up planting and seeding treatments in 2019. Seeding and planting treatments, alone and together, were implemented in 2019 across the LMF terrain only (Map 3, Table 1). The treatments for BRGWORKS-1 in 2019 were carried out before the monitoring for BRGMON-2 occurred.



Map 3. Treatments performed in polygons for BRGWORKS-1 in 2019.

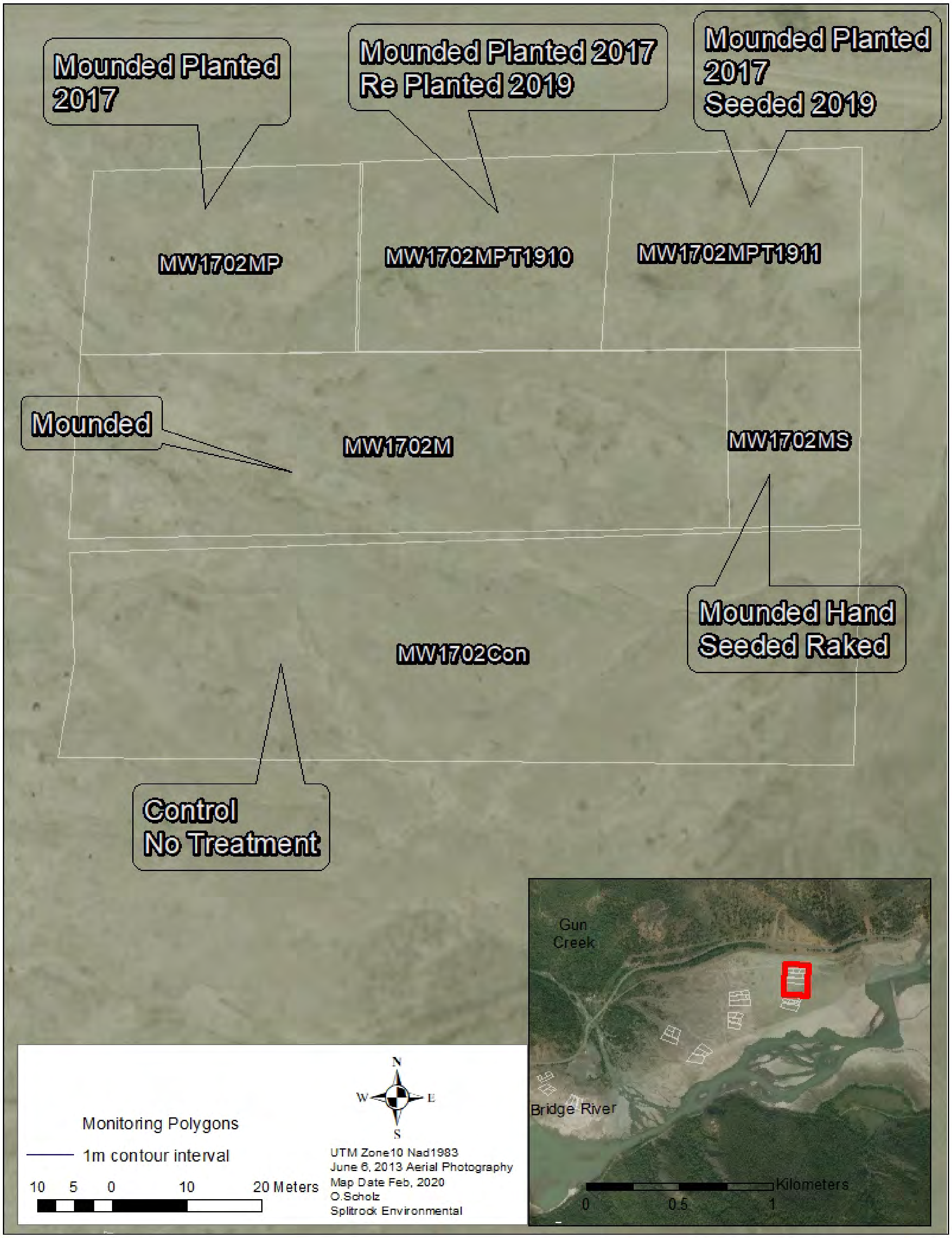
Table 1. Summary table of the treatments performed for BRGWORKS-1 in 2019. Note: Planting polygons on LMF terrain contain gaps.

Treatment	Polygons	Area (ha)
Mounding	4	2.06
Planting	9	1.55
Seeding	3	0.23
Tilling	2	0.9
Till and planting	2	1.15
Till and seed	3	1.94
Total	23	7.83

3. Methods

3.1 Field monitoring

Field monitoring was carried out in early June 2019. Nine polygons established in 2017 for BRGWORKS-1 and treated by machine-mounding were prioritized for monitoring in 2019. Control sites were also mapped and monitored in areas adjacent to the mounded polygons. Planting and seeding treatments were applied within the mounding areas as well as areas maintained with just machine treatments. These combined treatments were separated into sub-polygons for monitoring purposes (Map 4). We refer to polygons at the general level; e.g. MW1701 and sub-polygons MW1701m (mounded), MW1701mp (mounded planted), MW1701ms (mounded seeded), MW1701mpt (mounded planted and replanted 2019)). In addition, planting sites established in 2015 and 2016 that were performing relatively well in 2018 were again monitored in 2019.

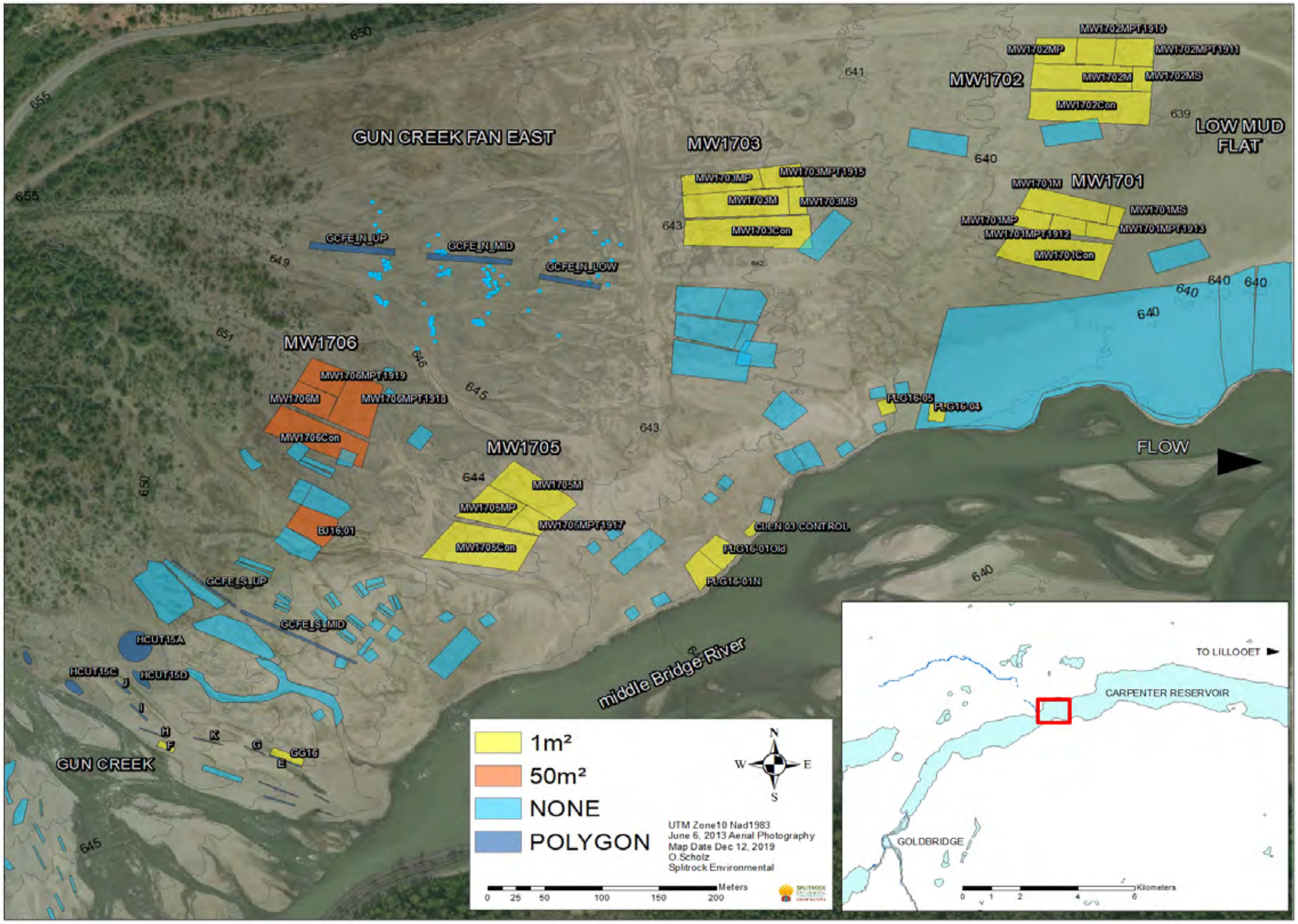


Map 4. Large-scale example of layout of polygon with treatment and control sub-polygons for monitoring.

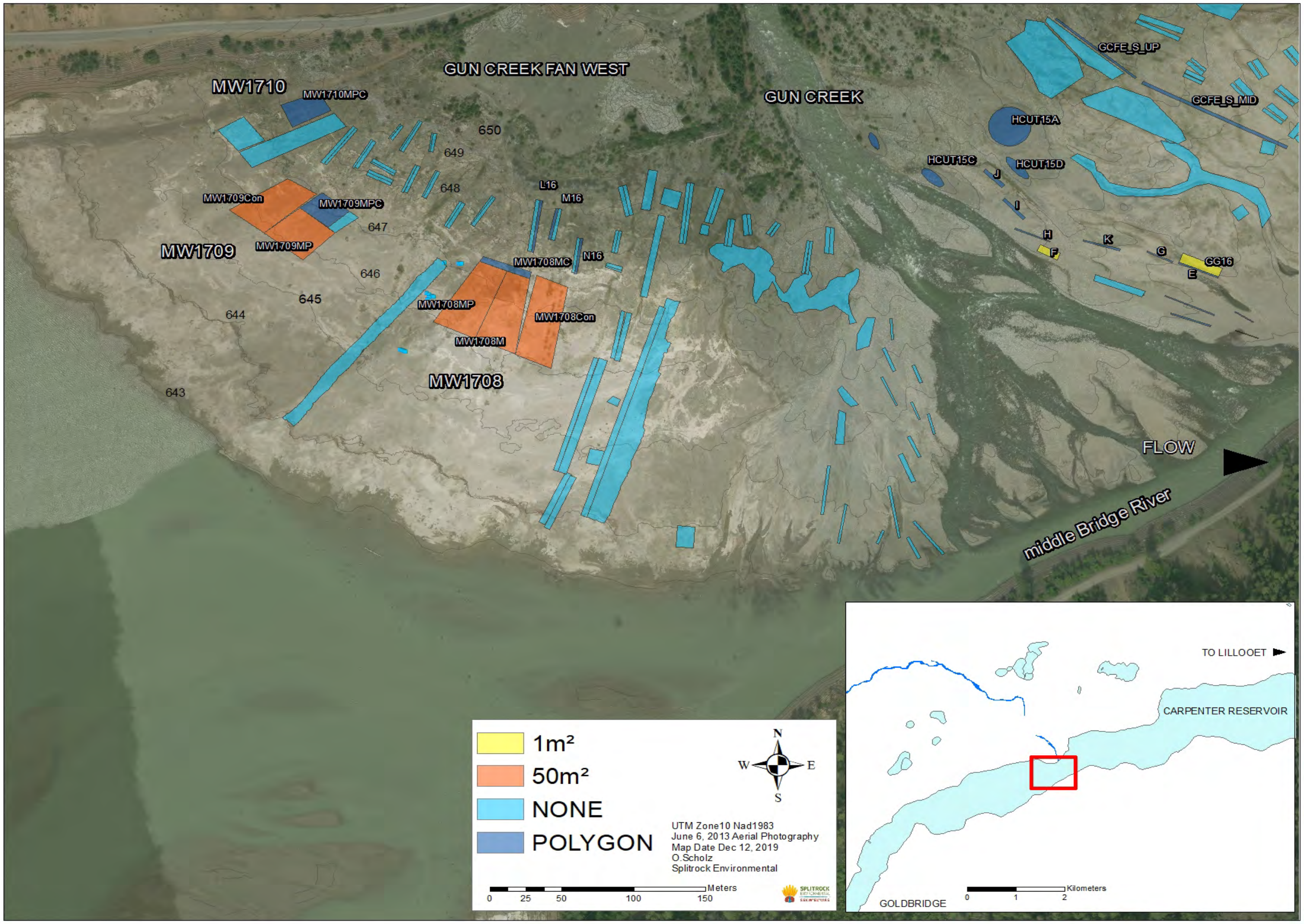
Three methods were employed to sample treated polygons (Map 5, 6, and 7):

1. Fine-scale monitoring using 1X1 m quadrats. Quadrats were placed at regular intervals along randomly placed transects run through each treatment polygon. Quadrats were used to assess site and vegetation conditions.
2. Medium-scale monitoring using 3.99 m-diameter (50 m^2) circular plots. The 50 m^2 plots were used to sample density of native plant species in addition to overall species richness.
3. Large-scale monitoring assessing polygon areas up to 0.5 hectare, including treatments of live-stake cuttings assessed for survival and vigor.

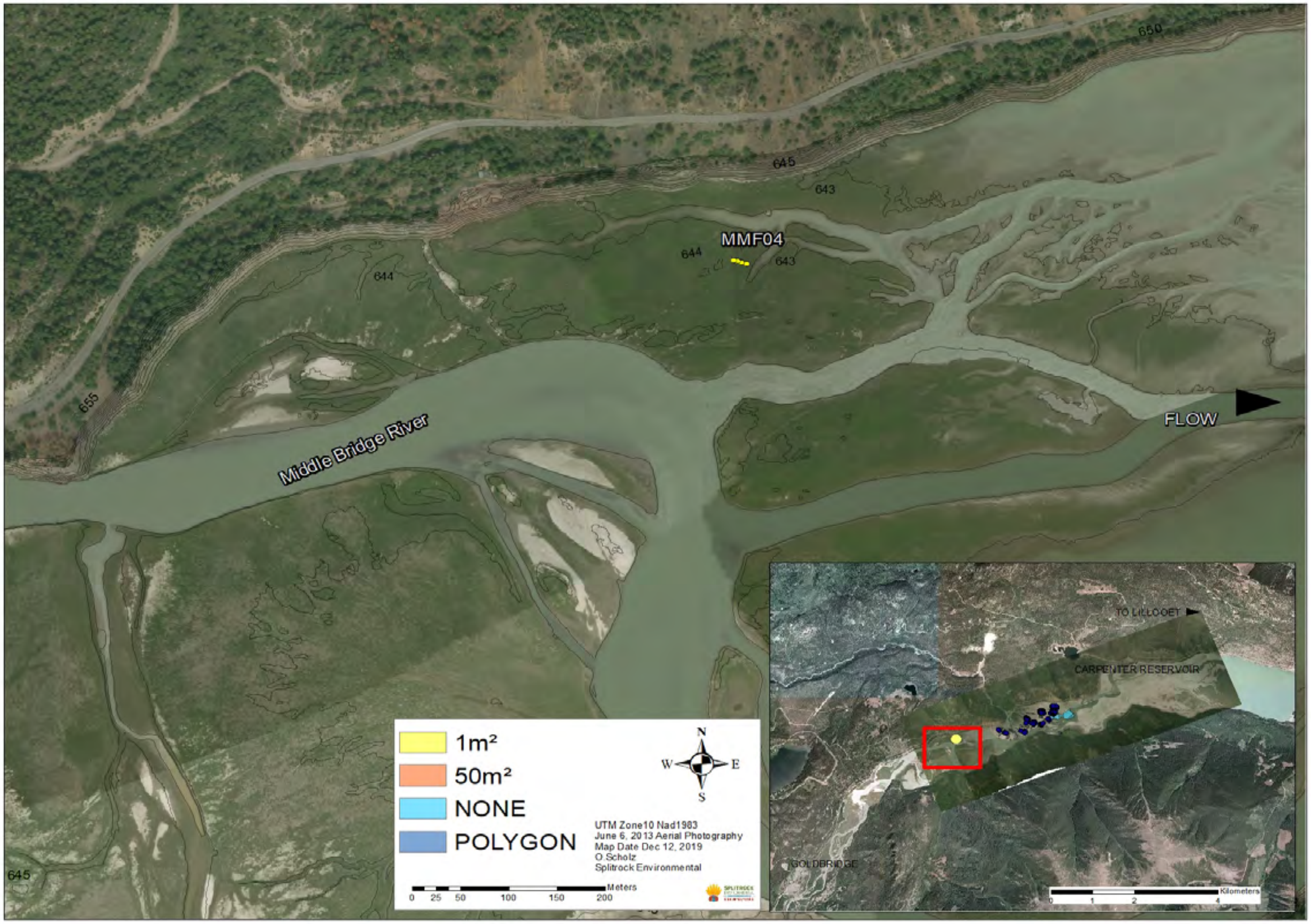
Appendix 1 contains the complete list of site, soils and vegetation data collected within quadrats and plots. Quadrat and plot data were digitally recorded in the field using data sheets created using Doforms © software. Photographs were taken for each quadrat and plot, from the overhead vertical perspectives for the 1m x 1m quadrat frame, while oblique photos were used for the 50m^2 plots. General photos were taken for large-scale monitoring. Additional attributes were added post-field work including species origin (Native vs Exotic), whether quadrat was treated or part of a control polygon, and terrain type (LMF, GCFE, GCFW). Finally, the photo-monitoring points established in 2017 for mounding and control polygons were re-photographed.



Map 5. Monitoring layout in 2019 of the polygons treated for BRGWORKS-1 in Low Mud Flat (LMF) and Gun Creek Fan East (GCFE) terrain types.



Map 6. Monitoring layout in 2019 of the polygons treated for BRGWORKS-1 Gun Creek Fan West (GCFW) terrain types.



Map 7. Location of transect MMF04 established in 2013 and monitored again in 2019 as a reference site to treated and control polygons in LMF.

The 2018 BRGMON-2 report (Scholz and Gibeau, 2019) recommended to carry out an investigation looking for variability in physical conditions within Polygon PLG16-01. The intention was to try explaining the dramatic patchiness in planted plant survival and vigor (Figure 1). In 2019, we thus stratified polygon PLG16-01 by plant vigour. The majority of the Kellogg's sedge (*Carex kelloggii*) planted in the polygon were growing well in terms of size and seed production and with excellent vigor (4), but three distinct patches within the polygon were observed with either dead (0) or poor (1) vigor. Initially, soil pits were dug to determine the soil profile and depth. We found that at fine silty soil sites that dominated the LMF, depth could be determined by using a probe and pushing it into the soil surface until it hit the coarse, compacted gravel layer. A 2mm thick, 75cm long wire stake was used to probe soil depth by pushing it into the ground until resistance was met, at which point the depth of the probe penetrated was measured. Five separate areas within PLG1601 were sampled and 10 depth readings were sampled across each area. Depth readings were plotted against site plant vigor. Measurements of soil depth were also opportunistically taken at several locations within other polygons when doing site and vegetation assessments.

Biomass sampling was carried out in 2019 for estimating standing crop and comparing between reference (MMF04), Control, and Treatment (fall rye seeding) sites. In each area sampled, clip plots were randomly placed in 1mX1m plots. All herbaceous vegetation within plot was clipped to ground level and biomass placed into paper bags. Samples of biomass were air dried and test samples were weighed after several weeks. Samples were weighed again a week later and when it was determined there was no change in sample dry weight (ie. all moisture was removed), all samples were weighed. Samples collected in 2018 at PLG1601 (site planted with Kellogg's sedge) were used conjointly with the 2019 samples in data summaries to avoid further destructive sampling in 2019.

Figure 1. Example of patchy vigor shown by planted Kellogg's sedge plugs, with poor and dead plants bounded by plants in excellent condition (polygon PLG1601, 2019).

3.2 Water levels and growing degree days

A summary of water levels for Carpenter Reservoir was based on data provided by BC Hydro Power Records. Water level data included reference to elevation of treatment polygons monitored through BRGMON-2. Data provided by the Ministry of Forests Range and Natural Resource Operations at the Fire Zone weather station located on 5-Mile ridge were used to calculate growing degree-days. The 5-Mile ridge station is within 5 km of the monitoring sites for Component 2 of BRGMON-2. Accumulated growing degree days (GDD) were computed based on the BC government range readiness approach (Fraser, 2006). Days were tabulated annually beginning on March $15^{th.}$. Base temperature, below which plant growth is impeded, was presumed to be 0°C (as in range management). GDD were calculated using formula:

[daily Max. temp (°C) + Daily Min. temp (°C)] / 2 – base temperature 0 (°C).

Computation of growing degree-days for many crop species recognize that plants do not grow any faster when temperatures are over 30°C (Rawson and Macpherson, 2000); therefore, in order to take a conservative estimate of GDD, the mean daily temperatures were filtered to cap the high temperature at 30°C. Growing degree days were presented to highlight the length and proportion of growing season experienced by vegetation at different elevations within the drawdown zone since 2014.

3.3 Statistical analyses

Species survival, cover, and frequency of occurrence (total, and for exotic and native species separated) were assessed per planting trial and terrain types with a series of figures and maps to compare between control and treatment sub-polygons. The significance of differences in cover among controls and types of treatments were assessed by using a general linear model fitted with beta regression, which allows dealing with cover data that vary between 0 and 1. A transformation was used for dealing with cases when cover was exactly 0: $Cover_t$=(Cover*(n-1)+0.5)/n, where n is the sample size (Smithson and Verkuilen 2006).

Univariate regression trees were used to explore the relationships between the cover of native species and a series of site and environmental variables across all plots and quadrats sampled. Regression trees deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values, and outliers (De'ath and Fabricius 2000). A regression tree is built by partitioning the independent variables (e.g., elevation, soil moisture) into a series of boxes (the leaves) that contain the most homogeneous groups of objects (i.e. plots/quadrats). Splits are created by seeking the threshold levels of independent variables that produce groups with highest homogeneity, by minimizing the sums of squares within groups (De'ath and Fabricius 2000). The length of the vertical lines associated with each split graphically approximate the proportion of total sum of squares explained by each split; the longer the line is, the more variance the split is explaining (De'ath and Fabricius 2000). The value shown at each terminal leaf corresponds to the average value of the dependent variable (here, cover). The method allows computing a pseudo-R2 that corresponds to the proportion of variance explained by the tree (1-the deviance of the tree / by overall sum of squares).

The variables included in the regression trees were plot size (1 or 50m2), elevation, terrain type, slope, microtopography, primary growing season water source, substrate cover per cent rock, per cent mineral soil, soil texture, nutrient regime, soil drainage, and soil moisture regime. To limit the number of categories per variable and the cases when one level only represented one or two plots/quadrats, some levels were merged per variable. For example, soil texture comprised four levels (silt, sandy loan, sand, loamy sand), while levels very poor was merged with poor for nutrient regime, and very rapid was merged with rapid for soil drainage. Treatment type was also included and represented whether a plot/quadrat belonged to control, reference, or treated (machine-worked, machine-planted, or machine-seeded) sub-polygons.

Multivariate regression trees (MRT) were also performed to look at species composition in relation to the same site and environmental variables (Legendre and Legendre 2012). The response variables were the cover of the species in the plots/quadrats. Multivariate regression trees also deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values in both dependent and independent variables, and outliers (Death and Fabricious 2000, Moisen 2008). Similarly to an univariate regression tree, a multivariate regression tree results from the recursive partitioning of the response variables into a series of boxes (the leaves) that contain the most homogeneous groups of objects (in our case, of plots/quadrats), constrained by the independent variables (De'ath 2002, Legendre and Legendre 2012). Creating the splits is constructed by seeking the threshold levels of independent variables that account for the greatest similarity among transects, and each group also corresponds to a species assemblage and its associated habitat (De'ath 2002). The amount of variation in the data explained by the tree is expressed in terms of cross-validation error (CV error), corresponding to the ratio of variation unexplained by the tree to the total variation in the dependent variables (Legendre and Legendre 2012). The trees are read from the top to the bottom. The variables that create the splits at each node are labelled with the threshold at which the splits occur. By reading the tree, one can interpret the characteristics in terms of species composition and environmental characteristics that describe the plots/quadrats that are grouped at each terminal leaf. The analysis was completed by looking for indicator species using the index *IndVal* (Dufrêne and Legendre 1997). The index is based on within-species abundance and occurrence comparisons and tested with randomization procedures (Legendre and Legendre 2012). The index *Indval* combines a species mean cover and its frequencies of occurrence in the group. It looks for species that are both necessary and sufficient (Borcard et al. 2011). Its value is maximal (i.e. 1) when the species is observed at all the plots/quadrats belonging to the same group; high values mean a combination of large mean cover within a group compared to other groups (specificity) and presence in most sites (fidelity). A table was built to summarize the information expressed by the MRT and indicator species analyses.

All analyses were performed in the R language software (version 3.5.1).

4. RESULTS

4.1 Hydrograph and growing degree days in Carpenter Reservoir

Water levels in Carpenter Reservoir have had similar drawdown patterns in terms of time and duration of low pools in 2017 to 2019 (Figure 2). Low pool occurred around the first week of May over the past three years, followed by rapid filling during freshet. Water levels in Carpenter Reservoir reached the elevation of treatments for BRGWORKS-1 (639.5m) on July 1, 2019. The hydrograph for the growing season in 2019 was similar to the 18yr average, with peak pool at 645 m for a brief period in September 2019 before drafting. Consequently, treatments above elevations of 645 m performed for BRGWORKS-1 in 2017 have not been affected by inundation (Table 2).

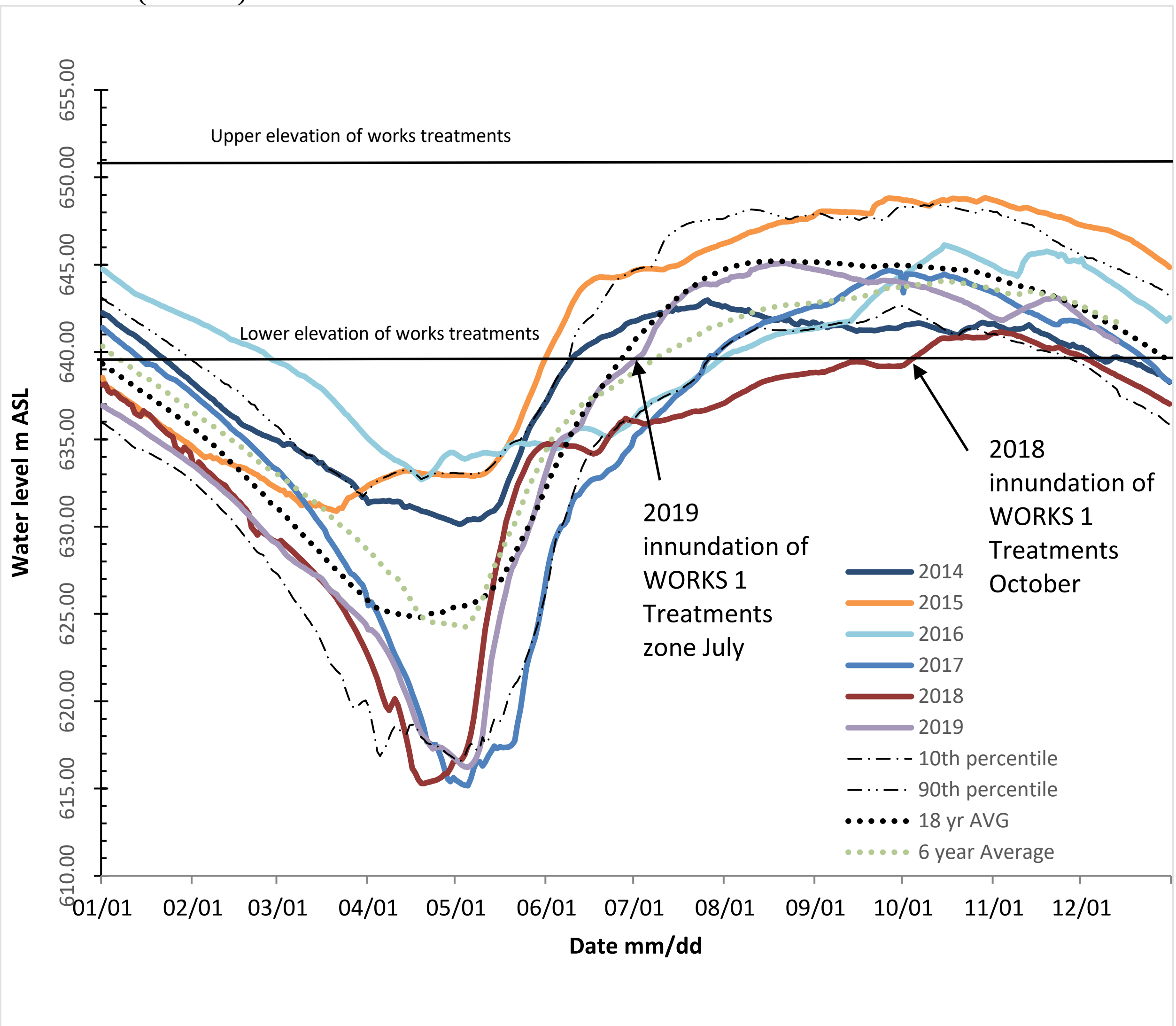


Figure 2. Hydrograph of Carpenter Reservoir from 2014 to 2019.

Table 2. Proportion of time (per cent/month) during the growing season when vegetation was exposed to air across the range of treatment elevations. Green: little to no effect of inundation on vegetation, yellow: moderate impact, red: high impact of inundation on vegetation due to inundation period > 50 per cent of growing degree days that month.

MONTH		Low (LMF)					Mid Drawdown		Upper Drawdown		Buffer		
		639	640	641	642	643	644	645	646	647	648	649	650
March	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	100	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
April	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	100	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
May	2014	100	100	100	100	100	100	100	100	100	100	100	100
	2015	23.68	100	100	100	100	100	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
June	2014	28.35	30.59	35.4	100	100	100	100	100	100	100	100	100
	2015	0	25.24	26.86	28.95	30.84	33.48	100	100	100	100	100	100
	2016	100	100	100	100	100	100	100	100	100	100	100	100
	2017	100	100	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	100	100	100	100	100	100	100	100	100	100	100	100
July	2014	0	0	0	41.9	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	53.55	60.3	100	100	100	100
	2016	58.9	100	100	100	100	100	100	100	100	100	100	100
	2017	43.1	62.5	100	100	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	13	22	32	51	97	100	100	100	100	100	100
Aug	2014	0	0	0	50.7	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	70.6	100	100	100
	2016	0	64	74.3	100	100	100	100	100	100	100	100	100
	2017	0	0	67.5	75.6	100	100	100	100	100	100	100	100
	2018	100	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	0	71	100	100	100	100	100
Sept	2014	0	0	0	65.1	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	81.43	100	100
	2016	0	0	0	88.4	90.3	93.4	100	100	100	100	100	100
	2017	0	0	0	0	86.75	90.19	100	100	100	100	100	100
	2018	89	100	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	0	30	100	100	100	100	100	100
Oct	2014	0	0	0	73.7	100	100	100	100	100	100	100	100
	2015	0	0	0	0	0	0	0	0	0	0	100	100
	2016	0	0	0	0	0	0	95.8	97.1	100	100	100	100
	2017	0	0	0	0	0	94.7	100	100	100	100	100	100
	2018	0	96.4	100	100	100	100	100	100	100	100	100	100
	2019	0	0	0	0	35	100	100	100	100	100	100	100

4.2 Treatments in Low Mud Flat (LMF; polygons MW1701, MW1702)

Polygons situated on the Low Mud Flat (LMF) terrain have similar elevations and substrate conditions, lending them well to grouped comparisons. Mounding treatment polygons MW1701 and MW1702 are very similarly situated (Map 5), and were both established and treated in 2017 with some sub-polygons treated again in 2019. One difference between the two polygons was that mounds created in MW1702 in 2017 tended to be larger than in MW1701, and MW1701 had more consistent-sized mounds. Both polygons were fully inundated in 2017 and 2019, and partially affected by inundation in October 2018.

4.2.1 Changes in polygon MW1701

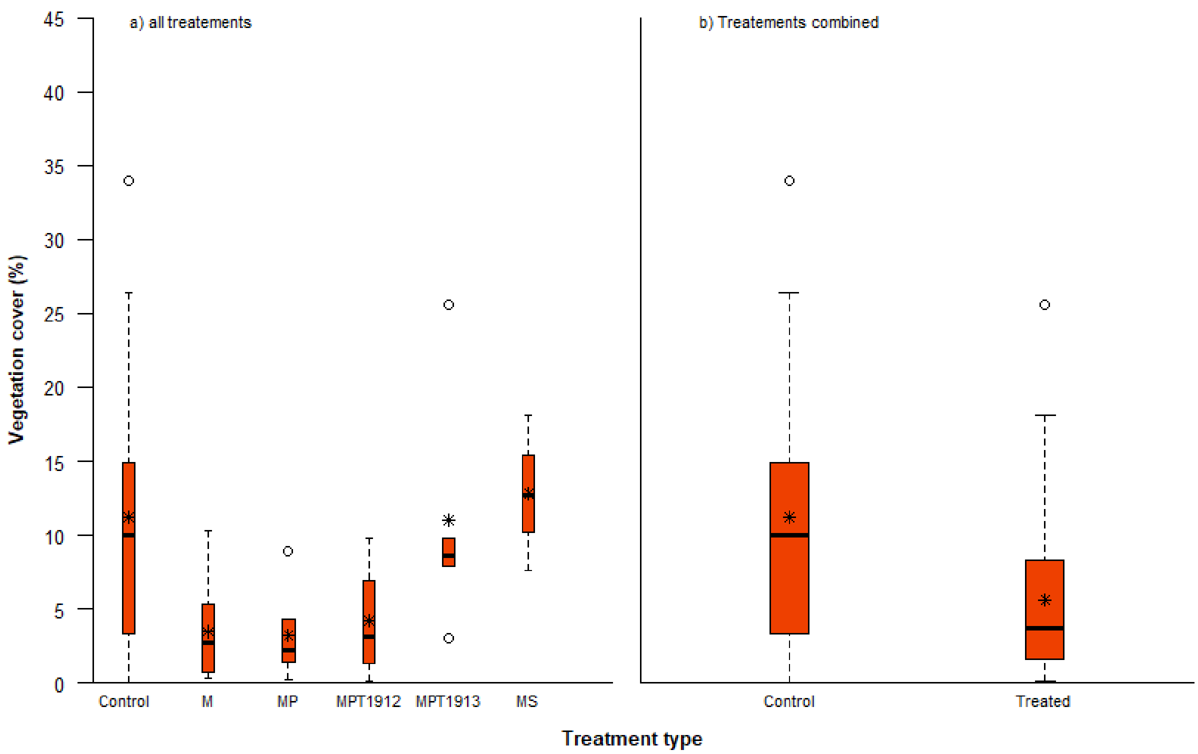


Figure 3. Cover of vegetation (total, %) per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in polygon MW1701 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

Total cover of vegetation was, on average, higher in the control quadrats of polygon MW1701, as well as in quadrats of MW1701MPT1913 and machine-work/seeded quadrats (Figure 3.a). Those differences between the treatments and the control were however not found significant (beta regression GLM, $p>0.05$), likely because of the large variation in total cover per quadrat within the controls. Total cover of vegetation was on average marginally higher in control quadrats of polygon MW1701 as opposed to the treated quadrats with all treatments combined, though there was large variation among sub- (Figure 3.b). Differences between all treatments combined and the controls were not found significant either (beta regression GLM, $p>0.05$). We can infer based on vegetation cover that, two years post-mounding, treated sub-polygons have generally recovered to plant cover levels similar to the controls. However, cover of vegetation remains low in both treatment and control, at usually 10% or less. A notable outlier quadrat with cover values over 20 % occurred in the quadrat control where there was a dense patch of weedy exotic annual lamb's quarters (*Chenopodium album*). In MPT1913, a dense patch of the weedy exotic annual sand spurry (*Spergularia rubra*) also raised cover of vegetation. Overall, cover of exotic species was much higher than that of native species, in both control and treated polygons (Figure 4).

Increasing the diversity and cover of native species is a goal of the BRGWORKS program. Cover of native species was significantly lower than that of exotics in the control and treatment sub-polygons (all types of quadrats combined, $Z=-5.9$, $p=0$). Although very low (<5%) cover of native species was significantly higher in treatment sub-polygons machine-work (M, $Z=1.8$, $p=0.07$) and MPT1913 ($Z=2.95$, $p=0.003$) and overall for all treated quadrats combined ($Z=2.15$, $p=0.0318$) than in control quadrats. We can infer from this result that mounding treatments is having some positive effect on native species occurrence.

Species richness was higher in MW1701 treatment sub-polygons (n=19 species in 33 quadrats) relative to the control sub-polygon (n=9 species in 12 quadrats) (Table 3). The majority of the species found in treatment sub-polygons are exotic, weedy annuals. Two perennial exotic grasses Timothy (*Phleum pratense*) and quack grass (*Elytrigia repens*) were found only in the control sub-polygon, while two native species were observed only in the control sub-polygon (marsh yellow cress (*Rorippa palustris*) and Douglas-fir seedlings). Native species found only in treatment sub-polygons were Kellogg's sedge, and black cottonwood (*Populous balsamifera ssp. trichocarpa*) both the result of planting[1]. Kellogg's sedge occurred in treated 19 quadrats (57%). Three of these occurrences (9%) were natural colonizing seedlings, while two quadrats were seedlings in seeded area (6%) and the other 14 occurrences were planted plugs (47%). It was observed that Kellogg's sedge plants from both 2017 and 2019 plantings were doing well with many plants heavy with seeds. It was also observed that very few sedges survived atop of the mounds where extruded plugs were common.

[1] Cottonwoods were incidental plantings as 'hitchhikers' on sedge plugs.

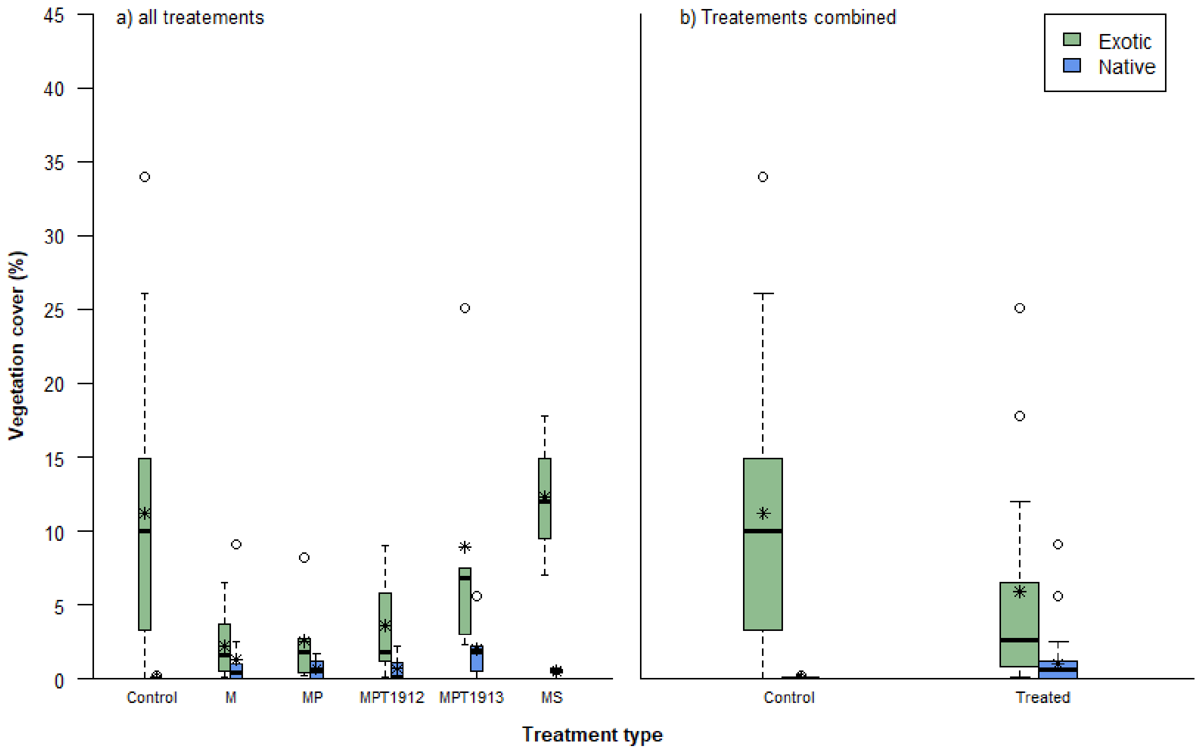


Figure 4. Cover of vegetation (%) of exotic and native species per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in polygon MW1701 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

Compared with the controls in polygon MW1701, the species composition in the treatment sub-polygons had a higher percentage of native species, led by naturally-recruited marsh yellow cress and planted Kellogg's sedge. A sub-polygon-wide search of the control revealed three additional species that did not occur in small quadrat sampling: marsh horsetail (*Equisetum palustre)*, white sweet clover (*Melilotus alba*) and curly dock (*Rumex crispus*). Two of these detections are exotic species commonly found in mid elevations (>644m) of the drawdown zone. The native perennial marsh horsetail was part of a small (<10m²) sparse patch naturally colonizing at the north east edge of the control polygon. The horsetail patch predated mounding treatments and extended to the south east corner of adjacent machine-seeded treatments in MW1701.

Table 3. Summary of species found in control and treatments sub-polygons of MW1701 (1X1m quadrats; T=trace <0.01%).

Species	Origin	Control (n=12)			Treatments (combined, n=33)		
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	% Comp
Rorippa palustris	Native	0.025	25	T	0.73	58	13
Pseudotsuga menziesii		0.0002	33	T	0	0	T
Amsinckia lycopsoides		0.000008	8	T	0.04	24	T
Carex kelloggii[2]		0	0	0	0.29	55	5
Populus balsamifera[1,2]		0	0	0	0.0015	6	0.03
Equisetum palustre		0	0	0	0.00003	3	0
Epilobium latifolium		0	0	0	0.006	3	0.1
Chenopodium album	Exotic	7.2	83	64	0.6	85	11
Spergularia rubra		3.8	100	34	2.1	94	39
Polygonum aviculare		0.2	100	1.5	1.4	100	25
Persicaria maculosa		0.010	58	T	0.12	33	2
Poa compressa		0.0001	50	T	0.12	52	2
Matricaria discoidea		0.00002	17	T	0.00	12	T
Elytrigia repens		0	0	0	0.003	3	0.06
Melilotus alba		0	0	0	0.0055	12	0.1
Sisymbrium altissimum		0	0	0	0.010	27	0.2
Trifolium repens		0	0	0	0.045	3	0.8
Capsalla bursa		0	0	0	0.003	3	0.06
Phleum pratense		0	0	0	0.006	3	0.1
Draba sp.	Unknown	0	0	0	0.000009	6	0
Total richness		9			19		

[1]In Low Shrub layer, planted
[2]At least some of those individuals were planted

Three juvenile Western terrestrial garter snakes (*Thamnophis elegans vagrans*) were observed within sub-polygon MW1701MPT1913 and one in MW1701MPT1912.

4.2.2 Changes in polygon MW1702

Polygon MW1702 was similar in elevation (640m +/- 2m) to MW1701, but mounding treatments were slightly larger in scale. Sub-polygons were either planted, seeded or replanted.

Total vegetation cover was low in both control and treatment sub-polygons of MW1702, averaging <12% (Figure 5.a). Total cover of vegetation was on average marginally higher in quadrats of MW1702MPT1911 as opposed to the control quadrats or quadrats of other treatments (Figure 5.a). Total vegetation cover in treatments of machine-work (Z=3.2, 0.0015), machine-work/planted (Z=4.2, =0.00003), MPT1911 (Z=4.9, p=0.0000008), and machine-work/seeded (Z=3.6, p=0.0003) was statistically higher than the controls. Total cover of vegetation was also higher than control when all treatments were combined (Figure 5.b) (Z=3.8, p=0.0001). Though cover values were very low, we may infer two years post-treatment that vegetation cover in treated sub-polygons of MW1702 has recovered and now generally exceeds that of the control sub-polygon.

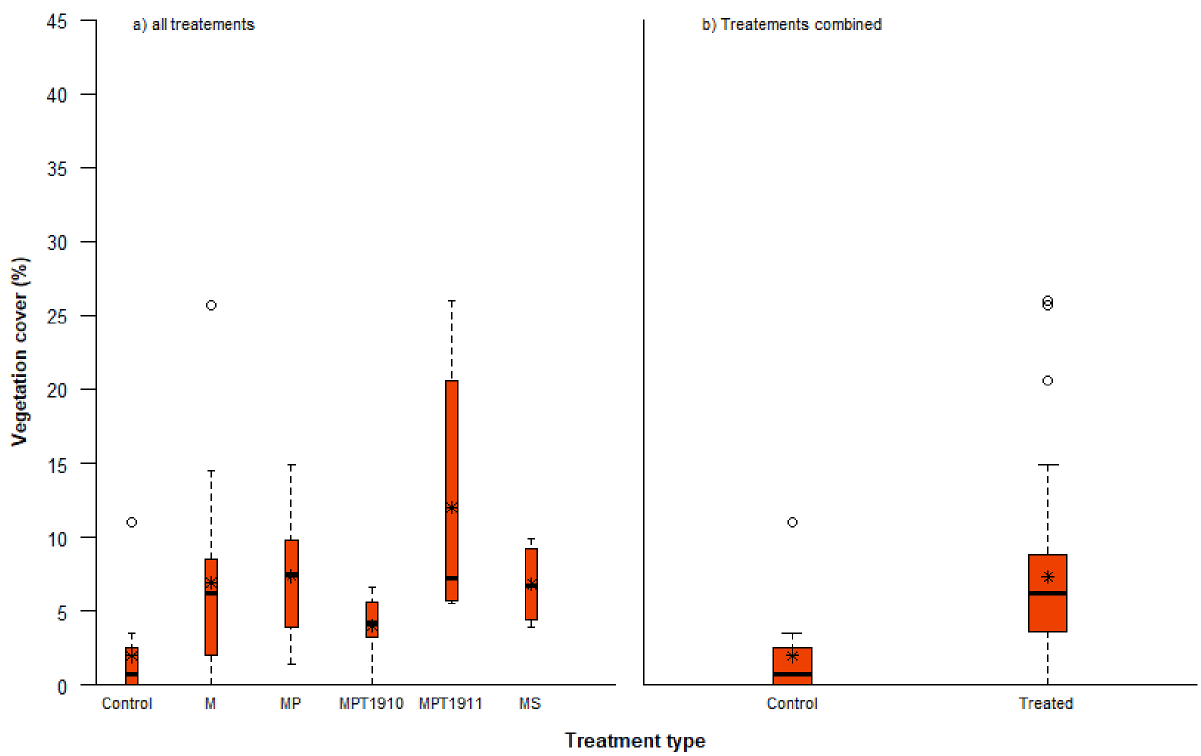


Figure 5. Cover of vegetation (total, %) per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in polygon MW1702 in 2019. The median is

represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

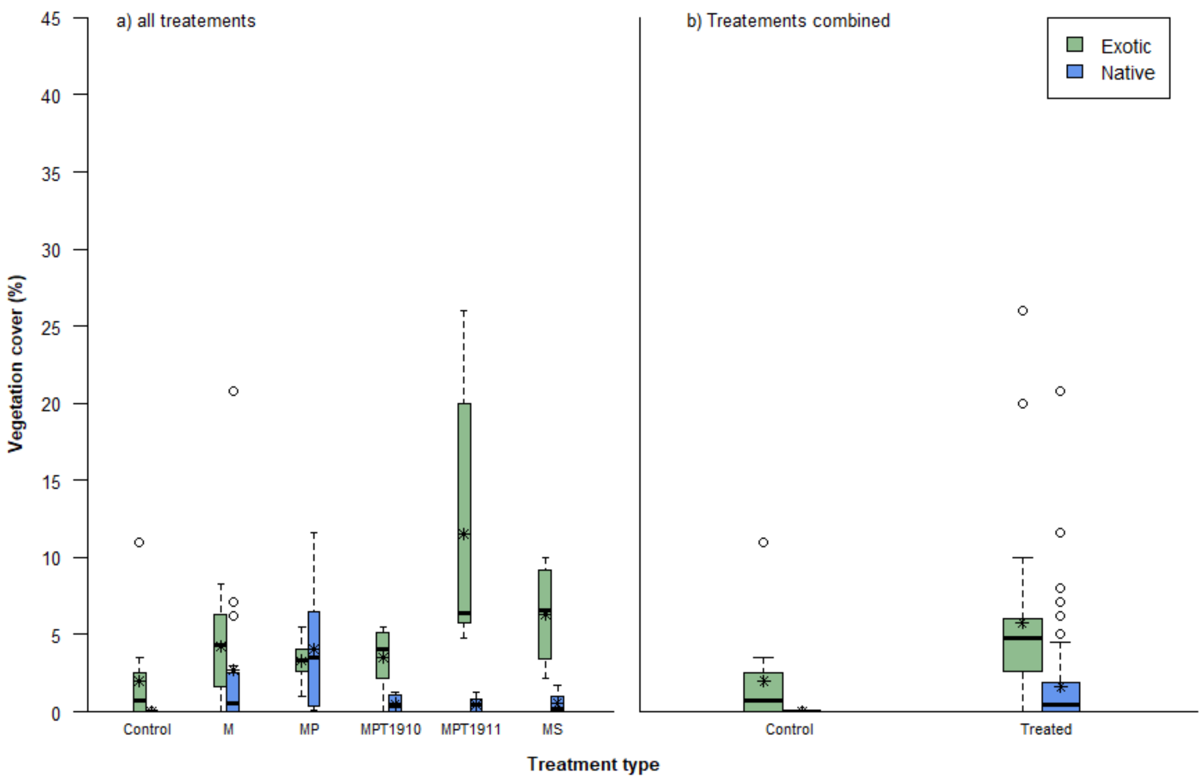


Figure 6. Cover of vegetation (%) of exotic and native species per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in polygon MW1702 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

High densities of commonly occurring, exotic, annual species were responsible for higher cover values in sub-polygon MPT1911. Native species cover was higher in machine-work and machine-work/planted quadrats (Figure 6.a). The annual bugloss fiddleneck (*Amsinckia lycopsoides)*, annual/biennial species marsh yellow cress, and planted, perennial Kellogg's sedge provided the bulk of the higher cover by native species. Overall, native species cover was significantly lower than that of exotic species (all quadrats combined, Z=-4.2, p=0.00003). Though the cover values are low, native species cover in treatment sub-polygons (all treatments combined) has equaled or surpassed total vegetation cover in the control quadrats. Cover of native species was significantly higher in treatment sub-polygons machine-work/planted (MP, Z=2.65, p=0.008) than in control quadrats but not for all treated quadrats combined (p>0.05). Plugs of planted Kellogg's sedge account for most occurrences of native species. An additional 10 native species were detected in treatment sub-polygons of MW1702 as compared to the control (Table 4).

Table 4. Summary of species found in control and treatments sub-polygons of MW1702 (1X1m quadrats; T=trace <0.01%).

Species	Origin	Control (n=10) Cover (Ave, %)	Control Frequency per polygon (%)	Control (%) Comp	Treatments (combined, n=40) Cover (Ave, %)	Treatments Frequency per polygon (%)	Treatments (%) Comp
Epilobium ciliatum	Native	0.0002	20	T	0.0004	25	T
Plagiobothrys scouleri	Native	0.0002	20	T	0.00001	5	T
Amsinckia lycopsoides	Native	0.0001	40	T	0.6	92.5	8
Pseudotsuga menziesii[1]	Native	0.00001	10	T	0.0003	7.5	T
Carex kelloggii[2]	Native	0	0	0	0.5	27.5	7
Carex microptera	Native	0	0	0	0.006	5	T
Erysimum cheiranthoides	Native	0	0	0	0.0025	7.5	T
Hordeum jubatum	Native	0	0	0	0.49	40	7
Rorippa palustris	Native	0	0	0	0.32	35	4.5
Populus balsamifera[2]	Native	0	0	0	0.000025	2.5	T
Poa palustris	Native	0	0	0	0.0015	7.5	T
Lotus denticulatus[2]	Native	0	0	0	0.00025	5	T
Prunus virginiana	Native	0	0	0	0.0013	2.5	T
Spergularia rubra	Exotic	1.7	90	86	1.12	60	16
Polygonum aviculare	Exotic	0.24	100	12	2.8	100	39.5
Chenopodium album	Exotic	0.025	70		0.58	92.5	8
Poa compressa	Exotic	0.01	30	T	0	0	0
Persicaria maculosa	Exotic	0.01	10	T	0.27	72.5	4
Matricaria discoidea	Exotic	0.00003	30	T	0.028	30	T
Sisymbrium altissimum	Exotic	0.00002	20	T	0.17	25	2
Trifolium pratense	Exotic	0	0	0	0.0001	2.5	T
Trifolium repens	Exotic	0	0	0	0.23	12.5	3
Total richness			11			21	

[1]In moss layer
[2]At least some of those individuals were planted

Three species (Kellogg's sedge, black cottonwood, meadow bird's-foot trefoil (*Lotus denticulatus*)) were directly introduced through treatments of both planting and seeding. Other ecologically significant perennial, native colonizers were fowl bluegrass (*Poa palustris*), small-winged sedge (*Carex microptera*), and foxtail barley (*Hordeum jubatum*). The single occurrence of choke cherry (*Prunus virginiana*) is an ephemeral colonizer with low survival potential, as are the Douglas-fir seedlings.

4.2.3 Changes in polygons MW1701 and MW1702 (combined)

Physical conditions and geographic locations were comparable for polygons MW1701 and MW1702, and data from all quadrats sampled across all treatments were grouped for comparison with the controls (MW1702MPT1912, MW1701MPT1913, MW1702MPT1910, MW1702MPT1911 were all included in the MP treatment). Substrates in both polygons are principally fine silty, lacustrine deposits located at elevations between 639.5 and 641m, with similar aspects (see Appendix for photos of the sites).

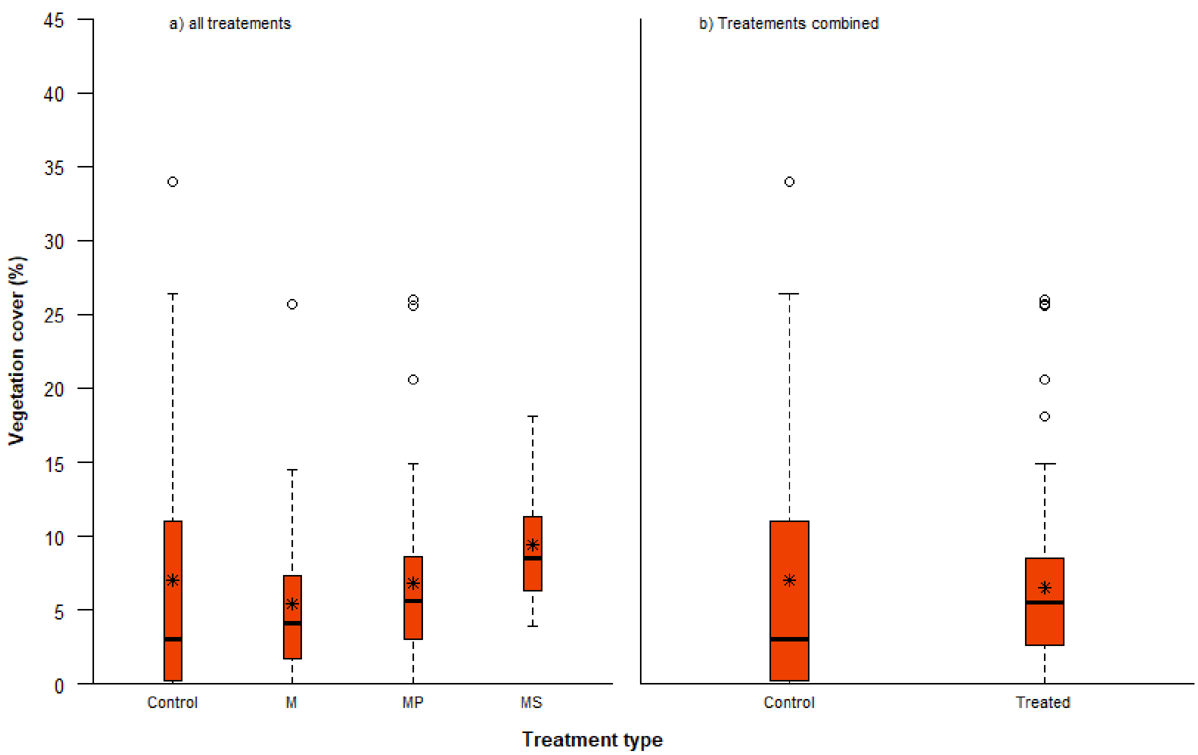


Figure 7. Cover of vegetation (total, %) per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in MW1701 and MW1702 polygon in 2019.

Total vegetation cover in quadrats that were machine-work/seeded (MS) in polygons MW1701 and MW1702 was higher on average than in the other treatments or in control quadrats (Figure 7.a). Unique to each of these polygons was that the ground was raked after seeding. Since seeded sedges provide minimal contribution to the cover values, it is possible that raking activity may have increased colonization by exotic annuals. Values were not high enough to yield a significant difference. Total vegetation cover was also slightly higher in the treated quadrats (all treatment types combined) as compared to the controls (Figure 7.b). Cover in the machine-work quadrats (Z=2.04, p=0.041), the machine-work/planted quadrats (Z=3.2, p=0.0015), and machine-work/seeded quadrats (Z=3.6, p=0.0003) were significantly higher than in the control quadrats; treated quadrats (all treatments combined) also had significantly higher cover of vegetation than in control quadrats (Z=3.1, p=0.0017). We conclude again that two years post-treatment, the vegetation cover in the treated sub-polygons has recovered to equal or exceed that in the control sub-polygon, though cover values remain low.

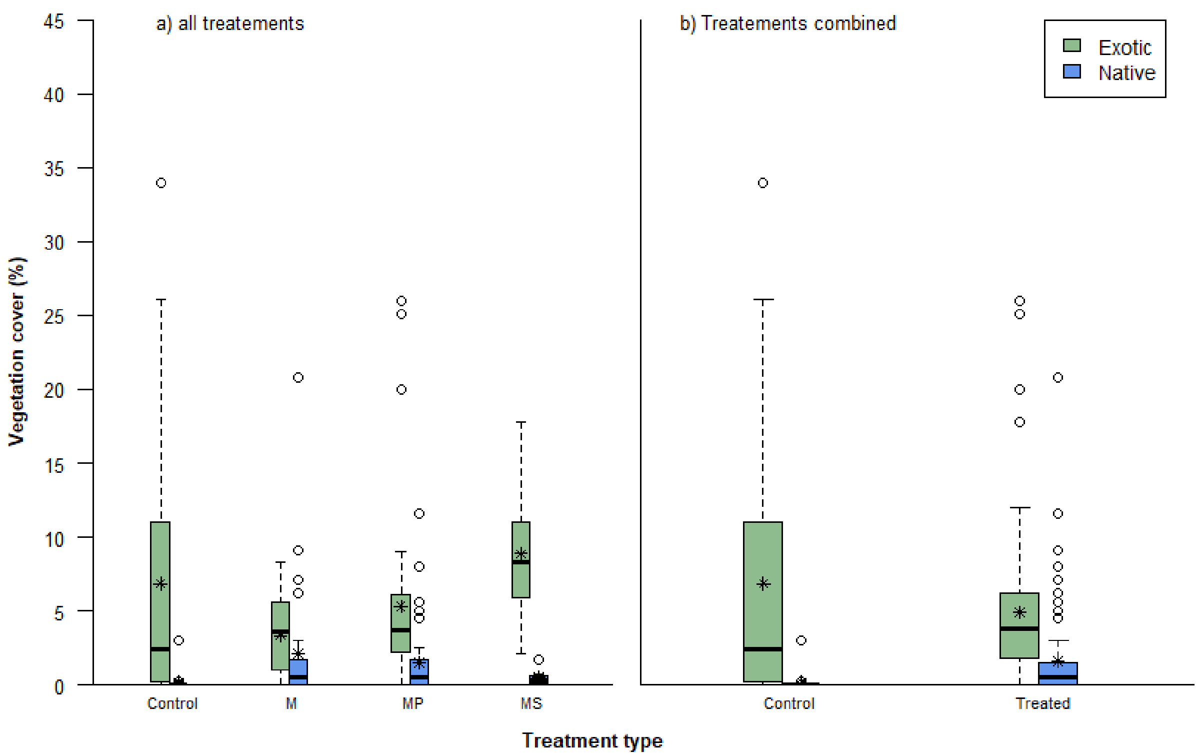


Figure 8. Cover of exotic and native species (%) per quadrat sampled in a) controls and each treatment type, and b) all treated quadrats combined in MW1702 polygon in 2019.

Cover of native species was lower than that of exotic species (Figure 8) (all quadrats combined, Z=-6, p=0). Native species cover was negligible in control sub-polygon but more measurable in the treated sub-polygons (Figure 8). Differences in native species cover were statistically significant for machine-work (Z=2.1, p=0.036) and machine-work/planted quadrats (Z=2.3, p=0.02) as compared to control quadrats. Cover of native species was significantly higher in treated quadrats (all treatment combined) than control quadrats (Z=2.4, p=0.02).

Species richness was higher in treatment vs control quadrats, with over twice the number of species observed in treatment quadrats (note however that more than three times more quadrats were sampled in the treated sub-polygons; Table 5). Notable increases in richness of native species were observed in treatment sub-polygons, attributable in part to planting and seeding of Kellogg's sedge, black cottonwood, meadow birds-foot trefoil, as well as some natural recruitment of small winged sedge (*Carex microptera*), foxtail barley, and broad-leaved willowherb (*Epilobium latifolium*). Also, we observed seedings from upland species Douglas-fir and choke cherry that will likely not survive inundation. Finally, interestingly, cottonwood saplings > 1 year old were observed in 2019, meaning that they survived through the inundations of 2017 and 2018.

Table 5. Summary of species found in control and treatments sub-polygons of MW1701 and MW1702 combined (1X1m quadrats; T=trace <0.01%).

Species	Origin	Control (n=22) Cover (Ave, %)	Control Frequency per polygon (%)	Control % Comp	Treatments (combined, n=73) Cover (Ave, %)	Treatments Frequency per polygon (%)	Treatments % Comp
Amsinckia lycopsoides	Native	0.00006	23	T	0.44	52	7
Plagiobothrys scouleri	Native	0.0001	9	T	0.00001	3	T
Pseudotsuga menziesii	Native	0.0001	23	T	0.0001	4	T
Rorippa palustris	Native	0.014	14	T	0.49	44	7.5
Epilobium ciliatum	Native	0.14	14	2	0.0002	14	T
Amsinckia lycopsoides	Native	0	0	0	0.014	1	T
Carex kelloggii	Native	0	0	0	0.4	40	6
Carex microptera	Native	0	0	0	0.003	3	T
Erysimum cheiranthoides	Native	0	0	0	0.0014	4	T
Hordeum jubatum	Native	0	0	0	0.27	22	4
Equisetum palustre	Native	0	0	0	0.00001	1	T
Lotus denticulatus	Native	0	0	0	0.0001	3	T
Populus trichocarpa	Native	0	0	0	0.0007	3	T
Populus trichocarpa	Native	0	0	0	0.00001	1	T
Epilobium latifolium	Native	0	0	0	0.0027	1	T
Prunus virginiana	Native	0	0	0	0.0007	1	T
Poa palustris	Native	0	0	0	0.0008	4	T
Sisymbrium altissimum	Exotic	0.00001	9	T	0.10	26	1.5

Matricaria discoidea		0.00002	23	T	0.06	23	T
Poa compressa		0.005	41	T	0.05	23	T
Persicaria maculosa		0.010	36	T	0.2	55	3
Polygonum aviculare		0.20	100	3	2.2	99	33
Spergularia rubra		2.7	91	39	1.6	75	24
Chenopodium album		3.9	77	56	0.6	89	9
Elytrigia repens		0	0	0	0.001	1	T
Melilotus alba		0	0	0	0.0025	5	T
Trifolium pratense		0	0	0	0.00005	1	T
Trifolium repens		0	0	0	0.15	8	2.
Capsella bursa-pastoris		0	0	0	0.001	1	T
Phleum pratense		0	0	0	0.003	1	T
Draba sp.	unknown	0	0	0	0.00000	3	T
Total richness		12			29		

[1]In low shrub layer, [2]in moss layer

4.3 Biotic and physical observations on polygons PLG1601, PLG1604, PLG1605, and CLEN-03

The polygons PLG1601, PLG1604 and PLG1605 as well as CLEN-03 are located on the Low Mud Flat (LMF) terrain close to the Bridge River channel, at 641-642 m (Map 5). Treatment polygons were evenly planted with plugs of Kellogg's sedge in 2016 (approximately 4-6 plants per m^2). Polygon PLG1604 was also seeded with fall rye prior to being planted with sedge plugs.

Cover of total vegetation was slightly higher in the control polygon CLEN-03 than in the treated polygons, individually or combined (Figure 9). Total vegetation cover in polygon PLG16-01 was significantly lower than in the control (Z=-3.15, p=0.0017), but only barely for PLG16-04 (Z=-1.9, p=0.055) and PLG16-05 (Z=-1.9, p=0.055) (Figure 9). When all PLG16 polygons were combined, the total cover of vegetation was significantly lower than in the controls (Z=-2.6, p=0.0093).

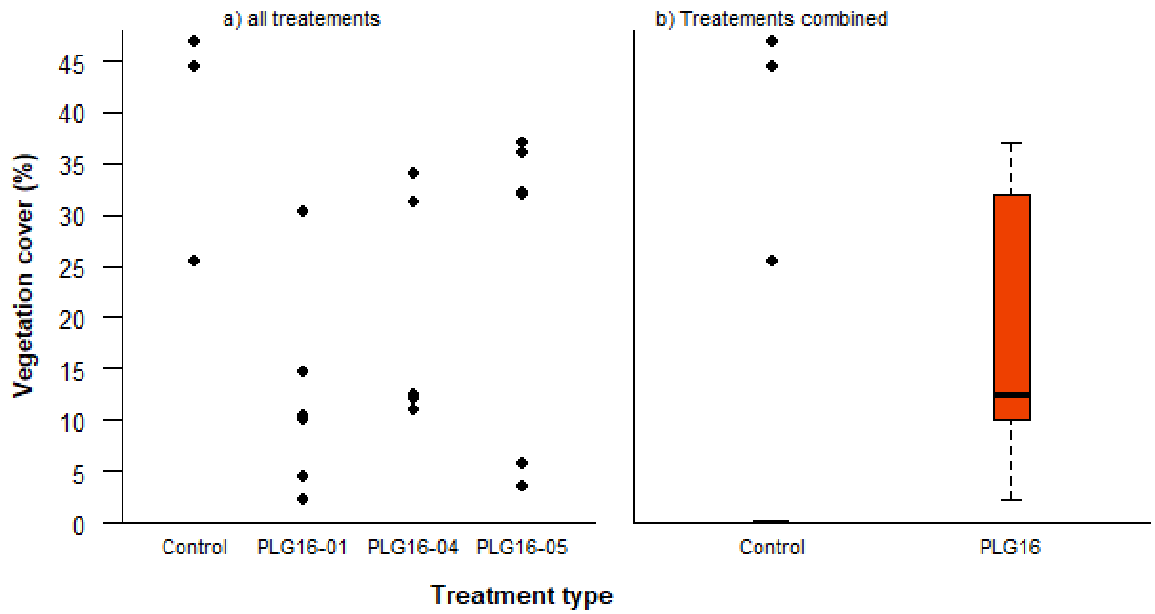


Figure 9. Cover of vegetation (total, %) per quadrat sampled in a) controls and individual PLG16 polygons, and b) all PLG16 polygons combined in 2019. Quadrats were 1 m2.

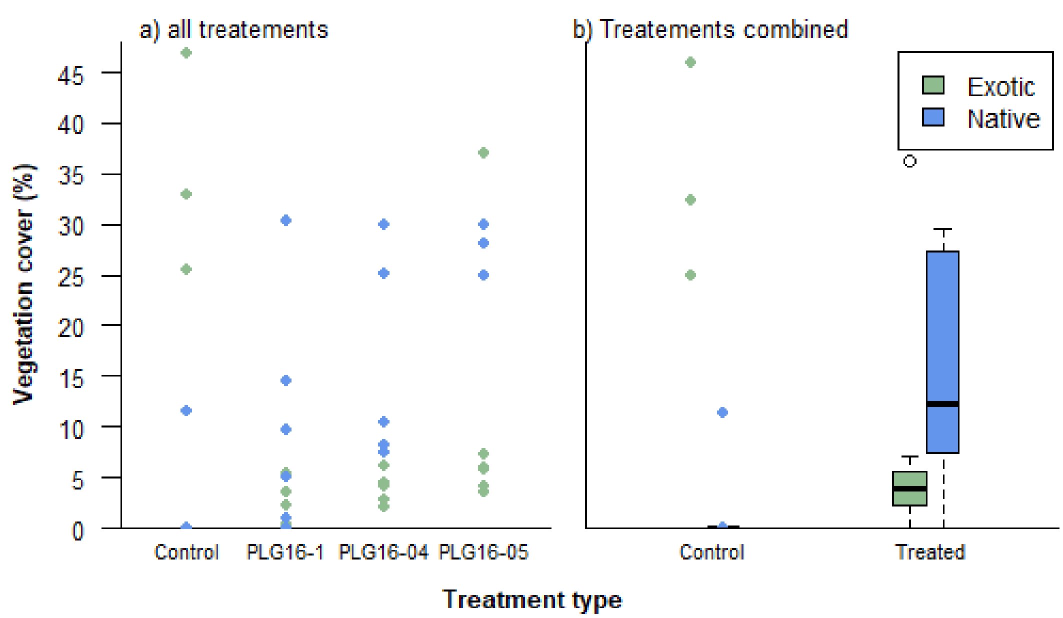


Figure 10. Cover of vegetation (%) of exotic and native species per quadrat sampled in a) controls and individual PLG16 polygons, and b) all PLG16 polygons combined in 2019.

Exotic species dominated the cover of vegetation in Control quadrats, while planted native species dominated the vegetation cover in treatment quadrats (Figure 10). Cover of native species was barely significantly higher in polygon PLG16-04 (Z=1.7, p=0.0.08) as compared to the control (i.e. polygon CLEN-03). Cover of native species in all PLG16 quadrats combined was significantly higher than that of controls (Z=2.8, p=0.00465). Annual exotic sand spurry comprised most of the vegetation cover in Control quadrats (Table 7). Planted native perennial Kellogg's sedge was the dominant vegetation cover in treatment polygons (Table 6). Native species cover exceeded cover of exotic species within all treatment polygons. Planted Kellogg's sedge occurred in all quadrats sampled in the PLG1604 polygon. In addition, thousands of self-seeded seedlings, both first- and second-year seedlings, were observed in PLG16-01.

Table 6. Summary of species found in treated polygons PLG16-01, PLG16-04, and PLG16-05 (1X1m quadrats; T=trace <0.01%).

Species	Origin	PLG16-1 (n=6) Cover (Ave, %)	PLG16-1 (n=6) Frequency per polygon (%)	PLG16-1 (n=6) % Comp	PLG16-04 (n=5) Cover (Ave, %)	PLG16-04 (n=5) Frequency per polygon (%)	PLG16-04 (n=5) % Comp	PLG16-05 (n=6) Cover (Ave, %)	PLG16-05 (n=6) Frequency per polygon (%)	PLG16-05 (n=6) % Comp
Calamagrostis canadensis	Native	0.00	0	0	0	0	0	0	0	0
Equisetum arvense		0.00	0	0	0	0	0	0	0	0
Hordeum jubatum		0.94	100	8	0.3	80	1	0.0002	17	T
Carex kelloggii		9.00	50	75	16	100	79	14	50	57
Potentilla rivalis		0.08	17	T	0	0	0	0	0	0
Rorippa palustris		0.08	33	T	0	0	0	0.003	17	T
Pinus ponderosa		0.00	0	0	0.0002	20	T	0	0	0
Pseudotsuga menziesii		0.00	0	0	0.002	20	T	0	0	0
Spergularia rubra	Exotic	1.47	83	12	3.4	100	17	9.5	100	39
Melilotus alba		0.14	33	1	0	0	0	0.08	17	T
Chenopodium album		0.00	67	T	0.01	80	T	0.8	100	3
Persicaria maculosa		0.00	67	T	0.0002	20	T	0	0	0
Matricaria discoidea		0.02	33	T	0.06	80	T	0	0	0
Polygonum aviculare		0.04	100	T	0.2	80	1	0.2	100	T
Trifolium repens		0.25	17	2	0	0	0	0	0	0
Elytrigia repens		0.00	0	0	0.2	20	T	0	0	0

[1] Planted
[2] in Moss layer

Table 7. Summary of species found in the control polygon (CLEN-03) and the treated polygons combined (PLG16-01, PLG16-04, and PLG16-05) (1X1m quadrats; T=trace <0.01).

Species	Origin	Control (n=3) Cover (Ave, %)	Control (n=3) Frequency per polygon (%)	Control (n=3) % Comp	Treatments (all PLG16 combined, n=17) Cover (Ave, %)	Treatments Frequency per polygon (%)	Treatments % Comp
Calamagrostis canadensis	Native	1.50	33	4	0	0	0
Equisetum arvense	Native	1.50	33	4	0	0	0
Hordeum jubatum	Native	0.87	100	2	0.4	65	2
Carex kelloggii[1]	Native	0.00	0	0	13	65	68
Potentilla rivalis	Native	0.00	0	0	0.03	6	T
Rorippa palustris	Native	0.00	0	0	0.03	18	T
Pinus ponderosa[2]	Native	0.00	0	0	0.00006	6	T
Pseudotsuga menziesii[2]	Native	0.00	0	0	0.0006	6	T
Spergularia rubra	Exotic	33.33	100	86	5	94	26
Melilotus alba	Exotic	1.00	33	3	0.08	18	T
Chenopodium album	Exotic	0.53	67	1	0.3	82	1.5
Persicaria maculosa	Exotic	0.10	67	T	0.0009	29	T
Matricaria discoidea	Exotic	0.09	67	T	0.02	35	T
Polygonum aviculare	Exotic	0.03	100	T	0.1	94	T
Trifolium repens	Exotic	0.00	0	0	0.09	6	T
Elytrigia repens	Exotic	0.00	0	0	0.06	6	T

[1] Planted

[2] in Moss layer

4.4. Biotic and physical observations for reference transect MMF04 and comparison with treated polygons

Transect MMF04 was surveyed in 2019 to compare with control and treatment quadrats in LMF terrain. The MMF terrain is at slightly higher elevations (643-644 m) relative to polygons in LMF terrain. Substrate cover in MMF04 quadrats was entirely organics (100%), as it was made up of primarily decaying bluejoint reedgrass leaves, some sedge and horsetail. Soils were textured as silty clay loam. The MMF quadrats were the only sites monitored where clay was detectible through hand-texturing. The finer soils pointed to slightly richer sites than in LMF terrain. Rodent tunnels, likely from deer mice (*Peromyscus maniculatus*), and burrows, tunnels and scat were observed winding through built-up litter layers.

Total cover of vegetation was generally higher in the reference transect than in the control or treated polygons (Figure 11). Total covers of vegetation for Controls, M, MP, MS, and PLG16 polygons were all significantly lower than for reference polygons (Z=-6.4, p=0; Z=-5.7, p=0; Z=-5.2, p=0.0000001; Z=-3.2, p=0.0015; and Z=-2.7, p=0.006, respectively). Similarly, covers of vegetation were significantly lower for controls and treated polygons (all treatments combined) (Z=-5.7, p=0; Z=-4.7, p=0.000003, respectively) relative to reference quadrats.

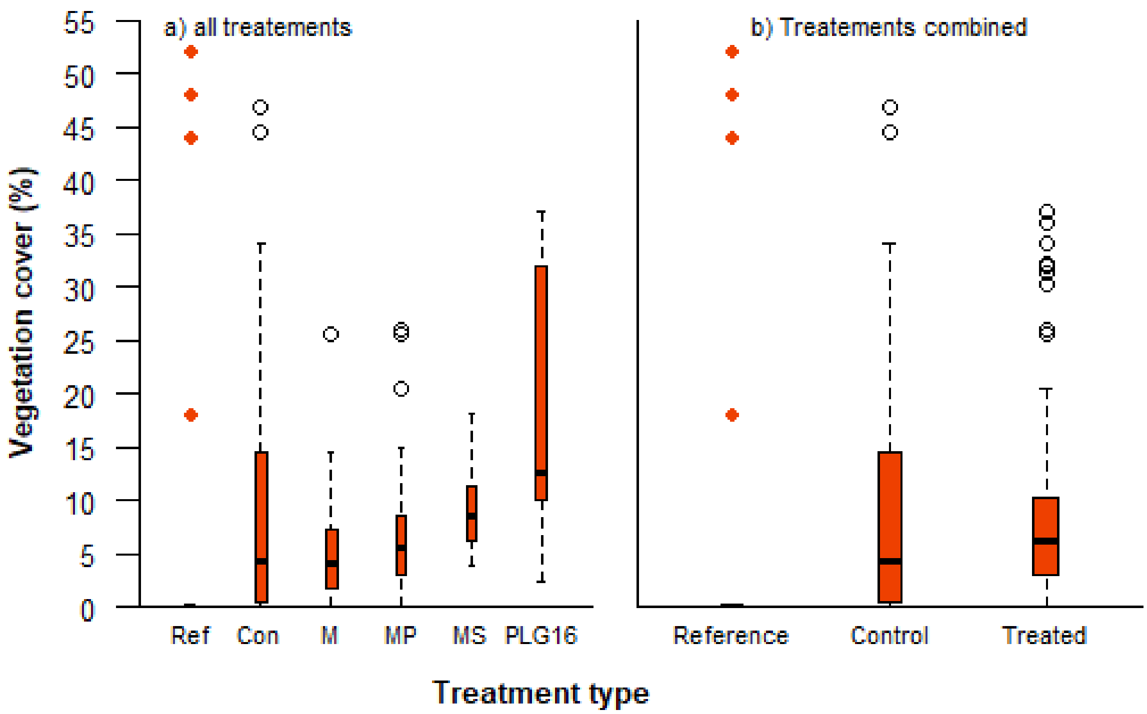


Figure 11. Cover of vegetation (total, %) per quadrat sampled in a) reference (MMF04), controls (MW1701, MW1702 and CLEN03) and each treatment type (MW1701 and MW1702 M, MP, MS) and Combined PLG1601, PLG1604, PLG1605, and b) with all treated quadrats combined in 2019. Note that the filled red dots mean that there weren't enough replicates to build a boxplot, so each individual data point for MMF04 is plotted (n=4).

Only native species were sampled in the reference transect, while cover of exotic species dominated cover of vegetation in the control and treatment polygons, with the exception of PLG15 polygons (Figure 12). Total covers of native species for Controls, M, MP and MS treatments were all significantly lower than for reference polygons (Z=-9.7, p=0; Z=-9, p=0; Z=-9, p=0; Z=-6.8, p=0, respectively). Similarly, covers of native species were significantly lower for controls and treated polygons (all treatments combined) (Z=-10, p=0; Z=-9.4, p=0, respectively). Bluejoint reedgrass and horsetails were the dominant cover species in MMF04 quadrats. Richness was very low in MMF04 quadrats with only three native species detected in the four quadrats sampled (Table 8). The quadrats in polygon PLG16 had the highest average cover of native species of treated polygons, over that in Control quadrats but less than Reference quadrats.

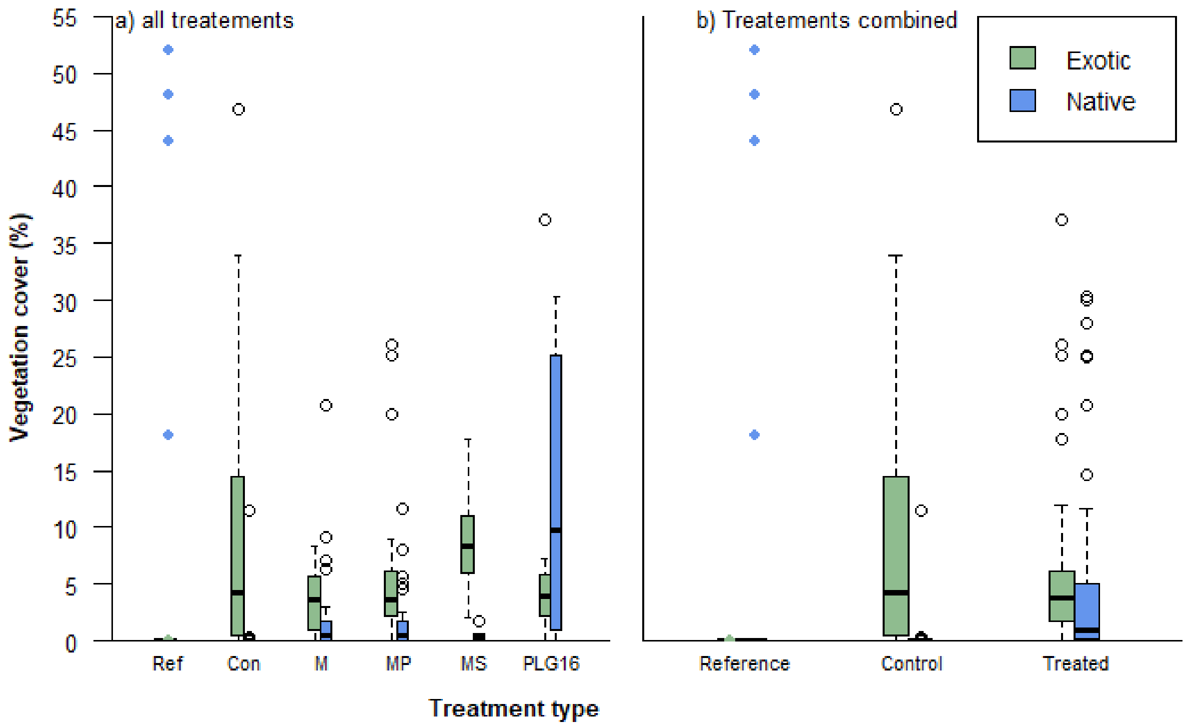


Figure 12. Cover of vegetation (%) of exotic and native species per quadrat sampled in a) reference (MMF04), controls and each treatment type, and b) with all treated quadrats combined in 2019.

Table 8. Summary of species found in the reference transect (MMF04), control polygons (CLEN-03, MW1701Con, MW1702CON) and the treated polygons in LMF terrain (MW1701, MW1702, PLG01, 04,05 combined) (1X1m quadrats; T=trace <0.01).

Species	Origin	Reference (MMF04, n=4)			Control (n=25)			Treatments (combined, n=90)		
		Cover (Ave, %)	Frequency per polygon (%)	%	Cover (Ave, %)	Frequency per polygon (%)	%	Cover (Ave, %)	Frequency per polygon (%)	%
Calamagrostis canadensis	Native	27	100	67	0.2	4	2	0	0	0
Equisetum palustre		11.3	100	28	0	0	0	0.00001	1	0
Carex kelloggii		2.25	100	6	0	0	0	2.7	44	31
Equisetum arvense		0	0	0	0.2	4	2	0	0	0
Hordeum jubatum		0	0	0	0.1	12	T	0.3	30	3
Rorippa palustris		0	0	0	0.012	12	T	0.4	40	5
Pseudotsuga menziesii		0	0	0	0.0001	20	T	0.0002	4	0
Plagiobothrys scouleri		0	0	0	0.00008	8	T	0.00001	2	0
Amsinckia lycopsoides		0	0	0	0.00006	20	T	0.4	42	4
Epilobium ciliatum		0	0	0	0.00001	8	T	0.0002	11	0
Carex microptera		0	0	0	0	0	0	0.003	2	0.03
Erysimum cheiranthoides		0	0	0	0	0	0	0.001	3	0.01
Poa palustris		0	0	0	0	0	0	0.0007	3	0.01
Lotus denticulatus		0	0	0	0	0	0	0.0001	2	0
Pinus ponderosa		0	0	0	0	0	0	0.00001	1	0
Populus balsamifera[1]		0	0	0	0	0	0	0.0006	3	0.01
Populus balsamifera[21]		0	0	0	0	0	0	0.00001	3	0
Potentilla rivalis		0	0	0	0	0	0	0.006	1	0.06

Species	Origin	Reference (MMF04, n=4)			Control (n=25)			Treatments (combined, n=90)		
		Cover (Ave, %)	Frequency per polygon (%)	%	Cover (Ave, %)	Frequency per polygon (%)	%	Cover (Ave, %)	Frequency per polygon (%)	%
Epilobium latifolium		0	0	0	0	0	0	0.002	1	0.03
Prunus virginiana		0	0	0	0	0	0.	0.0006	1	0.01
Spergularia rubra	Exotic	0	0	0	6.5	96	60	2.2	79	25
Chenopodium album		0	0	0	3.5	76	32	0.5	88	6
Polygonum aviculare		0	0	0	0.2	100	2	1.8	99	20
Melilotus alba		0	0	0	0.1	4	1	0.02	8	0.2
Persicaria maculosa		0	0	0	0.02	40	T	0.2	50	2
Matricaria discoidea		0	0	0	0.01	28	T	0.02	24	0.2
Poa compressa		0	0	0	0.004	36	T	0.04	19	0.5
Sisymbrium altissimum		0	0	0	0.000008	8	T	0.08	21	0.9
Elytrigia repens		0	0	0	0	0	0	0.01	2	0.1
Trifolium pratense		0	0	0	0	0	0	0.00004	1	0
Trifolium repens		0	0	0	0	0	0	0.1	8	1.5
Capsella bursa-pastoris		0	0	0	0	0	0	0.001	1	0.01
Phleum pratense		0	0	0	0	0	0	0.002	1	0.03
Draba sp.	unknown	0	0	0	0	0	0	0.000003	2	0
Total			3			16			32	

[1] Low shrub layer
[2] Moss layer

4.5 Treatments in Gun Creek Fan East (polygons MW1703, MW1705, MW1706)

4.5.1 Biotic and physical conditions in polygon MW1703

Polygon MW1703 situated in a transitional zone between the alluvial fan and the low mud flat at elevations of 642m and 643m on the lower Gun Creek Fan was formed in 2017. Treatments conducted included mounding (MW1703M), mounding and planting (MW1703MP), and mounding and seeding (MW1703MS). A section of sub-polygon MW1703MP was also re-planted in 2019 (MW1703MPT1915). An adjacent area was identified for control (sub-polygon MW1703CON). Mounding treatments changed the substrate by shifting the dominant composition from mineral soils to rock (Figure 13). Estimates of soil texture coarseness were slightly higher in treatment vs control plots. Soil coarse fragment content in both treatment and control plots was, on average, estimated to vary between 35 and 65%. Soil texture in control plots tended to have a higher silt content, as opposed to treatment polygons that had sandier texture. As expected, mounding treatments mixed soils and brought coarser subsurface, alluvial deposits to the surface. The surface substrate and soil texture of the control polygon were predominantly mineral soils made up of fine lacustrine silt deposits that were the result of annual inundation and sedimentation.

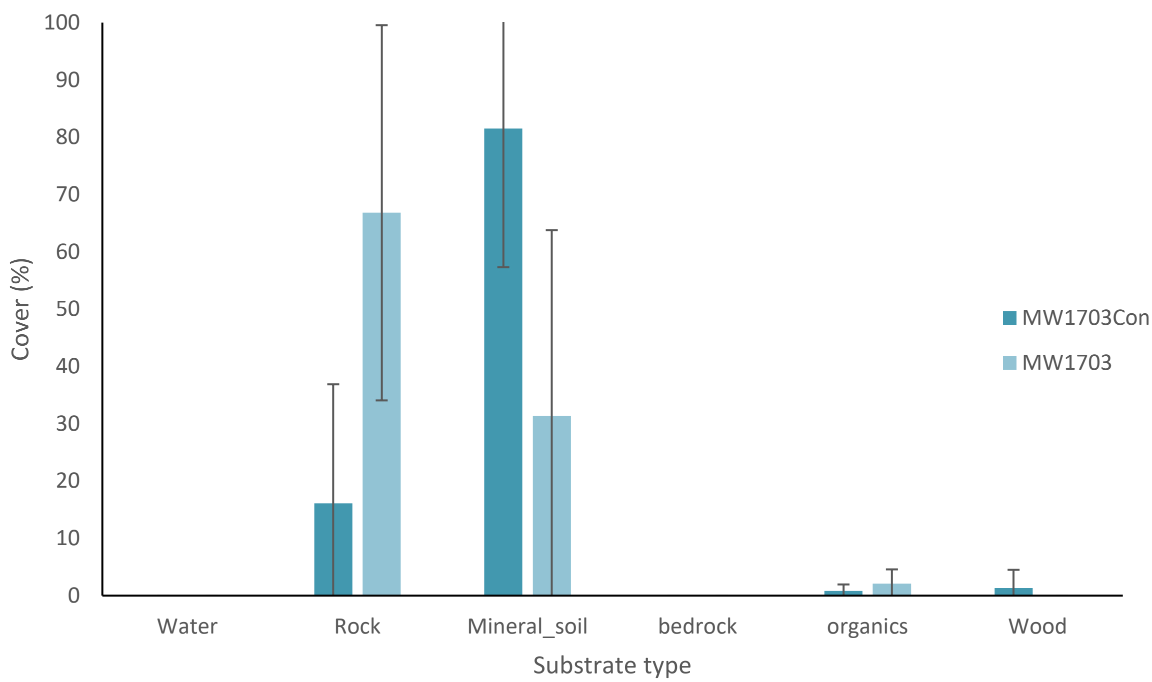


Figure 13. Total substrate cover (average) for treatment and control sub-polygons of MW1703. Error bars are standard deviations.

There was very little vegetation cover in control plots of polygon MW1703; cover in treated plots, and particularly in machine-work/planted plots was generally higher (Figure 14).

None of these differences were significant between treated and control plots (p>0.05). Outlier plots with higher cover in the treatment sub-polygons contained relatively dense patches of exotic species like white sweetclover and great mullein (*Verbascum thapsus*). One outlier plot with high cover in the control sub-polygon contained a natural patch of foxtail barley and white clover (*Trifolium repens*).

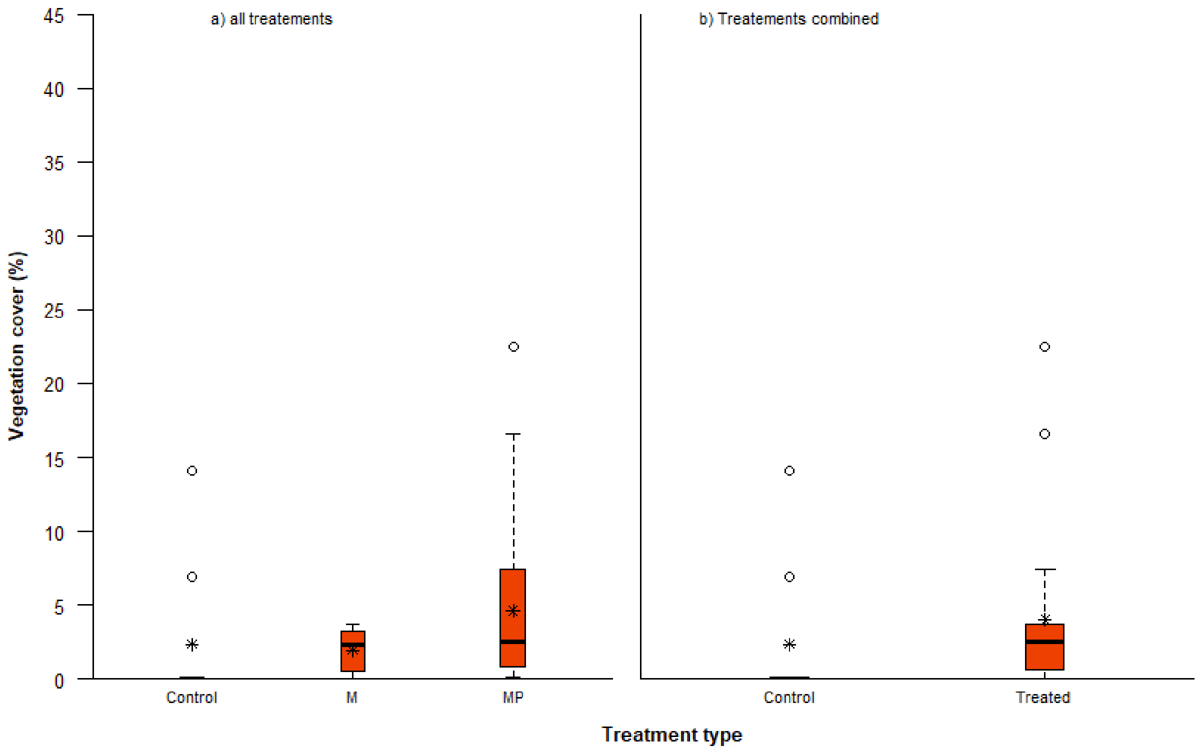


Figure 14. Cover of vegetation (total, %) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1703 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

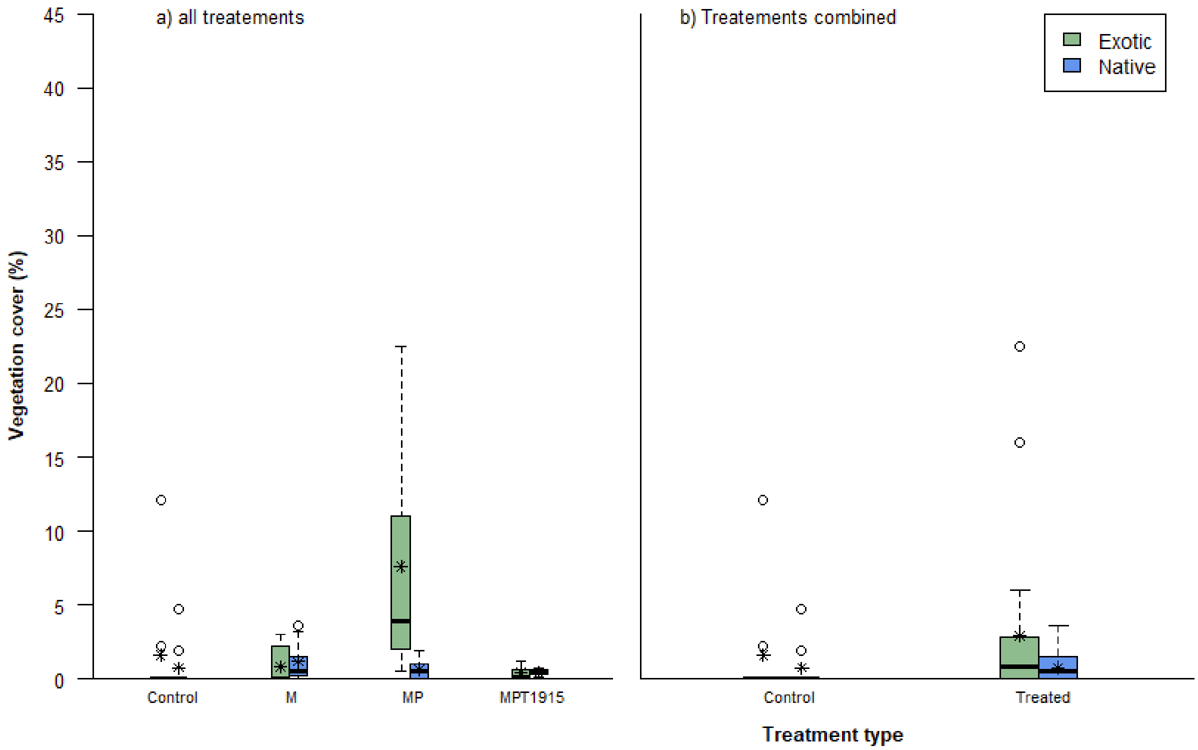


Figure 15. Cover of vegetation (%) of exotic and native species per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1703 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

In both control and treatment sub-polygons, the cover of native species was lower than that of exotics (Figure 15) though not significantly (all types of plots combined, $p>0.05$). Cover of native species was not significantly higher than in control plots, for treatment sub-polygons separately ($p>0.05$), nor overall for all treated plots combined ($p>0.05$). In both treatment and control sub-polygons, the cover of native species was very low (typically <5%). This result suggests that two years post-treatment, the cover of vegetation was not affected by treatments yet, with possible exception of exotic species that have established in patches within the treatment sub-polygons.

While vegetation cover was comparable between treatment and control sub-polygons of MW1703, species richness was much higher in treatment sub-polygons with over twice the number of species than observed in control sub-polygons (although more than twice the number of plots were sampled in the treatment sub-polygons as in the control sub-polygons species richness would not change with more plots in the control areas, Table 9). The natural recruitment of small winged sedge a perennial native sedge with no previous occurrence in the monitoring program, is noteworthy. The occurrence of Kellogg's sedge is due to planting treatments. Annual and biennial species of the drawdown make up the bulk of the species responsible for the increase in native species richness. A single occurrence of upland species penstemon (*Penstemon fruticosus*) will not survive inevitable inundation. A single occurrence of bluejoint reedgrass in the control sub-polygon is also notable. Bluejoint did not occur in 1m² quadrats but was detected in larger 50m² plots, suggesting some plugs survived planting. Density tallies in polygon MW1703 indicated Kellogg's sedge of 33 plants per 100m² in machined-planted sub-polygon, but of only four plants per 100m² in machine-treatment sub-polygons, which suggests some low-level natural recruitment. No Kellogg's sedge was detected in plots of the control sub-polygon. Foxtail barley, a native perennial grass, was colonizing in higher densities in treatment sub-polygons (37 plants per 100m²) than in control sub-polygon (eight plants per 100m²).

Table 9. Summary of species found in the control and treated sub-polygons of MW1703 (50 m^2 plots; T=trace <0.01).

		Control (n=9)			Treatments (combined, n=20)		
Species	Origin	Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	% Comp
Hordeum jubatum	Native	0.5	33	20	0.18	35	4
Amsinckia lycopsoides		0.2	67	7	0.05	30	1
Calamagrostis canadensis		0.09	11	4	0	0	0
Epilobium ciliatum		0.01	11	T	0.10	60	2
Carex microptera		0	0	0	0.025	5	T
Plagiobothrys scouleri		0	0	0	0.11	30	3
Potentilla rivalis		0	0	0	0.20	10	5
Rorippa palustris		0	0	0	0.19	10	5
Collomia linearis		0	0	0	0.005	5	T
Penstemmon fruticosus		0	0	0	0.013	5	T
Carex kelloggii[1]		0	0	0	0.005	5	T
Trifolium repens	Exotic	1.25	22	53	0.05	10	1
Melilotus alba		0.2	11	8	0.93	10	23
Matricaria discoidea		0.09	78	4	0.005	15	T
Chenopodium album		0.02	44	T	0.0005	10	T
Polygonum aviculare		0.02	22	T	0.20	35	5
Medicago lupulina		0.02	11	T	0.45	10	11

Poa compressa		0.000 02	22	T	0.000005	5	T
Capsella bursa-pastoris		0	0	0	0.1	10	2.5
Descurainia sophia		0	0	0	0.005	5	T
Lactuca serriola		0	0	0	0.013	5	T
Spergularia rubra		0	0	0	0.00005	5	T
Trifolium pratense		0	0	0	0.23	10	6
Verbascum thapsus		0	0	0	1.14	15	28
Draba sp	Unknown	0	0	0	0.015	5	T
Total richness		11			24		

[1]Planted

4.5.2 Biotic and physical conditions in polygon MW1705

The polygon MW1705 is located at elevations of the mid-drawdown (643-644 m) (Map 5). The substrate texture increased in coarseness as elevation increased on the Gun Creek Fan East (Scholz and Gibeau, 2019). Mounding treatment changed the dominant substrate cover from mineral soils to rock (Figure 16). Tracks of mule deer were observed in several plots of the control sub-polygon.

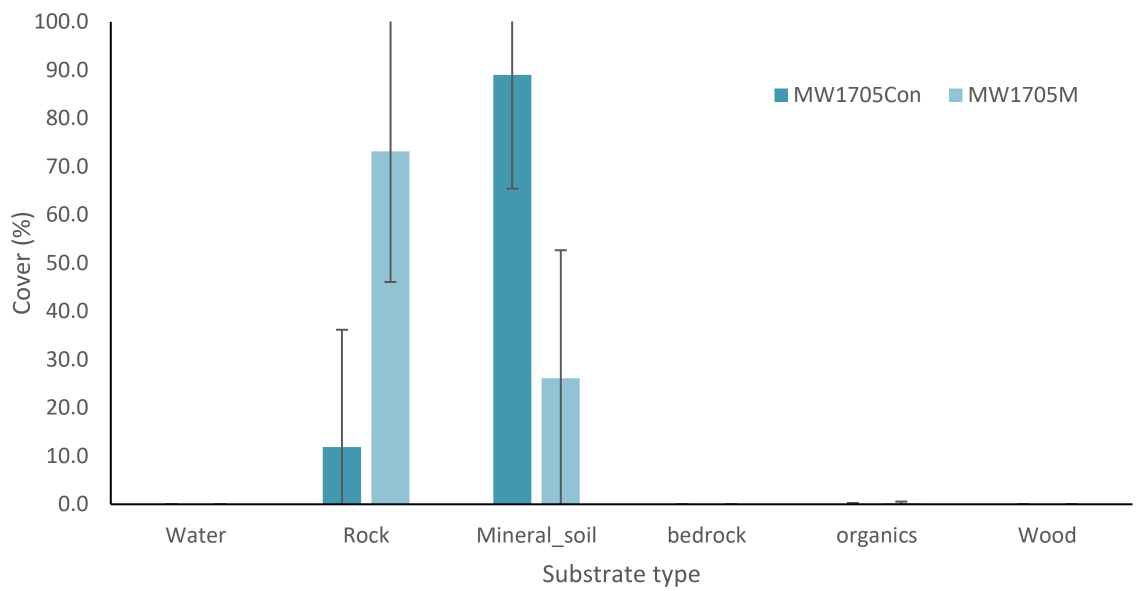


Figure 16. Total substrate cover (average) for treatment and control sub-polygons of MW1705. Error bars are standard deviations.

Cover of vegetation was lower in control sub-polygon of MW1705 (Figure 17.a); vegetation in machine-work/planted plots was barely significantly higher than controls (Z=1.9, p=0.06) and cover in MPT1917 was significantly higher than in controls (Z=2.9, p=0.0043), but cover in treated plots was not different from controls when all treatment types were combined (Figure 17.b, p>0.05).

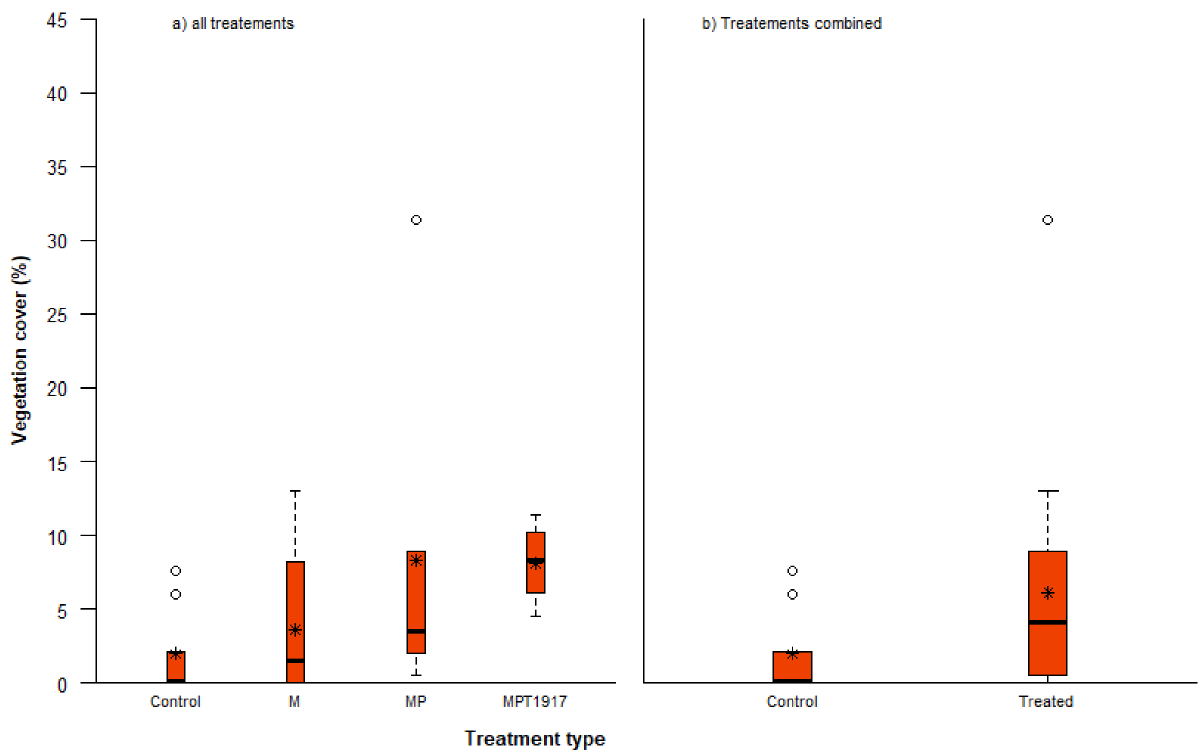


Figure 17. Cover of vegetation (total, %) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1705 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

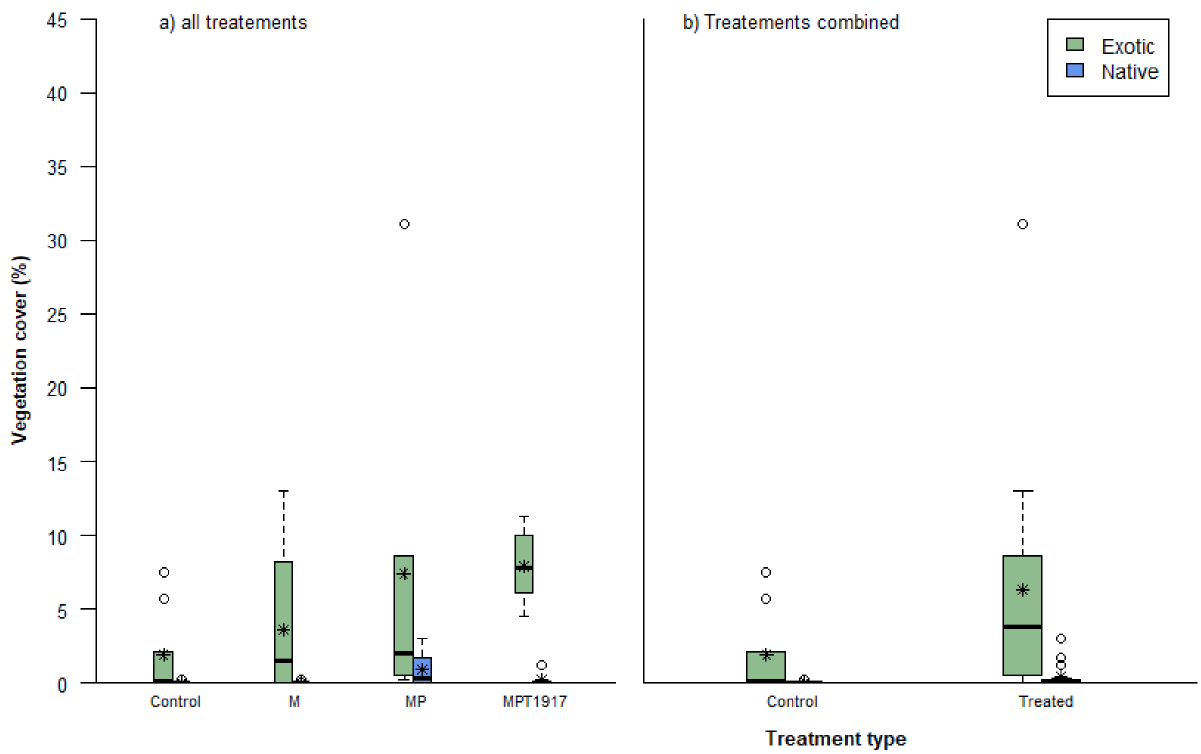


Figure 18. Cover of vegetation (%) of exotic and native species per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1705 in 2019. The median is represented by a horizontal line in the box, that is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data). The largest and smallest observations within 1.5 interquartile range are represented by whiskers drawn from the top and bottom of the box, respectively. Outliers are shown by open circles and average is represented by *.

Cover of exotic species was much higher than that of native species, in control as well as treatment sub-polygons (Figure 18), and cover of native species was significantly lower than exotics (all treatments combined, Z=-3.7, p=0.00023). Cover of native species was also higher in MW1705MP than in controls (Z=2.6, p=0.008). Plots in treatment sub-polygons had two more native species than control sub-polygons (Table 10). Foxtail barley was the only perennial native species found in the control plots. Treatment sub-polygons included bluejoint reedgrass and Kellogg's sedge (both planted). The number of exotic species was comparable with similar species of annuals found most frequently in control and treatment plots. White-sweet clover, though not very frequent, was notable as a robust plant providing high cover in a few plots. Overall, the number of native species detected was much higher in treatment sub-polygons than in the controls, though once again more than twice the number of plots were sampled in treatment sub-polygons as opposed to controls (16 species in treated sub-polygons vs 5 in controls). Richness in exotic species in treatment sub-polygons was also twice that of the controls (n=17 vs 9, respectively). The dominant exotic perennial species were clover sp.

(*trifolium sp.*), Canada bluegrass (*Poa compressa*), quack grass and Canada thistle (*Cirsium arvense*). The native annual species the most commonly occurring in control and treatment plots was foxtail barley, established through natural colonization. Kellogg's sedge and bluejoint were only detected where they were planted in treatment sub-polygons. Thus, we can conclude that physical treatment of substrate in treatment sub-polygons increased species richness.

Table 10. Summary of species found in the control and treated sub-polygons of MW1705 (50 m^2 plots; T=trace <0.01).

Species	Origin	Control (n=9)			Treatments (Combined; n=22)		
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	% Comp
Lepidium densiflorum	Native	0.05	89	3	0.010	32	T
Amsinckia lycopsoides		0.002	11	T	0	0	0
Epilobium ciliatum		0.0001	22	T	0	0	0
Hordeum jubatum[1]		0.00001	11	T	0.1	64	2
Rorippa palustris		0	0	0	0.05	27	T
Carex kelloggii[1]		0	0	0	0.1	5	2
Plagiobothrys scouleri		0	0	0	0.01	5	T
Calamagrostis canadensis[1]		0	0	0	0.027	14	T
Spergularia rubra	Exotic	1.7	56	85	2.83	86	46
Chenopodium album		0.11	56	6	0.3	64	6
Polygonum aviculare		0.09	67	5	0.05	55	T
Matricaria discoidea		0.02	56	T	0.01	18	T
Elytrigia repens		0.01	11	T	0	0	0
Persicaria maculosa		0.0001	11	T	0	0	0
Trifolium repens		0.0001	11	T	0.1	14	2
Medicago lupulina		0	0	0	0.04	9	T
Melilotus alba		0	0	0	2.4	27	40
Poa compressa		0	0	0	0.000005	5	T

Draba sp.	Unknown	0.01	56	T	0	0	0
Total richness		12			14		

[1] planted

4.5.3 Biotic and physical conditions in polygon MW1706

Polygon MW1706 straddles the upper drawdown and lower buffer zone[2] (647-649 m) of the Gun Creek Fan East side. Soils of in the control and treatment sub-polygons were both skeletal with coarse fragments exceeding 85% in most plots. Substrate cover was primarily composed of alluvial rock made up of sub-rounded cobbles and boulders (Figure 19). Physical treatments had little effect on substrate texture and composition, though a slight increase in rock cover was observed in treatment sub-polygons as compared to the control. Tracks of mule deer and scat were observed in several plots in the control sub-polygon.

Total covers of vegetation in the machine-worked plots (Z=-1.9, p=0.06) and MPT1918 sub-polygon (Z=-1.7, p=0.08) were barely significantly lower than in control plots (at alpha=0.1) (Figure 20). Similarly, total cover was only barely significantly lower than in control plots when all treatments were merged (Z=-1.9, p=0.06). Mounding treatment has, at least temporarily, reduced vegetation cover, and two years post-treatment, the cover values remain lower in treatment sub-polygons than in controls.

[2] Water levels in the Carpenter Reservoir are managed with a buffer zone (between 648 and 651 m) where inundation is restricted to less than 57 days each year.

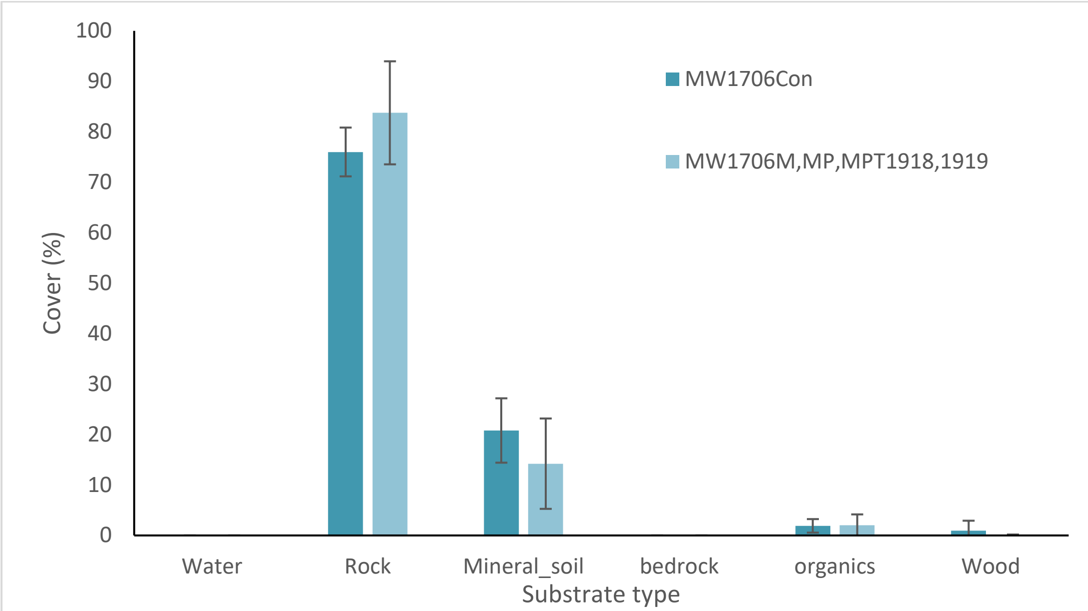


Figure 19. Total substrate cover (average) for treatment and control sub-polygons of MW1706. Error bars are standard deviations.

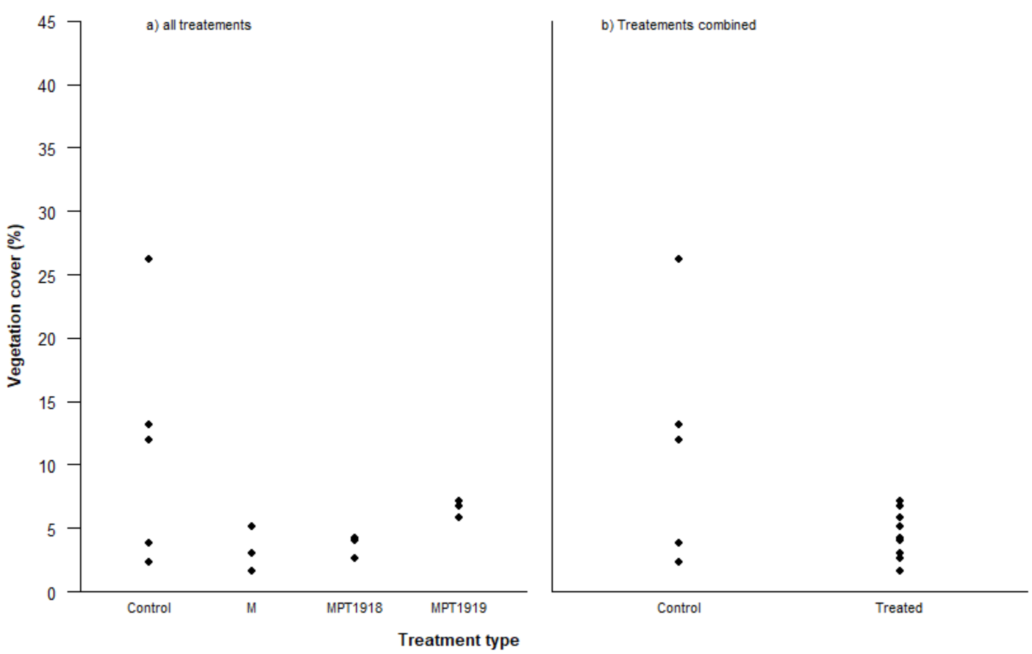


Figure 20. Cover of vegetation (total, %) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1706 in 2019.

Cover of native species was similar to that of exotic species in control and treated sub-polygons (Figure 21) and thus did not vary significantly among plots (all p>0.05 and 0.1). Cover of moss was responsible for the high cover observed in one plot of the control sub-polygon (15%).

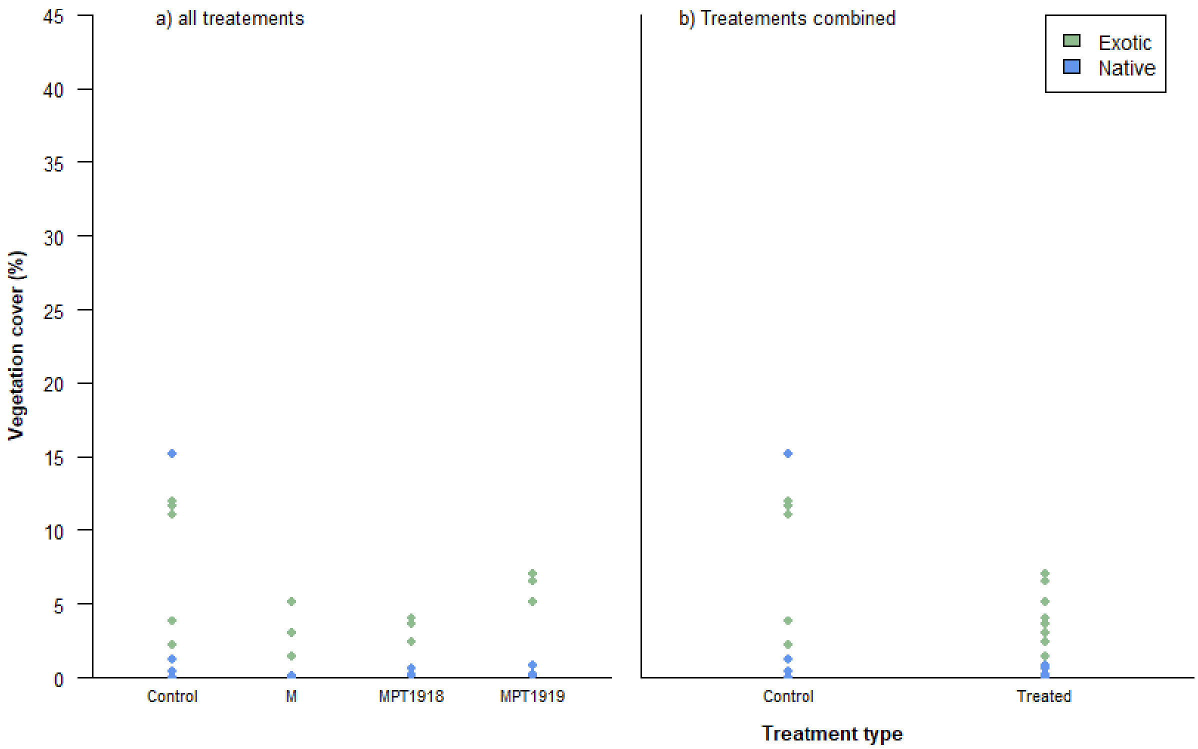


Figure 21. Cover of vegetation (%) of exotic and native species per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1706 in 2019.

Silver cinquefoil (*Potentilla argentea*) and white sweet clover were the dominant exotic species in the control sub-polygon. Although total cover was lower in treatment sub-polygons, nine additional species were detected in treatment sub-polygons than in control (Table 11). The species richness in treatment sub-polygons was twice that of control sub-polygon (though twice as many plots were also sampled in the treatment sub-polygons). Eight of the additional native species found in treatment sub-polygons were the result of planting. Five of the planted species were either a tree or shrub (green alder (*Alnus crispa ssp. sinuate)*, mountain alder (*Alnus incana ssp. tenuifolia*), black cottonwood, Ponderosa pine and Bebb's willow (*Salix bebbiana*). These shrubs were planted in either 2017 and 2019. In contrast, no tree or shrub species were observed in control sub-polygon.

Table 11. Summary of species found in the control and treated sub-polygons of MW1706 (50 m^2 plots; T=trace <0.01).

Species	Origin	Control (n=5) Cover (Ave, %)	Control (n=5) Frequency per polygon (%)	Control (n=5) % Comp	Treatment (combined; n=10) Cover (Ave, %)	Treatment (combined; n=10) Frequency per polygon (%)	Treatment (combined; n=10) % Comp
Moss sp.	Native	3.1	40	27	0	0	0
Rumex triangulivalvis	Native	0.24	20	2	0.03	20	T
Achillea millefolium	Native	0.04	60	T	0	0	0
Epilobium ciliatum	Native	0.008	100	T	0.025	100	T
Collomia linearis	Native	0.004	80	T	0.002	40	T
Hordeum jubatum	Native	0.002	40	T	0.006	30	T
Erigeron compositus	Native	0.002	20	T	0.003	40	T
Lepidium densiflorum	Native	0.0006	60	T	0.006	20	T
Amsinckia lycopsoides	Native	0.0004	40	T	0.003	40	T
Crepis occidentalis	Native	0.0002	20	T	0.04	60	T
Plagiobothrys scouleri	Native	0	0	0	0.002	40	T
Potentilla rivalis	Native	0	0	0	0.005	50	T
Alnus viridis[1]	Native	0	0	0	0.008	30	T
Alnus incana[1]	Native	0	0	0	0.009	40	T
Calamagrostis canadensis[1]	Native	0	0	0	0.002	20	T
Elymus glaucus[1]	Native	0	0	0	0.0003	10	T
Lotus denticulatus	Native	0	0	0	0.001	10	T
Pinus ponderosa[1]	Native	0	0	0	0.03	40	T
Poa palustris	Native	0	0	0	0.002	20	T
Populus balsamifera[1]	Native	0	0	0	0.05	30	1
Salix bebbiana[1]	Native	0	0	0	0.005	20	T
Elymus canadensis[1]	Native	0	0	0	0.008	20	T
Potentilla argentea	Exotic	4.5	80	39	0.1	20	2
Melilotus alba	Exotic	2.5	100	22	3.6	100	81
Verbascum thapsus	Exotic	0.4	80	4	0.3	100	7
Elytrigia repens	Exotic	0.2	20	2	0.0001	10	T

Species	Origin	Control (n=5) Cover (Ave, %)	Control (n=5) Frequency per polygon (%)	Control (n=5) % Comp	Treatment (combined; n=10) Cover (Ave, %)	Treatment (combined; n=10) Frequency per polygon (%)	Treatment (combined; n=10) % Comp
Silene latifolia		0.2	20	1	0	0	0
Medicago lupulina		0.14	20	1	0.01	60	T
Rumex crispus		0.06	20	T	0.05	20	1
Medicago sativa		0.05	20	T	0	0	0
Poa compressa		0.014	100	T	0.12	50	3
Taraxacum officinale		0.006	80	T	0.003	20	T
Tragopogon dubius		0.002	20	T	0.001	10	T
Matricaria discoidea		0.0004	40	T	0.002	10	T
Sisymbrium altissimum		0.0004	40	T	0.01	20	T
Filago arvense		0.0002	40	T	0.001	10	T
Chenopodium album		0	0	0	0.003	50	T
Lactuca serriola		0	0	0	0.001	10	T
Draba sp.	unknown	0.002	40	T	0	0	0

[1]Planted
Alnus, Populus, Salix are in low shrub layer

4.6 Treatments in Gun Creek Fan West (polygons MW1708, MW1709)

4.6.1 Biotic and physical conditions in polygon MW1708

Polygon MW1708 is located on the west side of Gun Creek Fan, in the upper drawdown zone between 647 and 648 m. It is evident, when comparing the control sub-polygon to the treatment sub-polygons, that physical works changed the substrate cover from predominantly mineral soils (loamy sand) to rock (Figure 22). Lacustrine deposits of finer minerals were buried, and coarse fluvial and alluvial rock was brought to the surface by physical treatment.

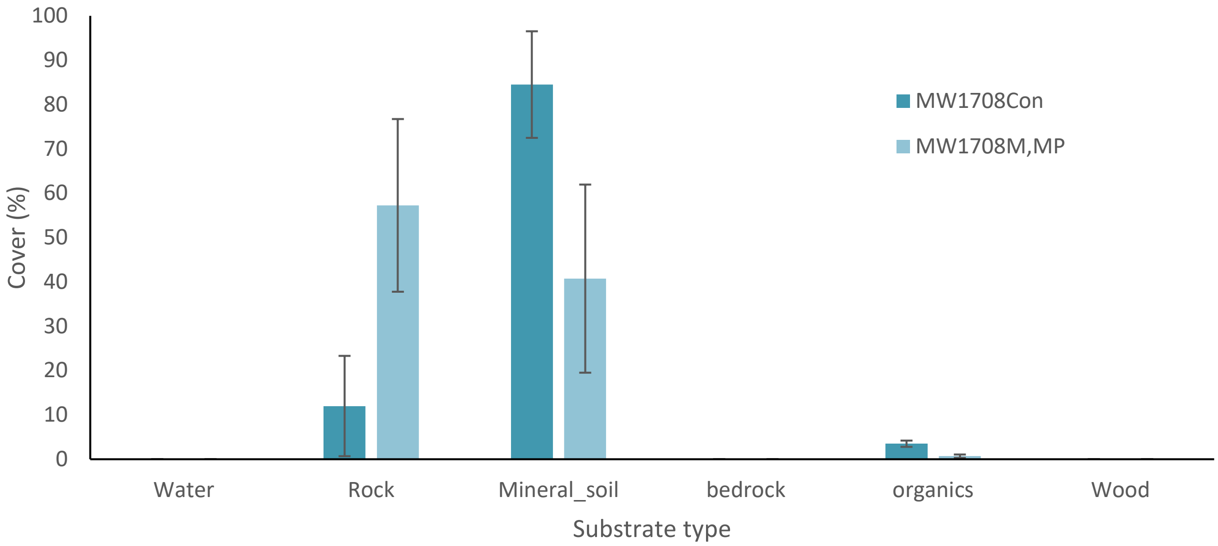


Figure 22. Total substrate cover (average) for treatment and control sub-polygons of MW1708. Error bars are standard deviations.

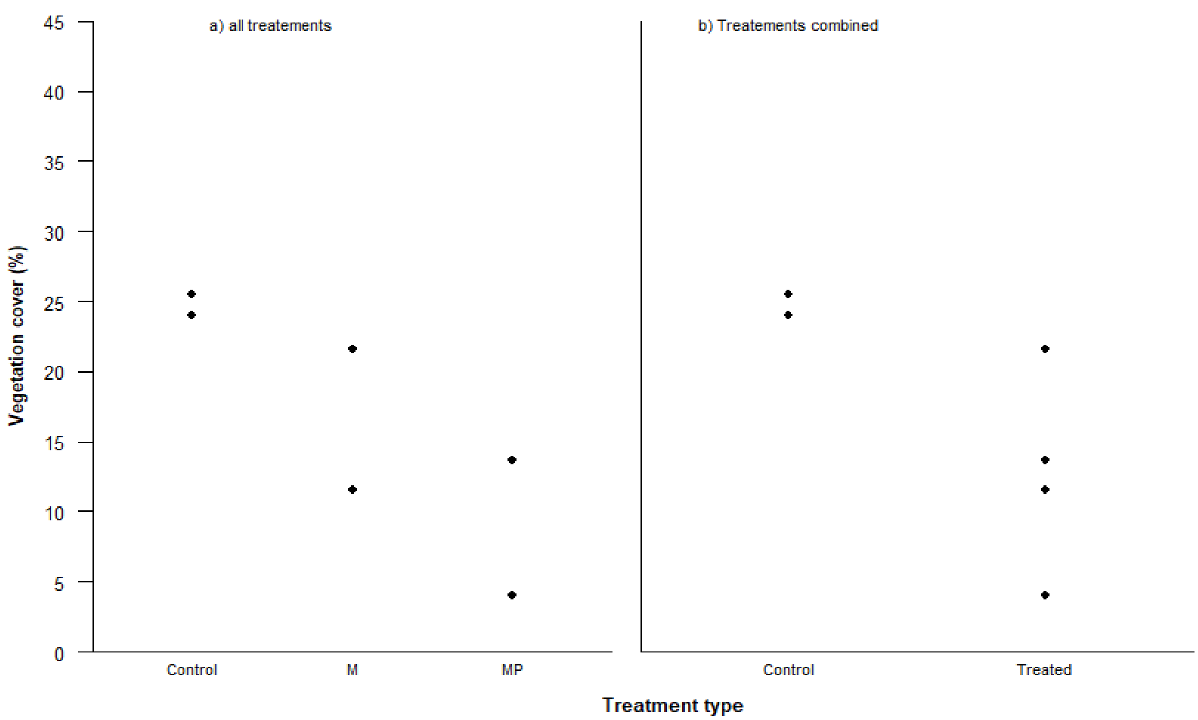


Figure 23. Cover of vegetation (total, %) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1708 in 2019.

Total vegetation cover in M (Z=-1.7, p=0.09) and MP (Z=-3.5, p=0.00052) sub-polygons were barely significantly lower than in control plots (at alpha=0.1 for M but 0.05 for MP) (Figure 23). Similarly, total cover was significantly lower than in control plots when all treatments were merged (Z=-2.5, p=0.013). As with machine-treatment sub-polygon in the upper elevation on Gun Creek Fan East, total vegetation cover remains lower in treatment as opposed to control sub-polygons two years post-treatment in Gun Creek Fan West. However, overall vegetation cover was higher, on average, in the polygons on the west side of Gun Creek Fan.

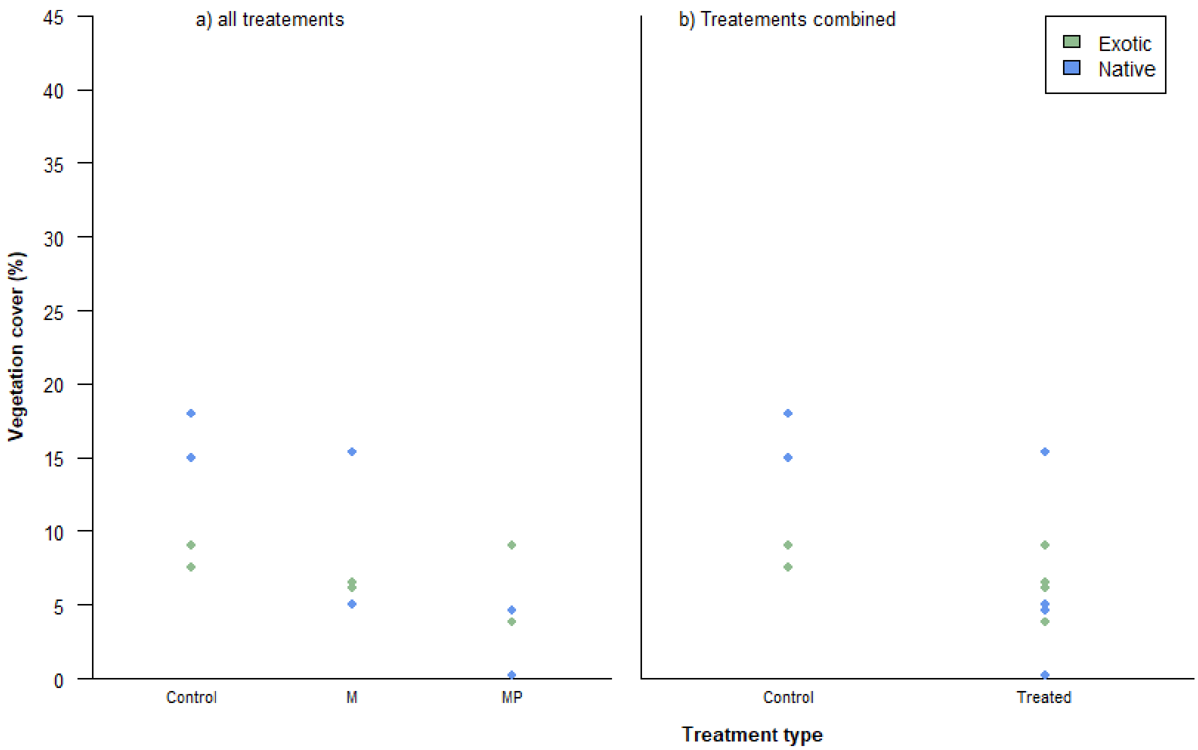


Figure 24. Cover of vegetation (%) of exotic and native species per plot sampled in a) controls and each treatment type, and b) all treated plots combined in polygon MW1708 in 2019.

Total cover of native species was significantly lower in MP sub-polygons than controls (Z=-3.5, p=0.00048) (Figure 24). Similarly, total cover was significantly lower than in control plots when all treatments were merged (Z=-2.4, p=0.017). Common horsetail (*Equisetum arvense*) was primarily responsible for the higher cover in control plots (Table 12). The rhizomatous native species was also the dominant native species in the treatment sub-polygons. Perennial white clover and quack grass were the dominant exotic species in both control and treatment sub-polygons. The noxious weed species yellow toadflax was found in relative high frequency in both control and treatment plots. Species richness was four times higher in the treatment sub-polygons than in the controls. An additional three native species were observed only in the treatment sub-polygons, that were the direct result of planting (bluejoint, foxtail barley, black cottonwood).

Table 12. Summary of species found in the control and treated sub-polygons of MW1708 (50 m^2 plots; T=trace <0.01).

Species	Origin	Control (n=2)			Treatments (combined, n=4)		
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	% Comp
Equisetum arvense	Native	16.5	100	67	6	100	47
Potentilla rivalis		0.0005	50	T	0.03	75	T
Achillea millefolium		0.00005	50	T	0	0	0
Collomia linearis		0.00005	50	T	0.003	50	T
Erysimum cheiranthoides		0.00005	50	T	0	0	0
Lepidium densiflorum		0.00005	50	T	0	0	0
Amsinckia lycopsoides		0	0	0	0.0003	25	T
Calamagrostis canadensis[2]		0	0	0	0.008	50	T
Mentzelia albicaulis		0	0	0	0.06	50	T
Plagiobothrys scouleri		0	0	0	0.0005	50	T
Hordeum jubatum[2]		0	0	0	0.025	50	T
Populus balsamifera[1]		0	0	0	0.25	25	2
Trifolium repens	Exotic	5.5	100	22	3.4	100	27
Elytrigia repens		2.4	100	10	1.1	100	9
Linaria vulgaris[3]		0.205	100	T	0.003	25	T
Verbascum thapsus		0.105	100	T	1	100	8
Trifolium pratense		0.055	100	T	0	0	0
Poa compressa		0.0055	100	T	0.6	75	4
Sisymbrium altissimum		5.00E-04	50	T	0.0005	50	T
Medicago lupulina		0	0	0	0.3	50	2
Melilotus alba		0	0	0	0.0075	50	T

[1]Planted, low shrub
[2]Some planted, some natural
[3] Provincial Noxious weed

4.6.2 Biotic and physical conditions in polygon MW1709

Polygon MW1709 is located on the upper drawdown zone of Gun Creek Fan West. Substrate cover was predominantly rock in both control and treatment sub-polygons (Figure 25). Cover of mineral soils was higher in the treatment sub-polygon compared with the control. Soils in the control sub-polygon were sands, while treatment plots had loamy sand. Both soils were very coarse to skeletal in places, with over 65% of coarse fragment content.

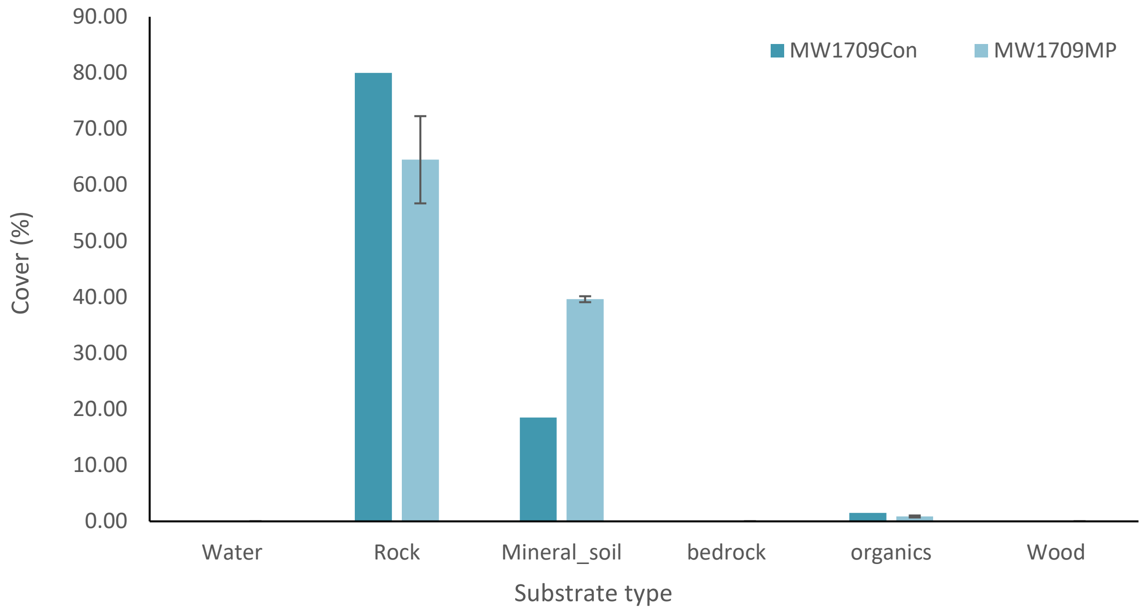


Figure 25. Total substrate cover (average) for treatment and control sub-polygons of MW1709. Error bars are Standard deviations.

The coarse soils of the treatment sub-polygon had lower total vegetation cover than control plots. Given the lack of replication, no model was fitted. Results so far suggest that vegetation cover two years post-treatment has not recovered to pre-treatment (control) levels. Only exotic species were present in the control sub-polygon, while the treatment sub-polygon had some very low cover of native species (Figure 26).

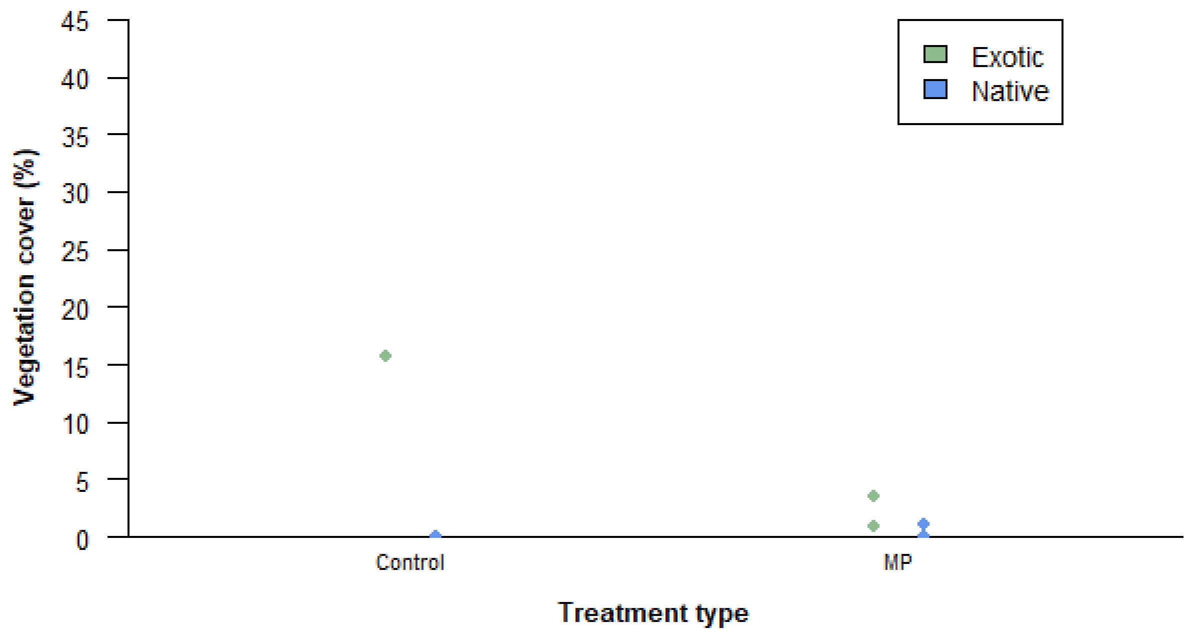


Figure 26.   Cover of native and exotic species (%) per plot sampled in controls and machine-planted plots of polygon MW1709 in 2019. Only one plot was sampled in control sub-polygon, and two plots in machine-planted sub-polygon. Plots measured 50 m^2.

The only native species detected in control sub-polygon was bluejoint reedgrass (Table 13). White clover was the dominant exotic species in the control plot, along with noxious weed species spotted knapweed (*Centaurea stoebe*). There isn't enough replication to test differences in native species cover, but unlikely to be different given cover of native species in control and MP plots was below 1%.

Table 13. Summary of species found in the control and treated sub-polygons of MW1709 (50 m^2 plots; T=trace <0.01).

Species	Origin	Control (n=1) Cover (Ave, %)	Control (n=1) Frequency per polygon (%)	Control (n=1) % Comp	Treatment (n=2) Cover (Ave, %)	Treatment (n=2) Frequency per polygon (%)	Treatment (n=2) % Comp
Calamagrostis canadensis	Native	0.05	100	T	0	0	0
Achillea millefolium		0	0	0	0.001	50	T
Amsinckia lycopsoides		0	0	0	0.1	50	4
Collomia linearis		0	0	0	0.0015	100	T
Elymus canadensis [1]		0	0	0	0.4	100	15
Epilobium ciliatum		0	0	0	0.0005	50	T
Hordeum jubatum		0	0	0	0.0005	50	T
Poa palustris		0	0	0	0.0005	50	T
Potentilla rivalis		0	0	0	0.0005	50	T
Trifolium repens	Exotic	11	100	70	0.75	100	28
Centaurea stoebe [2]		3.5	100	22	0.0005	50	T
Poa compressa		1	100	6	0.0025	50	T
Filago arvense		0.06	100	T	0.0005	50	T
Elytrigia repens		0.05	100	T	0.0000	0	0
Potentilla argentea		0.01	100	T	0	0	0
Verbascum thapsus		0.01	100	T	1	50	37
Silene latifolia		0.008	100	T	0.0015	50	T
Medicago lupulina		0.002	100	T	0.45	100	17
Melilotus alba		0.001	100	T	0	0	0
Tragopogon dubius		0.001	100	T	0	0	0
Sisymbrium altissimum		0	0	0	0.0005	50	T

[1] Planted, [2] Provincial Noxious weed species

4.6.3 Biotic and physical conditions in polygons MW1708 and MW1709 (combined)

Polygons MW1708 and MW1709 are situated at similar elevations with similar substrate conditions on the Gun Creek Fan West.

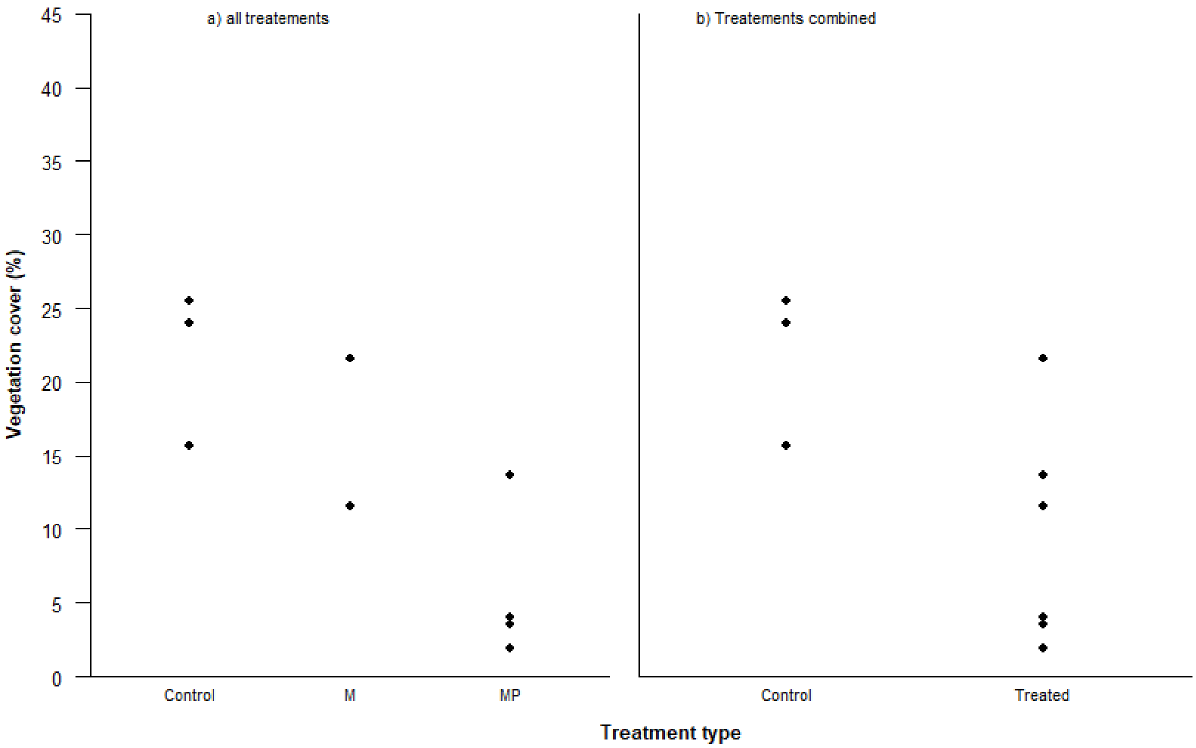


Figure 27. Cover of vegetation (total, %) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in MW1708 and MW1709 polygons (combined) in 2019.

Total vegetation cover was slightly higher on average in the control plots than in the treatment plots (Figure 27). The total cover in treated plots (all combined) was significantly lower than in control plots (Z=-2.8, p=0.036). Total vegetation cover remained lower in treatment plots than control plots two years post-treatment.

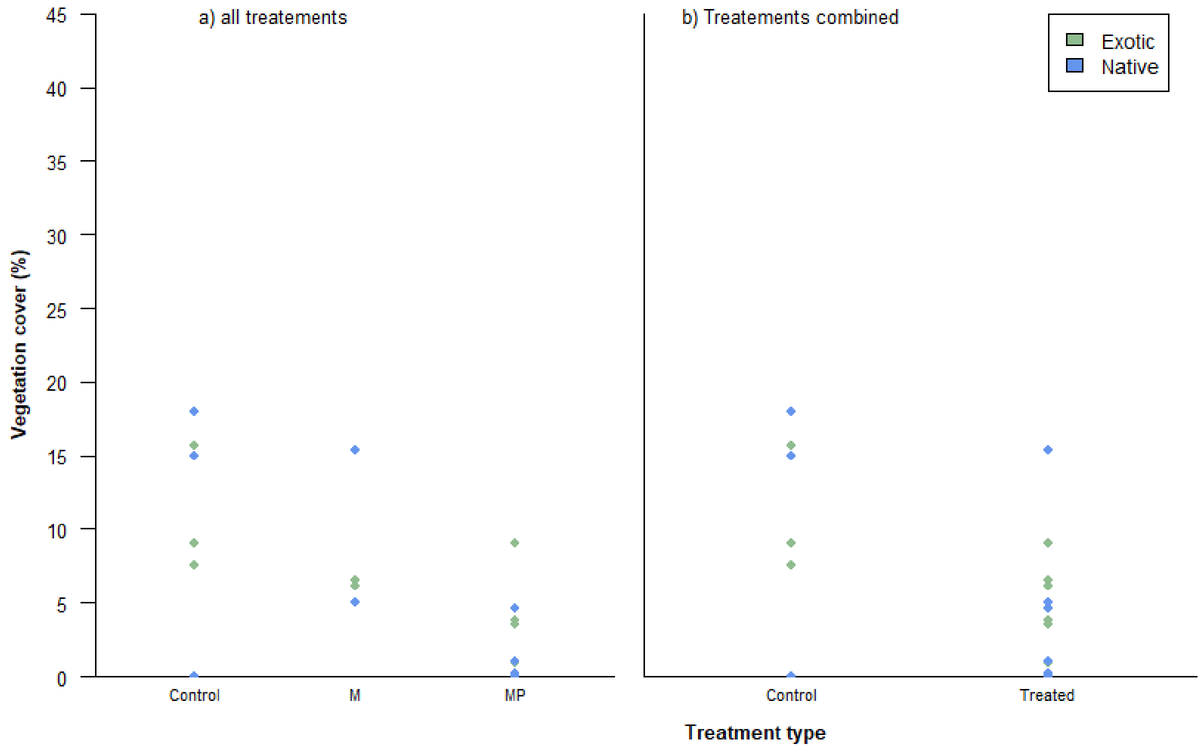


Figure 28. Cover of exotic and native species (%) per plot sampled in a) controls and each treatment type, and b) all treated plots combined in MW1708 and MW1709 polygons (combined) in 2019.

Cover of native and exotic species was similar between the control plots and the treatment plots in 2019 (Figure 28), and so no significant differences in cover of native species between control and treated plots were detected (all combined, p>0.05 or 0.1). Native species common horsetail was the dominant species in control and treatment sub-polygons (Table 14).

Table 14. Summary of species found in the control and treated sub-polygons of MW1708 and MW1709 combined (50 m^2 plots; T=trace <0.01).

		Control (n=3)			Treatments (combined, n=6)		
Species	Origin	Cover (Ave, %)	Frequency per polygon (%)	% Comp.	Cover (Ave, %)	Frequency per polygon (%)	% Comp.
Equisetum arvense	Native	11	67	51	3.9	67	42
Calamagrostis canadensis[2]		0.02	33	T	0.005	33	T
Potentilla rivalis		0.0003	33	T	0.02	67	T
Achillea millefolium		0.00003	33	T	0.0003	17	T
Collomia linearis		0.00003	33	T	0.002	67	T
Erysimum cheiranthoides		0.00003	33	T	0	0	0
Lepidium densiflorum		0.00003	33	T	0	0	0
Amsinckia lycopsoides		0	0	0	0.03	33	T
Mentzelia albicaulis		0	0	0	0.04	33	T
Plagiobothrys scouleri		0	0	0	0.0003	33	T
Elymus canadensis[1]		0	0	0	0.14	33	1
Epilobium ciliatum		0	0	0	0.0002	17	T
Hordeum jubatum[2]		0	0	0	0.02	50	T
Poa palustris		0	0	0	0.0002	17	T
Populus balsamifera[1]		0	0	0	0.2	17	2
Trifolium repens	Exotic	7.3	100	34	2.5	100	27
Elytrigia repens		1.6	100	7	0.75	67	8
Centaurea stoebe		1.2	33	5	0.0002	17	T
Poa compressa		0.3	100	1	0.4	67	4
Linaria vulgaris		0.1	67	T	0.002	17	T
Verbascum thapsus		0.07	100	T	1	83	11
Trifolium pratense		0.04	67	T	0	0	0
Filago arvense		0.02	33	T	0.0002	17	T
Potentilla argentea		0.003	33	T	0	0	0
Silene latifolia		0.003	33	T	0.0005	17	T
Medicago lupulina		0.0007	33	T	0.3	67	3

Melilotus alba		0.0003	33	T	0.005	33	T
Sisymbrium altissimum		0.0003	33	T	0.0005	50	T
Tragopogon dubius		0.0003	33	T	0	0	0

[1]Planted, [2]some planted

4.7 Summary Analysis

4.7.1 Overview

Generally, each treatment sub-polygon had greater species richness than its associated control sub-polygon. Treatment sub-polygons also had a greater number of perennial species than in control sub-polygons (Figure 29). The potential for long-term establishment of native vegetation appears thus greater in the treatment sub-polygons. The oldest treatment sub-polygon monitored was 3 years-old (PLG16-01, -04, and -05, treated in 2016). The remainder of the sub-polygons were two years-old with some repeated treatments performed in 2019.

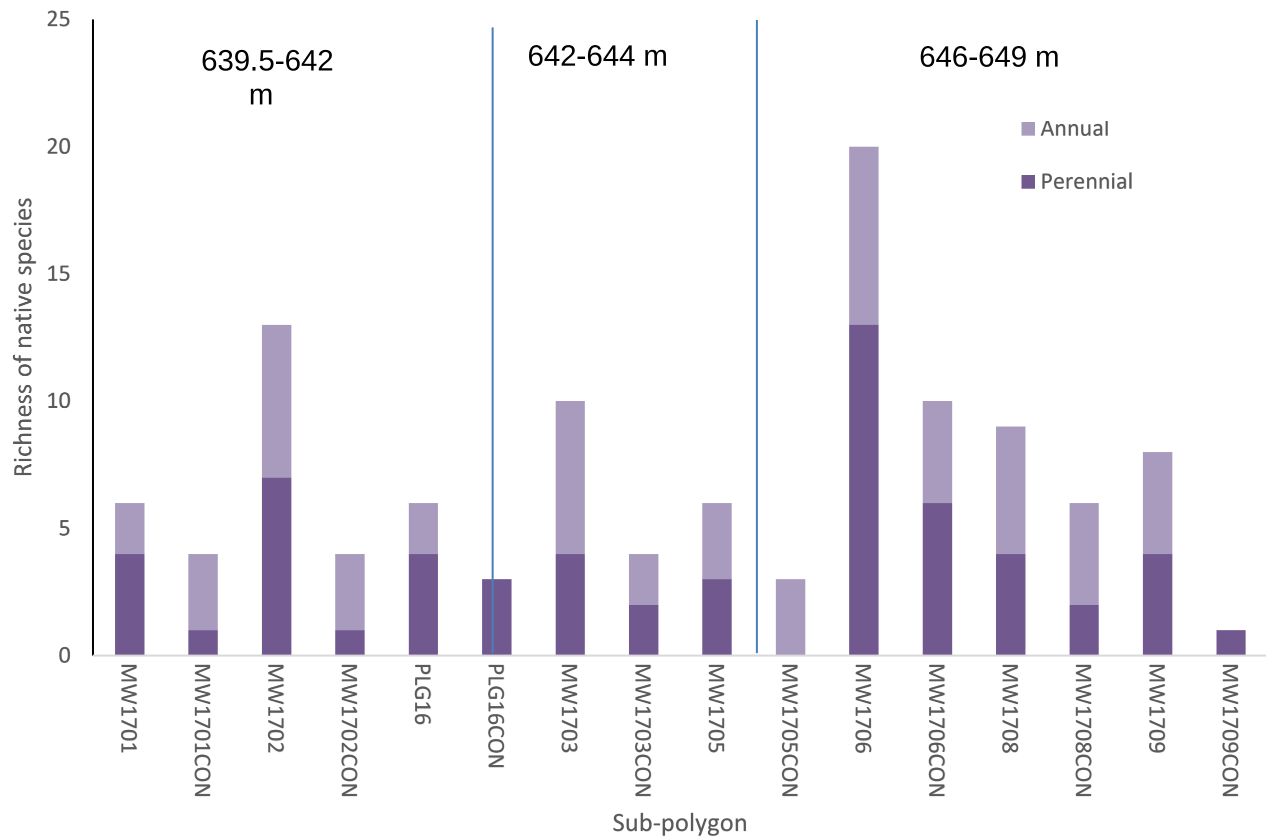


Figure 29. Richness (number) of native species recorded in treatment and control sub-polygons monitored in 2019 (PLG16= PLG1601, 04 and 05).

4.7.2 Multivariate modelling

Regression trees predicted the cover of native species based on a series of site and environmental variables. Results show that the cover of native species was higher (ave of 35.5%) in GCFW and MMF quadrats (MMF quadrats were the only reference quadrats) that had less than 2% of rock cover (Figure 30). Cover of native species was also high in machine-planted quadrats of GCFE and LMF terrain that were smooth, with mineral soil between lower than 97%, and less than 11% of rocks. Control and machine-worked quadrats with smooth terrain were the quadrats with the lowest cover of native species. Thus, the model does not indicate any improvement in native species cover in mounded treatments.

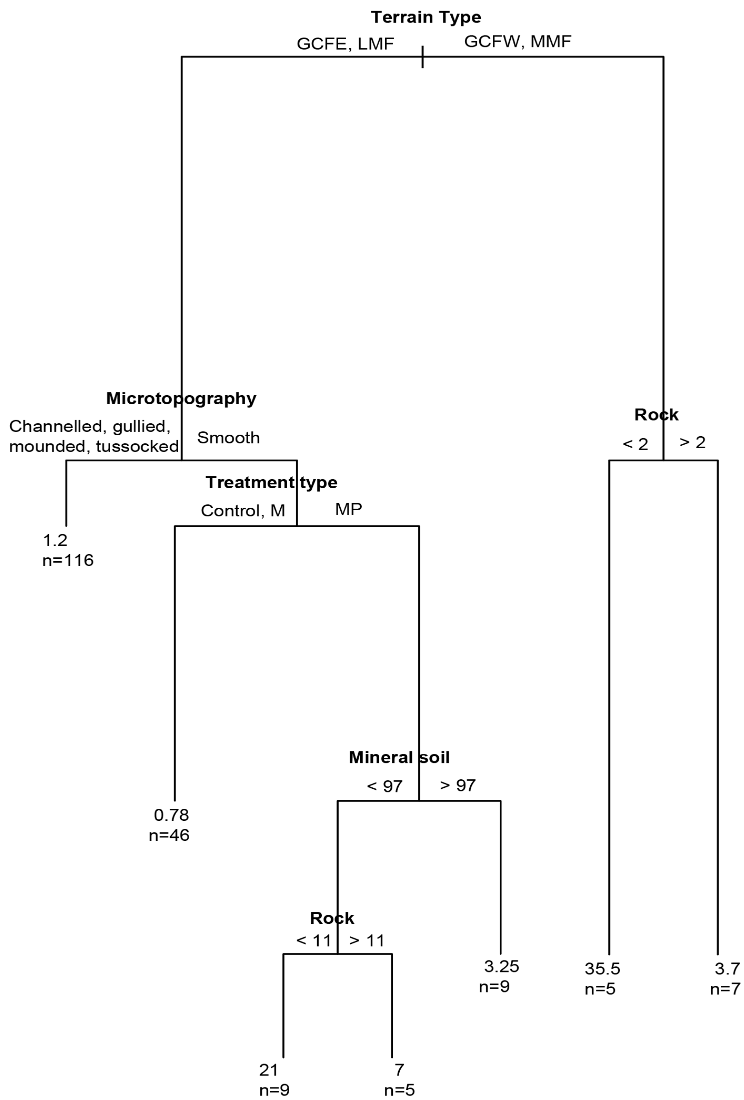


Figure 30.   Regression tree showing the environmental variables important in partitioning the quadrats based on native species cover (detailed treatment types). Numbers at the terminal leaves

are average cover of native species and number of quadrats constituting the leaf. The length of the branches approximates the proportion of total sum of squares explained by each split. The R2 of the tree was 0.67.

The same environmental variables were included in a multivariate regression tree to look at species composition and indicator species. Results show that elevation played a big role in splitting quadrats based on species composition (elevation is a proxy/confounded with size of quadrats since the 1m2 were at low elevation and the 50m2 quadrats were at high elevation) (Figure 31). The tree explained 40% of the variation in species composition. Table 15 shows the species indicative of each leaf. For example, Kellogg's sedge (CAREKEL) was the indicator species for quadrats located at less than 641.5m of elevation, in channelled, gullied or smooth quadrats, and that were machine-planted (leaf 8).

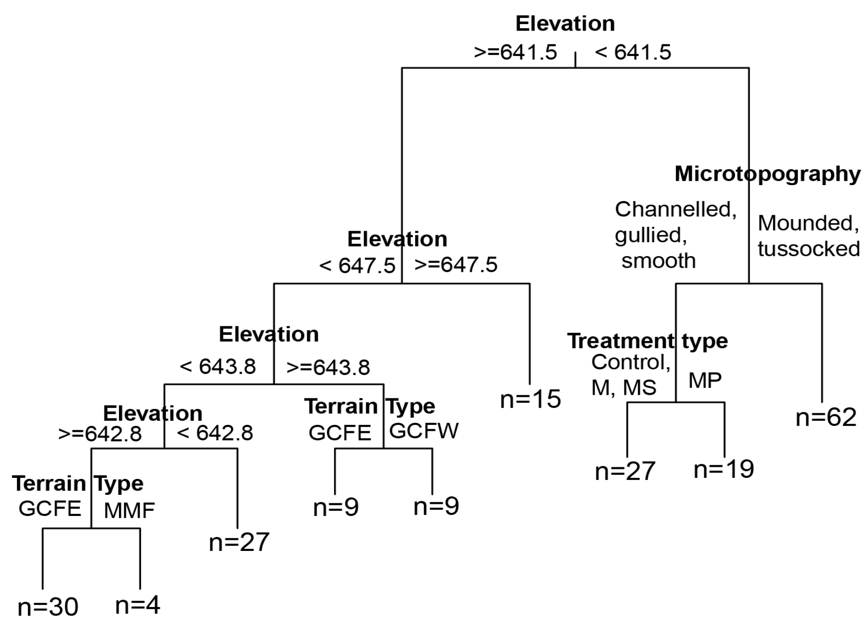


Figure 31. Multivariate regression tree showing the environmental variables important in partitioning the quadrats based on species compositions. Numbers at the terminal leaves are number of quadrats constituting the leaf. The length of the branches approximates the proportion of total sum of squares explained by each split. The R2 of the tree was 0.40.

Table 15. Indicator species for each leaf (read left to right) of the multivariate regression tree.

Leaf	Species	Indval	p-value
1	LEPIDEN	0.43	0.005
2	EQUIPAL	0.9996	0.001
	CALACAN	0.53	0.002
3	--	--	--
4	--	--	--
5	TRIFREP	0.61	0.001
	EQUIARV	0.51	0.001
	ELYTREP	0.47	0.002
	VERBTHA	0.38	0.003
	LINAVUL	0.33	0.001
	MEDILUP	0.27	0.012
	ELYMCAN	0.19	0.03
6	MELIALB	0.57	0.001
	CREPOCC	0.47	0.001
	TARAOFF	0.4	0.002
	POTEARG	0.39	0.003
	EPILCIL	0.35	0.006
	ERIGCOM	0.33	0.004
	COLLLIN	0.27	0.012
	PINUPON	0.26	0.004
	RUMETRI	0.2	0.037
7	SPERRUB	0.26	0.001
	CHENALB	0.23	0.018
8	CAREKEL	0.3	0.007
9	PERSMAC	0.35	0.005
	POLYAVI	0.33	0.001
	RORIPAL	0.22	0.03

4.8 Biomass Sampling

Sampling of biomass from 2018 and 2019 were combined to provide comparison of standing crop in reference, control, and seeding and planting treatments sub-polygons. Standing crop in control sub-polygons of the LMF terrain represents pre-treatment or no treatment conditions. Biomass was low in control and fall-rye-seeded sub-polygons and highest in reference and planted sub-polygons (Figure 32). For example, control and fall-rye-seeded sub-polygons typically yielded <200kg/ha whereas some quadrats in areas of excellent vigor (e.g. in polygon PLG1601) produced over 3000kg/ha, for an average of 1500kg/ha over the planted sub-polygons (Figure 33). Biomass in the reference quadrats (MMF04) averaged around 1700kg/ha. In one year under optimum growth conditions, planted Kellogg's sedge were able to produce nearly as much biomass as that sampled in the upstream reference sub-polygon. Biomass samples across reference and control sub-polygons were fairly similar while biomass in planted sub-polygons showed a broad range of values, survival and vigor was patchy.

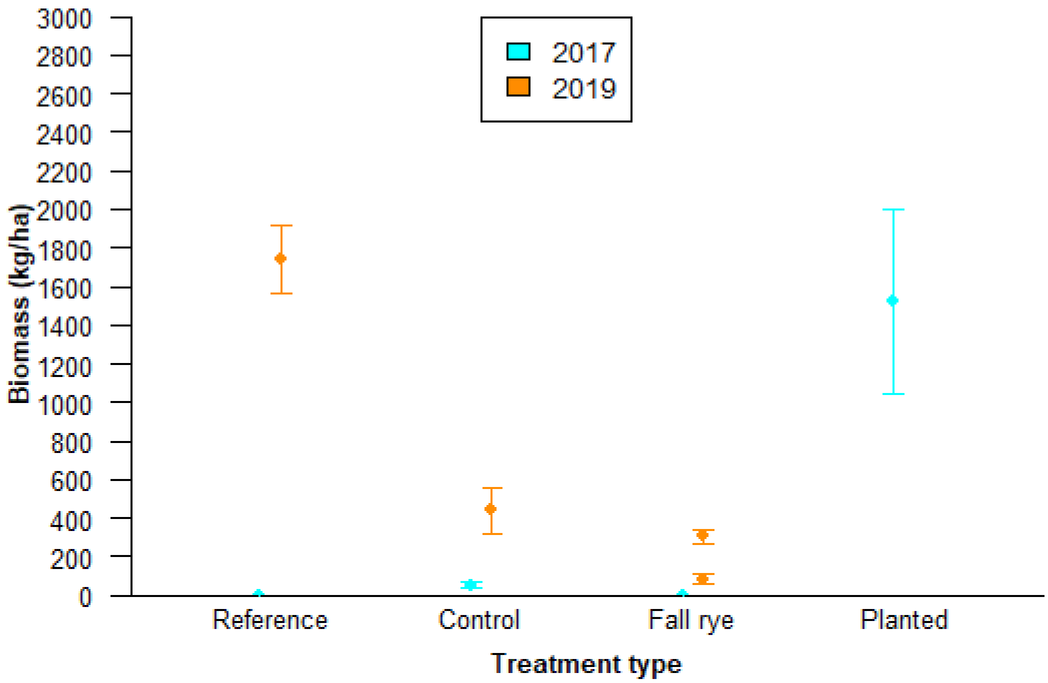


Figure 32. Average biomass (kg/ha) of vegetation sampled in reference quadrats (only in 2019), control quadrats, quadrats planted with fall rye (only in 2019), and planted quadrats in 2017 and 2019.Error bars are standard deviations.

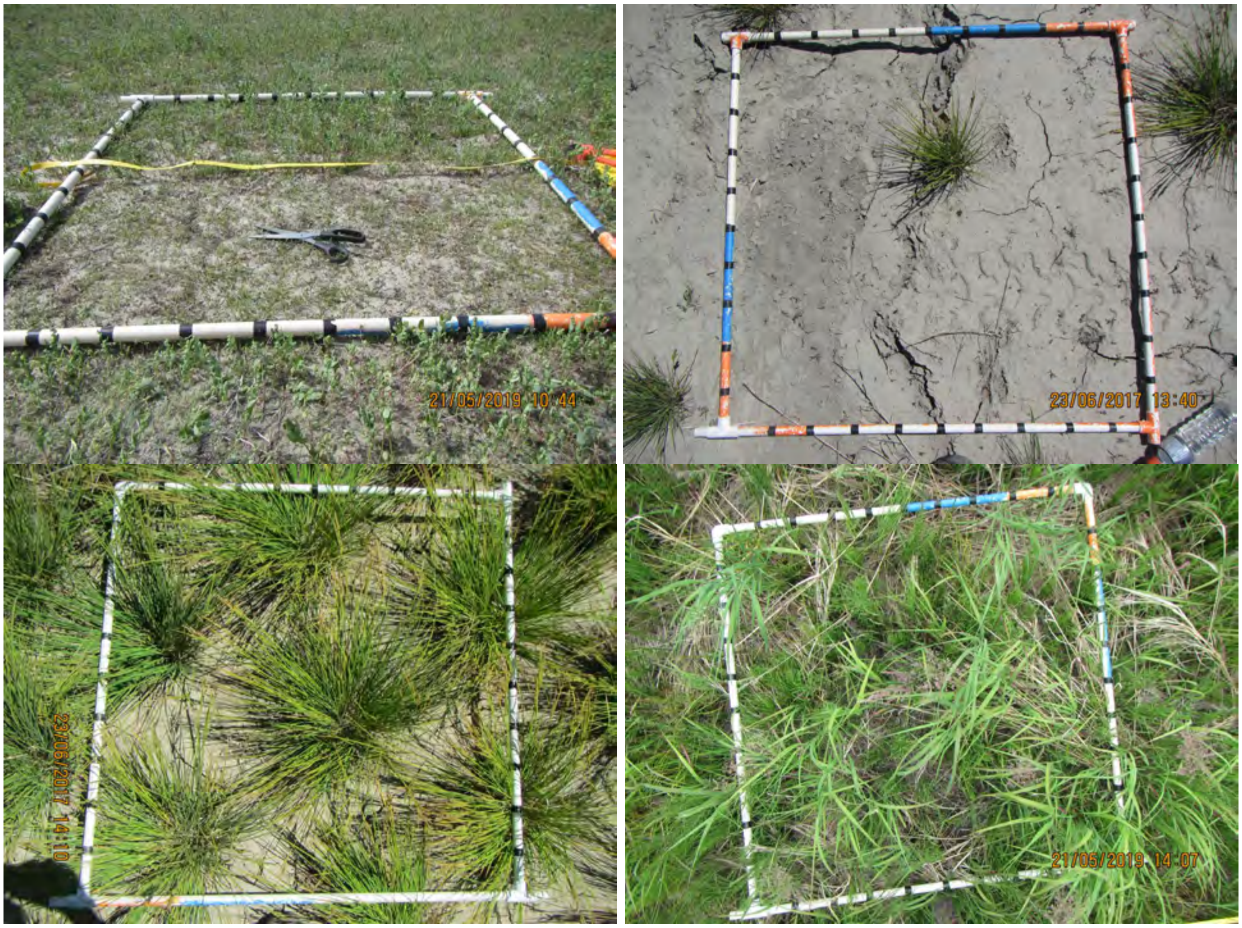


Figure 33. Examples of biomass sampled in various sub-polygons in 2019: top left, in control quadrats of LMF terrain (ave. 250 kg/ha); top right, in planted quadrats from 2017 (PLG1601, 65 kg/ha); bottom left, in planted quadrat of good vigor (PLG1601, 1500 kg/ha); bottom right, in the reference quadrats from MMF04 (1700 kg/ha).

4.9 Investigating patchiness in planting success (polygon PLG1601)

Soil physical characteristics were sampled in polygons PLG1601, PLG1604 and PLG1605 (Map 5) to investigate reasons behind observed variability in treatment success. These polygons where planted with Kellogg's sedge plugs in 2016. Monitoring in 2018 indicated good establishment, growth, and seed and seedling production from the planted sedges in these polygons (Scholz and Gibeau, 2019). However, distinct patches where sedges showed poor or no survival were also evident, particularly in PLG1601 (Figure 34).

Soil pits and hand texturing revealed substrate was predominantly mineral soils composed of lacustrine silt deposits overlying fluvial sands and gravels. Soil pits dug within patches with dissimilar vigor (based on vigor class of excellent (4), poor (1) or dead (0) (B.C. MoFR, MOE, 2010)), revealed no organic horizons. A homogenous, distinct upper mineral soil horizon of fine lacustrine deposits (B1) layer on top of fluvial deposits of coarse sands and gravels (B2) (Figure 35). The texture of the B1 layer was consistently a silt loam, while the B2 layer was very coarse sands and gravel. The depth of the B1 silt layer varied. Thickness of the silt loam deposits in areas of poor survival were relatively shallow (12cm-22 cm), while in the areas where plant vigor was excellent, soil depth ranged 52-54 cm. Plant vigor was consistently higher in deeper soils (Figure 36). Vegetation cover among patches in treatment polygon PLG16-01 was also greater in deeper soils (Figure 37). Vegetation cover (almost exclusively planted Kellogg's sedge) when soils were deeper than 40 cm was more than double that in shallower soils. There was limited survival of planted sedges when silt layers were less than 30 cm deep.

Figure 34. Patch with poor survival in centre and excellent sedge survival on either side (PLG1601, 2019).

Figure 35. Example of test soil pit with piles of lighter coloured, fine silts on left next to deeper layer coarse sand gravels on right (PLG1601, 2019).

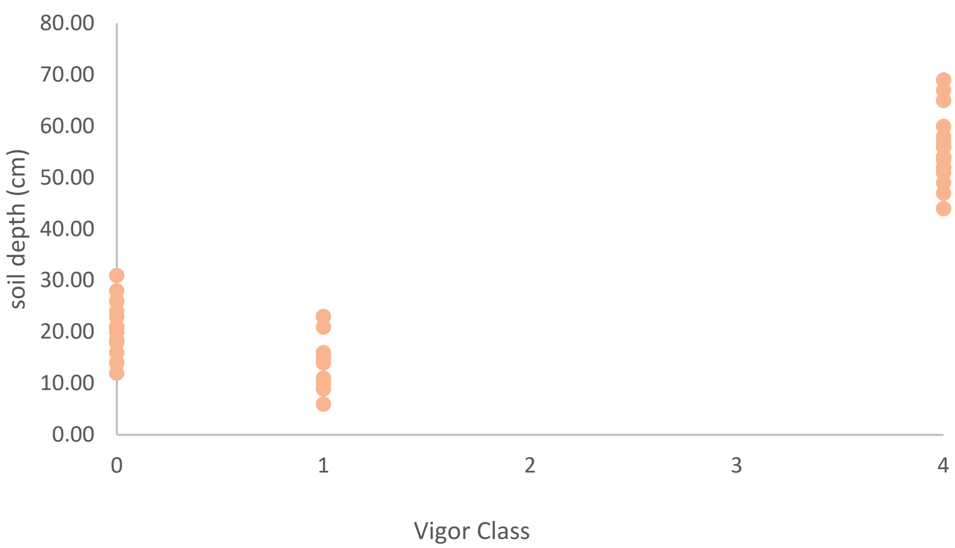


Figure 36. Soil depth (cm) in relation to vegetation vigor (0=dead, 1= poor 2= fair, 3= good, 4= excellent), in polygon PLG1601 in 2019.

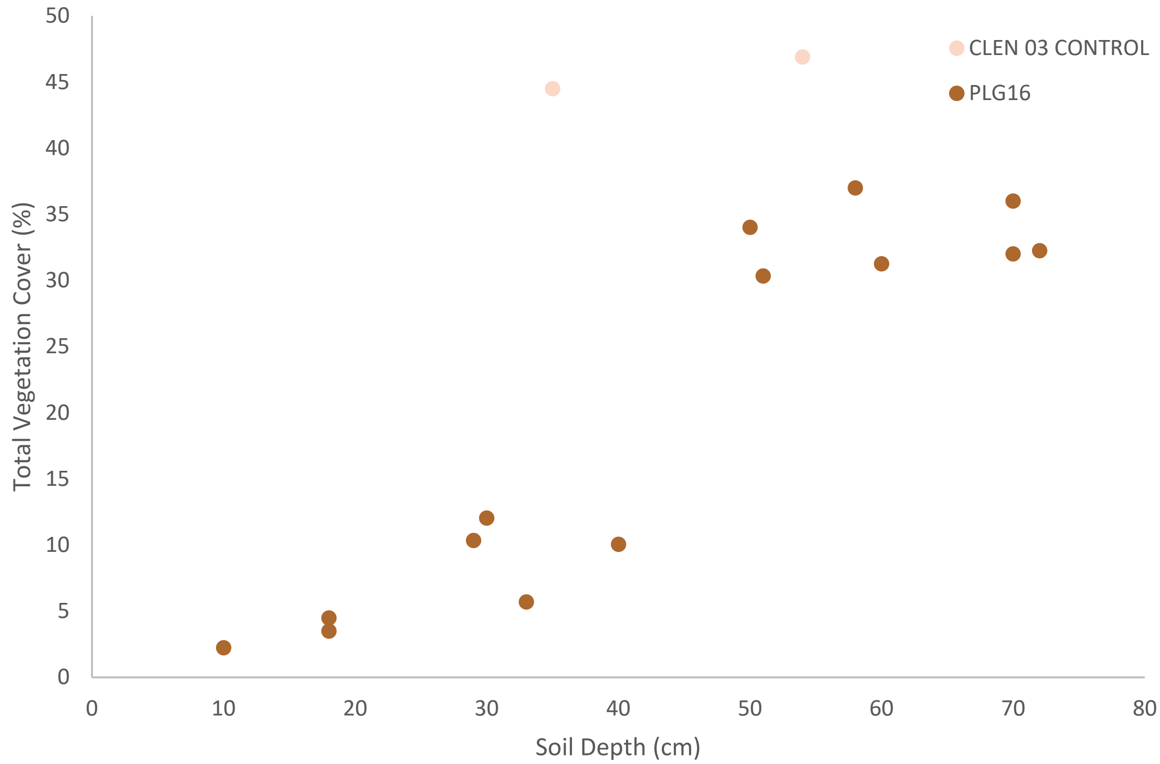


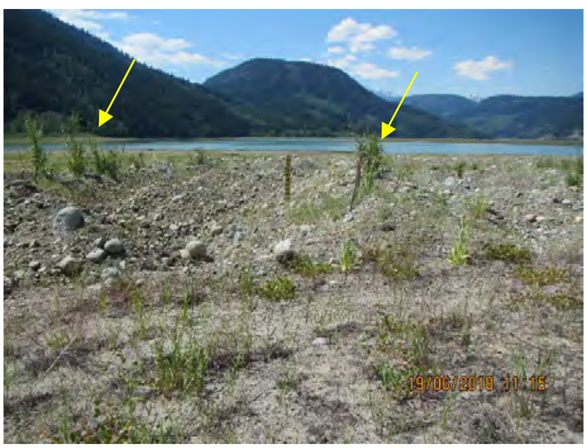
Figure 37. Total vegetation cover (%) in relation to soil depth (cm) in quadrats of sub-polygons PLG16-01, PLG16-04, PLG16-05 and in control quadrats of polygon CLEN-03. Both values of soil depth and vegetation cover were relatively high in control quadrats (CLEN03), vegetation cover was primarily a dense growth of annual exotic species. Conversely, perennial native species (planted Kellogg's sedge) dominated the treatment sub-polygons of PLG16.

4.10 Overview of other treatments (Bluejoint planting and live-stake cuttings)

2019 monitoring indicated rates of survival of live-stake cuttings planted in conjunction with machine-mounding between 30 and 60% after two years. This was a higher success rate than for cuttings planted by machine in non mounded sites in 2014 (Scholz and Gibeau, 2019) (Table 16). Vigor was good to excellent among most live-stake cuttings in mounded polygons (Figure 38). As discussed in the 2018 report, the third year since planting is when confirmation of the survival of live-stake cuttings is more certain.

Table 16. Survival (%) of live-stake cuttings in mounded polygons on Gun Creek Fan West in 2018 and 2019.

Sub-polygon	Survival in 2018 (year 1, %)	Survival in 2019 (year 2, %)	Note
MW1710MPC	--	32	Not measured in 2018
MW1708MC	73	49	Decline of 24%
MW1709MPC	57	59	Increase of 2%



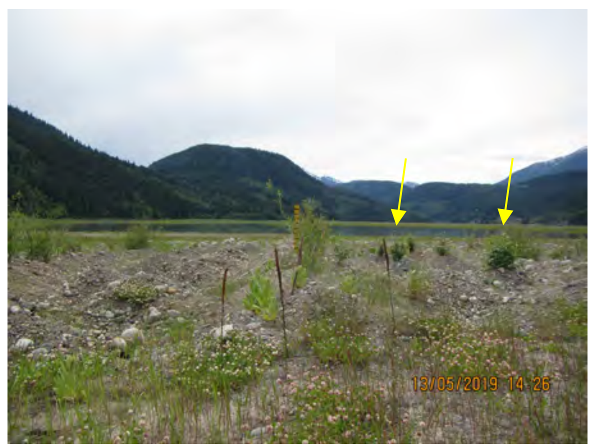


Figure 38. Example of survival of two rows of willow (*Salix sp.*) live-stake cuttings (shown by arrows) in 2018 (left) and (polygon MW1709mpc in Gun Creek Fan West). Note the darker growth in June 2019 (right) is due to excellent growth of cottonwood (yellow arrows) that were planted as rooted container plants (note placement of metre board shifts by about 2m).Polygons planted with bluejoint plugs had mixed results. Cover and survival of planted vegetation was very low in polygons BJ1601and HH16 as compared with GG16 (Table 17, Figure 39). Bluejoint plants survived at each polygon, but vigor was poor with plants definitely struggling at BJ1601. Bluejoint plants at GG16 had the best vigor as well as higher richness of native and exotic species.

Table 17.   Summary of species found in treated polygons BJ1601 (50 m²), GG16 (1m²), and HH16 (1m²) (T=trace <0.01).

Species	Origin	BJ1601 (n=1)			GG16 (n=6)			HH16 (n=3)		
		Cover (ave, %)	Freq (%)	% Comp.	Cover (ave, %)	Freq (%)	% Comp.	Cover (ave, %)	Freq (%)	% Comp.
Achillea millefolium	Native	1.5	100	7	0	0	0	0	0	0
Calamagrostis canadensis	Native	0.1	100	T	9	100	30	2	67	68
Carex kelloggii	Native	0	0	0	0.01	17	T	0	0	0
Collomia linearis	Native	0.01	100	T	0	0	0	0	0	0
Epilobium ciliatum	Native	0.001	100	T	0	0	0	0	0	0
Equisetum arvense	Native	0	0	0	9	33	30	0	0	0
Hordeum jubatum	Native	5	100	24	2	83	7	0	0	0
Plagiobothrys scouleri	Native	0.001	100	T	0	0	0	0	0	0
Potentilla rivalis	Native	0	0	0	0.5	17	2	0	0	0
Rorippa palustris	Native	0	0	0	0.1	33	T	0	0	0
Chenopodium album	Exotic	0	0	0	0.001	17	T	0.001	33	T
Elytrigia repens	Exotic	0	0	0	0.7	67	2	0	0	0
Filago arvense	Exotic	0.01	100	T	0	0	0	0	0	0
Leucanthemum vulgare	Exotic	0.01	100	T	0	0	0	0	0	0
Matricaria discoidea	Exotic	0.001	100	T	0.0001	33	T	0	0	0

Species	Origin	BJ1601 (n=1)			GG16 (n=6)			HH16 (n=3)		
		Cover (ave, %)	Freq (%)	% Comp.	Cover (ave, %)	Freq (%)	% Comp.	Cover (ave, %)	Freq (%)	% Comp.
Medicago lupulina		0.01	100	T	0	0	0	0	0	0
Melilotus alba		0.001	100	T	2	67	8	1	67	25
Persicaria maculosa		0	0	0	0.0001	17	T	0	0	0
Poa compressa		15	100	94	2	17	6	0.1	67	4
Polygonum aviculare		0	0	0	0.0001	50	T	0	0	0
Potentilla argentea		0.01	100	T	0	0	0	0	0	0
Rumex crispus		0	0	0	0	0	0	0.1	33	3
Sisymbrium altissimum		0	0	0	0.001	33	T	0	0	0
Spergularia rubra		0.001	100	T	0.0001	17	T	0	0	0
Taraxacum officinale		0.03	100	3	0	0	0	0	0	0
Trifolium pratense		0	0	0	2.5	17	8	0	0	0
Trifolium repens		1	100	100	2	67	6	0	0	0
Total Richness		16			17			5		

Figure 39. Images of the polygons planted with bluejoint reedgrass (top left: GG16, top right: HH16, lower left: BJ1601).

5.0 Discussion

It was evident from the mid-term comprehensive report in 2018 that more time was required to better assess the effects of the 2017 treatments, and thus no treatments under BRGWORKS-1 were carried out in 2018. The monitoring for BRGMON-2 in 2019 focused on assessing the areas where intensive riparian enhancement treatments were implemented in 2017 on the Low Mud Flat (LMF), Gun Creek Fan East (GCFE), and Gun Creek Fan West (GCFW) terrains. The objective in 2019 was to assess vegetation characteristics in treatment, control and reference polygons to answer the management question:

Does the implementation of a short term (7 year) intensive reservoir riparian enhancement program expand the quality (as measured by diversity, distribution, and vigour) and quantity (as measured by cover, abundance and biomass) of riparian habitats in the drawdown zone of the Carpenter Reservoir.

We discuss below the results from the monitoring of vegetation performed in the drawdown zone of Carpenter Reservoir in 2019 by addressing each of the null hypothesis.

H3A: There is no significant difference in ***native vegetation establishmen****t (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.*

Native vegetation includes annuals and perennial species. Both types of species provide ecosystem functions, but it is assumed that perennial native species provide greater long-term ecological, aesthetic and dust control benefits. Consequently, increasing the cover and abundance of perennial native species has been the primary objective of the BRGWORKS-1 program. Our results from the 2019 monitoring show that both native annual and perennial species tended to colonize in higher numbers in treatment than in control sub-polygons. The cover of perennial native species was higher in treatment sub-polygons due to the planting of Kellogg's sedge at low elevations, of grasses at mid elevations, and of shrubs and trees at upper elevations.

The monitoring of a reference transect (MMF04) in 2019 revealed the presence of only perennial native species (bluejoint reedgrass, marsh horsetail and Kellogg's sedge). When we look at photos of that transect taken in 2013 (Scholz and Gibeau, 2014), we notice a greater diversity of species in 2013 than in 2019, though not all were native species (Figure 40). It appears from the photo-monitoring that bluejoint has increased in cover over horsetail across the transect. This shift may be a response to recent, relatively longer growing seasons and drier conditions. Although the management of the water levels in Carpenter Reservoir has not varied outside of the operating parameters stated in the water use license (BC Hydro, 2011), the timing of low pool and full pool over the past three years hovered around the 90th percentile relative to the past 18 years of management (Figure 2). Despite the changes since 2013, the MMF04 reference transect had an undeniable aesthetically pleasing appearance in 2019 with its vast expanse of green. Ecological function included ample rodent habitat, evidenced by scat, tunneling, and burrowing, that resulted in a rare observation of mineral soil on the site (Figure 41). The mineral soil excavated by rodents may create unique micro-sites where vegetation could diversify. Presence of rodents also means that the area is producing prey species for a plethora of predator species. Moreover, organic matter (largely decomposing bluejoint leaves) covered 100% of the substrate and prevented wind erosion. The continuous vegetation growth also likely limits water erosion, thus fulfilling two objectives (erosion control and aesthetics) of the BRGWORKS-1 program (BC Hydro, 2017b).

We note that conditions in polygons PLG16-01, -04, and -05 three years post-treatment correspond to some of the values noted in the reference transect (i.e. the target for treatments in LMF terrain for BRGWORKS-1). For example, it appears that treatments in those polygons enhanced the establishment of native vegetation (Kellogg's sedge), cover by native species, plant vigor and biomass. Colonization was also enhanced as seedlings produced from planted sedges were observed surviving into their second year in dense patches (Figure 42). We also observed a spotted sandpiper (*Actitis macularius*) nest with hatched egg shells, indicating successful nesting habitat was provided by the revegetation project (Figure 41).

Figure 40. Images of reference transect MMF04 taken in 2013 (left) and 2019 (right).

Figure 41. Image of exposed mineral soil from rodent excavations along transect MMF04 (June 21, 2019, left); spotted sandpiper nest with hatched eggshells (right, treatment polygon PLG16-04, June 12, 2019; note that date settings on camera were off by one month).

Figure 42. Example of organic litter layer development, and seedlings both arising from mature planted Kellogg's sedge plants in 2016 revegetation treatment PLG1601.

Perennial native species naturally recruited in polygons MW1701 and MW1702 in LMF terrain included grasses foxtail barley, bluejoint reedgrass; Kellogg's and small winged sedges, marsh horsetail and infrequently, herb broad leaved willowherb. Kellogg's sedge was largely only detected where mounding treatments were combined with either seeding or planting revegetation treatments.

Douglas-fir seedlings were repeatedly observed throughout all treatment polygons. Douglas-fir was the pre-dominantly observed native perennial tree/shrub species. It was obvious that 2018 was a mast production year for Douglas-fir seeds, resulting in the ubiquitous observation of seedlings, including on the LMF but also throughout the entire study area. Douglas-fir is flood intolerant and seedlings will not survive long in the drawdown zone, nor will the few observed seedlings of choke cherry and shrubby penstemon. However, a pulse recruitment of Douglas-fir may occur in the upper buffer zone of the reservoir resulting from this high production year.

Seedlings of black cottonwood were also surviving in low elevations (639.5-641 m) of polygons MW1701 and MW1702. At both polygons, these plants were accidental plantings of 'hitchhikers' on plugs of Kellogg's sedge. It is expected that these cottonwoods will not survive the inevitable future extended flooding expected at these elevations. It will however be interesting to observe the survival and conditions of these individuals in the final year of this monitoring program (2021). Given the observed survival of cottonwood at low elevations, it may be worth including intentional plantings of both cottonwood and willow seedlings into low elevation (641-642 m) machine-worked areas treated in 2019. It could be that these lower elevations support shrub and tree establishment while experiencing the period of 'favourable' growing conditions during modified operations, which allowed for slightly longer growing season at LMF elevations and no inundation at upper drawdown and buffer zone elevations. If the observed lower drafting and later filling pattern is related to modified operations on Downton Reservoir, these conditions may continue for the next 10-15 years. This management pattern could have a beneficial effect for vegetation establishment in the upper drawdown elevations, thus complimenting (or perhaps confounding) monitoring results of riparian enhancements.

While diversity in native annual and perennial species was higher in treated LMF polygons, diversity of exotic species was also higher than in control sub-polygons. Colonizing species included exotic perennial species quack grass, clover species (*Trifolium pratense*, *T. repens*), and Timothy. White sweetclover was also observed at low elevations. Of these species, quack grass is perhaps most concerning at low elevations as it is an aggressive, rhizomatous species of grass that could dominate the drawdown zone. Occurrence of quack grass in 2019 was still low. Quack grass and clover were dominant species on the GCFW treatment and control polygons. At upper elevations Melilotus alba and Centaurea stoebe may be of high concern both with known allelopathic characteristics (Rice, 1984).

Results in polygon MW1703, which had coarser substrate and slightly higher elevations (642-643 m), were similar to those in polygons at lower elevations. For example, all vegetation cover was low in both treatment and control sub-polygons, but the number of species found in treatment sub-polygons was greater than in controls. Most desirable native perennial species were observed in treatment sub-polygons and were a result of being planted. Observations suggest that machine mounding plus revegetation treatments increased occurrence of native perennial species, at least in the short-term. As the soils and substrate increased in coarseness with elevation, cover of species remained very low. The presence of desirable perennial native species in MW 1706 upper drawdown appeared almost exclusively due to planting. Species richness was the highest at the highest elevation treatments on the GCFE (polygon MW1706, 646-649 m), though vegetation cover remained very low. Native perennial grass, shrub and tree species detected in upper treatment polygons were all planted.

Native species with potential restoration application to provide cover and biomass, reasonable potential for seed collection, and with best observed survival at treatment elevations , appear in Table 18. These species were growing in dense enough patches or with high production per plant, making seed collection more efficient. We assume that these species have the potential to increase in cover and importance in the riparian drawdown zone over time, and that this growth could be enhanced by restoration treatments including physical works and revegetation.

Table 18. List of native species with high restoration potential (*G =grass, Ha =annual herb, Hp= perennial herb, S =shrub, T =tree).*

Species	TYPE	Mid elevation (639-644 m)	Upper elevations (644-648 m)	Buffer zone (648-651 m)
Poa palustris	G	X	X	
Hordeum jubatum	G	X	X	X
Calamagrostis canadensis	G	X	X	X
Rorippa palustris	Ha	X		
Potentilla rivalis	Ha	X	X	X
Lotus denticulatus	Ha	X	X	X
Equisetum palustre	Hp	X		
Equisetum arvense	Hp	X		
Epilobium latifolium	Hp	X		
Salix bebbiana	S	X	X	X
Carex microptera	S	X		
Carex kelloggii	S	X	X	X
Populus balsamifera	T	X	X	X
Elymus glaucus	G		X	X
Elymus canadensis	G		X	X
Lepidium densiflorum	Ha			X
Rumex triangulivalvis	Hp		X	X
Erigeron compositus	Hp			X
Crepis occidentalis	Hp			X
Alnus viridis	S			X
Alnus incana	S			X

Pinus ponderosa	T	X

H3B: There is no significant difference in the ***cover of native vegetation*** *in control versus treatment locations.*

In most treatment polygons, the cover of native vegetation remains low (often <5%) two years post-treatments. Sampling in the reference polygon represented by MMF04 revealed total average vegetation cover around 40 per cent and 100% substrate cover by organics. Treated polygons PLG1601, -04 and -05 came closest to the reference target with an average of 14% cover in native vegetation but ranging as high 30% in plots with deeper soils (Figure 43). Though vegetation covers were typically low in both treatment and control sub-polygons, statistically significant higher cover in native species was observed in LMF polygons MW1701, MW1702, and PLG16-01, PLG16-04, PLG16-05, as compared to their respective controls. At mid elevations (polygons MW1703, MW1705) we observed statistically higher cover of native species where planting was combined with machine treatments, than in control sub-polygons. At upper elevations, no statistically significant differences in cover were observed two years post-treatment. An encouraging trend is the survival of planted cottonwood, willow and pine from 2017, though prior monitoring showed that plant survival declined in the second and, especially, third year post-treatments so far (Scholz and Gibeau, 2019). Declines in survival seemed to be less pronounced in mounding treatments. If perennial native species survive through 2020 in these upper polygons, it is likely native vegetation will be established. Cover of vegetation will then likely rise above that of the control polygons as shrub, and eventually tree layers, develop.

Figure 43. Images of areas producing comparable cover, standing crop, and native species dominance; reference transect MMF04 on left, and treated polygon PLG1601 on right.

H3C: There is no significant difference in ***native vegetation establishment and the cover of native vegetation communities*** *(based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.*

As discussed, species richness increased in treatment polygons and native vegetation cover is higher particularly in treatments at low to mid elevations. There are examples of biomass, vigor, diversity, and distribution of native species expanding and improving across different treatments. The crux of the question is to define what is ‘significant’. At the time of the 2019 monitoring, it appears that the treatments in polygons PLG16 were the best examples of success. Of ecological significance is the observed successful use of the restored/created habitat for nesting by spotted sandpiper. The gaps in vegetation cover observed in PLG1601 appear to relate to substrate depth. In theory, mounding treatments should mitigate soil depth as a limiting factor by mixing and de-compacting soils. An attempt to analyse mounded treatments to explore where the most beneficial microsites were located for successful establishment of desirable perennial native species failed to show any correlation with microsite conditions, likely due to low sample sizes (results not showed). This supports observations in the field that yielded no obvious pattern as to what microsite conditions lead to plants surviving or dying. Mounding and planting increased the establishment of native perennial species, and we expect vegetation cover to increase with time. Given monitoring has only covered two years post mounding treatments, it is difficult to predict how significant native vegetation establishment and cover will be in the future. We may hypothesize that both will increase over time, especially if water level patterns continue to extend growing season as it has in the past three years. Ecologically significant observations included multiple incidental records of juvenile wandering terrestrial garter snakes (*Thamnophis elegans vagrans*) observed in MW1701 in early June. This implies there is some habitat being created in the mounded microsites. Western toad (*Anaxyrus boreas*) toadlets were observed earlier in the year in polygons MW1702 and MW1701 (Figure 44). It is possible that pools formed at the base of mounds in the treatment MW1701 and MW1702 polygons provided reproductive habitat for Western toads. By extension we may hypothesize that the garter snakes were drawn to the site to prey on toadlets. If the latter proves true, 2020 treatments may want to include provision of some connectivity between treatment areas and the Bridge River. Cover may be provided by extending fall rye seeding treatments closer to MW1701 and MW1702.

Figure 44. Presence of western toad in polygon MW1702, and example of pool found at base of mounds.

H3D: There is no significant difference in the ***species composition of naturally re-colonizing vegetation*** *in treated versus control areas.*

Monitoring two or three years-old treatments indicates a difference in species composition within treatment polygons when compared with controls. Species richness, of both exotic and native species, was consistently higher in most treatment polygons than in controls. It appears that some seed dispersal to the treatment polygons is coming from wind, water and biotic sources (e.g. in the case of prunus by birds), and through introduction via restoration treatments. We assume that there would have been little seed on site immediately post treatment in 2017. Apart from revegetation planting and seeding, wind dispersal followed by water dispersal under inundation would have brought in colonizing plants for the 2018 season. One exception was annual golden corydalis (*Corydalis aurea)* plants in treated polygon MW1702 likely originating from seed that was brought to the surface by the disturbance. Plants colonizing in 2019 would have come from seed added by wind, water and to some extend biota, from off site but also from seed generated by annual and perennial plants that colonized in 2018. With each successive year of growth, the *in-situ* seed supply should increase, which should serve to increase densities of both annual and perennial (exotic and native) species. It remains unclear whether desirable native perennial and annual species colonization will exceed that of exotic species.

Higher elevations on the Gun Creek Fan West have developed a high cover of perennial exotic species quack grass and clover. Quack grass has responded quickly from rhizomes, as did horsetail. These species were present in some of the lower elevation treatment polygons and may become more dominant at these elevations over time.

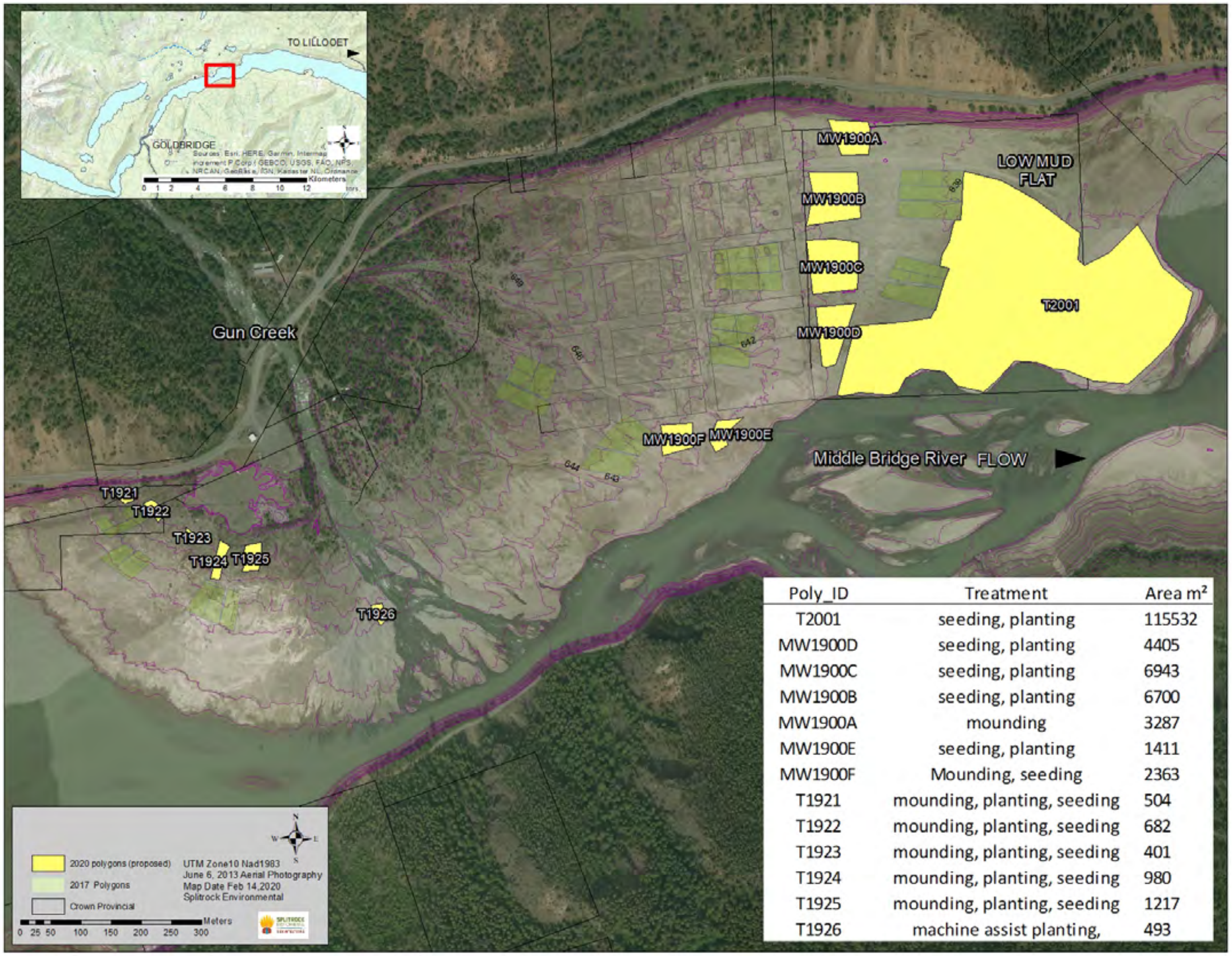
6.0 Recommendations

As there is one year left in the planned treatments under BRGWORKS-1, we recommend continuing in 2020 with the recommendations from the 2018 comprehensive report. Some treatments not completed in 2019 included machine-work mounding, and some treatments were intended to follow and build on 2019 treatments. Recommendations are summarized in Table 19.

Table 19. Recommended treatments in 2020 under BRGWORKS-1. Polygons are shown in Map 8.

Treatment	Detail	Treatment recommendations	Polygons targeted
Physical Works	Excavator Mounding	Carry out machine treatments mounding and roughening surface in polygons on Gun Creek Fan East and West side (staying outside Minto lot lines).	MW1900A, MW1900F, T1921, T1922, T1923, T1924, T1925, T1926
Seeding	Kellogg's sedge	Harvest local seed from upstream stands; process and sow directly into patches. Hand-rake seeded areas to lightly cover seed.	MW1900 A- F
	Native legume mix. meadow bird's-foot trefoil, timber milk vetch	Sow meadow bird's-foot trefoil seed in patches.	MW1900 A-F T2001
	Fall Rye	Sow fall rye seed.	T2001
Container plants	Kellogg's sedge	Plant Kellogg's sedge plugs (grown from local seed) in patches. In un-mounded areas (T2001), ensure planting sites have at minimum 40 cm depth of fine silty deposits.	MW1900A-F T2001
Container plants continued	Container shrubs and trees, Ponderosa pine, cottonwood, aspen, alder, willows	Plant container-grown plants in upper elevation polygons on GCFW.	T1921, T1922, T1923, T1924, T1925, T1926,
		Plant cottonwood and willow at 2019 treated LMF mounded polygons (100:1 mix).	MW1900 A-F

Treatment	Detail	Treatment recommendations	Polygons targeted
	bluejoint reedgrass	Plant bluejoint plugs in mix with sedge seedlings (recommending 10:1 mix sedge/bluejoint)	MW1900A-F
	Horsetails	Treatment trial patches of horsetail were planted in 2019. Assess survival early 2020; if successful, consider planting horsetail plugs as part of the lower elevation planting mix.	T1900A-F T2001
Rooted live stakes	Coyote willow	plant rooted live stakes close to Gun Creek	T1926



Poly_ID	Treatment	Area m²
T2001	seeding, planting	115532
MW1900D	seeding, planting	4405
MW1900C	seeding, planting	6943
MW1900B	seeding, planting	6700
MW1900A	mounding	3287
MW1900E	seeding, planting	1411
MW1900F	Mounding, seeding	2363
T1921	mounding, planting, seeding	504
T1922	mounding, planting, seeding	682
T1923	mounding, planting, seeding	401
T1924	mounding, planting, seeding	980
T1925	mounding, planting, seeding	1217
T1926	machine assist planting,	493

Map 8. Polygon areas proposed for treatment 2020.

7.0 Conclusion

The monitoring for BRGMON-2 in 2019 was the 5th year of assessing BRGWORKS-1 riparian enhancement treatments on Carpenter Reservoir near Gold Bridge BC. The focus of the 2019 monitoring was to assess if the treatments affected the quality and quantity of riparian habitats in the drawdown zone. Treatment and control polygons, and one reference transect, were monitored and assessed for native species colonization, establishment, cover and composition. Two years post-treatments with machine works, there is evidence that mounding combined with revegetation treatments increased species richness, and particularly native species richness. Perennial native species Kellogg's sedge continues to have the best results for establishment at low elevations (<642 m), reproducing on site from planted plants in several polygons. Slight increases in native species cover in treatment polygons suggest that density and cover will increase over time, compared to control polygons with low richness and cover of native species. Given the limited passage of time since certain treatments were imposed, recommendations for the final year of treatment are based on observations to date and include a range of treatments including physical works, seeding, and planting. We also note that treatment successes and failures are subject to weather and water management in Carpenter Reservoir. Water management in Carpenter Reservoir over the past three years has been somewhat beneficial to vegetation colonization, establishment and growth at the target restoration sites. The favourable conditions are due to a longer growing season prior to flooding relative to the previous 20 years. There should be a positive effect on vegetation establishment and growth, if the pattern of a low pool and mid to late summer inundation timing, continues under the planned period of modified operations. especially within project treatment polygons in the Carpenter Reservoir drawdown zone.

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Appendix

List of variables assessed in 1X1m² quadrats.

General:

- Date,
- Surveyor’s,

- GPS coordinates,
- Unique quadrat ID,

Site data:

- Aspect
- Slope
- General topography,
- microtopography
- Primary water source
- Substrate cover % water, rock, mineral soil, bedrock, organics, wood must total 100%

Soils:

- texture
- Coarse fragment content
- Estimate of nutrient regime
- Drainage class
- Moisture regime

Wildlife sign

Vegetation:

- Species name,
- Structural layer (D=Moss, C=herb and grass, B2=low shrub, B1=tall shrub)

- % cover of each species, Distribution within quadrat (9 categories- rare individual single occurrence, a few sporadically occurring individuals, a single patch or clump, several sporadically occurring individuals, a few patches or clumps, several well-spaced patches or clumps, continuous uniform occurrence of well-spaced individuals, continuous uniform occurrence of a species with a few gaps in distribution, continuous dense occurrence of a species).
- Density per m² (<=1, 2-5, 6-10, >10)

- Plant vigor (5 classes: 0=dead, 1= poor, 2= fair, 3= good, 4=excellent),
- Utilization (degree of browse: 0=0%, 1=1-15 %, 2= 16-36%, 3=36-65%, 4= 66-80%, 5=>80%),
- Whether individuals were planted or naturally occurring.

Notes.

Table 20. Full list of vegetation species nomenclature.

EnglishName	ScientificName	Authority	Code
yarrow	Achillea millefolium	L.	ACHIMIL
mountain alder	Alnus incana	L.	ALNUINC
alder	Alnus sp.		ALNUS
sitka alder	Alnus viridis	(Chaix) DC.	ALNUVIR
bugloss fiddleneck	Amsinckia lycopsoides	Lehm.	AMSILYC
paper birch	Betula papyrifera	Marsh.	BETUPAP
birch	Betula sp.		BETULA
bluejoint reedgrass	Calamagrostis canadensis	(Michx.) Beauv.	CALACAN
shepherd's purse	Capsella bursa-pastoris	(L.) Medik.	CAPSBUR
Kellogg's sedge	Carex kelloggii	Boott	CAREKEL
small-winged sedge	Carex microptera		CAREMIC
spotted knapweed	Centaurea stoebe	L.	CENTSTO
lamb's-quarters	Chenopodium album	L.	CHENALB
Canada thistle	Cirsium arvense	(L.) Scop.	CIRSARV
thistle	Cirsium sp.		CIRSIUM
bull thistle	Cirsium vulgare	(Savi) Tenore	CIRSVUL
narrow-leaved collomia	Collomia linearis	Nutt.	COLLLIN
bunchberry	Cornus canadensis	L.	CORNCAN
red-osier dogwood	Cornus stolonifera	Michx.	CORNSTO
golden corydalis	Corydalis sp.		CORYDAL
black hawthorn	Crataegus douglasii	Lindl.	CRATDOU
slender hawksbeard	Crepis atribarba	Heller	CREPATR
western hawksbeard	Crepis occidentalis	Nutt.	CREPOCC
orchard-grass	Dactylis glomerata	L.	DACTGLO
flixweed	Descurainia sophia	(L.) Webb ex Prantl	DESCSOP
Draba sp	Draba sp.		DRABA
Canada wildrye	Elymus canadensis	L.	ELYMCAN
blue wildrye	Elymus glaucus	Buckl.	ELYMGLA
slender wheatgrass	Elymus trachycaulus	(Link) Gould ex Shinners	ELYMTRA
quack grass	Elytrigia repens		ELYTREP
fireweed	Epilobium angustifolium	L.	EPILANG

EnglishName	ScientificName	Authority	Code
purple-leaved willowherb	Epilobium ciliatum	Raf.	EPILCIL
broad-leaved willowherb	Epilobium latifolium	L.	EPILLAT
common horsetail	Equisetum arvense	L.	EQUIARV
scouring-rush	Equisetum hyemale	L.	EQUIHYE
smooth scouring-rush	Equisetum laevigatum	A. Br.	EQUILAE
marsh horsetail	Equisetum palustre	L.	EQUIPAL
common rabbit-brush	Ericameria nauseosa	(Pall. ex Pursh) Nesom & Baird	ERICNAU
cut-leaved daisy	Erigeron compositus	Pursh	ERIGCOM
wormseed mustard	Erysimum cheiranthoides	L.	ERYSCHE
field filago	Filago sp.		FILAGO
wild strawberry	Fragaria virginiana	Duchesne	FRAGVIR
oceanspray	Holodiscus discolor	(Pursh) Maxim.	HOLODIC
foxtail barley	Hordeum jubatum	L.	HORDJUB
Rocky Mountain juniper	Juniperus scopulorum	Sarg.	HORDJUB
prickly lettuce	Lactuca serriola	L.	LACTSER
Dalmatian toadflax	Linaria genistifolia	(L.) P. Miller	LINAGEN
butter-and-eggs	Linaria vulgaris	P. Miller	LINAVUL
meadow birds-foot trefoil	Lotus denticulatus	Waldst. & Kit.	LOTUDEN
Pacific crab apple	Malus fusca	(Raf.) Schneid.	LOTUDEN
apple	Malus sp.		MALUS
pineapple weed	Matricaria discoidea	DC.	MATRDIS
black medic	Medicago lupulina	L.	MEDILUP
alfalfa	Medicago sativa	L.	MEDISAT
white sweet-clover	Melilotus alba	Desr.	MELIALB
small-flowered evening star	Mentzelia albicaulis	(Dougl. ex Hook.) T. & G.	MENTALB
lady's-thumb	Persicaria maculosa	Gray	PERSMAC
mock-orange	Philadelphus lewisii	Pursh	PHILLEW
common Timothy	Phleum pratense	L.	PHLEPRA
Engelmann spruce	Picea engelmannii	Parry ex Engelm.	PICEENG
whitebark pine	Pinus albicaulis	Engelm.	PINUALB
ponderosa pine	Pinus ponderosa	Dougl. ex P.& C. Lawson	PINUPON
pine	Pinus sp.		PINUS
Scouler's popcornflower	Plagiobothrys scouleri	(H. & A.) I.M. Johnst.	PLAGSCO
Plantain	Plantago sp.		PLANTAG
Canada bluegrass	Poa compressa	L.	POA COM
fowl bluegrass	Poa palustris	L.	POA PAL
Kentucky bluegrass	Poa pratensis	L.	POA PRA
Sandberg's bluegrass	Poa secunda	J. Presl	POA SEC
common knotweed	Polygonum aviculare	L.	POLYAVI

EnglishName	ScientificName	Authority	Code
balsam poplar	Populus balsamifera	L.	POPUBAL
black cottonwood	Populus balsamifera ssp. trichocarpa	T. & G. ex Hook. Brayshaw	POPUBAL
poplar	Populus sp.		POPULUS
trembling aspen	Populus tremuloides	Michx.	POPUTRE
silvery cinquefoil	Potentilla argentea	L.	POTEARG
brook cinquefoil	Potentilla rivalis	Nutt.	POTERIV
choke cherry	Prunus virginiana	L.	PRUNVIR
Rocky Mountain Douglas-fir	Pseudotsuga menziesii var. glauca	(Beissn.) Franco	PSEUMEN
marsh yellowcress	Rorippa palustris	(L.) Bess.	RORIPAL
prickly rose	Rosa acicularis	Lindl.	ROSAACI
red raspberry	Rubus idaeus	L.	RUBUIDA
black raspberry	Rubus leucodermis	Dougl. ex T. & G.	RUBULEU
thimbleberry	Rubus parviflorus	Nutt.	RUBUPAR
curled dock	Rumex crispus	L.	RUMECRI
willow dock	Rumex triangulivalvis	(Danser) Rech. f.	RUMETRI
Bebb's willow	Salix bebbiana	Sarg.	SALIBEB
Pacific willow	Salix lucida	Muhl.	SALILUC
willow	Salix sp.		SALIX
fall rye	Secale cereale	L.	SECACER
white cockle	Silene latifolia	Poir.	SILELAT
tall tumble-mustard	Sisymbrium altissimum	L.	SISYALT
red sand-spurry	Spergularia rubra	(L.) J.& K. Presl	SPERRUB
common snowberry	Symphoricarpos albus	(L.) Blake	SYMPALB
common dandelion	Taraxacum officinale	G.H. Weber ex Wiggers	TARAOFF
yellow salsify	Tragopogon dubius	Scop.	TRAGDUB
red clover	Trifolium pratense	L.	TRIFPRA
white clover	Trifolium repens	L.	TRIFREP
clover	Trifolium sp.		TRIFOLI
moss	Unknown moss		MOSS
great mullein	Verbascum thapsus	L.	VERBTHA

Sub-Polygon Vegetation Cover by Species Tables

Species	Origin	MW1701 Control (n=12)			Machine-Work (n=12)		Machine-Work/Planted (n=6)		MPT1912 (n=7)		MPT1913 (n=5)		Machine-Work/Seeded (n=3)	
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)
Rorippa palustris		0.025	25	T	1.2	50	0.07	50	0.05	29	1.6	100	0.4	100
Pseudotsuga menziesii		0.0002	33	T	0	0	0	0	0	0	0	0	0	0
Amsinckia lycopsoides		0.000008	8	T	0.063	33	0.00002	17	0.07	14	0.0002	20	0.0003	33
Carex kelloggii	Native	0	0	0.00	0.02	25	0.5	67	0.5	86	0.5	60	0.07	67
Populus balsamifera		0	0	0.00	0	0	0	0	0.01	29	0	0	0	0
Equisetum palustre		0	0	0.00	0	0	0	0	0	0	0.0002	20	0	0
Epilobium latifolium		0	0	0.00	0	0	0	0	0	0	0	0	0.07	33
Chenopodium album		7.2	83	63.98	0.2	83	0.25	83	0.5	71	1.4	100	1.7	100
Spergularia rubra		3.8	100	34.22	0.4	100	0.875	67	1.8	100	6	100	6	100
Polygonum aviculare		0.2	100	1.49	1.3	100	1.00	100	1.1	100	1.0	100	4.2	100
Persicaria maculosa		0.010	58	T	0.02	17	0.13	50	0.07	14	0.4	80	0.07	33
Poa compressa		0.0001	50	T	0.2	67	0.008	33	0.09	43	0.04	40	0.2	67
Matricaria discoidea	Exotic	0.00002	17	T	0.0	25	0	0	0.00001	14	0	0	0	0
Elytrigia repens		0	0	0.00	0.008	8	0	0	0	0	0	0	0	0
Melilotus alba		0	0	0.00	0.00008	8	0	0	0.007	14	0.006	20	0.03	33
Sisymbrium altissimum		0	0	0.00	0.03	42	0.00005	33	0.002	29	0	0	0	0
Trifolium repens		0	0	0.00	0	0	0.25	17	0	0	0	0	0	0
Capsalla bursa		0	0	0.00	0	0	0	0	0	0	0.02	20	0	0
Phleum pratense		0	0	0.00	0	0	0	0	0	0	0	0	0.07	33
Draba sp.	Unknown	0	0	0.00	0	0	0	0	0.00003	14	0	0	0.00003	33
Total richness		9			12		10		12		11		11	

[1]In Low Shrub layer

[2]At least some of those individuals were planted

Species	Origin	MW1702 Control (n=10)			Machine-Work (n=16)		Machine-Work/Planted (n=8)		MPT1910 (n=6)		MPT1911 (n=6)		Machine-Work/Seeded	
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)
Epilobium ciliatum		0.0002	20	T	0.0002	44	0.00001	13	0.002	17	0.0002	17	0	0
Plagiobothrys scouleri		0.0002	20	T	0.000006	6	0.00005	13	0.000	0	0.0000	0	0	0
Amsinckia lycopsoides		0.0001	40	T	1.5	75	0.69	88	0.22	67	0.01	67	0.04	75
Pseudotsuga menziesii		0.00001	10	T	0.0006	6	0.00001	13	0.000	0	0.0000	0	0.00008	25
Carex kelloggii		0	0	0	0.000006	6	2.25	50	0.25	50	0.034	50	0	0
Carex microptera		0	0	0	0.02	13	0	0	0.000	0	0.0000	0	0	0
Erysimum cheiranthoides	Native	0	0	0	0.006	19	0	0	0.000	0	0.0000	0	0	0
Hordeum jubatum		0	0	0	0.6	31	1.0	50	0.014	50	0.25	33	0.21	50
Rorippa palustris		0	0	0	0.5	25	0.13	25	0.22	50	0.18	50	0.25	50
Populus balsamifera		0	0	0	0	0	0	0	0.0002	17	0.0000	0	0	0
Poa palustris		0	0	0	0.003	6	0.0013	13	0	0	0	0	0.0003	25
Lotus denticulatus		0	0	0	0	0	0	0	0	0	0.002	33	0	0
Prunus virginiana		0	0	0	0	0	0	0	0	0	0	0	0.013	25
Spergularia rubra		1.7	90	85.60	0.3	44	0.32	63	0.55	83	5.3	67	0.57	75
Polygonum aviculare		0.24	100	12.06	2	100	2.2	100	2.4	100	4.6	100	5.3	100
Chenopodium album		0.025	70	1.29	0.8	94	0.5	88	0.04	83	0.93	100	0.18	100
Poa compressa		0.01	30	T	0	0	0	0	0	0	0	0	0	0
Persicaria maculosa	Exotic	0.01	10	T	0.25	81	0.13	75	0.0002	17	0.78	83	0.3	100
Matricaria discoidea		0.00003	30	T	0.0006	25	0.00001	13	0.18	67	0.00002	17	0.0005	50
Sisymbrium altissimum		0.00002	20	T	0.35	44	0.14	25	0	0	0	0	0.0003	25
Trifolium pratense		0	0	0	0.00025	6	0	0	0	0	0	0	0	0
Trifolium repens		0	0	0	0.5	19	0	0	0.3	17	0.008	17	0	0
Total richness		11			19		14		12		12		12	

[1]In moss layer

[2]At least some of those individuals were planted

Species	Origin	MW1703 Control (n=9) Cover (Ave, %)	MW1703 Control (n=9) Frequency per polygon (%)	MW1703 Control (n=9) % Comp	Machine-Work (n=10) Cover (Ave, %)	Machine-Work (n=10) Frequency per polygon (%)	Machine-Work/Planted (n=7) Cover (Ave, %)	Machine-Work/Planted (n=7) Frequency per polygon (%)	MPT1915 (n=3) Cover (Ave, %)	MPT1915 (n=3) Frequency per polygon (%)
Hordeum jubatum	Native	0.5	33	20	0.11	40	0.28	29	0.17	33
Amsinckia lycopsoides		0.2	67	7	0.025	20	0.09	43	0.07	33
Calamagrostis canadensis		0.09	11	4	0	0	0	0	0	0
Epilobium ciliatum		0.01	11	T	0.1	70	0.06	57	0.17	33
Carex microptera		0	0	0	0.05	10	0	0	0	0
Plagiobothrys scouleri		0	0	0	0.23	60	0	0	0	0
Potentilla rivalis		0	0	0	0.35	10	0.07	14	0	0
Rorippa palustris		0	0	0	0.3	10	0.11	14	0	0
Collomia linearis		0	0	0	0	0	0.014	14	0	0
Penstemmon fruticosus		0	0	0	0	0	0.036	14	0	0
Carex kelloggii		0	0	0	0	0	0	0	0.03	33
Trifolium repens	Exotic	1.25	22	53	0	0	0.14	29	0	0
Melilotus alba		0.2	11	8	0	0	2.6	29	0	0
Matricaria discoidea		0.09	78	4	0.0001	10	0.00001	14	0.03	33
Chenopodium album		0.02	44	T	0	0	0.0014	29	0	0
Polygonum aviculare		0.02	22	T	0.0001	30	0.39	14	0.4	100
Medicago lupulina		0.02	11	T	0.3	10	0.86	14	0	0
Poa compressa		0.00002	22	T	0.00001	10	0	0	0	0
Capsella bursa-pastoris		0	0	0	0.2	20	0	0	0	0
Descurainia sophia		0	0	0	0.01	10	0	0	0	0
Lactuca serriola		0	0	0	0.025	10	0	0	0	0
Spergularia rubra		0	0	0	0.0001	10	0	0	0	0
Trifolium pratense		0	0	0	0.25	10	0.29	14	0	0
Verbascum thapsus		0	0	0	0	0	3.2	43	0	0
Draba sp	Unknown	0	0	0	0	0	0	0	0.10	33
Total richness		11			16		15		8	

[1]In low shrub layer

[2]Planted

Species	Origin	MW1705 Control (n=9)			Machine-Work (n=10)		Machine-Work/Planted (n=6)		MPT1917 (n=6)	
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)
Lepidium densiflorum	Native	0.05	89	3	0.0002	20	0.002	50	0.03	33
Amsinckia lycopsoides	Native	0.002	11	T	0	0	0	0	0	0
Epilobium ciliatum	Native	0.0001	22	T	0	0	0	0	0	0
Hordeum jubatum1	Native	0.00001	11	T	0.025	50	0.25	50	0.09	100
Rorippa palustris	Native	0	0	0	0.001	10	0.18	83	0	0
Carex kelloggii1	Native	0	0	0	0	0	0.42	17	0	0
Plagiobothrys scouleri	Native	0	0	0	0	0	0.042	17	0	0
Calamagrostis canadensis1	Native	0	0	0	0	0	0	0	0.1	50
Spergularia rubra	Exotic	1.7	56	85	1.6	70	1.5	100	6.25	100
Chenopodium album	Exotic	0.11	56	6	0.13	50	0.8	50	0.3	100
Polygonum aviculare	Exotic	0.09	67	5	0.02	50	0.06	50	0.09	67
Matricaria discoidea	Exotic	0.02	56	T	0	0	0.002	17	0.045	50
Elytrigia repens	Exotic	0.01	11	T	0	0	0	0	0	0
Persicaria maculosa	Exotic	0.0001	11	T	0	0	0	0	0	0
Trifolium repens	Exotic	0.0001	11	T	0.1	10	0	0	0.17	33
Medicago lupulina	Exotic	0	0	0	0.02	10	0.1	17	0	0
Melilotus alba	Exotic	0	0	0	1.7	30	5	17	1.1	33
Poa compressa	Exotic	0	0	0	0	0	0	0	0.00002	17
Draba sp.	Unknown	0.01	56	T	0	0	0	0	0	0
Total richness			12		9		11		10	

[1] Some were planted

Species	Origin	MW1706 Control (n=5)			Machine-Work (n=3)		MPT1918 (n=4)		MPT1919 (n=3)	
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)
Moss sp.		3.1	40	26.72	0	0	0	0	0	0
Rumex triangulivalvis		0.24	20	2.10	0.003	33.3	0.075	25	0	0
Achillea millefolium		0.04	60	T	0	0	0	0	0	0
Epilobium ciliatum		0.008	100	T	0.04	100.0	0.03	100	0.007	100
Collomia linearis		0.004	80	T	0.003	33.3	0.0028	50	0.0003	33.3
Hordeum jubatum		0.002	40	T	0.00003	33.3	0.015	50	0	0
Erigeron compositus		0.002	20	T	0.003	33.3	0.0025	25	0.004	66.7
Lepidium densiflorum		0.0006	60	T	0	0	0.015	50	0	0
Amsinckia lycopsoides		0.0004	40	T	0.0003	33.3	0.005	50	0.003	33.3
Crepis occidentalis		0.0002	20	T	0.02	66.7	0.018	25	0.1	100
Plagiobothrys scouleri	Native	0	0	0.00	0.003	66.7	0.0028	50	0	0
Potentilla rivalis		0	0	0.00	0.007	66.7	0.005	50	0.003	33.3
Alnus viridis1		0	0	0.00	0	0	0.005	25	0.02	66.7
Alnus incana1		0	0	0.00	0	0	0.0075	50	0.02	66.7
Calamagrostis canadensis1		0	0	0.00	0	0	0.005	50	0	0
Elymus glaucus1		0	0	0.00	0	0	0.0005	25	0	0
Lotus denticulatus		0	0	0.00	0	0	0.0025	25	0	0
Pinus ponderosa1		0	0	0.00	0	0	0.0025	25	0.09	100
Poa palustris		0	0	0.00	0	0	0.0025	25	0.003	33.3
Populus balsamifera1		0	0	0.00	0	0	0.038	50	0.1	33.3
Salix bebbiana1		0	0	0.00	0	0	0.0125	25	0.0003	33.3
Elymus canadensis1		0	0	0.00	0	0	0	0	0.03	66.7
Potentilla argentea		4.5	80	39.43	0.3	33.3	0.025	25	0	0
Melilotus alba		2.5	100	21.90	2.6	100	3.1	100	5.2	100
Verbascum thapsus		0.4	80	3.73	0.2	100	0.2	100	0.7	100
Elytrigia repens		0.2	20	1.75	0.0003	33.3	0	0	0	0
Silene latifolia		0.2	20	1.40	0	0	0	0	0	0
Medicago lupulina		0.14	20	1.26	0.01	66.7	0.005	50	0.02	66.7
Rumex crispus		0.06	20	T	0.003	33.3	0	0	0.17	33.3
Medicago sativa	Exotic	0.05	20	T	0	0	0	0	0	0
Poa compressa		0.014	100	T	0.07	66.7	0.13	50	0.17	33.3
Taraxacum officinale		0.006	80	T	0	0	0	0	0.01	66.7
Tragopogon dubius		0.002	20	T	0	0	0.0025	25	0	0
Matricaria discoidea		0.0004	40	T	0	0	0.005	25	0	0
Sisymbrium altissimum		0.0004	40	T	0	0	0.025	25	0.0003	33.3
Filago arvense		0.0002	40	T	0.003	33.3	0	0	0	0
Chenopodium album		0	0	0.00	0.004	100	0.005	50	0	0
Lactuca serriola		0	0	0.00	0.003	33.3	0	0	0	0
Draba sp.	unknown	0.002	40	T	0	0	0	0	0	0

[1]Planted

ALNUCRI, ALNUINC, POPUBAL, SALIBEB are in low shrub layer

Species	Origin	MW1708 Control (n=2)			Machine-Work (n=2)		Machine-Work/Planted (n=2)	
		Cover (Ave, %)	Frequency per polygon (%)	% Comp	Cover (Ave, %)	Frequency per polygon (%)	Cover (Ave, %)	Frequency per polygon (%)
Equisetum arvense	Native	16.5	100	66.61	10	100	1.8	100
Potentilla rivalis		0.0005	50	T	0.05	50	0.006	100
Achillea millefolium		0.00005	50	T	0	0	0	0
Collomia linearis		0.00005	50	T	0.0005	50	0.005	50
Erysimum cheiranthoides		0.00005	50	T	0.0000	0	0	0
Lepidium densiflorum		0.00005	50	T	0.0000	0	0	0
Amsinckia lycopsoides		0	0	0.00	0.0005	50	0	0
Calamagrostis canadensis2		0	0	0.00	0.0005	50	0.015	50
Mentzelia albicaulis		0	0	0.00	0.075	50	0.05	50
Plagiobothrys scouleri		0	0	0.00	0.0005	50	0.0005	50
Hordeum jubatum2		0	0	0.00	0	0	0.05	100
Populus balsamifera1		0	0	0.00	0	0	0.5	50
Trifolium repens	Exotic	5.5	100	22.20	3.325	100	3.5	100
Elytrigia repens		2.4	100	9.69	0.7505	100	1.5	100
Linaria vulgaris		0.205	100	T	0.005	50	0	0
Verbascum thapsus		0.105	100	T	1.2535	100	0.775	100
Trifolium pratense		0.055	100	T	0	0	0	0
Poa compressa		0.0055	100	T	1	50	0.1255	100
Sisymbrium altissimum		5.00E-04	50	T	0	0	0.001	100
Medicago lupulina		0	0	0.00	0.015	50	0.5	50
Melilotus alba		0	0	0.00	0	0	0.015	100

[1]Planted, low shrub

[2]Some planted, some natural

Machine-works permanent photo-monitoring points

MW1701

Figure 45. MW1701 before treatment top left, immediately post treatment 2017 top right, lower left 2019 two years post treatment.

MW1701Control

Figure 46. MW1701Con left 2017, right 2019

MW1702

Figure 47.   MW1702 after treatment 2017 left, one year later and post inundation 2018 right.

Figure 48.   MW1702 control on the left and right one year apart., .

MW1703

Figure 49. MW1703 left post treatment 2017, right treatment area 2019.

Figure 50. MW1704CON on the left 2017 and one year later 2018.

MW1705

Figure 51. MW1705 before and one-year post treatment.

MW1706

Figure 52.   MW1706 before treatment in 2017 on left and one year later. Lower 2019.

Figure 53. MW1706Con left 2017, right 2019

MW1709

Figure 54. MW1709 before top left 2017, one year later, 2018, top right, Left: June 2019.