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Galiano Conservancy Association

Cedars for the Next Century

Monitoring vegetation and revegetation response to rough and loose soil treatment in an agriculturally-degraded watershed

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This project took place on the shared, asserted, unceded and traditional territories of Hul'qumi'num-speaking First Nations Peoples and those who hold traditional rights and responsibilities in and around what is now known as Galiano Island.

Abstract

Ecological restoration of post-agricultural lands is a relatively unusual practice, relying heavily on methods developed in the disciplines of reclamation, agriculture, and forestry. However, post-agricultural lands face a suite of challenges that, while not unique in and of themselves, are distinctive in terms of the severity of their cumulative impact on the potential for recovery of these sites. We applied rough and loose soil treatments to approximately 1.33 ha of land in the Coastal Douglas-fir biogeoclimatic zone (CDFmm) or British Columbia that had been logged, stumped, drained, and used for small-scale agriculture and pasture for over 100 years prior to acquisition by the Galiano Conservancy Association (GCA). We also excavated 18 individual wetland pools, distributed coarse woody debris, fenced the site, and applied four distinct revegetation treatments: outplanting, live-staking, seeding, and passive restoration. After two years of monitoring for plant survival and percent cover, we observed minor increases in native cover that were overshadowed by a remarkable recovery of the suite of introduced grasses that had previously dominated the site. Restoration treatments in the study area were successful in decompacting soils, reintroducing complex microtopography and coarse woody debris, excluding abundant native herbivores, and restoring wetland hydrology. However, the combination of limited natural regeneration of native woody species, annual losses of established plants and live stakes, and continued dominance of aggressive introduced species poses significant challenges for long-term recovery. At this early stage, it is not possible to compare the performance of the different revegetation treatments.

Management Implications

Based on formal data collection, informal observations, and lessons learned during the project planning and implementation, we recommend the following for the restoration of post-agricultural sites:

- Long-term monitoring of this site and other similar sites for revegetation success
  - Even under the best conditions, two years is not sufficient time for post-agricultural sites to transition from bare soil to majority native cover. Modest gains in native cover in the first years of similar projects are often overshadowed by larger gains in later years.
- Increased density of outplanting and live-staking on this site and other similar sites
  - Planting and staking efforts on sites with weedy seed banks should be as dense as possible to create rapid shrub and canopy closure. Weedy grasses begin to reassert dense cover as early as six months following rough and loose treatments.
  - Additional density should help to account for inevitable losses, especially during dry years.
  - Natural recruitment (i.e. passive regeneration) may supplement plantings but is unreliable.
- Research and capacity building to identify and develop native seed sources and methods to establish competitive cover to aid succession on post-agricultural sites, especially in dry areas
  - With one minor exception, seed treatments across the site appear to have been ineffective during the two year study period, although delayed germination may still occur in the future.
  - A collection of native species displayed a promising ability to self-recruit across the project area, but were largely confined to the shifting borders of wetland pools, where fluctuating water levels limited grass growth; native regeneration in dry areas was much poorer.
- Additional work to optimize plant species and nursery stock size selection
  - Several live-stake species far outperformed the others that were trialled.
  - Survival across outplanted nursery stock was generally good, but several species notably struggled, due to either poor planting stock quality and/or site suitability.

Context

The 28-hectare Chrystal Creek watershed is contained entirely within the Galiano Conservancy Association's (GCA) 76-hectare Millard Learning Centre (MLC) property. The MLC is located mid-island along the western coastline of Galiano Island, which occurs within the Coastal Douglas-fir moist maritime (CDFmm) biogeoclimatic zone of the Southern Gulf Islands of southwestern British Columbia, Canada. The study area is 1.33 ha of old field where restoration treatments were implemented in October of 2021.

Historically forested, much of the lower watershed had been cleared, stumped, drained, and used for mixed pasture and small-scale agriculture; the study area was in use as pasture prior to the first aerial photograph in 1932. Old wooden dwellings, storage structures, a chicken house, ditches, and sheep fencing were found across the watershed and were later removed as part of the restoration effort. Feral sheep were still grazing on the property until 2021, and native black-tailed deer (*Odocoileus hemionus hemionus*) - considered to be at very high population densities across the archipelago[1] - continue to apply heavy browsing pressure throughout the watershed.

Surface water flow is seasonal throughout the watershed. In the study area, flows were intermittent in the ditches throughout the wet months (mid-September through May); despite the persistent drainage, the water table was regularly at or near the soil surface during this time. In the dry summer months, groundwater levels typically drop off, and surface flow disappears. Soils on site are derived from sedimentary rocks and include the Saturna, Brigantine, and Tolmie series.[2] Soil compaction was widespread across the study area due to livestock and heavy machinery use.

Prior to treatments, the study area was vegetated almost exclusively by a small suite of introduced (or hybridized) agronomic grasses and rushes: these included creeping bentgrass (*Agrostis stolonifera*), colonial bentgrass (*Agrostis capillaris*), orchardgrass (*Dactylis glomerata*), reed canarygrass (*Phalaris arundinacea*), tall fescue (*Schedonorus arundinaceus*), common velvetgrass (*Holcus lanatus*), and common rush (*Juncus effusus*). We observe that this agronomic guild of highly competitive species is firmly established on similar sites across our region, and that the study area is broadly representative of the impacts of agricultural land-use across the Gulf Islands.

Although a few native herbaceous species were sporadically present - including slough sedge (*Carex obnupta*) and great horsetail (*Equisetum telmateia*) in wet areas - no sign of natural regeneration of native woody species was observed in the ten years following the Galiano Conservancy's acquisition of the property and the cessation of all direct intervention (agriculture, forestry) activities on the site. A singular exception was noted: a healthy western redcedar (*Thuja plicata*) sapling growing on a pile of partially combusted wood. We observed that the favourable substrate and the slightly raised elevation above the winter water table account for the exceptional success of this individual. Restoration treatments were directly informed by this observation.

Figure 1: Single western redcedar sapling growing on a mound of partially combusted wood in the middle of the old field, surrounded by agronomic grasses

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[1] See Martin et al., 2011; Arcese et al., 2014
[2] Green et al., 1989

Methods

Restoration Treatments

Restoration treatments were targeted towards:

- Undoing hydrological alterations to the study area by removing drainage features, constructing wetlands, and retaining as much water on site as possible
  - Indicator species for success: northern red-legged frog (*Rana aurora*)
- Restoring complex microtopography to the study area through rough and loose microtopography and additions of coarse woody debris - mimicking the establishment conditions for the lone western redcedar sapling on site
  - Indicator species for success: western redcedar

Restoration treatments were implemented in September and October of 2021 - see supplementary information for a complete timeline of activities. At this point, cover across the entire 1.33 ha of treated area consisted either of bare soil or open water, with sporadic living root fragments of the previous cover scattered throughout.

Revegetation Treatments

Revegetation treatments were designed to provide an opportunity to compare the efficacy of different methods of plant establishment, aided by complete exclusion of ungulate herbivores through fencing of the entire site. Revegetation treatments were implemented in October and November of 2021.

Four commonly employed methods of revegetation were tested. To create study plots, we overlaid a grid across 1 ha of the treatment area and marked plot centres every 10 m, excluding potential plots located entirely within planned wetlands. This resulted in 85 circular plots (radius = 5 m), which were divided into 12 treatment groups based on relative soil moisture regime (determined through baseline terrestrial ecosystem mapping, elevation, and wetland locations) and revegetation treatment. Plot centres were marked with rebar and flagged. Ultimately, the constructed wetlands were larger than planned, and plot centres had to be adjusted in the field based on local conditions to avoid plots that were primarily wetland. As a result, of the original 85 plots, 37 were retained for long-term monitoring. Plots were retired due to one or more of the following issues:

- Plot overlapped other plots or fenceline
- Plot was not representative of assigned moisture regime and/or treatment
- Plot data collection in 2022, upon review, was deemed unreliable

At least one plot per treatment type was retained. Data on red alder recruitment and plant and live stake survival was collected for all relevant plots in 2022 and 2023; percent cover was noted for all plots in 2022, and only on retained plots in 2023.

Table 1: Monitoring Plots by Treatment Type

Method	Moisture	Plots	Plots Retained
Plant	Dry	8	2
	Mesic	10	4
	Wet	5	5
Live Stake	Dry	7	1
	Mesic	8	5
	Wet	7	3
Seed	Dry	7	2
	Mesic	10	5
	Wet	6	2
Passive	Dry	6	3
	Mesic	9	4
	Wet	2	1
Total		85	37

Plant Treatment

We revegetated the planted plots with 37 native shrubs and tree species. In each plot, we planted 8 plants (typically, four trees and four shrubs), selected based on the relative soil moisture regime; this represents a planting density of just over 1000 plants per hectare. Plants were evenly distributed throughout the plot, and three burlap sacks were placed around each plant to suppress grass. 92% of the plants were sourced from the Galiano Conservancy's nursery, with the rest sourced from Salt Spring Island. In 2023, bamboo stakes were added to each plant to aid in monitoring. See supplementary information for plot-by-plot details.

Figure 2: Plant establishment; note that cages were initially installed prior to fencing, then removed

Live Stake Treatment

We revegetated the live stake plots with nine native shrub and tree species. Stakes were collected on the property or adjacent lands, and were soaked for 24-48 hours prior to staking. 20 stakes were established in each plot, with species mixtures selected based on the relative soil moisture regime; this represents a staking density of just over 2500 stakes per hectare. See supplementary information for plot-by-plot details.

Figure 3: Live stake establishment in the study area

Seed Treatment

We revegetated the seed plots with 29 native species. Seeds were collected on the property or adjacent lands, and seed mixtures were based on the relative soil moisture regime. Proper seeding density was challenging to determine, given the differences in weight between different species; seeds were distributed as evenly as possible between plots. We seeded 75.9 g of native species in 6 dry plots, 28.9 g of native species in 6 mesic plots, and 22.4 g of native species in 11 wet plots (note: the disproportionate weight of *Arbutus menziesii* berries accounts for the relatively high value for dry plots). We used a hard rake to break up the soil prior to evenly spreading the seed mix by hand. See supplementary information for specific weights of seed.

Figure 4: Preparing seeds for seed treatment by plot

Passive Treatment

No actions were taken other than fencing.

Additional Revegetation Treatments

In addition to planting in the designated plots, we salvaged and transplanted slough sedge (*Carex obnupta*) and western redcedar (*Thuja plicata*) individuals from areas that were treated by the excavator, and planted 18 Douglas' aster (*Symphyotrichum cf. subspicatum*) throughout the study area. We also used an excavator to establish several patches of larger diameter live stakes of black cottonwood (*Populus trichocarpa*) after destroying an individual to remove a ditch. These unplanned treatments were immediate on-site decisions intended to benefit the overarching restoration targets, but they inadvertently resulted in the need to retire several monitoring plots.

Management

We conduct several ongoing management activities across the study area. These include:

- Control of target introduced species
    - Reed canary grass
    - Himalayan blackberry (*Rubus armeniacus*)
    - Cutleaf blackberry (*Rubus laciniatus*)
    - English holly (*Ilex aquifolium*)
    - English hawthorn (*Crataegus monogyna*)
    - Scotch broom (*Cytisus scoparius*)
    - Tansy ragwort (*Jacobaea vulgaris*)
    - Sweetbriar (*Rosa rubiginosa*)
    - Yellow flag iris (*Iris pseudacorus*)
    - Daffodil (*Narcissus spp.*)
- Annual weeding to prevent grasses from overtopping outplanted plants (June)
- Live staking and installation of rock aprons as needed to prevent erosion in spillways

Monitoring

Monitoring activities take place in June and July, and are carried out by GCA staff, and at times aided by volunteers.

Plant and Live Stake Survival

We visit each plot and count the surviving individuals. In the Plant Treatment plots, each individual plant is marked with burlap (slowly decomposing) and a bamboo stake, so survival is noted on an individual basis. For Live Stake Treatment plots, the total number of surviving stakes of each species is tallied. Due to the dominant cover of knee-to-chest high agronomic grasses across the study area, survival monitoring is subject to detection error, where an individual might still be alive, but is not detected by the monitoring team. Thus, we believe the results are conservative.

Red Alder Recruitment

For each plot, the presence or absence of volunteer red alder (*Alnus rubra*) seedlings is noted. Red alder is an important nitrogen-fixing early seral tree species for our region, and all of our revegetation treatments assumed that some natural regeneration of red alder would occur in the study area. We observe that red alder regeneration generally occurred in areas with lower grass cover, making it easy to detect.

Vegetation Cover Estimation

We make visual estimates of percent cover for each 5m radius plot in the study area. Values for the following are estimated:

- Bare soil (includes burlap, woody debris)
- Open water (wetted land area)
- A1 = tree (>3 m tall)
- A2 = tree (< 3 m tall, anticipated >3m)
- B = shrub (woody vegetation <3 m)
- C = herb (includes *Typhaceae* and ferns)
- D1 = grass

- D2 = sedge (+ species in *Cyperaceae*)
- D3 = rush (+ species in *Juncaceae*)

In addition, percent cover is estimated for several identified indicator species, including:

- Red alder (*Alnus rubra*)
- Arbutus (*Arbutus menziesii*)
- Black cottonwood (*Populus trichocarpa*)
- Salal (*Gaultheria shallon*)
- Oceanspray (*Holodiscus discolor*)
- Salmonberry (*Rubus spectabilis*)
- Trailing blackberry (*Rubus ursinus*)
- Great horsetail (*Equisetum telmateia*)
- Sword fern (*Polystichum munitum*)
- Bracken fern (*Pteridium aquilinum*)
- Stinging nettle (*Urtica dioica*)
- Slough sedge (*Carex obnupta*)
- Small-head bulrush (*Scirpus microcarpus*)

Percent cover is also estimated for all target introduced species (see 'Management', above).

For each layer, percent cover estimates are made separately for native and non-native vegetation. We use non-additive percent cover (i.e. cover of all layers combined will equal or exceed 100%), as this allows us to provide estimates for each overlapping layer of vegetation. Plot boundaries are measured and marked prior to estimation. Estimates are made systematically by a minimum of two observers, who compare observations until arriving at consensus for each estimate, and then review for consistency once all estimates are made at each plot. Percent cover estimates are limited to one of the following values: 0%, <1%, 1% through 5%, and then multiples of 5% (i.e. 10%, 15%, 20%...) up to 100% to introduce a 'threshold" system for estimation at higher cover values. Where available, we reference values from the previous estimates in the same plot to help calibrate estimates. A photo is collected at each plot for future reference.

In 2022, the large number of plots (n=85) compelled us to invite students from the annual University of Victoria summer field study course (ES 471/ER 412) to assist GCA staff in conducting percent cover monitoring. We divided the class into six groups, provided training, and assigned a staff member or UVic instructor to accompany each group. In 2023, we repeated this activity with a new group of ES 471 students, but observed upon reviewing the data collected that estimates were too unreliable when compared to the previous year's results. As a result, we retired over half of the study plots (due to inconsistency and other related issues identified during the first two years of monitoring - see Revegetation Treatments, above), and generated new estimates of percent cover using only GCA staff on the retained plots (n=37). Where we noted minor inconsistencies in retained plots between 2022 estimates and 2023 staff estimates for percent cover of static features (such as established trees or shrubs with minimal observed growth in cover year-to-year), we modified 2022 estimates to reset the baseline for future years. Moving forward, GCA staff will make all estimates of percent cover in retained plots.

Lessons learned during this monitoring activity will be applied in future years for what we anticipate will be a long-term study (see Discussion, below). However, the unusually high contribution of observer bias (i.e. incorporation of student volunteers into initial monitoring activities) to the 2022 results, coupled with the preliminary nature of the analysis (i.e. just two years of data) means that no attempt will be made here to draw conclusions from differences in revegetation success *between* treatment types at this stage. Instead, results and discussion will be confined to trends observed *across all plots*, for which we have high confidence in the data.

Figure 5: Example monitoring plot - observer positioned at plot centre, pink flags mark perimeter

Figure 6: Map of restoration treatments and both retained and retired monitoring plots for the West Branch of the Chrystal Creek Watershed

Results

Percent Cover

Table 2 and Figure 7 summarize the results for the first two years of percent cover estimates across the 37 retained treatment plots in the study area. Notable shifts in cover from 2022 to 2023 include:

- >50% reduction in bare soil cover
- >85% reduction in open water cover
- > 65% increase in grass cover
- Minor increases across all cover types for native species, with the exception of herbs

Introduced herbs decreased in cover overall, but results were inconsistent on a plot by plot basis. Two-sided, paired T-tests confirmed significant decreases in cover of bare soil (p=0.0012) and open water (p=5.2e-05), as well as increases in the cover of grasses (p=6.8e-07) and native trees (p=0.0002). Changes in cover for native shrubs (p=0.043) and both introduced (p=0.96) and native herbs (p=0.30) did not meet the Bonferroni threshold (p=0.00714). Percent cover estimates revealed, on average, between 10-15% overlap in cover types across all plots. See supplementary materials for statistical analysis.

Introduced shrubs and trees are subject to annual removal efforts in the study area, and were therefore mostly noted for later removal. Grass, sedge, and rush layers are composed of both native and introduced species: grasses are within the family *Poaceae* and are almost exclusively introduced, with the exception of occasional occurrences of species like blue wild rye (*Elymus glaucus*) and California brome (*Bromus sitchensis var. carinatus*); sedges are mostly native, and include all observed species within the family *Cyperaceae*, including *Scirpus* and *Eleocharis*; and rushes include a mix of native and introduced species in the family *Juncaceae*, with cover dominated by the variables species *Juncus effusus*, which has both native (*var. pacifica*) and introduced (*var. effusus*) variants present on site. The family *Typhaceae* can be considered to be graminoid, but was included in Herbs for convenience.

Table 2: Summary of mean percent cover estimates by cover type across all retained treatment plots (n=37) between 2022 and 2023

Revegetation Monitoring - Percent Cover											
	% Cover - Other		% Cover - Trees		% Cover - Shrubs		% Cover - Herbs		% Cover - Graminoids		
Year	Bare Soil	Water	Native	Introduced	Native	Introduced	Native	Introduced	Grass	Sedge	Rush
2022	13.7%	13.9%	0.4%	0.0%	8.4%	0.2%	9.1%	24.8%	37.2%	0.3%	3.5%
2023	6.50%	1.8%	1.0%	0.0%	9.2%	0.3%	9.0%	20.5%	61.2%	0.5%	3.8%

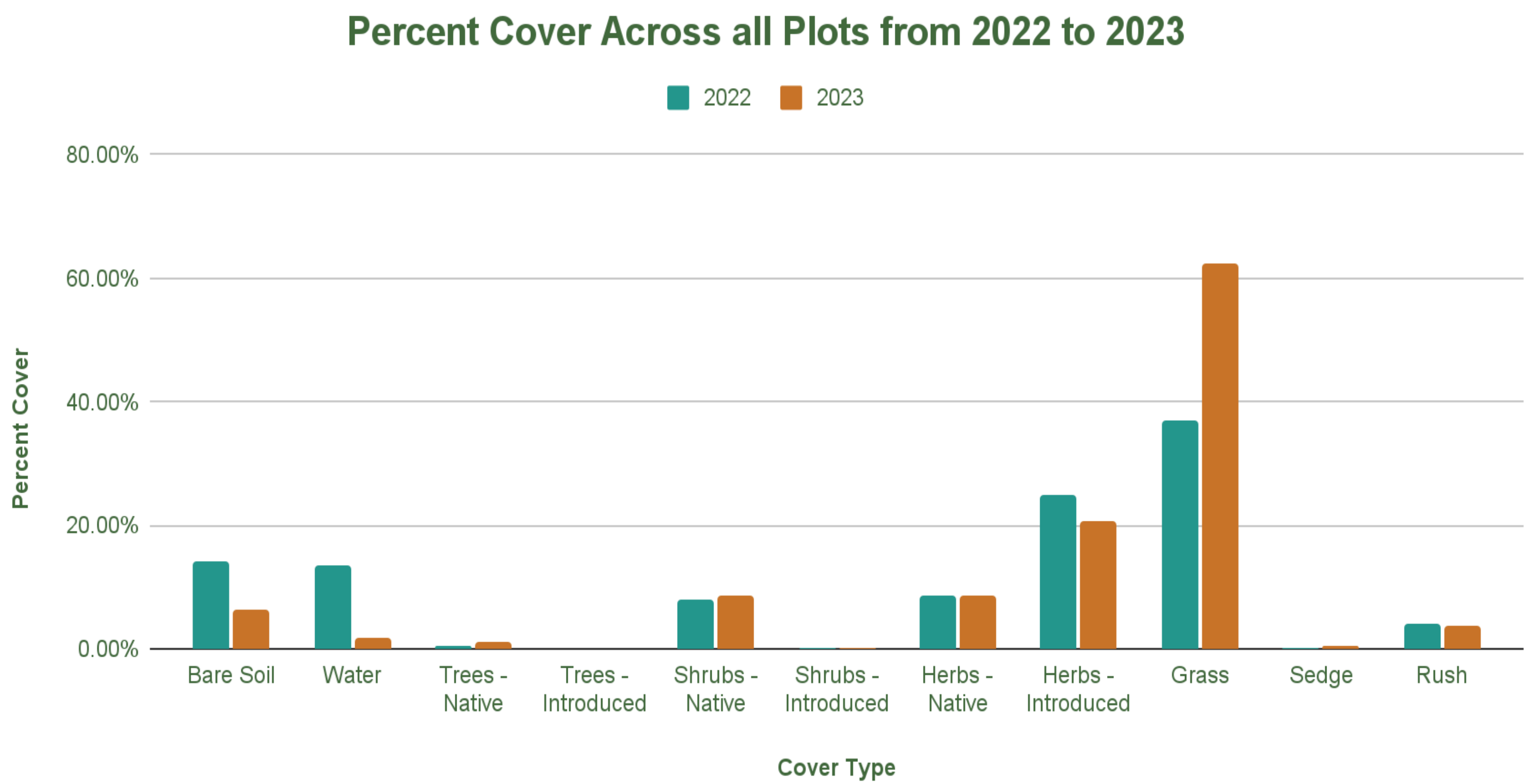

Figure 7: Chart comparing percent cover by cover type between 2022 and 2023 across all retained plots

Plant and Live Stake Survival

The following values were recorded for the survival of established individual propagules in Plant and Live Stake Treatments plots. The results for the first two years of the study indicate approximately 10% annual loss of the original nursery stock, and approximately 50% annual loss of live stakes from the previous year's count.

For nursery stock, losses were largely confined to a handful of species that performed comparatively poorly, these included: Douglas maple (*Acer glabrum*), juneplum (*Oemleria cerasiformis*), Douglas-fir (*Pseudotsuga menziesii*), and stink currant (*Ribes bracteosum*). For live stakes, only four of the eight species trialled had any survivors: these include red-osier dogwood (*Cornus sericea*), black cottonwood (*Populus trichocarpa*), hardhack (*Spiraea douglasii*), and Scouler's willow (*Salix scouleriana*).

Table 3: Survival of plants and live stakes by year

Revegetation Monitoring - Survival				
Year	Method	Established	Survived	% Survival
2022	Plant	184	167	90.8%
	Live Stake	449	221	49.2%
2023	Plant	184	147	79.9%
	Live Stake	449	109	24.3%

Figure 8: Black cottonwood live stake in the watershed

Red Alder Recruitment

Red alder seedlings were detected in just over 40% of the original study plots by July of 2023. Recruitment increases with increasing relative soil moisture regime, with over 50% of wet plots containing alder seedlings. We observed that red alder typically recruits in small patches of 10-20 individuals in areas with reduced grass cover, either due to substrate type (i.e. heavy clay) or seasonal inundation (i.e. along the margins of wetland pools). Results are reported only for 2023.

Despite an apparently clear trend, these results did not meet the threshold for Pearson's Chi-squared Test ($p=0.41$), indicating that additional observations would be required to achieve statistical significance for this indicator. Additional monitoring with a larger sample size and reduced plot size would yield more robust results. See supplementary materials for statistical analysis.

Table 4: Recruitment of red alder by plot moisture

Revegetation Monitoring - Red Alder			
Moisture	# Plots	Present	%
Dry	28	10	35.71%
Mesic	36	16	44.44%
Wet	20	11	55.00%

Figure 9: Example of red alder regeneration on site

Discussion

Plant and Live Stake Survival

Hypotheses

We hypothesized that:

- Plants would have a higher survival rate than live stakes
- There would be some die off in both Plant and Live Stake Treatment plots in the early years following establishment

Discussion of Results

Trends for plant and live stake survival on the site were consistent with our hypotheses. Losses of outplanted nursery stock were minor (only 10% of total outplanted), but consistent for the first two years.

Losses of live stakes were more severe, with only 25% of the original stakes remaining after two years. An exceptionally dry summer (see Figure 10) may partially account for the significant mortality in the second year. Our results showed no relationship between relative soil moisture regime and survival; instead, survival appears species specific, with hardhack and black cottonwood exhibiting >50% survival, and Scouler's willow and red osier dogwood exhibiting between 20-25% survival. The other four species selected did not survive. These results are consistent with other studies demonstrating that live stake performance is primarily species specific, with additional influences including depth to water table, period of spring inundation, diameter, and age of material.[3] Even where mostly successful, the current density of established plants via either method has not generated sufficient cover within the first two years to suppress (re)colonization of the site by aggressive introduced grasses.

[3] See Darris, 2003; Cereghino, 2004; Darries, 2006;, and Wetzel et al., 2023

Red Alder Recruitment

Hypotheses

We hypothesized that:

- Red alder would be detected within the first two years across all plot types
- Red alder recruitment would be more successful with increasing moisture

Discussion of Results

Natural red alder recruitment was irregular across the study area, typically occurring in clumps on wet or mineral substrates. Recruitment increased with increasing relative soil moisture regime, but this result was not statistically significant due to an insufficient sample size. Nevertheless, the observed recruitment trend was consistent with the documented ecology of this early seral species,[4] and provides confirmation that, while some recruitment of early seral native vegetation can be expected on similar sites following rough and loose soil decompaction, recruitment is too inconsistent to guarantee native canopy cover in the near term in the context of passive restoration.

Percent Cover

Hypotheses

We hypothesized that:

- Plant and Live Stake treatments would outperform Seed and Passive Treatments in terms of speed and success of native cover establishment
- Introduced grasses and herbs would dominate cover throughout the first decade of the project, but would be replaced by native cover once a native canopy was established

[4] Villarin et al., 2009

Discussion of Results

We were unable to evaluate either hypothesis due to the short time frame of this study, but we anticipate being able to do so in future years. Instead, we can draw the following conclusions from changes in percent cover in the study area in the first two years following rough and loose decompaction of post-agricultural soils:

- Regeneration of native woody vegetation - whether from natural recruitment, retained mature plants, or revegetation treatments - produces only minor increases in cover in the first two years. These increases - while encouraging - are insufficient to prevent weedy introduced vegetation from reasserting dominance.
- Bare soil is quickly (re)occupied by introduced grasses and a mix of native and introduced herbs. After two years, the only bare soil remaining is on the margins of wetlands, on patches of heavy clay subsoil that was brought to the surface, and under woody debris.
- By year two, introduced grasses have achieved majority cover across most of the study area. The persistent dominance of these species and their favourable response to the rough and loose soil decompaction treatment poses the greatest challenge to revegetation by native species on our site.

These results highlight significant and commonly encountered challenges to restoring native wetland vegetation on post-agricultural sites, where introduced species, highly altered soils, and altered soil seed banks[5] present significant barriers to recovery. Rhizomatous species such as reed canary grass, creeping bentgrass, and creeping buttercup (*Ranunculus repens*) were particularly successful. Long term monitoring will reveal which (if any) of our revegetation treatments is sufficient to overcome these barriers.

One important variable affecting these results is precipitation. A comparison of the months during and on either side of the June-July study window reveals significant differences between 2022 and 2023 (Figure 10). At the North Cowichan weather station (approx. 12 km from the study area), 391 mm of rain fell between March and August of 2022, compared to only 214.6 mm during the same period in 2023. This climatic variability is visible in our data, where the percentage of open water cover observed in plots fell from 13.9% in 2022 to 1.8% in 2023. Differential precipitation may account for some variation in cover between years.

What is not captured in these percentages is the arrival of a variety of moisture-loving herbaceous species that were not previously observed in the study area but which appeared on site following restoration treatments. These include species in the genera *Carex*, *Juncus*, *Veronica*, *Myosotis*, *Potamogeton*, *Typha*, *Eleocharis*, and *Sparganium*. Their arrival on the site is indicative of broad and rapid dispersal ability (ex. *Typha*) and/or persistence in the soil seed bank despite decades of drainage and agricultural use (ex. *Sparganium*). The greater persistence of native herbaceous species in the seed bank when compared with native woody species on agriculturally-disturbed wetland sites has been noted previously,[6] although soil seed banks can be poor predictors of plant abundance following restoration treatments.[7]

Key trends identified in the results between 2022 and 2023 were statistically significant and of sufficient magnitude to overcome potential biases in estimated cover due to differences in observers and observation dates. In future years, we hope to increase observation consistency to allow for comparison of revegetation treatments.

[5] Salaria et al., 2019

[6] Middleton, 2003

[7] Brown, 1998

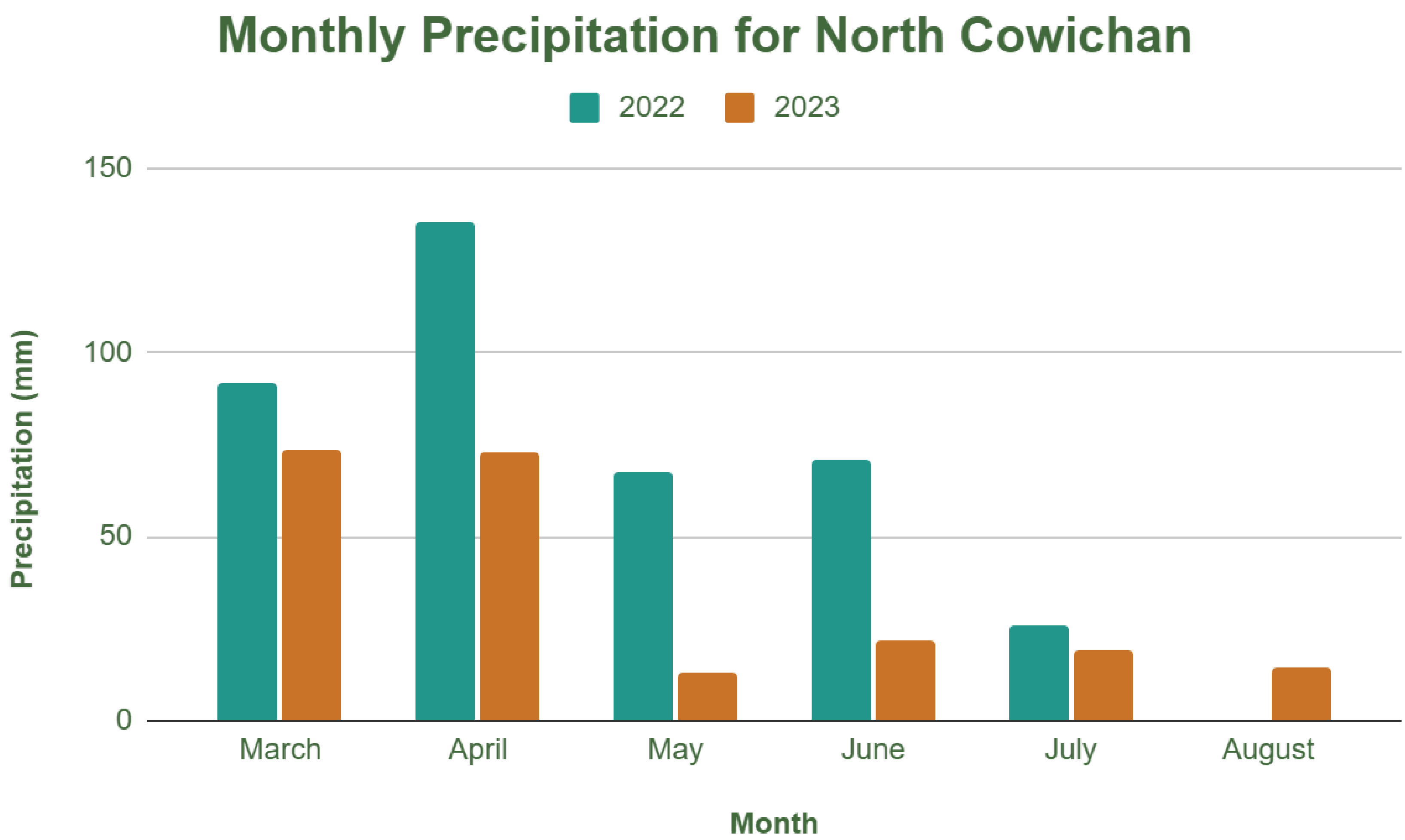

Figure 10: Chart comparing precipitation recorded at the North Cowichan weather station for six months in 2022 and 2023

Summary and Recommendations

Summary

Restoration treatments in the study area were successful in decompacting soils, reintroducing complex microtopography and coarse woody debris, excluding abundant native herbivores, and restoring wetland hydrology. Rough and loose decompaction created bare soil across the site, but provided only about six months of disruption to the dominant cover of introduced grasses and herbs, during and after which these species reasserted themselves from the soil seed bank and root fragments.

Four distinct approaches to revegetation were applied to the study area. It is too early to compare the success of these treatments, but several striking trends are clear across all study plots. Importantly, we observed that very modest increases in native cover across the study area were overshadowed by an extraordinary increase in the cover of introduced grasses. Other trends include an associated decline in the cover of bare soil (which we expect to be permanent), as well as a decline in open water from 2022 to 2023 related to inter-annual fluctuations in precipitation. Some natural recruitment of red alder trees and native herbaceous vegetation was observed in the study area, but this was sporadic and largely confined to bare soil patches and the margins of constructed ponds. Very little activity was observed in Seed Plots, although this may change in the future if delayed germination occurs. In Plant Plots, about 90% of plants survived the first year, and by year two 80% of the original plants remained. In the Live Stake plots, roughly half of the live stakes died in each of the first two years, leaving about a quarter of live stakes alive at the end of year two. Monitoring and management activities in the watershed are ongoing, with the intent for this to be a long-term study.

Recommendations

Recommendations are summarized in the Management Implications section at the beginning of this document. Where possible, recommendations will be carried out to improve both revegetation and monitoring success on this and other associated sites stewarded by the Galiano Conservancy. Recommendations related to plant establishment density, methods, and species selection are already being applied to other sites within the Chrystal Creek watershed at the Millard Learning Centre.

Acknowledgements

This project took place on the shared, asserted, unceded and traditional territories of the Hul'qumi'num-speaking First Nations Peoples and those who hold traditional rights, responsibilities, and Indigenous rights and title in and around what is now known as Galiano Island.

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Supplemental Information

Nursery Plant List by Plot

Table 5: Comprehensive list of species established from nursery stock across 23 Plant Plots in the study area

Plot 1 - Mesic *Acer macrophyllum* (bigleaf maple) *Amelanchier alnifolia* (saskatoon berry) *Gaultheria shallon* (salal) *Holodiscus discolor* (oceanspray) *Pseudotsuga menziesii (*Douglas-fir) *Rubus parviflorus* (thimbleberry) *Rosa gymnocarpa* (baldhip rose) *Thuja plicata* (western redcedar)	**Plot 2 - Dry** *Abies grandis* (grand fir) *Alnus rubra* (red alder) *Arbutus menziesii* (arbutus) *Gaultheria shallon* (salal) *Holodiscus discolor* (oceanspray) *Lonicera hispidula* (hairy honeysuckle) *Pseudotsuga menziesii (*Douglas-fir) *Rubus parviflorus* (thimbleberry)	**Plot 3 - Dry** *Acer macrophyllum* (bigleaf maple) *Holodiscus discolor* (oceanspray) *Lonicera ciliosa* (orange honeysuckle) *Prunus emarginata* (bitter cherry) *Rosa gymnocarpa* (baldhip rose) *Salix scouleriana* (Scouler's willow) *Symphorocarpus albus* (common snowberry) *Thuja plicata* (western redcedar)
Plot 4 - Wet *Abies grandis* (grand fir) *Malus fusca* (pacific crab apple) *Physocarpus capitatus* (pacific ninebark) *Populus trichocarpa* (black cottonwood) *Rhamnus purshiana* (cascara) *Ribes bracteosum* (perfume currant) *Salix scouleriana* (Scouler's willow) *Thuja plicata* (western redcedar)	**Plot 5 - Wet** *Abies grandis* (grand fir) *Cornus sericea* (red osier dogwood) *Populus trichocarpa* (black cottonwood) *Rosa nutkana* (Nootka rose) *Salix scouleriana* (Scouler's willow) *Sambucus racemosa* (red elderberry) *Spiraea douglasii* (hardhack) *Thuja plicata* (western redcedar)	**Plot 6 - Mesic** *Acer macrophyllum* (bigleaf maple) *Amelanchier alnifolia* (saskatoon berry) *Arbutus menziesii* (arbutus) *Lonicera ciliosa* (orange honeysuckle) *Pseudotsuga menziesii (*Douglas-fir) *Ribes sanguineum* (red-flowering currant) *Symphorocarpus albus* (common snowberry) *Thuja plicata* (western redcedar)
Plot 7 - Mesic *Abies grandis* (grand fir) *Cornus nuttallii* (pacific dogwood) *Crataegus douglasii* (black hawthorn) *Lonicera ciliosa* (orange honeysuckle) *Oemleria cerasiformis* (osoberry) *Ribes divaricatum* (wild gooseberry) *Salix scouleriana* (Scouler's willow) *Thuja plicata* (western redcedar)	**Plot 8 - Wet** *Abies grandis* (grand fir) *Cornus nuttallii* (pacific dogwood) *Holodiscus discolor* (oceanspray) *Oemleria cerasiformis* (osoberry) *Prunus emarginata* (bitter cherry) *Ribes divaricatum* (wild gooseberry) *Rubus spectabilis* (salmonberry) *Salix scouleriana* (Scouler's willow)	**Plot 9 - Wet** *Abies grandis* (grand fir) *Crataegus douglasii* (black hawthorn) *Populus trichocarpa* (black cottonwood) *Ribes divaricatum* (wild gooseberry) *Rubus spectabilis* (salmonberry) *Spiraea douglasii* (hardhack) *Thuja plicata* (western redcedar) *Viburnum edule* (highbush cranberry)
Plot 10 - Dry *Abies grandis* (grand fir) *Arbutus menziesii* (arbutus) *Gaultheria shallon* (salal) *Holodiscus discolor* (oceanspray) *Lonicera hispidula* (hairy honeysuckle) *Pseudotsuga menziesii (*Douglas-fir) *Ribes sanguineum* (red-flowering currant) *Rosa gymnocarpa* (baldhip rose)	**Plot 11 - Wet** *Abies grandis* (grand fir) *Alnus rubra* (red alder) *Crataegus douglasii* (black hawthorn) *Oemleria cerasiformis* (osoberry) *Ribes bracteosum* (perfume currant) *Rubus parviflorus* (thimbleberry) *Spiraea douglasii* (hardhack) *Thuja plicata* (western redcedar)	**Plot 12 - Wet** *Acer macrophyllum* (bigleaf maple) *Malus fusca* (pacific crab apple)*Populus trichocarpa* (black cottonwood) *Rhamnus purshiana* (cascara) *Rubus spectabilis* (salmonberry) *Salix lucida* (pacific willow) *Symphorocarpus albus* (common snowberry) *Thuja plicata* (western redcedar)
Plot 13 - Wet *Acer glabrum* (Douglas maple) *Physocarpus capitatus* (pacific ninebark) *Populus trichocarpa* (black cottonwood) *Ribes divaricatum* (wild gooseberry) *Rosa nutkana* (Nootka rose) *Salix lucida* (pacific willow) *Sambucus racemosa* (red elderberry) *Thuja plicata* (western redcedar)	**Plot 14 - Wet** *Abies grandis* (grand fir) *Acer macrophyllum* (bigleaf maple) *Alnus rubra* (red alder) *Berberis aquifolium* (tall Oregon-grape) *Pseudotsuga menziesii (*Douglas-fir) *Ribes sanguineum* (red-flowering currant) *Rosa gymnocarpa* (baldhip rose) *Symphorocarpus albus* (common snowberry)	**Plot 15 - Dry** *Abies grandis* (grand fir) *Acer macrophyllum* (bigleaf maple) *Alnus rubra* (red alder) *Amelanchier alnifolia* (saskatoon berry) *Arbutus menziesii* (arbutus) *Lonicera ciliosa* (orange honeysuckle) *Lonicera hispidula* (hairy honeysuckle) *Vaccinium ovatum* (evergreen huckleberry)
Plot 16 - Wet	**Plot 17 - Mesic**	**Plot 18 - Wet**

Acer glabrum (Douglas maple) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Physocarpus capitatus* (pacific ninebark) *Populus trichocarpa* (black cottonwood) *Rhamnus purshiana* (cascara) *Salix lucida* (pacific willow) *Thuja plicata* (western redcedar)	*Acer glabrum* (Douglas maple) *Populus trichocarpa* (black cottonwood) *Rhamnus purshiana* (cascara) *Salix lucida* (pacific willow) *Salix scouleriana* (Scouler's willow) *Sambucus racemosa* (red elderberry) *Spiraea douglasii* (hardhack) *Viburnum edule* (highbush cranberry)	*Acer glabrum* (Douglas maple) *Cornus sericea* (red osier dogwood) *Malus fusca* (pacific crab apple) *Populus trichocarpa* (black cottonwood) *Ribes bracteosum* (perfume currant) *Taxus brevifolia* (western yew) *Thuja plicata* (western redcedar) *Viburnum edule* (highbush cranberry)
Plot 19 - Wet *Acer glabrum* (Douglas maple) *Cornus stolonifera sericea* (red osier dogwood) *Populus trichocarpa* (black cottonwood) *Rosa nutkana* (Nootka rose) *Sambucus racemosa* (red elderberry) *Taxus brevifolia* (western yew) *Thuja plicata* (western redcedar) *Viburnum edule* (highbush cranberry)	**Plot 20 - Dry** *Abies grandis* (grand fir) *Alnus rubra* (red alder) *Arbutus menziesii* (arbutus) *Berberis aquifolium* (tall Oregon-grape) *Lonicera hispidula* (hairy honeysuckle) *Pseudotsuga menziesii* (Douglas-fir) *Ribes sanguineum* (red-flowering currant) *Vaccinium ovatum* (evergreen huckleberry)	**Plot 21 - Mesic** *Abies grandis* (grand fir) *Acer macrophyllum* (bigleaf maple) *Lonicera ciliosa* (orange honeysuckle) *Prunus emarginata* (bitter cherry) *Ribes sanguineum* (red-flowering currant) *Rubus parviflorus* (thimbleberry) *Rubus spectabilis* (salmonberry) *Salix scouleriana* (Scouler's willow)
Plot 22 - Mesic *Acer macrophyllum* (bigleaf maple) *Alnus rubra* (red alder) *Crataegus douglasii* (black hawthorn) *Ribes divaricatum* (wild gooseberry) *Ribes sanguineum* (red-flowering currant) *Rubus parviflorus* (thimbleberry) *Thuja plicata* (western redcedar) *Vaccinium ovatum* (evergreen huckleberry)	**Plot 23 - Dry** *Abies grandis* (grand fir) *Acer macrophyllum* (bigleaf maple) *Alnus rubra* (red alder) *Crataegus douglasii* (black hawthorn) *Rubus spectabilis* (salmonberry) *Symphorocarpus albus* (common snowberry) *Thuja plicata* (western redcedar) *Vaccinium ovatum* (evergreen huckleberry)	

Live Stake List by Plot

Table 6: Comprehensive list of species established as live stakes in 22 Live Stake Plots in the study area

Plot 1 - Mesic *Cornus sericea* (red osier dogwood) *Salix scouleriana* (Scouler's willow) *Spiraea douglasii* (hardhack)	**Plot 2 - Dry** *Salix scouleriana* (Scouler's willow) *Spiraea douglasii* (hardhack)	**Plot 3 - Wet** *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)

Plot 4 - Wet *Salix scouleriana* (Scouler's willow) *Spiraea douglasii* (hardhack)	**Plot 5 - Mesic** *Holodiscus discolor* (oceanspray) *Salix scouleriana* (Scouler's willow)	**Plot 6 - Mesic** *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)
Plot 7 - Wet *Holodiscus discolor* (oceanspray) *Salix scouleriana* (Scouler's willow)	**Plot 8 - Wet** *Cornus sericea* (red osier dogwood) *Betula papyrifera* (paper birch) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)	**Plot 9 - Dry** *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)
Plot 10 - Wet *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)	**Plot 11 - Wet** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)	**Plot 12 - Wet** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Spiraea douglasii* (hardhack)
Plot 13 - Wet *Cornus sericea* (red osier dogwood) *Holodiscus discolor* (oceanspray) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Salix scouleriana* (Scouler's willow) *Spiraea douglasii* (hardhack)	**Plot 14 - Dry** *Holodiscus discolor* (oceanspray) *Salix scouleriana* (Scouler's willow)	**Plot 15 - Wet** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)
Plot 16 - Mesic *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)	**Plot 17 - Wet** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)	**Plot 18 - Wet** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock orange) *Populus trichocarpa* (black cottonwood) *Spiraea douglasii* (hardhack)
Plot 19 - Dry *Holodiscus discolor* (oceanspray) *Salix scouleriana* (Scouler's willow)	**Plot 20 - Mesic** *Betula papyrifera* (paper birch) *Cornus sericea* (red osier dogwood) *Oemleria cerasiformis* (osoberry) *Philadelphus lewisii* (Lewis' mock	**Plot 21 - Mesic** *Spiraea douglasii* (hardhack) *Salix scouleriana* (Scouler's willow)

	orange) *Salix scouleriana* (Scouler's willow) *Spiraea douglasii* (hardhack)	
Plot 22 - Dry *Spiraea douglasii* (hardhack) *Salix scouleriana* (Scouler's willow)		

Seed Mixture by Plot

Table 6: Comprehensive list of species seeded across relative moisture regimes (23 Seed Plots) in the study area

Dry (n=7)			
Layer	**Scientific Name**	**Common Name**	**Approximate weight/plot (g)**
A	*Acer macrophyllum*	Bigleaf maple	7.3
A	*Alnus rubra*	Red alder	1.0
A	*Arbutus mensiezii*	Arbutus (berry)	54.2
A	*Arbutus mensiezii*	Arbutus (seed)	3.8
A	*Pseudotsuga menzeisii*	Douglas-fir	0.2
B	*Berberis nervosa*	Dull Oregon-grape	0.3
B	*Gaultheria shallon*	Salal	0.3
B	*Holodiscus discolor*	Oceanspray	1.5
B	*Rosa gymnocarpa*	Baldhip rose	0.5
B	*Rubus leucodermis*	Blackcap raspberry	0.2
B	*Symphoricarpos albus*	Common snowberry	0.2
C	*Achillea millefolium*	Yarrow	0.2
C	*Anaphalis margaritacea*	Pearly everlasting	0.2
C	*Chamerion angustifolium*	Fireweed	0.2
C	*Epilobium densiflorum*	Dense rose primrose	0.2
C	*Grindelia stricta*	Coastal gumweed	0.2
C	*Lonicera hispidula*	Hairy honeysuckle	0.9
C	*Solidago canadensis*	Canada goldenrod	0.4
D	*Elymus glaucous*	Blue wildrye	4.2

Mesic (n=10)			
Layer	**Scientific Name**	**Common Name**	**Approximate weight/plot (g)**
A	*Acer macrophyllum*	Bigleaf maple	7.3
A	*Alnus rubra*	Red alder	1.0
A	*Crataegus douglasii*	Black hawthorn	0.6
A	*Physocarpus capitatus*	Pacific ninebark	0.2
A	*Sambucus racemosa*	Red elderberry	0.5
A	*Thuja plicata*	Western redcedar (seed)	0.1
A	*Thuja plicata*	Western redcedar (cone)	3.4

B	*Berberis nervosa*	Dull Oregon-grape	0.3
B	*Gaultheria shallon*	Salal	0.3
B	*Holodiscus discolor*	Oceanspray	1.5
B	*Rosa gymnocarpa*	Baldhip rose	0.5
B	*Rubus leucodermis*	Blackcap raspberry	0.2
B	*Symphoricarpos albus*	Common snowberry	0.2
C	*Chamerion angustifolium*	Fireweed	0.2
C	*Epilobium densiflorum*	Dense rose primrose	0.2
C	*Lonicera hispidula*	Hairy honeysuckle	0.9
C	*Symphyotrichum subspicatum*	Douglas aster	0.1
D	*Carex obnupta*	Slough sedge	5.4
D	*Elymus glaucous*	Blue wildrye	4.2
D	*Juncus bolanderii*	Bolander's rush	0.4
D	*Scirpus microcarpus*	small-headed bulrush	1.4

Wet (n=6)			
Layer	**Scientific Name**	**Common Name**	**Approximate weight/plot (g)**
A	*Acer macrophyllum*	Bigleaf maple	7.3
A	*Alnus rubra*	Red alder	1.0
A	*Crataegus douglasii*	Black hawthorn	0.6
A	*Physocarpus capitatus*	Pacific ninebark	0.2
A	*Sambucus racemosa*	Red elderberry	0.5
A	*Thuja plicata*	Western redcedar (seed)	0.1
A	*Thuja plicata*	Western redcedar (cone)	3.4
B	*Spiraea douglasii*	Hardhack	0.9
C	*Chamerion angustifolium*	Fireweed	0.2
C	*Epilobium densiflorum*	Dense rose primrose	0.2
C	*Oenanthe sarmentosa*	Water parsley	0.1
C	*Symphyotrichum subspicatum*	Douglas aster	0.1
D	*Carex macrocephala*	Big-head sedge	0.4
D	*Carex obnupta*	Slough sedge	5.4
D	*Juncus bolanderi*	Bolander's rush	0.4
D	*Scirpus microcarpus*	small-headed bulrush	1.4

Project Timeline

Restoration Treatments

Data Range	Activity
April - August 2021	Target introduced species removal
April - August 2021	Derelict structure and garbage removal
September - October 2021	Logging road removal
September - October 2021	“Rough and loose” soil decompaction
September - October 2021	Shallow-water wetland creation
September - October 2021	Distribution of woody debris, including installation of standing snags
March - April 2022	Erosion control, including live-staking and rock aprons between wetlands

Revegetation Treatments

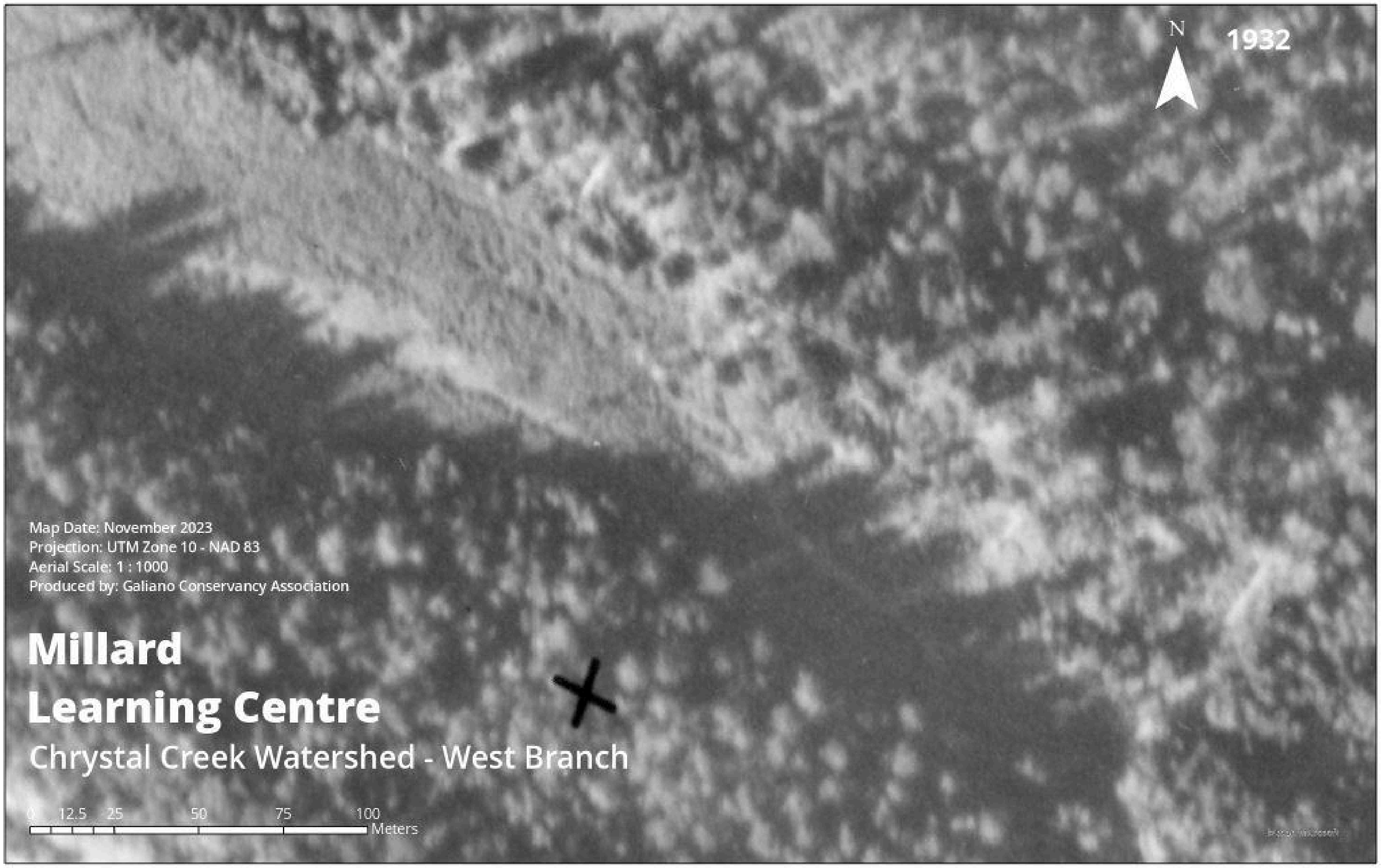
Data Range	Activity
October - December 2021	Revegetation through outplanting of nursery stock, live-staking, seeding, and passive regeneration
November 2021	Deer fence installation
November 2021 - Present	Periodic revegetation maintenance and target introduced species removal

Monitoring Activities

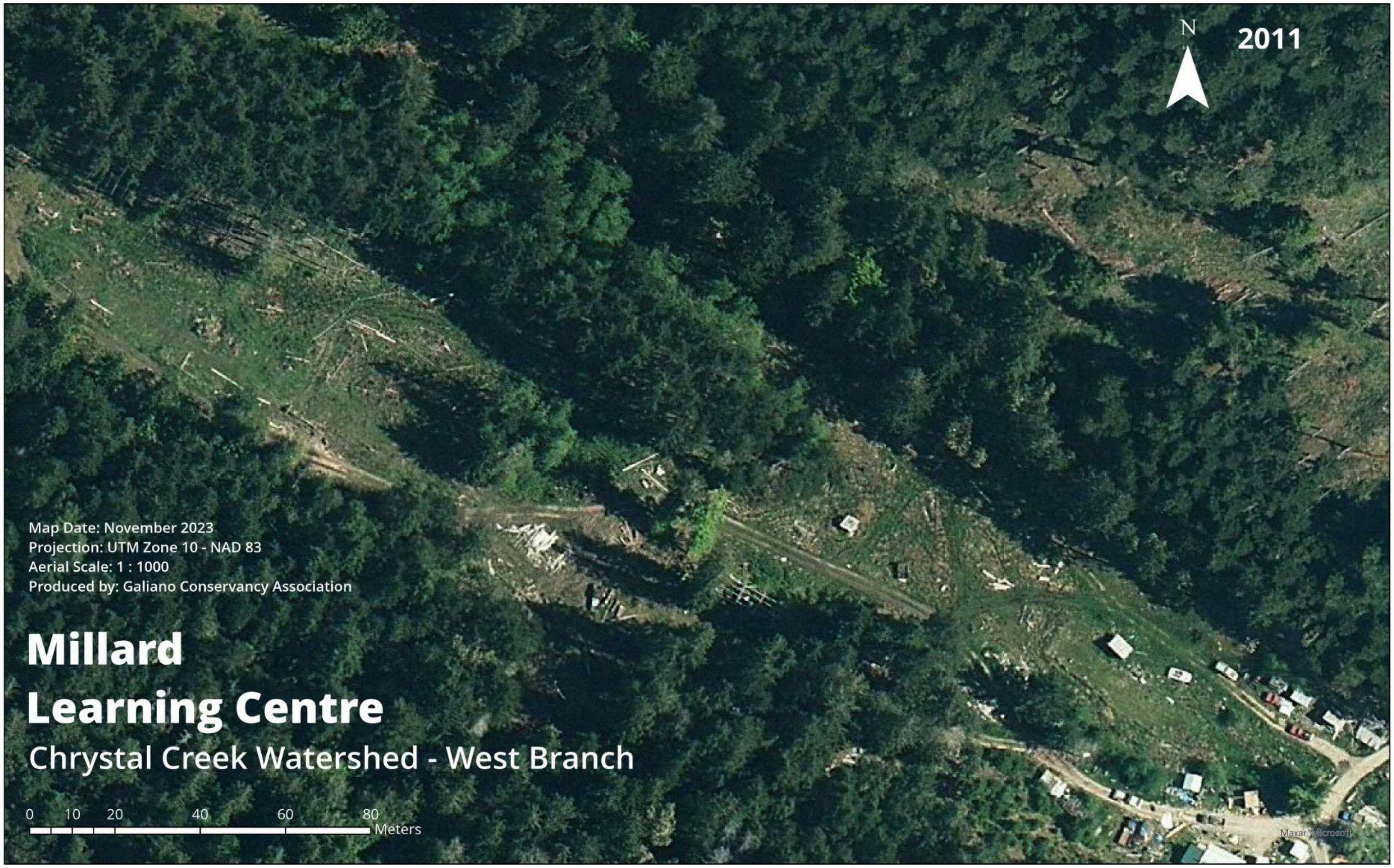
Data Range	Activity
June 11-20, 2022	Year 1 monitoring for survival, percent cover, and recruitment
June 21 - July 10, 2023	Year 2 monitoring for survival, percent cover, and recruitment

Aerial Photography

1932 - Earliest Photograph on Record



2011 - Year Prior to GCA Acquisition of DL 57



2021 - Baseline conditions

2023 - Prior to second round of monitoring activities

Statistical Analysis

All statistical analyses were performed using the software program RStudio. Results are provided below.

Vegetation Percent Cover: Paired T-test

```
> # paired t.tests
> t.test(x = vegPlots2022$`Bare Soil`,
+       y = vegPlots2023$`Bare Soil`,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$`Bare Soil` and
vegPlots2023$`Bare Soil`
t = 3.5171, df = 36, p-value = 0.0012
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
  3.037858 11.313494
sample estimates:
mean difference
       7.175676

> t.test(x = vegPlots2022$`Water`,
+       y = vegPlots2023$`Water`,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$Water and vegPlots2023$Water
t = 4.5941, df = 36, p-value = 5.156e-05
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
  6.73275 17.37536
sample estimates:
mean difference
       12.05405

> t.test(x = vegPlots2022$'Native Trees (<3m
height)',
+       y = vegPlots2023$'Native Trees (<3m height)',
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$"Native Trees (<3m height)" and
vegPlots2023$"Native Trees (<3m height)"
t = -4.1034, df = 36, p-value = 0.0002227
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
 -0.7875106 -0.2665434
sample estimates:
mean difference
      -0.527027

> t.test(x = vegPlots2022$`Native Shrubs`,
+       y = vegPlots2023$`Native Shrubs`,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$`Native Shrubs` and
vegPlots2023$`Native Shrubs`
t = -2.0987, df = 36, p-value = 0.04292
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
 -1.54118165 -0.02638592
sample estimates:
mean difference
     -0.7837838

> t.test(x = vegPlots2022$`Native Forbs`,
+       y = vegPlots2023$`Native Forbs`,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$`Native Forbs` and
vegPlots2023$`Native Forbs`
t = 0.046104, df = 36, p-value = 0.9635
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
 -4.066595  4.255784
sample estimates:
mean difference
     0.09459459

> t.test(x = vegPlots2022$`Introduced Forbs`,
+       y = vegPlots2023$`Introduced Forbs`,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$`Introduced Forbs` and
vegPlots2023$`Introduced Forbs`
t = 1.0426, df = 36, p-value = 0.3041
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
 -4.061744 12.656338
sample estimates:
mean difference
       4.297297

> t.test(x = vegPlots2022$Grass,
+       y = vegPlots2023$Grass,
+       alternative = "two.sided",
+       paired = TRUE)

data:  vegPlots2022$Grass and vegPlots2023$Grass
t = -6.0056, df = 36, p-value = 6.83e-07
alternative hypothesis: true mean difference is not
equal to 0
95 percent confidence interval:
 -32.10476 -15.89524
sample estimates:
mean difference
            -24
```

Red Alder Recruitment: Chi-square test

```
> table(alders$Moisture, alders$Alders)

     0  1
  1 18 10
  2 21 16
  3  9 11

> chisq.test(table(alders$Moisture, alders$Alders))

        Pearson's Chi-squared test

data:  table(alders$Moisture, alders$Alders)
X-squared = 1.7675, df = 2, p-value = 0.4132
```

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