GORGE WATERWAY NATURE HOUSE

POLLINATOR MEADOW PHASE 2

ABSTRACT

Pollinator populations face threats from urbanization, making restoration essential for their survival in urban areas. This project aims increase pollinator presence by trialing different methods of invasive species suppression and native plant establishment in a series of test plots in Esquimalt Gorge Park, Victoria, B.C. This acts as Phase 2 of an existing pollinator meadow planted by the Gorge Waterway Action Society (GWAS) in 2020.

Species coverage data was analyzed for Phase 1 of the Pollinator Meadow, along with moisture and light preferences. All test plots were analyzed for their hours and costs per square metre as well as their ratio of native to non-native species coverage to date. Phase 1 is currently the most cost-effective method used, likely due to the increased plot area which allowed resources to have a larger-scale impact. Sticky cinquefoil (*Drymocallis glandulosa*), woolly sunflower (*Eriophyllum lanatum*), entire-leaved gumweed (*Grindelia stricta*), hairy honeysuckle (*Lonicera hispidula*), Lewis's mock-orange (*Philadelphus lewisii*), Pacific ninebark (*Physocarpus capitatus*), red-flowering currant (*Ribes sanguineum*), Nootka rose (*Rosa nutkana*), Henderson's checker-mallow (*Sidalcea hendersonii*), and Douglas' aster (*Symphyotrichum subspicatum*) increased in percent cover from 2021 to 2022. Yarrow (*Achillea millefolium*), self-heal (*Prunella vulgaris*), Western Canada goldenrod (*Solidago lepida*), and common snowberry (*Symphoricarpos albus*) also performed well. Entire-leaved gumweed (*Grindelia stricta*) was the highest performing species.

Invasive species management techniques including mechanical methods, chemical methods, prescribed fire, and native seeding were analyzed for their applicability to the project site. Mechanical methods continue to be the most accessible and plausible management technique for the site, although it is recommended that they be scaled up and timed precisely to be more effective.

Future data collection by GWAS summer students will continue to inform GWAS's understanding of the most cost-effective and successful techniques used, as well as the species best suited to the site. A list of recommendations for future site management has been provided to GWAS.

Trialing methods of invasive plant suppression and native plant establishment in Esquimalt Gorge Park, Victoria, BC

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ER 390 Final Restoration Project

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1. Introduction

A major threat facing pollinator populations is urbanization and the associated loss of native ecosystems (Wray & Elle, 2015). Pollinating insects provide vital ecosystem services, including the transfer of energy between plants and animals in a food web (Tallamy, 2019; Wray & Elle, 2015). To persist in a location, pollinators require specific nectar, pollen, and nesting sources to meet their needs at all times of the year (Pollinator Partnership Canada, 2017). To cultivate these resources in an area, it is necessary to encourage the presence of native plant species while suppressing the invasive plant species that threaten them. Literature indicates that planting native species in urban areas can combat the loss of native habitat and supplement the resources required for pollinators to survive in these landscapes (Wray & Elle, 2015).

This project focused on increasing pollinator presence through trialing techniques of invasive species suppression and native plant establishment in Esquimalt Gorge Park, Victoria, B.C. Three test plots were created for this purpose. The project was carried out in collaboration with the Gorge Waterway Action Society (GWAS) as Phase 2 of their existing Pollinator Meadow project. GWAS is an environmental non-profit located in Esquimalt, British Columbia.

The costs and hours associated with the test plots were examined, along with the ratio of native to non-native species and the coverage of all planted species over time. Literature on invasive species management in grassland ecosystems was also explored. Altogether, this provided GWAS with recommendations that can inform future management decisions in the project area.

2. Study Area

The site is situated in the southwestern part of Esquimalt Gorge Park in Victoria, B.C. (Figure 1). It is a part of the Coastal Douglas-fir Biogeoclimatic Zone, experiencing dry summers and mild, wet winters (Nuszdorfer et al., 1991). The site has a southwest facing exposure, creating dry, sunny conditions. It is situated at the base of a gradual hill that becomes forested at its peak. The site's main environmental stressors include herbivory, invasive species, poor soil conditions, and increasingly common periods of drought.

Figure 1: *Phase 2 site map (small scale).*

Currently, the site is dominated by common velvetgrass (*Holcus lanatus*), common soft brome (*Bromus hordeaceus*), salt barley (*Hordeum marinum*), tall oatgrass (*Arrhenatherum elatius*), quack grass (*Elymus repens*), barren brome (*Bromus sterilis*), and orchard grass (*Dactylis glomerata*). Purple deadnettle (*Lamium purpureum)*, cutleaf geranium (*Geranium dissectum*), Smith's peppergrass (*Lepidium heterophyllum*), and clover species (*Trifolium spp.*) are common as well (Figure 2; Table A1). The site's historical state, prior to anthropogenic activities in the area, is assumed to be a mature forest (Government of Canada, 1928).

Figure 2: *Species at the Phase 2 site pre-project installation.*

Note: Photo taken March 13, 2022.

3. Goals and Objectives

The site has a complex history of anthropogenic activities that drove major transformations in the landscape (CRD, n.d.; Gorge Waterway Initiative, 2008). Consequently, a historical forested state will not be the restoration target for this site. Rather, the site is a suitable target for a novel Garry Oak meadow assemblage because of the collection of Garry oak (*Quercus garryana*) trees already established and the historical presence of Garry Oak ecosystems nearby (GOERT, 2002). Additionally, the site appears to function well as a shrub-meadow mix as evidenced through current observations of insects, birds, and other wildlife.

This project aims to increase pollinator presence while trialing different methods of invasive species management and native plant establishment. The project will also create educational material for distribution in the GWAS Nature House. There are multiple (**4**) goals contained within these focal areas, each of which is accompanied by measurable objectives. These are as follows:

- **Goal:** Increase pollinator presence at the project site.
    - **Objective:** Plant and seed native species at high densities in Phase 2 test plots in 2022, targeting species that attract pollinators.

- **Goal:** Increase native species presence at the project site.
    - **Objective:** Trial methods of native plant establishment in Phase 2 test plots in 2022 and track their progress for two consecutive summers.
- **Goal**: Decrease invasive and non-native species presence at the project site.
    - **Objective:** Trial methods of invasive plant suppression in Phase 2 test plots in 2022 and track their progress for two consecutive summers.
    - **Objective:** Research invasive species management techniques for grassland ecosystems and present GWAS with recommendations site management starting in 2023.
- **Goal:** Determine the most effective use of GWAS resources for restoring the project area and provide recommendations for future GWAS summer students.
    - **Objective:** Compare hours and costs per square metre for all test plots beginning at their installation and spanning until the end of August 2022.
    - **Objective:** Compare the ratios of native to non-native species composition across all test plots for the first two summers after planting.
    - **Objective:** Compare the percent cover of planted species in all test plots to inform future planting choices.
- **Goal:** Contribute to GWAS community engagement efforts.
    - **Objective:** Create an educational flyer related to the project for distribution in the GWAS Nature House in 2023.

4. Methods

4.1 Project Research

4.1.1 Site History

As part of the project's research, the site's history was examined to determine the impact of historical activities on current site characteristics. The site is located on the unceded territories of the Songhees and Esquimalt First Nations, whose historical village sites exist along the Gorge Waterway. These Nations used the waterway for spiritual purposes and as a source of food (Gorge Waterway Initiative, 2008). After European settlement, industrial activities in Victoria Harbour created pollution that flowed into the Gorge Waterway for many years (CRD, n.d.). This, combined with years of fire suppression, caused the landscape to transform drastically from its historical state (Turner, 1999).

The earliest available data for this site, detailing the distribution of Garry Oak ecosystems in 1800 and 1997, shows Esquimalt Gorge Park (EGP) in a pocket of non-Garry Oak habitat (GOERT, 2002). However, the park was bordered by Garry Oak habitat on its western and eastern boundaries (GOERT, 2002). Aerial photos from 1928 show the project site in dense forest cover, with a daylit Gorge Creek flowing along its southwestern edge (Government of Canada, 1928). By 1997, Gorge Creek was diverted underground, and a large tennis court and saltwater swimming pool were installed (Gorge Waterway Action Society, 2017). In 2006, Gorge Creek was daylighted through a major restoration project. During this, the site area was hydroseeded with a non-native grass mix that persists today (S. Gurney, personal communication, January 6, 2021).

4.1.2 GWAS Pollinator Meadow Construction

In the summer of 2020, GWAS removed invasive grasses from a large swath of land along Gorge Creek and planted an assortment of native wildflowers, creating a pollinator meadow. The species planted were selected for their ability to attract pollinators. The meadow's goal was to combat the effects of urbanization, restore this native ecosystem, and increase pollinator presence. This constituted Phase 1 of GWAS's Pollinator Meadow project.

4.2 Phase 2 Installation

A grassland patch directly adjacent to the Phase 1 Pollinator Meadow was selected as the Phase 2 project site. Using a large Garry oak (*Quercus garryana*) tree as a reference point, a baseline was created 1 metre south of the tree extending 9 metres southeast at 131°. Three transects were laid down perpendicular to this baseline at the 4, 6, and 8 metre marks, each extending 8 metres out from the baseline at an orientation of 41°. Transect 2, which would receive the first treatments, was surveyed using a 1 x 1 metre PVC pipe quadrat on March 23, 2022. Beginning on the left side of the transect, the quadrat was laid down and the distance it covered along the transect was noted (Figure 3). Using visual estimates, the percent cover of each identified species or element falling inside the quadrat was recorded (Appendix E) (Luttmerding et al., 1990). A piece of paper was placed along the quadrat's upper edge indicating the date and transect number, and the quadrat was photographed (Figure 4). It was then repositioned to cover the next 1 metre distance along the transect on its opposite side, and the previously mentioned steps were repeated for the remainder of Transect 2. For this and all future transects, labels indicating the transect number and date were only included in photographs of the first quadrat for each new transect. Transects 1 and 3 were surveyed on May 4th, 2022. Altogether, this constituted Phase 2's baseline data.

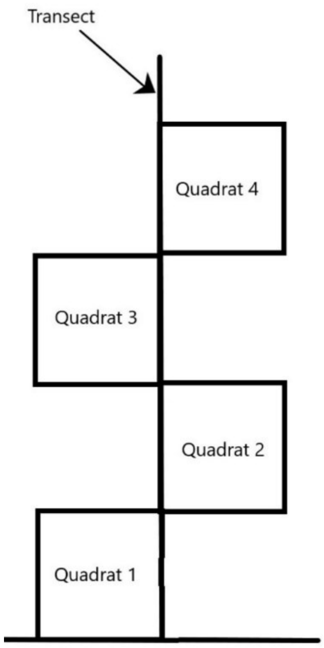

Figure 3: *Reference diagram for conducting alternating belt transect surveys.*

Figure 4*: Quadrat 2.1 from March 23, 2022 survey.*

Figure 5: *Phase 2 site map (large scale).*

On March 26, 2022, a 2 x 7 metre plot was identified along either side of Transect 2 (Figure 5). The upper 2 x 5 metre portion of the plot was sectioned off with flags, becoming the leaf mulch test plot. The grass mat in this plot was removed mechanically using a large gardening shovel, and a layer of leaf mulch was added to a depth of approximately four inches. The lower 2 x 2 metre plot was harrowed by hand using a hand-held gardening fork, becoming the harrowed test plot. On March 27, 2022, we planted 88 plants of 11 different species the Leaf Mulch Test Plot and seeded it with Douglas' aster (*Symphiotrichum subspicatum*), Sandberg's bluegrass (*Poa secunda*), field chickweed

(*Cerastium arvense*), and Farewell-to-Spring (*Clarkia amoenia*) (Figure 6). Additionally, sea blush (*Plectritus congesta*) and Blue-eyed Mary (*Collinsia parviflora*) transplants were later salvaged with the help of Habitat Acquisition Trust and planted in this plot on April 3, 2022.

Figure 6: *Plants purchased for Phase 2 Leaf Mulch Test Plot.*

Note: Photo taken March 27, 2022.

Figure 7: *Rows dug for seeding Phase 2 Harrowed Test Plot.*

Note: Photo taken March 27, 2022.

The Phase 2 Harrowed Test Plot was also seeded with Douglas' aster (*Symphiotrichum subspicatum*), Sandberg's bluegrass (*Poa secunda*), field chickweed (*Cerastium arvense*), and Farewell-to-Spring (*Clarkia amoenia*) (Figure 7). A full list of starters and seeds used for the Leaf Mulch and Harrowed test plots is outlined in Appendix A (Table A3). Transect 2 was surveyed again on July 29, 2022, using previously described methods, to collect the first summer of data for these two test plots. Figure 8 shows the progression of these plots from March until August 2022.

Figure 8: *Phase 2 Leaf Mulch and Harrowed test plots.* ***a)*** *March 23, 2022.* ***b)*** *March 26, 2022.* ***c)*** *March 26, 2022.* ***d)*** *March 27, 2022.* ***e)*** *July 18, 2022.* ***f)*** *August 22, 2022.*

Note: Photo taken at an orientation of 221°.

On July 13, 2022, a third test plot was identified in a 2 x 2 metre section along Transect 3, becoming the Solarized Test Plot (Figure 9). Debris and grass were cleared using hand tools, and the plot was watered thoroughly. A trench was dug around the perimeter of the plot to a depth of three to five inches, and a clear plastic drop sheet was laid down. The edges of the sheet were placed in the trench and secured by adding soil on top. This structure was left for 48 days and removed on August 30th, 2022. On this day, a small amount of compost was added before the plot was planted and seeded with species outlined in Appendix A (Table A4).

Figure 9: *Solarization of Phase 2 Solarized Test Plot.*

Note: Photo taken July 13, 2022.

4.3 Data Manipulation

To begin with, average precipitation and maximum temperature for the months of March to August in 2021 and 2022 were recorded for Victoria, B.C. using data available through Environment and Climate Change Canada (Appendix D) (ECCC, 2023). This data was plotted using Microsoft Excel (Figure 10).

Phase 1 percent cover data for planted native species over two consecutive summers was then compiled in Excel. Trends in coverage were also calculated using the difference between the second and first summer's values. Only planted native species were included in this analysis to identify desired target species; non-native species were excluded from this data. This information was then plotted using Microsoft Excel and R software (Figures 11-12). Using R, this Phase 1 data was then plotted against light and moisture preferences derived from Pollinator Partnership Canada, the

Invasive Species Council of B.C., Minnesota Wildflowers, and Satinflower Nurseries (Figures 13-18) (Invasive Species Council of BC, n.d.; Minnesota Wildflowers, 2023; Pollinator Partnership Canada, 2023; Satinflower Nurseries, 2023). Light preferences were separated into part shade to shade, sun to part shade to shade, sun to part shade, and sun categories, while moisture preferences were separated into wet, normal, and dry categories.

Additionally, biophysical inventory data was compiled for Phase 1 and all Phase 2 test plots. The total percent cover of non-native and native species was identified within this data and separated by the year of data collection (Appendix B). Using Microsoft Excel, this information was then plotted for all test plots (Figures 19-22).

The hours and costs associated with each plot were also compiled, and separated into site preparation, installation, and ongoing maintenance-related tasks (Appendix C). This information was then plotted for Phase 1 and all Phase 2 test plots (Figures 23-24).

Species data plotted for Phase 1, shown in Figures 11-18, can also be plotted for Phase 2 test plots when two summers of data have been collected for each plot. To begin this process, species data for these plots are compiled in Appendix A (Tables A3-A4).

5. Results

5.1 Climate Data

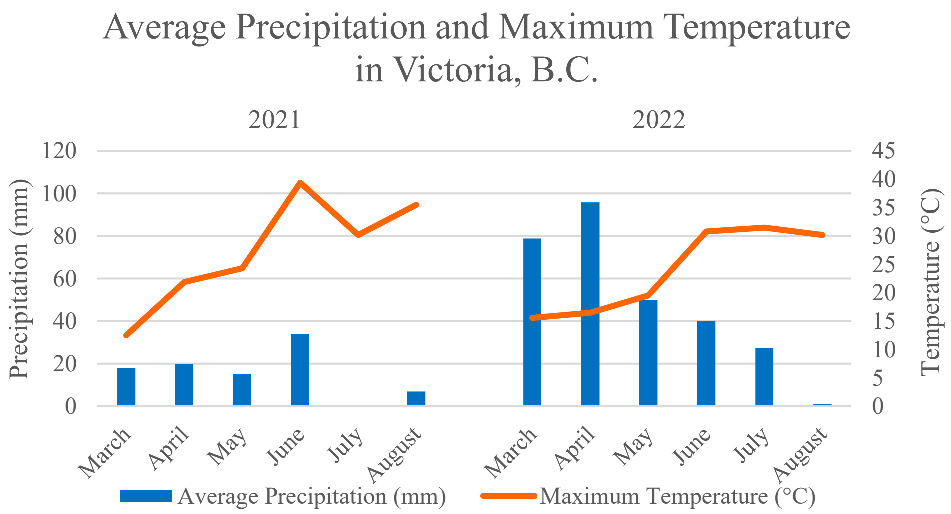

Figure 10: *Average precipitation and maximum temperature in Victoria, British Columbia.*

Note: Data recorded from March – August 2021 and 2022 (Appendix D) (ECCC, 2023).

5.2 Phase 1 Percent Cover by Species

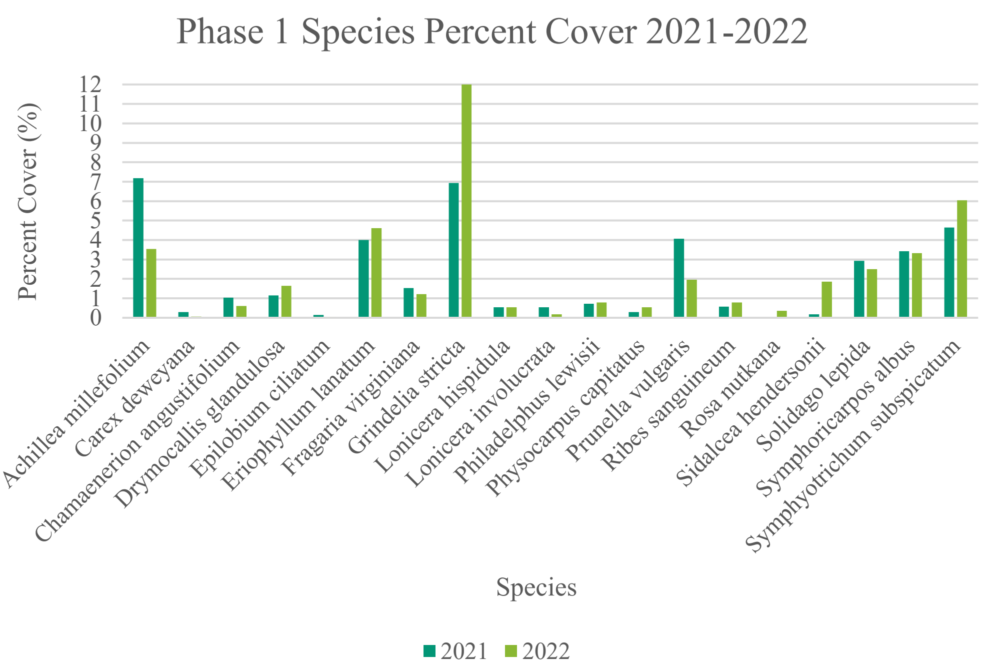

Figure 11: *Phase 1 percent cover by species in 2021 and 2022.*

Note: 2021 data was collected from July 9, 2021, to July 14, 2021. 2022 data was collected from June 10, 2022, to June 20, 2022.

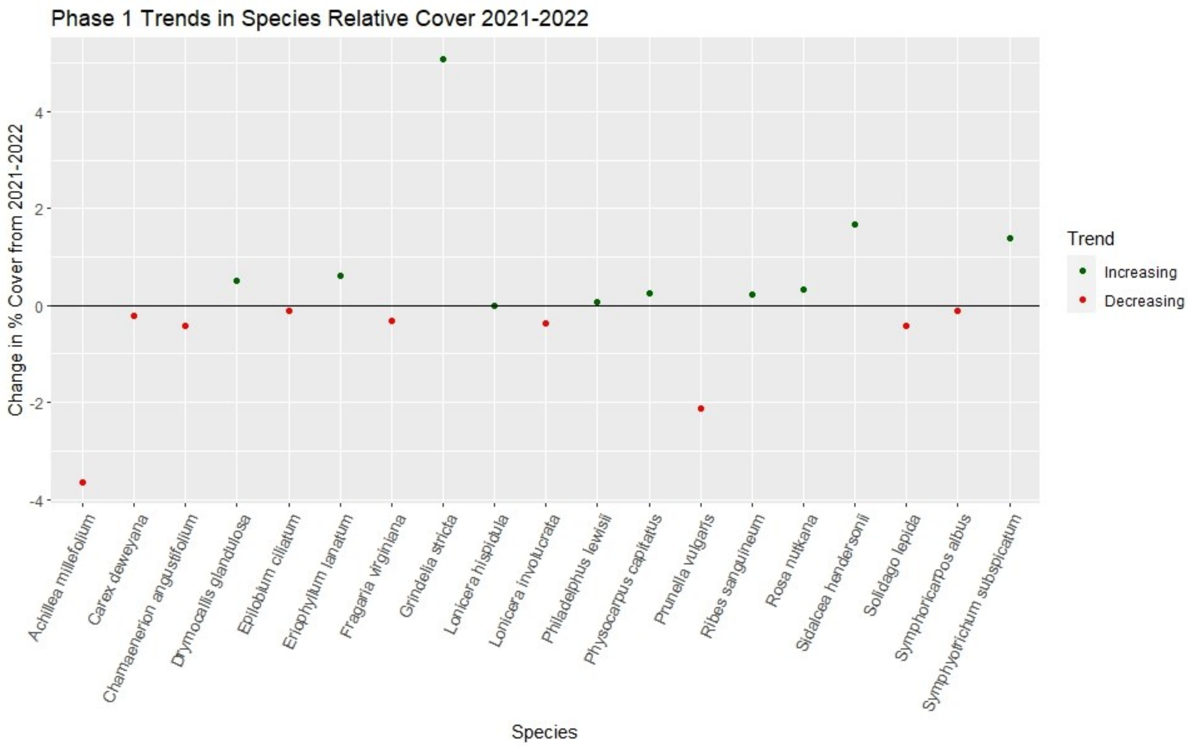

Figure 12: *Trends in Phase 1 species' percent cover from 2021-2022.*

5.3 Phase 1 Percent Cover by Light Preference

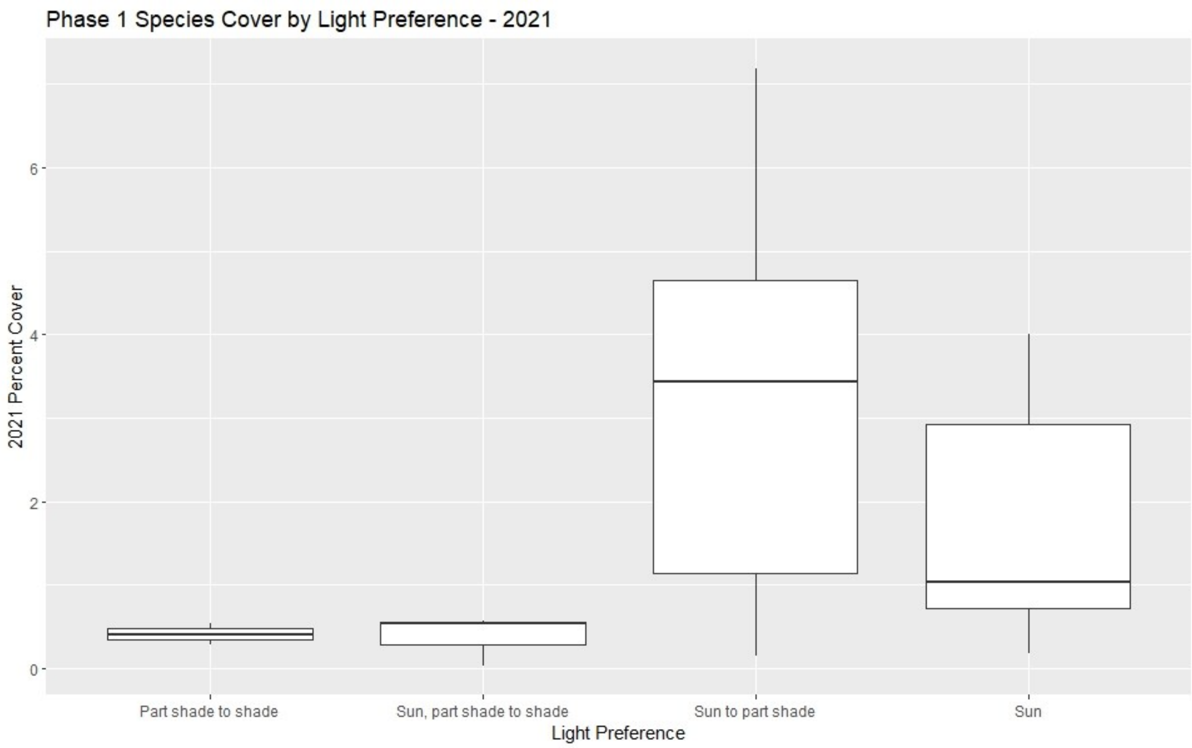

Figure 13: *2021 Phase 1 species cover by light preference.*

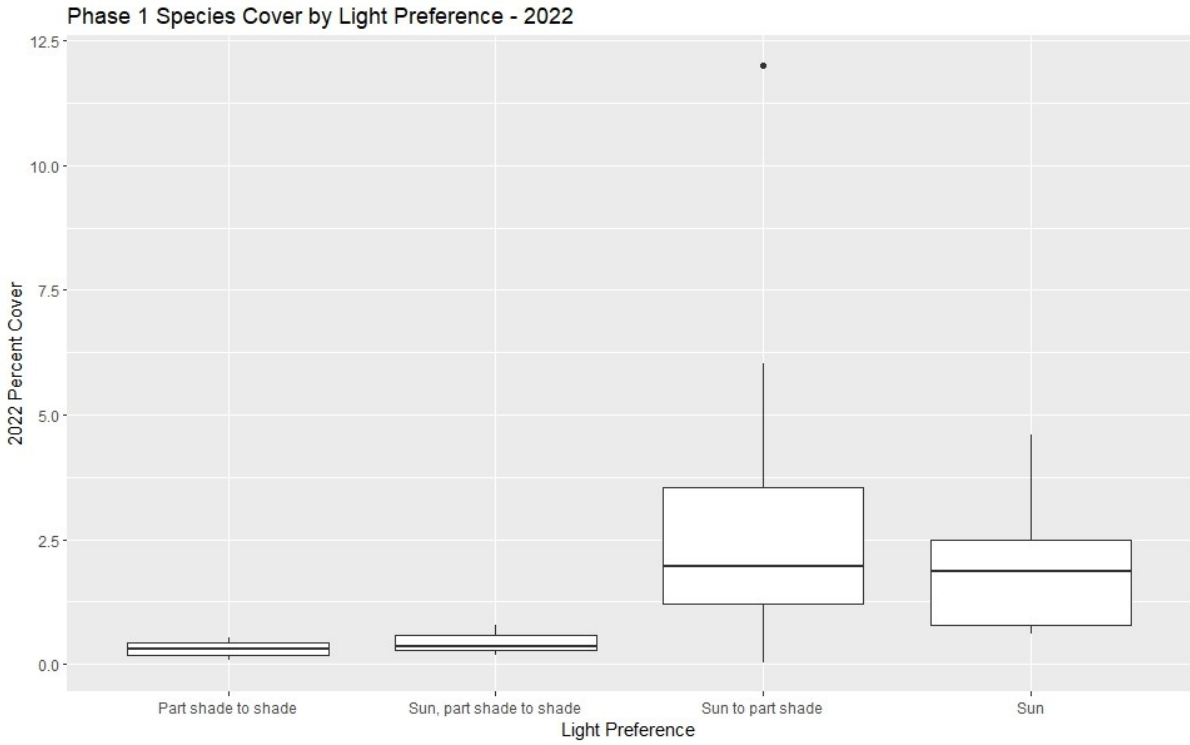

Figure 14: *2022 Phase 1 species cover by light preference.*

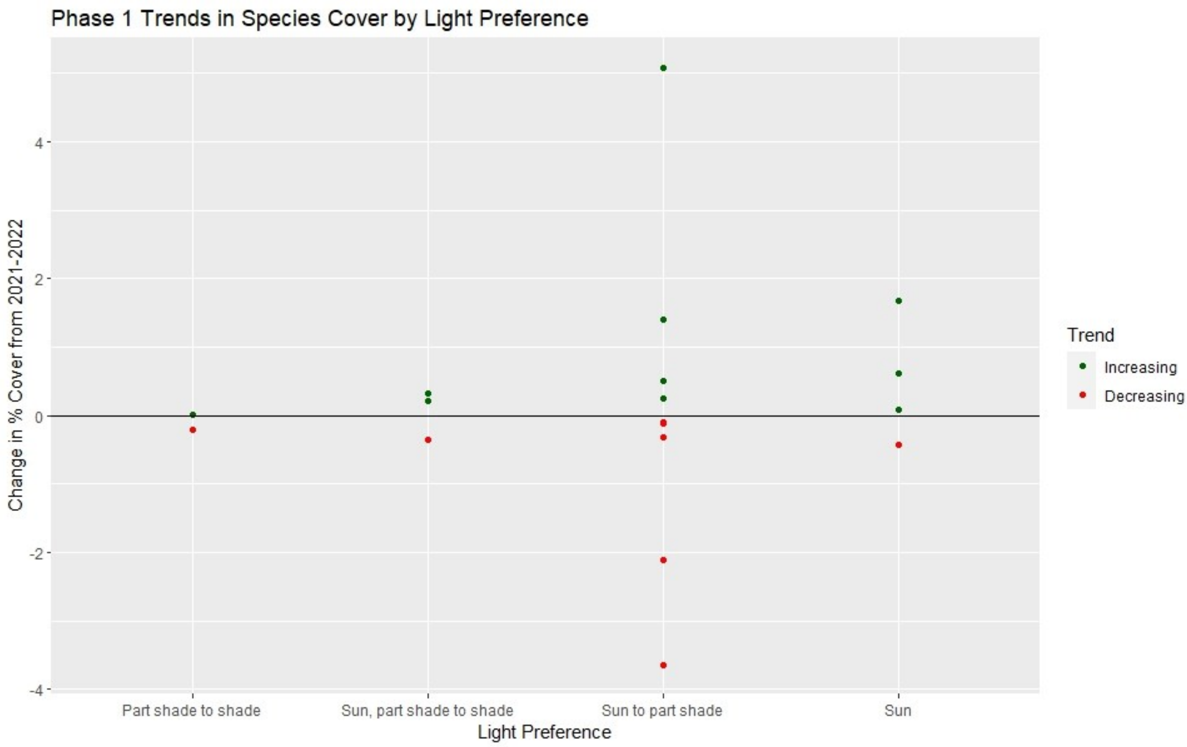

Figure 15: *Phase 1 trends in species cover by light preference.*

5.4 Phase 1 Percent Cover by Moisture Preference

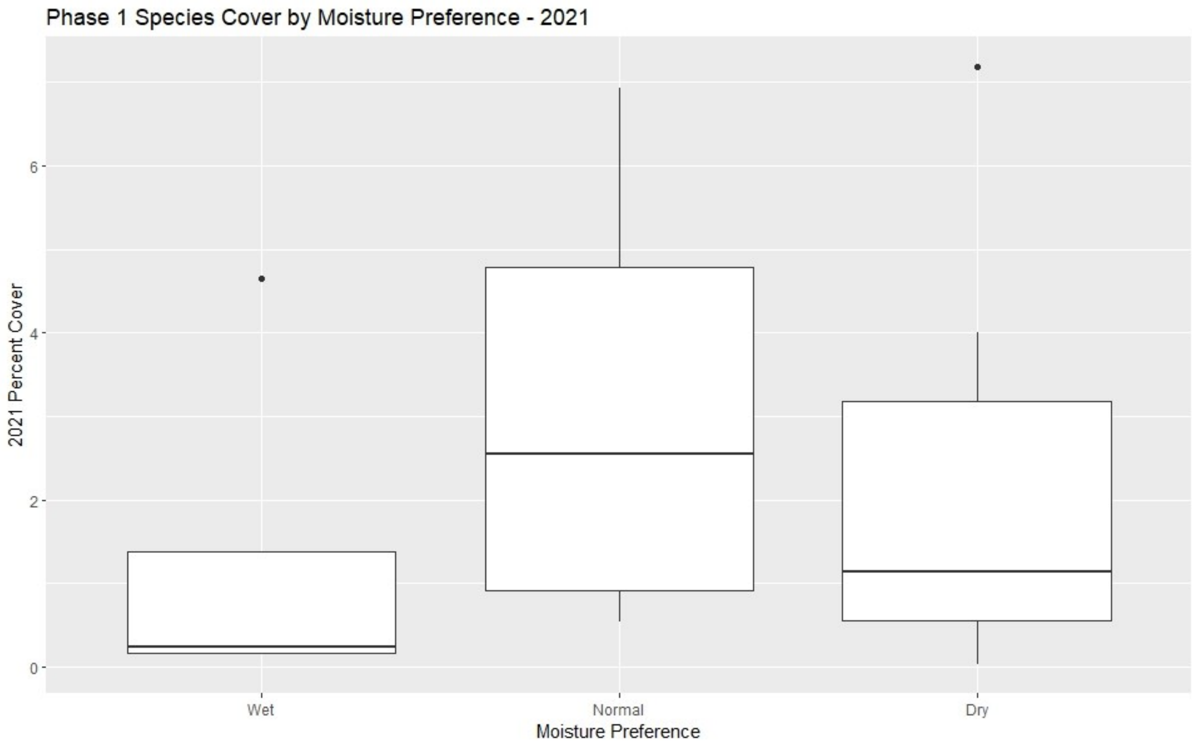

***Figure 16**: 2021 Phase 1 species cover by moisture preference.*

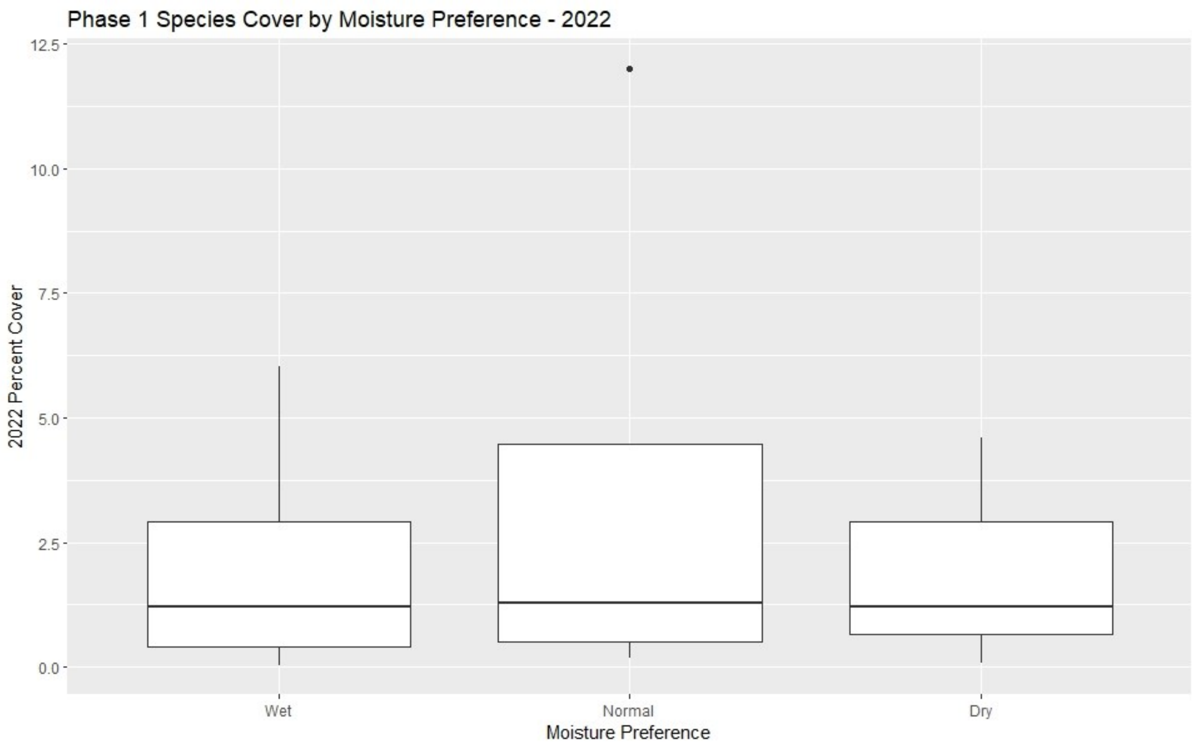

***Figure 17:** 2022 Phase 1 species cover by moisture preference.*

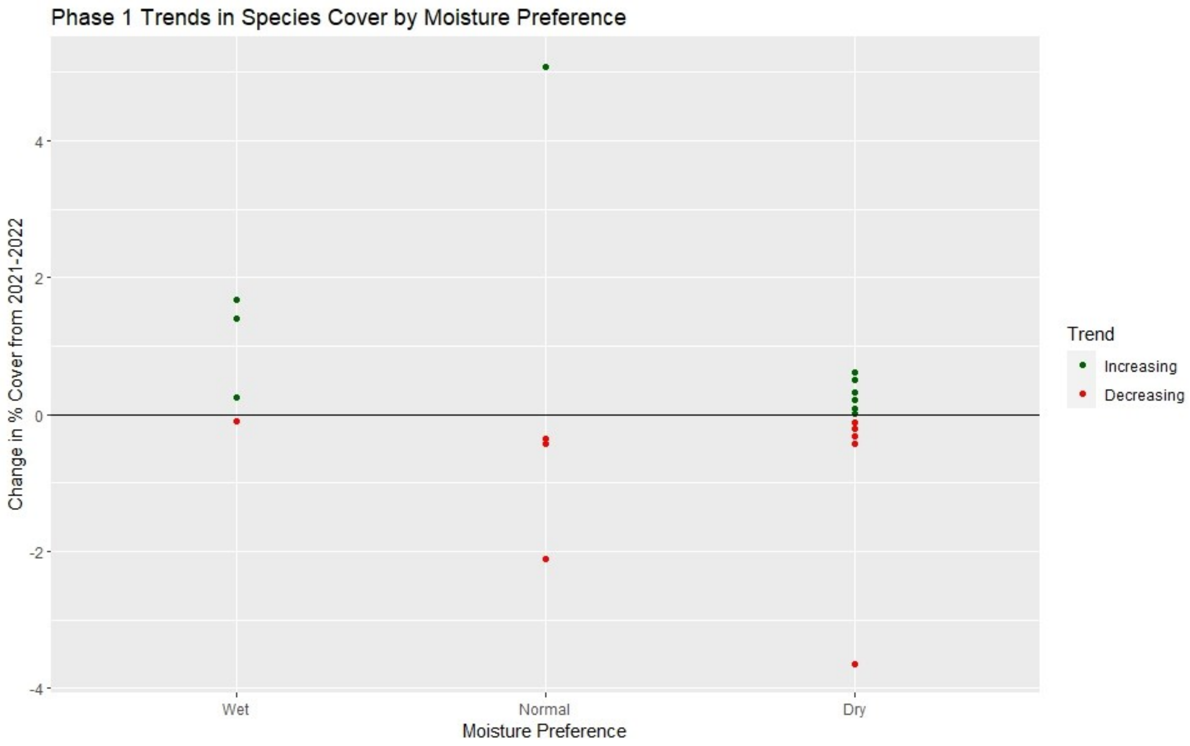

Figure 18: *Phase 1 species trends in cover by moisture preference.*

5.5 Native versus Non-native Cover by Plot

5.5.1 Phase 1

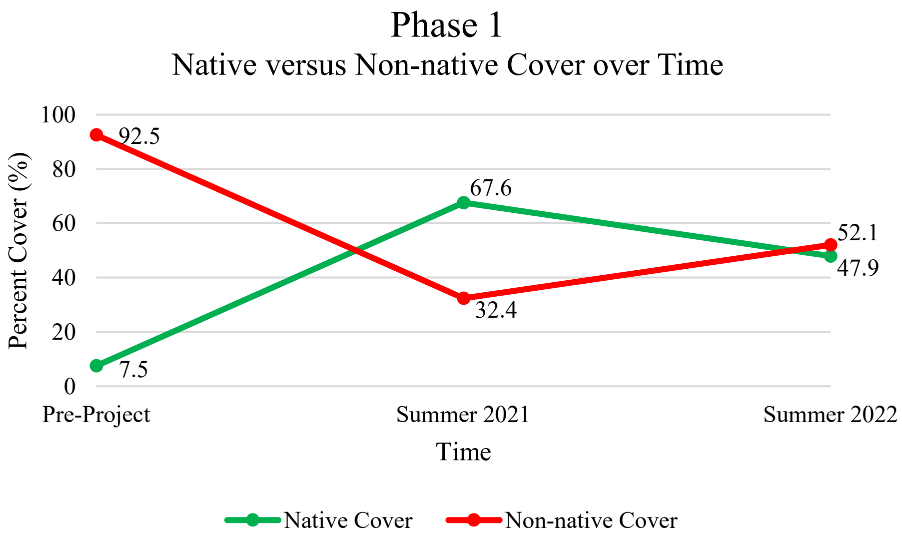

Figure 19: *Percent cover of native and non-native species in Phase 1.*

Note: Pre-project data for Phase 1 was collected on July 15, 2020. Summer 2021 data was collected from July 9, 2021 to July 14, 2021. Summer 2022 data was collected from June 10, 2022 to June 20, 2022.

5.5.2 Phase 2 Leaf Mulch Test Plot

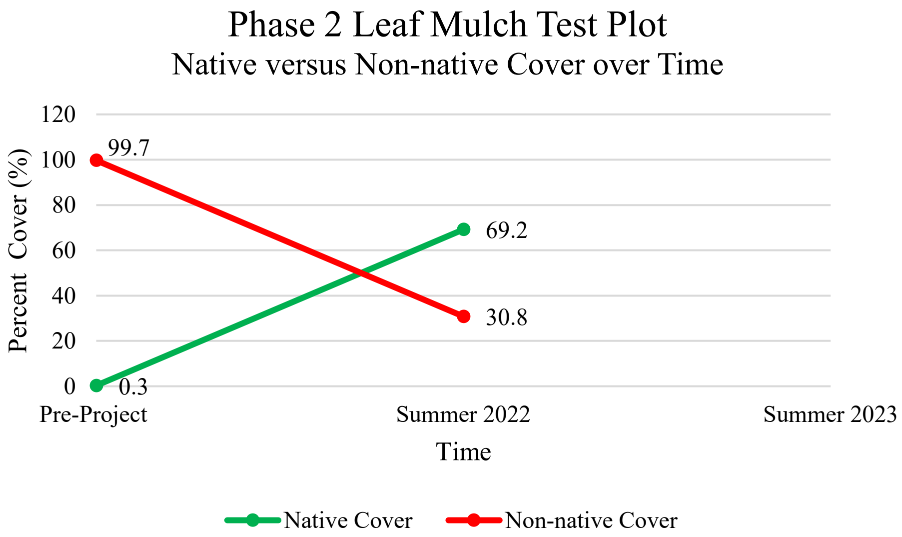

Figure 20: *Percent cover of native and non-native species in the Phase 2 Leaf Mulch Test Plot.*

Note: Pre-project data for this plot was collected on March 23, 2022. Summer 2022 data was collected on July 29, 2022. The next round of data for this plot will be collected in the summer of 2023. Spring 2022 observations revealed that Great Camas (Camassia leichtlinii) and fool's onion (Triteleia hyacinthia) were dug up and removed, likely by local herbivores previously observed in the area.

5.5.3 Phase 2 Harrowed Test Plot

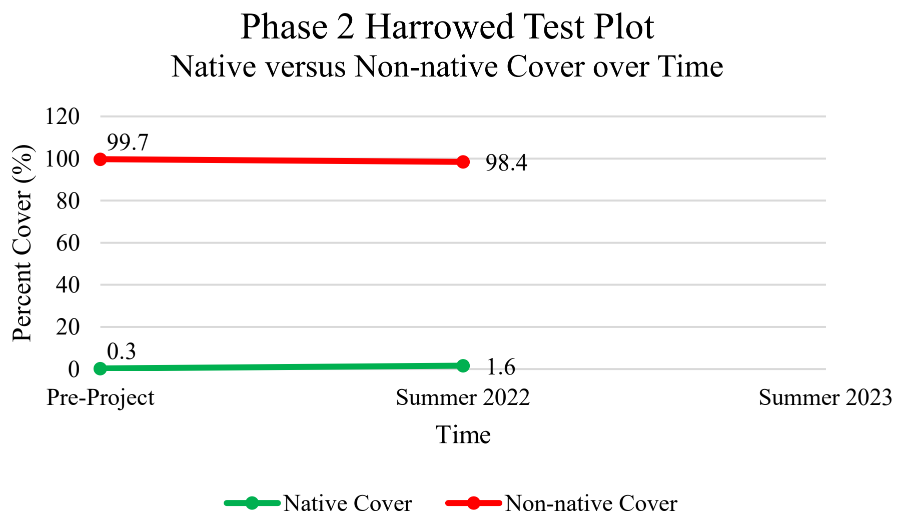

Figure 21: *Percent cover of native and non-native species in the Phase 2 Harrowed Test Plot.*

Note: Pre-project data for this plot was collected on March 23, 2022. Summer 2022 data was collected on July 29, 2022. The next round of data for this plot will be collected in the summer of 2023. Spring 2022 observations revealed several emerging sprouts of Farewell to Spring (Clarkia amoenia) that diminished slightly into the summer months.

5.5.4 Phase 2 Solarized Test Plot

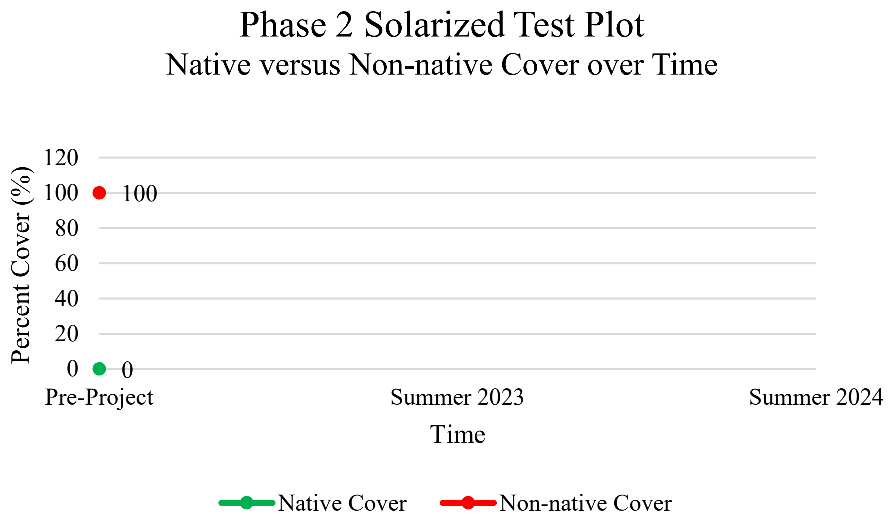

Figure 22: *Percent cover of native and non-native species in the Phase 2 Solarized Test Plot.*

Note: Pre-project data was collected on March 23, 2022. The next rounds of data for this plot will take place in the summer of 2023 and again in the summer of 2024. Visual observations after solarization revealed multiple holes in the plastic material used to solarize the plot. Small, unidentified sprouts were also visible.

5.6 Hours and Costs by Plot

5.6.1 Phase 1

Phase 1 of the Pollinator Meadow underwent mechanical invasive removal, mowing, mechanical tilling, and soil addition as site preparation. After this, the site was planted, seeded, and mulched with woodchips to a depth of approximately 3-5 inches before a fence was constructed. Three rounds of invasive species removal have taken place in the winter of 2021, the summer of 2021, and the summer of 2022 (Appendix C).

5.6.2 Phase 2 Leaf Mulch Test Plot

The Phase 2 Leaf Mulch Test Plot underwent mechanical invasive removal and leaf mulch addition as site preparation, followed by high density seeding, planting, and regular deer repellant application while plants established. Follow-up invasive species removal efforts took place on July 12 and 14, 2022 (Appendix C).

5.6.3 Phase 2 Harrowed Test Plot

The Phase 2 Harrowed Test Plot underwent hand tilling as site preparation, followed by high density seeding and regular deer repellant application for the initial establishment phase. Follow-up invasive species management efforts took place on July 12 and 14, 2022, wherein the seed heads of tall grasses were cut using secateurs (Appendix C).

5.6.4 Phase 2 Solarized Test Plot

The Phase 2 Solarized Test Plot underwent mechanical invasive species removal and a 48 day-long solarization period as site preparation, followed by high density seeding, planting, compost addition, and initial deer repellant application (Appendix C).

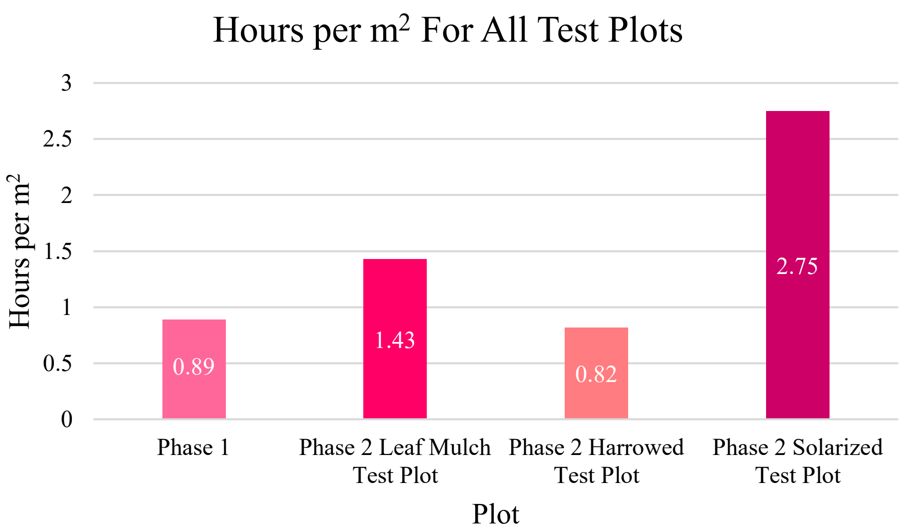

Figure 23: *Hours per square metre associated with all test plots.*

Note: Hours for each plot were totalled from their installation until the end of August 2022.

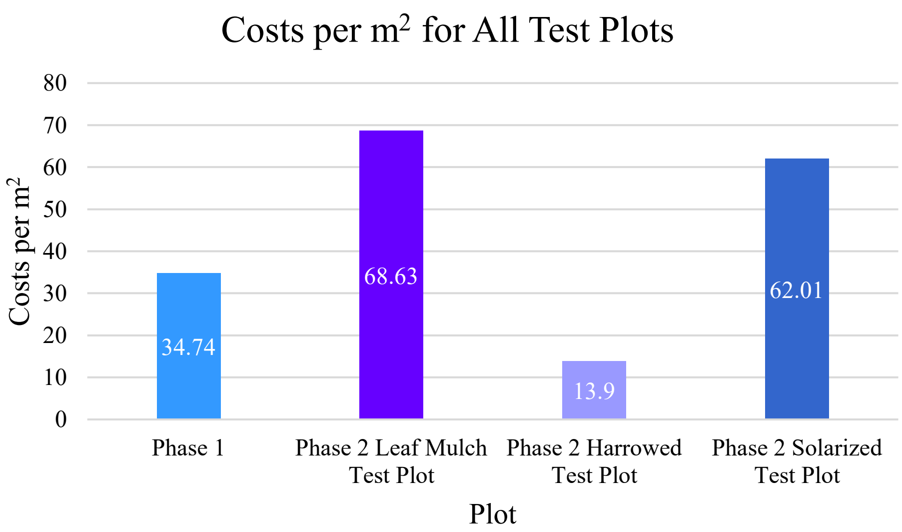

Figure 24: *Costs per square metre associated with all test plots.*

Note: Costs for each plot were totalled from their installation until the end of August 2022.

6. Discussion

6.1 Target Species

Unless intensive management and intervention is carried out, species that are naturally able to tolerate the site's environmental stressors are most likely to persist in the long term (Rainer & West, 2015). Phase 1 data reveals a strong resurgence of invasive grass growth between the summer of 2021 and 2022 (Figure 19). Despite this, sticky cinquefoil (*Drymocallis glandulosa*), woolly sunflower (*Eriophyllum lanatum*), entire-leaved gumweed (*Grindelia stricta*), hairy honeysuckle (*Lonicera hispidula*), Lewis's mock-orange (*Philadelphus lewisii*), Pacific ninebark (*Physocarpus capitatus*), red-flowering currant (*Ribes sanguineum*), Nootka rose (*Rosa nutkana*), Henderson's checker-mallow (*Sidalcea hendersonii*), and Douglas' aster (*Symphyotrichum subspicatum*) increased in percent cover from 2021 to 2022 and are suitable target species for future plantings (Figures 12). Additionally, yarrow (*Achillea millefolium*), self-heal (*Prunella vulgaris*), Western Canada goldenrod (*Solidago lepida*), and common snowberry (*Symphoricarpos albus*) performed well in 2021 (Figure 11). Although their percent cover declined in 2022, they are still suitable target species for this site if additional measures are taken to suppress invasive species between future growing seasons. Entire-leaved gumweed (*Grindelia stricta*) was the highest performing species in Phase 1 overall (Figures 11-12). Further data collection is needed to determine desired Phase 2 species, although it is evident that Great Camas (*Camassia leichtlinii*) and fool's onion (*Triteleia hyacinthia*) are not likely to be successful unless fencing is installed to prevent herbivory.

Light and moisture preference data does not indicate a clear connection between species preference and performance at this site, although it appears that species tolerant of dry, sunny conditions have performed consistently well.

6.2 Invasive Species Management

The ratio of native coverage to non-native coverage in the first summer of observations was optimal in the Phase 2 Leaf Mulch Test Plot (Figure 20). Unexpectedly, however, hours and costs per square metre were higher for most Phase 2 test plots compared to Phase 1 (Figures 23-24). The exception to this was the Phase 2 Harrowed Test Plot; however, this plot showed high invasive species coverage and low native species coverage in the first summer of observations (Figure 21). The Phase 2 Solarized Test Plot had the highest hours and second highest associated costs per square metre (Figure 22). The high hours stemmed from the long solarization period required, while the high costs were likely attributed to the planting materials that were concentrated in a small area (Appendix C). As a result, Phase 1 hours and costs per square metre are the lowest to date with a relatively high success rate. This indicates that hours and costs per square metre decrease with an increased plot size, suggesting that future GWAS projects in this area should expand over larger areas where possible to be more cost-effective.

The recorded regrowth of invasive grasses in Phase 1 provides further evidence that incidental, mechanical removal of invasive species in this grassland ecosystem will not successfully eradicate these species in the long term. This, combined with the naturalized state of the invasive species at this site, indicate that a goal of continued suppression by mechanical methods may be more suitable than complete eradication (Dennehy et al., 2011).

Phase 1 underwent intensive site preparation, fencing installation, and a round of invasive species removal prior to the first summer of data collection. Given that the first summer's native versus non-native coverage for Phase 1 and the Phase 2 Leaf Mulch Test Plot were similar, it appears that these measures did not have a strong impact on Phase 1's success rate. However, future data collection is required to confirm this.

Currently, invasive species management at this site has taken the form of planting small garden-like plots of native plants and mechanically removing invasive species from inside these plots. Future management in this study area could choose to scale up the most cost-effective and successful techniques previously used. Alternatively, other techniques could be introduced to manage invasive species outside of these planted spots with the goal of continued suppression rather than eradication.

Invasive and non-native species present at the project site are listed in Appendix A (Table A1). One study explored the management of many of these listed species, including tall oatgrass (*Arrhenatherum elatius*), orchard grass (*Dactylis glomerata)*, and Hairy Cat's Ear (*Hypochaeris radicata*) (Dennehy et al, 2011). A combination of mowing and herbicide application was cited as the most effective management technique for these species. Mowing alone was also recommended, provided it is timed adequately and repeated often (Dennehy et al., 2011).

Existing literature on invasive species management for grassland ecosystems also outlines mechanical methods, chemical methods, prescribed fire, and the addition of native seeds as recommended techniques. In most cases, integrated management strategies combining two or more techniques yielded the best results (Assis et al., 2021; Dennehy et al., 2011; Mahmood et al., 2018). These techniques are explored in further detail below.

6.2.1 Mechanical Methods

Common mechanical methods for eliminating invasive species include mowing, tilling, and hand-pulling. Mechanical methods are best suited to dealing with small infestations and should be combined with herbicide application if targeting larger infestations (Dennehy et al., 2011). However, mechanical methods can be beneficial when herbicide application is not possible or when there are concerns about collateral damage to native species. One study indicated that when the restoration target was to improve the structure and richness of native species without any planting, hoeing alone was the most successful and cost-effective management technique (Assis et al., 2021). Mowing can also be an effective management technique; however, it should be executed in mid to late summer or before species have gone to seed to effectively target invasive annual species (Dennehy et al., 2011).

6.2.2 Chemical Methods

Literature reveals that chemical management techniques, including herbicide application, can be highly effective (Assis et al., 2021; Dennehy et al., 2011; Mahmood et al., 2018). Chemical methods are best used in combination with other techniques, such as mowing or prescribed fire (Assis et al., 2021). However, there are often jurisdictional barriers to herbicide application and active restoration in the form of planting native species is often required (Assis et al., 2021). There are also risks associated with herbicide use, as it can eliminate rare or desired native species (Rinella et al., 2009).

6.2.3 Prescribed Fire

Historical stewardship practices carried out by Indigenous Peoples on southern Vancouver Island included prescribed burns (Turner, 1999). Burns were carried out for a myriad of purposes, some of which included encouraging the growth of edible or medicinal plants, promoting deer habitat, and preventing the encroachment of forests in Garry oak meadows (Turner, 1999). Literature indicates that fire has been used effectively today to eliminate invasive species from seed banks and alter site conditions to favour native species growth (Assis et al., 2021; Grace at al., 2000). However, competitive interactions between species must be considered when using fire because some invasive species, such as Hairy Cat's Ear (*Hypochaeris radicata*), respond favourably to prescribed burns (Grace et al., 2000; Dennehy et al., 2011).

6.2.4 Native Seeding

Direct seeding of native species is often an integral part of restoring native ecosystems. A study in Victoria, Australia showed that when aiming to suppress invasive species and encourage the growth of native species, each management technique failed to support the regeneration of native vegetation unless combined with direct seeding (Mahmood et al., 2018). Additionally, a study in Nebraska, USA, showed that higher density seeding with higher species richness in the seed mix resulted in greater richness and cover of native seeded species and lower richness and cover of non-native species (Carter & Blair, 2012). While costs can be high, native seeding is a low-effort and effective method of restoring native seedbanks at a site.

6.3 Recommendations

It is recommended that future management efforts at the project site consider the following:

- Sticky cinquefoil (*Drymocallis glandulosa*), woolly sunflower (*Eriophyllum lanatum*), entire-leaved gumweed (*Grindelia stricta*), hairy honeysuckle (*Lonicera hispidula*), Lewis's mock-orange (*Philadelphus lewisii*), Pacific ninebark (*Physocarpus capitatus*), red-flowering currant (*Ribes sanguineum*), Nootka rose (*Rosa nutkana*), Henderson's checker-mallow (*Sidalcea hendersonii*), and Douglas' aster (*Symphyotrichum subspicatum*) increased in percent cover from 2021 to 2022 (Figure 12). Yarrow (*Achillea millefolium*), self-heal (*Prunella vulgaris*), Western Canada goldenrod (*Solidago lepida*), and common snowberry (*Symphoricarpos albus*) also had high coverages compared to other species. Entire-leaved gumweed (*Grindelia stricta*) was the highest performing species. All are suitable target species for future planting at the site.
- Great Camas (*Camassia leichtlinii*) and fool's onion (*Triteleia hyacinthia*) are easily predated where no fencing is installed and should be avoided for future plantings at this site.
- Species suited to dry conditions and full sunlight have performed consistently well at this site and should be targeted for future plantings.

- Future restoration techniques at this site should, where possible, be scaled up to ensure cost-effectiveness.
- Research suggests that a combination of mechanical and chemical methods is most effective at suppressing non-native and invasive species in the long term (Assis et al., 2021; Dennehy et al., 2011; Mahmood et al., 2018). However, resource limitations and park regulations will likely prevent the use of chemical herbicide or fire by future GWAS summer students. The plausibility of combining chemical methods with current management techniques at this site should therefore be further investigated.
- If mechanical methods continue to be the primary method of invasive species management at this site, they should be executed more frequently and include repeated mowing at critical times outside of current plot boundaries.
- Invasive species at this site may never be completely eradicated, and active management to suppress them is likely required.

Future data collection carried out by GWAS summer students in 2023 and 2024 will add to the understanding of this site and inform any additional recommendations.

6.4 Project Limitations

Phase 1 was planted in the fall of 2020, the Phase 2 Leaf Mulch and Harrowed test plots were implemented in the spring of 2022, and the Phase 2 Solarized test plot was planted in late summer 2022. As a result, comparisons between these plots must recognize that these projects are at different stages of establishment. This is particularly important to consider when looking at the hours and costs per square metre for each test plot. Hours and costs were calculated until the end of August 2022, as any future management efforts by future GWAS students are currently unknown. Hours and costs calculations can be updated with new data collected by future summer students to facilitate more accurate comparisons. Furthermore, hours and costs for Phase 1 were estimated by Esquimalt Parks in

2023. This could be a source of error as the estimates were drawn from memory three years after the process took place.

Data collection was dependent on the availability of GWAS summer students and was consequently conducted at varying times. Seasonal differences in plant growth could affect visual estimates of percent cover in data collection. Differences in climate and weather conditions between 2021 and 2022, outlined in Figure 10, also impacted data collected for this project.

7. Monitoring

Continued monitoring at this site should include the repeated execution of biophysical inventories on Phase 1 and all Phase 2 test plots on an annual basis. Surveys should be repeated, where possible, on the same dates each year to ensure continuity of data collection. The Phase 1 monitoring plan also includes a photo point monitoring survey, annual invasive species removal, and a net sweep insect survey. These surveys should continue each year in Phase 1 and can be implemented in Phase 2 plots if deemed appropriate.

Any future management and monitoring of this project will be carried out by GWAS summer students. GWAS receives funding from the Canada Summer Jobs programs for summer students, and as a result, ongoing monitoring will be dependent on this funding.

8. Conclusion

Increasing resources for native pollinators is likely to improve the overall health of an ecosystem and is therefore an apt restoration goal for this site (Tallamy, 2019). Phase 1 of the GWAS Pollinator Meadow project in Esquimalt Gorge Park, initiated in 2020, was the organization's first attempt to suppress the growth of invasive species at this site and establish a native wildflower meadow for pollinators. Phase 2 aims to trial multiple techniques of invasive species suppression and native plant establishment near the existing Phase 1 site. The results of this study indicate that Phase 1 methods were cost-effective because they were able to cover a larger portion of the project area compared to Phase 2 methods. They also reveal that species tolerant of the site's dry, sunny conditions have been relatively successful, although future data collection must be carried out to confirm if moisture and light preferences have a strong impact. A preliminary list of successful plant species has been created, which can be updated with future data collection. Continued management of this site should consider invasive species management outside of existing plots and explore alternative management techniques where appropriate. The information collected through this project will inform ongoing management decisions and work carried out by future GWAS summer students at this site.

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11. Appendix A

Species tables for Phase 1 and all Phase 2 test plots. Light and moisture preferences taken from Pollinator Partnership Canada, and supplemented by data from Minnesota Wildflowers, the Invasive Species Council of B.C., and Satinflower Nurseries where needed.

Table A1: Species Catalogue for Site Area. Table produced by Shawn Brescia (former GWAS Restoration Technician) in 2022.

Species Observed	Scientific Name	Status
Natives		
Self-heal	*Prunella vulgaris*	Native
Coastal Strawberry	*Fragaria chiloensis*	Native
Wild Strawberry	*Fragaria virginiana*	Native
Douglas Aster	*Symphyotrichum subspicatum*	Native
Common Yarrow	*Achillea millefolium*	Native
Common Snowberry	*Symphoricarpos albus*	Native
Black Twinberry	*Lonicera involucrata*	Native
Henderson's Checker-mallow	*Sidalcea hendersonii*	Blue-listed
Western Canada Goldenrod	*Solidago lepida*	Native
Entire-leaved Gumweed	*Grindelia stricta*	Native
Red Columbine	*Aquilegia formosa*	Native
Thimbleberry	*Rubus parviflorus*	Native
Fireweed	*Chamaenerion angustifolium*	Native
Lewis's Mock-orange	*Philadelphus lewisii*	Native
Red-flowering Currant	*Ribes sanguineum*	Native
Dewey's Sedge	*Carex deweyana*	Native
Nootka Rose	*Rosa nutkana*	Native
Nodding Onion	*Allium cernuum*	Native
Hairy Honeysuckle	*Lonicera hispidula*	Native
Common Woolly Sunflower	*Eriophyllum lanatum*	Native
Pacific Ninebark	*Physocarpus capitatus*	Native
Kinnikinnick	*Arctostaphylos uva-ursi*	Native
Sticky Cinquefoil	*Drymocallis glandulosa*	Native

Cleavers	*Gallium aparine*	Native
Fringed Willowherb	*Epilobium ciliatum*	Native
Hornemann's Willowherb	*Epilobium hornmannii*	Native
Exotics		
Curled Dock	*Rumex crispus*	Invasive
Wild Carrot	*Daucus carota*	Exotic
Prickly Lettuce	*Lactuca serriola*	Exotic
Cutleaf Geranium	*Geranium dissectum*	Exotic
Hairy Vetch	*Vicia hirsuta*	Exotic
Common Vetch	*Vicia sativa*	Exotic
Red Deadnettle	*Lamium purpureum*	Exotic
Canada Thistle	*Cirsium arvense*	Provincial Noxious
Wild Garlic	*Allium vineale*	Exotic
Creeping Buttercup	*Ranunculus repens*	Invasive
Subterranean Clover	*Trifolium subterraneum*	Exotic
Knotted Clover	*Trifolium striatum*	Exotic
Common Dandelion	*Taraxacum officinale*	Exotic
Ribwort Plantain	*Plantago lanceolata*	Exotic
Black Medic	*Medicago lupulina*	Exotic
Spotted Medic	*Medicago arabica*	Exotic
Narrowleaf Bird's-foot Trefoil	*Lotus tenuis*	Exotic
Common Daisy	*Bellis perennis*	Exotic
Scotch Broom	*Cytisus scoparius*	Invasive
Common Catsear	*Hypochaeris radicata*	Exotic
Prickly Sowthistle	*Sonchus asper*	Exotic
Purple Salsify	*Tragopogon porrifolius*	Exotic
Smith's Peppergrass	*Lepidium heterophyllum*	Exotic
Grasses		
Common Velvetgrass	*Holcus lanatus*	Invasive
Common Soft Brome	*Bromus hordeaceus*	Invasive
Salt Barley	*Hordeum marinum*	Invasive
Tall Oatgrass	*Arrhenatherum elatius*	Invasive

Quack Grass	*Elymus repens* *Poa sp.* *Agrostis sp.?*	Invasive
Barren Brome	*Bromus sterilis*	Invasive
Orchard grass	*Dactylis glomerata*	Invasive

Table A2: Phase 1 Species Data

Scientific Name	Common Name	Light Preference	Moisture Preference	Percent Cover Summer 2021 (%)	Percent Cover Summer 2022 (%)	Trend
Achillea millefolium	Yarrow	Sun to part shade	Dry to moist	7.178571	3.54	-3.63857
Carex deweyana	Dewey's sedge	Part shade to shade	Dry to moist	0.285714	0.07	-0.21571
Chamaenerion angustifolium	Fireweed	Sun	Moist	1.035714	0.61	-0.42571
Drymocallis glandulosa	Sticky cinquefoil	Sun to part shade	Dry to moist	1.142857	1.64	0.497143
Epilobium ciliatum	Fringed willowherb	Sun to part shade	Normal to wet	0.142857	0.04	-0.10286
Eriophyllum lanatum	Woolly sunflower	Sun	Dry	4	4.61	0.61
Fragaria virginiana	Wild strawberry	Sun to part shade	Dry	1.535714	1.21	-0.32571
Grindelia stricta	Entire-leaved gumweed	Sun to part shade	Normal to moist	6.928571	12	5.071429
Lonicera hispidula	Hairy honeysuckle	Part shade to shade	Dry to moist	0.535714	0.54	0.004286
Lonicera involucrata	Black twinberry	Sun, part shade to shade	Moist	0.535714	0.18	-0.35571
Philadelphus lewisii	Lewis's mock-orange	Sun	Dry to moist	0.714286	0.79	0.075714

Physocarpus capitatus	Pacific ninebark	Sun to part shade	Moist to wet	0.285714	0.54	0.254286
Prunella vulgaris	Self-heal	Sun to part shade	Moist	4.071429	1.96	-2.11143
Ribes sanguineum	Red-flowering currant	Sun, part shade to shade	Dry to moist	0.571429	0.79	0.218571
Rosa nutkana	Nootka rose	Sun, part shade to shade	Dry to moist	0.035714	0.36	0.324286
Sidalcea hendersonii	Henderson's checker-mallow	Sun	Wet	0.178571	1.86	1.681429
Solidago lepida	Western Canada goldenrod	Sun	Dry to moist	2.928571	2.5	-0.42857
Symphoricarpos albus	Common snowberry	Sun to part shade	Dry	3.428571	3.32	-0.10857
Symphyotrichum subspicatum	Douglas' aster	Sun to part shade	Normal to wet	4.642857	6.04	1.397143

Table A3: Phase 2 Leaf Mulch and Harrowed Test Plots Species Data

Scientific Name	**Common Name**	**Light Preference**	**Moisture Preference**	**Percent Cover Summer 2022 (%)**		**Percent Cover Summer 2023 (%)**		**Trend**	**Type**
				Leaf Mulch Test Plot	Harrowed Test Plot	Leaf Mulch Test Plot	Harrowed Test Plot		
Achillea millefolium	Yarrow	Sun to part shade	Dry to moist	3.6	-				20 x 10 cm starters
Camassia leichtlinii	Great Camas	Sun	Moist	0	-				4 x 1 gal pots
Cerastium arvense	Field chickweed	Sun	Dry	0.8	0				4 x 10 cm starters; Seed (3g)
Clarkia amoena	Farewell-to-Spring	Sun	Dry	16	1.5				Seed (10 g/approx. 50,000 seeds)
Collinsia parviflora	Blue-eyed Mary	Sun to part shade	Dry to normal	1.6	-				Transplants
Danthonia californica	California Oatgrass	Sun to part shade	Dry to moist	4.4	-				20 x 10 cm starters
Danthonia spicata	Poverty Oatgrass	Sun	Dry to normal	0.6	-				3 x 10 cm starters

Plectritis congesta	Sea blush	Sun to part shade	Moist	1.6		-	Transplants
Poa secunda	Sandberg's Bluegrass	Sun	Dry	0.6	0		3 x 10 cm starters; Seed (4 packets of 450 seeds each)
Potentilla gracilis var. gracilis	Graceful Cinquefoil	Sun	Dry to moist	1		-	3 x 10 cm starters; 1 gal pot
Sisyrinchium idahoense	Blue-eyed Grass	Sun	Normal to wet	7		-	20 x 10 cm starters
Symphiotrichum subspicatum	Douglas' Aster	Sun to part shade	Normal to wet	0.6	0		4 x 10 cm starters; Seed (2 packets of 190 seeds each)
Trifolium wormskioldii	Springbank Clover	Sun to part shade	Moist to wet	2.6		-	3 x 10 cm starters; 3 x 1 gal pots
Triteleia hyacinthia	Fool's Onion	Sun	Normal to moist	0		-	4 x 10 cm starters

Table A4: Phase 2 Solarized Test Plot Species Data

Scientific Name	**Common Name**	**Light Preference**	**Moisture Preference**	**Percent Cover Summer 2023 (%)**	**Percent Cover Summer 2024 (%)**	**Trend**	**Type**
Anaphalis margaritacea	Pearly Everlasting	Sun	Dry to moist				11 x 10 cm starters
Calandrinia ciliata	Red Maids	Sun	Dry to normal				Seed (packet of 431 seeds)
Drymocallis glandulosa	Sticky Cinquefoil	Sun to part shade	Dry to moist				7 x 10 cm starters
Lomatium utriculatum	Spring Gold	Sun to part shade	Dry to moist				12 x 10 cm starters
Lupinus polyphyllus ssp. pallidipes	Large-Leaved Lupine	Sun to part shade	Dry to moist				2 x 10 cm starters

12. Appendix B

Native and non-native species coverage for all plots pre-project, Summer 2021, and Summer 2022.

	Pre-Project	Summer 2021	Summer 2022
Phase 1			
Native Species Cover (%)	7.5	67.6	47.9
Non-native Species Cover (%)	92.5	32.4	52.1
Phase 2 Leaf Mulch Test Plot			
Native Species Cover (%)	0.3	-	69.2
Non-native Species Cover (%)	99.7	-	30.8
Phase 2 Harrowed Test Plot			
Native Species Cover (%)	0.3	-	1.6
Non-native Species Cover (%)	99.7	-	98.4
Phase 2 Solarized Test Plot			
Native Species Cover (%)	0	-	-
Non-native Species Cover (%)	100	-	-

13. Appendix C

Hours and costs breakdown for all plots.

			Phase 1				**Phase 2**											
							Leaf Mulch Test Plot				**Harrowed Test Plot**				**Solarized Test Plot**			
			Total hours	Hours/m^2	Total costs ($)	Costs/ m^2 ($)	Total hours	Hours/m^2	Total costs ($)	Costs/ m^2 ($)	Total hours	Hours/m^2	Total costs ($)	Costs/ m^2 ($)	Total hours	Hours/ m^2	Total costs	Costs/ m^2
Site preparation	Mechanical invasive removal		6	0.05	0	0	1.5	0.15	0	0	0	0	0	0	3	0.75	0	0
	Mowing		2	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mechanical Tilling		4	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hand Tilling		0	0	0	0	0	0	0	0	0.5	0.13	0	0	0	0	0	0
Installation	Soil addition		3	0.03	1155	9.63	0	0	0	0	0	0	0	0	0	0	0	0
	Leaf mulch addition		0	0	0	0	1.25	0.13	0	0	0	0	0	0	0	0	0	0
	Woodchip mulch addition		8	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Initial planting/seeding		3	0.03	2013.7	16.78	4	0.4	634.65	63.47	0.5	0.13	34.97	8.74	3	0.75	201.6	52.65
	Fence Installation		8	0.07	1000	8.33	0	0	0	0	0	0	0	0	0	0	0	0
	Solarization		0	0	0	0	0	0	0	0	0	0	0	0	3	0.75	16.79	4.2
Maintenance	Deer repellant application		0	0	0	0	9	0.5	92.92	5.16		0.5		5.16		0.5		5.16
	Invasive species removal	Round 1	9	0.08	0	0	2.5	0.25	0	0	0.25	0.06	0	0			0	0
		Round 2	17	0.14	0	0			0	0	0	0	0	0			0	0
		Round 3	44.5	0.37	0	0			0	0	0	0	0	0			0	0
Total				**0.89**		**34.74**		**1.43**		**68.63**		**0.82**		**13.9**		**2.75**		**62.01**

14. Appendix D

Climate data for Victoria, B.C. from March to August 2021 and 2022.

Month	Average Precipitation (mm)	Maximum Temperature (°C)
2021		
March	18	12.5
April	19.9	21.9
May	15.2	24.3
June	33.8	39.4
July	0	30.2
August	7	35.5
2022		
March	78.8	15.6
April	95.8	16.5
May	49.9	19.5
June	40.2	30.8
July	27.2	31.5
August	1	30.2

15. Appendix E

Diagram for estimating percent cover of elements in a quadrat (Luttmerding et al., 1990).

CHAPTER FOUR — VEGETATION DESCRIPTION

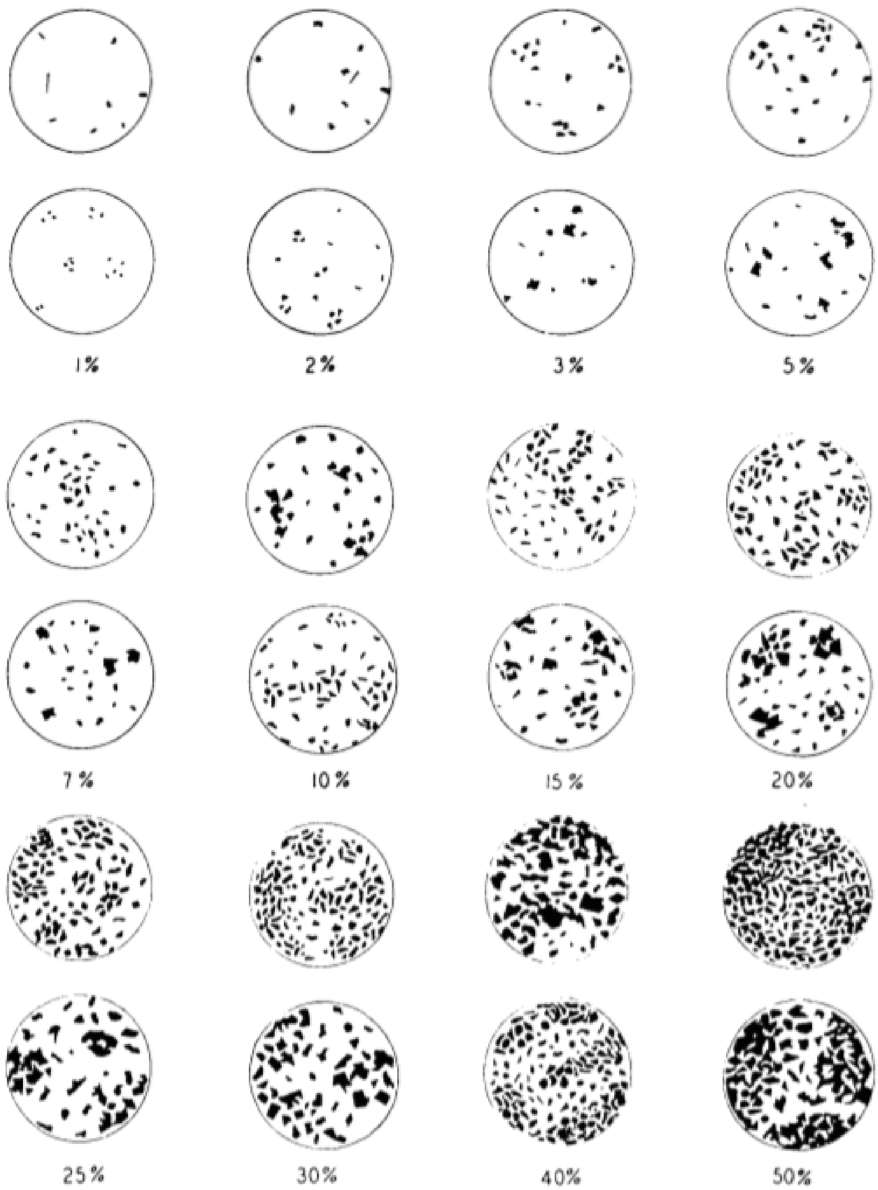

Figure 4.2 Comparison charts for visual estimation of foliage cover.

Developed by Richard D. Terry and George V. Chilingar. Published by the Society of Economic Paleontology and Minerology in Journal of Sedimentary Petrology 25(3): 229–234, September 1955.