The effect of mowing and hand removal on the regrowth rate of Himalayan blackberry (*Rubus armeniacus*)

by

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Bachelor of Science, University of British Columbia, 2016

Project Submitted in Partial Fulfilment of the
Requirements for the Degree of
Master of Science

in the
Ecological Restoration Program

Faculty of Environment (SFU)
and
School of Construction and the Environment (BCIT)

SIMON FRASER UNIVERSITY
BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY
2018

Approval

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Degree:	**Master of Science**
Title:	**The effect of mowing and hand removal on the regrowth rate of Himalayan blackberry (*Rubus* armeniacus)**

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Date Defended/Approved: April 19, 2018

Abstract

Himalayan blackberry (*Rubus armeniacus* Focke) is an invasive species in the Pacific Northwest. Mowing and hand removal are two of the common treatments used for controlling Himalayan blackberry. I examined the effectiveness of mowing, hand removal, and control treatments by measuring the mean number of stem and mean stem length during a growing season. Treatments were applied on March 2017. Bi-weekly sampling was from April to August 2017. Data were analyzed with a two-factor split-plot Analysis of Variance (ANOVA) test. The overall trend showed no statistically significant difference between mowing and hand removal treatments in one growing season. Integrated treatments (e.g. mowing + hand removal + planting) are recommended to be used to effectively reduce Himalayan blackberry cover because one removal treatment showed to be insufficient to eliminate Himalayan blackberry.

I dedicate this project to Casper J. Co, my best friend and love.

Acknowledgements

I want to thank my supervisor, Dr. Scott Harrison, who provided guidance throughout my project. I also want to thank my sponsor, Dana McDonald, from the Vancouver Board of Parks and Recreation for all her support. In addition, I want to thank Dr. Carl James Schwarz and Erin Zhang for the statistical data analysis assistance in my project.

I am thankful to have family and friends who have given me their care through my master program journey. The time and donations that everyone has kindly given to me is deeply appreciated. Many thanks to: Adriano De Torres, Annie Yin, Casper Co, Chloe Hartley, Chris Yeung, Corissa Durcharme, Eric Zhou, Farrah Shing, Fiona Wong, Frederick Wong, Ian Tom, Jackson Chow, Janet Fang, Jeffrey Chen, Jennifer Chen, Jerold Brito, John McDonald, Joti's No Frills, Kuklam Wong, Lawrence Wong, Lenna Chung, Mai Situ, Precidia Tom, Sally Mei, Sam Mertens, Samira Jalizi, Simone Payne, Sonya Oetterich, Steven Woo, Thadoe Wai, Wendy Yan, and Wesley Chenne.

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1. Introduction

Himalayan blackberry (*Rubus armeniacus* Focke) is an invasive species in the Pacific Northwest and the most common invasive species in British Columbia (Pojar and MacKinnon 2004; Caplan and Yeakley 2006; Dennehy et al. 2011; ISCBC 2014). The mean annual temperature in the Pacific Northwest will increase because of the effects of climate change, resulting in changes to the phenology of plant species and will shift species upwards in elevation (Cramer et al. 2014; PCIC 2017). The projected changes caused by climate change will result in a longer growing season for Himalayan blackberry and greater competition for native plants (Cramer et al. 2014; PCIC 2017). Himalayan blackberry is resilient to climate change because of fewer stress trade-offs compared to native species, such as no competition, the ability to store and maintain favourable water volume in the root system during growing season, and tolerance to many environmental conditions including anthropogenic disturbed areas (Caplan and Yeakley 2006; Caplan and Yeakley 2010).

Himalayan blackberry is a biennial plant (ISCBC 2014; Gaire et al. 2015). During the first year, the stems are primocanes that produce no flowers (ISCBC 2014; Gaire et al. 2015; Krueger et al. 2016). During the second year, the stems are floricanes that produce flowers and fruits (ISCBC 2014; Gaire et al. 2015; Krueger et al. 2016). The plant flowers in late May and produces fruit in late July (Gaire et al. 2015). Himalayan blackberry has many competitive advantages over native species. For example, the main root crown of blackberries can develop a large lateral root system that stores water and nutrients and can sprout new plants (DiTomaso 2002; Soll 2004; ISCBC 2014; Gaire et al. 2015). Himalayan blackberry stems can grow up to 7-m in length in a growing season and grows in clumps, forming dense thorny thickets that outcompete low-growing vegetation by shading and prevents tree establishment by limiting space (Dennehy et al. 2011; ISCBC 2014; Cal-IPC 2015). Himalayan blackberry can tolerate a range of conditions, such as acidic and alkaline soil conditions (Amor 1973; Caplan and Yeakley 2006).

Himalayan blackberry spreads aggressively and predominates an ecosystem by adapting to many environmental conditions. These characteristics makes removing and controlling Himalayan blackberry difficult. Mowing and hand removal are two of the common treatments used for controlling Himalayan blackberry (Figure 1). The purpose of my research was to examine the effectiveness of mowing, hand, and control treatments by measuring the post-treatment regrowth rate after removal.

Mowing is a cost-effective treatment used to control large areas of blackberry (Dennehy et al. 2011). Mowing uses a type of mower (e.g. flail mower, riding mower, and tractor-mounted mower) to remove the aboveground vegetation (Soll 2004; ISCBC 2014). Mowing leaves 5 to 30 cm of the blackberry stems and all the blackberry roots on the site. Mowing needs to be repeated for many growing seasons to deplete the energy reserve in the plants (ISCBC 2014; Gaire et al. 2015). Mowing cost about $4,000/ha (D. McDonald, pers. comm.). Mowing results in a short-term plant canopy reduction to provide an opportunity for native plants to grow and survive (DiTomaso 2002; Dennehy et al. 2011).

Hand removal is a slow, labour-intensive but effective treatment used to control areas of blackberry. The treatment requires removing the stems, the root crowns, and plant fragments thoroughly to prevent blackberry regrowth (Soll 2004). Approximately 28,000 person-hours/ha are needed to remove blackberry.

A. B.

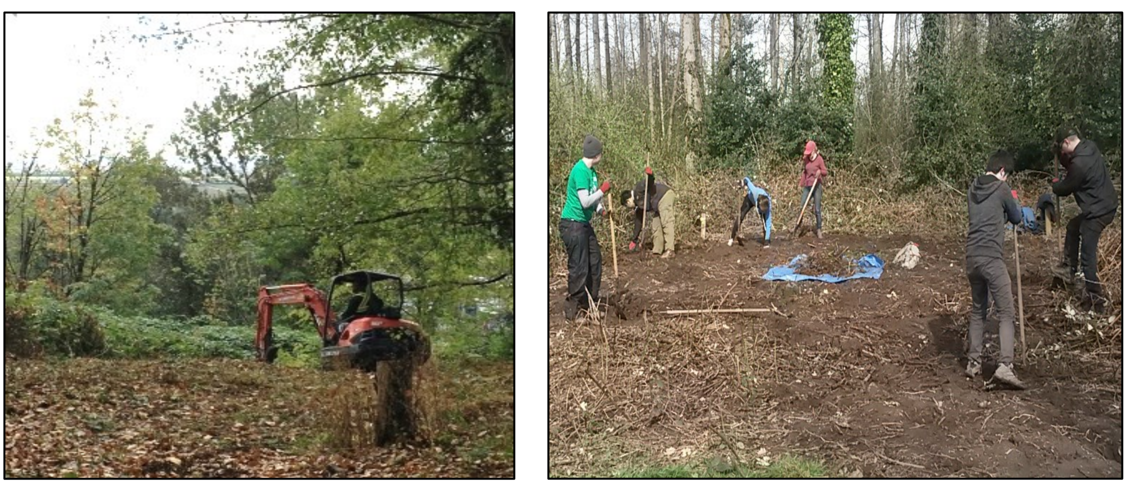

Figure 1 – A. A flail mower removing Himalayan blackberry by mowing in the Everett Crowley Park (Photo credit: D. McDonald). B. A group of volunteers removing Himalayan blackberry from an experimental plot by hand in the Everett Crowley Park (Photo credit: J. Chow).

2. Methods

2.1 – Study Site

My study site was Everett Crowley Park, Vancouver, B.C (**Error! Reference source not found.**). The 38-ha park is the fourth largest park in Vancouver (LEES + Associates Consulting Ltd. 2005). The park is in the Coastal Western Hemlock (CWH) biogeoclimatic (BEC) zone (MFLNRO 2016). The park was on the Tsukhulehmult (Musqueam community) First Nations territory until settlers arrived in 1860 (LEES + Associates Consulting Ltd. 2005). Then the settlers used the park land for logging and farming, leading to the park land becoming part of Vancouver (LEES + Associates Consulting Ltd. 2005). The park later became a city landfill in 1944 until 1966 (LEES + Associates Consulting Ltd. 2005). After the closure of the landfill, an estimated 1.5-m layer of nutrient poor fill was placed over the surface, resulting in mainly loamy sand and undeveloped organic layer soil conditions that are not suitable for native species (LEES + Associates Consulting Ltd. 2005; Norman and Prentice 1997).

In 1987, the park officially became the "Everett Crowley Park," managed by three stakeholders: Vancouver Board of Parks and Recreation (VBPR), Everett Crowley Park Committee (ECPC), and the Evergreen Foundation. VBPR is a committee elected by Vancouver residents. The committee has jurisdiction over 230 public parks and a large public recreation system. The goal is to provide park and recreation services that will benefit the community and the environment. ECPC is a sub-committee of the Champlain Heights Community Association that is made up of local residents and park users who volunteer to protect and enhance the park. Evergreen Foundation is a Canadian charity established in 1991. The foundation transforms public spaces into spaces with environmental, social, and economic benefits to the community.

My Sponsor, Dana McDonald from the VBPR, provided space that had or still have about 95-100% cover of Himalayan blackberry for all my experimental plots. Mowing experimental plots were chosen based on where mowing was completed in 2017. Hand experimental plots were chosen for safe access. Control experimental plots were chosen for limited accessibility to the public (Figure 2). The mean temperature during the duration of my study was 3.0°C for February 2017, 6.8°C for March 2017, 9.5°C for April

2017, 12.8°C for May 2017, 15.6°C for June 2017, 18.3°C for July 2017, and 18.8°C for August 2017 (Government of Canada 2017).

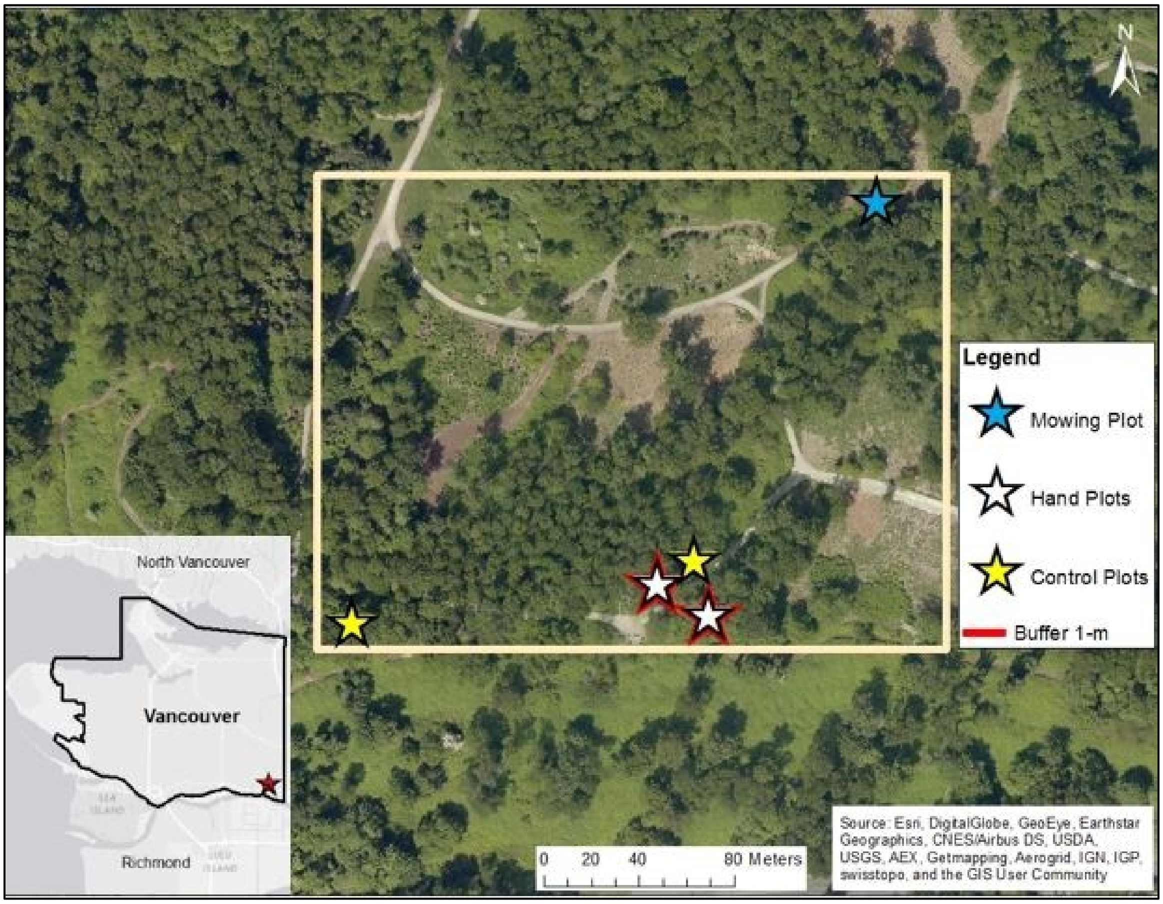

Figure 2 – Everett Crowley Park in the context of Vancouver, B.C. represents the red star in the insert map. The map shows my five experimental plots in the Everett Crowley Park.

2.2 – Alternative Restoration Treatments

I examined the effectiveness of mowing, hand, and control treatments by measuring the post-treatment regrowth rate after removal for one growing season from April to August 2017. Regrowth rate was calculated by the average number of stem and the average stem length for one growing season. I developed two hypotheses: (1) The mean number of Himalayan blackberry stems in hand treatment sites is less than in mowing treatment sites in one growing season because hand treatment thoroughly removes the above- and belowground vegetation. (2) The mean Himalayan blackberry stem length in hand treatment sites is shorter than in mowing treatment sites in one growing season because hand treatment thoroughly removes the above- and belowground vegetation.

I used an Adaptive-Management experimental design with three blackberry removal treatments: mowing, hand removal, and a control. In February 2017, the Vancouver Board of Parks and Recreation contracted a flail mower with an articulating arm to cut the blackberry stems to 5-30 cm from the soil surface. The foliage and stems of the mown blackberry was left in place. Hand removal was completed in March 2017. I organized a group of volunteers to cut the blackberry stems at approximately 45-60 cm with loppers and then dig out the blackberry roots with shovels. Hand-removed blackberry stems and roots were moved away from the area. After removal, the soil surface was raked evenly. Control plots were installed in March 2017. Control plots were untreated throughout the study. The control had approximately 95-100% cover of blackberry visually. Mowing treatment had one replicate. Hand and control treatments had two replicates. I had a total of five, 5-m x 5-m experimental plots. Hand experimental plots had a 1-m buffer area that surrounded the plots. The purpose of the buffer area was to reduce the effect of the surrounding blackberry. Mowing and hand treatment were completed once throughout my study.

2.3 – Sampling Design

Each experimental plot had 25, 1-m x 1-m sample units. A random number generator selected seven sample units in each experimental plot (Figure 3). I used a square sampling frame made of 1.25 cm polyvinyl chloride (PVC) pipes to sample blackberry stems in each sample unit. In each sample unit, I counted blackberry stems and measured the length from the ground surface to the tip or to the edge of the sampling frame. Sampling bi-weekly from 7 April 2017 to 26 August 2017 with a total of 11 survey events (survey event 1 – 7 April 2017; 2 – 21 April 2017; 3 – 6 May 2017; 4 – 19 May 2017; 5 – 2 June 2017; 6 – 16 June 2017; 7 – 30 June 2017; 8 – 14 July 2017; 9 – 28 July 2017; 10 – 11-12 August 2017; 11 – 26 August 2017).

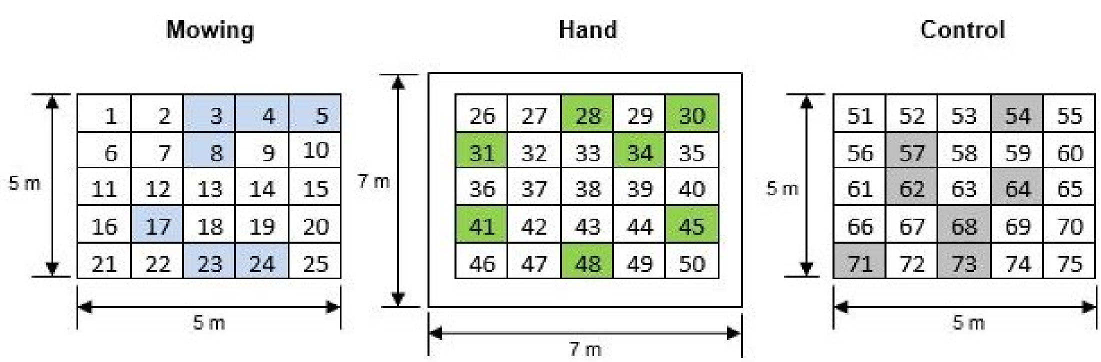

Figure 3 – Sampling design for each experimental plot. Mowing and control plots were 5-m x 5-m. Hand removal experimental plots were 7-m x 7-m with a 1-m buffer at both sides. The shaded squares represent the seven sample units at each experimental plot.

2.4 – Statistical Analysis

Data from my experimental design were analyzed using Linear Mixed Effects Models (lmerTest) to perform a two-factor split-plot Analysis of Variance (ANOVA) to test for the effect of treatments on the regrowth of blackberry (i.e., mean number of stems and mean stem length). The number of stems and stem lengths from my seven sampling plots were averaged to get the mean number of stems and mean stem length for the interactions among treatment, survey event, and experimental plot. The treatments and survey events were the two fixed effects and the experimental plots were the one random effect. A post hoc test, Tukey's honestly significant difference (HSD), was used to make pairwise comparisons for all the treatment effects, survey event effects, and treatment-survey event interaction for the response variables of mean number of stem and mean stem length. I used R (ver. 3.4.3) and RStudio (ver. 1.1.423) for all my data analyses.

3. Results

3.1 – Mean number of stems in treatments

Prior to survey event 1, hand treatment had no visible stems (Figure 7B) and mowing and control treatment stem counts were unmeasured, but there were numerous stems in both treatments (Figure 6A, Figure 8A). The analysis showed a statistically significant interaction effect between treatment and survey event ($F_{19, 20}$ = 11.26, *P* < 0.0001, Table 1), and no statistically significant difference on the main treatment effect ($F_{2, 2}$ = 2.35, *P* = 0.30, Table 1) and survey event effect ($F_{10, 20}$ = 1.38, *P* = 0.26, Table 1). The Tukey's HSD determined that the only statistically significant difference was on survey event 4 for the control and hand treatment (*P* = 0.04). The mean number of stem on survey event 1 and 11 was 5.6 and 4.1, 0.3 and 7.1, and 9 and 5.4 for mowing, hand removal, and control treatments, respectively (Figure 4). There are no data on mowing treatment for survey event 9 because of unexpected inaccessibility to the site on the day of sampling. The mean number of stems in control treatment decreased over time may be due to sampling error.

Table 1 – ANOVA results from the ImerTest to assess the significant difference of the fixed effects of treatments (i.e. mowing, hand removal, and control) and survey event for the mean number of stem of Himalayan blackberry m^{-2}. Bold indicates statistically significant differences.

Fixed effect	NumDF	DenDF	*F*-value	*P*-value
Treatment	2	2	2.35	0.30
Survey Event	10	20	1.38	0.26
Treatment:Survey Event	**19**	**20**	**11.26**	**<0.0001**

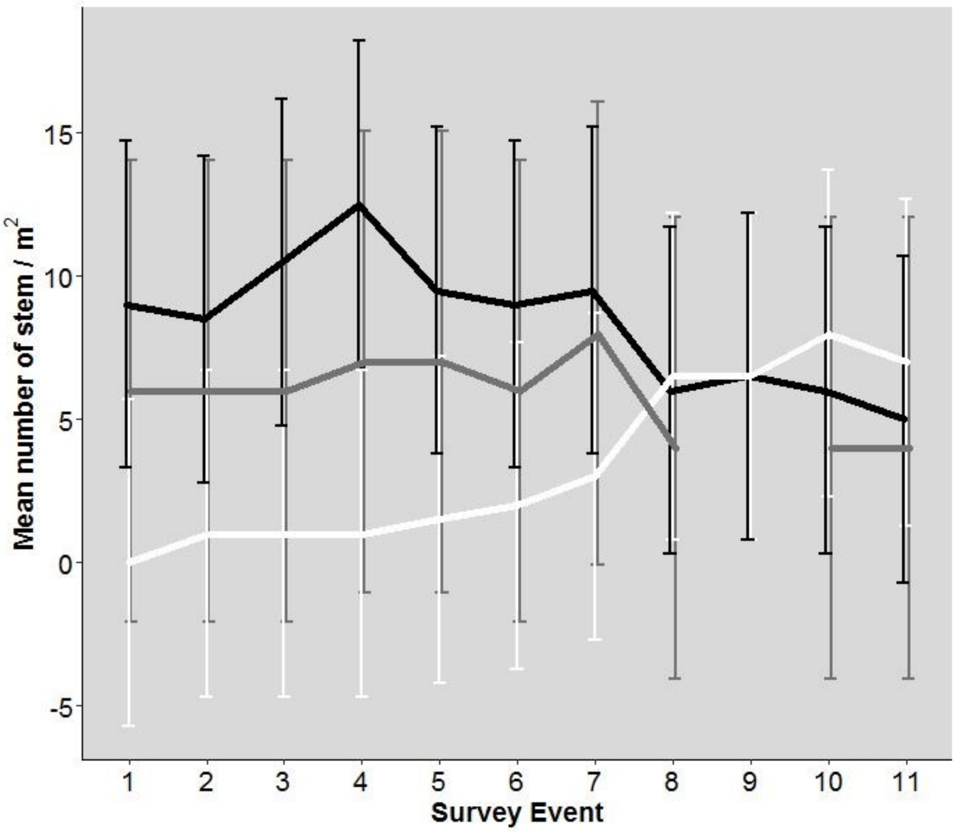

Figure 4 – Mean number of stems in the mowing (n=1), hand removal (n=2), and control (n=2) treatments from survey event 1 to 11. The grey line represents mowing treatments. The white line represents hand removal treatments. The black line represents control treatments. The whiskers indicate 95% confidence intervals (CIs).

3.2 – Mean stem length in treatments

Prior to survey event 1, hand treatment had no visible stems length, therefore length data were not collected (Figure 7B). Mowing and control treatments stem lengths were unmeasured (Figure 6A, Figure 8A). The analysis showed a statistically significant difference for the main treatment effect ($F_{2, 2}$ = 17.01, P = 0.05, Table 2), main survey event effect ($F_{10, 20}$ = 19.01, P < 0.05, Table 2), and interaction between treatment and survey event effect ($F_{19, 20}$ = 3.20, P < 0.05, Table 2). The Tukey's HSD showed no statistically significant difference between hand and mowing treatment throughout all the survey event. The statistically significant difference for the interaction and treatment effects were between control and hand or control and mowing. The mean stem length on survey event 1 and 11 was 20.7 and 58 cm, 3.2 and 53.4 cm, and 66.8 and 63.4 cm for mowing, hand removal, and control treatments, respectively (Figure 5). There are no data on the mowing treatment for survey event 9 because of unexpected inaccessibility to the site on the day of sampling.

Table 2 – ANOVA results from the lmerTest to assess the significant difference of the fixed effects of treatments (i.e. mowing, hand removal, and control) and survey event for the mean number of stem of Himalayan blackberry cm * m^{-2}. Bold indicates statistically significant differences.

Fixed effect	NumDF	DenDF	*F*-value	*P*-value
Treatment	**2**	**2**	**17.01**	**0.05**
Survey Event	**10**	**20**	**19.01**	**<0.0001**
Treatment:Survey Event	**19**	**20**	**3.20**	**<0.001**

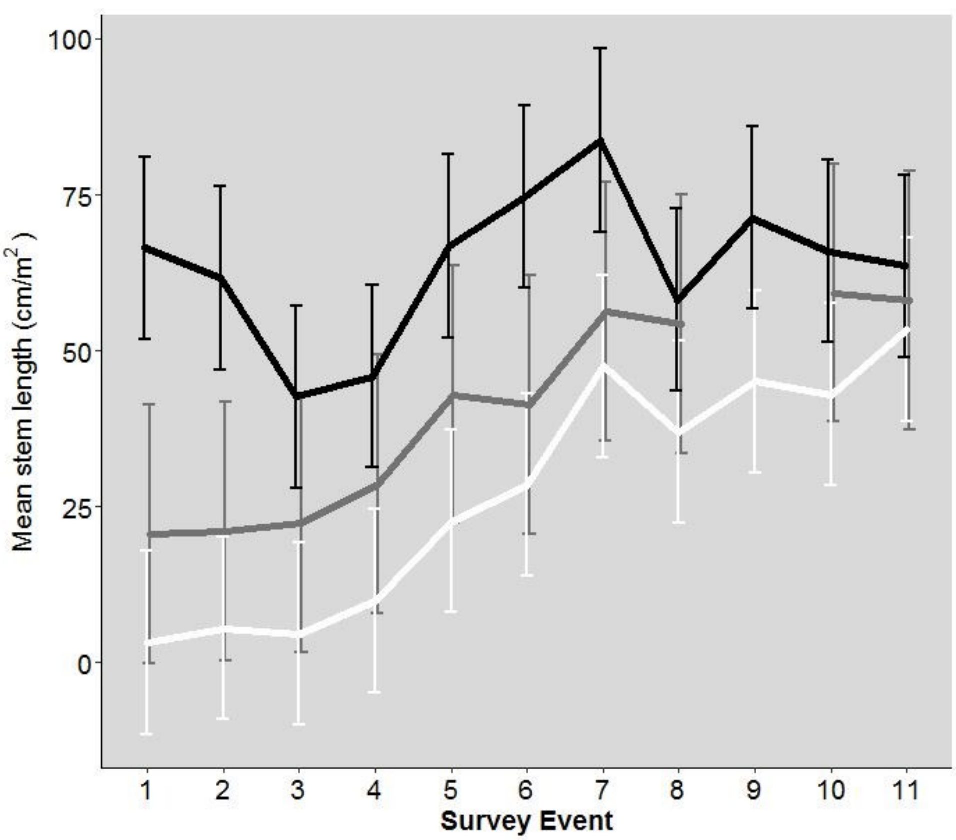

Figure 5 – Mean length of stems in the mowing (n=1), hand removal (n=2), and control (n=2) treatments from survey event 1 to 11. The grey line represents mowing treatments. The white line represents hand removal treatments. The black line represents control treatments. The whiskers represent 95% confidence intervals (CIs).


A.

B.

Figure 6 – Example of a mowing experimental plot. A. After treatment (25 March 2017). B. Regrowth of Himalayan blackberry after one growing season (26 August 2017). The yellow rectangle is a marker use for comparing the pictures. (Photo credit: C. Co).

A.

B.

C.

Figure 7 – Example of a hand experimental plot. A. Before treatment (24 March 2017). B. After treatment (25 March 2017). C. Regrowth of Himalayan blackberry after one growing season (11 August 2017). The yellow rectangle is a marker use for comparing the pictures. (Photo credit: C. Co).

A.

B.

Figure 8 – Example of a control experimental plot. A. Beginning of the growing season (21 April 2017). B. After one growing season (26 August 2017). The yellow rectangle is a marker use for comparing the pictures. (Photo credit: C. Co).

4. Discussion

The purpose of my research is to determine which treatment method, mowing or hand, is the most effective in Himalayan blackberry removal. Mean number of stem and mean stem length were the response variables in evaluating the effectiveness of the post-treatments. I hypothesised that hand removal treatment would have a lower mean number of stem and shorter stem length than mowing treatment in one growing season. My results for the mean number of stem and the mean stem length rejected my hypotheses. The overall trend showed no statistically significant difference between mowing and hand removal treatments in one growing season.

Mowing and hand removal treatments removes Himalayan blackberry canopy which provide immediate benefits to other species, native and non-native, such as light availability (Ingham 2014). According to my data, both treatments were not effective in suppressing the regrowth of Himalayan blackberry after removal. Himalayan blackberry grew back after one growing season after a single treatment. The trend in mean number of stem and mean stem length showed that all treatments (i.e. mowing, hand removal, and control) converged together after the growing season.

Other studies show that mowing-only treatment is less effective at controlling Himalayan blackberry regrowth compared to other treatments because the stems and root crowns still occupy the soil space which remains an issue for regrowth and the treatment favours seedling germination which may promote spreading of other non-native species (Clark and Wilson 2001; Bennett 2004; Jones 2004; Ingham 2009). From my data, one single mowing treatment on Himalayan blackberry showed the same results in mean number of stem and mean stem length as applying no treatment (i.e. control treatment). Therefore, mowing treatment is not feasible for Himalayan blackberry removal. Hand removal-only treatment is effective in controlling Himalayan blackberry regrowth, but may be difficult (Bennett 2004; Soll 2004). Himalayan blackberry stems and root crowns must be thoroughly removed when doing hand removal treatments because regrowth can occur from plant and root fragments. In addition, root crowns are 30 cm or deeper in soil, causing disturbances when removed (i.e. optimal conditions for seedbank and offsite non-native species invasion) (Sheley and Krueger-Mangold 2003; Bennett 2004). According to my data, one single hand removal treatment displayed the highest mean stem count with approximately seven stems and fastest growth rate with approximately

50 cm increase in mean stem length at end of the growing season. Hand removal treatment is feasible for the first 2 months post-treatment, but then the results will end up the same as the control treatment.

From my field observations, regrowth of Himalayan blackberry and other non-native species (i.e. Japanese knotweed (*Fallopia japonica*), English ivy (*Hedera helix*) and black locust (*Robinia pseudoacacia*)) occupied both mowing and hand removal sites post-treatment. For the sites to achieve the desirable natural ecological trajectory (i.e. CWH forest), integrated treatments must be applied for the removal of Himalayan blackberry (see section 4.2).

4.1 – Management Considerations

The Adaptive Management experimental design was designed to be a balanced experimental design with two replicates for the three treatments, but one of the mowing treatment experimental plots experienced knotweed infestation. Throughout the entire survey events, the plot had only Japanese knotweed (*Fallopia japonica*), instead of Himalayan blackberry. From my literature review, Japanese knotweed negatively affects the growth and fitness of species through allelopathy (Gaire et al. 2015; Murrell et al. 2011). Therefore, that mowing experiment plot was removed to prevent an inaccurate analysis. In addition, as the experimental design was implemented for one growing season with a small sample size, the data are inadequate to determine the long-term effects of mowing and hand removal treatments in Himalayan blackberry. However, the data shows one growing season effect that mowing and hand removal treatments are not effective in removing Himalayan blackberry. Due to time and resource constraints, two response variables were measured during the survey events. For further learning, biomass, soil seedbank, and stem diameter should be included as response variables to understand the site conditions and Himalayan blackberry growing patterns which can lead to choosing the most effective Himalayan blackberry treatment for the site.

4.2 – Implications to Ecological Restoration

Mowing and hand removal treatments overall trend showed no statistically significant difference in mean number of stem and mean stem length for one growing season. One single mowing and hand removal treatments were not effective in Himalayan blackberry removal for one growing season. Therefore, integrated treatments must be used to effectively removal Himalayan blackberry (Bennett 2004; Ingham 2014; Krueger et al. 2016). Recommendations of integrated treatments for the Everett Crowley Park: Mowing + Planting, Mowing + Hand removal + Planting, and Mowing + Goat browsing + Planting.

Mowing treatment is a fast and cost-effective method to remove large Himalayan blackberry infestation (Bennett 2004, Soll 2004). Post treatment result in opening up the canopy and increasing space availability for native species (Bennett 2004, Soll 2004). However, my data shows Himalayan blackberry will grow back to a state like a control site (i.e. no treatment was applied) in a growing season. Therefore, a secondary treatment must be applied immediately (i.e. within 2 months) after mowing treatment before mean number of stem and mean stem length increases. For the mowing treatment, remove the aboveground vegetation leaving 8 cm or less of the Himalayan blackberry stems (Clark and Wilson 2001; Soll 2004; Bennett 2004; Ingham 2014; Krueger et al. 2016). Remove the plant fragments from the site to prevent regrowth, except if the secondary treatment is goat browsing (Clark and Wilson 2001; Bennett 2004; Soll 2004; Ingham 2014). For mowing sites with slope over 30 percent (i.e. south area of the park), use mowers that are safe to run with that condition (Soll 2004). Apply treatment once before growing season (e.g. January to March or October to December) to prevent seed dispersal (Bennett 2004). Adding mulch is optional because the effectiveness deteriorates after a year (Bennett 2004).

Hand removal is a slow and labour-intensive method but effective treatment used to remove Himalayan blackberry (Bennett 2004; Soll 2004). Hand removal Post treatment, the site is bare land, planting treatment must follow immediately (i.e. within 2 months). For hand removal treatment, dig out the Himalayan blackberry stems and root crowns with shovels. Remove the plant fragments from the site to prevent regrowth (Clark and Wilson 2001; Bennett 2004; Soll 2004; Ingham 2014). Hand removal is required after planting treatment for maintenance until native species suppress the regrowth of Himalayan blackberry (Bennett 2004).

For planting treatment, choose native species within the CWH BEC zone with a rapid growth rate (e.g. willows). Planting native species to create at least 73% shading of forest floor can successfully suppress the regrowth of Himalayan blackberry (Jones 2004; Bennett 2004). Apply planting treatment within the first two months after mowing or hand removal treatments to site is optimal because my data shows that mean number of stem and mean stem length remains the same post-treatment before the mean number of stem and mean stem length increases. Competition from native species is an important factor in reducing Himalayan blackberry population (Ainsworth and Mahr 2006).

Goat browsing treatment must be applied within a month after the mowing treatment and then allow the goats browse for the whole growing season. The goats will consume the plant fragments, defoliate the plants, and deplete the root reserves at the site for at least two growing seasons. Goat browsing treatment must be applied for at least two years to be successful in reducing Himalayan blackberry cover (Ingham 2014). First year goat browsing would eliminate the primocanes and second year browsing would eliminate the floricanes (i.e. reproduction parts for Himalayan blackberry) (Ingham 2009). Before applying goat browsing treatment, mowing treatment must be applied first. Prior to goat browsing treatment, install fences to secure the area for goats to browse the regrowth of stems and leaves over the growing season (Bennett 2004). Goat browsing treatment has some challenges at the site, such as acquiring goats and having a secure space for browsing because the park is a dog park.

5. Conclusion

Himalayan blackberry spreads aggressively and predominates the ecosystem by adapting to many environmental conditions. To restore the ecosystem to the CWH forest in the park and eradicate Himalayan blackberry, effectiveness of invasive species removal treatments is an important factor to understand. My data showed no statistically significant difference in mean number of stem and mean stem length for mowing and hand removal treatments in one growing season in comparison with the control treatments. Himalayan blackberry will grow back after one growing season after one single treatment. Therefore, integrated treatments (e.g. mowing + hand removal + planting) are recommended to be used to effectively reduce Himalayan blackberry cover because one removal treatment showed insufficient effect in removing Himalayan blackberry. For integrated treatments, secondary method must be applied within 2 months after the post first method before mean number of stem and mean stem length increases. Invasive species management requires lots of time and resources. To be successful, treatments must be applied within the timeline to prevent sites reverting to the original state.

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