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English Holly (*Ilex aquifolium*) Herbicide Treatment Study

EARTH CORPS

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Executive Summary

This paper provides a summary of the results of a study designed to test the effectiveness of different herbicide treatment methods to control invasive English holly (*Ilex aquifolium*) trees in the Puget Sound region. The study compares the results of using three different treatment methods (frilling, cut-stump, and lance stem injection) with three different herbicides (glyphosate, triclopyr, and imazapyr) applied in both the spring and fall seasons. Data was collected from five sites within the Puget Sound region of Washington. Herbicide applications occurred in the fall of 2010 and the spring of 2011. Post-treatment data collection occurred after one year following each treatment. Funding and support for this project was provided in part by the City of Shoreline Parks Department, the City of Seattle Parks Department, the City of Mercer Island Parks Department, the King County Noxious Weed Control Program (KCNWCP), and EarthCorps.

The most effective and time-efficient method to control English holly examined in this study is stem injection with imazapyr. This combination was very effective at killing the tree and resulted in the fewest number of trees with additional stump sprouts. Furthermore, stem injection with imazapyr was also the most time-efficient application method studied, even without taking into account the additional time necessary to mix, clean, handle, and store liquid chemical herbicides required with the other treatments. Using the stem injection treatment method reduces exposure risk to the applicator and reduces non-target herbicide effects to adjacent plants. Along with effectiveness, these factors give this treatment method a clear advantage over the traditional cut stump and frilling treatment methods. In addition, it may also be possible to utilize the stem injection treatment method in any weather including rain. (This factor was not evaluated in this study).

Finally, results of this study suggest that it is equally effective to inject English holly with imazapyr in either the fall or the late spring. Because of the relatively small sample size for this treatment, further research would be necessary to verify if there are any differences in the effectiveness with regard to temperature, seasonality, or weather.

As an alternative to stem injection, frilling with triclopyr is recommended. Cut stump treatments with triclopyr can also be effective, although this study suggests that more stump sprouts may potentially result with this treatment compared to frilling. Although these treatments were as effective in killing English holly, the time necessary to handle the liquid chemicals and conduct frilling or cut stump treatments make them much less efficient compared to stem injection. Because of the lower effectiveness and the increased occurrence of stump sprouts and stem budding from the crown, it is not recommended that glyphosate is used for either frilling, cut stump, or stem injection applications

1. Report Introduction

This report summarizes the results of a study designed to test the effectiveness of different herbicide treatment methods to control invasive English holly (*Ilex aquifolium*) trees in the Puget Sound region. The study compares the results of using different treatment methods (frilling, cut-stump, and lance stem injection) with three different herbicides (glyphosate, triclopyr, and imazapyr) applied in both the late spring and fall seasons. This report summarizes data collected from five sites within the Puget Sound region of Washington (Map 1). Herbicide applications occurred in the fall of 2010 and the spring of 2011. Post-treatment data collection occurred after one year following each treatment. Included in this report are a project overview, a description of the treatment and monitoring methods, and a summary of the monitoring results. Funding and support for this project was provided in part by Seattle Parks and Recreation, the City of Shoreline Parks Department, the City of Mercer Island Parks Department, the King County Noxious Weed Control Program and EarthCorps.

2. Project Overview

Invasive trees are a serious and growing concern in urban forests within the Puget Sound region and throughout the Pacific Northwest. Although land managers have known about the impacts of invasive trees on forest health for some years, the first systematic effort to quantify both native and invasive species in Seattle came in 1999-2000, when Seattle Urban Nature (SUN, now EarthCorps) mapped the vegetation and wildlife habitat on approximately 8,000 acres of Seattle's public land. Information collected during the 1999-2000 survey included cover estimates for English holly (*Ilex aquifolium*). A summary of this survey showed that this species occupies a substantial area of Seattle's public lands and was the fourth most abundant non-native species by acreage (Ramsay et al. 2004).

Since the survey was completed in 2000, SUN and EarthCorps have conducted numerous vegetation studies within Seattle parks, showing that the majority of forests on public lands are substantially invaded by numerous species of invasive trees including relatively high densities of English holly (Elman et al. 2004, Elman et al. 2005, Elman et al. 2006, Elman et al. 2007, Elman & Salisbury 2008, Elman & Salisbury 2009, and SUN 2006). These studies have highlighted the specific threat of invasive trees in general, and English holly in particular, by measuring stem densities of regenerating trees in survey plots stratified throughout these parks and various forest types throughout the region.

English holly is carried by birds into forests where it can form dense thickets that dominate the tall shrub layer and suppress germination and growth of native tree and shrub species (King County 2012). This species is listed as a “Weed of Concern” by the King County Noxious Weed Control Program. EarthCorps has been advocating for listing English holly as a Class C noxious weed in Washington State for the past several years and has provided survey data and support to the King County Noxious Weed Control Program in this effort.

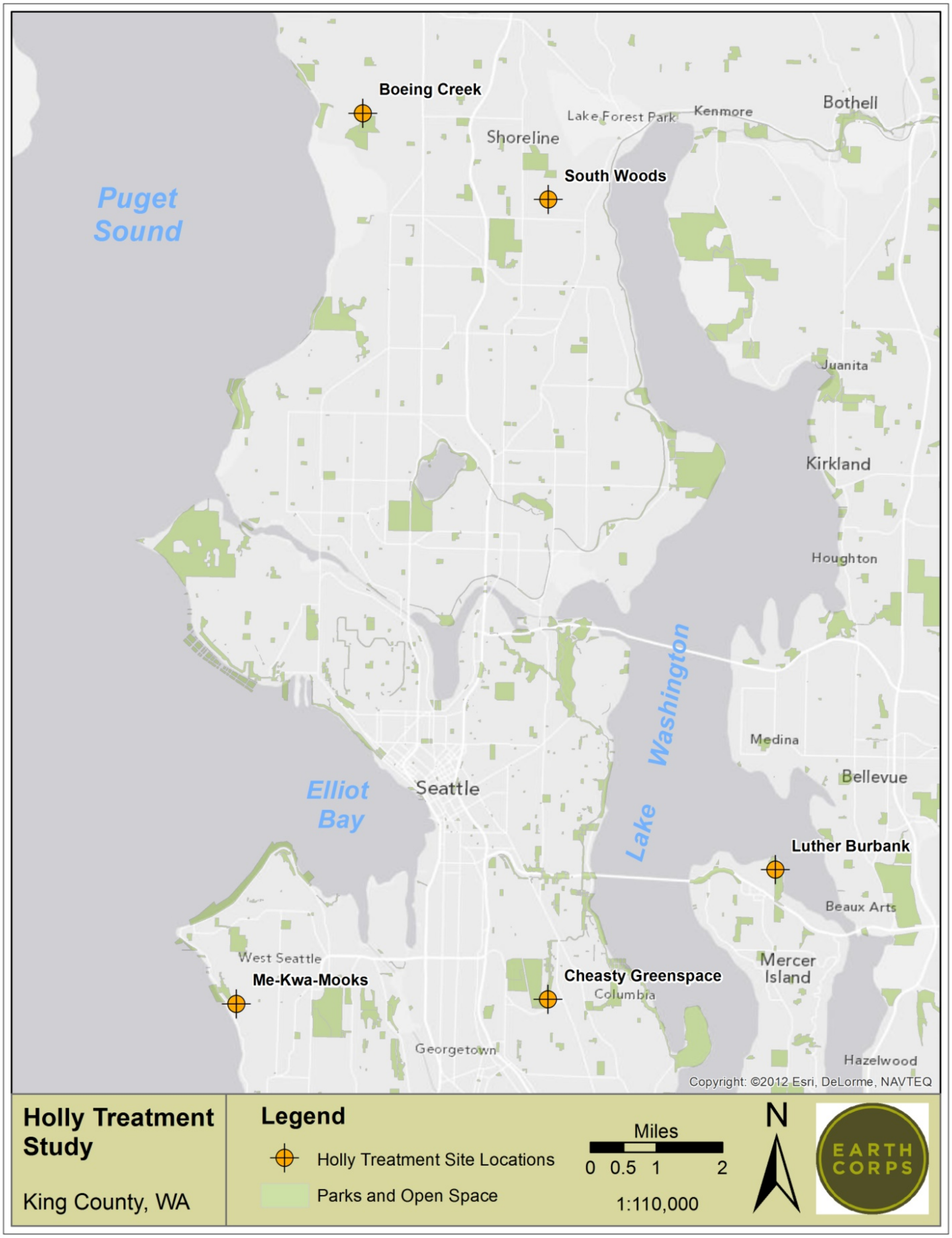
Efforts to eradicate and control English holly are currently widespread throughout King County and western Washington. Numerous organizations, friends-of groups, contractors and government agencies routinely address the removal and control of this species from natural areas and active restoration projects. The Seattle Parks Department includes English holly in its list of “obnoxious weeds” targeted for control in Seattle’s natural areas (City of Seattle 2005). Seattle Public Utilities is reported to have spent nearly $90,000 towards eradicating English holly at Lake Youngs from 2007 to 2009 (Watts 2012).

To date, relatively few formal studies have looked at which methods are the most effective and cost efficient for control and eradication of this species. Due to the propensity of English holly to stump-sprout after being cut, herbicide application is recommended in conjunction with manual control efforts (King County 2012). Foliar application of herbicides is generally not effective in controlling this species due to the thick, waxy coating present on the leaves (King County 2012). The purpose of this study is to determine the effectiveness of different stem-targeted herbicide treatment methods to control invasive English holly trees in the Puget Sound region. Questions addressed during the course of this study include:

1) The type of treatment that is most effective for control of English holly
2) The type of herbicide that is most effective for control
3) The season (late spring or fall) in which chemical control is most effective
4) The type of treatment that is most time efficient to apply

Effectiveness was evaluated by monitoring which treatment/herbicide combination resulted in the highest percentage of dead holly trees. Because of the propensity for holly to stump-sprout following cutting or other treatment, the treatment/herbicide combination that was less likely to result in additional sprouting was also evaluated. All treatments were repeated in the fall and late spring to assess any differences in seasonality.

Map 1. Project Location



3. Methods

The following sections describe the study area (3.1), the treatment and application methods (3.2), and the monitoring methods (3.3).

3.1 Study Area

Five sites located in three municipalities in Puget Sound were selected as the study area (Map 1). Two sites each in Seattle and Shoreline and one in Mercer Island where English holly was prevalent were chosen. All site locations are public parks managed by their respective municipalities. Natural areas at all sites are generally composed of upland forests that range from conifer to deciduous and dominated primarily by a mix of Douglas fir (*Pseudotsuga menziesii*) and bigleaf maple (*Acer macrophyllum*) with lesser amounts of Pacific madrone (*Arbutus menziesii*) and western red cedar (*Thuja plicata*) on some sites.

3.2 Treatment Methods

Three different treatments were carried out at each location at two different times of year, fall and late spring. Treatments include frilling, cut stump, and stem injection, each using two different kinds of herbicide. Untreated control trees were monitored at each site. For cut stump and frilling treatments, either glyphosate (AquaMaster) or triclopyr (Element 4) were applied to the cut or frilled stems at full strength. Glyphosate and triclopyr were chosen because of their widespread use to treat invasive plants throughout the Puget Sound region. For the stem injection treatment, either glyphosate (Diamondback) or imazapyr (Copperhead) herbicide shells were used because they are currently the only herbicide formulations available for use with the EZ-Ject lance used in this study (EZ-Ject 2011). Because of city herbicide regulations, only glyphosate shells were used for the injection treatment at the Seattle sites. Imazapyr shells were used at both the Shoreline and Mercer Island sites. Therefore, comparisons of the effectiveness of herbicide using stem injection were made by comparing results from the two sites in Seattle with results from the two sites in Shoreline and one in Mercer Island. The following three treatment methods were used:

Frilling treatments: Several rows of cuts encircling the stem were made at a 45 degree angle through the bark at the base of each tree with a small hatchet. Herbicide was then immediately applied to the cut surface using a plastic spray bottle. The study design called for all sprouts or stems within a one foot radius of the main stem to be either frilled or cut and treated at this time.

Cut stump treatments: Stems were cut with a hand saw near the ground (approx. four inches to one foot) and herbicide was immediately applied directly to the cut surface using a plastic spray bottle. The study design called for all sprouts or stems within a one foot radius of the main stem to be cut and treated at this time.

Stem Injection: An Ez-Ject lance tool was used to inject herbicide shells into the base of each tree. The application rate calls for one shell to be used for trees with less than 2.5 inches DBH (diameter at breast height). For larger trees, one shell is injected every four inches around the base of the stem (EZ-Ject 2011).

For each site, approximately 40 to 110 stems of English holly were located and each stem was marked with a metal tag bearing a unique number. Baseline data collected for each tree included stem diameter and approximate height. The number and size of all existing root sprouts within one foot of the main stem were enumerated. Groups of stems at each site were randomly divided into each of five possible treatment and herbicide combinations plus a control group: 1) cut-stump application with glyphosate, 2) cut-stump application with triclopyr, 3) frilling application with glyphosate, 4) frilling application with triclopyr, 5) stem injection with glyphosate on Seattle sites or 5) stem injection with imazapyr on Shoreline and Mercer Island sites. Half of the stems were treated in the fall and the remaining stems were treated in the late spring. Fall treatments occurred between October 14th and November 2nd, 2010 and spring treatments occurred between May 24th and June 16th, 2011. The amount of time necessary to treat each stem was recorded for all treatment methods.

All treatments and herbicide applications were carried out by staff from the King County Noxious Weed Control Program and/or EarthCorps. Baseline and follow-up monitoring was carried out by EarthCorps staff. Overall, a total of 419 individual holly trees were tagged, treated, and monitored during the course of this study (Table 1). Treated stems were between one and four inches DBH (average of all treated trees was 1.99 inches DBH) and were spaced at least ten feet apart from other holly trees that met these criteria (in order to lessen the potential for nutrient transport from adjacent treated and non-treated holly trees).

Table 1. Total numbers of holly trees by season treated and monitored across all five treatment location sites located in Seattle, Shoreline, and Mercer Island, WA in 2010-2012.

Treatment and Herbicide	Fall	Spring	Total
Frilling with glyphosate	38	38	76
Frilling with triclopyr	39	36	75
Cut Stump with glyphosate	39	39	78
Cut Stump with triclopyr	38	39	77
Injection with glyphosate	16	16	32
Injection with imazapyr	22	22	44
Control			37
Total	**192**	**190**	**419**

3.3 Monitoring Methods

Monitoring occurred approximately one year following each treatment for both fall and late spring treatments. Individual trees were relocated and assessed for health and re-sprouting. Cut stump treatments were only evaluated for re-sprouting. Trees from all other treatments were evaluated for health based on the percent of live canopy remaining. The number of sprouts were re-counted and compared to the baseline data. Each treatment and control tree was evaluated using the following criteria:

A. Crown Rating

- Healthy: Appears in good health, no major branch/leaf mortality, 0-10% crown dieback
- Light Decline: 10-50% crown dieback
- Moderate Decline: 50-75% crown dieback
- Severe Decline: greater than 75% crown dieback
- Dead: crown completely dead

B. Stump Sprouting

- All sprouts within a one foot radius of the main stem were enumerated into 1 foot height categories from <1' to >8'. This information was compared against the sprout counts collected at the time of initial baseline data collection.

The average number of trees for each treatment/herbicide combination given a particular crown rating at each site and/or season was calculated. Also, the average number of trees for each treatment/herbicide combination with more sprouts after one growing season was calculated. Statistical analyses using these percents normalized to arcsine values were used to determine significance between each treatment/herbicide/season combination. A one way ANOVA was performed to determine if there was a significant difference between the mean of each combination. A Tukey-Kramer multiple comparisons post test was performed to indicate where treatment combinations may be significantly different from each other.

The percent of trees that were considered "dead" during monitoring in each treatment/herbicide combination was used as the primary indicator of success. Additionally, the treatment/herbicide combination that resulted in the fewest occasions of additional stump sprouting was also considered. Because of the potential error in documenting the number of sprouts before and after treatment, it was determined that only trees exhibiting three or more additional sprouts following treatment were considered to have more sprouts.

4. Results

The following sub-sections present the results for each treatment/herbicide combination. Frilling (4.1) and stem injection (4.2) treatment results consist of percentages of crown health. Cut stump (4.3) treatment results compare trees with additional basal sprouts following treatment as they could not be evaluated for crown health. A separate sub-section (4.4) summarizes the percentage of trees from each treatment/herbicide/season combination with higher numbers of basal sprouts after one year following treatment. Also, a summary of the amount of time needed to perform each treatment is presented (4.5).

4.1 Frilling Treatment

A total of 151 trees across all five sites were treated using stem frilling; 75 with glyphosate and 76 with triclopyr (Table 1). Frilling with glyphosate in both the fall and spring resulted in the least successful treatment combination with only 65% of treated trees recorded as dead. Overall, frilling with triclopyr resulted in the highest percentage of dead trees across both seasons (99%) with only one tree treated in the spring that was recorded in severe decline (Table 2 & Figure 1).

A one way ANOVA performed on all treatment/herbicide/season combinations shows that the means are significantly different. The post test indicates that frilling with triclopyr in the fall or spring resulted in significantly higher (at either a 99% or a 95% probability level respectively) percentages of dead trees than frilling with glyphosate in either the fall or spring. Differences between the same herbicide (either glyphosate or triclopyr) in different seasons were not found to be significant.

Table 2. Results of frilling treatments by percent health category for all treatment sites. N= total number of trees in each treatment/herbicide category at each site.

		Health Category			
Site	**N**	**Dead**	**Severe Decline**	**Moderate Decline**	**Light Decline**
Frilling Glyphosate Fall 2010					
Boeing Creek	4	50%	25%	25%	
Cheasty Greenspace	9	67%	33%		
Luther Burbank	8	50%	38%	13%	
Me-Kwa-Mooks	7	43%	43%	14%	
South Woods	10	100%			
Frilling Glyphosate Spring 2011					
Boeing Creek	4	75%		25%	
Cheasty Greenspace	9	33%	44%	11%	11%
Luther Burbank	9	78%	22%		
Me-Kwa-Mooks	6	67%	33%		
South Woods	10	80%	20%		
Frilling Triclopyr Fall 2010					
Boeing Creek	4	100%			
Cheasty Greenspace	9	100%			
Luther Burbank	9	100%			
Me-Kwa-Mooks	7	100%			
South Woods	10	100%			
Frilling Triclopyr Spring 2011					
Boeing Creek	4	75%	25%		
Cheasty Greenspace	9	100%			
Luther Burbank	8	100%			
Me-Kwa-Mooks	5	100%			
South Woods	10	100%			

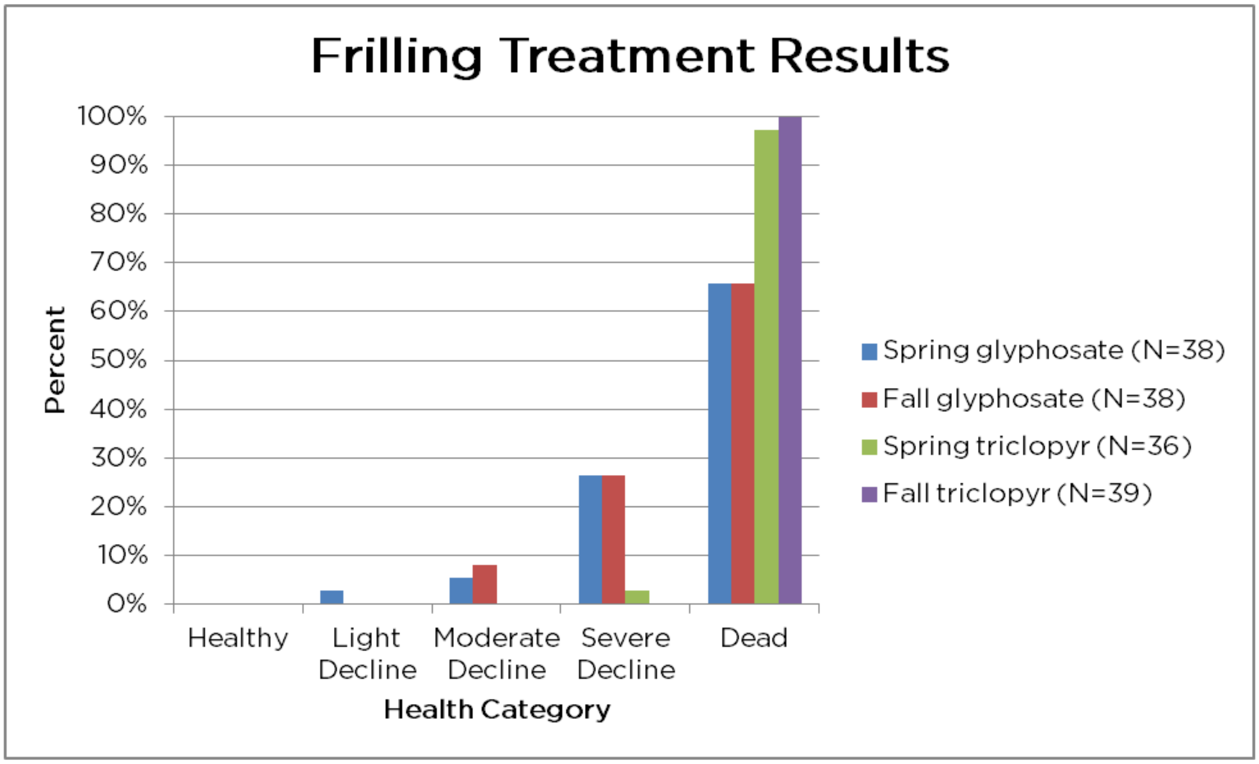


Figure 1: Percent of trees by health category and season resulting from frilling treatments with either glyphosate or triclopyr across all five sites. N= the number of trees in each treatment.

4.2 Stem Injection

Seventy six trees across all five sites were treated with the stem injection lance, 44 with imazapyr and 32 with glyphosate (Table 1). Injection with imazapyr resulted in higher percentages of dead or severely declined trees compared to injection with glyphosate in all sites and in both seasons (Table 3 & Figure 2). Nearly all of the trees injected with imazapyr in either the spring or the fall were determined to be dead at the time of monitoring. In contrast, injection with glyphosate resulted in fewer percentages of dead or severely declined trees: only 9% of all trees injected with glyphosate were considered dead at the time of monitoring. Nineteen percent of spring glyphosate stem injection treatments were dead compared to zero fall glyphosate stem injection treatments. Approximately 30% of all trees treated with glyphosate in the fall were determined to be healthy at the time of monitoring (Figure 2).

Table 3. Results of stem injection treatments by percent health category for all treatment sites. N= total number of trees in each treatment/herbicide category at each site.

		Health Category				
Site	**N**	**Dead**	**Severe Decline**	**Moderate Decline**	**Light Decline**	**Healthy**
Stem Injection Glyphosate Fall 2010						
Cheasty Greenspace	9		11%	11%	44%	33%
Me-Kwa-Mooks	7		14%	14%	43%	29%
Stem Injection Glyphosate Spring 2011						
Cheasty Greenspace	9	11%	11%	56%	22%	
Me-Kwa-Mooks	7	29%		29%	43%	
Stem Injection Imazapyr Fall 2010						
Boeing Creek	4	100%				
Luther Burbank	9	100%				
South Woods	9	89%	11%			
Stem Injection Imazapyr Spring 2011						
Boeing Creek	4	100%				
Luther Burbank	9	100%				
South Woods	9	100%				

A one way ANOVA performed on all treatment/herbicide/season combinations shows that the means are significantly different. The post test indicates that stem injection with imazapyr in the fall or spring resulted in significantly higher (at a >99% probability level) percentages of dead trees than injection with glyphosate in either the fall or spring. This test also indicates that stem injection with glyphosate in the spring resulted in significantly higher percentages of dead trees (at a 95% probability level) than stem injection with glyphosate in the fall. There were no significant differences found in the percentages of dead trees in the fall versus spring treatments with imazapyr.

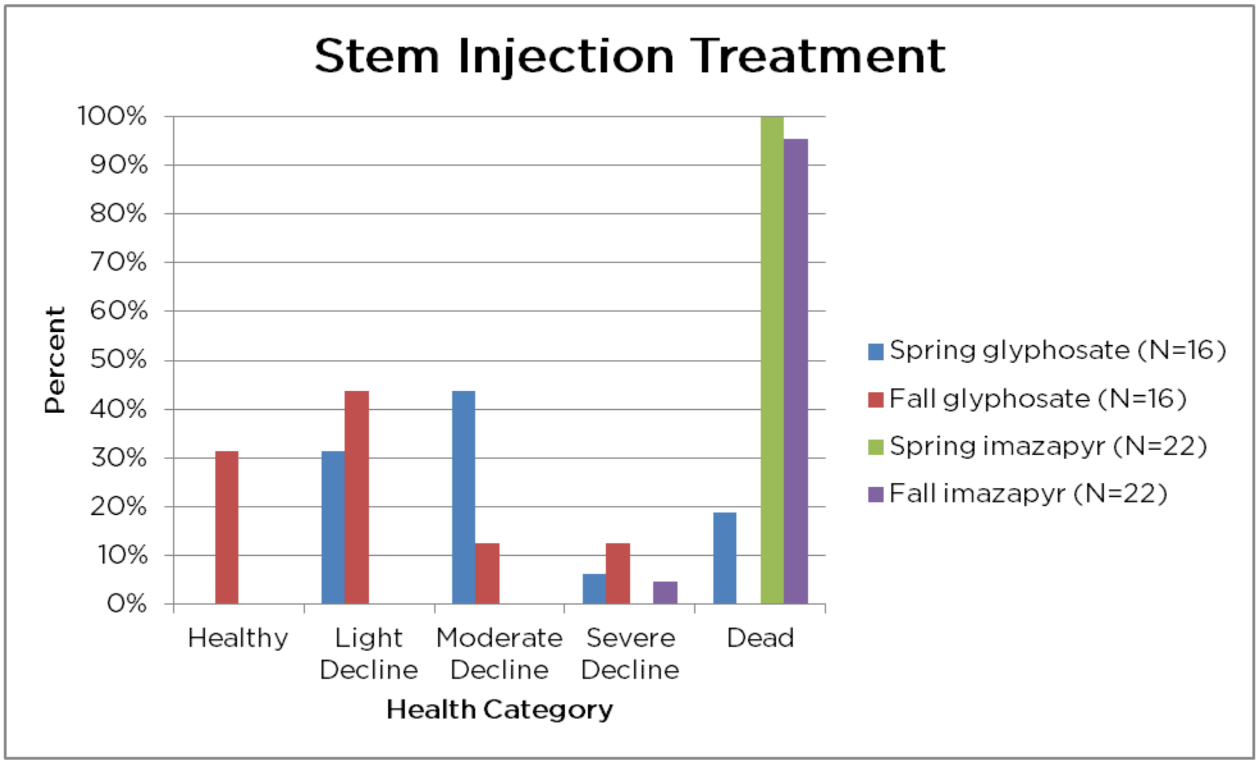


Figure 2: Percent of trees by health category and season resulting from stem injection treatments with either glyphosate or imazapyr across all five sites. N= the number of trees in each treatment.

4.3 Cut Stump Treatment

The cut stump treatment results in the complete removal of the live crown of the treated trees. Therefore, no crown health ratings were recorded. The effectiveness of these treatments was evaluated by comparing the number of additional sprouts following one year of treatment. Overall, cut stump treatments with glyphosate resulted in a substantially higher percentage of trees with three or more sprouts within a one foot radius during post-treatment monitoring compared to baseline monitoring. Thirty-three percent of all stems cut and treated with glyphosate in the spring had additional sprouts at the time of monitoring (Figure 3). A smaller percentage of trees that were cut and treated with triclopyr (3% of spring treatments and 5% of fall treatments) also exhibited additional sprouts following treatment. More information regarding stump sprouts is given in section 4.4 below.

4.4 Stump Sprouts Comparison

A total of 52 out of 419 trees (12%) had more sprouts within a one foot radius during post-treatment monitoring compared to baseline monitoring. Twenty six (6%) had three or more additional sprouts with seven of these having more than 10. Of those trees with three or more sprouts, the majority were either spring cut stump or spring frilling treatments with glyphosate (Figure 3). The frilling with triclopyr and stem injection treatments did not result in any occurrence of three or more additional sprouts. No trees in the control group had three or more additional sprouts recorded during post-treatment monitoring.

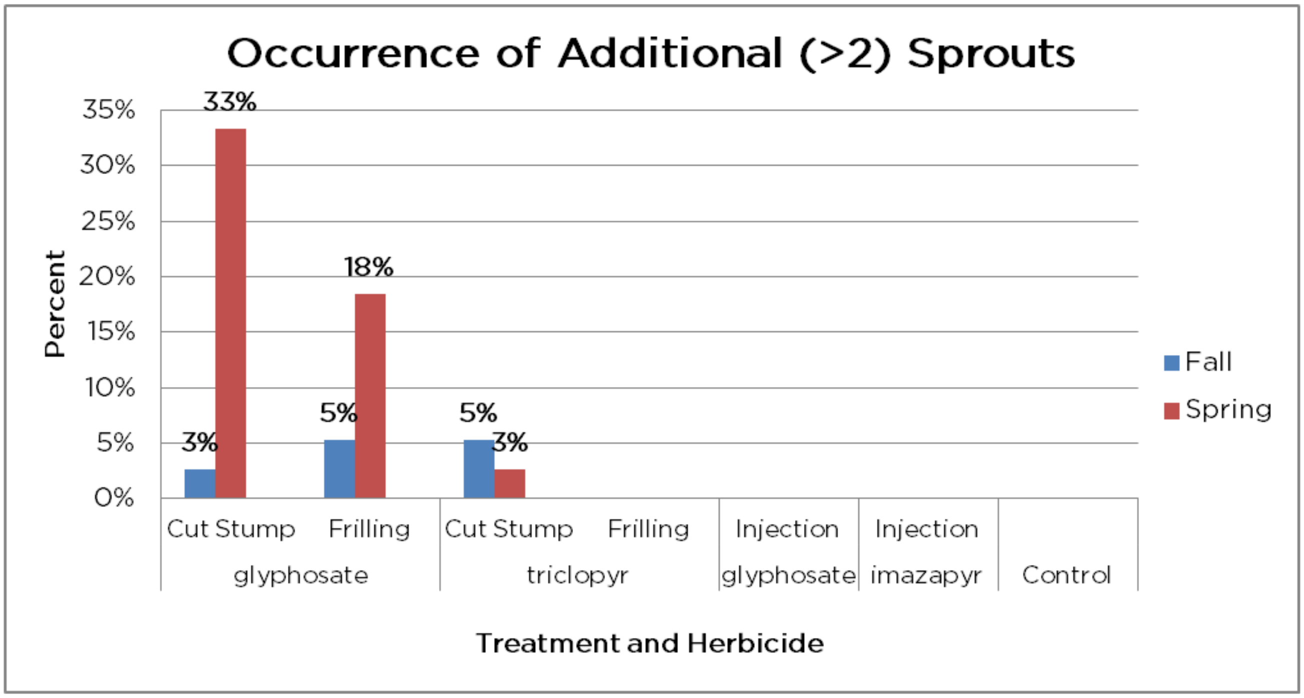


Figure 3. Percent of trees in each treatment/herbicide/season combination with three or more sprouts within a one foot radius of the main stem during post-treatment monitoring compared to baseline monitoring.

A one way ANOVA performed on the percents of all frilling and cut stump treatment/herbicide/season combinations shows that the means are significantly different. However, the post test indicates that only the spring cut stump glyphosate treatment was significantly different (at a 95% probability level) from both the spring and fall frilling treatments with triclopyr, which had no instances of additional sprouts. Likely due to the variability between sites and relatively small sample size, the percents of all other frilling and cut stump treatment/herbicide/season combinations with excessive sprouts were not statistically different.

In addition to sprouts, many treated trees also exhibited small stem enations or buds that may represent potential new sprouts (Figure 4). A total of 69 trees were noted to have these enations (33% of all treated trees), with the majority of those occurring with the glyphosate treatments in the spring (Figure 5). A high percentage of stems either frilled (74%) or cut (59%) and treated with glyphosate in the spring were noted to have these enations. In contrast, less than three percent of trees cut with triclopyr in the spring and none of the trees frilled with triclopyr were noted to have this condition (Figure 5).

Figure 4. Close-up photo of enations or buds emerging from the stem of a tree frilled with glyphosate in the spring, taken the following year (2012) during monitoring.

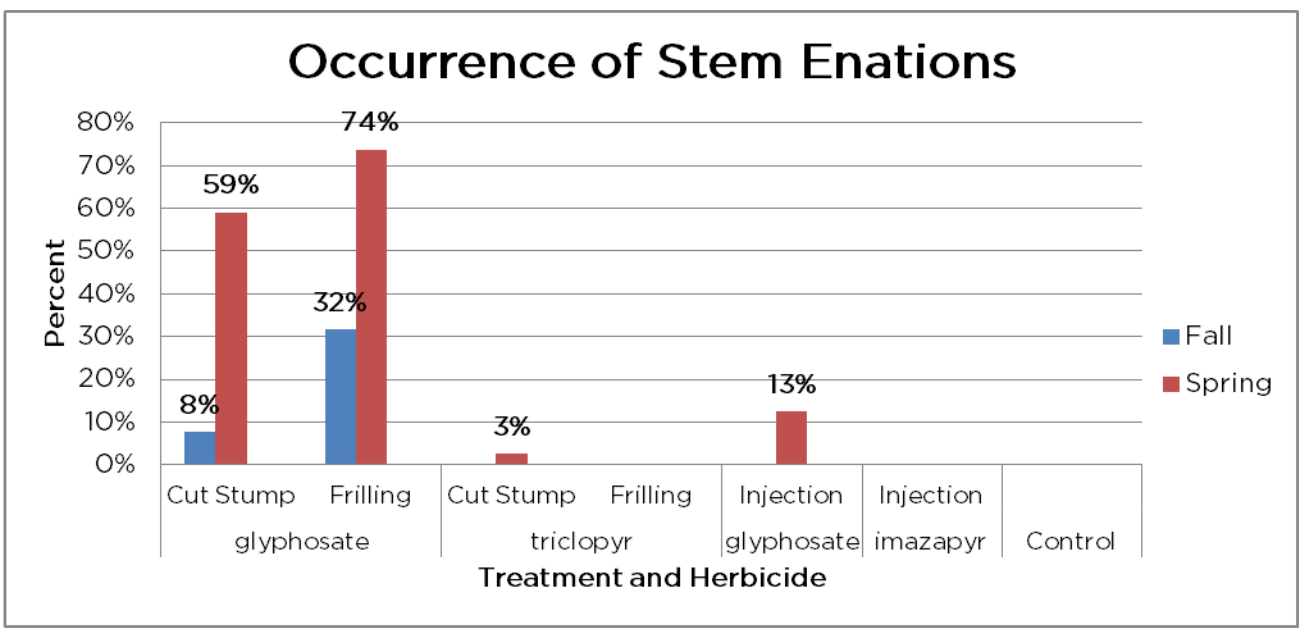


Figure 5. Percent of trees exhibiting stem enations or buds by treatment and herbicide combination and season after one year following treatment.

4.5 Treatment Time

The length of time for each treatment to be conducted was documented at each tree. This included the time required to gain access to the stem (such as pruning branches as necessary) to perform each treatment. These times were then averaged to determine the relative time it would take an applicator to treat one English holly tree. The results indicate that the time to conduct the stem injection treatment is seven to eight times faster than either the frilling or cut stump treatments (Table 5). On average, stem injection took less than 18 seconds per tree compared to over two minutes per tree for both the frilling and cut stump treatments.

Table 5. The average length of time it took to perform each of three treatment methods during both spring and fall applications. N = the number of trees in each treatment.

Treatment	Average Time per Tree	N
Cut Stump	2 Min 15 Sec	155
Frilling	2 Min 2 Sec	151
Injection	0 Min 17 Sec	76

5. Discussion

The goals of this study were to determine the effectiveness and efficiency of different stem-targeted herbicide treatment methods to control invasive English holly trees in the Puget Sound region. Overall, stem injection with imazapyr was very effective at completely killing the tree, resulted in the fewest occurrences of re-sprouting from the crown, and was by far the fastest method to employ (Figures 2 & 3, Table 5). Frilling and cut stump treatments with triclopyr were equally effective at killing the tree as stem injection with imazapyr, although data from this study suggests that cut stump methods may be more likely to result in excessive stump sprouting (Figures 1 & 3). Frilling and cut stump treatments also took considerably longer to carry out compared to the stem injection treatment (Table 5). All treatment and herbicide combinations with glyphosate were the least effective at killing the tree and resulted in the highest numbers of stump sprouts (Figures l, 2 & 3). This study suggests that it is equally effective to use stem injection control methods with imazapyr in either the fall or the late spring (Table 3 & Figure 3). Frilling and cut stump treatments with triclopyr can also be effective during either the fall or the late spring (Figures 1 & Table 2).

5.1 Stump Sprouting

In addition to effectiveness and treatment time, this study compared different treatment and herbicide combinations and their potential to result in excessive stump sprouting. During the course of post treatment monitoring, it became evident that accurately counting sprouts (especially in cases where numerous existing sprouts were present prior to treatment) before and after treatment was not always achievable. Another issue with accurately counting additional sprouts was the possibility that different applicators may have treated sprouts differently. In most cases, existing sprouts were cut and/or frilled and herbicide was applied to the cut surface during the application (for both frilling and cut stump treatments) as called for in the treatment methodology. However, in many cases it appeared that existing sprouts were not always treated this way. Therefore, it was not readily possible to determine if the post treatment sprout counts were always a true indication of new sprouts following treatment. To help account for possible errors in enumerating sprouts between seasons, it was determined that only trees exhibiting three or more additional sprouts following treatment would be considered to have excessive sprouts. It should also be noted that the overall number of trees that met this condition was quite small (26 out of 419 trees), resulting in a relatively small sample size for comparison between treatment/herbicide/season combinations.

Taking these issues into consideration, the data does appear to indicate that treatments with glyphosate are more likely to cause re-sprouting, especially in the spring (Figure 3). These data also suggest that stem injection and triclopyr treatments appear less prone to causing excessive stump sprouting compared to glyphosate treatments.

Another condition observed during the course of monitoring was the presence of enations or buds arising primarily from the bases of stems cut or frilled with glyphosate. The likelihood that these buds will develop into viable holly plants is currently unknown and requires further study. However, all treatments with triclopyr resulted in very low occurrence of this condition and no occurrences were noted with imazapyr injection treatments.

5.2 Summary

The most effective and time-efficient method to control English holly examined in this study is stem injection with imazapyr. This combination was very effective at killing the tree and resulted in the fewest number of trees with additional stump sprouts. Furthermore, stem injection with imazapyr was also the most time-efficient application method studied, even without taking into account the additional time necessary to mix, clean, handle, and store liquid chemical herbicides required with the other treatments. Using the stem injection treatment method reduces exposure risk to the applicator and reduces non-target herbicide effects to adjacent plants. Along with effectiveness, these factors give this treatment method a clear advantage over the traditional cut stump and frilling treatment methods. In addition, it may also be possible to utilize the stem injection treatment method in any weather including rain. (This factor was not evaluated in this study).

Finally, results of this study suggest that it is equally effective to inject English holly with imazapyr in either the fall or the late spring (Figure 3). Because of the relatively small sample size for this treatment, further research would be necessary to verify if there are any differences in the effectiveness with regard to temperature, seasonality, or weather.

Additional research could also investigate the length of time following stem injection required for effective control of the tree. This study only looked at effectiveness following a full year after treatment, although it may be desirable to cut and remove the treated trees after a shorter time interval. Literature indicates that imazapyr is a slow-acting herbicide with a rate of plant death ranging from several weeks (Tu et al, 2001) to one month (Cox 1996) following application. Additional research should evaluate the specific length of time following stem injection treatment on English holly where tree removal would be possible without compromising the effectiveness of the herbicide.

As an alternative to stem injection, frilling with triclopyr is recommended. Cut stump treatments with triclopyr can also be effective, although this study suggests that more stump sprouts may potentially result with this treatment compared to frilling. Although these treatments were as effective in killing English holly, the time necessary to handle the liquid chemicals and conduct frilling or cut stump treatments make them much less efficient compared to stem injection. Because of the lower effectiveness and the increased occurrence of stump sprouts and stem enations, it is not recommended that glyphosate is used for either frilling, cut stump, or stem injection applications.

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