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ER 390 – Selected Project

Restoring native biodiversity within urban landscapes: A community restoration initiative to remove invasive species from an urban forest ecosystem in Esquimalt Gorge Park in Victoria, BC

Abstract

Urbanization continuously threatens native biodiversity through natural habitat alteration, decreased connectivity between remnant native habitats, and the introduction of exotic species. Urbanization's ongoing pressures on remnant natural environments makes ecological restoration critical for the conservation of urban biodiversity. The purpose of this study was to remove invasive species, specifically English ivy (*Hedera helix*) and Daphne laurel (*Daphne laureola*), from an urban forest within Esquimalt Gorge Park in Victoria, BC. Invasive species removal from the western margin of the forest would hopefully increase species diversity and reduce future invasive spread into adjacent invasive free areas. A thorough terrestrial biophysical inventory was conducted of the entire forest study site, which included identification of all plant species present on site and alternating belt transect analysis to determine species ground cover abundance. Observations along ten alternating belt transects resulted in identification of 41 species; eight of which were non-native/invasive species. Most abundant species were English ivy (*Hedera helix*), grass (various species), and trailing blackberry (*Rubus ursinus*) and the most widely distributed species were English ivy (*Hedera helix*), Himalayan blackberry (*Rubus armeniacus*), grass (various species), Oregon beaked moss (*Eurhynchium oreganum*), and trailing blackberry (*Rubus ursinus*). Following the biophysical inventory, the treatment site was selected based on the highest densities of invasive species. A Community Restoration Event was developed and on March 11, 2018, 11 volunteers gathered to remove invasives from the marked 360m^2 treatment site. Following the invasives removal, it is recommended that native plants be seeded and planted within the treatment site and repeated removal of invasives occur to minimize potential species regrowth. Revegetation and reseeding with native plant species, as well as repeated treatments, are all viable options moving forward with the continued partnership and support of the Township of Esquimalt and the Gorge Waterway Action Society.

1.0 Introduction

Anthropogenic land-use changes continue to transform Earth's terrestrial landscapes at a startling pace. For millions of years, environmental change was dominantly driven by natural forces, such as wind, water, geologic activity and the efforts of microorganisms, plants, and animals (Meffe and Carroll, 1997); however, in only a few centuries, anthropogenic forces have become the dominant driver of environmental change globally. Urbanization, agricultural intensification, and deforestation land-use practices continue to degrade natural environments all over the world, and of these practices, urbanization exerts the greatest pressure on local biodiversity (McKinney, 2002; Meffe and Carroll, 1997; Sheikh Goodarzi et al., 2017; Yu et al., 2012). In the last century, urban environments have become increasingly more widespread worldwide. Urban environments continuously threaten native biodiversity by altering natural habitats, decreasing connectivity between remnant native habitats, and by introducing exotic plant and animal species into new habitats. Scientific literature expresses increasing consensus that there are global consequences for the cumulative effects of anthropogenic-induced environmental impacts, which have forced the planet into the current biodiversity extinction crisis (Paker, 2013; Zeunet, 2013). Urbanization's ongoing pressure of environmental destruction makes ecological restoration critical for the conservation of biodiversity (Meffe and Carroll, 1997), and therefore, the preservation and restoration of remnant natural ecosystems is crucial to urban conservation initiatives.

Urban expansion has transformed many natural environments into an urbanized landscape, causing severe habitat fragmentation (Meffe and Carroll, 1997) and extensive deterioration of many natural systems (Yu et al., 2012). With nearly half the global population living in cities (Gobster, 2010; Paker, 2013), there is continuous intense competition between ecological conservation and land development (Yu et al., 2012). With a rapidly rising global population, this competition is likely only to increase in the coming decades. However, in recent years, the destructive pattern of urbanization has encouraged a growing number of conservation initiatives to focus their energy into restoring remnant patches of local natural diversity (Gobster, 2010) and helping to mitigate negative effects on potentially affected ecosystems (Simmons et al., 2016; Yu et al., 2012). With increasing emphasis on the importance on natural environments within urbanized areas, the *quality* of urban nature has now emerged as an important issue due to the positive effects that natural environments (versus urbanized outdoor spaces) have on the public's perception of nature and environmental conservation (Paker, 2013). A new emphasis on nature quality highlights the growing awareness that remnant greenspaces have various levels of ecological health. An ecologically inspired and informed public is an important means to promote effective conservation to those who live in an urban environment (McKinney, 2002), which is why collaborative community conservation initiatives can provide beneficial education and understanding through ecological restoration activities. Ecological restoration activities intentionally seek to aid in the recovery of damaged, degraded, or destroyed ecosystems with respects to ecological integrity, health, and sustainability (S.E.R., 2004). However, complications in urban restoration can arise from the degree of habitat fragmentation, level of soil degradation, and presence of invasive exotic species (Simmons et al., 2016).

Exotic species are non-native species, introduced from outside their native range, whose introduction, establishment, spread and/or increased densities have devastating impacts on local native biodiversity (Ormsby and Brenton-Rule, 2017; Senator and Rozenberg, 2017). Globally, biological invasion is now a prominent driver of ecological change (Miehls et al., 2009) and one of the most severe ecological problems facing humankind (Senator and Rozenberg, 2017). Actions are taken all over the world to reduce the risk of biological invasion; however, globalization continues to encourage the exchange of species between natural zones, countries, and continents (Padayachee et al., 2017; Senator and Rozenberg, 2017). On many continents, invasive species constitute one of the greatest threats to native biodiversity, yet trade and transportation pathways continuously aid countries in the exchange of non-native species

(Ormsby and Brenton-Rule, 2017). The "four-T rule" – trade, transport, travel, and tourism—is regularly used to determine the cause of most invasions (Senator and Rozenberg, 2017), since these all "provide vectors and pathways for live plants, animals and biological material to cross the biogeographical barriers that would usually block their way" (Ormsby and Brenton-Rule, 2017, pp. 3356). Urbanized cities are hubs for anthropogenic activities, acting as an entry point for many exotic species (Padayachee et al., 2017) and why actions to combat species invasion is necessary in high traffic urban areas.

Invasive species decrease native biodiversity by significantly altering native ecosystems, modifying habitats, disrupting food web dynamics and changing biogeochemical cycles (Miehls et al., 2009). Invasive species are also known to decrease the frequency and relative dominance of native species, which result in significant impacts to populations, biotic communities, and ecosystem structure and function (Ormsby and Brenton-Rule, 2017). Biologic invasion creates adverse effects on native biota by forcing native species to compete for habitat, food, water, and other resources; this intense competition for resources often results in native species displacement from traditional habitats or their disappearance entirely (Senator and Rozenberg, 2017). In urban areas, where resources are already limited due to habitat loss and fragmentation, invasive species can easily suppress the growth of native plant communities (Simmons et al., 2016) with devastating consequences.

Cities are concentrated centers for anthropogenic activity characterized by high environmental heterogeneity, high transport intensity, and high levels of disturbance – all characteristics that increase ecosystem susceptibility and sensitivity to biological invasion (Padayachee et al., 2017). Continuous invasive species management and intensive conservation planning are critical in urban areas to combat biological invasion and help promote urban biodiversity, especially in isolated urban forests. In most cases, urban forest ecosystems are unable to sustain their own ecological functions without anthropogenic intervention due to high levels of fragmentation, soil degradation, and invasive species (Simmons et al., 2016). Urban forest restoration initiatives must focus on the repeated removal of invasive species to support native plant diversity and structural complexity necessary to improve forest ecosystem health and local biodiversity. The purpose of this paper is to document an invasive species removal within an urban forest near Victoria, BC as part of the University of Victoria's Restoration of Natural Systems Diploma Program requirements.

1.2 Site Description

The study site (Figure 1a) is located on the southern tip of Vancouver Island on unceded Lekwungen Territory of the Esquimalt and Songhees Nations. The site is located within a forested area of Esquimalt Gorge Park (48°26'44.89"N, 123°24'23.39"W), located within the Municipality of Esquimalt in Victoria, British Columbia (Figure 1b). Victoria is located in the Nanaimo Lowlands ecoregion and found within the Coastal

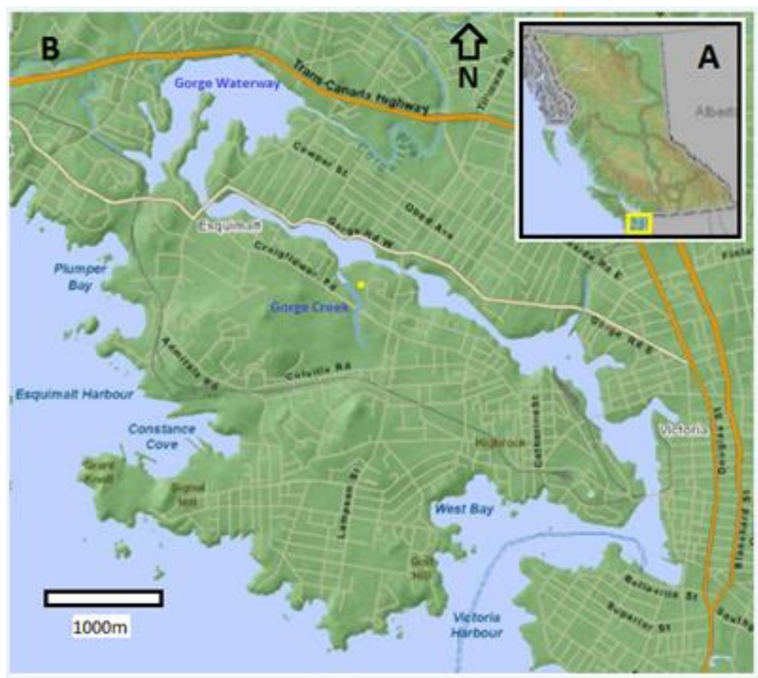

Figure 1: (a) The Municipality of Esquimalt is located on the southern tip of Vancouver Island in coastal British Columbia. (b) The study site – indicate by the yellow dot on the map—is located in Esquimalt Gorge Park, slightly north-west of Downtown Victoria.

Douglas-fir (CDF) Biogeoclimatic Zone - a zone limited to a small portion of southeastern Vancouver Island, several Gulf Islands and a narrow portion of the adjacent mainland and characterized by warm, dry summers and mild, wet winters (Meidinger and Pojar, 1991). Due to the location within the rain shadow of the mountains of Vancouver Island and the Olympic Peninsula this site experiences drier climatic conditions compared to the rest of Vancouver Island and other coastal areas.

Esquimalt Gorge Park, originally established in 1905, is an 11.65-hectare recreational park that features waterfront paths, forested and horticultural areas, a children's playground, and the Gorge Waterway Nature House—sponsored by the World Fisheries Trust and the Gorge Waterway Action Society (Visitor in Victoria, 2016). Southern and outer margins of the park are bordered by residential properties, where the northern section is defined by the Gorge Waterway. The Gorge Waterway is a shallow, narrow tidal estuary extending northwesterly from Victoria's inner harbour to Portage Inlet. The entire waterway is part of a federally designated Migratory Bird Sanctuary, which provides valuable habitats for birds and many other wildlife species. Common species found in the Gorge include harbour seals (*Phoca vitulina*), river otters (*Lontra canadensis*), Pacific herring (*Clupea pallasii*), and the native Olympia oyster (*Ostrea lurida*), as well as spawning populations of Coho (*Oncorhynchus kisutch*) and Chum (*Oncorhynchus keta*) salmon who use the waterway to access Craigflower and Colquitz creeks (CRD, 2018).

The Gorge Waterway was once a popular recreational destination in Victoria, however, a long history of industrial pollution and mismanagement has taken a significant toll on the quality of water in the Gorge. In the 1990s, to combat decades of abuse on the Gorge Waterway, individuals, NGOs, and government began collaborative clean-up initiatives. Since then, the Gorge Waterway has gradually transformed back into one of Victoria's cleanest bodies of water. As an effort to improve water quality further, in the Township of Esquimalt undertook a major restoration project to daylight Gorge Creek, which decades before had been culverted to divert stormwater runoff (Earth Tech Canada Inc., 2002). Since Gorge Creek was daylighted in 2005, the creek now drains over 200 ha - nearly ⅓ of Esquimalt. The creek restoration project was designed to return stream, riparian, native grassland, saltmarsh, and estuarine environments to the area, as well as a means to help treat stormwater runoff (Earth Tech Canada Inc., 2002).

With much of the restoration in Esquimalt Gorge Park focused around Gorge Creek, and its associated ecosystems, this restoration project sought to incorporate the western margin of the forest adjacent to the footpath that separates the forest from the previously restored salt marsh, creek, riparian, and grassland areas. Within this portion of forest there are large quantities of English ivy (*Hedera helix*; Figure 2) and Daphne laurel (*Daphne laureola*; Figure 3), which threaten the health of native vegetation and overall biodiversity of the forest. The purpose of this study was develop a community restoration initiative for the removal of invasive species within the forest. The study goals are to prevent potential invasive species growth expansion into the previously restored areas and to enhance overall ecological health and native species diversity within Esquimalt Gorge Park. Thanks to urbanization, urban forests have continued to

Figure 2: English ivy (*Hedera helix).*

Figure 3: Daphne laurel (*Daphne laureola).*

decrease in size, becoming less common entirely, therefore, it is critical to preserve and restore the urban forests that remain.

2.0 Methods

2.1 Study Site Selection

The approximate study site was first selected based on the presence of large quantities of English ivy (*Hedera helix*) and Daphne laurel (*Daphne laureola*) – both considered invasive species on British Columbia—within close proximity to the previously restored creek and associated ecosystems. The adjacent footpath was selected as the study site baseline and western boundary of the study site. To determine the exact site location in which invasive species were removed from, a biophysical inventory was conducted to identify areas with the greatest concentrations of invasives. A compass and 30-meter tapes were used to measure accurate boundaries around the removal site and then marked with flagging tape on wooden stakes.

2.2 Biophysical Plant Inventory

A biophysical inventory of the entire forest area was conducted to determine species diversity and abundance based on total percent ground coverage of each species. The western site boundary footpath acted as the transect baseline, which spanned 90m along a 336^o trajectory from the southernmost forested area (0m mark at 48°26'43.59"N, 123°24'22.85"W). Using a compass and 30m measuring tape, transects extended 90^o off the baseline at 10m intervals. There were ten transects total, ranging in length from 51m to 78m (**Figure 4);** length variation is due to ununiformed in forest limits.

Figure 4: The forest Biophysical inventory involved ground cover analysis along 10 transects to determine species diversity and abundance. Transects were spaced every 10m along a predetermined baseline.

For the biophysical inventory, an alternating belt transect survey method was used to analyze total percent ground coverage. A 1x1m PVC quadrant frame was placed on the ground at the 0-1m markers adjacent to the right side of the transect line, all species within the quadrant were identified and ground cover abundance was recorded. The 1x1m quadrant was then placed on the opposite side (left) of the transect line at the 1-2m markers and the recording process done again; this pattern of alternate recording occurred for the entire transect length (Figure 5). Each quadrant

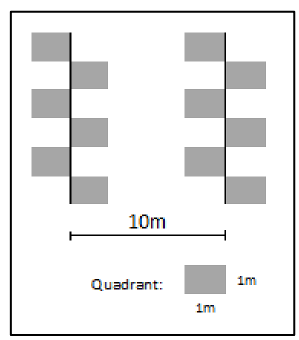

Figure 5: Diagram indicating alternating belt transect survey method used for ground cover analysis.

area totaled 100 percent, therefore, the sum of individual species coverage within a quadrant had to equal 100 percent. For the purpose of this study, soil, decomposing organic matter, and/or coarse woody debris were classified as 'bare ground', where 'grass' represents all grass species observed and classified together.

The following information was recorded for each quadrant: plot number, distance along transect (meters), species observed, and percent ground coverage. Data from each transect was then input into Microsoft Excel. Total sample space was determined by multiplying quadrant area by total number of quadrants per transect (i.e. total sample space = quadrant area x quadrant per transect = 1m^2 x 686 quadrants = 686 m^2).

2.2.1 Transect Data Analyzation

Upon data entry into Excel, total species abundance was calculated per transect by taking the sum of all quadrant ground cover percent for each observed species. This was a relative analysis to determine which species occupy the greatest amount of ground cover over a given transect and in relation to the forested area as a whole. A list of all species observed within the study site was compiled into a table, listed from most abundant to least.

2.3 Community Outreach

A 'Community Restoration Event' was developed in collaboration with the Township of Esquimalt and the Gorge Waterway Action Society (GWAS). Two meetings with Rick Daykin, Esquimalt Manager of Parks and Facilities, occurred in October (2017) and March (2018) to discuss the restoration project. Esquimalt Parks Department donated all the removal equipment needed for the event, including 15 pairs of gloves, 8 hand clippers, 6 hedge sheers, and 3 tarps.

Esquimalt also agreed to dispose of all plant refuse removed from the forest following the event, which took place on Sunday, March 11, 2018. Equipment was returned to Esquimalt Parks Department on March 12.

The Gorge Waterway Action Society (a local not-for-profit dedicated to the preservation and enhancement of the Gorge Waterway) donated the use of the Gorge Waterway Nature House as a meeting place for event volunteers and acted as the event's Social Media advertising platform. Facebook (FB) was the main advertising platform for community outreach and volunteer recruitment. An Event Page was created on FB using the Gorge Waterway Nature House Group Page and initially shared on several related FB Group Pages. These groups included the following: Jobs in Environmental Studies and Ecology @ UVic; Township of Esquimalt; UVic Ecological Restoration Volunteer Network; World Fisheries Trust Volunteer Social Page; Gorge Waterway Nature House; Greater Victoria Green Team; Habitat Acquisition Trust; Restoration of Natural Systems; and Esquimalt Community Connection. See *Appendix A* for volunteer recruitment advertisement. The Community Restoration Event FB Page was posted publically on Tuesday, March 6; posting a short time before the event ensures that it remained fresh in the mind of interested individuals. The Event Page was reposted on Saturday, March 10 – one day before the actual volunteer event as a reminder.

Refreshments were all donated for the event. Fairfield Thrifty Foods donated cups, coffee, cream, juice, and chips, and Marlene Gurney – an event volunteer—donated a variety of cookies. Refreshments were offered before the event commenced and halfway through the event at the Nature House as a means to say thank you and to get to know each other.

2.4 Community Restoration Event - Invasive Species Removal

On March 10, 2018, the treatment site was marked using stakes and flagging tape to ensure volunteers worked within the designated area – determined to have the greatest density of invasive species following the biophysical inventory. A directional sign was placed on the gravel footpath to indicate the treatment site location within the forest. The treatment site was 30 x 12 meters, located along the south-west margins of the forest (Figure 6). Photographs were taken as a visual reference to allow for comparison before and after treatment. As a precautionary measure to ensure the safety of volunteers, removal of large Daphne laurel shrubs occurred at this time. Daphne laurel is a noxious weed that is notorious for causing skin irritation and producing a toxic vapor, therefore, protective clothing was worn to prevent contact during removal. Daphne laurel removal occurred in accordance to the Garry Oak Ecosystem Recovery Team's website publication on *Best Practices for Daphne Management,* excluding the notes on when to take action. All mature and young shrubs removed were cut below the soil line with minimal soil disturbance.

Figure 6: General location of the 360m^2 restoration treatment site.

On March 11, 2018, the actual Community Restoration Event occurred. Volunteers met at 11:00am at the Gorge Waterway Nature House for a brief introduction of the project and review of best practices for removing Daphne laurel and English ivy before heading into the forest to commence the restoration.

Volunteers were given a tour of the treatment site and encouraged to start work in one of two areas with the highest invasive species densities. Necessary equipment (i.e. gloves and clippers) was divided among the volunteers. All invasive species were removed by hand and with the aid of hand clippers to minimize soil disturbance during removal. Volunteers gathered all plant waste on top of tarps; the tarps were later dragged out of the forest and piled on the grass outside the Nature House for Esquimalt Parks Department to pick up following the event.

After one and a half hours of work, volunteers were invited to the Nature House for refreshments. Coffee, tea, and juice were served along with cookies, chips, and apples. During the refreshment break, volunteers were thanked and encouraged to share a little about themselves, including why they decided to come to the Community Restoration Event.

3.0 Results

3.1 Biophysical Plant Inventory

The total sample space analyzed during the flora biophysical inventory was 686m^2. The biophysical inventory concluded that species diversity was a minimum of 41 in the forest ecosystem; thirty-nine distinct plant species and various grass species (at least two) were observed (Table 1). Grass species were largely undistinguishable from each other, and therefore, grouped together for the analysis which could result in a higher species diversity if more grass species were undetected; identified grass species included sweet vernal grass (*Anthoxanthum odoratum*) and orchard grass (*Dactylis glomerata*). There were 16 shrub species (Table 2), 14 herbaceous species (Table 3), seven tree species (Table 4), and two moss species (Table 5) observed along the 10 transects within the forest. Of those species, eight are non-native exotic/invasive species (Table 6). English ivy (*Hedera helix*), grass (various species), trailing blackberry (*Rubus ursinus*) were the overall most abundant species found within the forest; although, trailing blackberry (*Rubus ursinus*), Oregon beaked moss (*Eurhynchium oreganum),* salal (*Gaultheria shallon*)*,* and Douglas-fir (*Pseudotsuga menziesii*) were the most abundant native species observed. See *Appendix B* for detailed ground cover data for each transect.

Table 1: Species observed within the urban forest study site listed from most abundant ground coverage through least abundant. Species observed in densely vegetated areas along transect sections have no ground cover data and are grouped separately. Non-native species are indicated with (***) to highlight their abundance relative to native species.

COMMON NAME	SCIENTIFIC NAME	
grass - various species		
English ivy	*Hedera helix*	***
trailing blackberry	*Rubus ursinus*	
Oregon beaked moss	*Eurhynchium oreganum*	
salal	*Gaultheria shallon*	
common daisy	*Bellis perennis*	***
Himalayan blackberry	*Rubus armeniacus*	
Douglas-fir	*Pseudotsuga menziesii*	
Pacific sanicle	*Sanicula crassicaulis*	
dandelion	*Taraxacum officinale* ssp.	***
electrified cat's-tail moss	*Rhytidiadelphus triquetrus*	
dull Oregon grape	*Mahonia nervosa*	
grand fir	*Abies grandis*	
Daphne laurel	*Daphne laureola*	***
bracken fern	*Pteridium aquilinum*	
snowberry	*Symphoricarpos albus*	
western redcedar	*Thuja plicata*	
white clover	*Trifolium repens*	
oceanspray	*Holodiscus discolor*	
Herb-Robert	*Geranium robertianum*	***
hairy honeysuckle	*Lonicera hispidula*	
soapberry	*Shepherdia canadensis*	
English holly	*Ilex aquifolium*	***
arbutus	*Arbutus menziesii*	
salmonberry	*Rubus spectabilis*	

ribwort plantain	*Plantago lanceolata*	***
unknown herbaceous species		
baldhip rose	*Rosa gymnocarpa*	
bigleaf maple	*Acer macrophyllum*	
western yew	*Taxus brevifolia*	
common laurel	*Prunus laurocerasus*	***
common privet	*Ligustrum vulgare*	***
tall Oregon grape	*Mahonia aquifolium*	
star-flowered false Solomon's-seal	*Maianthemum stellatum*	
Observation - no ground cover data		
black hawthorn	*Crataegus douglasii*	
Garry oak (saplings)	*Quercus garryana*	
Nootka rose	*Rosa nutkana*	
Scouler's willow	*Salix scouleriana*	
Sitka alder	*Alnus viridis* ssp. *sinuata*	
swordfern	*Polystichum munitum*	

Table 2: Shrub species observed within the urban forest study site listed from most abundant ground coverage through least abundant.

salal	*Gaultheria shallon*
dull Oregon grape	*Mahonia nervosa*
Himalayan blackberry	*Rubus armeniacus*
Daphne laurel	*Daphne laureola*
oceanspray	*Holodiscus discolor*
soapberry	*Shepherdia canadensis*
English holly	*Ilex aquifolium*
salmonberry	*Rubus spectabilis*
baldhip rose	*Rosa gymnocarpa*
common laurel	*Prunus laurocerasus*
common privet	*Ligustrum vulgare*
tall Oregon grape	*Mahonia aquifolium*
black hawthorn	*Crataegus douglasii*
Nootka rose	*Rosa nutkana*
Scouler's willow	*Salix scouleriana*
Sitka alder	*Alnus viridis* ssp. *sinuata*

Table 3: Herbaceous species observed within the urban forest study site listed from most abundant ground coverage through least abundant.

English ivy	*Hedera helix*
trailing blackberry	*Rubus ursinus*
common daisy	*Bellis perennis*
Pacific sanicle	*Sanicula crassicaulis*
dandelion	*Taraxacum officinale* ssp.
bracken fern	*Pteridium aquilinum*
snowberry	*Symphoricarpos albus*
white clover	*Trifolium repens*
Herb-Robert	*Geranium robertianum*
hairy honeysuckle	*Lonicera hispidula*
ribwort plantain	*Plantago lanceolata*
unknown herbaceous species	
star-flowered false Solomon's-seal	*Maianthemum stellatum*
swordfern	*Polystichum munitum*

Table 4: Tree species observed within the urban forest study site listed from most abundant ground coverage through least abundant.	
Douglas-fir	*Pseudotsuga menziesii*
grand fir	*Abies grandis*
western redcedar	*Thuja plicata*
arbutus	*Arbutus menziesii*
bigleaf maple	*Acer macrophyllum*
western yew	*Taxus brevifolia*
Garry oak (sapling)	*Quercus garryana*

Table 5: Moss Species observed within the urban forest study site listed from most abundant ground coverage through least abundant.	
Oregon beaked moss	*Eurhynchium oreganum*
electrified cat's-tail moss	*Rhytidiadelphus triquetrus*

Table 6: Non-native exotic/invasive species observed within the urban forest study site.

COMMON NAME	SCIENTIFIC NAME
English ivy	*Hedera helix*
common daisy	*Bellis perennis*
Daphne laurel	*Daphne laureola*
Herb-Robert	*Geranium robertianum*
English holly	*Ilex aquifolium*
ribwort plantain	*Plantago lanceolata*
common laurel	*Prunus laurocerasus*
common privet	*Ligustrum vulgare*

Various species distribution was observed; three species – English ivy (*Hedera helix*), Himalayan blackberry (*Rubus armeniacus*), and grass—were found along all ten transects and two species – Oregon beaked moss (*Eurhynchium oreganum*) and trailing blackberry (*Rubus ursinus*)—were found along nine transects. Species diversity and abundance was greatest along the outer edges of the forest. English ivy (*Hedera helix*) occurred at highest densities along forest edges and interior patches with increased sunlight exposure; most often observed by downed trees and open canopy. Species diversity and abundance were lowest underneath the four largest Douglas-fir (*Pseudotsuga menziesii)* trees located on the upper slope near the northern study site margins, where several narrow footpaths converge. Vegetation growth was minimal along several narrow footpaths throughout the forest, most often resulting in patches of bare ground. Coarse woody debris (CWD) was prominent throughout the forest floor, however, this study focused on vegetation ground coverage so quantification of CWD did not occur at this time.

3.2 Community Restoration Event - Volunteers

Eleven volunteers, ranging in age from four to 60, attended the Community Restoration Event. Of the 11 volunteers, eight had confirmed attendance online via the Facebook Event Page, four said this was their first restoration related event, three had volunteered with GWAS before, and one had never been to Esquimalt Gorge Park prior to this event. Two interested park-goers saw the event sign on the footpath and came into the forest to inquire as to other potential restoration related activities within the park at a future date.

3.2 Community Restoration Event - Invasive Species Removal

To begin, volunteers targeted two main areas identified during the biophysical inventory to have the highest invasive species densities and then branched out from there to other sections within the flagged treatment site. Most commonly removed species were Daphne laurel (*Daphne laureola* L.), English ivy (*Hedera helix*), English holly (*Ilex aquifolium*), and Himalayan blackberry (*Rubus armeniacus*). Volunteers removed several large tarp loads of invasive plant waste from the forest treatment site and consolidated the waste outside the forest next to the Nature House (Figure 7); this allowed for easy offsite removal by Esquimalt Parks

Figure 7: Pile of invasive species plant waste removed from the forest.

Department. Following the event, visible differences across the entire treatment site were observed and photographed (Figure 8, 9, 10, and 11).

Figure 8: Study site section before (A) and after (B) treatment.

Figure 9: Study site section before (A) and after (B) treatment.

Figure 10: Study site section before (A) and after (B) treatment.

Figure 11: Study site section before (A) and after (B) treatment.

4.0 Discussion

Invasive species, particularly English ivy (*Hedera helix*), are the biggest threat to native biodiversity within the study site. Though English ivy seems to concentrate in more open canopy areas of the outer 25m of the forest, it was prolific throughout the entire forest ecosystem. Over the last century, English ivy has naturalized in many parts of the world, including the many forests in North America (Biggerstaff and Beck, 2007; Clark et al., 2006). English ivy's widespread establishment has many potential impacts on natural areas and native species diversity, particularly in urban parks and forests (Dlugosch, 2005). English ivy aggressively spreads to form continuous cover that can exclude native species and significantly change understory composition and structure over time (Dlugosch, 2005). English ivy's dense ground cover drastically reduces understory light availability and prevents germination or growth of most native plant species (Biggerstaff and Beck, 2007; Clark et al., 2006; Dlugosch, 2005). Invasion of English ivy into forest ecosystems is facilitated by its rapid growth, climbing and spreading abilities, root-sprouting capability, and excellent shade tolerance (Biggerstaff and Beck, 2007). English ivy's ability to climb trees for light and nutrients increases its competitive advantage in forest ecosystems (Clark et al., 2006). Rapid growth and widespread dispersal make English ivy extremely successful suppressing local plant community diversity, as observed during this study's biophysical inventory. Areas with dense ivy cover had overall less species diversity, although trailing blackberry (*Rubus ursinus)* was the most commonly observed species growing with English ivy; the vine-like species often grew intertwine with each other. Removal of English ivy from the treatment site will hopefully facilitate regrowth of trailing blackberry and other native plants in the area.

Although not as abundant within the study site as English ivy, removal of Daphne laurel (*Daphne laureola* L.) occurred with equal vigor. Since Daphne laurel is considered a noxious weed with irritant sap found in its leaves and bark, additional care was taken during removal. Daphne laurel has rapidly naturalized throughout the Pacific Northwest, becoming a dominant understory shrub (Lei, 2014). Invasion of Daphne laurel into forest ecosystems is facilitated by its ability to form dense thickets, high reproductive fitness, and proficiency at re-sprouting from the root base after shoot removal (Lei, 2014); these attributes have proven to be a challenge for eradication programs. Species invasion is attributed to several factors, most often related to resource availability, competition, predation, and disease (Senator and Rozenberg, 2017), however, competitive interactions between Daphne laurel and native shrub cover appear inherently weak, suggesting that Daphne laurel establish in vacant niches where Mediterranean climatic conditions are present (Lei, 2014). Though competitive interactions between Daphne laurel and native shrub cover appears weak, the species growth attributes will likely preclude growth of other native species. Due to its potential detrimental effects on native flora, Daphne laurel was removed from the treatment site to ensure the study objective to remove all invasive species was achieved. Removal of Daphne laurel also helped to restrict future dispersal by frugivorous bird species (Lei, 2014) and limit alterations to soil chemistry (Dennehy et al., 2011).

Hindering dispersal of invasive species is another critical restoration strategy to prevent further ecological destruction in urban environments. Pathways that facilitate the introduction and spread of invasive species in cities must be identified and prioritized for an effective response to biological invasion (Padayachee et al., 2017). For example, Clark et al. (2006) identify the use of English ivy in the nursery and landscape industries is a significant challenge to combat species invasion since it would be extremely difficult to suppress trade of ivies, however, further invasion must be prevented to maintain ecological integrity of native forests. With English ivy being the most pervasive invader of urban and suburban forests of the Pacific Northwest (Clark et al., 2006), it is essential for urban biodiversity conservation and restoration programs to help minimize invasive dispersals to more rural, isolated, and/or environmentally sensitive areas.

As invasion rates escalate, it is critical that ecosystem responses to invasion are understood to help prevent further spread (Miehls et al., 2009). A rational approach is critical for effective invasive species control, which accounts for "individual ecological-biological features of the species, their relations with other components of the community, the properties of the ecosystem invaded by them, expenditures for their control, and the period and consequences of their eradication" (Senator and Rozenberg, 2017, pp. 273). Invasive control programs must go beyond simplistic goals of just the removal of problematic species to ensure restoration of an entire vibrant functioning native community occurs (Dennehy et al., 2011).

Today, exotic species invasion constitutes one of the greatest global threats to native biodiversity, secondary to habitat loss (Biggerstaff and Beck, 2007; Ormsby and Brenton-Rule, 2017), therefore, invasive species removal initiatives are critical to combat the ongoing threat of species invasion in all environments, especially urban environments. Globalization is closely associated with the introduction of invasive species through travel, tourism, trade, and transport (Ormsby and Brenton-Rule, 2017), yet due to the ever-increasing connectivity of geographically isolated areas, these vectors are expected to significantly increase species introduction to urban areas in the future. Escalated invasion rates will force higher-level understanding of ecosystem responses to and impacts from invasive species to predict—and prevent—future spread and associated consequences (Miehls et al., 2009). Mitigation of urbanization's negative environmental effects will be an ongoing process (Sheikh Goodarzi et al., 2017). However, a more ecologically informed public may be an important catalyst to promote effective conservation of urban biodiversity (McKinney, 2002). Improved understanding of the issues surrounding invasive species and mitigation efforts may even encourage action in the average individual. This study showed the importance of community restoration initiatives to support urban biodiversity conservation and provided foundational information on how individuals can take collaborative action to combat a global issue from within their community.

4.2 Recommendations

Land managers are constantly challenged to develop prioritized and aggressive treatment strategies with limited budgets and resources that can respond rapidly to new invasions and minimize impacts on native flora and fauna communities (Dennehy et al., 2011). As so, a comprehensive restoration plan is critical to restoring natural areas to ensure long-term success of the restoration efforts. Invasive species management strategies work best when several different methods are utilized, such as removal treatment followed by direct seeding and planting of native plants, since invasive plants will likely reestablish after a treatment unless native plants are seeded and planted (Dennehy et al., 2011). Unfortunately, due to funding limitations for this study, native plant species were not seeded or planted following invasive species removal at this time. It is recommended that native plants be seeded and planted within the treatment site and repeated treatments occur to minimize potential invasive species regrowth. Revegetation and reseeding with native plant species, as well as repeated treatments, are all viable options moving forward with the continued support of the Township of Esquimalt and the Gorge Waterway Action Society (GWAS). With Canada Summer Jobs funding, GWAS is able to hire a student for their *Ecological Restoration Technician* position, whose work-term will hopefully focus on monitoring the forest study site and re-treating the site if necessary; guided by GWAS Board Members, including myself. Potential additional funding may be integrated into long-term monitoring and revegetation strategies for the study site, however, monitoring and re-treatment are currently only proposed for May through August, 2018.

5. Conclusion

Urban sprawl most often results in vast consumption of natural areas and land resources, which leads to extensive modification of ecosystem function, ecosystem services, and habitat fragmentation (Sheikh Goodarzi et al., 2017). Urbanization is irreversible (Yu et al., 2012), although, with the right management practices, urban biodiversity can be preserved and promoted for its important role in mitigating global biodiversity loss (Simmons et al., 2016). Globally, anthropogenic changes are rapidly shaping the natural environment. Native habitat alteration, decreased connectivity of remnant native habitats, and introduction of invasive species continue to threaten native biodiversity worldwide, generating the dire need for community-based conservation efforts. Invasive species management is complex and it will take collaborative environmental stewardship initiatives within cities to combat the detrimental effects of this species invasion and maintain urban biodiversity into the future.

6. Acknowledgments

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APPENDIX A – Community Restoration Event Volunteer Recruitment Advertisement

Volunteers Wanted: Join the Gorge Waterway Action Society for a Community Restoration Event in Esquimalt Gorge Park!

In collaboration with the Township of Esquimalt and the University of Victoria's Restoration of Natural Systems Program, the Gorge Waterway Action Society will be hosting a community event to remove invasive species in the forest behind the Gorge Waterway Nature House, nearest the footpath that intersects the forest from the previously restored grassland/creek ecosystems. The event will be held this coming weekend on Sunday, March 11th and focus on the removal of English ivy and Daphne laurel.

No volunteer experience necessary! All park-goers and nature enthusiasts are encouraged to participate! Work gloves and tools provided!

Refreshments will be shared at the Nature House after 1.5hrs of work!

Date: Sunday, March 11th, 2018.

Time: 11:00am to 3:00pm (Stay for a little bit or the whole time!)

Location: Meet at the Gorge Waterway Nature House at 11:00am for volunteer sign-in and introductions. (The Nature House is located in Esquimalt Gorge Park, beyond the parking lot to the left, and near the children's playground.)

Background Information:

The Gorge Waterway Action Society (GWAS) is a registered not-for-profit charity founded in Victoria, BC whose mission is dedicated to the preservation and enhancement of the Gorge Waterway. GWAS's vision is a Waterway that is a place of beauty for human habitation and recreation, and a safe and healthy place for animals and plants that make it their home. They facilitate education programs, organize and attend restoration events, and operate the Gorge Waterway Nature House - a public education space in Gorge Park. The Nature House operates in partnership with World Fisheries Trust and the Township of Esquimalt.

This Community Restoration Event has been developed as part of the University of Victoria's School of Continuing Studies Restoration of Natural Systems Diploma Program's capstone project requirements for Stephanie Gurney, who is a member of GWAS Board of Directors.

Web link to Facebook Event Page:
https://www.facebook.com/events/1415095528595987??ti=ia

APPENDIX B – Detailed Ground Cover Data for Each Transect

Species Abundance - Transect 1 (66m) 6 quadrants within forest ecosystem	
unknown grasses	320
English ivy (Hedera helix)	120
Herb-Robert (Geranium robertianum)	65
trailing blackberry (Rubus ursinus)	45
Himalayan blackberry (Rubus armeniacus)	10

Species Abundance - Transect 2 (71m)	
bare ground	3011
salal (Gaultheria shallon)	380
English ivy (Hedera helix)	340
trailing blackberry (Rubus ursinus)	335
unknown grasses	257
bracken fern (Pteridium aquilinum)	190
Oregon beaked moss (Eurhynchium oreganum)	170
snowberry (Symphoricarpos albus)	147
Himalayan blackberry (Rubus armeniacus)	85
grand fir (Abies grandis)	52
Douglas-fir (Pseudotsuga menziesii)	50
dandelion (Taraxacum officinale ssp.)	43
western redcedar (Thuja plicata)	35
Daphne laurel (Daphne laureola)	27
English holly (Ilex aquifolium)	15
common daisy (Bellis perennis)	7
soapberry (Shepherdia canadensis)	5
star-flowered false Solomon's-seal (Maianthemum stellatum)	5
tall Oregon grape (Mahonia aquifolium)	5

Species Abundance - Transect 3 (73m)	
bare ground	1943
trailing blackberry (Rubus ursinus)	745
Oregon beaked moss (Eurhynchium oreganum)	700
unknown grasses	665
salal (Gaultheria shallon)	390
English ivy (Hedera helix)	347
Himalayan blackberry (Rubus armeniacus)	98
dandelion (Taraxacum officinale ssp.)	72
grand fir (Abies grandis)	65
Douglas-fir (Pseudotsuga menziesii)	45
Daphne laurel (Daphne laureola)	44

snowberry (Symphoricarpos albus)	30
Pacific sanicle (Sanicula crassicaulis	22
soapberry (Shepherdia canadensis)	20
oceanspray (Holodiscus discolor)	10
English holly (Ilex aquifolium)	7
bracken fern (Pteridium aquilinum)	3
Nootka rose (Rosa nutkana)	obs
black hawthorn (Crataegus douglasii)	obs
arbutus (Arbutus menziesii)	obs
dull Oregon grape (Mahonia nervosa)	obs
Sitka alder (Alnus viridis ssp. sinuata)	obs
western redcedar (Thuja plicata)	obs
western yew (Taxus brevifolia)	obs

Species Abundance - Transect 4 (78m)	
bare ground	2604
English ivy (Hedera helix)	852
trailing blackberry (Rubus ursinus)	704
unknown grasses	516
dull Oregon grape (Mahonia nervosa)	145
Oregon beaked moss (Eurhynchium oreganum)	135
salal (Gaultheria shallon)	95
Daphne laurel (Daphne laureola)	92
Douglas-fir (Pseudotsuga menziesii)	60
bigleaf maple (Acer macrophyllum)	45
grand fir (Abies grandis)	35
common daisy (Bellis perennis)	25
western yew (Taxus brevifolia)	20
snowberry (Symphoricarpos albus)	18
western redcedar (Thuja plicata)	15
arbutus (Arbutus menziesii)	10
dandelion (Taraxacum officinale ssp.)	10
oceanspray (Holodiscus discolor)	10
ribwort plantain (Plantago lanceolata)	5
Himalayan blackberry (Rubus armeniacus)	2
Pacific sanicle (Sanicula crassicaulis) (Tiarella trifoliata)	2
Nootka rose (Rosa nutkana)	obs

Species Abundance - Transect 5 (74m)	
bare ground	2300
English ivy (Hedera helix)	785
trailing blackberry (Rubus ursinus)	680
unknown grasses	420

salal (Gaultheria shallon)	365
Oregon beaked moss (Eurhynchium oreganum)	205
Douglas-fir (Pseudotsuga menziesii)	105
dull Oregon grape (Mahonia nervosa)	105
Daphne laurel (Daphne laureola)	74
dandelion (Taraxacum officinale ssp.)	71
grand fir (Abies grandis)	50
common daisy (Bellis perennis)	48
Pacific sanicle (Sanicula crassicaulis)	37
snowberry (Symphoricarpos albus)	35
Himalayan blackberry (Rubus armeniacus)	30
western redcedar (Thuja plicata)	25
English holly (Ilex aquifolium)	18
arbutus (Arbutus menziesii)	17
oceanspray (Holodiscus discolor)	15
salmonberry (Rubus spectabilis)	10
Sitka alder (Alnus viridis ssp. sinuata)	obs

Species Abundance - Transect 6 (71m)	
bare ground	1615
unknown grasses	736
English ivy (Hedera helix)	565
bracken fern (Pteridium aquilinum)	183
grand fir (Abies grandis)	170
Oregon beaked moss (Eurhynchium oreganum)	160
dull Oregon grape (Mahonia nervosa)	158
trailing blackberry (Rubus ursinus)	145
common daisy (Bellis perennis)	142
salal (Gaultheria shallon)	140
Pacific sanicle (Sanicula crassicaulis)	103
Daphne laurel (Daphne laureola)	46
dandelion (Taraxacum officinale ssp.)	40
hairy honeysuckle (Lonicera hispidula)	25
unknown herbaceous species	25
Douglas-fir (Pseudotsuga menziesii)	15
English holly (Ilex aquifolium)	10
snowberry (Symphoricarpos albus)	5
tall Oregon grape (Mahonia aquifolium)	5
white clover (Trifolium repens)	5
Himalayan blackberry (Rubus armeniacus)	2
western redcedar (Thuja plicata)	obs
common privet (Ligustrum vulgare)	obs
soapberry (Shepherdia canadensis)	obs

Species Abundance - Transect 7 (78m)	
unknown grasses	2041
bare ground	1321
Oregon beaked moss (Eurhynchium oreganum)	768
trailing blackberry (Rubus ursinus)	758
English ivy (Hedera helix)	373
common daisy (Bellis perennis)	359
Pacific sanicle (Sanicula crassicaulis)	222
Douglas-fir (Pseudotsuga menziesii)	170
dandelion (Taraxacum officinale ssp.)	160
white clover (Trifolium repens)	108
electrified cat's-tail moss (Rhytidiadelphus triquetrus)	85
western redcedar (Thuja plicata)	35
Herb-Robert (Geranium robertianum)-Robert	32
Daphne laurel (Daphne laureola)	31
grand fir (Abies grandis)	30
ribwort plantain (Plantago lanceolata)wort plantain	30
hairy honeysuckle (Lonicera hispidula)	15
arbutus (Arbutus menziesii)	10
salmonberry (Rubus spectabilis)	10
Himalayan blackberry (Rubus armeniacus)	9
oceanspray (Holodiscus discolor)	3

Species Abundance - Transect 8 (61m)	
English ivy (Hedera helix)	1481
unknown grasses	1364
bare ground	881
Oregon beaked moss (Eurhynchium oreganum)	630
trailing blackberry (Rubus ursinus)	476
electrified cat's-tail moss (Rhytidiadelphus triquetrus)	290
Pacific sanicle (Sanicula crassicaulis)	111
Himalayan blackberry (Rubus armeniacus)	95
dandelion (Taraxacum officinale ssp.)	92
Douglas-fir (Pseudotsuga menziesii)	75
oceanspray (Holodiscus discolor)	70
Daphne laurel (Daphne laureola)	52
common daisy (Bellis perennis)	42
salmonberry (Rubus spectabilis)	37
baldhip rose (Rosa gymnocarpa)	25
hairy honeysuckle (Lonicera hispidula)	25
soapberry (Shepherdia canadensis)	25
western redcedar (Thuja plicata)	25
arbutus (Arbutus menziesii)	20

common privet (Ligustrum vulgare)	15
snowberry (Symphoricarpos albus)	15
common laurel (Prunus laurocerasus)	10
English holly (Ilex aquifolium)	10
unknown herbaceous species	10
white clover (Trifolium repens)	10
grand fir (Abies grandis)	5
ribwort plantain (Plantago lanceolata)	2

Species Abundance - Transect 9 (63m)	
English ivy (Hedera helix)	1340
bare ground	867
unknown grasses	605
trailing blackberry (Rubus ursinus)	588
Oregon beaked moss (Eurhynchium oreganum)	285
Himalayan blackberry (Rubus armeniacus)	232
electrified cat's-tail moss (Rhytidiadelphus triquetrus)	155
Douglas-fir (Pseudotsuga menziesii)	65
arbutus (Arbutus menziesii)	30
dandelion (Taraxacum officinale ssp.) (Taraxacum officinale ssp.)	17
common daisy (Bellis perennis)	15
Daphne laurel (Daphne laureola)	15
Pacific sanicle (Sanicula crassicaulis)	15
soapberry (Shepherdia canadensis)	15
salal (Gaultheria shallon)	10
western redcedar (Thuja plicata)	10
common laurel (Prunus laurocerasus)	6
common privet (Ligustrum vulgare)	obs
English holly (Ilex aquifolium)	obs
Garry oak sapling (Quercus garryana)	obs
grand fir (Abies grandis)	obs
Scouler's willow (Salix scouleriana)	obs
swordfern (Polystichum munitum)	obs
snowberry (Symphoricarpos albus)	obs

Species Abundance - Transect 10 (51m) 7 quadrants within forest ecosystem	
bare ground	430
unknown grasses	215
Himalayan blackberry (Rubus armeniacus)	30
Oregon beaked moss (Eurhynchium oreganum)	20
English ivy (Hedera helix)	5