Letter of Transmittal

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April 22, 2020

RE: Invasive Plant Species Survey and Mapping in District of North Vancouver Parkland: Final Report

Dear Julia Alards-Tomalin,

The following document contains our final project report submission as part of the FNAM 4231, Technical Projects course requirements. Our project developed and piloted a user-friendly invasive species surveying protocol for the District of North Vancouver's managed parkland.

This project was conducted within three urban parks in the District of North Vancouver. In this report, we detail how we designed a methodology for mapping of invasive species. Using available GIS .shp files from the DNV Geoweb database; we created buffers around trails and streams where we executed our surveys. This report also describes the data dictionary we developed for use with TerraSync. Our results confirmed that natural areas more heavily managed showed less occurrence and density of invasive plant species.

We would like to thank you for your guidance, helpful insights, and hard work in ensuring the success of our project. To Hélène Marcoux, we thank you for your endless support throughout the project. We would also like to thank Matthew Branford and Jocelyn Herbert for providing details on the City of Surrey's invasive mapping protocol. Lastly, thank you to Jace Standish for suggestions on conducting a statistical study design.

Sincerely,

Aaron, Larissa, Morgan, and Aida

INVASIVE PLANT SPECIES SURVEY AND MAPPING IN DISTRICT OF NORTH VANCOUVER PARKLAND

FNAM4231- TECHNICAL PROJECTS
APRIL 22, 2020

AARON FROC, LARISSA LAU,
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Executive Summary

Urbanization is accelerating the introduction rate of invasive plant species within native ecosystems. Once established, invasive species disperse rapidly and cause negative economic, social, and ecological impacts. Among municipalities throughout British Columbia's lower mainland there is a common understanding that invasive management plans can help preserve native ecosystems, but they unfortunately lack the necessary tools to effectively monitor invasive presence and movement. As required by the *Weed Control Act*, the District of North Vancouver (DNV) currently manages noxious invasive plants such as giant hogweed (*Heracleum mantegazzianum)* and knotweed species (*Reynoutria* spp.). They now strive to improve their stewardship by expanding their invasive plant management program to include a wider range of species.

We developed and piloted a user-friendly invasive surveying protocol for the DNV to implement as part of a comprehensive management plan for all district-managed parkland. Following the professional insight of the DNVs Trail and Habitat Coordinator three parks were selected to trial our methodology: Harbourview (2.4ha), Princess (16.7ha), and Murdo Frazer (17.7ha). Harbourview is a single trail nestled in an industrial area along the mouth of Lynn Creek, while Princess and Murdo Frazer are forested parks with complex trail networks bordered by residential areas. All three parks have had some level of restoration work completed, but records of invasive species occurrence and extent are limited.

Consultation with the City of Surrey Natural Areas Management team and reviewing literature guided the design of our methodology. We produced base maps for each park using the DNV GEOWeb database and identified areas of interest areas to develop survey plans. Buffer areas for surveying were applied based on park features; a 10m buffer surrounding trails and 15m buffer from stream highwater marks. The first phase included field walkthroughs and highlighted the need to extend survey areas. The extensions eliminated "islands" between buffers and better captured invasive presence along park boundaries and unmapped watercourses. To support invasive occurrence surveying we developed a data dictionary to collect invasive attribute data.

A summary of the secondary phase, invasive-survey data is as follows:

- A total of 9.61ha of parkland was surveyed
    - 100% of Harbourview Park, 36.35% of Princess, and 12.15% of Murdo Frazer

- 1050 invasive occurrence points were logged within the surveyed area
- 75% of invasive occurrences fell into three invasive categories:
  - Ivy spp. (primarily *Hedera helix)*
  - English holly (*Ilex aquifolium)*
  - Laurel group (*Prunus laurocerasus, Prunus lusitanica and Daphne laureola)*
- Top three invasive categories by area covered:
  - 2.75ha, Ivy spp. (primarily *Hedera helix*)
  - 1.59ha, Blackberry spp. (*Rubus armeniacus, Rubus laciniatus),*
  - 1.31ha, English holly (*Ilex aquifolium)*

Generally, the occurrence and coverage of invasive infestations was greatest along park boundaries and the hydro right-of-ways. Such connections show the value in developing educational programs that inform residents on the potential damage of dumping yard and garden waste in parks and can encourage planting native species to reduce invasive encroachment from private property. Additionally, there's value in building positive working relationships with land management partners such as BC Hydro to coordinate invasive management responsibilities.

One encouraging observation is the reduction of invasive occurrence and density within previously treated portions of the parks. This shows the benefit of ongoing restoration projects as part of a long-term vision for invasive treatment. It is important to acknowledge that land managers such as the DNV must consider financial resources and broader management priorities when implementing invasive management systems. However, the versatile application of our methodology in priority areas will produce useable data without exhausting resources.

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1. Introduction

1.1 Invasive species

The term “invasive species” is used to describe any introduced organism that results in economic, public health, and environmental damages to the habitat it invades (ISCBC, 2019). These invasions are occurring globally and are increasing with the rate of urbanization (Hejda et al., 2009). It is widely recognized that this worldwide spread of invasive plant species has significantly altered the ecological properties across multiple scales, ranging from small plant communities to entire landscape ecosystems. Changes to the structural and species composition of ecosystems caused by invasive plants are long-lasting. The spread of these introduced species alters the plant and wildlife community, soil properties and even the physical landscape of the habitat (Corbin and D’Antonio, 2012). In addition to considering the ecological consequences to the native habitat, it is important to consider the economic cost associated with invasive species management (Corbin and D’Antonio, 2012).

The economic impact of invasive plants in Canada spans a multitude of sectors including agriculture, forestry, recreation, and public administration (CFIA, 2008). In BC alone, it’s estimated that the damages incurred from 6 invasive plants totaled more than $65 million in 2008 and this was projected to increase to $139 million by 2020 (Frid et al., 2009). Unfortunately, it is difficult to completely measure the economic impacts connected to invasive plants. There are associated non-financial costs such as volunteer time and it is difficult to quantify indirect economic losses associated with ecosystem services, biodiversity loss, and soil degradation (Vyn, 2019). Strategies for restoration of invaded natural areas and the management of invasive plant species must include: 1) monitoring entry points to reduce spread, 2) identifying existing invasive infestations and 3) prioritizing strategies for control and eradication (Sheley and Smith, 2012). Invasive species management remains a growing concern as globalization increases the pathways for introduction and economic budgets limit the management capacity.

1.2 Strategizing invasive management in urban areas

Considering the detrimental impacts that invasive species pose, it is important that communities develop effective and comprehensive management plans to combat these invasions. It is recognised that eradication is the most effective and cost efficient when infestations are newly established (Jones, 2010). There is a general trend, as introduced species establish and spread over time, the management cost increases and treatment effectiveness decreases [Figure 1] (Sheley and Smith, 2012). Logically, management strategies should prioritize management protocols that limit the spread of existing populations, allow rapid detection of new infestations, and establish efficient eradication procedures.

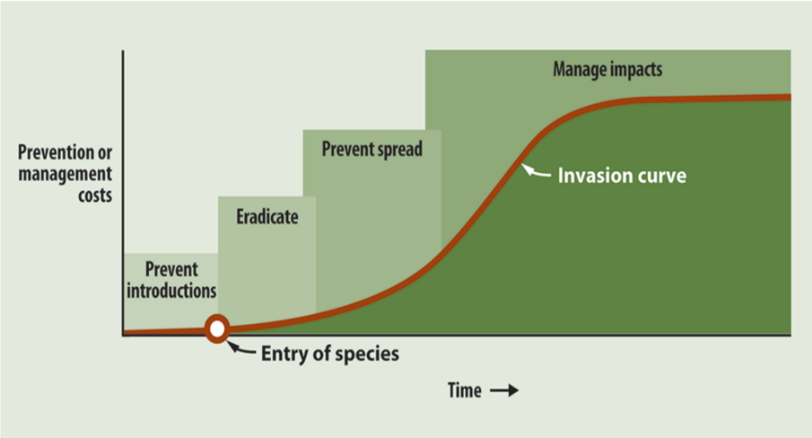


Figure 1. This graph represents the invasion curve in relation to prevention and management costs. It shows how prevention or management costs increase with the invasive species spread in an area. Image source: Office of the Auditor General of Canada (2018)

With over 3000 hectares (ha) of managed parkland, the District of North Vancouver (DNV) requires an efficient survey methodology to understand invasive distribution and abundance in priority areas. Within our study area, the DNV has prioritized the monitoring of trails and riparian areas. Anthropogenic edges such as roadways, trails, and park boundaries, are common urban areas with a high density of invasive plants. Urbanization and industrial development create heavily disturbed areas that act as vectors or pathways for the introduction of invasive plants (Fortuna-Antoszkiewicz et al., 2018). A study in urban parks by LaPaix et al. (2012) found that some invasive species have the potential to spread as far as 50 meters (m) from the park boundary and 3m from trail edges. Monitoring riparian areas is also essential since they are sensitive to degradation and are at a high risk of invasion (Foxcroft et al., 2007). It is crucial to manage upstream areas that are connected to important conservation regions to prevent them from acting as a method of dispersal (Foxcroft et al., 2007).

High priority areas require a thorough sampling method that produces precise spatially referenced locations of invasive species occurrence. An ideal survey method detects and monitors existing populations while recording various species and site attributes. Using this information, areas that are highly impacted by invasive plants and areas that are susceptible to infestations can be identified.

Many organizations, including the DNV, manage large spatial areas but have a limited capacity to complete a full inventory of invasive plant distributions (Backus et al., 2011). Complicating this further, methods that allow for quick detection may not be useful in tracking population dynamics and vegetative associations (Huebner, 2007). Additionally, methods that evaluate species' relative importance and vegetative patterns are exceptionally costly and time consuming (Huebner, 2007). For these reasons, a practical invasive management plan should implement a two-phase surveying approach. This approach employs an initial low-intensity survey method that provides general locations of existing invasive plant populations, an example of this can be a walkthrough of the study area, building on local knowledge of invasive occurrence (Sheley and Smith, 2012). The second phase applies more rigorous methods for identifying outbreaks and mapping based on priority levels. We applied this methodology in conjunction with a protocol adapted from the City of Surrey (COS), as outlined in Appendix A: City of Surrey Managed Park Inspections

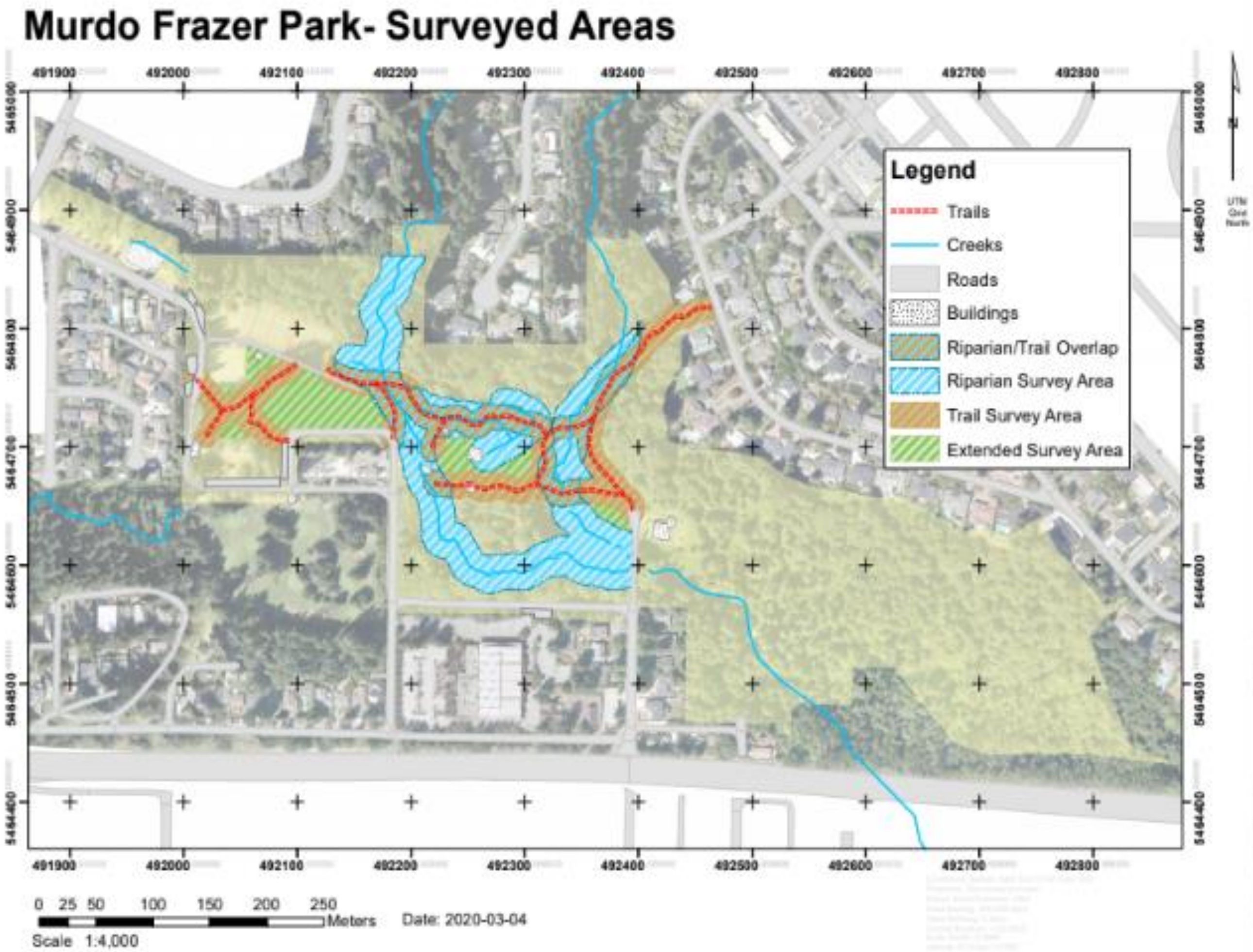
FacilityID	1001919394
Common_Name	English Ivy
Scientific_Name	Hedera helix
Inventory_Year	2018
Location	Redwood Park

Site_Number	5025
Invasive_Area	1
Riparian	No
Encroachment	No
Comments	Along trail
Treatment_History	2015,2016
Initial_Inventory	2015
Initial_Area	2

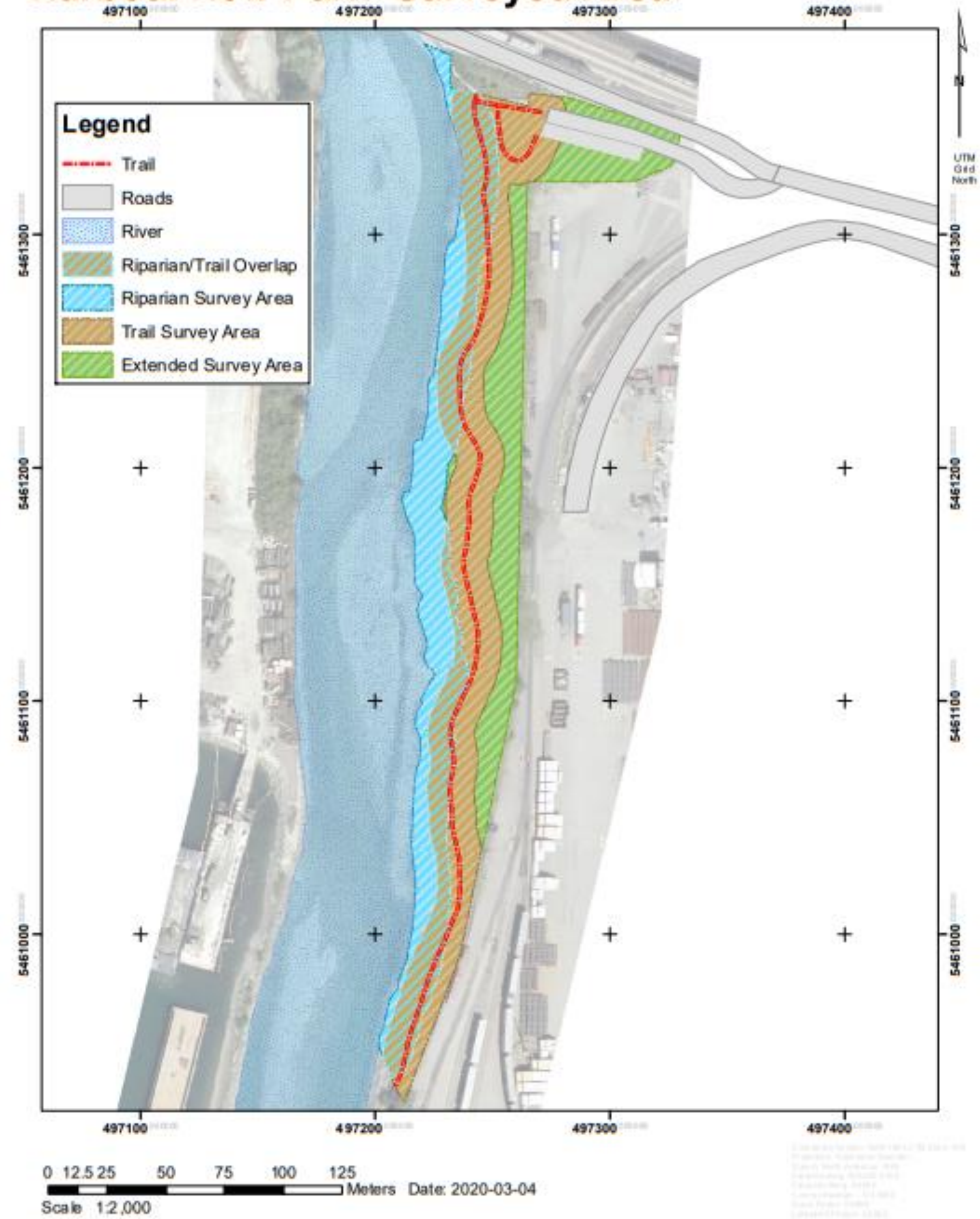
The COS with over 2700ha of parkland, has established an annual inspection program to monitor invasive species levels within parks based on their ecological priority. Through communication with COS employees Matthew Banford, Lead Invasive Management Technician, and Jocelyn Herbert, Natural Areas Practitioner, we learned their survey and mapping methods. In order to maximize efficiency, inventories are conducted every 3 years in high priority parks and on a demand basis for low priority parks. These inspections typically occur in late winter/early spring and may involve supplementary inspections to better capture plants with a short growing window. A walk-through method is used to inspect all border perimeters, sanctioned and unsanctioned trails, waterways, forest-meadow interfaces and transects through meadows. During the survey, a thorough examination of herbaceous remnants and yard waste is also conducted as these can be a source of new introductions of invasive species.

A Trimble JUNO GPS device is used to collect pertinent information at new and existing site. The table pictured is an example of an attribute table from the COS survey method, outlining several defining characteristics. Area of infestation is recorded as an estimation of coverage with $1m^2$ being the minimum value. For the purpose of these inspections, the COS requires an estimation of coverage rather than precise values. In addition to species and coverage data, the COS includes a comment section for inspectors to describe the locale. This comment section helps indicate the location of the investigation sites to technicians that may not have a GPS. If a technician returns to an existing infestation site and the infestation is not found, they record: CNL (Could Not be Located) and the year. Invasive plant mapping is done using points with area estimates and options for comments on dispersal characteristics.

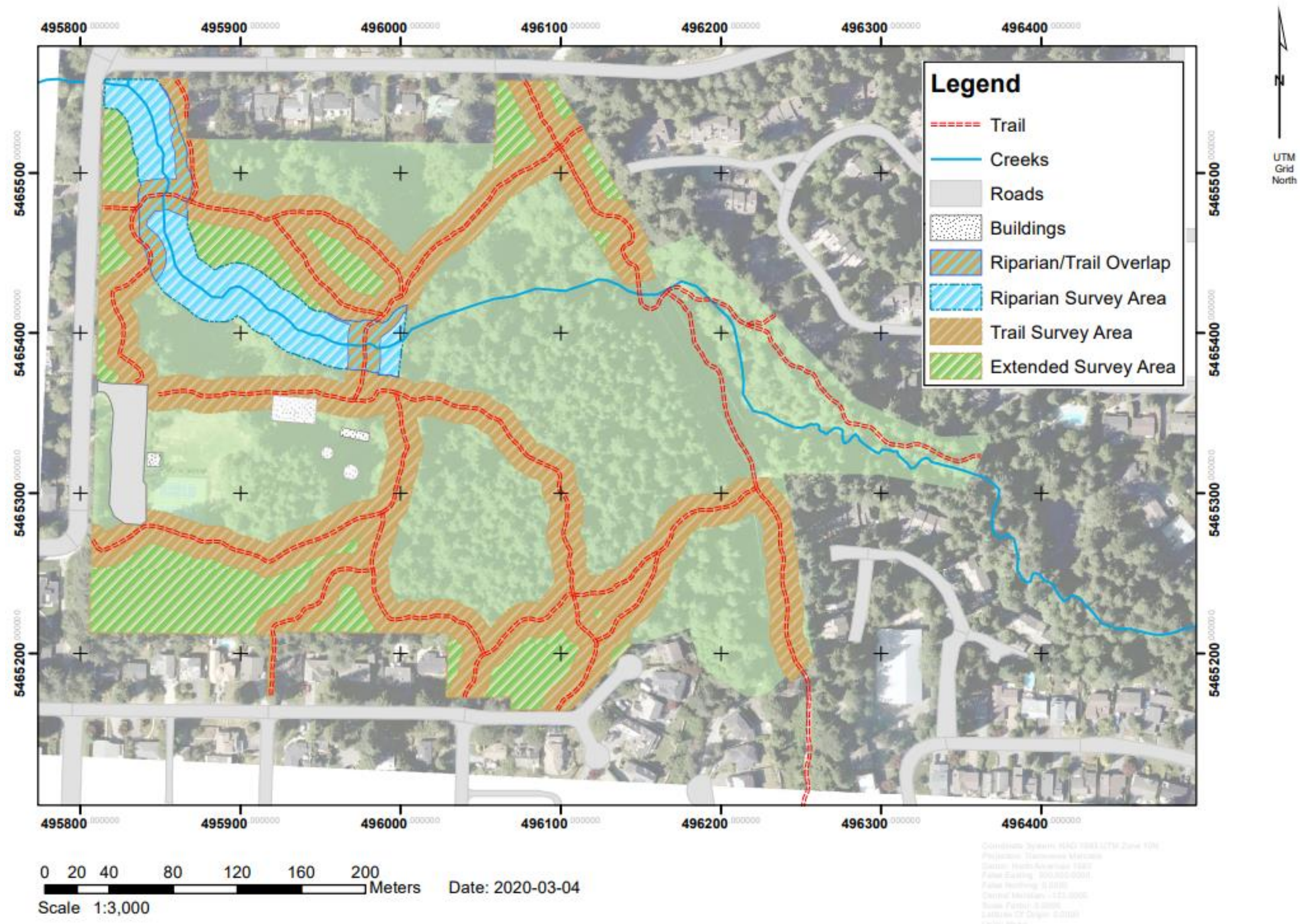
Appendix B: Surveyed Areas of Study Area Parks



Harbourview Park- Surveyed Area



Princess Park- Surveyed Area



. As trails and riparian areas have been identified as likely sites of invasive establishment, we applied a buffer to these areas and conducted a full survey using the adapted Surrey Model.

2. Goal and Objectives

Our goal was to develop and pilot a user-friendly invasive plant species surveying protocol to be used as a part of a comprehensive management system for all parks within the District of North Vancouver. To achieve this, we established the following objectives:

1. Generate maps for Harbourview (2.4ha), Princess (16.7ha) and Murdo Frazer (17.7ha) parks that stratify high priority invasive species management areas based on proximity to edge features, i.e. riparian, trail and boundary, prior to initiating vegetation surveys.
2. Propose a set of guidelines for surveying protocols with varying intensity levels to be piloted in spring and adapted for future use by the District of North Vancouver.
3. Conduct surveys in Harbourview (2.4ha), Princess (16.7ha) and Murdo Frazer (17.7ha) parks to collect data on invasive species presence and site characteristics to be compiled in an ArcGIS map.
4. Use survey data to generate maps and draw connections between the relationship of invasive plant species distribution and relative abundance surrounding trails and waterways for the purpose of creating an invasive plant management proposal for the DNV.

3. Study Area

The project focuses on three parks: Harbourview (2.4ha), Princess (16.7ha), and Murdo Frazer (17.7ha) [Figure 2]. These parks were identified by the DNV as sites with high invasive plant presence, but no formal documentation of severity of infestation. Additionally, these parks have been subject to various restoration projects.

Harbourview Park [Error! Reference source not found.**]**

At 2.4ha,

Figure 2: Overview map highlighting in yellow the locations of Harbourview, Princess, and Murdo Frazer Parks within the District of North Vancouver (DNV). These parks have been selected as the survey and mapping sites based on anecdotal knowledge of invasive plant species presence.

Harbourview is the smallest of the three parks and is located at sea level. Located in a heavily industrialized area, Harbourview is a linear park that borders the east side of Lynn Creek draining into the Burrard Inlet. A single trail runs through the park and allows dogs off-leash. The park has received an extensive amount of restoration work within the last few years.

Princess Park [Error! Reference source not found.**]**

At 16.7ha, Princess is the second largest park that has an elevation range of 160-230m. Located between the Lynn Canyon and North Lonsdale electoral district, the park attracts high use for tennis courts and off leash dog area. The park is bisected by Hastings Creek and contains an extensive, interconnected trail system throughout the park. Preliminary restoration work has targeted the removal of invasive species and replanting with local flora.

Murdo Frazer Park [Error! Reference source not found.**]**
At 17.7ha, Murdo Frazer is the largest park in our study area and sits at the middling elevation range of 40-80m. Notable features include a playground, tennis courts and a newly constructed raised boardwalk. A pond and several drainage systems flow into MacKay Creek that runs the length of the park. Murdo Frazer shows the highest levels of disturbance and concurrently invasive species occurrence.

4. Methods and Procedures

4.1 DNV invasive species survey design

We designed a two-phase approach, consisting of an initial walkthrough and a high-intensity survey that was modeled after the COS annual inspection program [**Error! Reference source not found.**]. Adaptations included limiting the survey to prioritized areas surrounding trails, streams and extending survey areas identified in the walkthrough. By focusing on high priority areas, we were able to collect data that was representative of all three parks but ensure that data collection was completed in a timely manner. Once high priority features were identified a buffer was applied to distinguish the areas where we would apply the next phase. Based on literature reviews and a field reconnaissance, we decided to apply a 15m buffer to riparian areas away from the highwater mark and a 10m buffer for trails from the trail center line.

4.2 Field reconnaissance

We conducted a walkthrough survey of each park in October and generated a list of invasive plants observed and identified any potential site limitations. Findings in this field survey, found in Appendix C: Walkthrough invasive species presence, guided the development of a list of invasive species present within each park, a crucial component of the data dictionary. Attributes of the data dictionary were chosen based on data collected by COS staff and the needs of our client [Table 1].

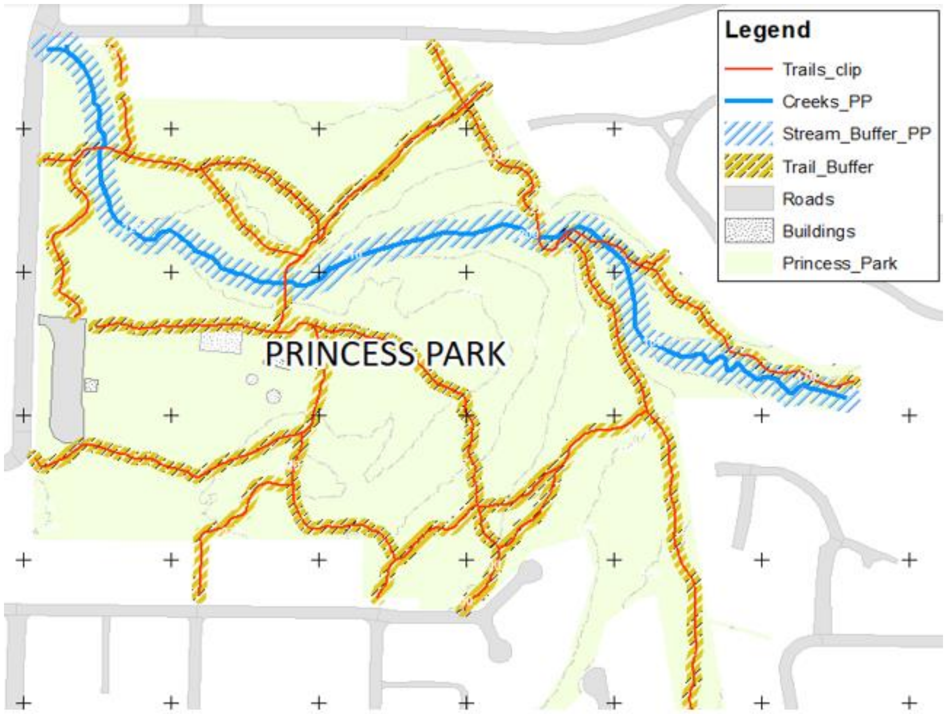
Table 1. Attribute table built for use in TerraSync to collect attributes of the invasive plant species located within buffered areas of Harbourview, Princess, and Murdo Frazer parks within the District of North Vancouver. Table shows the fields and values for collected point data.

Field	**Value**

CommonName	Common name of invasive species
LatinName	Latin name of invasive species
Date_of_survey	DD/MM/YYYY
Park_location	Princess, Harbourview, or Murdo Frazer
Riparian_area	Yes/No
Property_adjacent	Yes/No
Vertical_encroachment	Yes/No
Trail_proximity	Yes/No
Extension_NS	Meters: 1-4 or factors of 5
Extension_EW	Meters: 1-4 or factors of 5
Distribution	Based on cover class
Weather	Noted by observer
Surveyors	Initials of surveyors
Comments	Extends beyond buffer (EBB), height of vertical encroachment, etc

4.3 Pre-survey office preparation

In order to create a map database of our study area, we accessed the DNV's GEOweb to obtain the following shapefiles: park boundaries, trails, contours, and hydrological data. Using ArcMap, these files were used to construct a geodatabase for the study area focusing on the trail, riparian, and boundary line features of each park. Once the geodatabase was created, we applied buffers to the line features that were identified for survey; using 10m for trails and 15m for riparian areas [Figure 3]. Following the application of buffers, "islands" (slivers of unsurveyed parkland less than 10m in width) adjacent to existing buffer boundaries were identified and marked as extended survey areas to be included in the survey plan. Survey routes were devised utilizing park features such as stream crossings, residential boundaries, and trails. Further analysis of contours and landscape features outlined areas where access may be limited due to terrain or property restrictions.



4.4 Field survey of study area

Field days began by pairing the Mesa tablet and Trimble R1 GNSS using Bluetooth and the R1 COMM ports connected within TerraSync. We created new rover files in TerraSync, imported the data dictionary and connected the Trimble to the receiver to ensure GPS data was logged accurately. We began by discussing survey routes for each team and then establishing a POC. Teams of two would then search buffer areas to locate invasive plants by following the

Figure 3: Proposed survey area of Princess Park showing buffers around trails (10m) in yellow and streams (15m) in blue. This acts as a template for surveys as field walkthroughs and consultation with the client may alter the extent of the survey area

predetermined route. One surveyor used a TruPulse 360R Laser Rangefinder to measure distances and to determine the buffered survey area boundary while the other member logged points with the Mesa tablet. For each point, surveyors recorded all attributes, additional comments, and then spatially logged the point in TerraSync. Upon completion of surveying, files are closed in preparation for the post-processing of datapoints.

Defining invasive patch size

Each logged point has the capacity to represent an individual plant, multiple plants (evenly dispersed or clustered), or a large patch. To define the logged point we performed a search after locating an invasive plant until no other plants of the same species category were located within a 5m radius maximum. Within the resulting area, we determined the midpoint between all the plants to be the location of the spatially logged point. Using the TruPulse Laser Rangefinder, one surveyor determined the North-South and East-West spread distance of the invasive plant species with 1m being the minimum recordable value [Figure 4]. Large patches of an invasive species with a change in cover class, shape, or separated by park features were also differentiated. Cover class was visually estimated based on the percentage of area covered by the invasive within the NS-EW area [Figure 5].

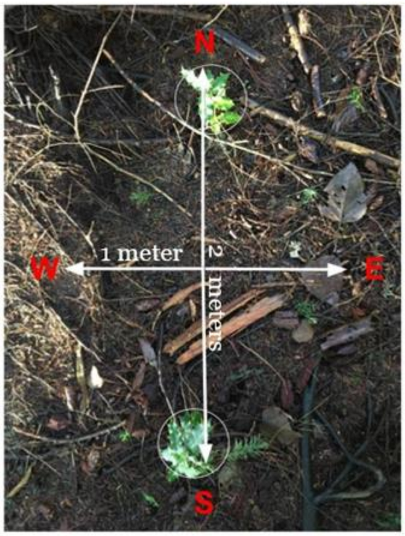


Figure 4: Example of an invasive species patch showing the midpoint between two English holly occurrences with a NS distance of 2m and the EW distance as the 1m minimum. This information is logged in TerraSync as part of the attributes of the infestation.

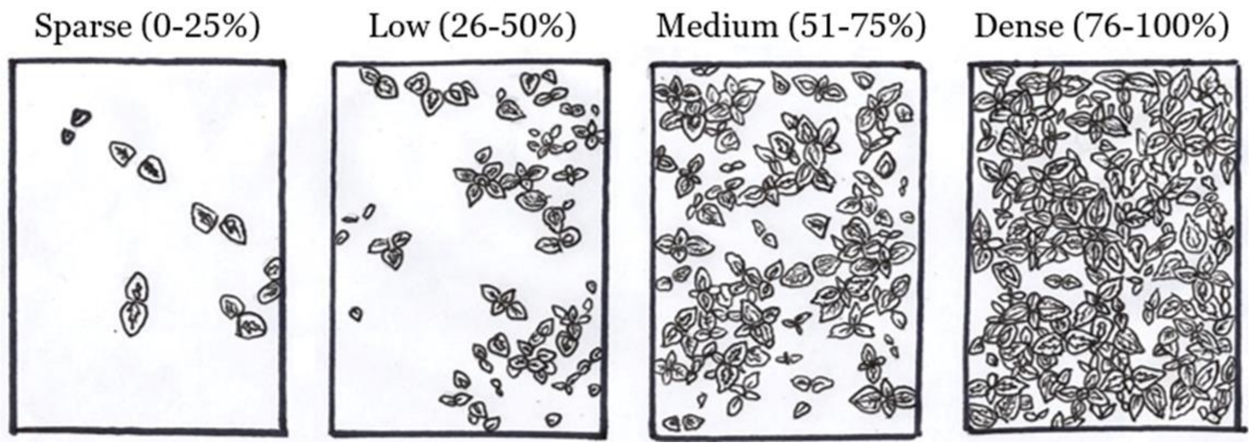


Figure 5. Cover classes of Sparse (0-25%), Low (26-50%), Medium (51-75%) and Dense (76-100%) were used to describe the amount of coverage of invasive plants within the defined patch. This was used to standardize the data collection, reduce bias between surveyors, and mitigate seasonal variation in invasive plant coverage. Artwork by Morgan Scott adapted from field photos of cover class.

Additional attributes

We included an attribute for vertical encroachment to help list and gather occurrences where invasive plants were climbing or overtopping other species. The height of the encroachment was recorded in the comments section. Patch sizes for infestations that continued beyond our survey area were only recorded up to the edge of the buffer to maintain the efficiency of the survey. To give some record of this extension, we added "extends beyond buffer (EBB)" in the comments section.

4.5 Post-processing and analysis of field data

Pathfinder Office was used to post-process invasive plant data points and convert raw GNSS files from TerraSync into usable .ssf files for integration into an ArcMap geodatabase. We exported the post-processed files as ESRI shapefiles to be utilized in ArcMap. We consolidated the invasive plant data files into one file to display the collected point features across our entire study area. Null points, those with empty or incomplete attribute fields, were deleted as they were deemed to be mistakenly input. We created a new attribute field and then multiplied the measured N-S and E-W extension values to calculate the overall area the invasive infestation covered.

Following the transformation of raw TerraSync data into GIS-compatible files, we were able to overlay the invasive plant data points onto georeferenced maps featuring boundaries of initial priority areas. From here, we adjusted survey areas to eliminate un-surveyed areas and add survey extensions. Updated survey areas were categorized into four groups: trail, riparian, overlap of riparian and trail, and extension for each park. To visualize spatial relationships we constructed georeferenced maps illustrating species occurrence, patch size, and cover class based on the invasive plant data. Further manipulation of spatial data can yield maps filtered based on specific fields within the attribute table to reveal severity of specific invasive plant species or isolate for specific fields such as riparian area or vertical encroachment.

To further analyze our data, we exported our entire attribute table from ArcMap as an Excel spreadsheet. Within Excel we were able to manipulate, and isolate invasive plant points based on defining attributes such as: species, adjacency to riparian areas, park location, cover class and area of infestation. To reveal trends, we transformed data into graphs and made calculations based on area covered, invasive plant occurrence and invasive plant proportion.

5. Results

5.1 Overview

We began our field survey and mapping on January 22, 2020 and completed data collection on February 22, 2020. It took a total of seven field days to successfully survey and map our identified priority areas within our study areas. Harbourview Park was the fastest to complete, spending a single field day with 14 person-hours (phr) in this park. Murdo Frazer took a total of two field days with 31phr in the field surveying and mapping. We spent the most time collecting invasive plant data at Princess Park, spending four field days with a total of 63phr. Overall, we spent 108phr surveying and mapping invasive plants across 9.85ha of parkland area or an average of 11phr/ha surveyed

In total, our three study parks accounted for 36.03ha, and we were able to survey 9.85ha, equating to about 26.67% of total area of the study parks [Table 2]. Based on our calculations we were able to survey 100% of Harbourview Park, 12.15% of Murdo Frazer Park and 36.35% of Princess Park. We surveyed a total of 1.63ha of Harbourview Park, 2.15ha of Murdo Frazer Park and finally 6.07ha of Princess Park.

*Table 2. Summary of surveyed areas per park: Surveyed areas have been divided into riparian, trail, overlap of riparian and trail, and extension areas. Percent surveyed was calculated by determining the proportion of total surveyed area over the total park area.*Any variances in the totals are factor of rounding.*

		Harbourview	Murdo Frazer	Princess	Total
Total Area (ha)		1.63	17.70	16.71	36.03
Surveyed Area (ha)	R: Riparian	0.66	0.17	0.68	1.51
	T: Trail	0.92	1.94	4.19	7.04
	O: Overlap of Riparian and Trail	0.37	0.82	0.21	1.40
	E: Extension	0.41	0.87	1.42	2.45
Total Surveyed Area (ha) (R+T+E-O=__)		1.63	2.15	6.07	9.61
Percent Surveyed (%)		100	12.15	36.35	26.67

5.2 General findings

We logged 1050 individual infestation points over our entire survey area. Princess Park accounted for over half of the total occurrences; as seen in Figure 6 we collected a total of 544 logged points within the priority areas of this park. Based on our calculated area all invasive plants covered a total area of 7.23ha. This means that 73.4% of our surveyed areas and 26.7% of the total park area is occupied by invasive species infestations. We calculated the proportions of surveyed area covered by infestations per park by taking the area of the park dividing it by the respective park survey area. The total area covered by invasive plants by park was: Harbourview at 40.8%, Princess at 61.3%, and 132.4% of Murdo Frazer [**Error! Reference source not found.**]. These proportions do not account for overlapping of infestations which occur when invasive plants grow in the same locations, sometimes on top of each other.

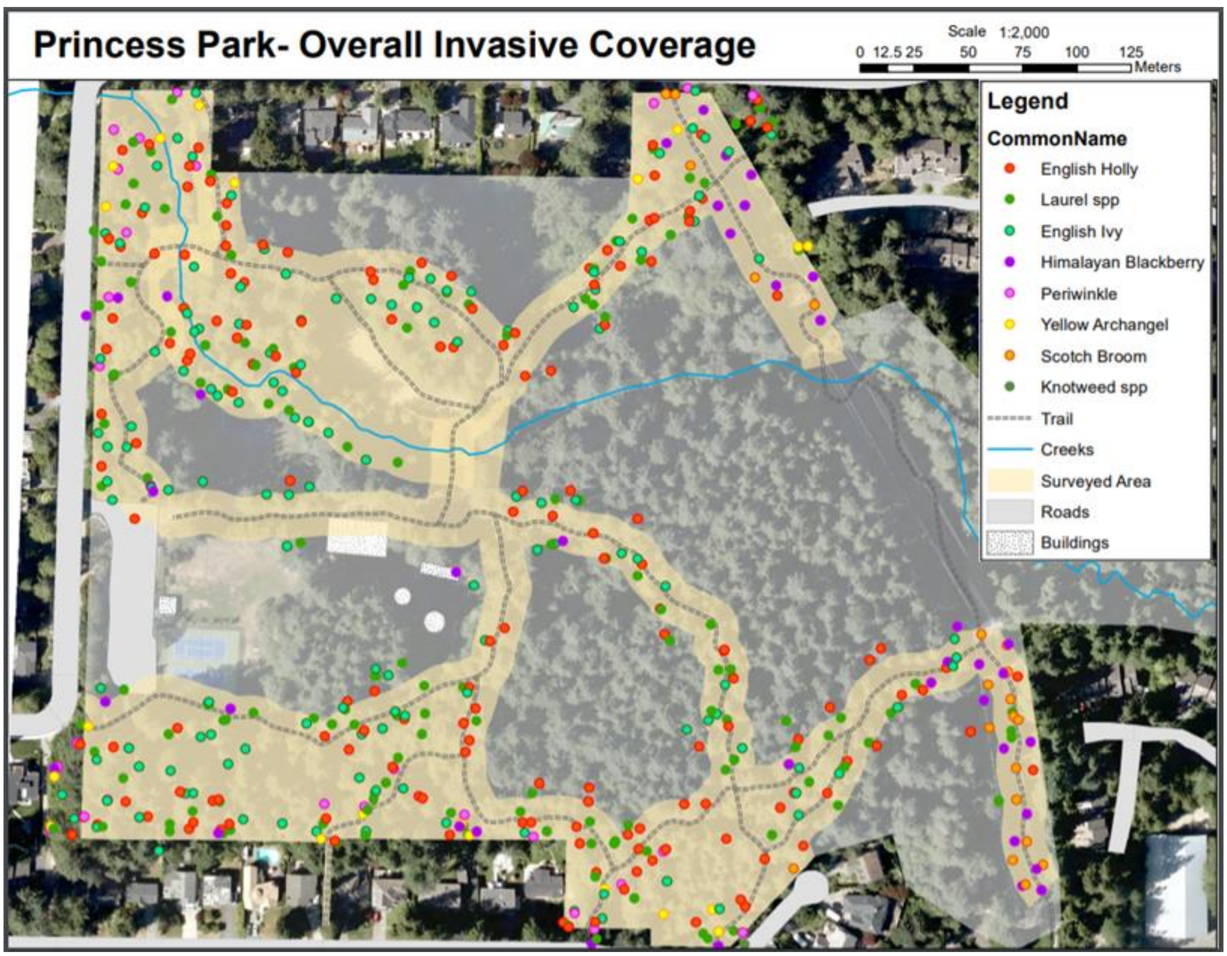


Figure 6.Thematic map of Princess Park showing all 544 logged points collected late January to early February. Points have been classified into their respective invasive species group.

Table 3. Comparison of occurrence of logged points, total invasive species infestation area covered and the proportion of surveyed area covered by invasive infestations (%) for each park within the study area.

Park	**Occurrence**	**Area (m^2)**	**Proportion of surveyed areas covered by infestations (%)**
Harbourview	101	6637	40.8
Murdo Frazer	405	28467	132.4
Princess	544	37237	61.3
Total	1050	72341	

In total we logged 1050 points and determined that ivy spp., Blackberry spp., English holly, and the laurel group were the most prolific in occurrence as well as area covered [**Error! Reference source not found.**]. During initial field walkthrough in October, a total of 19 species were encountered [

Appendix C: Walkthrough invasive species presence], but only 12 were logged in the second phase of our surveys due to difficulty surveying herbaceous species in late winter and time constraints [**Error! Reference source not found.**].

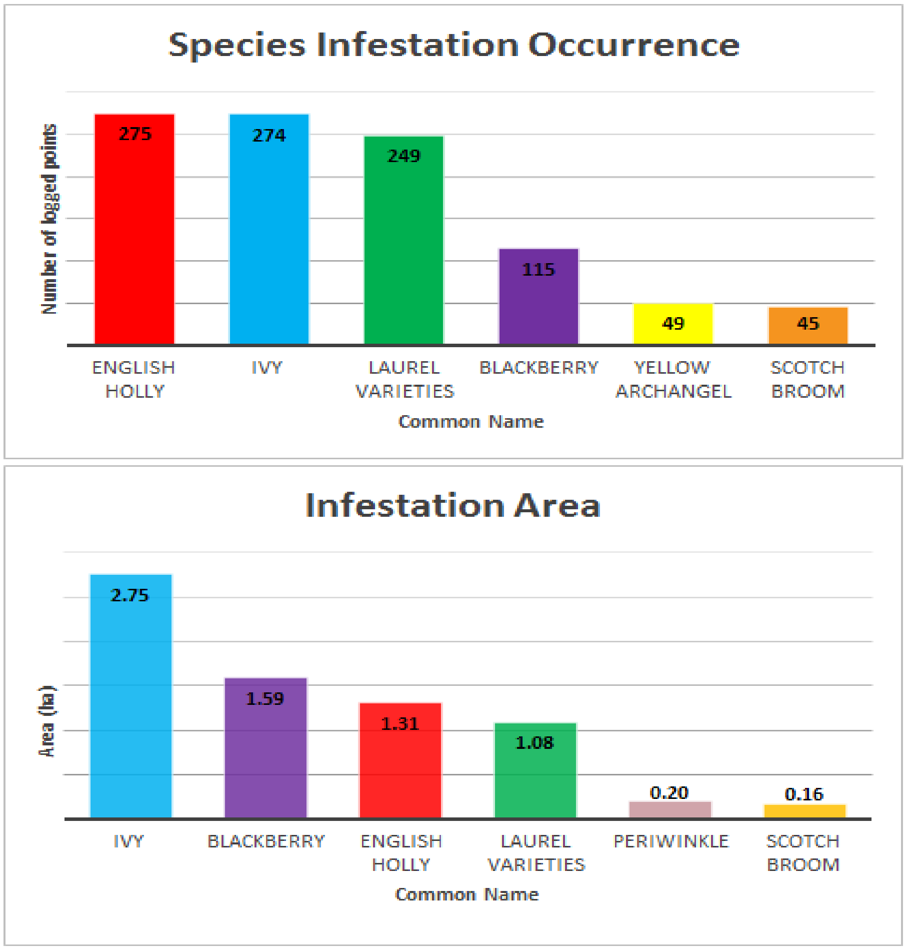


Figure 7. Bar graph displaying the top six invasive plant species based on the number of recorded infestation occurrences (Top) and by total area covered in hectares (bottom) across the surveyed area within Harbourview, Princess and Murdo Frazer Parks.

Table 4. Number of occurrences of invasive plant species points and total area (m2) covered within the surveyed area and proportions rounded to the nearest percent.

Species	**Occurrence**		**Area**	
	#	**%**	**m^2**	**%**
Bamboo	2	<1	10	<1
Common burdock (*Arctium minus)*	1	<1	4	<1
Curled dock (*Rumex crispus)*	1	<1	4	<1
Cutleaf blackberry (*Rubus laciniatus)*	1	<1	5	<1
English holly (*Ilex aquifolium)*	275	26	13083	18
English Ivy (*Hedera helix)*	274	26	27508	38
Himalayan blackberry (*Rubus*	115	11	15874	22

armeniacus)				
Knotweed (*Reynoutria spp)*	3	<1	18	<1
Lamium (*Lamium galeobdolon)*	49	5	1338	2
Laurel group: Daphne/surge laurel (*Daphne laureola)* Cherry laurel (*Prunus lauroceracus)*	249	24	10824	15
Common periwinkle (*Vinca minor*)	35	3	2047	3
Scotch broom (*Cytisus scoparius)*	45	4	1626	2
Total	1050		72341	

5.3 Sensitive areas

From our entire invasive plant dataset, we can isolate our data to show only logged points in what we categorized as sensitive areas. Infestations in sensitive areas are delineated as points that were observed to be adjacent (within the buffer width) to a trail, property boundary, or riparian area since some survey areas added were not adjacent to any of those features. There is a high occurrence of invasive plants in sensitive areas based on our initial selection of priority areas. Out of the 1050 data points, 1032 points occurred within a sensitive area, accounting for 98.2% of our total points. The occurrence and area covered by these invasive plant points are categorized further by distribution cover class [**Error! Reference source not found.**9]. Infestations that were classified with a sparse distribution cover class have the most logged points at 587, and they covered the highest amount of area at 2.3ha across all parks. As we can see within these sensitive areas there is a high proportion of sparsely categorized occurrences, often defining newly establishing invasive plants. The sensitive areas which are adjacent to prominent features pose as a high management priority as they act as invasive plant vectors into parkland.

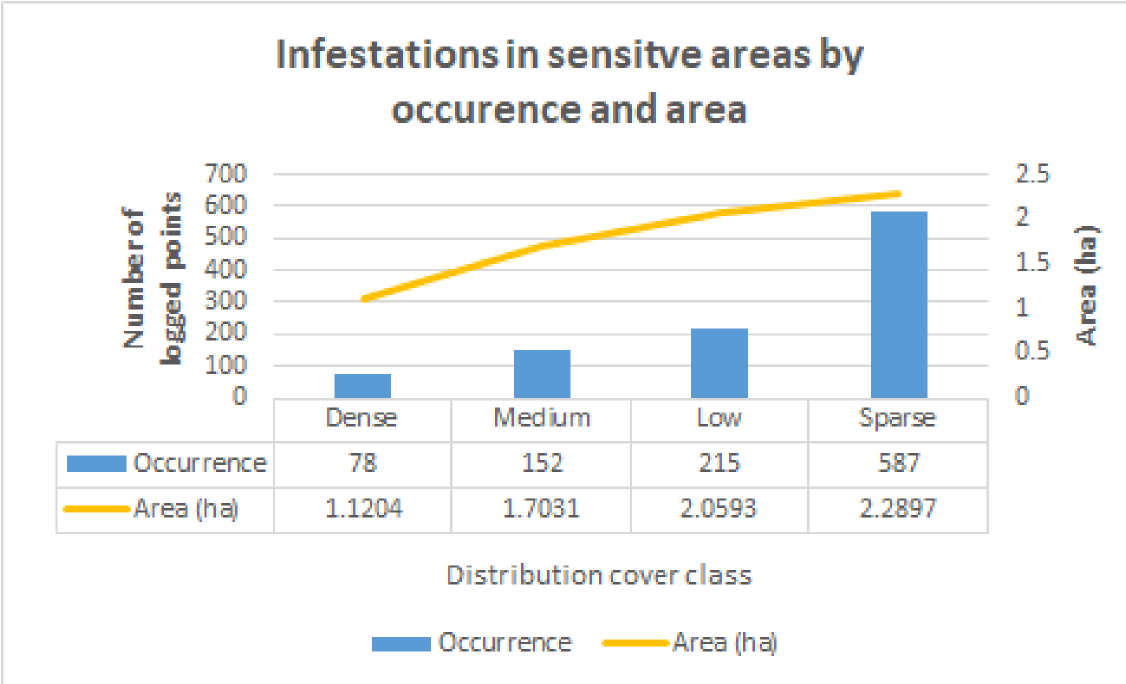


Figure 8: Comparison of invasive species points by occurrence and area grouped by differing distribution cover classes within sensitive areas of study area. Sensitive areas are defined as points adjacent to trails, property boundaries and riparian areas.

Property lines

By isolating invasive plant points that occur in areas near property boundaries, we can see an overall increase in occurrence and area covered by species that are usually planted on private property in residential areas [Figure 10]. For instance, occurrences of lamium and periwinkle increased within proximity to residential boundaries. It is common for these species to establish on parklands as many of these species are popular yard and garden plants. The laurel group has the highest number of infestation points whereas ivy covers the largest amount of area.

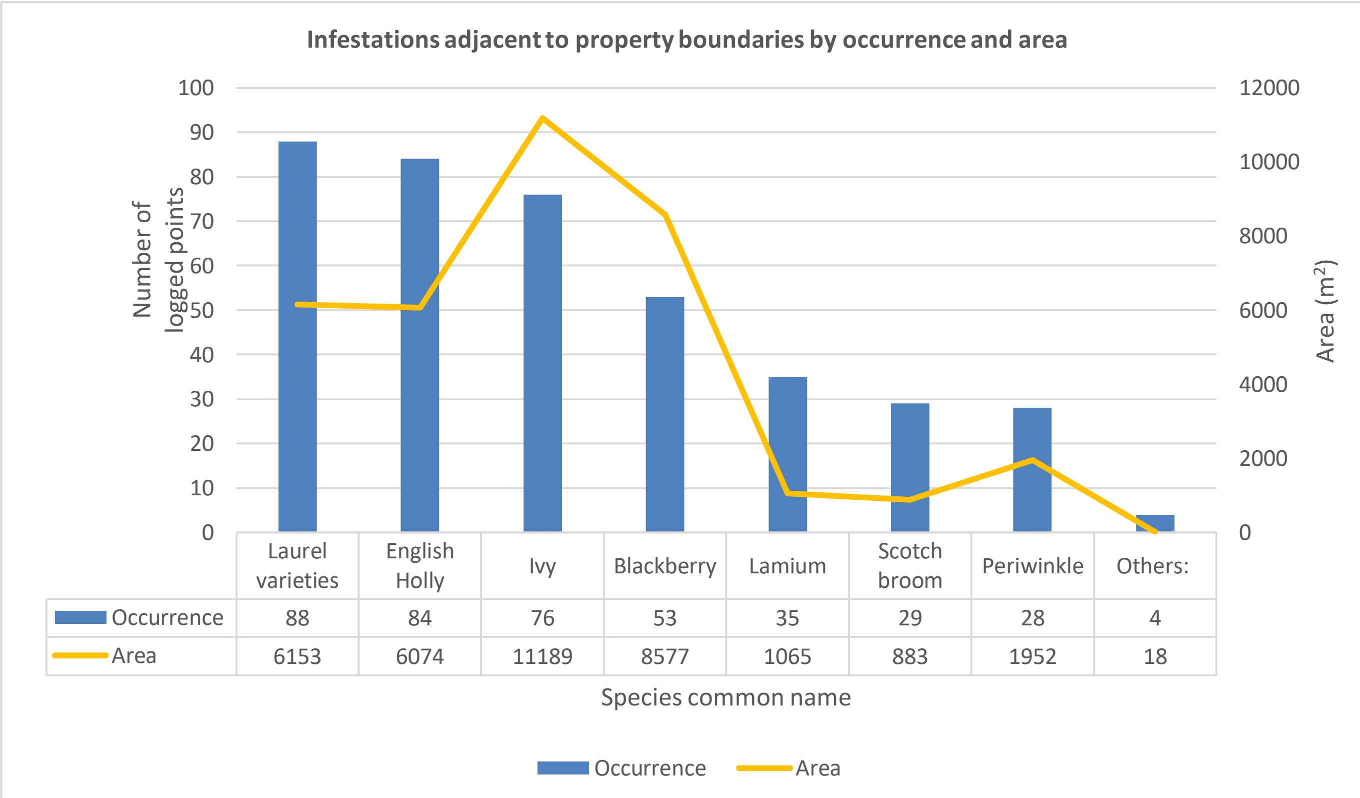


Figure 9: Invasive plant infestations that are adjacent to property boundaries by number of logged points and area (m2) covered across species. Species category "other" represents a combination of bamboo, common burdock, cutleaf blackberry and knotweed data points

5.4 Points that extend beyond buffers

There were 77 invasive plant infestations, for a total of 7.3% of the total logged points, that were classified as extending beyond the buffers (EBB) surrounding the trails and riparian areas. For Murdo Frazer, Princess and Harbourview the proportion of points logged as EBB was 11.8%, 4.4% and 5.0%, respectively. The number of EBB points observed help indicate the level of accuracy of our survey method. Since we did not collect additional data on patches that extended beyond our buffer boundaries, our survey buffers may not be sufficient in capturing invasive infestations.

5.5 Vertically climbing ivy

Analysis of ivy encroachment revealed that a cover class of medium corresponded to the most area and occurrence [Appendix D: Ivy Vertical Encroachment. Vertically climbing infestations account for 125 occurrences and covered a total of 20318m^2. Proportionally 46% of the total ivy occurrences are vertically moving and approximately 21.1% of the surveyed area is covered in ivy infestations that are vertically climbing.

6. Discussion

6.1 Incorporating low-intensity surveys into survey map development

A key finding of this project was the benefit of performing a low-intensity survey, or a walkthrough, prior to applying a more intense surveying protocol. The first phase allows surveyors to gain a general understanding of invasive plant locations within the study area and confirm spatial feature data (Sheley and Smith, 2012). Additionally, the creation of survey maps was improved by accessing the DNV's GEOweb. This resource allowed us to create base layer maps and plan our survey routes. Having access to the spatial data was important for our mapping process but the low-intensity survey was essential as some spatial data was occasionally lacking or did not accurately represent the study area. Within Princess Park, the trail system running along the hydro transmission line had been washed out, overgrown and unsafe for access. In close proximity there were a series of unsanctioned trails that had developed to accommodate this closure that were not included within the spatial data [Figure 11]. Due to time constraints, these trails were not included in the survey, but they continue to act as vectors for invasives and should be considered in future surveys. With our low-intensity survey we were able to adjust areas such as this from our survey plan.

Figure 10: This orange linear features displays sections of the trail that were washed out as well as two unsanctioned trails that we came across.

We also found that some watercourses did not reflect the preliminary spatial data. There was an unmapped riparian feature near the southern border of Princess Park and an inaccessible waterway within the southeast portion of Murdo Frazer. Initial low-intensity surveys have the power to capture these variations and allow for adaptive planning of future surveying. In some cases, it may be worthwhile to get an inventory of watercourses for future surveys. Collecting the inventory has the benefit of creating spatial data allowing for more accurate estimations of total area requiring intensive surveying. This may be an important factor for reporting or budget management of the area.

6.2 Determining if surveyed area is representative of the data

When designing a survey, it is important to consider the desired outcome. Our second phase of intensive surveying needed to generate actionable data for the DNV and their future management needs. If the DNV were to incorporate an 'early detection, rapid response' management strategy, the sampling would need to be efficient to capture new invasive plant establishment and dispersal (Backus, et al., 2011). This encouraged the prioritization of designing a model to generate a baseline dataset with avenues for future application and interpretation.

The DNV has 3000ha of managed parkland and is limited by financial resources and competing priorities making it difficult to complete full inventories (Backus, et al., 2011). Phase one provides the framework to build buffers and priority areas for the second phase of high-intensity surveying and mapping. As more resources become available there is an opportunity to increase the proportion of the park surveyed. Much like the City of Surrey's model, it may be useful to add survey buffers to all park boundaries and meadow-forest interface zones (Crosby and Herbert, 2019). Our final buffers (10m for trail features, 15m for riparian features) should be considered the minimum threshold to get a representation of invasive infestation within these sensitive areas.

One method to quantify if the surveyed area is representative is to filter the data based on the logged attribute EBB. If the proportion is high, it may be an indication that the survey did not capture enough of the invasive population. In our case, the proportion of points logged as EBB in our survey areas for Murdo Frazer, Princess and Harbourview was 11.8%, 4.4% and 5.0%, respectively. Murdo Frazer's proportion of 11.8% suggests that our survey did not capture an accurate level of the invasive species occurrence. Repeat surveys within this park will increase the accuracy of this data (Sheley and Smith, 2012). Visualization of these features will show where additional follow up surveys are required [Figure 12].

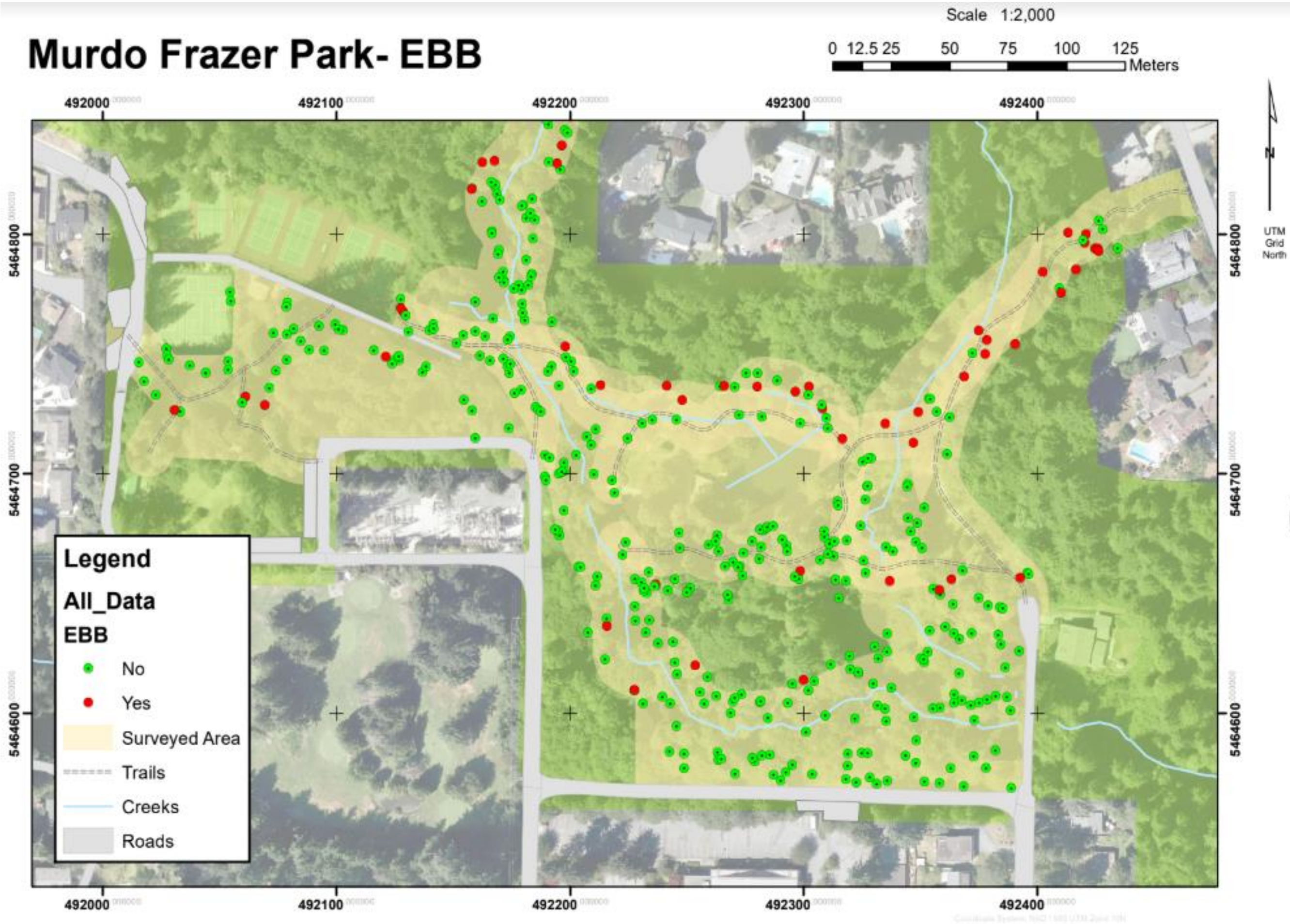


Figure 11: Map of Murdo Frazer Park showing invasive plant points logged in TerraSync and exported as a shapefile. Points outlined in red are infestations that extended beyond our 10m trail and 15m riparian buffers (EBB).

6.3 Recording invasive plant infestations

We surveyed invasive populations with a method that was easily replicable by surveyors of varying experience. A single point representing a larger patch would allow for ease of collection and better functionality of the data for future use. In order to define a single patch, we surveyed radially for 5m until no more of the species was found. This sampling takes advantage of the natural clustering and dispersal of invasive plants and minimizes the total number of logged points (Backus et al., 2011). Additionally, with $1m^2$ as our smallest unit it is possible that smaller patches or single plants would result in a compounded increase of recorded infested areas. The solution for evaluating actual effective areas may be found in our cover class attribute. Using cover classes expedites and standardizes data collection while describing the conditions within the logged area. Cover classes also minimize the effect of seasonal variation in invasive plant foliage. Considering both size and coverage is important to evaluating the whole picture.

6.4 Draw connections from data to guide future management

Completing phase two and intensive surveying has provided us with an opportunity to analyse the baseline data from the three parks. An encouraging finding is the benefit of the restoration work on reducing invasive populations within the parkland. Harbourview has received the most extensive restoration work and as a result only 40.8% of the surveyed area is considered infested. Princess has seen comparatively less restoration work recently and 61.3% of the surveyed area is infested. The relatively untreated Murdo Frazer has a staggering 132.4% area infested. It is of note that these proportions are based on the sum of total area of recorded invasive plants and does not eliminate areas of overlapping occurrence.

Another observable relationship is that as more of the park is surveyed, the proportion of infested area decreases. Murdo Frazer, which had the lowest proportion of surveyed parkland at 12.15%, had the highest proportion of area covered by invasive species at 132.4% while Harourview, which was completely surveyed, had 40.8% of its area occupied by invasives. These results strengthen the claim of past studies and our presumption that sensitive areas, such as trails and riparian areas, do have a higher proportion of invasive plant occurrence and are the most at risk for establishment (Foxcroft et al., 2007). This further supports our recommendation that focusing intensive surveying efforts to sensitive areas will be the most productive use of resources for capturing invasive plant establishment and dispersal.

For treatment of invasive plant species infestations, the dataset can be manipulated to uncover trends within a single species. Points can be isolated based on a target species to better visualize trends in patch size and coverage. Isolating a single species can reveal trends regarding its introduction and dispersal within parks, which is a practical tool for land managers when creating treatment plans [Figure 13]. In this case, it is apparent that the largest patch sizes and highest density infestations are adjacent to residential park boundaries. This knowledge can be used to shape treatment and community outreach programs.

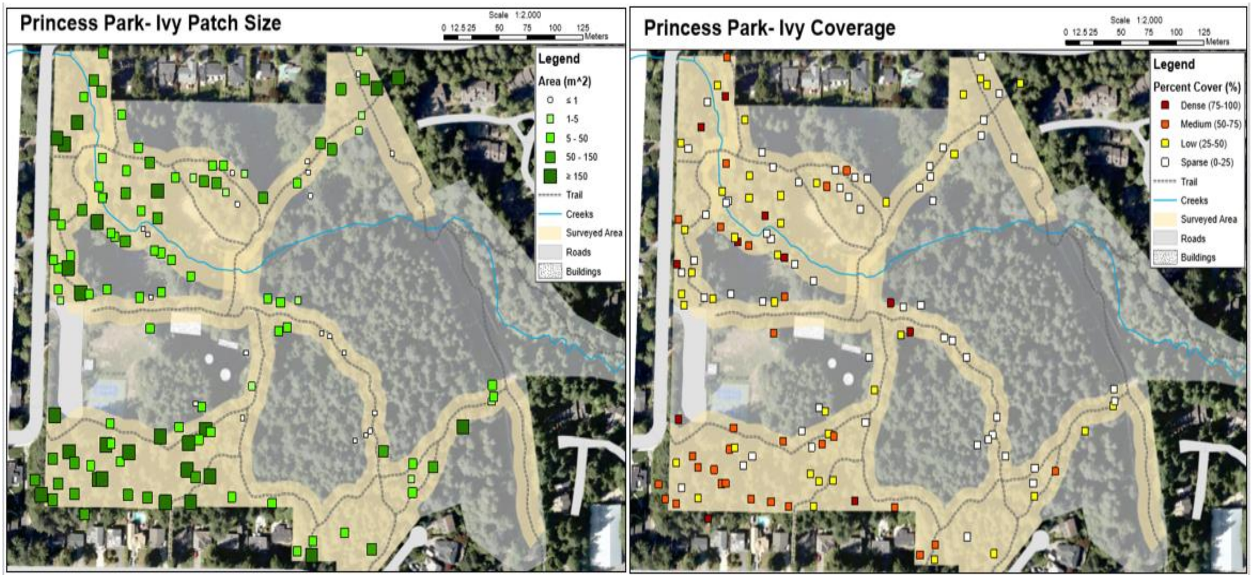


Figure 12: Left: Map of Princess Park showing ivy patch size based on area. The shade of green and size of the squares indicate the size class of the patch. Patch size classes are <1, 1-5, 5-50, 50-150, >150m^2 and go from light to dark green. Right: Map of Princess Park showing ivy patch size based on percent cover. Cover classes are sparse=0-25% (white), low=26-50% (yellow), medium=51-75% (orange), and dense=76-100% (red).

Garden Invaders

Park areas that border properties will be at the greatest risk for invasive introduction as we observed a dominance of horticultural species concentrated around private property boundaries [Figure 10]. The most prominent species in occurrence are the laurel group, ivy spp., and English holly. These infestations were likely introduced into the park through illegal dumping of yard waste or the unintentional dispersal by growth or seeds. We observed several substantially tall laurel and English holly trees growing on private properties, further facilitating potential seed dispersal. To combat these issues, it is necessary to educate property owners on proper yard waste disposal, maintenance of existing garden plants or suggesting alternative plant species. Collaboration with local organizations and public educators can help publicize such information.

Hydro right-of-way

Himalayan blackberry was prominent in the Hydro right-of-way and the industrial border of Harbourview Park, covering nearly 9000m^2 within park boundaries. Invasive plant infestations such as these are well established and often management strategies aim for control, rather than eradication. The blackberry brambles within the Hydro right-of-way are commonly trimmed back to clear trails and pathways. Since these infestations are not managed in an intensive manner, they may continue to reoccur and establish in DNV parkland. This highlights the need to manage adjacent areas and to determine collaborative strategies with other management organizations.

Continual monitoring

One encouraging aspect in reviewing the data is the comparative abundance of sparse points. More than 55% of all occurrences and 30% of all infested areas are characterized as sparse. These occurrences are likely recently dispersed, new infestations. Proactive management with the greatest economic returns should aim at controlling these new infestations (Sheley and Smith, 2012). Managing sparse points is a good starting place to begin isolating invasive plant species to more manageable areas. This removal should allow desirable native species the opportunity to reoccupy the parkland (Sheley and Smith, 2012). Continued monitoring will be required to determine changes in invasive plant population and allow for further adaptive management (Foxcroft, et al., 2007).

7. Recommendations

Our recommendations for the direction of this project are as follows:

1. Adapt multiple survey methods to meet client needs.
2. Standardize data collection methods to reduce variability.
3. Perform a statistical analysis of collected data.
4. Develop invasive plant management plans.

7.1 Adapting survey methods

We recommend that future students compare our methodology with other invasive plant survey methods. Land managers often juggle multiple objectives within their management areas and can be constrained by budget, time, and skill level of surveyors. For these reasons, employing a variety of survey methods dependent on need is recommended. We found two possible survey methods that could be compared to ours; Timed Meander and Adaptive Cluster which are outlined in Adaptive cluster methodology. Alternatively, students can conduct their own research and pilot existing or adapted methods. Comparison of different methods, or the adaptation of a new method, can aid in the survey of additional DNV parks to enhance their baseline invasive plant database.

7.2 Standardizing data collection

Variability in measurements between crew members is highly likely. To determine this variance, a study could be designed where each crew member surveys the same defined area and compares results, therefore quantifying differences in data among surveyors. This will provide insights into data accuracy and replicability of our surveying method. Additionally, it could provide the basis for the development of an adjustment factor to mitigate data variability between surveyors.

Growth characteristics of invasive plant species vary and can create challenges regarding full extent of infestation coverage. For instance, some invasive plant species grow vertically from a central stem and others disperse by climbing features such as trees, walls, or fences. In Murdo Frazer Park, we observed ivy fully engulfing boles of trees, and English holly and laurel growing to heights over 10m. Setting clearer guidelines for collecting vertical attribute data would enhance the quality of data collected. Our method of recording vertical encroachment was not consistent and often did not include specific heights. Future surveys could standardize data collected by setting thresholds for when to include plant or vertical encroachment heights

7.3 Incorporating statistical analysis

Incorporating a statistical test into this project can reveal whether species display significant species composition or spatial patterns. Students can run tests to determine if there is a significant difference between species richness or abundance between park features such as trails, riparian areas, or areas of overlap between the two.

Another example is testing for species that are commonly found together. We intended to trial such an analysis but were unable to due to time constraints. Following consultation from Julia Alards-Tomalin and Jace Standish, we designed a survey methodology that could be further developed and implemented in an urban park [Refer to Species Richness or Diversity Sampling Method].

7.4 Developing management plans

Now that there is baseline data for Harbourview, Princess, and Murdo Frazer parks, a future project could focus on treatment and monitoring of select invasive species in these specific parks. Students can work with the DNV to develop and implement a treatment plan based on the District's management goals for the study area. This project could incorporate volunteers and test the applicability of our survey methods as well as usability of the maps generated in our project. Field testing would provide feedback on the methodology and aid in further refining the survey and mapping protocol.

8. Conclusions

Managing the spread of invasive plant species is integral to minimizing the potential damage of native ecosystems and reducing the effect on community composition and ecosystem properties (Corbin and D'Antonio, 2012). As discussed by Sheley and Smith (2012), strategies for reducing the introduction and spread of invasive plant species include monitoring entry points, identifying existing populations, and prioritizing treatment. Understanding pathways of invasive entry into parks will guide and enhance management strategies and can add spatial visualizations of invasive occurrence and extent cover. We applied these principles to the design and implementation of our survey methodology, with consideration of its real-world applicability in supporting the DNV's desire to assess invasive extent within sensitive ecosystems and parks.

By reviewing literature, consulting with other municipalities, and discussing objectives with our client, we developed a survey model that provides the DNV with spatial information to include within their existing GEOWeb database. We built maps of Harbourview, Princess, and Murdo Frazer parks to outline our survey priority areas: trails, streams, and park boundaries. Low-intensity surveys (walkthroughs) provided insight into levels of infestation as well as the location and condition of trail and stream networks. Initially, trail and stream survey buffers were set to be 5m and 10m respectively, but fieldwork revealed the necessity to expand buffers by 5m to better capture invasive extent. We logged invasive infestations as point features using TerraSync with attributes defining patch size, coverage, and proximity to features (trails, property boundaries, and/or riparian areas). Using point features gave us greater ability to manipulate the data within ArcMap to visualize spatial relationships.

Surveys of Harbourview, Murdo Frazer and Princess Park were conducted with coverage of 100%, 12%, and 36% of the parks, respectively. Data collected from these surveys was transferred into ArcMap as a shapefile, allowing for the visualization of invasive presence based on their collected attributes. It was found that area infested by invasive species is 73.4% of the surveyed area which corresponds to approximately 26.67% of the total area of all three parks. Looking at invasive occurrence, the top three invasive species categories were the laurel group, English holly, and ivy species. In terms of area covered, the top three were ivy species, English holly, and blackberry species. Reviewing coverage and occurrence frequency indicates that higher densities of invasive species are located adjacent to park borders. This highlights the importance of public education on proper garden maintenance, yard waste disposal and the benefits of planting native species.

Piloting these survey designs came with some challenges, most notably the removal of timed meander and adaptive cluster from the survey plan due to time constraints [See Adaptive cluster methodology]. However, the goal of preparing guidelines for the DNV to assess invasive infestations was achieved. We stress the importance of study area walkthroughs prior to applying more intensive surveying methods and encourage creating survey maps and route planning to increase efficiency of field surveys. Walkthroughs enable surveyors to identify unsanctioned trails that can be added to the survey plan or sections with poor access or potentially hazardous terrain that need to be removed from the survey plan.

We began this project with an objective to provide the DNV with data for making connections between invasive distribution and relative abundance within parkland features such as trails and waterways. Our methodology highlights areas of invasive occurrence based on patch size and density, which can offer insight into the movement of invasive within parkland. Urban areas have been referred to as sinks for invasive plants and understanding their movement and spatial distribution within parkland is essential to developing a successful management program (Gulezian et al., 2010). The DNV now has a surveying tool that has been successfully applied to parks of varying size, topography, and site history. Further application of this survey methodology can identify sections of parkland requiring immediate intervention to reduce future impacts of invasive encroachment. Managing within urban parkland is an ongoing battle, but thoughtful planning and monitoring of infestations can reduce their overall ecological impact.

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Appendices

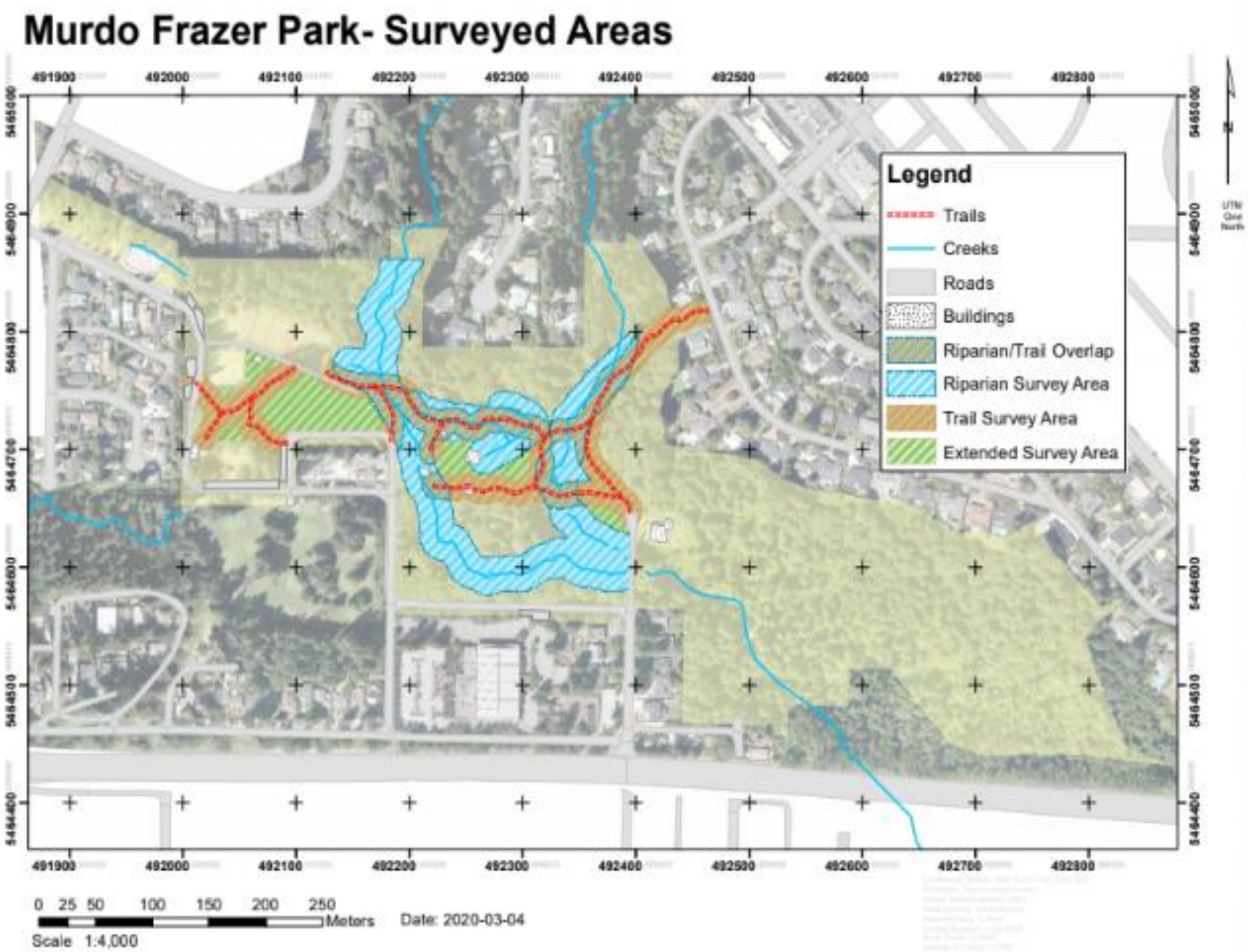
Appendix A: City of Surrey Managed Park Inspections

The COS with over 2700ha of parkland, has established an annual inspection program to monitor invasive species levels within parks based on their ecological priority. Through communication with COS employees Matthew Banford, Lead Invasive Management Technician, and Jocelyn Herbert, Natural Areas Practitioner, we learned their survey and mapping methods. In order to maximize efficiency, inventories are conducted every 3 years in high priority parks and on a demand basis for low priority parks. These inspections typically occur in late winter/early spring and may involve supplementary inspections to better capture plants with a short growing window. A walk-through method is used to inspect all border perimeters, sanctioned and unsanctioned trails, waterways, forest-meadow interfaces and transects through meadows. During the survey, a thorough examination of herbaceous remnants and yard waste is also conducted as these can be a source of new introductions of invasive species.

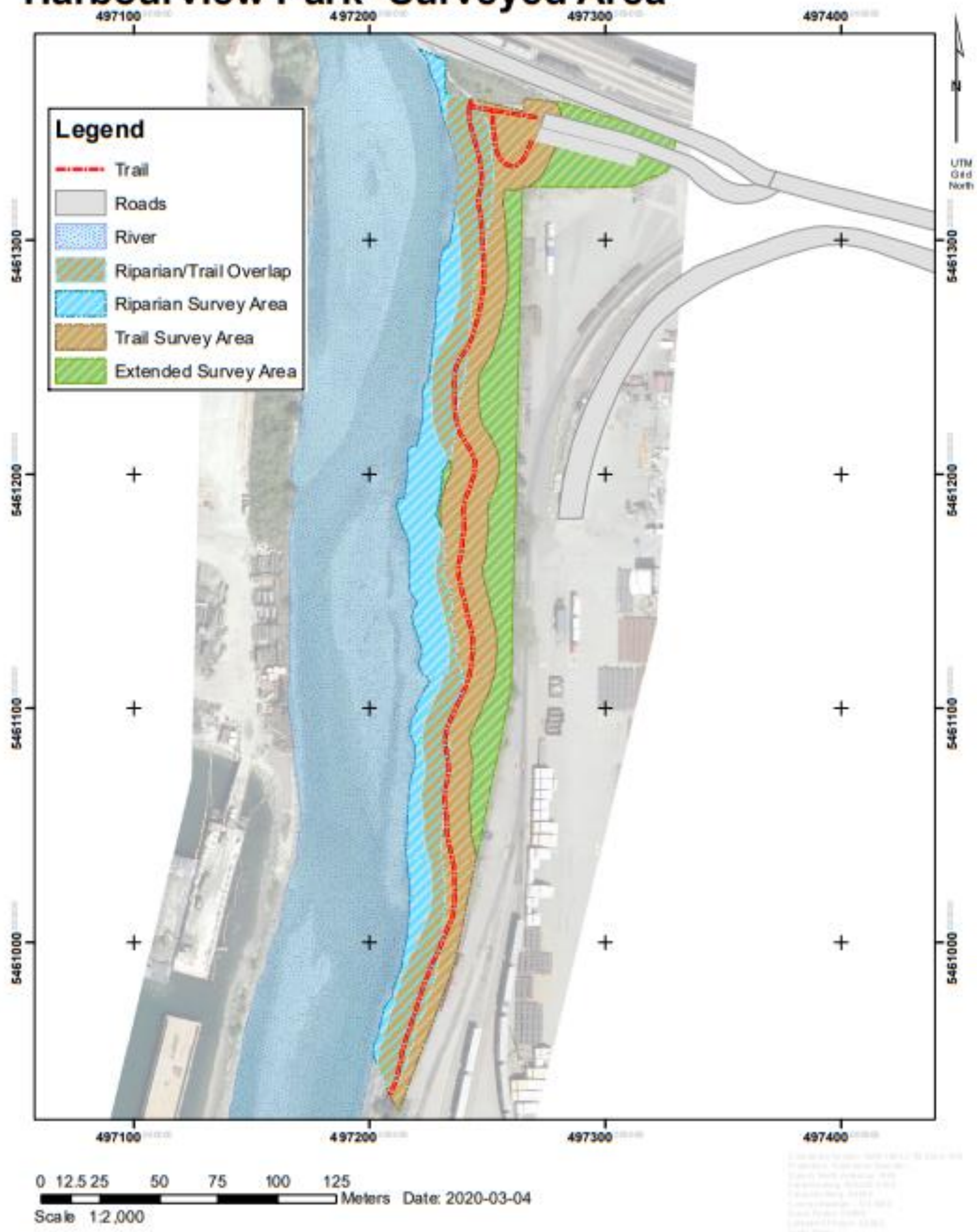
A Trimble JUNO GPS device is used to collect pertinent information at new and existing site. The table pictured is an example of an attribute table from the COS survey method, outlining several defining characteristics. Area of infestation is recorded as an estimation of coverage with $1m^2$ being the minimum value. For the purpose of these inspections, the COS requires an estimation of coverage rather than precise values. In addition to species and coverage data, the COS includes a comment section for inspectors to describe the locale. This comment section helps indicate the location of the investigation sites to technicians that may not have a GPS. If a technician returns to an existing infestation site and the infestation is not found, they record: CNL (Could Not be Located) and the year. Invasive plant mapping is done using points with area estimates and options for comments on dispersal characteristics.

FacilityID	1001919394
Common_Name	English Ivy
Scientific_Name	Hedera helix
Inventory_Year	2018
Location	Redwood Park
Site_Number	5025
Invasive_Area	1
Riparian	No
Encroachment	No
Comments	Along trail
Treatment_History	2015,2016
Initial_Inventory	2015
Initial_Area	2

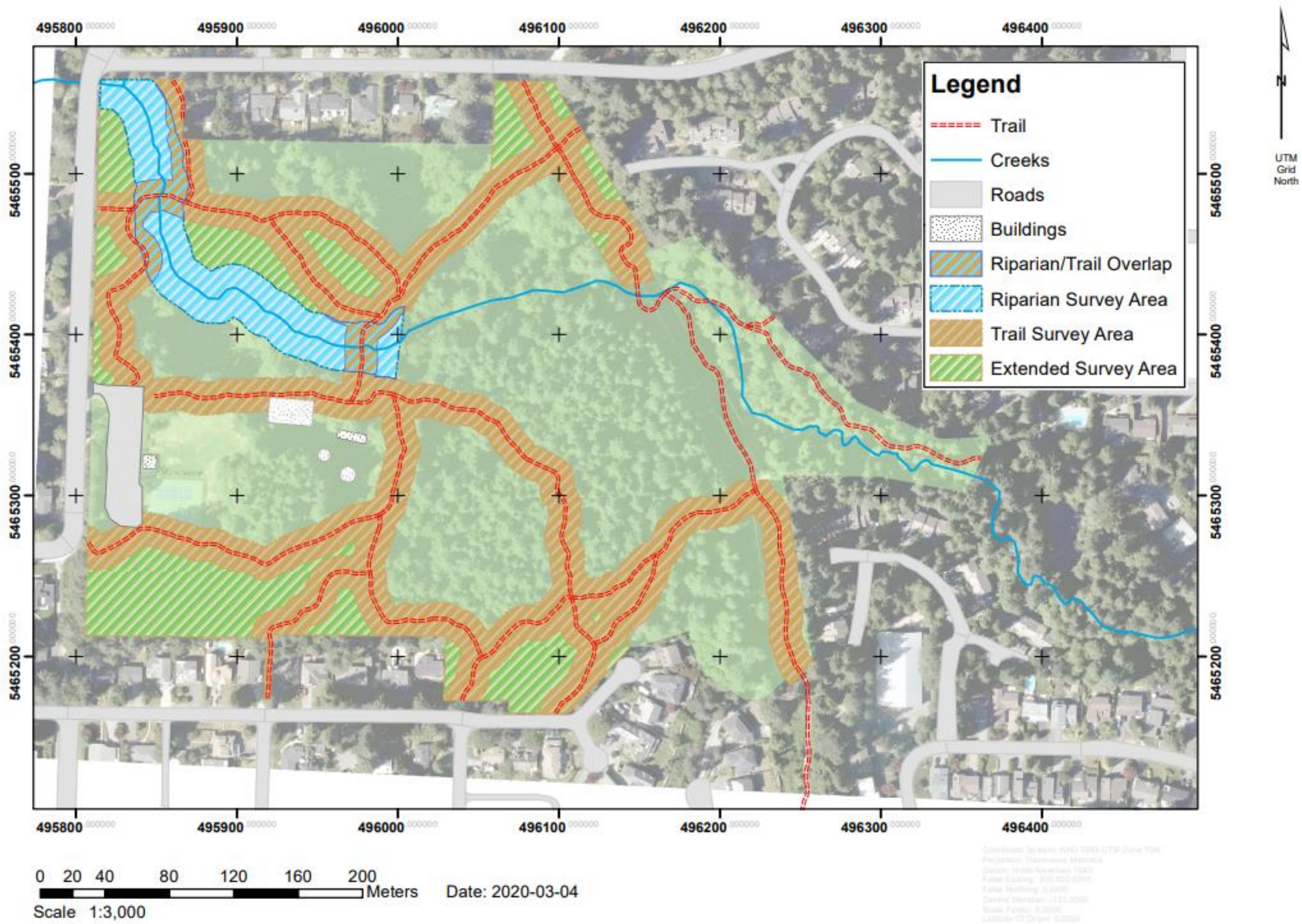
Appendix B: Surveyed Areas of Study Area Parks



Harbourview Park- Surveyed Area



Princess Park- Surveyed Area



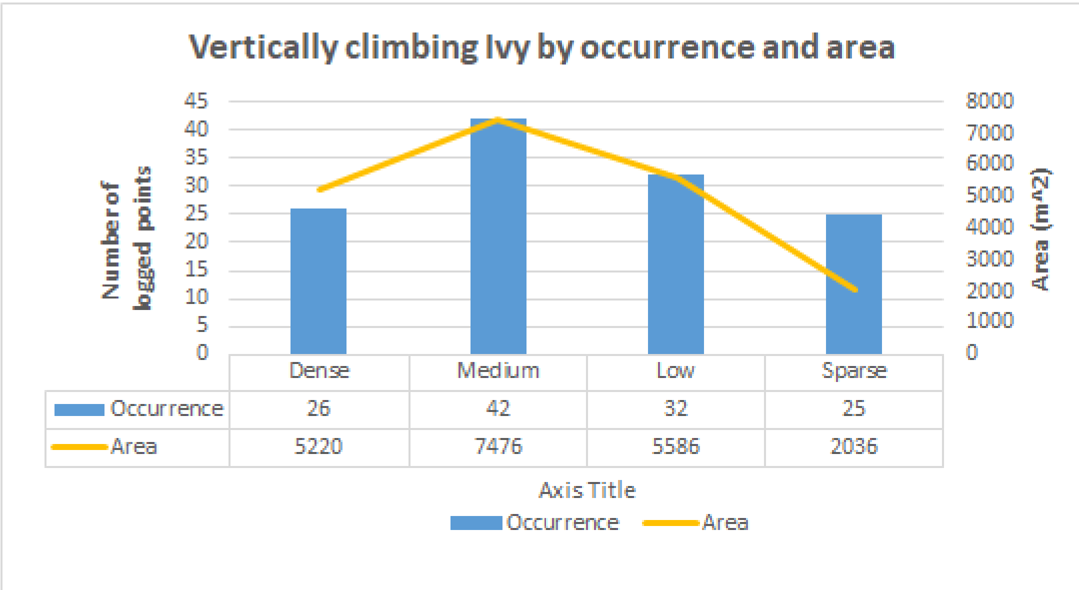
Appendix C: Walkthrough invasive species presence

The following is a list of species recorded in the three study areas during walkthrough surveys in October. Herbaceous species from this list were not selected for inclusion in our data dictionary due to difficulty with identification in winter. Future surveys may wish to include them.

Species	Harbourview	Princess	Murdo Frazer
Himalayan blackberry – *Rubus armeniacus*	**X**	**X**	**X**
Lamiastrum/yellow archangel – *Lamiastrum galeobdolon*		**X**	**X**
Knotweed species – *Fallopia japonica/Fallopia x bohemica*			**X**
English holly – *Ilex aquifolium*	**X**	**X**	**X**
Cherry laurel – *Prunus lauroceracus*		**X**	**X**
English ivy – *Hedera helix*	**X**	**X**	**X**
Periwinkle – *Vinca minor*		**X**	**X**
Scotch broom – *Cytisus scoparius*	**X**	**X**	
Policeman's helment/Himalayan balsam – *Impatiens glandulifera*		**X**	**X**
Goutweed/bishop's weed – *Aegopodium podgaria*		**X**	**X**
Saltmeadow cordgrass – *Spartina patens*			
Giant hogweed – *Heracleum mantegazzianum*			
Daphne/spurge laurel- *Daphne laureola*		**X**	**X**
Common burdock- *Arctium minus*	**X**		**X**
Curled dock- *Rumex crispus*			**X**
Common morning glory- *Calystegia sepium*	**X**		**X**
St. Johns Wort- *Hypericum perforatum*		**X**	
Butterfly bush- *Buddleja davidii*	**X**		
Chicory- *Cichorium intybus*	**X**		

Appendix D: Ivy Vertical Encroachment

Produced bar graph displaying invasive plant species points based on vertically climbing criteria and distribution type.

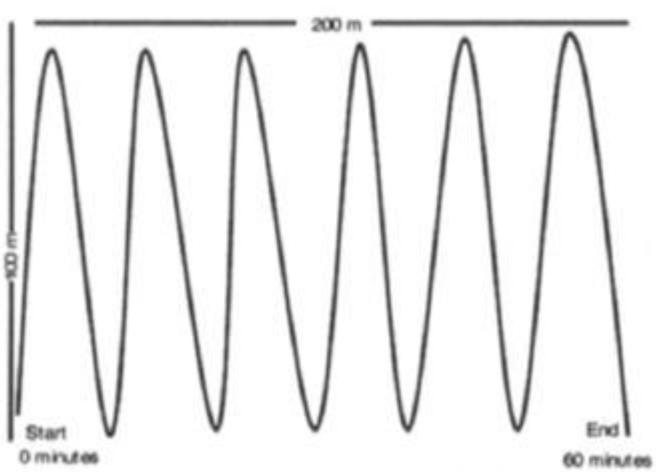


Appendix E: Alternative Survey Methods

Timed Meander

Timed Meander is a rapid method of performing a qualitative assessment. The following methodology is adapted from Huebner (2007), Trochlell (2016) and Bohnen and Galtowitsch (2016):

1. Divide the study area into Assessment Areas (AA) between 0.09-4.0ha ensuring that the area has a roughly homogeneous vegetation cover type.
2. Plan one meander route for every 2ha of AA. Ensure that the route passes through all potential microclimates of the site.
3. Prepare Timed Meander data collection sheets for survey.
4. Once the route is established, a pair of surveyors will walk the route at 5-minute intervals and record each species of plant identified.
5. Survey is completed when the route has been covered or after a time interval has passed and no new species have been observed.
6. Record estimations of plant percent cover and abundance upon completion of the route.
7. AAs can be classified into low, moderate, or high invasive-occurrence management categories based on the estimations of percent cover within each AA.



Assessment Area Timed Meander Route (Huebner, 2007). Method of performing a Timed Meander survey. Surveyors walk in 5-minute intervals along a pre-planned route and record plant species found.

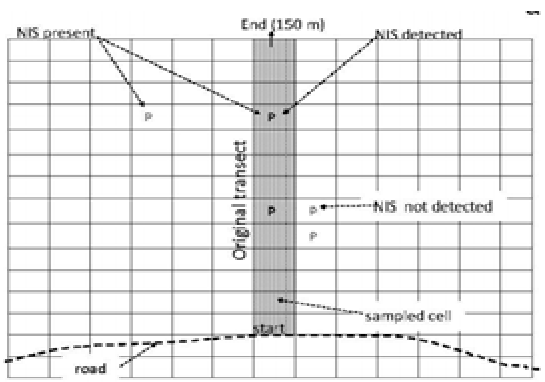
Adaptive cluster methodology

Adaptive cluster design is optimized to provide unbiased sampling that reflects the clustered, biological distribution of invasive plant species populations (Backus et al., 2011). It's an improvement on conventional methods as it adds spatially linked survey units when target invasive species are identified (Maxwell et al., 2012). The following method is from Maxwell et al. (2012):

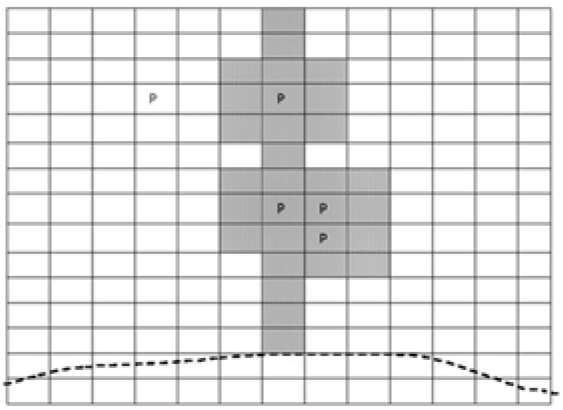
1. A fixed sample transect length is devised. This sets the parameters for minimum and maximum search distance as shown in the image on the left.

2. Surveyors follow a transect line and record instances of target invasive species presence.

3. For adaptive king cluster, each unit adjacent to a 'presence-detected' unit is surveyed until the maximum distance is reached or a new instance of invasive species is detected as shown in the image on the right.



Simple Random Transect with Survey Distances (Maxwell et al., 2012). Surveyors follow the transect and record presence of invasive plant species



Adaptive King Cluster Method (Maxwell et al., 2012). Surveyors follow transect and record presence of invasive plant species. Each adjacent unit to the 'presence-detected' unit is surveyed until maximum distance is reached or no new invasive species are detected

Species Richness or Diversity Sampling Method

This is a method that can be used to determine the species richness or diversity of a park. The idea is that by sampling along a transect within a park area, such as the trail buffer or along a stream, you can collect data on that area and then run statistics. The method is as follows:

1. Select the area you wish to survey; this can be open areas, within buffers, or along transects through an entire park.
2. Determine the bearing and distance that the transect will run. Calculate the distance between plots based on the total length of the transect divided by the desired number of plots. Based on the type of area being surveyed decide whether to use a 3.99m or 5.64m plot radius.
3. In the field, run the pre-determined transect and throw plots (3.99m or 5.64m) and count the number of species or number of individuals of each species within the plot.
4. Compile data in an excel document and run statistical analysis using RStudio.