Part 1: Jericho Park Baseline Inventory Report

University of British Columbia

Masters of Sustainable Forest Management

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Executive Summary

This report is the first of a two part report prepared for the Vancouver Parks Board in partnership with the Department of Forestry at the University of British Columbia. The premises behind the project were to design a baseline inventory methodology for forested parks in Vancouver, and to implement this methodology at one of these parks. Jericho Beach Park was chosen for its proximity to the University, its size, the high potential for restoration and habitat enhancement, and the high level of public investment in the park. Management recommendations based on the findings of this baseline inventory are made in Part 2.

Phases of the project included study design, field data collection, data compilation and analysis, limited stakeholder consultation, and formulation of management recommendations. Field data was primarily collected through September and October 2012, and was supported by several site visits made through the winter and into April 2013.

The results of the baseline inventory indicate that the vegetation at Jericho Park is largely dominated by non-native species trees and shrubs and aging red alder. Jericho Park has undergone several waves of land disturbance over the past 150 years, resulting in young stands that in some ways are fairly unnatural in composition. The forest at Jericho Park is transitioning from early successional stands dominated by shade intolerant native broadleaf species, to stands of shade tolerant hardwoods dominated by introduced sycamore maple, with smatterings of other exotic species such as horse chestnut and walnut. In many areas there are few regenerating conifers or native broadleaves. Instead the understory is widespread with Himalayan blackberry, Japanese knotweed and other invasive species. There is a deficit of downed woody material on the forest floor and of standing dead snags throughout the park. In general, although some elements of a natural coastal forest can be observed at Jericho, many ecologically significant components are missing.

Jericho Beach Park Baseline Report

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Summary of Contributions

This project was a combined effort by Joanna deMontreuil, Leah Ballin and Dr. Steve Mitchell. Joanna and Leah designed the methodology and collected the plot data. Joanna took the lead on the majority of Part 1 – Baseline Inventory including orthophoto interpretation and stratum delineation, vegetation data entry, analysis and interpretation, invasive plant mapping, biodiversity indices and the majority of the writing. Leah wrote the history and soils sections, and analyzed and interpreted the coarse woody debris and snag data, and wrote relevant text. Joanna and Leah contributed equally to Part 2 – Management Recommendations. Dr. Steve Mitchell acted as the academic advisor throughout the project, compiled the raw field data and provided editorial input on the final report.

Introduction

Scope and Approach

The objective of Part 1 of this report is to provide baseline information regarding the current state of the forested area of Jericho Beach Park. This baseline will be used to guide the formulation of management recommendations, in Part 2 – Management Recommendations. This project was initiated by Dr. Stephen Mitchell of the UBC Faculty of Forestry and Katherine Isaac of the Vancouver Parks Board. The project was completed in three main phases. Phase 1, project design and field data collection, was completed in the fall of 2012 by Leah Ballin and Joanna deMontreuil, students in the UBC Master of Sustainable Forest Management (MSFM) program, with the assistance of several undergraduate volunteers. Phase 2, data compilation and analysis, was completed during December 2012 and the early part of 2013. Phase 3, formulating management recommendations, occurred throughout the project and was completed in April 2013.

The information used in this report comes from multiple sources. Meetings and interviews with parks board staff (Isaac & Duncan, 2012; Page & Stevens, 2013) set the scope and application of this baseline report. The vegetation and site information was collected by the two authors and three volunteers. Geographic Information System (GIS) data was obtained through VanMaps, Google Earth, a GPS device, and BC Data Warehouse. The management recommendations are informed by the baseline inventory data, personal observations and experience, discussions with various stakeholders including members of the Jericho Stewardship Society, conversations with local biologists and restoration experts, and extensive literature review of current practices. A previous management completed by Dave Hawes (1981) provided valuable insight to the parks ecology, history and potential management actions.

Location

Jericho Beach Park (Jericho) is located in the West Point Grey neighbourhood of the city of Vancouver (Figure 1). Jericho is a relatively large city park, covering 46.7 hectares (ha) (City of Vancouver, 2012). It is close to the larger Pacific Spirit Regional Park, and several smaller city parks, including Locarno and Kits Beach. The park is immensely popular, and offers a variety of recreation facilities such as tennis courts and fields, picnic tables and an ocean swimming area, in addition to trails in the upland forested area (City of Vancouver, 2012).

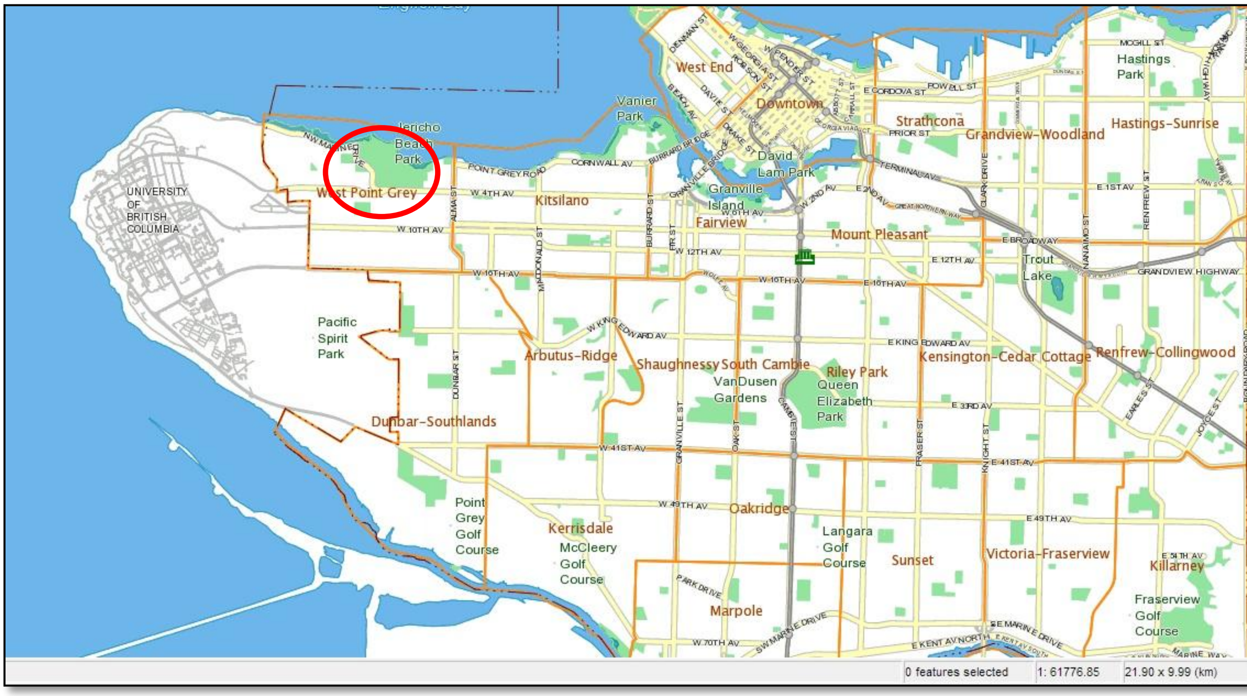


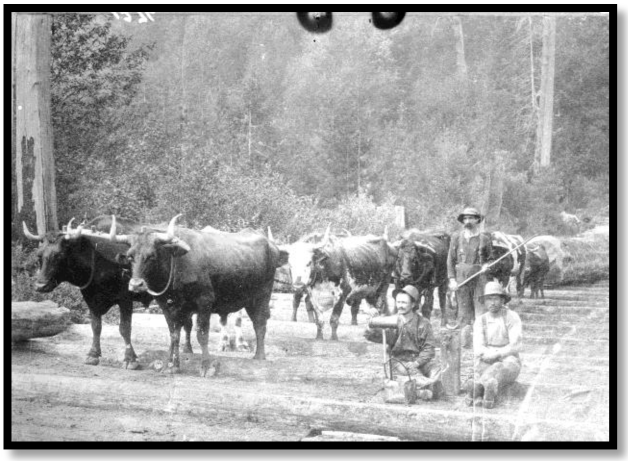
Figure 1: Jericho Beach Park location in the Metro Vancouver context. Map scale 1:61777. (City of Vancouver, 2012)

History

The condition and uses of the land which now forms Jericho Park have changed dramatically over the past 150 years. The area transitioned from a First Nations village, to a timber operation, to a golf course, to a military base, and now to a park (Figure 2; Appendix 1: Historical Photographs) (Hawes, 1981).

When Europeans first surveyed the site in 1863, the area was a natural lagoon and freshwater outflow to the ocean bordered by a Musqueam village to the west. The value of the large, straight timber on site for masts was recognized by surveyors and the land was set aside as an Admiralty reserve. In 1865, soon after the reserve was established, an entrepreneur named Jerry Rogers (after whom Jericho is named) set up an unauthorized logging camp on the east side of the forested park. Roger's operations focused on the cutting of spars for the new Hastings Mill. This unlicensed setup was eventually discovered, forcing the entrepreneur to obtain a Land and Timber lease from the Crown. Rogers freed himself of obligations to the

Hastings Mill and built his own successful logging operation based out of his home at what was then called Jerry's Cove. It was this operation that was eventually responsible for clearing all of what is now Jericho Park. Rogers died in 1875, leaving the property relatively unused until 1882 when the Vancouver Golf Club (also called the Jericho Country Club) was established on the site. This nine, and later eighteen-hole golf course, the first green west of Toronto, was intended for Vancouver's elite, who barged from the city centre to the park. However, the storms and high tides were unfavorable to the higher classes, so berms and flood gates were built in addition to the usual golf course landscaping. Golf remained the primary use of Jericho, save for a small seaplane hangar by the shore, until 1942, when the property reverted to the military for use as a base to support Second World War efforts. At this time the land was modified extensively by land filling, dredging ditches, paving operational areas and the construction of military buildings. Following the war, the military base was largely abandoned and nature slowly re-claimed the area. In 1976 the site was sold by the Federal Government to the City of Vancouver for the establishment of a new park. An array of landforms were built and the ponds excavated, lined and filled with water to enhance the recreational and wildlife habitat values of the foreshore and toe-slope areas (Hawes, 1981; Hanna, n.d.; Vancouver Natural History Society, 2001)(Figure 2: Historic uses of Jericho Park including Jerry Rogers logging operation in the late 1800's and the military base in the mid 1900's (Royal BC Museum Archives) (Use of these photographs has been permitted by the Royal BC Museum for the purpose of this project only and should not be used for any other purpose without permission of the Royal BC Museum).; Appendix 1: Historical Photographs). During the short history described the uplands were modified extensively. Some remnant tree planting such as the Lombardi poplar, excelsa cedar and apple trees can be viewed around the park.



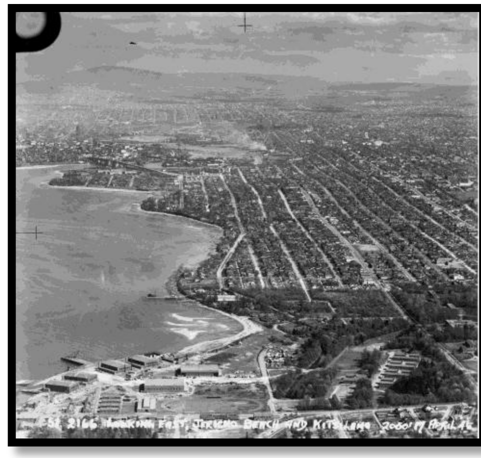


Figure 2: Historic uses of Jericho Park including Jerry Rogers logging operation in the late 1800's and the military base in the mid 1900's (Royal BC Museum Archives) (Use of these photographs has been permitted by the Royal BC Museum for the purpose of this project only and should not be used for any other purpose without permission of the Royal BC Museum).

Landscape and Physical Features

Jericho Beach Park extends from the shores of English Bay to 4th Avenue and supports a mix of forest, open meadow, and beach areas. The terrain in the wooded area gently slopes uphill to the south at an average slope of 6.5%. Geographically, the park is in the Coastal Western Hemlock biogeoclimatic zone, very dry maritime subzone (CWHxm1) (Meidinger & Pojar, 1991). In general, the CWH is the wettest biogeoclimatic zone in British Columbia (BC), with cool summers and mild winters, however the xm1 is the warmest variant and often experiences extended dry periods in the late summer, (Meidinger & Pojar, 1991). The park is surrounded by urban areas, and the native soils and plants typical of the CWH zone have been heavily disturbed. If the city of Vancouver did not exist, one would expect to find a coniferous forest dominated by Douglas-fir (*Pseudotsuga mensziesii*), western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*). The understory would have large components of salal (*Gultheria shallon*), dull Oregon-grape (*Mahonia nervosa*) and red huckleberry (*Vaccinium parviflorum*), with patches of herbs including vanilla-leaf (*Achlys triphylla*), sword fern (*Polystichum munitum*), twinflower (*Linnaea* borealis) and bracken fern (*Pteridium aquilinum*). The moss layer would be primarily Oregon beaked moss (*Kindbergia oregana*) and step moss (*Hyloclomium splendens*) (Meidinger & Pojar, 1991; Green & Klinka, 1994). Early accounts of the property describe tall trees, evergreen berries, and swampy forests (Hawes, 1981).

Soils

The soils at Jericho Park are complicated and largely variable over the landscape. One-hundred and fifty years ago, when European settlers first surveyed the site, the soils were described as very rich. The drainage basin at Jericho caught moisture originating from the slopes as far south as 28th Avenue and deposited some of the sediments in the Park, carrying the remainder out of the lagoon to the sea (Hawes, 1981).

Several waves of earthworks including fill, building, infrastructure development, and landscaping have taken place (

Figure 3 Development layout at Jericho Park over time). This intermittent development paired with an early succession forest and largely exotic vegetation composition has resulted in soils which have not yet re-developed the sequence of horizons that are typical in native forests.

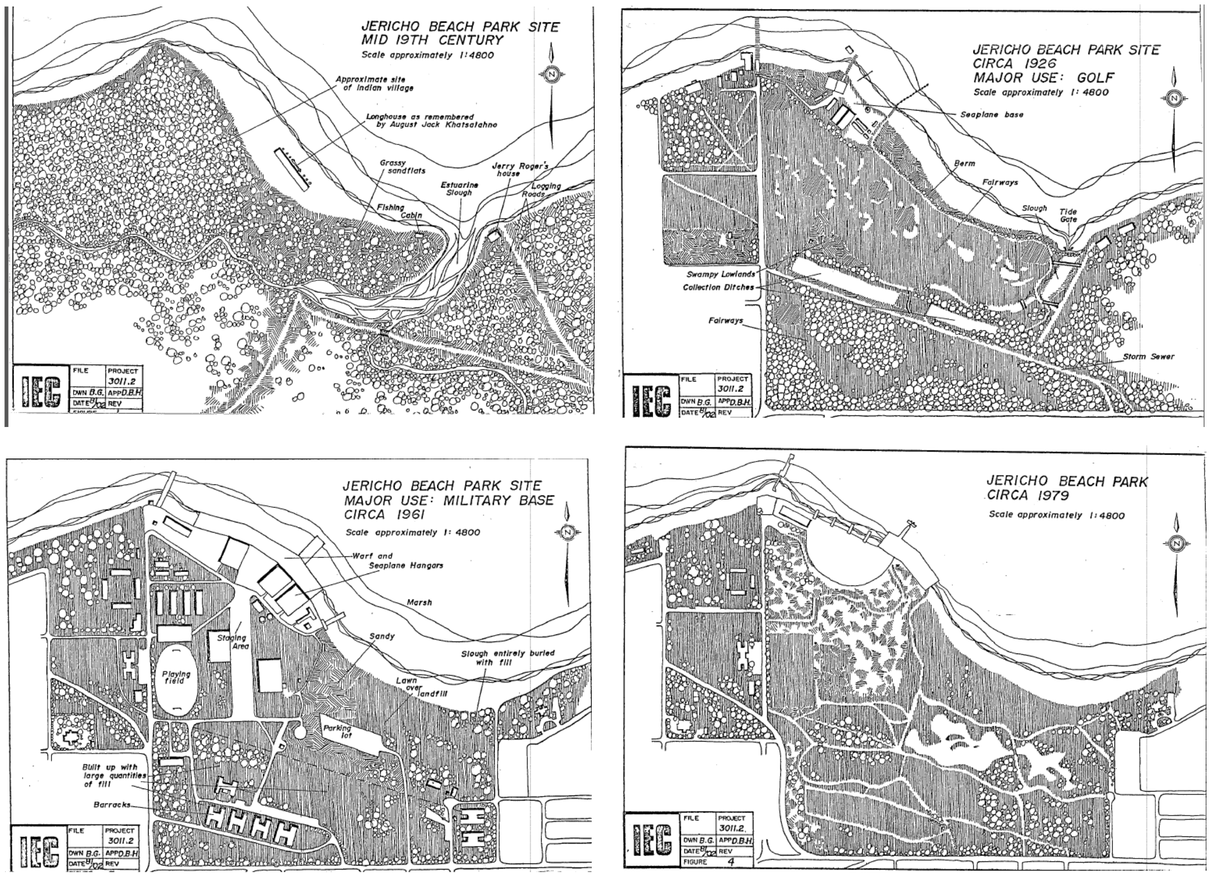


Figure 3 Development layout at Jericho Park over time (Hawes, 1981)

Stakeholders

The Jericho Stewardship Group (JSG) is a volunteer group actively involved in caring for and restoring the natural areas of the park. Their work has focused on invasive plant removal and maintaining native species throughout the forest, foreshore areas and meadows. Some members have worked in the park for several years, and are intimately familiar with the vegetation patterns and how they have changed in time.

The park is extremely popular and used all year round by residents as well as visitors. The forested area receives less use than the playing fields and beach, but is regularly visited by dog-walkers and joggers (Appleton & Coope, 2012).

Methods

Preliminary Stratification

For the purposes of this report, field data collection was limited to the forested area of the park and the meadow areas that are dispersed throughout the forested area. The western-most, non-forested wetland/marsh area that is adjacent to the forested area was included, but was not intensively sampled, as was the isolated strip west of Beach Drive (Figure 4).

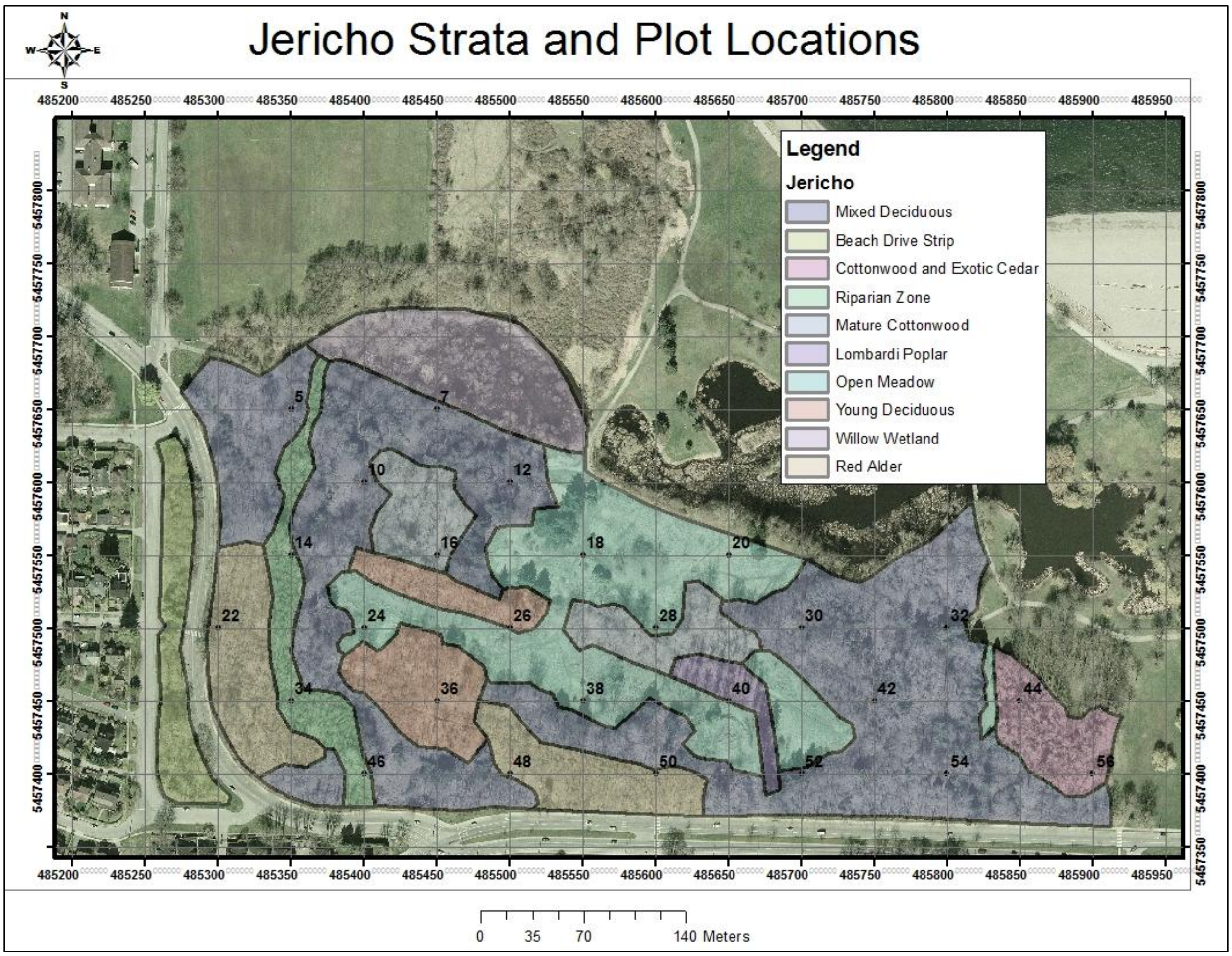


Figure 4: Strata and plot locations for the baseline inventory.

The boundary of the study area was determined using aerial photography from various sources, mainly Google Earth (Google Inc. , 2012) and Vanmaps (City of Vancouver, 2012). Both sources provide orthophoto images from multiple years, and from different times of year. Using these images, the different forest cover types were stratified (Table 3). A geodatabase was created in

ArcMap 10.1 (ESRI, 2012), and strata boundaries were digitized. After digital mapping, field reconnaissance was conducted to confirm the strata distinctions and boundaries.

After field reconnaissance, it was determined that although there are some areas where one or several species dominate (eg. the red alder leading stratum), most of the forest area is a heterogeneous and intergrading mix of species. However, the original strata were maintained for the survey, in order to determine if more subtle patterns would emerge following data analysis.

Field Sample Plots

The strata map was overlaid with a 50 x 50m UTM grid. Originally, all vertices were labelled (1-56) as potential plot locations. Due to time constraints, the plot spacing chosen was 50x100m, and plots were established at half (26) of these potential sampling points. The plots chosen were systematically chosen as every other plot from the grid. The 50m length is oriented north-south, to better sample the variability on a gradient downslope, which represents the gradient from upland to ocean. Plots at successive north-south positions were also offset 50m east to west, to better distribute plots between strata and capture variability across the study area. Most strata have at least two plots, except for the small Lombardi Poplar and the Mature Cottonwood strata, which only have one.

Plot Measurements

Measurement procedures generally followed the Land Management Handbook (LMH) 25 – Field Manual for Describing Terrestrial Ecosystems (Province of British Columbia, 2010), with some modifications specific to this project. The FS882 Ecosystem Field Form (Appendix 3: Data Collection Card-FS882) was used to collect the data.

All data (tree and understory vegetation) was collected using 5.64m (0.01ha) radius circular plots (Table 1). This plot size was chosen because it balanced a reasonable number of sample trees per plot, with efficiency.

There were certain circumstances where the procedures in LMH 25 were departed from, for example, where plots landed fully or partially on trails. In this case, plots were offset in increments of five metres in a cardinal direction. First the surveyor attempted to move five metres to the south, if that direction was still in a heavily disturbed area, then to the west, and then to the north, and lastly to the east. The intent was to move the plot center off of trails while minimizing bias.

Table 1: Data collected on the FS882 field card.

Section on Card	**Data Collected**
Site Description	
General location	Brief decription of plot location features, i.e., Stratum name plus identifying feature
East/North	UTM coordinates, determined using handheld GPS
Accur.	Accuracy of GPS unit at the time of plot determination
Elev. (m)	Elevation in metres, determined using GPS
Slope (%)	Determined using clinometer
Aspect	Direction of slope
Mensuration	
Tree spp.	Species code of trees recorded in the plot, i.e., red alder recorded as Dr
DBH	Diameter measured with a dbh tape for all trees larger than 7.5cm diameter
Total Ht	Height measured with the laser
Cnt. Ht	Estimated height using visual assessment
Small Trees (not on original version of card)	Record spp and tally number of each species in the plot
Regen Trees	As above
Vegetation	
Trees	Recorded by percent cover by layer (A1, A2, A3 etc)
Shrubs	Recorded by percent cover by layer (B1, B2)
Herb Layer	Recorded by percent cover

Moss/Lichen/Seedling	Recorded by percent cover

Table 2: Tree and shrub layers used in survey.

Layer	Description
A1 – Dominant trees	Tallest trees of the main canopy, usually veterans, or trees that survived one or more fires. Usually a minor portion of the stand.
A2 – Main tree canopy (codominant trees)	Main layer of tree cover, crowns form the upper layer of foliage.
A3 – Sub-canopy trees	Trees greater than 10m in height, but do not reach the main canopy.
B1 – Tall shrub	All woody plants 2-10m tall, and advance tree regeneration less than 10m in height.
B2 – Low shrub	All woody plants less than 2m in height, including tree regeneration

In addition to the FS882, an extra plot card was developed specifically for this project to collect data on coarse woody debris (CWD), photograph records, and wildlife features. See Appendix 3: Data Collection Card-FS882 for a sample card. Tree species were identified using (Pojar & MacKinnon, 2004). Some species that have 'tree-like' form, such as holly or laurel, are not included as tree species. The exception is vine maple, which was counted as a tree.

Coarse Woody Debris

Coarse woody debris is defined as dead woody material that is in various stages of decomposition that is located above the soil, and is self-supporting (Province of British Columbia, 2010). It is well accepted that coarse woody debris (CWD), and especially large coarse woody debris, is an important component of forest ecosystems because it plays a significant role in ecosystem function including nitrogen cycling, soil development and water retention, and provides habitat for several species of plants and wildlife (Chief Forester, 2010; Fenger, 2006; Gerzon M. , 2009).

Data on CWD was collected using a line-intercept transect sampling method. The methodology for this survey was modified from the LMH 25 guidelines. Due to time constraints, the transect length was reduced from the 24m suggested in the LMH 25 to 12m. The azimuth for the first transect was determined randomly by spinning the compass housing three times. The azimuth for the second transect was determined by adding 90 degrees to the first azimuth. As the transects were traversed, all CWD encountered was measured for log diameter at the transect line intersection, log length and decay class. The minimum diameter log recorded at the transect crossing was 7.5 cm (Province of British Columbia, 2010), as this is the minimum size that is expected to persist and contribute to habitat. If a strata edge or trail was encountered a "bounceback" method was used by changing direction to the right by 90 degrees if possible, and if not, then to the left by 90 degrees and finishing the transect (Bate, Torgersen, Wisdom, Garton, & Clabough, 2008). Figure 5 demonstrates the decay classes used for classifying coarse woody debris in this survey.

	Class 1	Class 2	Class 3	Class 4	Class 5
Wood Texture	Hard	Sap rot (but still hard, thumbnail penetrates)	Advanced decay (spongy/large peices)	Extensive decay (crumbly-mushy)	Small pieces, soft portions
Portion on Ground	Elevated on support points	Elevated but sagging slightly	Sagging or broken	Fully settled on ground	Partly sunken
Branches	Hard branches with twigs	Soft branches	Branches/stubs absent	Absent	Absent
Bark	Firm	Loose	Trace	Absent	Absent
Wood Appearance	Fresh/recent	Colour fading	Fading colour	Light or brown	Reddish brown
Wood strength	Supports person	May not support person	Breaks easily. Pieces snap	Collapses with weight. Pieces do not snap	Feels firm like ground
Invading Roots	None	None	In sapwood	In heartwood	In heartwood

Figure 5: Decay classes of coarse woody debris, from LMH 25.

Photographs

Photographs were taken at every plot. The view from each cardinal direction (north, east, south, and west) and the plot centre were photographed, along with distinguishing or unique features of the plot, or unknown plant species. The photo number (as automatically assigned by the camera) was recorded, along with the direction facing, and any features that were important to record.

Wildlife Features

All evidence of wildlife use was recorded on the bottom section of the form. This included observations of nesting cavities, evidence of animal presence (i.e. footprints), or potential wildlife habitat features (i.e. large snags).

Data Compilation

The data was collected on paper plot cards in the field, and was transcribed to digital format in MS Excel upon the completion of field sampling.

For interpretation using Statistical Analysis System (SAS) (SAS Institute, 2003), the vegetation and CWD data was first converted to flatfile (row/column) format in Excel. The SAS code for various analyses was written and executed by Dr. Stephen Mitchell, project supervisor.

Coarse woody debris summary statistics were calculated using SnagPro formulas (Bate, Torgersen, Wisdom, Garton, & Clabough, 2008) including those for logs per hectare (a), volume per hectare(b), and percent cover (c) of coarse woody debris (Figure 6 Formulas for calculating CWD volume, logs per hectare and percent cover).

$$\text{Logs per hectare} = \left(\frac{5\pi 10^3}{L_m}\right)\sum^{n}\left(\frac{1}{l_{m_i}}\right) \qquad [1a]$$

where

L_m = length of transect (meters),

n = number of logs intersected, and

l_{m_i} = length (meters) of the i^{th} log intersected.

$$\text{Volume (m}^3\text{/ha)} = \left(\frac{\pi^2}{8L_m}\right)\sum^n d^2_{cm_i}$$

b

d_{in_i} = diameter (in) of log i at point of intersection.

$$\text{Percent Cover} = \left(\frac{\pi}{2L_m}\right)\left(\sum^n d_{cm_i}\right)$$

c

Figure 6 Formulas for calculating CWD volume, logs per hectare and percent cover

Quantifying the forest structure was an important goal of this inventory. Structural attributes can be used to indicate various features of the forest, such as biodiversity (McElhinny, 2002). The attributes used for this inventory include measures of tree size (diameter and height), as well as the density (stems/ha). Collectively, these attributes are referred to as *stand structure*. Understory vegetation was also examined in terms of species richness (number of species by life form or vegetation type in each plot), and abundance (percent cover by life form or vegetation type). Non-native species in the tree or understory layers were classified as exotic or invasive. This designation was based on observations made during the survey. If a species was non-native, but appeared infrequently and was not displaying tendencies toward creating monocultures, it was deemed 'exotic'. Non-native species that had a wide distribution through the park, tended to form monocultures and were obviously out-competing native vegetation were classified as 'invasive'.

Project Limitations

The most important limitation of this project was the timing of the field work. Plant sampling in the fall was difficult and misleading, as many herbaceous species were dying back, and deciduous species were losing their leaves. Fall sampling also precludes short-lived spring and summer herbs from being included in the inventory. This base line could be improved through the addition of survey data from other seasons, to fully capture the diversity of plant species.

A systematic sampling design was used in order to facilitate data collection with the time available for field work, and to allow for easy plot re-location for future monitoring by those unfamiliar with the project. All sampling had to be completed before complete leaf-fall and the associated challenges in plant identification. Using a systematic grid sample meant that there was unequal plot distribution among the strata, and summary statistics had to be weighted by stratum size in order to accurately summarize data to the forest level. A plot density proportional to stratum size could have been used to ensure equal representation of all strata, but may lend to having more plots per stratum than necessary to adequately represent the within-strata variability.

Results

Vegetation Strata

The vegetation communities were divided into 10 strata ranging from 0.2 to 6.2 ha (Table 3). The mixed deciduous strata dominated the treed portions of the park.

Table 3: Strata names and descriptions. Descriptions are key features that were used in photostratificaiton.

Stratum Name	Stratum Size (ha)	Key attributes used in photo-stratification
A – Mixed Deciduous	6.2	Mixed species. Mb, Dr, Act and scattered conifer overstory.
B – Open Meadow	2.7	Open areas, dispersed through forest.
C – Alder leading	1.3	Fairly uniform canopy of Dr.
D – Cottonwood and Conifer	0.5	Isolated patch in east corner of sample area, overstory Act and Dr with understory Cw.
E – Riparian Zone	0.6	Small creek running south to north through western side of sample area.
F – Young Deciduous	0.9	Dominated by Dr, with some Act and Mb mixed throughout.
G – Mature Cottonwood	0.9	Areas with apparently broader topped trees, assumed to be Act.
H – Lombardi Poplar	0.2	Rows of large planted trees.
Recce – Willow wetland	1.0	Marshy area in north part of sampling area. Recce level assessment, no sample plots.

Recce - Beach Drive strip	0.6	Small isolated strip along Beach Drive. No sample plots.

Mixed deciduous– Stratum A

The mixed deciduous forest cover type is the largest and most heterogeneous of all the strata. It has the greatest variation in terms of species mix, distribution and age, and is mostly composed of deciduous species with small patches of young or mature conifers.

Open Meadow – Stratum B

The Open Meadow stratum encompasses all non-treed areas. Most of this area is adjacent to trails, and has significant encroachment by invasive plant species. This strata was landscaped and hydro-seeded in the 70's and 80's. Some areas are currently maintained by mowing, planting new shrubs and tending of old orchard trees, while other areas have been left in a semi-natural state..

Alder Leading - Stratum C

This stratum is dominated by even-aged red alder (*Alnus rubra*). This is the most distinct forested stratum, in terms of species composition, tree height and age.

Figure 7: Tree structure common to the Alder leading stratum, notice understory sycamore maple.

Cottonwood and Conifer - Stratum D

This stratum is located in the eastern corner of the survey area. It has an overstory that is predominately black cottonwood (*Populus trichocarpa*), with an understory of a horticultural variety of western redcedar, called 'excelsa cedar' (*Thuja plicata excelsa*). The excelsa cedars have a distinct growth form, differing from the native redcedar in that they have denser branching and leaf patterns.

They likely will not grow as tall as native western redcedar.

Riparian Zone - Stratum E

This stratum follows the small creek that flows south to north through the park's western side, terminating in the wetland at the north end of the study area. The vegetation cover is quite similar to the surrounding strata A and C.

Young Deciduous - Stratum F

This stratum was identified as having uniform stand structure, in height and age. Field reconnaissance confirms that the stand composition is relatively uniform. It is red alder leading, with more of a species mix than the Young Alder stratum.

Mature Cottonwood – Stratum G

This stratum has larger trees with a distinct visual texture. The crowns are wide and have substantial branching; giving the tree tops a 'fluffy' appearance in the orthophoto. Trees in this stratum are mostly black cottonwood, with a few bigleaf maple and red alder. They are generally older, widely spaced and have full canopies.

Lombardi Poplar – Stratum H

This small stratum encompasses an avenue of Lombardi poplars (*Populus nigra*) planted along the trail. These trees are large and easily distinguishable on the aerial photographs.

Willow Wetland Reconnaissance

The vegetation in the wetland is a mixture of trees, shrubs and moisture-loving herbs and exotic grasses. The northeast corner of the wetland has more tree species, including red alder and cottonwood, than the rest of the wetland. The trees transition into a willow/alder complex in the middle of the wetland, and then to a more open and wet grassy area with only occasional, isolated willows. The east side of the wetland has tall cattails and grasses. Bird boxes (mostly for swallows) have been installed in this area. The JSG has done substantial work in this area attempting to eradicate invasive purple loosestrife (*Lythrum salicaria*) and yellow flag iris (*Iris pseudacorus*), however young stems are still common.

Beach Drive strip

This small strip of forest was isolated from the main body of the park by the construction of Beach Drive, along the west side of the park. This strip is most closely associated with Stratum A (Mixed) in the main body of the park. It has a mix of red alder, western redcedar and some scattered maple (including bigleaf and other unidentified species). Understory vegetation includes salmonberry, sword fern, and dull Oregon grape. There is also the usual complement of invasive species observed in other areas of the park, namely Himalayan blackberry (Rubus armeniacus), English ivy (Hedera helix), English holly (Ilex aquafolium) and laurel (*Prunus laurocerasus*). In addition, the south end of the strip appears to be a dumping area for Christmas trees.

Forest Level Summary

Some general characteristics can be summarized for the whole survey area. Table 4 demonstrates the average values for some common stand attributes. These means are calculated from weighted mean stratum values, to account for the variability of strata sizes.

Table 4: Forest level summary of stems per hectare, dbh, basal area, height and crown closure, for big, small and regenerating trees.

	Stems per Hectare	Average DBH (cm)	Average Basal Area/ha (m^2/ha)	Average Height (m)	Crown closure (average of plots with overstory)
All	1370	-	-	-	36
Big Trees (>7.5cm dbh)	500	24.5	37	22.4	-
Small Trees (2-7.5cm dbh)	292	-	-	4.9	-
Regen Trees (<2cm dbh)	577	-	-	-	-

Stems per Hectare

Overall, most of the stems are in the big and regenerating (regen) tree classes, with the greatest number of stems in the regen size category. Small trees contribute the least to overall density. This has implications for understory recruitment, the succession of the stand, and the future stand composition and structure.

Tree Species Composition

In total, 22 species of tree were recorded during this survey. This includes several unidentified species, and a few specimens of the genus *Prunus* that were not identified to species level.

The following diagrams are colour coded by tree type: deciduous, conifer or small tree. Deciduous have purple-themed colours, small trees have an orange theme, and conifers have a green theme. This colour scheme is meant to demonstrate the relative abundances of deciduous or coniferous trees in each diameter class. Figure 8 shows the tree species composition, for all size classes.

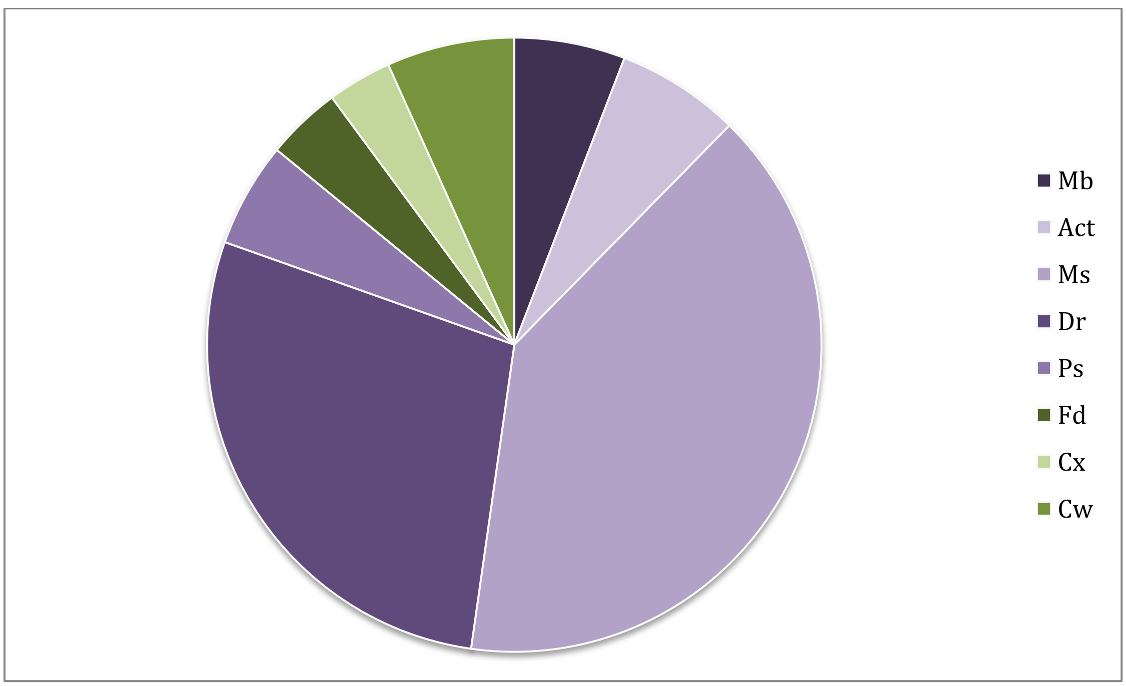


Figure 8: Tree species composition. Diagram includes major species only. Purple shades are deciduous, green shades are coniferous.

When all stems are considered, sycamore maple accounts for more than half the species composition. Red alder is the next highest, and below that the other species are more equally distributed. This diagram also demonstrates that conifers are only a minority component, and the forest is composed mainly of deciduous species.

It is more descriptive to summarize the stems per hectare by size class. This helps to demonstrate in more detail how the forest at Jericho is developing, and indicates the potential succession. The big tree size class is dominated by red alder (Figure 9: Tree species composition in the 'Big Tree' size class, weighted by stratum size.). This species is common and dispersed widely throughout the park. In this size class, sycamore maple is the least common species (included in 'Other' on graph). Coniferous trees make up 23% of species composition in this class.

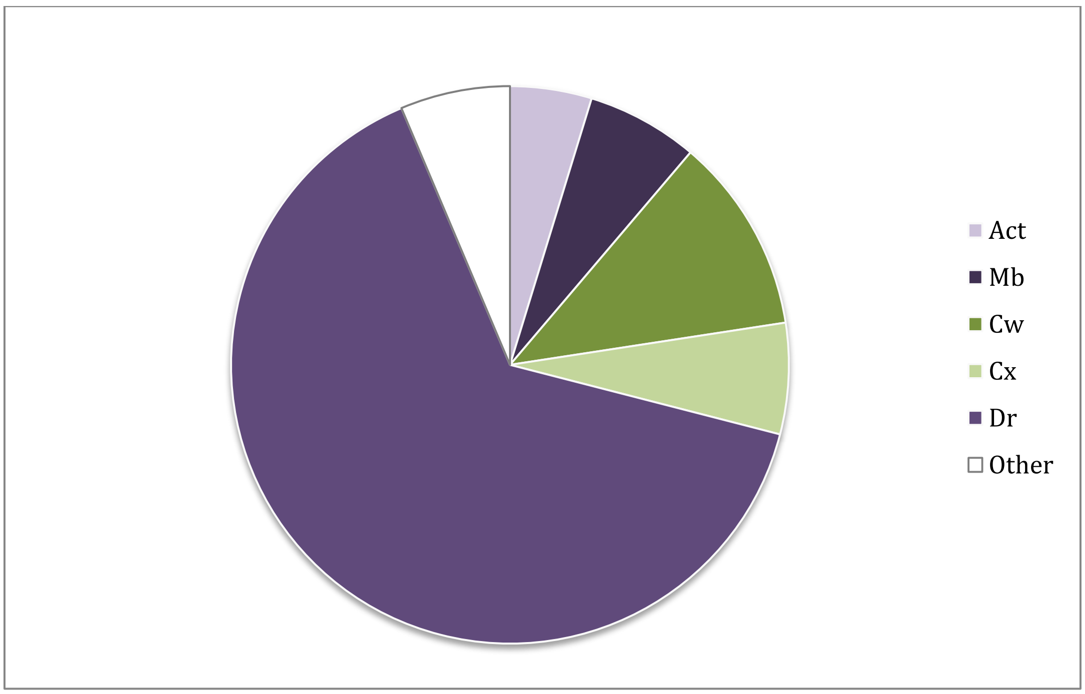


Figure 9: Tree species composition in the 'Big Tree' size class, weighted by stratum size.

Red alder is a 'pioneer' species that is often associated with disturbed sites. It can establish before other species on nutrient poor soils due to its ability to fix nitrogen. In native ecosystems, it often acts as a nurse crop for shade tolerant conifers, and in general enriches the site by making nitrogen more available in the soil (Klinka, Worrall, Skoda, & Varga, 2000). At Jericho, however, the alder is acting as a nurse crop for shade tolerant, sycamore maples. Very few regenerating conifers were counted in the survey or observed along the transects. Many of the conifers that do exist appear to have been planted. The alder on site is approaching maturity, and the understory that will replace it is mostly deciduous and non-native.

The small trees show a shift in species composition, red alder is a minor component, and sycamore maple represents over half of the stems per ha (Figure 10). Vine maple is included in 'Other' on this graph. In the survey individual vine maple stems were counted, but since this species has a multi-stem form, this results in an inflated value when comparing sph with single-stemmed species. The native bigleaf maple (*Acer macrophyllum*) is also strongly represented in this size class. Conifers account for only 3% of the stems per hectare in this size class, and are not displayed on the graph.

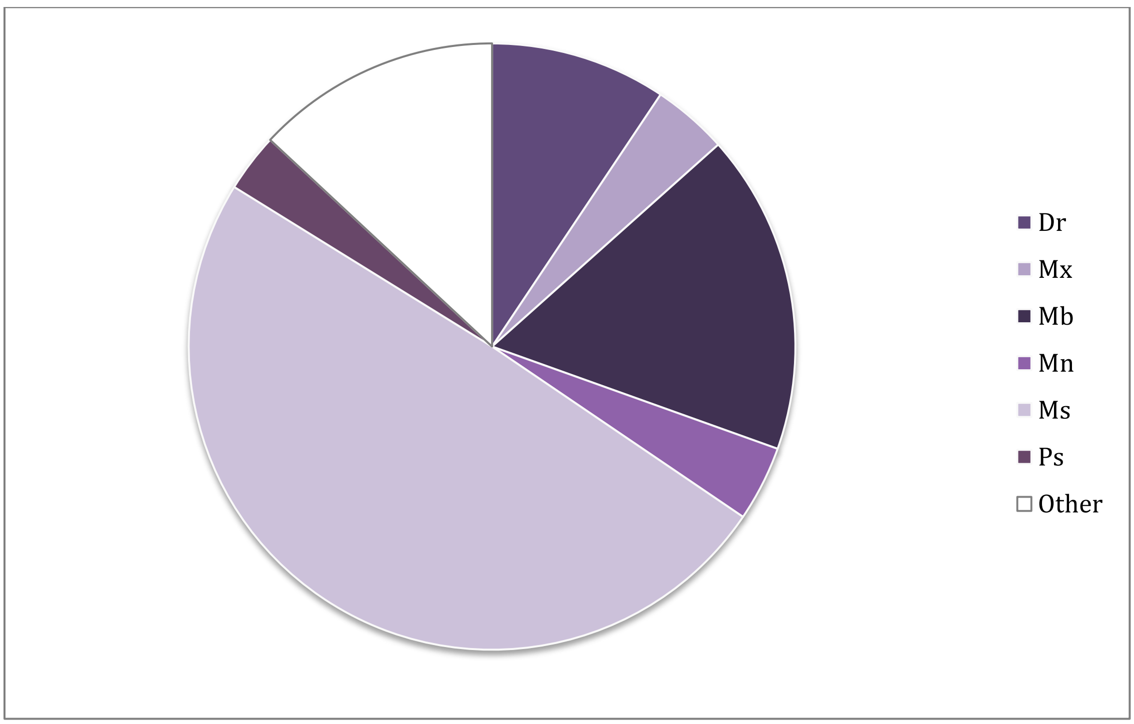


Figure 10: Tree species composition in the 'Small Tree' size class, over the treed portion of the study area. Mx refers to unidentified maple species. Mv is not included, due to the clumping nature of this species.

Sycamore maple dominates the regeneration layer (Figure 11). Coniferous trees in this size category, result largely from the planting efforts of the JSG and other conservation groups.

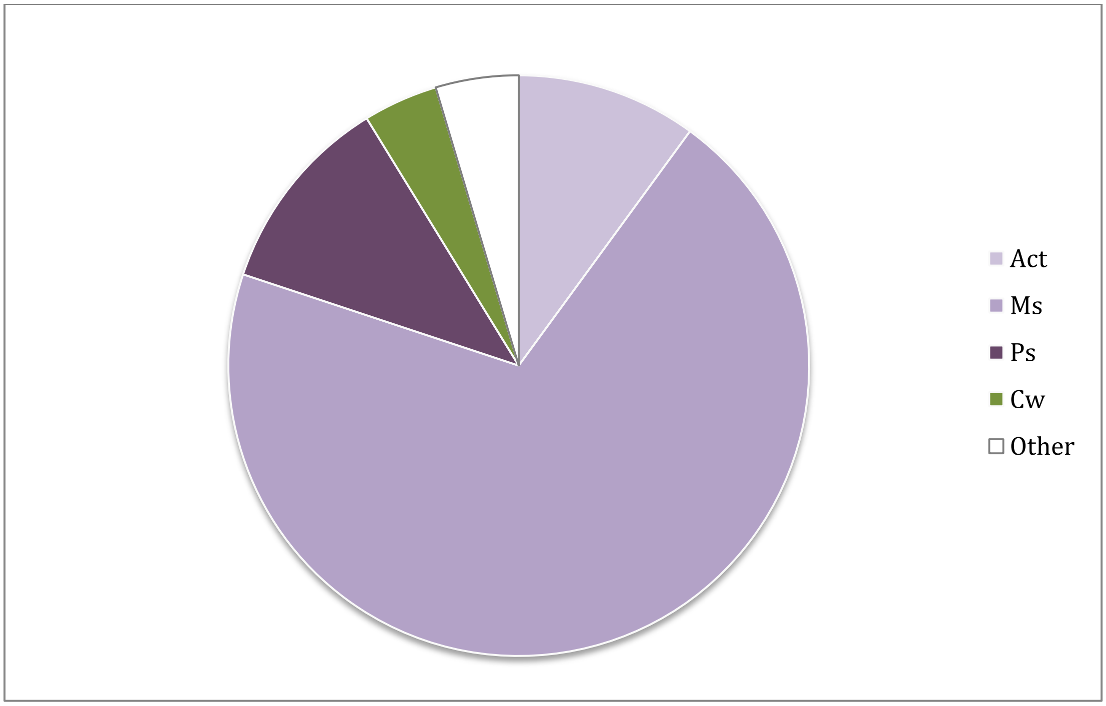


Figure 11: Tree species composition in the 'Regen Tree' size class, over the treed portion of the study area.

Diameter at Breast Height

The diameter at breast height (dbh) is a measurement of the stem diameter of trees. For this inventory, only big trees (>7.5cm dbh) were measured. The average overall dbh is 24.5cm. Using one average value is a very coarse measure, and it is more relevant to divide the stems into diameter classes. This is illustrated in a diameter-class distribution graph (Figure 12: Diameter class distribution for all big trees. The indicated value for the diameter class is the mid-point of that class. For example, diameter class 15 includes stems from 10-20cm in diameter. Diameter class 5 is actually representing diameters 7.5 to 10cm due to the dbh limit for big trees.). The bars below are colour coded in the same way as the stems per hectare diagrams.

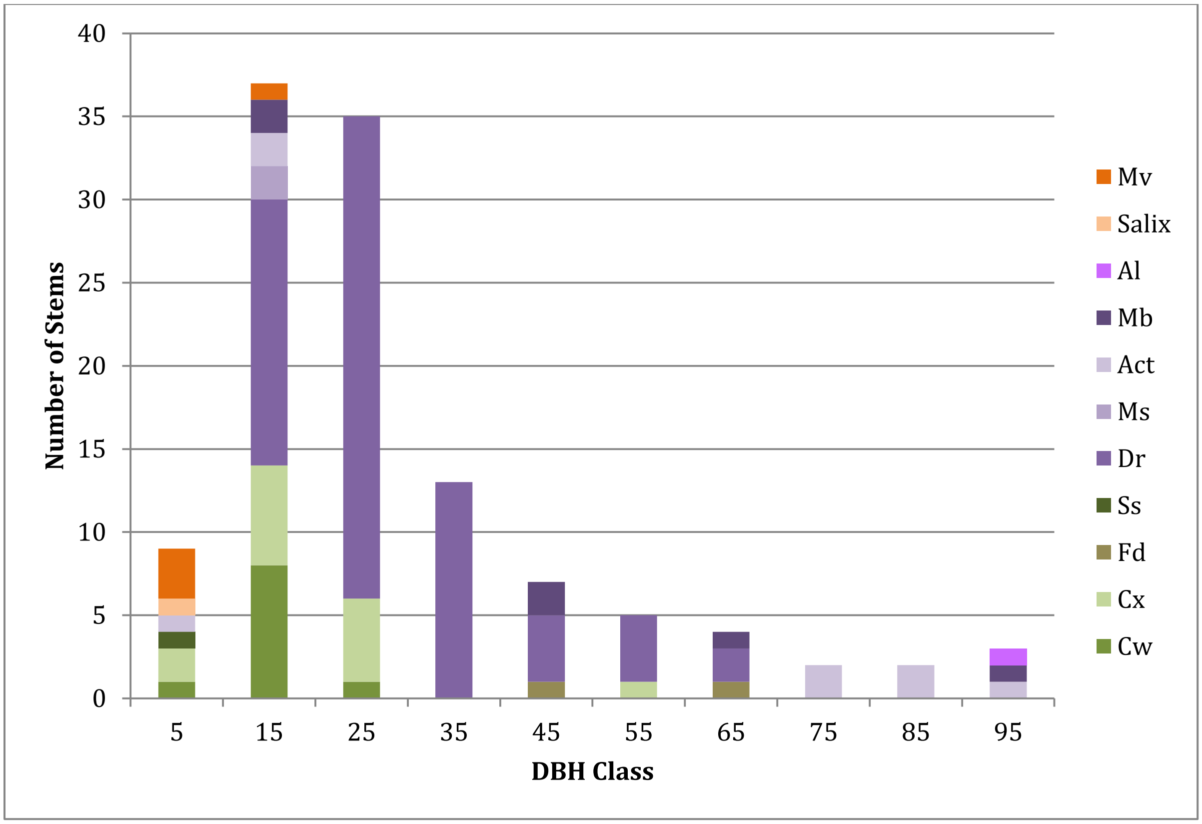


Figure 12: Diameter class distribution for all big trees. **The indicated value for the diameter class is the mid-point of that class. For example, diameter class 15 includes stems from 10-20cm in diameter. Diameter class 5 is actually representing diameters 7.5 to 10cm due to the dbh limit for big trees.**

The right-skewed distribution of the diameter classes indicates a predominance of stems in the 10-30cm diameter range. Over time, as trees grow and the stand self-thins, and the diameter distribution will likely shift to the right, but with fewer trees in each size class. Few deciduous trees are expected to reach diameters over 1 m.

Red alder dominates the large tree composition, especially in the diameter 10-50cm dbh range. There is a marked increase in the species diversity in the smaller size classes, and this includes exotics, and native tree species that do not attain large sizes.

Basal Area, Height, Crown Closure

Overall, the forest has an average basal area of 37m^2/ha. This is a very low value for a coastal forest. The second-growth conifer and mixed stands in Stanley Park have basal areas of 80 to 120m^2/ha (pers. comm. Mitchell, 2013).

The average height is 22.4m for large trees, and 4.9m for small trees. No heights were determined for regenerating trees. Jericho is dominated by deciduous species which can potentially attain heights of 30m, but the native conifer species would grow much taller at maturity (Klinka, Worrall, Skoda, & Varga, 2000).

The average crown cover, for the plots that had over story tree cover (i.e., A1 and A2 trees), was 35%. This is low for closed-canopy forests and indicates the amount of gaps and multi-storied nature of some strata.

Standing Dead Trees

There are approximately 19 standing dead trees (snags) per hectare at Jericho Park, all of which were red alder, averaging 14 cm dbh. Decay characteristics and heights were not recorded for these dead trees.

Coarse Woody Debris

The average volume of coarse woody debris (CWD) or downed wood (logs) in Jericho Park's forested areas is 21 m^3/ha, it covers 1.9% of the ground, has an average diameter of 10.7 cm, an average length of 5 metres, and an average piece size of 0.071 m3.

When this forest level summary is divided into decay classes, it becomes apparent that the largest volume, number of pieces, and piece size of CWD are in decay classes 1 and 2. Significantly fewer pieces were found in decay classes 3 and 4, and none were found in decay class 5 (Table 5: Number of pieces and volume per hectare, and average piece size of CWD in each of the five decay classes.

Table 5: Number of pieces and volume per hectare, and average piece size of CWD in each of the five decay classes.

Decay class	1	2	3	4	5
Pieces per hectare per decay class	188.0	134.5	16.8	7.5	0.0
Volume (m3) per hectare per decay class	9.5	8.3	3.6	0.1	0.0
Average piece size (m3) per decay class	0.052	0.069	0.050	0.0	0.0

Most of the CWD at Jericho has an average diameter of less than 30 cm (similar to the DBH of a mature alder tree) and is in decay classes 1 and 2. Logs ranging from 15-30 cm dbh have more wood in higher decay classes than logs with smaller dbh's. Only two pieces of CWD with a diameter over 30 cm were recorded on the transects, one in decay class 2, and one in class 3 (Figure 13: Pieces per hectare of each decay class of CWD by size class in the forested areas of Jericho Park..

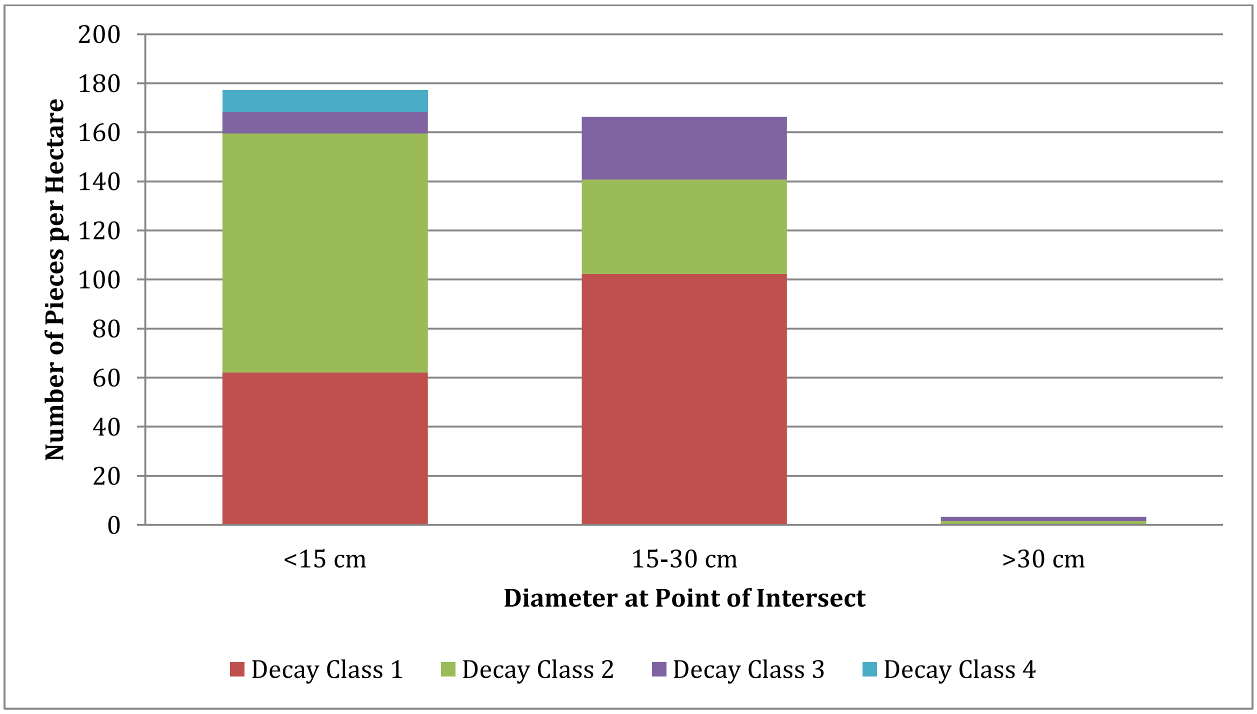


Figure 13: Pieces per hectare of each decay class of CWD by size class in the forested areas of Jericho Park.

Although most pieces of CWD have a diameter of less than 15 cm, the majority of the volume of CWD per hectare is between 15-30 cm diameters (Figure 14).

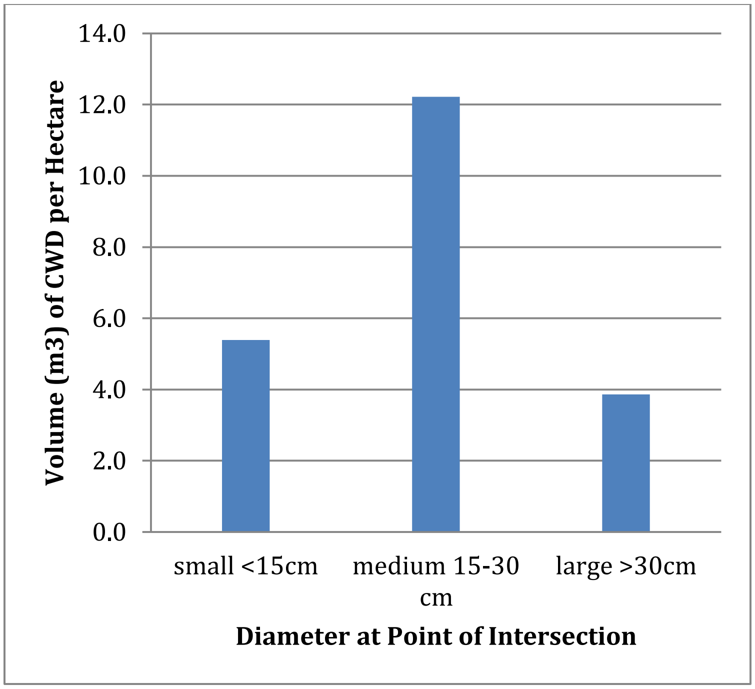


Figure 14: Volume (m3) per hectare of three size classes of CWD

Most of the coarse woody debris is deciduous in origin. Cottonwood branches constitute the largest pieces, and alder branches the highest number of pieces. Strata level summaries are in Appendix 2: Detailed Strata Level Summaries.

Understory Vegetation: Shrubs, Herbs, Moss and Lichen

The understory at Jericho includes shrubs, herbs, moss/lichen and small trees. Excluding tree species, 58 understory species were found in this survey (Table 6).

Within the understory, 24 species of non-native vegetation were found, most of which are herbs. The most frequently counted species was Himalayan blackberry (*Rubus armenicus*), counted in 21 of 26 plots. In fact, of the top five most frequently counted species, only one is native, salmonberry (*Rubus spectabilis*, 17 plots), and it is the third most frequent. The other top five most frequent species are English ivy (*Hedera helix*, 15 plots), English holly (*Ilex aquafolium*, 18 plots) and English hawthorn (*Crataegus laevigata*, 14 plots).

Overall, there is greater coverage by non-native species than by native species, in all vegetation types, except moss, where no non-native species were counted (Figure 15).

Table 6: Understory vegetation composition by vegetation type; shrub, herb or moss. All vegetation, including non-native species, are also displayed in terms of their percent cover.

	All vegetation	Shrubs	Herbs	Moss
Number of Understory Species, all	58	24	32	2
Percent Cover, all	63.1	39.1	20.9	5.2
Number of Non-native Understory Species	24	7	17	0
Percent cover non-native species	36.9	23.7	13.2	0

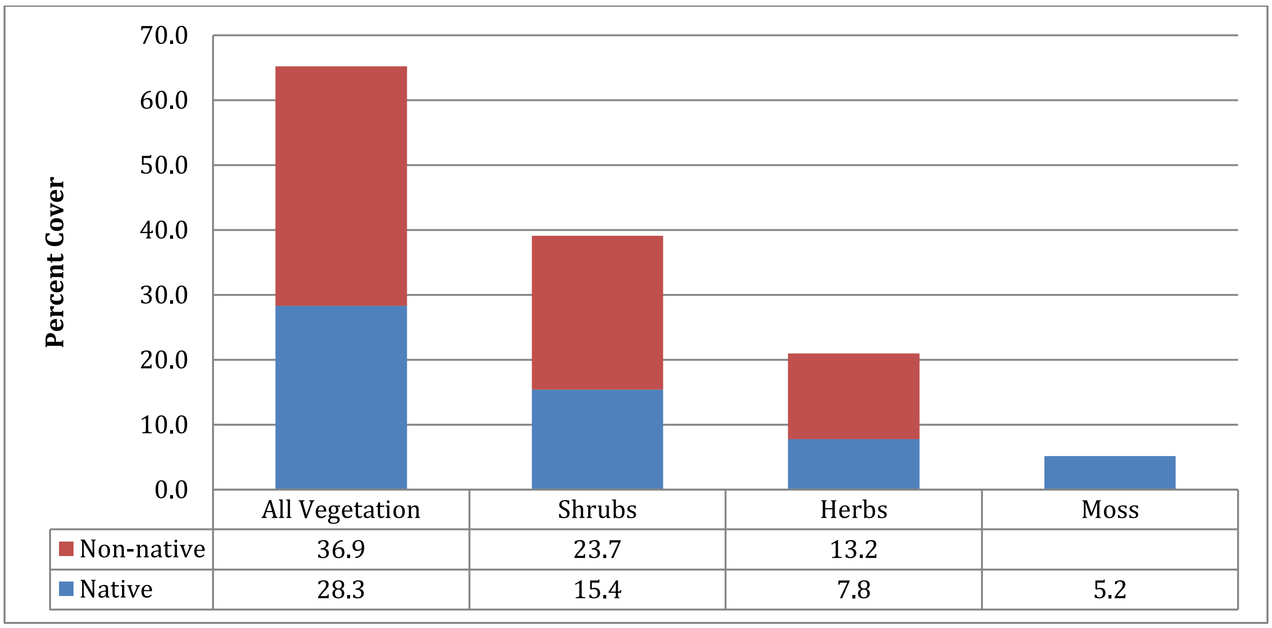


Figure 15: Forest level summary of percent cover by native and non-native species. Averages based on weighted mean values.

Several studies show that light availability is positively correlated with the percent cover of Himalayan blackberry (Caplan & Yeakley, 2006) however less may be known about the relationship between other invasive species and light availability. A simple linear regression of tree layer canopy closure versus percent cover by non-natives shows that there is only a very weak relationship between these two variables (R^2=10.9%, P=0.00) at Jericho. This is consistent with some research on Himalayan blackberry, where it has been concluded that while light is the primary factor limiting Himalayan blackberry growth, it is not the only factor determining its distribution (Caplan & Yeakley, 2006). Further comparing the top five most common non-natives species (discussed above) to light availability produced no significant results. This implies that the most common non-native species in the park are relatively tolerant to the current canopy conditions, and will persist given the current canopy closure and composition. However, these results do not differentiate between coniferous and deciduous canopy closure. Some invasive species, including Himalayan blackberry are evergreen and may incur significant growth before overstory deciduous trees leaf out.

Japanese Knotweed is also present in relatively discrete patches in the Park. It forms a relatively small proportion of percent cover (as determined by the survey), but it is a species of particular concern for management. The clumps of knotweed in Jericho appear to be situated close to the open meadow stratum, along trails, and in areas where crown closure is lower (Figure 16). The red arrow indicates a plot which is adjacent to a patch of knotweed, and while it is a forested plot, it only has 8% crown closure by overstory layers. This indicates the potential for the knotweed to spread into forested areas that have low crown closure. Forested strata with the lowest crown closure already have knotweed (Stratum G, B), or are close by existing clumps (Stratum E). The occurrence of these clumps along or nearby trails indicates that it is likely spreading through human, dog and wildlife traffic along these disturbed corridors.

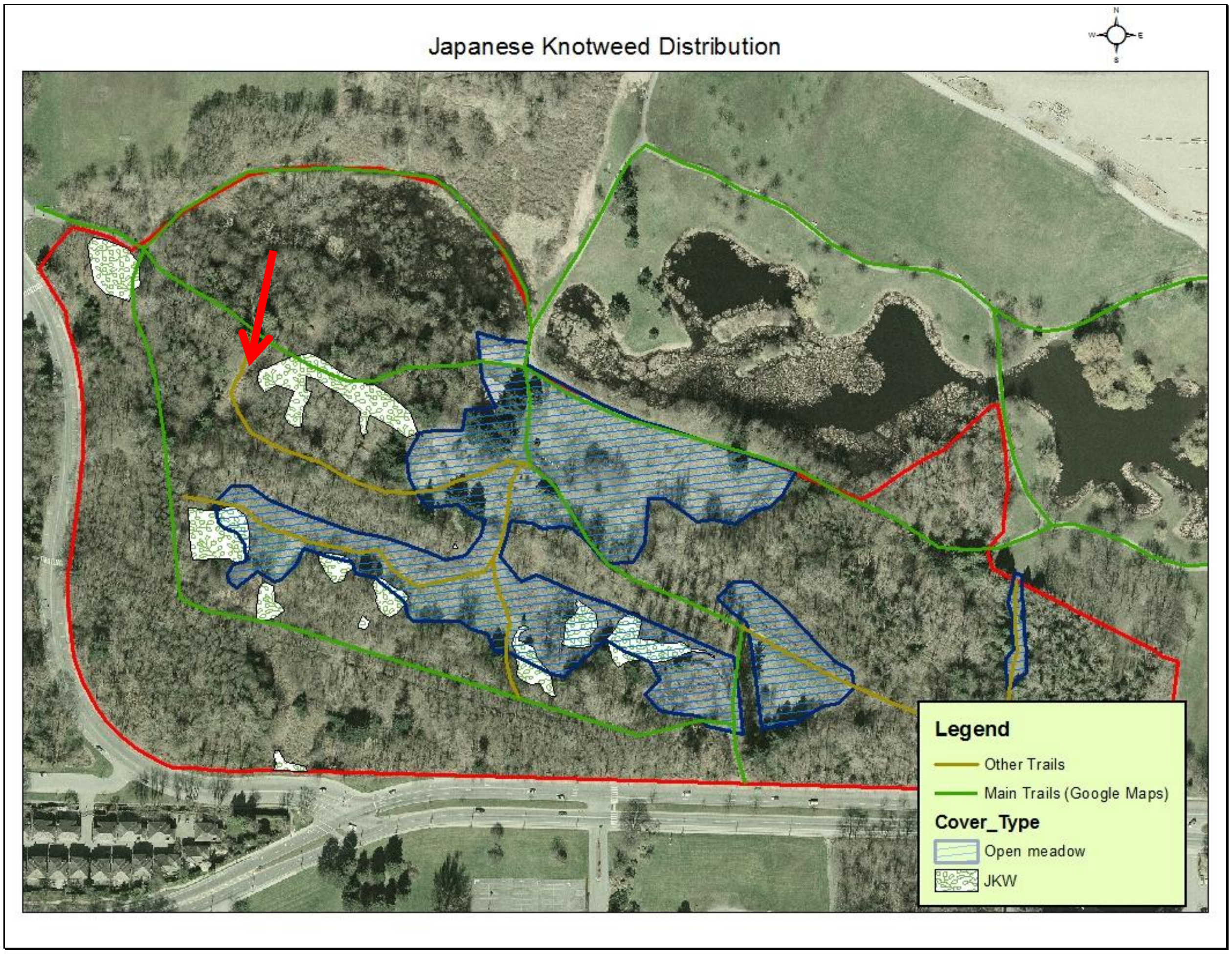


Figure 16: Distribution of Japanese knotweed throughout Jericho Beach Park, and the open meadow stratum

Discussion

Successional Trajectories

Based on the overstory and understory composition, the stands in Jericho Park are transitioning from early successional stands dominated by shade intolerant native broadleaf species (red alder, black cottonwood, bigleaf maple) to either stands of shade tolerant hardwoods dominated by introduced sycamore maple, with smatterings of other exotic species such as horsechestnut and walnut or blackberry thickets. The E-Flora website indicates that sycamore maple is considered a 'rare horticultural escape in forests near UBC' (Klinkenberg, E-Flora BC Atlas Page - Sycamore Maple, 2013), but it is well established in the forests at Jericho. This indicates a need for further inventory and assessment of the spread of sycamore maple into other forested areas of Vancouver. The shift away from red alder is expected, as red alder is highly shade intolerant, and generally does not regenerate in understory conditions (Klinka, Worrall, Skoda, & Varga, 2000). The long history of disturbance has created a situation in which site sensitive species such as late seral and climax conifers are being out-competed by hardier generalist species. The near-absence of native conifer regeneration and the lack of seed source for shade tolerant species such as redcedar, grand fir and hemlock indicate that progression of this woodland towards a conifer-dominated west coast rainforest is unlikely. Some coniferous seedlings have been planted, however, a few of these are inappropriately located in areas of high canopy closure, or are being taken over by aggressive non-native species such as blackberry. Development of old-growth characteristics in coastal forests takes at least 200 years, if not more (Gerzon, Seely, & MacKinnon, 2011). Development of conifer dominated or mixed forests similar to those in Pacific Spirit, or Stanley Park would require a long time and considerable intervention.

Habitat suitability

Song birds are an important attraction for visitors to Jericho Park. Many of the structural attributes found in the Jericho forest are not as conducive as they could be in terms of bird habitat. While introduced species such as Himalayan blackberry seem to provide an easy food source for birds, it has negative ecological impacts. A recent study of bird species diversity in relation to Himalayan blackberry thickets suggests that areas with thick cover by blackberry are not suitable for species with stringent habitat requirements, but may provide generalist birds such as the American robin with sufficient habitat (Astley, 2010). Thickets also increase nest predation by rats, racoons and snakes (Astley, 2010).

Although not largely represented in the plot data, there are some arboreal features at Jericho Park that are characteristic of an older forest and that can act as habitat anchors amidst a largely disturbed and successional forest. These include the large Douglas-fir trees on the southwest park border, aging cottonwood and bigleaf maple trees, a few snags and trunks and patches of maturing conifers. Additional features including the creek, open areas, shrubby vegetation and wetlands will continue to attract wildlife as long as they persist. There is potential to increase the amount and diversity of wildlife at Jericho Park by creating more habitat features and replacing and maintaining existing features.

Coarse Woody Debris

The low abundance of CWD is consistent with an early seral, broadleaf dominated stand that has originated following land clearing. There are very few legacy elements of the original west coast rainforest, such as old logs, large dead trees or stumps. The cottonwood trees on site will provide some excellent habitat features over the next few decades as they mature and break. Even as the present stand continues to self-thin and mature, the relatively small diameter, fast decaying broadleaf logs will contribute little too long term accumulation of CWD. If CWD is desired, the best solution would be to bring it in during site-preparation operations.

Standing Dead Trees

The number of standing dead trees (snags) at Jericho is moderately low, and the size is small. For comparison, a typical old growth CWH forest (vm) has approximately 52 dead stems per hectare (Gerzon M. , 2009). Different species of birds and other wildlife require different types of wood in a different decay classes for nesting and feeding. Additionally, most avian species require snags with a dbh over 25 cm (a range including those over 60 cm dbh is preferable) for nesting (Fenger, 2006). Incremental to the problem of low sizes and numbers of snags, is that the current snags are alder, and although many species prefer to use alder, it is not suitable for all species and will decay quickly. The next generation of snags will also primarily be recruited from the standing red alder trees, and will therefore mostly have dbh's ranging from 10-30 cm, and an average height representative of the current big trees on site which is 22.4 metres.

Several species of birds as well as some small mammals (eg. red squirrels) nest in dead or dying trees and snags. Many of these species require additional old forest characteristics along with snags, but several can survive using remnant elements of old-growth forests (such as snags and downed wood) amidst younger or fragmented stands (Hartwig C. E., 2002). Therefore maintaining, creating or adding snags to Jericho could help increase the numbers of cavity nesting birds and small mammals, as well as animals that feed on the insects that live in dead and dying wood.

An example of a species that is present in the nearby Pacific Spirit Park, but not observed at Jericho Park, is the pileated woodpecker (*Drycopus pileatus*). This bird is often considered both a keystone species and an ecological indicator in Canada and the Pacific Northwest because of its ability to excavate live and decadent trees that can subsequently be used by other wildlife species. Pileated woodpeckers often use elements of old forests in patchy managed (harvested) landscapes. However the average size of nest tree that they use is approximately 82 cm dbh, and the average feeding tree slightly smaller (Hartwig, Eastman, & Harestad, 2003). The choice tree species for pileated woodpeckers, such as Douglas-fir, alder, bigleaf maple, and grand fir (Hartwig, Eastman, & Harestad, 2003) all currently occur at Jericho, but they still need to grow, deteriorate and be replaced.

Downed Wood / Coarse Woody Debris

The volume, piece size, percent ground cover, and decay class distribution of coarse woody debris at Jericho Park is very different, and much lower than that that would be found in a similarly located Coastal Western Hemlock forest (Feller, 2003). Mature managed conifer stands in coastal British Columbia tend to have the greatest shortfall of CWD between 50 and 80 years (Chief Forester, 2010; Feller, 2003; Densmore, Parminter, & Stevens, 2004), so it would be expected that the 60-70 year old broadleaf-dominated forests at Jericho have less CWD than an old growth forest in a similar location. Additionally, historic development and earth works have depleted a large amount of the CWD and resultant soil structure that would have occurred here. Old-growth forests in the CWHxm typically have a mean CWD volume of 119 m^3 per hectare (Feller, 2003). Jericho Park's forested area has a mean of 21m^3 per hectare. Additionally, a natural CWHxm forest would have approximately 16% ground cover of CWD (Feller, 2003), yet the Jericho forest only has 1.9% ground cover.

Large pieces of CWD provide different ecological functions than small pieces and generally persist longer, have higher moisture retention, contribute more organic material to the soil and host a greater diversity of species (Chief Forester, 2010; Gerzon M. , 2009; Densmore, Parminter, & Stevens, 2004). In BC's wetter biogeoclimatic zones, small CWD with a diameter less than 12 cm accounts for an average of 11% of the total cover (Feller, 2003). Managed stands typically retain only those pieces larger than 30 cm dbh until the next rotation

(Densmore, Parminter, & Stevens, 2004). The average diameter at Jericho is 10.7 cm, with strata averages ranging from 7.4-16.5 cm, and only two pieces recorded over 30 cm dbh. Also, only two pieces of CWD over 20 cm by 10 m were found in the forest, compared to 34-59 pieces in an average coastal managed stand (Chief Forester, 2010).

Coarse woody debris in decay classes 3 and 4 is most often used for seedling establishment (Motta, Berretti, Lingua, & Piussi, 2006) because the wood is both soft enough for the seed to establish and for nutrients to persist in the log. The majority of CWD in natural old growth stands is in decay class 4, followed by 3, with little in decay classes 1 and 2, and is mostly coniferous in origin. As is characteristic of an early successional broadleaf forest, most of the coarse woody debris in Jericho Park is in decay classes 1 and 2, and deciduous in origin. This result is likely due to the young age of the forest, compounded by the removal or decay of pre-disturbance CWD, as well as the increased rate of decay of smaller deciduous pieces of wood (Chief Forester, 2010; Densmore, Parminter, & Stevens, 2004; Harmon M. H., 1991). Most of the small wood currently within decay class 1 will decay within 10 years (Feller, 2003) and will not ever reach later decay classes.

Conclusion

The results of this baseline survey will form the basis and rationale for the development of the ecological management plan.

The results indicate that in order to increase biodiversity in Jericho Beach Park and to increase habitat for urban creatures such as birds and small mammals, the priorities for management are the reduction of invasive species, native species recruitment, especially of conifers, coarse woody debris and snag recruitment and wildlife habitat enhancement.

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Appendix 1: Historical Photographs

Photos were received from the VPB and permission should be asked before replication.


HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES
SA MAJESTE LA REINE DU CHEF DU CANADA. MINISTERE DE L'ENERGIE, DES MINES ET DES RESSOURCES


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Appendix 2: Detailed Strata Level Summaries

The individual strata are summarized separately in the following section. It is important to note that Stratum G and H values do not represent true mean values, as they are calculated from single plots. Table 7 and Table 8 summarize the stratum level variables, including stems per hectare, dbh, basal area, height, and crown closure, along with standard deviations of these measures to provide an indication of variability.

Table 7: Stratum level descriptive statistics for big trees (>7.5cm DBH)

Stratum	Area (ha)	Mean DBH	Standard Deviation of DBH	Average basal area (m2/ha)	Average Height	Standard Deviation of Height	Average % Crown Closure
A	6.21	31.5	18.6	45.8	19.90	8.72	34
B	2.7	9.2	1.43	15.7	3.70	0.14	5
C	1.3	19.7	6.66	20.5	19.42	5.15	32
D	0.5	34.3	32.91	64.0	22.53	19	50
E	0.6	31.5	19.65	56.9	25.55	12.5	28
F	0.9	25.8	12.27	63.5	23.93	6.7	33
G	0.9	0.0	-	-	-	-	25
H	0.2	97.0	-	73.9	37.00	-	50

Table 8: Stratum level summary of stems per hectare, by tree size category.

Stratum	Area (ha)	SPH Big Trees (>7.5cm dbh)	% of Total	SPH Small Trees (2-7.5cm dbh)	% of Total	SPH Regen Trees (<2cm dbh)	% of Total	Total
A	6.21	544	69	11	1	233	30	788
B	2.7	160	13	680	55	400	32	1240
C	1.3	1000	21	767	16	3100*	64	4867
D	0.5	650	76	200	24	0	0	850
E	0.6	533	28	1100	57	300	16	1933
F	0.9	1000	43	200	9	1100	48	2300
G	0.9	0	-	0	-	0	-	0

H	0.2	100	25	200	50	100	25	400

*high density attributed to sycamore maple

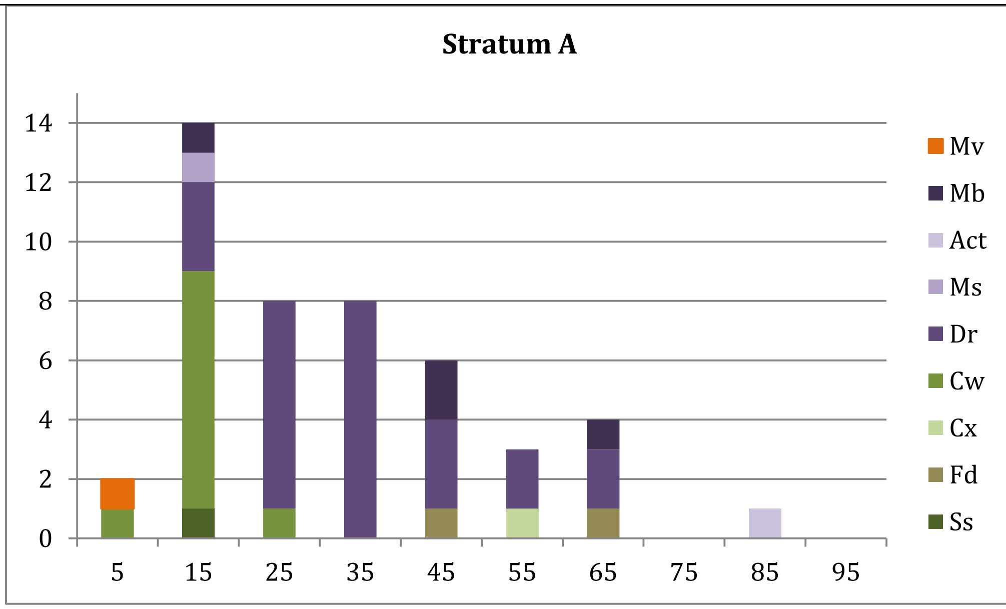
Stems per Hectare

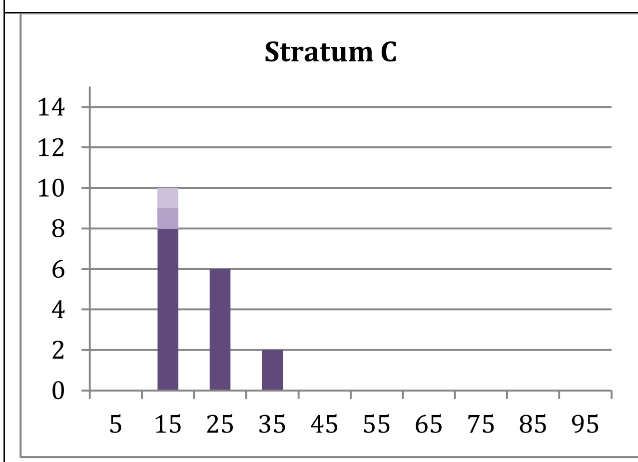
The heterogeneity of tree sizes across the forest indicates different levels of forest structure, and potentially indicates a variety of habitat (McElhinny, 2002). The most important attributes to note regarding the stems per hectare at the stratum level is that the most big trees are in stratum A and D, while strata B, E and H have the most trees in the small category. Stratum C has very high levels of regeneration, mostly attributed to sycamore maple. The variation in stems per hectare by size class also indicates areas for potential management. Strata D, E and G have very low rates of regeneration; therefore these areas could be targeted for planting. Strata C and F have high proportions of sycamore maple in the regeneration size classes, and may indicate the need for density management along with planting with more desired species.

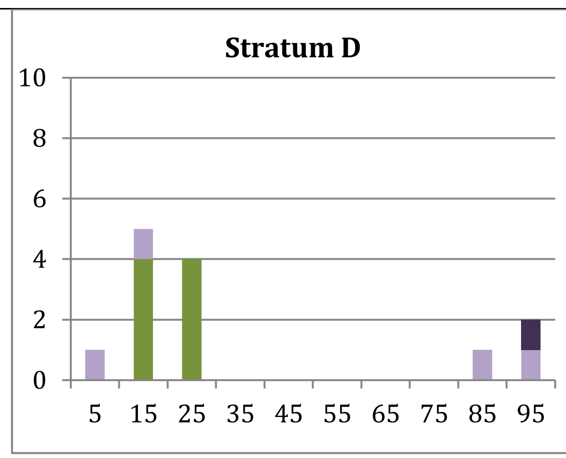
Diameter at Breast Height

There is a high level of heterogeneity among the strata in terms of stem diameter. The means of dbh are significantly different between the strata, with Stratum H and B varying most significantly from the others. See Appendix 3 for the results of statistical analysis. The standard deviation of dbh was determined as an indicator of the horizontal structural diversity. A larger standard deviation indicates a greater range of tree diameters in the stand, and therefore the potential for a greater diversity of habitats within that stand (McElhinny, 2002). The largest standard deviation of dbh was found for Stratum D, which also had the highest mean dbh, after Stratum H. This is likely due to this stratum having some very large stems (the cottonwoods) with smaller diameter understory trees, the Excelsa cedars. The next highest in terms of variability is Stratum E followed by Stratum A. The lowest variation (excluding strata with one or no tree measurements) is found in Stratum B.

This heterogeneity is also evident in the diameter class distributions for each stratum. The diameter class distributions were determined for each stratum. Overall, the park has a right skewed distribution, but individually the strata vary considerably. Figure 17 below shows the diameter class distribution for all strata except Stratum G, which had no trees, Stratum H because it only had one large tree recorded, and Stratum B, which only had shrubby trees.Stratum C only has trees in three diameter classes, and they are the three smallest size classes. Stratum F has stems only in the larger size classes. Stratum D has a distinct split between small and large stems, with no intermediate sized trees. By examining the colour coding, it is interesting to note that conifers occur mainly in the smaller diameter classes. The only stratum that has large diameter conifers is Stratum A. The only other strata with conifers are stratum D and stratum E.







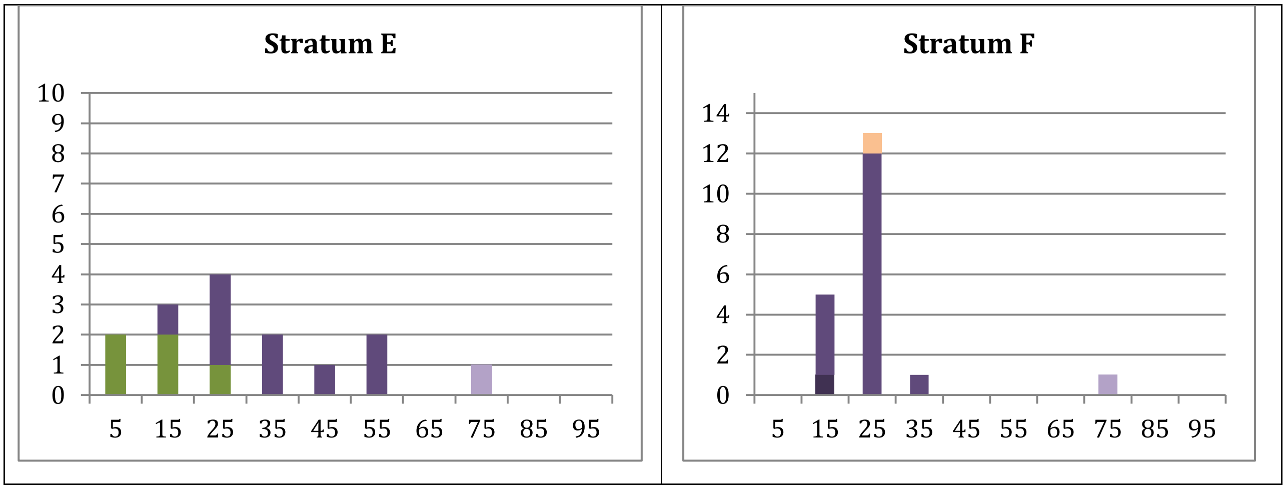


Figure 17: Diameter class distributions of big trees in each stratum (excluding Stratum B, Stratum G and Stratum H).

The distribution of trees among diameter classes shows that most of the strata are heavily skewed to the smaller classes of stem diameter. The largest DBH was 97cm, attributed to a Lombardi poplar. The range of DBH values is from 7.5cm to 97cm.

At the stratum level, stratum A shows the widest distribution of stems over the range of size classes. Stratum C has trees only in diameter classes of 25cm or less. Stratum D is split, with representation in small diameter classes (5-25cm), as well as large diameter classes (85 and 95cm). Stratum E has stems up to 65cm in diameter. Stratum F has trees that mostly fall into the 15 to 35 cm diameter classes, with one stem in the 75cm diameter class. Only one large tree was recorded in Stratum H, and it is the largest, falling within the 95cm diameter class. Stratum C and Stratum F do not have coniferous trees in the big tree category. Although Stratum G is treed, no large trees were captured in the plot.

Tree Height and Crown Closure

Tree heights were measured or estimated for big trees at each plot. Crown closure was estimated for trees in each canopy layer (see Methods section). The average crown closure for each stratum was determined for trees in the A1 and A2 canopy classes (i.e., the overstory.

The results indicate that Stratum H has the tallest trees. However, this is based on only one plot measurement, and is the smallest stratum. Of the larger, more diverse strata, E and F have the tallest trees, approximately 23m tall. The strata with no standard deviation of height are

Stratum B (the meadow), Stratum G (no large trees recorded), and Stratum H (only one plot with one large tree recorded). Stratum H has the tallest tree. Stratum D has the largest amount of vertical heterogeneity (highest standard deviation). This result is similar to the dbh results; some very large cottonwoods with smaller understory trees are creating a wide range of tree heights.

The crown closure is highest in Stratum H and D (both 50%), with Strata A, F, C, E, and G falling within approximately 10% of each other (range from 25-34% closure). Stratum B has very low crown closure.

Coarse Woody Debris

The average number of pieces and volume per hectare, and average diameter, length and volume per piece of coarse woody debris (CWD) varies by strata and is likely related to the tree composition of that stratumFigure 9(Table 9;Figure 18;Figure 19;Figure 20).

The largest volumes of CWD, and highest numbers of pieces her hectare are found in stratum D (Cottonwood and Conifer) followed by stratum E (Riparian Zone). The largest diameter downed wood was measured in stratum D, and the longest and highest volume pieces in stratum C (Alder Leading) (Table 9).

Table 9: Average number of pieces and volume per hectare, and average diameter, length and volume per piece of CWD by strata.

Strata	Volume (m3) per ha	Pieces per ha	Average Diameter (cm)	Average Length (m)	Average Volume (m3) per piece
A	17.1	385	10.6	5.0	0.062
B	0.0	0	0.0	0.0	0.000
C	13.1	115	13.3	9.7	0.143
D	81.3	507	16.5	4.6	0.110
E	48.7	657	10.9	1.8	0.042
F	17.0	200	7.4	2.5	0.042
G	0.0	0	0	0	0
H	0.0	0	0	0	0

Most of the coarse woody debris pieces observed were deciduous in origin. Alder (i.e. Stratum C) and Cottonwood (i.e. stratum D) stands have the largest pieces of CWD on the ground. Alder stands (i.e. Strata C and F [Young Deciduous]) also have the highest number of snags, highest density of live stems, and the fewest pieces and lowest total volume of CWD. These pieces of alder were in early stages of decay. This is likely a product of the successional status of this stand, when competition and stem exclusion are beginning to accelerate, and because of the rate of decay of deciduous wood.

Stratum D (Cottonwood and Conifer) and stratum E (Riparian Zone) have the highest volumes of wood in decay class 3 (Figure 18), however the total size of these stratum is .5 ha and .6 ha (less than 5 percent of the total area each), and therefore they do not significantly contribute to the overall composition of the forest. Stratum A (Mixed Deciduous) is the most represented forest type, followed by alder stands (i.e. Strata C and F). These strata that make up most of the forest have a low total volume of CWD and have no CWD in decay classes 3 or 4 (Figure 18).

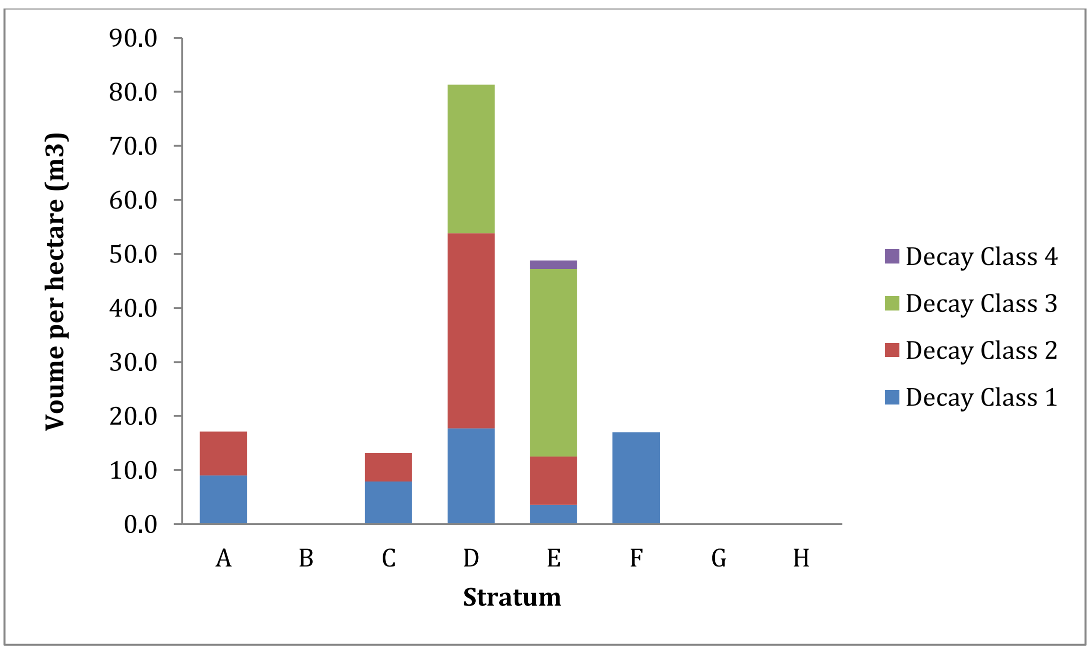


Figure 18: Distribution of volume per hectare per decay class in each stratum.

There are the highest number of pieces of CWD in decay classes 1 and 2 in each strata, except for Stratum D (Cottonwood and Conifer) which has the most pieces per hectare in decay class 3 (Figure 19).

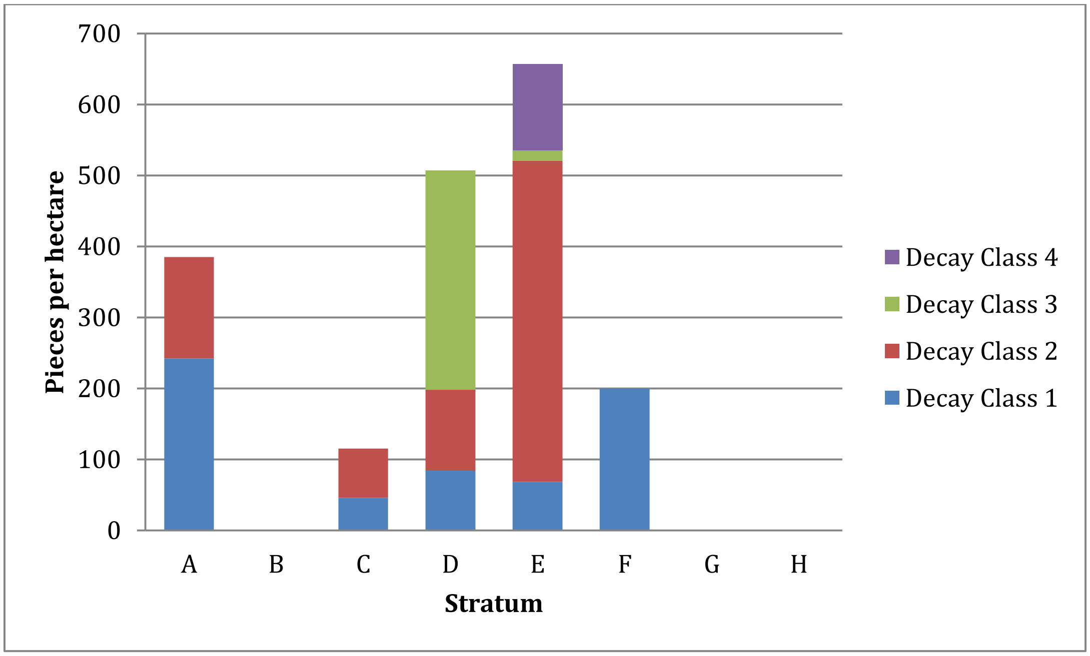


Figure 19: Average number of pieces of each decay class per hectare in each stratum.

Although Stratum E (Riparian Zone) had few pieces of CWD in decay class 3, those pieces were the largest (Figure 20).

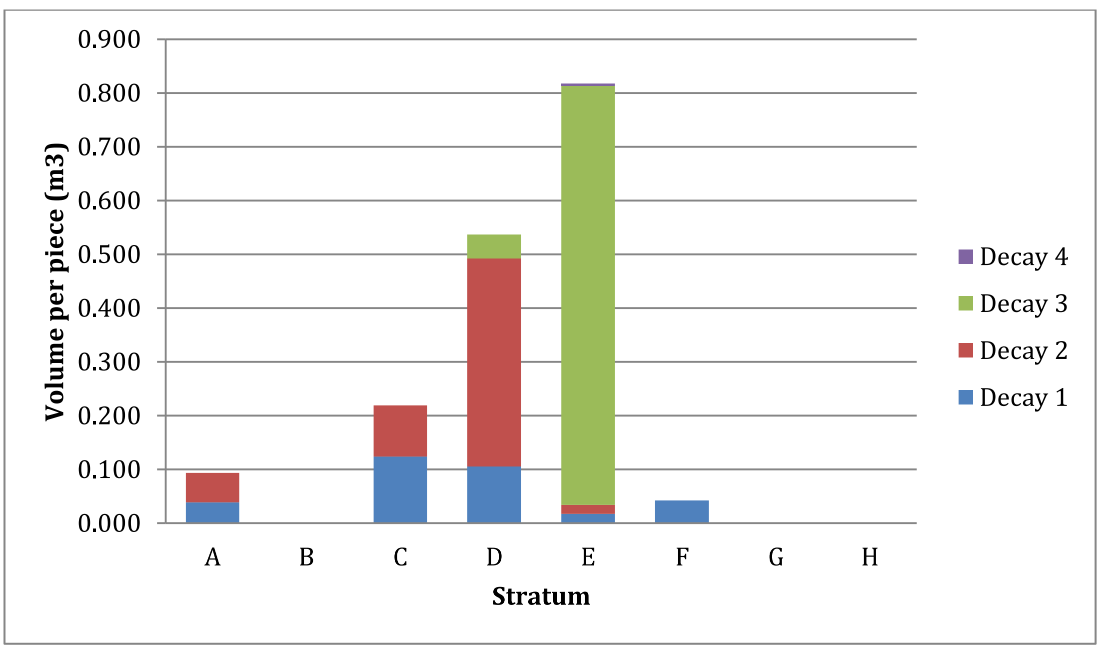


Figure 20: Average piece size (m3) per decay class per strata.

Understory Vegetation

The understory vegetation varies dramatically between strata. The percent cover of all understory vegetation (shrubs, herbs and moss) ranges from 9.5 to 132% cover; with Stratum D being the lowest and Stratum G being the highest. See Table 10. The greatest cover of shrubs is found in Stratum G, followed by Stratum H. However, these 'means' were calculated from one plot in each of these strata, and may not be representative. Stratum D had very low cover by shrubs (as well as herbs and moss), which is likely due to the high crown closure by overstory layers (average closer of 50%, see Table 10). Herb cover was fairly low in most strata (less than 20% for six of eight strata). It was highest in Stratum B (the meadow), and Stratum E (the riparian zone), and lowest in Stratum D. Moss cover was very low for each stratum. The plot in Stratum G had significantly more cover by moss than the other strata. Only two species of moss were identified during this survey. Strata F, G, and H in particular have high ratios of non-native cover to native cover.

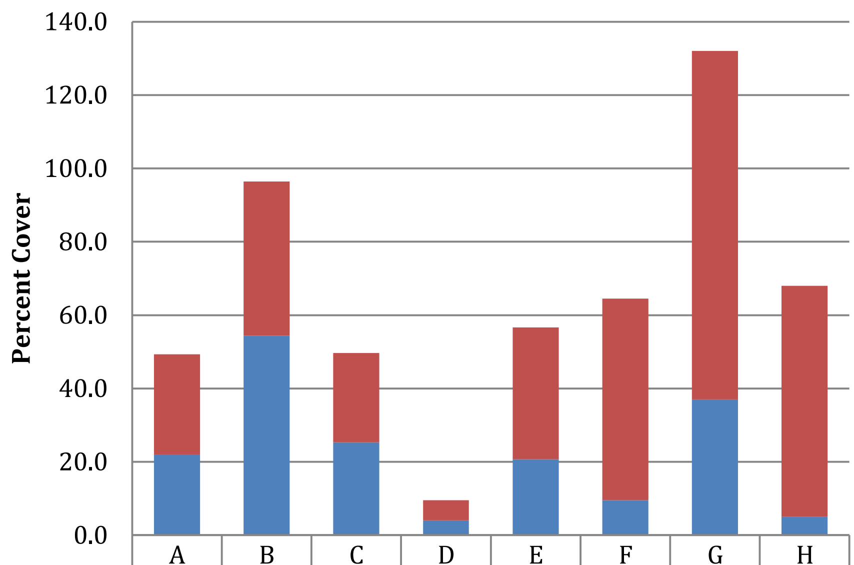
Table 10: Mean percent cover of understory vegetation for each stratum.

Stratum	Area	Mean % Vegetative Cover	Mean % Cover Shrubs	Mean %Cover herbs	Mean % Cover Moss
A	6.21	49.3	32.9	14.2	2.2
B	2.7	96.4	50.4	45.6	0.4
C	1.3	49.7	23.7	13	13
D	0.5	9.5	8	1	0.5
E	0.6	56.7	19.3	33.3	4
F	0.9	64.5	40.5	16.5	7.5
G	0.9	132.0	91	11	30
H	0.2	68.0	57	11	1

*percent cover determined using ocular estimate of ground cover created by the vegetation. Total cover can be more than 100% due to vertical layering of vegetation.

Most strata have a relatively high cover attributed to shrubs, but are generally lacking in herbaceous and moss cover.

The non-native percent cover is also summarized at the strata level. The most common non-native species was Himalayan Blackberry. It was counted in 21 of 26 plots, and ranged from 1 to 90% cover in those plots. The top five most common non-natives were Himalayan Blackberry, English holly, English ivy, English hawthorn and Laurel. Overall, the percent cover of non-native species is high; it is approximately half or more of the total cover determined in the inventory, depending on the stratum. Strata B and C are the only strata with higher native cover than non-native cover. See Figure 21 below.



	A	B	C	D	E	F	G	H
NN	27.3	42.0	24.3	5.5	36.0	55.0	95.0	63.0
Native	22.0	54.4	25.3	4.0	20.7	9.5	37.0	5.0

Figure 21: Native and non-native understory vegetation percent cover by stratum.

Himalayan blackberry is the most ubiquitous of the non-native species, and will provide a substantial challenge for management. It is shade tolerant, and survives easily on disturbed sites, riparian areas, forest edges, and road and trail sides; in addition to the plentiful seed source provided by its wide distribution throughout the Lower Mainland and west coast (Invasive Species Council of BC, 2012). Himalayan blackberry is an aggressive competitor and creates dense thickets that prevent the regeneration of other species. These thickets are capable of producing 7000-13000 seeds per square metre (Invasive Species Council of BC, 2012). It is listed by the Greater Vancouver Invasive Plant Council in the top 12 most problematic species in the Vancouver region (Klinkenberg, E-Flora Atlas Page: Himalayan Blackberry, 2013).

Biodiversity and Species Richness

The Shannon-Wiener Index was calculated as a measure of the biodiversity in the Jericho Park forest. This diversity index combines species richness with species evenness to generate an index value (H’) indicating diversity. Species richness (R) refers to the number of species in a community, and species evenness (E) refers to the relative abundance of each species (Molles, Jr, 1999). Richness is a simple count of all species. Evenness indicates whether all species are equally represented. Evenness varies from 0-1, with a value of 1 indicating all species are present. The analysis of diversity was conducted for all species of vegetation, including trees, shrubs, herbs and moss, and used percent cover as the variable to calculate relative abundance.

Table 11: Shannon-Wiener diversity index variables, including maximum potential index value (Max H'), the highest stratum average (Maximum H') and the lowest stratum average (Minimum H'), as well as the mean for all plots, and the Evenness (E) of all plots.

	All Species	Native species only
Max H'	4.37	4.03
Maximum H’	2.78	2.19
Minimum H’	0.46	0
Mean H' (all plots)	1.57	1.10
E (all plots)	0.36	0.27

Shannon-Wiener formula:

$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$

The maximum potential H’ value was also calculated, to determine the possible diversity for each plot. A plot with all species present would have H’=H’max. In this case, the evenness would equal one. The maximum H’ for Jericho is 4.37, when all species are considered, and 4.03 when only native species are considered.

H’ maximum: $H'max = ln\mathrm{S}$ where S= number of species

Evennness: *E= lnS/H’*

Table 12: Variables determined for each stratum in calculating the diversity index.

Stratum	**Species Richness (R)**	**H' (all species)**	**E (all species)**	**H’ (native only)**	**E (native only)**

A	9	1.73	0.80	1.24	0.58
B	11	1.73	0.73	1.35	0.57
C	11	1.33	0.56	0.68	0.29
D	6	1.01	0.60	0.89	0.52
E	13	1.87	0.72	1.38	0.53
F	8	1.68	0.81	0.85	0.41
G	8	1.13	0.54	0.64	0.31
H	9	0.52	0.24	0.41	0.19

When only native species are considered in the H' calculation, an overall decrease in diversity is seen compared to the 'all-species' calculation. This further emphasizes the dominant role that invasive species have in Jericho Park. This index provides a way to compare the strata in terms of diversity. These attributes of the most diverse stratum may provide some management direction as to the key structural attributes to manage for when the goal is to increase diversity.

Higher H' values indicate higher diversity. The results of the diversity analysis indicate that the diversity of each stratum is well below the potential (max H'). The highest H' for a plot was 2.78 (plot # 34 in the Riparian zone, Stratum E). However, the mean H' for all plots is 1.57, only 36% of the potential diversity. The evenness values also indicate a relatively low evenness (0.38, average over all plots), indicating that there were few species represented in each plot compared to the total number of species.

Stratum D and Stratum H have the lowest diversity (H'=1.01 and 0.52), and Stratum H also has the lowest evenness (E= 0.24). The highest evenness is found in Stratum F, the Young Deciduous (E= 0.81). Of the forested strata, E had the highest percent cover by herbs, which may relate to increased diversity. Stratum E also has the highest average species richness, at 13 species. This stratum also has the highest standard deviation of tree height, indicating a variety of vertical layers. This is also evident in the diameter class distribution of Stratum E, which showed even representation across most size classes.

Comparing the 'all-species' with the 'native only' values, shows that all strata lose some diversity, however, the same strata are the most and least diverse. Some strata have more significant difference than others. For example, Stratum C drops from an H' value of 1.33 (30%

of maxH'), to 0.68 (17% of maxH'), indicating that non-native species accounted for nearly half of the vegetation diversity in this stratum.

Appendix 3: Data Collection Card-FS882

This appendix describes the detailed methodology for the field data collection, and filling out the Ecosystem Field Form (FS882).

Plot locations were determined using handheld GPS units. The units were a Garmin Etrex and a Garmin GPSmap 76CSx. The accuracy of the units varied from +/- 3 to 9 metres, with an average accuracy of +/- 4.8 metres.

All plots were marked with a ribbon hung near the centre of the plot, and a ribbon inserted into the ground at the exact plot centre. The hanging ribbon was marked with the plot number and date.

Plots were sampled from October to December 2012. The conditions were generally wet and cool, with rainfall most sampling days. Leaf fall was nearly complete for much of the sampling period.

Site Description

This part of the field card is used to record general information about the location of the plot. For the purposes of this study, the information collected on this part of the form included the date, plot number, easting, northing, GPS accuracy, elevation, slope, aspect, a site diagram and any notes. The General Location was recorded as the stratum in which the plot was located.

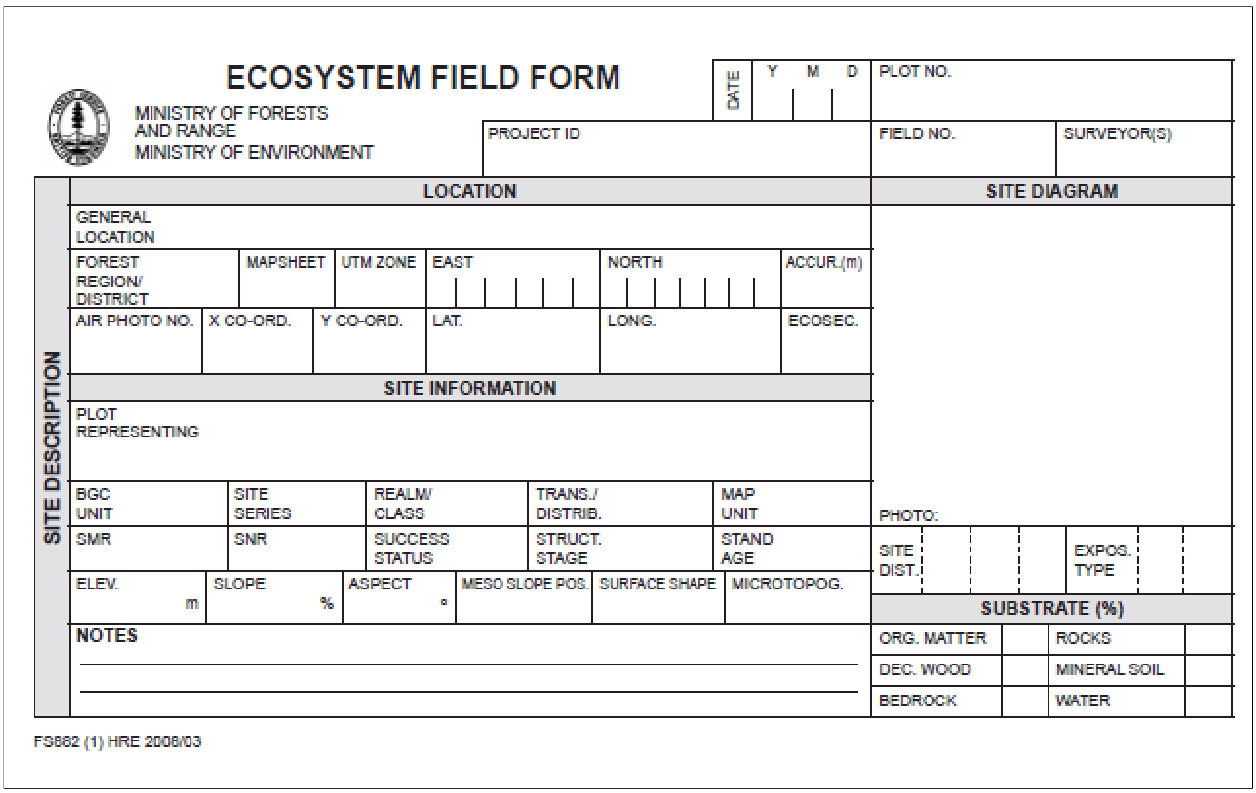
Overstory trees

Trees were counted and measured in the fixed area plot, according to diameter-at-breast-height (DBH) class. This part of the field form was modified to better reflect the detail of tree data desired for this project. Trees were divided into DBH classes. Regeneration was classified as having DBH less than 2cm, small trees had DBH from 2cm to 7.5cm, and big trees had DBH over 7.5cm. Big trees were counted individually. DBH was recorded for every big tree, and an estimated or measured height was taken for at least two trees in every plot. Heights were measured using a LASER. A few age samples were taken with an increment bore. Small and regeneration stems were tallied by species. Some heights for small trees were estimated.

Vegetation

This portion of the card was used to collect data on trees, shrubs, herbs and bryophytes by percent cover. The trees and shrubs are divided into layers by height, summarized in Table 2 below (from the LMH 25).

Herbs and bryophytes are not divided into layers. Percent crown closure for each species was recorded on the field card, as well as percent cover by life form (tree, shrub, herb, moss/lichen).



ECOSYSTEM FIELD FORM

MINISTRY OF FORESTS
AND RANGE
MINISTRY OF ENVIRONMENT

DATE Y M D

PLOT NO.

PROJECT ID

FIELD NO.

SURVEYOR(S)

SITE DESCRIPTION

LOCATION

GENERAL LOCATION

FOREST REGION/ DISTRICT | MAPSHEET | UTM ZONE | EAST | NORTH | ACCUR.(m)

AIR PHOTO NO. | X CO-ORD. | Y CO-ORD. | LAT. | LONG. | ECOSEC.

SITE INFORMATION

PLOT REPRESENTING

BGC UNIT | SITE SERIES | REALM/ CLASS | TRANS./ DISTRIB. | MAP UNIT

SMR | SNR | SUCCESS STATUS | STRUCT. STAGE | STAND AGE

ELEV. m | SLOPE % | ASPECT ° | MESO SLOPE POS. | SURFACE SHAPE | MICROTOPOG.

NOTES

SITE DIAGRAM

PHOTO:

SITE DIST. | EXPOS. TYPE

SUBSTRATE (%)

ORG. MATTER		ROCKS	
DEC. WOOD		MINERAL SOIL	
BEDROCK		WATER	

FS882 (1) HRE 2008/03

VEGETATION

SPP. LIST | COMP. ☐ | PART. ☐

% COVER BY LAYER | TREE (A) | SHRUB (B) | HERB (C) | MOSS / LICHEN (D)

SURVEYOR(S) | PLOT NO. | PAGE OF

COL.	TREES	A1	A2	A3	A	B1	B2	B

COL.	SHRUBS	B1	B2	B

COL.	HERB LAYER (C)	%

COL.	MOSS / LICHEN / SEEDLING (D)	%

COL.	ADDITIONAL SPECIES	LAYER	%

NOTES:

FS882 (3) HRE 2008/03

MENSURATION

TREE SURVEYOR(S)

PLOT No.

PLOT SIZE (m^2)

DBH LIMIT

B.A.F.-B

B.A.F.-A

CRUISE ☐ INFORMAL ☐

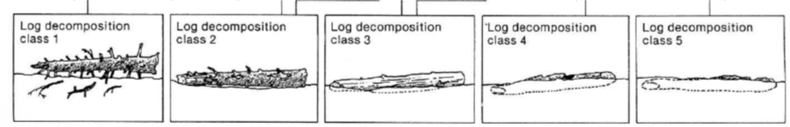
	EXCLUDE ?
	SUBPLOT
	TREE #
	SPP.
	DBH (cm)
	TOTAL HT. (m)
	CNT. HT. (m)
	COUNT AGE
	CROWN C
	TREE C
PATH. REMARKS	CONK
	BL. CONK
	SCAR
	FRK. OR CRK.
	F. CRACK
	MISTLETOE
	R. BRAN.
	D. OR B. TOP
DAM.	TYPE
	SEVERITY
WILDLIFE / OTHER	CROWN CON.
	APPEAR.
	BARK RET.
	WOOD COND.
	LICHEN L.

NOTES

FS882 (4) HRE 2008/03

Coarse Woody Debris Transect			
Plot	Line 1 Bearing: Line 2 Bearing:	GPS E: N:	Comments:

Line	CWD No.	Diameter (cm)	Decay Class	Length (m)	Species (decid/conifer)



Plot Photos		
Photo Number	Direction	Representing

Appendix 4: Statistical Analysis

The following results show the statistical analysis that was done for the data collected in the Jericho Park Baseline inventory.

Stems per Hectare

Big Trees (ANOVA- sph vs stratum)

The results of this ANOVA show that there is no significant difference in the stems per hectare of big trees between the strata. The data are suitable to this analysis, shown in Figure XX. The data is linear, has an equal distribution of residual values, and a nearly normal histogram.

```
Ho: There is no significant difference in the mean stems per hectare of big trees between the strata.
H1: There is a significant difference in the mean stems per hectare of big trees between the strata.

Source   DF      SS      MS     F      P
Stratum   7  2285265  326466  2.02  0.108
Error    18  2905889  161438
Total    25  5191154

S = 401.8   R-Sq = 44.02%   R-Sq(adj) = 22.25%

                      Individual 95% CIs For Mean Based on
                      Pooled StDev
Level  N    Mean  StDev  --+---------+---------+---------+-------
A      9   544.4  332.1              (---*---)
B      5   160.0  357.8          (----*-----)
C      3  1000.0  435.9                 (------*------)
D      2   650.0  777.8            (-------*--------)
E      3   533.3  513.2            (------*------)
F      2  1000.0    0.0               (-------*--------)
G      1     0.0      *  (-----------*-----------)
H      1   100.0      *    (-----------*-----------)
                         --+---------+---------+---------+-------
                         -700        0       700      1400

Pooled StDev = 401.8
Grouping Information Using Tukey Method

Stratum  N    Mean  Grouping
F        2  1000.0  A
C        3  1000.0  A
D        2   650.0  A
A        9   544.4  A
E        3   533.3  A
B        5   160.0  A
H        1   100.0  A
G        1     0.0  A

Means that do not share a letter are significantly different.
```

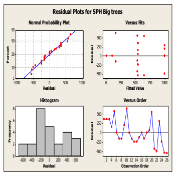


Figure 22: Residual plots of ANOVA of the stems per hectare of big trees (>7.5cm dbh) vs. stratum

Small Trees (ANOVA- sph vs. stratum)

The results of this ANOVA show that there is no significant difference in the stems per hectare of small trees between the strata. The data are not quite perfect for the analysis (Figure 23).

```
Ho: There is no significant difference in the mean stems per hectare of small trees between the strata.
H1: There is a significant difference in the mean stems per hectare of small trees between the strata.

Source   DF       SS      MS     F      P
Stratum   7   3982983  568998  0.90  0.524
Error    18  11323556  629086
Total    25  15306538

S = 793.1   R-Sq = 26.02%   R-Sq(adj) = 0.00%
                       Individual 95% CIs For Mean Based on
                        Pooled StDev
Level  N    Mean   StDev  -------+---------+---------+---------+--
A      9    11.1    33.3           (----*-----)
B      5   680.0  1465.3               (-------*------)
C      3   766.7   450.9              (---------*--------)
D      2   200.0   282.8        (-----------*-----------)
E      3  1100.0  1053.6                 (---------*---------)
F      2   200.0   141.4        (-----------*-----------)
G      1     0.0       *  (----------------*----------------)
H      1   200.0       *    (----------------*----------------)
                        -------+---------+---------+---------+--
                          -1000         0      1000      2000

Pooled StDev = 793.1
Grouping Information Using Tukey Method
Stratum  N    Mean  Grouping
E        3  1100.0  A
C        3   766.7  A
B        5   680.0  A
H        1   200.0  A
F        2   200.0  A
D        2   200.0  A
A        9    11.1  A
G        1     0.0  A

Means that do not share a letter are significantly different.
```

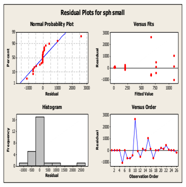


Figure 23: Residual plots for small tree stems per hectare vs stratum

Regeneration

The ANOVA for regen sized trees shows that while technically there is no statistically significant relationship, the result is very close rejecting this hypothesis (Pcalc=0.059, Pcrit=0.05). The Tukey grouping does reveal that Stratum C (Alder leading) does not share a letter and hence is significantly different from the other stratum means. Stratum C has a much higher mean stems per hectare of regen than the other strata do. The residual plot diagram shows that the data may not be well suited for an ANOVA, as the data are not perfectly linear, however the residuals are fairly well distributed around zero, and the histogram indicates a normal distribution of the data.

```
Ho: There is no significant difference in the mean stems per hectare of regen trees between the strata.
H1: There is a significant difference in the mean stems per hectare of regen trees between the strata.

Source   DF       SS       MS     F      P
Stratum   7  22221538  3174505  2.45  0.059
Error    18  23280000  1293333
Total    25  45501538

S = 1137   R-Sq = 48.84%   R-Sq(adj) = 28.94%


                 Individual 95% CIs For Mean Based on Pooled StDev
Level  N  Mean  StDev   --+---------+---------+---------+-------
A      9   233    387          (---*---)
B      5   400    840          (----*----)
C      3  3100   3000                   (------*-----)
D      2     0      0     (-------*-------)
E      3   300    520        (------*-----)
F      2  1100    849          (--------*-------)
G      1     0      *   (-----------*-----------)
H      1   100      *     (-----------*----------)
                        --+---------+---------+---------+-------
                     -2000         0      2000      4000

Pooled StDev = 1137


Grouping Information Using Tukey Method

Stratum  N  Mean  Grouping
C        3  3100  A
F        2  1100  A B
B        5   400  A B
```

E	3	300	A B
A	9	233	B
H	1	100	A B
G	1	0	A B
D	2	0	A B

Means that do not share a letter are significantly different.

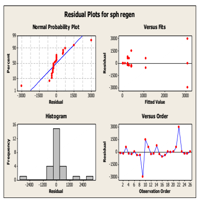


Figure 24: Residual plots for regeneration tree stems per hectare vs stratum

Diameter at Breast Height

Diameter at breast height is only analyzed for big trees (>7.5cm dbh). The following summarizes the descriptive statistics for this variable, and the ANOVA's that were run to determine whether the mean dbh was significantly different between the strata.

Descriptive Statistics:

Variable	Stratum	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
dbh	A	31.47	2.65	18.16	9.00	29.00	81.00	72.00
	B	9.213	0.505	1.428	7.500	9.050	12.000	4.500
	C	19.73	1.62	6.88	10.70	19.20	33.60	22.90
	D	34.31	9.13	32.91	7.90	20.70	95.20	87.30
	E	31.54	4.91	19.65	8.40	26.50	79.30	70.90
	F	25.77	2.74	12.27	12.20	24.00	72.10	59.90
	H	97.000	*	*	97.000	97.000	97.000	0.000000

One-way ANOVA (dbh vs stratum)

The results of the ANOVA indicate that there is a significant difference in the mean dbh of each stratum (Pcalc=0.00). Examining the Tukey groupings reveals that stratum H and B are different from each other, and from the other strata. This result should be interpreted carefully, as stratum H had only one plot, which happened to have a very large tree in it. The other treed strata are grouped together (B's), indicating that overall, the treed strata do actually have similar mean dbh.

Ho: There is no significant difference in the mean dbh of big trees between the strata.
H1: There is a significant difference in the mean dbh of big trees between the strata.

```
Source    DF     SS    MS     F      P
Stratum    6  10194  1699  5.23  0.000
Error    116  37648   325
Total    122  47842

S = 18.02   R-Sq = 21.31%   R-Sq(adj) = 17.24%

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level   N   Mean  StDev  -+---------+---------+---------+--------
A      47  31.47  18.16        (*)
B       8   9.21   1.43  (---*--)
C      18  19.73   6.88     (--*-)
D      13  34.31  32.91        (--*--)
E      16  31.54  19.65       (--*--)
F      20  25.77  12.27      (-*--)
H       1  97.00      *                (---------*---------)
                         -+---------+---------+---------+--------
                          0        35        70       105

Pooled StDev = 18.02

Grouping Information Using Tukey Method

Stratum   N   Mean  Grouping
H         1  97.00  A
D        13  34.31    B
E        16  31.54    B C
A        47  31.47    B C
F        20  25.77    B C
C        18  19.73    B C
B         8   9.21      C
```

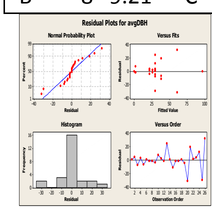


Figure 25: Residual plots for the ANOVA for dbh vs stratum

Height

Descriptive Statistics:

Descriptive Statistics: Ht (m)

Variable	Stratum	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
Ht (m)	A	20.70	1.68	8.72	7.00	23.00	37.00	30.00
	B	3.600	0.100	0.141	3.500	3.600	3.700	0.200
	C	20.31	1.82	5.15	14.00	21.50	28.00	14.00
	D	22.1	13.5	19.0	8.6	22.1	35.5	26.9
	E	23.50	4.42	12.51	9.00	27.50	43.00	34.00
	F	23.63	2.53	6.70	12.00	25.00	33.60	21.60

The data for height do not perfectly fit the assumptions of the ANOVA, The data is linear and the histogram does has a fairly normal distribution. however the residual plots vary unevenly around zero See Residual Plots graphs. The results of the ANOVA show that there is a significant difference in the mean height between strata. The Tukey grouping shows where the differences lie.

Ho: There is no significant difference in the mean height of big trees between the strata.
H1: There is a significant difference in the mean height of big trees between the strata.

```
Source   DF     SS     MS      F      P
Stratum   7  2400.9  343.0  11.17  0.000
Error    18   552.8   30.7
Total    25  2953.7

S = 5.542   R-Sq = 81.28%   R-Sq(adj) = 74.00%

                       Individual 95% CIs For Mean Based on
                       Pooled StDev
Level  N    Mean  StDev  -------+---------+---------+---------+--
A      9  17.686  8.005              (-*-)
B      5   0.740  1.655   (--*---)
C      3  19.417  2.454             (---*---)
D      2  22.525  0.672              (----*----)
E      3  25.547  2.430                (---*---)
F      2  23.925  2.227              (----*----)
G      1   0.000      *  (------*------)
H      1  37.000      *                    (------*------)
                         -------+---------+---------+---------+--
                                0        16        32        48

Pooled StDev = 5.542
Grouping Information Using Tukey Method

Stratum  N    Mean  Grouping
H        1  37.000  A
E        3  25.547  A
F        2  23.925  A
D        2  22.525  A B
C        3  19.417  A B
A        9  17.686  A B
B        5   0.740      C
G        1   0.000    B C

Means that do not share a letter are significantly different.
```

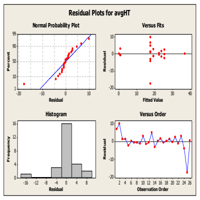


Figure 26: Residual plots for the ANOVA of height versus stratum.

Understory Vegetation:

Shrubs (All)

This section summarizes the descriptive statistics and the ANOVA for all shrub species, native and non-native.

Descriptive Statistics:

Variable	Stratum	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
Shrub-all	A	32.9	10.1	30.3	4.0	6.5	28.0	51.5
	B	50.2	16.9	37.8	0.0	20.5	46.0	82.0
	C	23.67	8.84	15.31	12.00	12.00	18.00	41.00
	D	8.00	1.00	1.41	7.00	*	8.00	*
	E	19.33	5.61	9.71	11.00	11.00	17.00	30.00
	F	40.5	16.5	23.3	24.0	*	40.5	*

One-way ANOVA

The results of the ANOVA show that there is no significant difference in the mean percent cover by shrubs between the strata. The percent cover of non-native shrubs was not tested using ANOVA, as the data did not meet the assumptions of this test.

```
Source   DF     SS   MS     F      P
Stratum   5   3648  730  0.92  0.490
Error    18  14252  792
Total    23  17900

S = 28.14   R-Sq = 20.38%   R-Sq(adj) = 0.00%


                 Individual 95% CIs For Mean Based on
                 Pooled StDev
Level  N   Mean  StDev  -+---------+---------+---------+--------
A      9  32.89  30.30             (------*------)
B      5  50.20  37.76                (--------*--------)
C      3  23.67  15.31         (----------*----------)
D      2   8.00   1.41  (-------------*-------------)
E      3  19.33   9.71       (----------*-----------)
F      2  40.50  23.33            (-------------*------------)
                        -+---------+---------+---------+--------
```

```
                -30       0      30       60

Pooled StDev = 28.14


Grouping Information Using Tukey Method

Stratum  N   Mean  Grouping
B       5  50.20  A
F       2  40.50  A
A       9  32.89  A
C       3  23.67  A
E       3  19.33  A
D       2   8.00  A
```

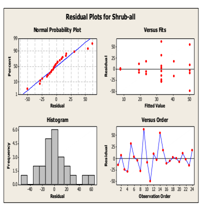


Figure 27: Residual plots for the ANOVA of all shrub percent cover versus stratum.

Herbs (All)

One way ANOVA

There was no significant difference in the mean percent cover of herbs between the strata.

```
Source   DF    SS   MS    F     P
Stratum   7   5113  730  0.85  0.561
Error    18  15438  858
Total    25  20551

S = 29.29   R-Sq = 24.88%   R-Sq(adj) = 0.00%


                Individual 95% CIs For Mean Based on
                Pooled StDev
Level  N   Mean  StDev  ----+---------+---------+---------+-----
A      9  14.33  20.78           (-----*-----)
B      5  45.60  44.58               (-------*-------)
C      3  13.00  17.35        (---------*---------)
D      2   1.00   0.00   (-----------*------------)
E      3  33.33  39.15            (----------*---------)
F      2  16.50  19.09      (------------*-----------)
G      1  11.00      *  (----------------*-----------------)
H      1  11.00      *  (----------------*-----------------)
                ----+---------+---------+---------+-----
```

```
                -35       0      35      70

Pooled StDev = 29.29


Grouping Information Using Tukey Method

Stratum  N   Mean  Grouping
B        5  45.60  A
E        3  33.33  A
F        2  16.50  A
A        9  14.33  A
C        3  13.00  A
H        1  11.00  A
G        1  11.00  A
D        2   1.00  A
```

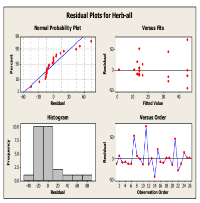


Figure 28: Residual plots for the ANOVA of all herb percent cover versus stratum.

Moss

One way ANOVA

The ANOVA revealed that there was a significant difference in the mean percent cover of moss between the strata. The Tukey grouping shows that Stratum G varies from all other strata.

```
Source   DF     SS     MS      F      P
Stratum   7  1060.4  151.5  11.28  0.000
Error    18   241.8   13.4
Total    25  1302.2

S = 3.665   R-Sq = 81.43%   R-Sq(adj) = 74.21%

                   Individual 95% CIs For Mean Based on
                   Pooled StDev
Level  N    Mean  StDev  ------+---------+---------+---------+---
A      9   2.222  3.346       (-*-)
B      5   0.400  0.894    (--*--)
C      3  13.000  7.000            (---*---)
D      2   0.500  0.707    (---*----)
E      3   4.000  3.606       (--*---)
F      2   7.500  4.950         (---*----)
G      1  30.000      *                      (-----*-----)
```

```
H     1   1.000     *  (------*-----)
                  ------+---------+---------+---------+---
                     0       12       24       36

Pooled StDev = 3.665

Grouping Information Using Tukey Method

Stratum  N    Mean  Grouping
G        1  30.000  A
C        3  13.000    B
F        2   7.500    B C
E        3   4.000    B C
A        9   2.222      C
H        1   1.000    B C
D        2   0.500      C
B        5   0.400      C
```

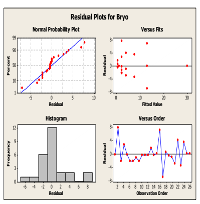


Figure 29: Residual plots for the ANOVA for moss (Bryo) percent cover versus stratum.

Regression Analysis: Non-native vs Percent cover all tree layers (A1, A2,A3)

This analysis was conducted to determine if greater percent cover by overstory trees would influence the percent cover of non-native species. There is no significant relationship between non-native percent cover and percent cover by tree layers.

```
The regression equation is
NN total = 48.5 - 0.435 %cov all tree layers


Predictor              Coef  SE Coef      T      P
Constant              48.52    10.19   4.76  0.000
%cov all tree layers -0.4350   0.2535  -1.72  0.099


S = 33.7873   R-Sq = 10.9%   R-Sq(adj) = 7.2%


Analysis of Variance

Source          DF     SS    MS     F      P
Regression       1   3363  3363  2.95  0.099
Residual Error  24  27398  1142
Total           25  30761
```

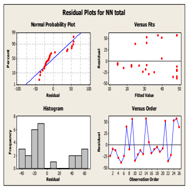


Figure 30: Residual plots for the regression and ANOVA for percent cover by tree layers and percent cover by non-native species.

Shannon-Wiener

Descriptive Statistics

Variable	Stratum	Mean	SE Mean	StDev	Minimum	Median	Maximum
H	A	1.5832	0.0760	0.2279	1.1260	1.6000	1.8900
	B	1.562	0.303	0.677	0.460	1.640	2.310
	C	1.966	0.181	0.313	1.728	1.850	2.320
	D	0.813	0.296	0.418	0.517	0.813	1.108
	E	2.253	0.434	0.751	1.770	1.870	3.119
	F	1.983	0.187	0.264	1.796	1.983	2.170
	G	0.88000	*	*	0.88000	0.88000	0.88000
	H	1.7885	*	*	1.7885	1.7885	1.7885

One way ANOVA

The ANOVA was conducted to determine if there was a significant difference in the mean H' between strata. The data fit the assumptions quite well; being linear, residuals evenly distributed around zero, and showing a nearly normal distribution. The analysis shows that there was not a statistically significant difference, although the result is very close ($P=0.056$, $\alpha=0.05$). The Tukey grouping reveals that stratum E and stratum D in fact do not share a mean, and these are in fact the most diverse (H'=2.25 in stratum E) and the lease diverse (H'=0.81 in stratum D).

```
Source   DF   SS     MS     F     P
Stratum   7  3.704  0.529  2.50  0.056
Error    18  3.817  0.212
Total    25  7.521
S = 0.4605   R-Sq = 49.25%   R-Sq(adj) = 29.52%

                    Individual 95% CIs For Mean Based on
                    Pooled StDev
Level  N    Mean   StDev   -+---------+---------+---------+--------
A      9  1.5832  0.2279            (---*---)
B      5  1.5619  0.6767           (-----*----)
C      3  1.9659  0.3127              (------*------)
D      2  0.8128  0.4180   (-------*--------)
E      3  2.2529  0.7514                (------*------)
```

```
F      2  1.9832  0.2642                  (--------*-------)
G      1  0.8800       *   (-----------*-----------)
H      1  1.7885       *           (-----------*-----------)
                      -+---------+---------+---------+--------
                      0.00      0.80      1.60      2.40

Pooled StDev = 0.4605

Grouping Information Using Tukey Method

Stratum  N    Mean  Grouping
E        3  2.2529  A
F        2  1.9832  A B
C        3  1.9659  A B
H        1  1.7885  A B
A        9  1.5832  A B
B        5  1.5619  A B
G        1  0.8800  A B
D        2  0.8128    B
```

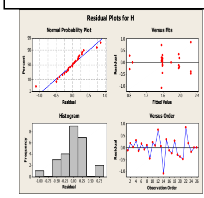


Figure 31: Residual plots for the ANOVA of H' versus stratum.