Tracking Salal (*Gaultheria shallon*) and Western Red Cedar (*Thuja plicata)* Die-off in Pacific Spirit Regional Park

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Abstract

In the spring of 2019, multiple citizens raised concerns of western red cedar (*Thuja plicata*) and salal (*Gaultheria shallon)* disease and death in Pacific Spirit Regional Park (PSRP), Vancouver, B.C. Upon investigation by Metro Vancouver Parks staff, a few cases of such die off was confirmed. The purpose of this observational study was to identify and record the current extent of die-off of both western red Cedar and salal. The study also aimed to determine spatial trends of disease and die-off that might indicate the types of further research required, such as research into hydrology, topography, and soil structure. The geographic location and physical characteristics of each dying plant within view of existing trail infrastructure was collected, with the trails acting as transects. The data has been synthesized into the form of a Google MyMap™ , which was made available to staff at Metro Vancouver Regional Parks and can be disseminated to organizations affiliated with the park, so that they may assess and compare population changes in the future. Although analysis of salal data was ultimately not conducted in this report due to low sample size, general trends for western red cedar indicate a higher concentration of disease and mortality near the eastern edge of the park possibly associated with disturbance in the form of residential construction, as well as near other localized sites of human disturbance of topography and soils. For example, concentrations of disease seem to exist near the Metro Vancouver Camosun drinking water reservoir, and near mounds of clay, gravel, concrete, or asphalt possibly deposited during trail construction or construction of UBC campus facilities such as the Sedgewick library. These findings

should be taken as indications for further research, as no hypothesis testing was performed during this study. Initial findings suggest a review of construction and development practices in and around Pacific Spirit Regional Park, including appropriate removal and past and present construction related wastes and continued development of vegetation and soil restoration capacity.

Introduction

Motivation

As climate change progresses faster than scientific expectations, the alteration or preservation of global forest systems will have an impact on the degree and consequences of warming (Pan et al., 2011). Globally, forests play a crucial role in providing many ecological services, including the sequestration of carbon, mitigation of climate change, control of erosion, management of water, and providing habitat allowing for preservation of biodiversity (Ma et al., 2014). The exact nature of forest responses to climate change are uncertain, but it is known that climatic variables such as temperature, precipitation amounts and patterns have the ability to significantly alter forest composition by altering the range and moving environmental parameters away from those preferred by certain species (IPCC, 2007). In addition to abiotic effects of climate change on forest composition, climate change also has the potential to increase stress by disease and infection as the range and interactions of pathogens changes (Sturrock et al., 2011). Changes in forest composition as a result of these climate driven effects has the potential to significantly alter the rates of carbon sequestration that forest ecosystems are capable of (Ma et al., 2014). In addition to climate change, deforestation and disturbance plays a major role in the degradation of forest ecosystems (Runyan & D'Odorico, 2016).

Across British Columbia, citizens, conservancy groups, and a handful of experts have become increasingly alarmed by what they perceive as a significant number of dying or already deceased western red cedar (*Thuja plicata)* and salal plants (*Gaultheria shallon*) (Brend, 2019; Watson, 2019; Wilson, 2018). Some experts note that this phenomenon has now been observed across Metro Vancouver and Vancouver Island (Brend, 2019). Although media coverage has been intense over the past couple of years, it is clear that some experts believe that this gradual die-off has been occurring for several decades (Brend, 2019). Quantitative research on changing forest composition (and causes) in the Lower Mainland of British Columbia, particularly relating to western red cedar, is lacking. The current research project attempts to quantify a baseline composition of western red cedar and salal die-off in a park in Metro Vancouver that can be used to estimate composition change in the future.

Western Red Cedar (*Thuja plicata)*

The western red cedar is an economically, ecologically, and culturally significant tree used by coastal communities for countless generations (Larson, Dahal, and Barry, 2010). Its mature leaves are scale-like and decurrent, and they pair off at 90 degree angles from one another (Burton & Trevor 1999). The tree itself can grow up to 70m in height and has a trunk that can be multiple meters in diameter. Western red cedar grows across the Pacific Coast from California to Alaska (Burns, 1990). Western red cedar is often present in forest ecosystems of all successional stages, but as a shade-tolerant tree that can grow from the

understory, reproduction tends to peak in stable communities, and tends to be considered a climax species (Minore, 1983).

Western red cedar tends to tolerate a range of moisture conditions. They have been observed in swamp conditions with a water table that approaches the surface (Burns, 1990), but can also tolerate drier conditions than other climax species such as Western Hemlock due to their deep and extensive root formations, and can also tolerate more poorly drained soil conditions (Burns, 1990). However, long periods of elevated water table and waterlogged conditions can be detrimental to any tree species by creating conditions of anoxia and poor nutrient remineralization, effectively lowering the availability of essential nutrients such as nitrogen (Paavilainen & Päivänen, 1995). This is especially true following disruption of scale sufficient to impact community rates of evapotranspiration (Paavilainen & Päivänen, 1995). Western red cedar tends to have a stronger preference for moist sites with more abundant nitrogen (Burns, 1990). Because of the correlation between soil moisture content and soil clay content, long periods of elevated water table conditions may be exacerbated by high soil clay content (Prescott and Lavkulich, 2012). There is also a significant lag time of 5-7 years between when unfavourable moisture conditions occur and when symptoms show in trees (Prescott and Lavkulich, 2012).

Overall, Western red cedar has a moderate tolerance of drought and a high tolerance of water excess (Ninemets & Valladares, 2006). Western red cedar can be susceptible to fungal infection, but tends to fare better than related species such as Western Hemlock or Douglas Fir (Burns, 1990; Minore, 1983).

Salal (*Gaultheria shallon*)

Salal is an evergreen shrub that typically stands 0.5m - 2m in height on the forest floors of the Pacific Northwest (Fraser et al., 1993). Its 7cm x 4cm leaves present an alternating pattern with finely serrated edges (Fraser et al., 1993). It has been classified as an extreme competitor for water in soil where its rhizomes extend and regenerate the shrub via clonal expansion of new shoots (Huffman et al., 1994). Salal die-off presents itself as browned and desiccated plant sections, which can be found amongst live sections due to plant regrowth.

Salal is associated with western red cedar in that they are often found together and share a similar geographic range, and is known to compete with coniferous species including western red cedar and Western Hemlock (Minore, 1983).

Pacific Spirit Regional Park

Pacific Spirit Regional Park (PSRP) is located on the unceded ancestral lands of the Musqueam First Nation (Musqueam Indian Band, 2019). The park was originally granted to the University of British Columbia as a part of the UBC educational endowment lands, before being established as a natural forest preserve in 1989 and is now a park within the Metro Vancouver Regional Parks system.

PSRP covers 763 hectares of dense forest and foreshore land on and is home to a wide variety of plant and animal species, including salal and western red cedar, the two plant species we are concerned with in this project. The park is largely used as a recreational space, hosting a network of over 50km of walking and biking trails (Pacific Spirit Park Society, 2017). These trails are used by hundreds of people daily for

a wide range of recreational activities. The recreational value of the park is closely related to its health, as it is enjoyed by naturalists and outdoor enthusiasts (Pacific Spirit Park Society, 2017). Therefore, the widespread plant death is likely to decrease the recreational value of the park, making it a less desirable recreational area.

The dominant soil type found in Pacific Spirit Regional Park are Podzolic soils. Podzols are prevalent under cool and humid conditions, and cover a wide range of the Earth's surface, from the sub-arctic to the temperate zone (Thompson, 1985). The parent material of podzolic soil is glacial till (Armstrong, 1990). Vancouver was once under large glaciers, and as the glaciers melted and retreated they deposited sediments onto the land, leading to the formation of soil (Armstrong, 1990). Podzols are slightly acidic, due to the quartz rich deposits from the glaciers (Thompson, 1985). They are coarse-grained, dominated by a sandy textured mineral fraction, resulting in low water and nutrient retention. The A-horizon is enriched with soil organic matter (Bhoojedur, 1969).

An area of particular interest in Pacific Spirit Regional Park is the Camosun Bog. The Camosun Bog was formed as the glaciers receded, leaving a small indentation in the land and trapping glacial meltwater into a lake (Wynn, Hermansen, 2005). Water drainage and the growth of sphagnum moss transitioned this lake into its current bog conditions (Armstrong, 1990, Wynn, Hermansen, 2005). These conditions retain water effectively, which could help restrict plant die-off in the area if drought is causing death.

Pacific Spirit Regional Park has a long history of disturbance and development (Image 1). All of the area within the park has been logged at least once (Thompson, 1985). Our entire sample area was either clearcut or selectively logged up until 1930 (Thompson, 1985). The UBC campus was cleared in 1912 for development (Thompson, 1985). Clearing of forest continues to occur in multiple locations around the university campus, primarily for residential development (Hernandez, 2017; Chan, 2017).

Image 1. A history of development in Pacific Spirit Park (formed 1989). Images from 1930, 1959, 2004, and 2019 show the encroachment of urbanized space. (Department of Energy, Mines, and Resources, 1930; Department of Energy, Mines, and Resources, 1959; Google Earth Pro, 2004; Google Earth Pro, 2019)

Research Objectives

The objectives of this project are to track western red cedar die-off in Pacific Spirit Regional Park, and produce a map that indicates the spatial distribution of die-off. Interpretations of our project focused on topographical, disturbance, and hydrological features and possible correlations between vegetation die-off, geographic location, and disturbance and features. This project aimed to deliver geospatial data in an accessible format that might provide information to inform monitoring and restoration efforts in the future. Our research questions can be summarized as follows:

- How is salal and western red cedar distributed in Pacific Spirit Regional Park?
- Are there any evident spatial trends to disease and die-off?

Although salal was initially included in our project, and data about salal is available on our final maps, interpretations or analysis for this species were not pursued due to lack of available data (low sample size, possibly due in part to difficulties identifying the species). Initially, however, our research questions also included:

- What is the approximate area of affected salal plants?

Methods

Field Methodology

Throughout this observational study, sampling was conducted within the boundaries of Pacific Spirit Regional Park, with an emphasis with sections of the park south of 16th avenue. Using a sampling method known as "viewshed sampling," sometimes used in invasive species research, which refers to recording observations within sightlines of a transect. By partner request, existing trail infrastructure (Figure 1) was used as transects, despite the lack of ability to randomize transects throughout the park

using this methodology, in order to preserve the integrity of ecologically sensitive zones, mitigate safety concerns of off-trail sampling in certain areas, and to improve replicability of the project for Metro Vancouver Parks staff in future years.

Figure 1. Pacific Spirit Regional Park. Due to time constraints, in consultation with community partner, priority sampling area was considered to be trails south of 16th avenue. Western regions of the park were specifically avoided due to safety concerns related to sampling near steep cliffs.

GPS points of each observed salal and western red cedar are recorded using Trimble Geo7X (Image 2), an industry standard device due to high accuracy, on loan from our community partner at Metro Vancouver Regional Parks. Along with the geographical location of each dead and dying plant, a number of other pieces of attribute data was collected for each plant. Firstly, each plant was given a unique identification number for ease of data storage analysis in software. In addition, height and percentage of death for each species was collected, diameter at breast height (dbh) was recorded for each western red cedar, and any other qualitative notes or features about the plant or environment were also recorded.

Image 2. A Trimble Geo7X device was used for data collection.

Diameter at breast height and plant height were recorded using a tape measure. When the height of a western red cedar was too tall for measurement by tape measure, approximations were made using trigonometric approaches. Percentage of death was estimated using approximations of the percentage of the tree exhibiting browning, made by the entire team, and the average was recorded (Image 3). Although consultations with forestry and botany experts, literature review, and field work guided us in making these estimations, the method remains prone to error. Because this approximation wasn't necessarily the most quantitatively accurate approach, pictures of each plant were also taken. This may provide an enhanced ability to monitor changes in each plant if the study is repeated in the future. Pictures were taken with standard cell phones (iPhone 11 running iOS 13). This eased the data upload process, and pictures were also automatically geo-tagged to a low level of accuracy, but aided in some respects with piecing the data together in arcGIS. Waterproof notebooks were used to record and match respective photos with the geographical point for each plant. Noteworthy qualitative features of each plant and its environment was recorded in both the Trimble device and the notebook.

Image 3. High and low percentage of death respectively. ID 31 (left) was recorded as 100% deceased. ID 32 (right) was recorded as 10% deceased.

Analytical Methodology

Once the data was collected, the photos were uploaded to a cloud based storage solution to improve collaborative capability between multiple researchers. In addition to the original plan to produce a map viewable in standard arcGIS software, our team believed that presenting the data in a Google MyMap™ would provide benefits to community members who may not have access to arcGIS software. This also improves the ability to access data from any smartphone while in the field. Final maps depicting the diseased trees were produced in arcGIS, and histograms showing the distribution of the size of the trees (diameter at breast height), and the amount of dead (percentage of browning) were produced from the attribute table (Figure 2).

Plant ID	Species	Percent Dead/Browning	Height (m)	DBH (cm)
115	c	100%	10	15

Figure 2. The completed data point on the Trimble. "c" represents cedar
(J.Kim, Personal Communication, 2019)

<u>Results</u>

A total of 205 western red cedar and 69 salal plant die-off points were recorded over the entire southern area of the park. The main product of the project is a map showing the geographic distribution of diseased western red cedar and salal (Figure 4). Although our project made no attempt to perform hypothesis

testing or evaluate the geographic spread using a statistical framework, our map shows that the diseased units are likely not randomly distributed. The majority of the data seems to occur in three areas: Camosun Bog (salal), near the Sasamat Trail outhouse and picnic area (WRC), and near the Metro Vancouver Sasamat Reservoir (WRC). Results showed that 78/205 (38%) WRC were within 50m of sites identified as disturbed or noteworthy.

Some of the noteworthy results include the observation that the majority of the diseased cedar trees identified were small (meaning also young) (Figure 3). This is consistent with vegetative stress to which young trees have not developed resilience, but older trees may be less impacted. Another noteworthy result is that the majority of our trees were entirely consumed by browning (indicating that they were completely deceased), with few trees being identified as only partly consumed by the browning (Figure 4), which would perhaps suggest only mild stress. This may be due in part to researcher bias (trees with only a very low number of affected branches were assumed to be undergoing natural growth processes).

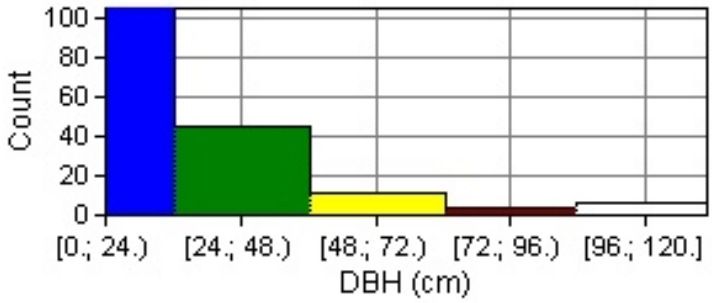

Figure 3. Recorded age distribution (as a proxy for age) of the diseased cedars.
Most of the diseased units were young, consistent with not having the resilience of older trees. The DBH of each point was collected using a tape measure.

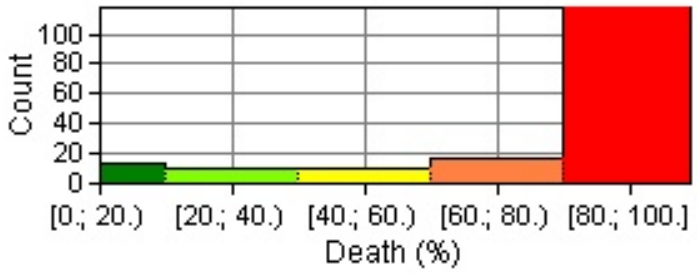

Figure 4. Histogram showing the percentage of death of the cedar trees. The percentage of death was estimated visually as described in the project methodology.

A map in the form of a Google MyMap™ was also produced to improve data accessibility for a variety of users and for access in the field. The MyMap can be found here: https://drive.google.com/open?id=1MxjwifzZOySjlToj6HDrlxZRX9qUkeg6&usp=sharing.

Discussion

In mapping the distribution of die-off in Pacific Spirit Regional Park, a number of trends became visually evident. First among these was a pattern of disease clumping, or concentrated areas of die-off for both salal and western red cedar (Appendix A). For salal, deceased shrubs were found exclusively within Camosun Bog. Although salal is an evergreen species, it is possible that variations in foliage density of it or other species made it difficult to identify in the field, introducing researcher error. Data was collected

in November and December immediately prior to snowfall. Die-off was identified by dried out, dessicated leaves of struggling salal plants, which are only weakly attached to plant stems. Heavy snowfall could have removed dead leaves, making diseased plants difficult or impossible to identify. Alternatively, due to salal's fast regeneration time (Huffman et al., 1994), patches of die-off could have been hidden by new growth later in the data collection window. This lead to a general lack of confidence in our salal data, as die-off may have been much more extensive than recorded (in the case of snow stripped, unidentified die-off patches) or inconsequential (in the case of fast regeneration times).

As cedar trees regenerate much more slowly than salal (Paavilainen & Päivänen, 1995), and are more easily identified when foliage is lost, we are more confident that our mapped die-off is more representative of actual die-off. Clustering seems to suggest some spatialized, non-random cause of die-off. As evident in the data found in Appendix A, die-off is much greater on the eastern side of the park, and seems to be more concentrated at park edges than in the centre of the park. It is possible that plants on the edge of the park are more affected by human activities such as vehicle exhaust, off-leash pets, root and soil compaction from off-trail use, or by non-human activities such as invasive species or encroachments. The east-west gradient may occur because the east side neighbours a more dense residential area than on the west. The areas of concentrated cedar death also exhibit very visible human development and environmental alteration. For example, very concentrated die-off is observed near the Camosun electrical substation and Sasamat Reservoir. In these areas, human development has very obviously changed the characteristics of the area (Image 1), especially hydrologically with large areas of ponded water forming in forested areas. Ponding restricts airflow to tree roots, potentially drowning the trees. In other areas of concentrated death, dumping of trail building material (clays, gravel, and even cracked pavement) is evident (figure 6). Although there is no clear, direct link proving that these material dumps are harming cedar trees, they could have an effect by restricting water penetration deep into the soil or redirecting water, causing more pooling. These hydrological changes are likely to affect mostly young trees with more shallow root systems, as the deeper root systems of older cedars make them more resistant to both drought and flood (Breda *et al.,* 2006, Burns, 1990). That theory seems to be supported by our data, as we found a much larger proportion of young, small trees dying than mature trees (Figure 3).

We recorded a much higher proportion of complete die-off than partial die-off in this project (Figure 4). It is possible that this is because die-off has only recently been noticed, and we observed this phenomenon at the stage of complete death. If this is the case, at this point most of the trees that are likely to be affected by past changes within the park are already deceased. Partial death may reflect more recent changes within the park, which may progress in the future, if stressors continue to be present. This data likely contains some inherent bias for a number of reasons. First, the seasonal lysing of needles from cedar trees (Paavilainen & Päivänen, 1995) has led us to ignore trees with very small, patchy die off, as those are likely unrelated to significant die-off trends. Low die-off observed near the top of the tree, however, was recorded as it may indicate the beginnings of water scarcity, when transporting water to the top of the tree becomes impossible (Prescott and Lavkulich, 2012). Secondly, low die off rates are much harder to identify than full die-off, especially high up large trees. We may have missed smaller die-off events if we just could not see them. Finally, percentages of death are all estimated. Although we attempted to standardize our estimations, there is potentially a reasonable level of error and uncertainty involved.

Although much of the literature and public concern with western red cedar die-off is concerned with climate change related effects (Brend, 2019; Watson, 2019; Wilson, 2018), we do not find clear evidence of these direct effects in this study. We would expect a more uniform distribution of die-off were climate change the only variable controlling die-off, as climate change should affect the whole area roughly equally, or at least more predictably. It is quite possible that climate change is responsible for some death, or is accelerating die-off for plants that are otherwise vulnerable, however this study cannot make such claims with any confidence.

Conclusion

Although the root causes of plant die-off in Pacific Spirit Regional Park remain unclear, this project provides the integral first step in determining causation and reducing plant death. It confirms objectively that extensive, seemingly non-random die-off is occurring, affirming the concerns of experts and community members. It determines the spatial distribution of plant die-off, as well as trait distributions of die-off, providing a baseline to which future studies can compare in analyzing changes to die-off over time. Additionally, the qualitative findings from this report may lead to future studies of ecological and soil restoration policies concerning construction events occurring prior to park designation in 1989, especially regarding hydrological best practices. Finally, we suggest a more thorough, focussed assessment of salal morbidity and mortality, as our study was not able to confidently reach any conclusions regarding current trends.

Appendix A - Maps

Pacific Spirit Park Vegetation Die-Off

Legend

- Dying Cedar
- Dying Salal
- Data Collection Boundary

0 0.5 1
Kilometers

N

Map 1. Entire dataset of salal and western red cedar points.

Map 2. Western red cedar only, classified by the percentage of browning occuring on each observed tree.

Pacific Spirit Park Cedar Die-Off

The locations where disturbances were noticed next to dying cedar trees

Legend

Data Collection Boundary

Disturbed Sites 50(m) Buffer

0 0.25 0.5
Kilometers

N

ID	BUFFER (m)	DISTURBANCE TYPE
A	50	Soil Disturbance and Standing Water
B	50	Soil Disturbance
C	50	Standing Water
D	50	Standing Water
E	50	Standing Water
F	50	Soil Disturbance
G	50	Soil Disturbance
H	50	Standing Water
I	50	Soil Disturbance
J	50	Standing Water
K	50	Soil Disturbance and Standing Water

Map 3. Locations of disturbed or unusual environmental sites observed while sampling.

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