Stanley Park
Hemlock Looper Impact and Wildfire Risk Assessment

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EXECUTIVE SUMMARY

Stanley Park is a key landscape feature that is central to the identity of Vancouver residents and the local First Nations (Musqueam, Squamish, and Tsleil-Waututh). Since 2019, the forested areas in Stanley Park have been increasingly impacted by an outbreak of western hemlock looper (*Lambdina fiscellaria*) (looper) which is a defoliating insect. This endemic forest pest has been responsible for substantial tree damage and mortality across the Lower Mainland, especially in western hemlock (*Tsuga heterophylla*) trees. In response to concerning levels of attack and subsequent mortality in the Stanley Park forest, Vancouver Park Board staff commissioned an assessment of the looper impact and related wildfire risks in Stanley Park in 2022.

The assessment captured the severity and extent of looper impact in the Stanley Park forest and the risk of tree failures in areas of high public use. In addition to looper impacts, wildfire risk was assessed, so that recommendations could address both the current and future risk of tree failure and wildfire throughout the Park. Due to continued looper feeding throughout summer 2023, it is indeterminate how much additional tree mortality will occur.

To conduct the assessments, the Park was stratified into estimated areas of high, moderate, and low looper impact severity using ortho-photography. A detailed inventory of looper impact and wildfire risk was created using plot-based sampling. Large tree, small tree, and fuel transect data were collected in a total of 121 plots across the forested areas of the Park. Additional observations were collected, relating to: understory vegetation species and cover; understory tree regeneration and vigor; invasive plant occurrences; forest composition and structure; forest health agents; and wildlife / human use.

As of April 2023, approximately 30% of the trees >20 cm in diameter[1] in Stanley Park have been killed or severely defoliated by looper defoliation, and an additional 36% have been moderately defoliated. The majority of trees requiring removal due to looper impact are western hemlock, however Douglas-fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*) have also been impacted, but to a lesser extent. Drought and other forest health stressors may have contributed to the severity of the impact. Over time, as these trees die and decay, failure of tops, branches, and whole trees pose an increasing risk to human safety and park infrastructure. Risk to human safety throughout the impacted area will increase significantly over the next 3 to 10 years.

Inherent with this risk is an increased risk of wildfire. As trees die, and branches, tops, and whole trees fail, dry woody surface fuel will build up, creating conditions that are prone to natural- and human-caused fire ignitions. The high proportion of standing dead hazard trees and surface fuel build-up will create conditions that hinder effective and safe emergency response. Wildfire risk and fire growth potential were modeled over present and future scenarios. Currently, 24% of the Park can be classified as high and extreme wildfire risk, with an additional 60% as moderate risk. Removal of dead trees is imperative due to the high risk to human safety and park infrastructure, and is recommended to commence in the highest risk areas as soon as is reasonably possible.

[1] Greater than 20 cm in diameter at breast height (measured 1.3 m above ground).

REPORT AUTHORS

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Bruce Blackwell, MSc. RPF RPBio	• Fire Ecologist • Restoration Plan Specialist • Ecologist
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1.0 INTRODUCTION

Acknowledgement:

Vancouver is situated on the unceded traditional territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations ("MST"). These First Nations have been stewards of these lands since time immemorial and have used trails and corridors to travel across their territory to bring their communities together and manage resources. The Vancouver Board of Parks and Recreation's reconciliation goal is to decolonize the Park Board and seek truth as a foundation for reconciliation.

Stanley Park (the "Park") is Vancouver's flagship forested park and recognized throughout British Columbia, Canada, and internationally as a unique and iconic urban park. It attracts large numbers of both local users and international tourists, and is approximately 75% forested and accounts for 75% of Vancouver's native forest.[2] Since its establishment in 1888, Stanley Park has been impacted by several large-scale disturbances: Hurricane Freda (1962); the 2006 windstorm; and, most recently, a severe outbreak of the hemlock looper moth (*Lambdina fiscellaria*). The concern for wildfire in the Park has also increased in recent years, with high numbers of Park visitors, unauthorized/illegal campers, and hot, dry summers.

The purpose of this report is to assess the scale and extent of the hemlock outbreak looper and associated wildfire risk in the Park, and to provide direction to the City of Vancouver, as represented by the Vancouver Park Board ('VPB' or 'Park Board') on mitigation and response actions. This report provides an opportunity to enhance near and long-term forest health and visitor experience through detailed recommendations for operational treatment that will mitigate risk and for ecological restoration that will increase forest resilience over time.

The outline of the report is as follows: Section 1 will present an introduction of the report objectives; Section 2 describes the current forest condition in Stanley Park and history of disturbance, as well as background information on the looper outbreak; Section 3 describes the field assessments of looper impact and wildfire risk; Section 4 outlines the results of the two assessments; Section 5 outlines recommendations; and Section 6 summarizes the findings of the assessments.

[2]VanPlay. 2019. Inventory and Analysis Chapter 5 - Nature.

1.1 VISION AND PROJECT OBJECTIVES

Figure 1. Stanley Park forest near Prospect Point. (B.A. Blackwell, March 2023)

The vision for the Stanley Park forest, as stated in the 2007 Stanley Park Restoration Plan and the 2009 Stanley Park Forest Management Plan, is:

'That Stanley Park's forest be a resilient coastal forest with a diversity of native tree and other species and habitats, that allows park visitors to experience nature in the city.'

This report is delivered in the context of this overarching vision for the Stanley Park forest. The list below outlines key objectives that should guide mitigation and response action in the Park:

1) Establish and maintain conditions that protect public safety in the areas impacted by the looper that foster a resilient coastal forest with a diversity of native tree and plant species with robust habitats, using methods and equipment that protect the environment, archaeological resources, park visitors, workers, volunteers, and infrastructure;
2) Reduce the risk of personal injury or property damage caused by whole- or partial-tree failures;
3) Protect environmentally sensitive areas and habitat for species-at-risk found within the Park and near looper impacted areas, as well as critical cultural, aesthetic, and recreation assets;
4) Reduce the likelihood of uncontrolled wildfires, to minimize the extent of damage and risk to park users and adjacencies; and
5) Protect newly forested areas from being damaged or destroyed by natural occurrences or human activity.

1.2 PARK CONTEXT

Figure 2. Overview map of Stanley Park. Adapted from City of Vancouver print resources.[3]

Stanley Park, Vancouver's oldest and largest park, occupies a prominent position within the landscape. At the end of a peninsula extending out into the inner harbour of Burrard Inlet, most of the Park boundary interfaces with ocean water. A rich variety of habitats make up the Park, including lakes, tidal and intertidal zones, water courses, cliffs, and upland forest.

In addition to natural features, the Park contains a multitude of well-used recreational, commercial, and cultural assets. As well as the 27 kilometers of trails and the 9-kilometer paved Sea Wall, the Park includes sports fields, tennis courts, beaches, restaurants, and tourist attractions such as the Vancouver Aquarium. Many of the Park's assets are concentrated in the southeast corner of the Park near Brockton Point (Figure 2). Lion's Gate Bridge connects Stanley Park to the North Shore, less than a kilometer north. Proximity to the forests of the North Shore makes Stanley Park susceptible to insect outbreaks occurring in and spreading from North Shore forests. This is further discussed in Section 2.1 – Hemlock Looper Outbreak.

[3] https://vancouver.ca/files/cov/stanley-park-map-and-guide.pdf

2.0 FOREST DESCRIPTION

Natural forest comprises approximately 263 hectares (ha) and is the most dominant feature within the Park's 418 ha (Figure 3). Like other low-elevation forests in the Lower Mainland, the Stanley Park forest is located in the dry maritime Coastal Western Hemlock biogeoclimatic zone (CWHdm).[4] Forests in the CWHdm tend to be dominated by a mix of western hemlock, Douglas-fir, and western red cedar. Red alder and big leaf maple occur on more nutrient rich sites. Summers are warm and winters are mild.

The forest has had a history of natural and human-related disturbances, including First Nations and colonial settlement, logging, wildfire, and wind blowdown events. The legacy of past logging and the expanding footprint of facilities, landscaped areas, and trails and roads, has interrupted ecological processes in the Park. Historically, the forest was dominated by a mix of tree species that were defined by natural forest succession processes. Given the human disturbance history from the settlement of the City of Vancouver and related forest fragmentation within the Park, western hemlock has become the dominant tree species in the Park (over 40% of large trees sampled – see Section 3.1 - Tree Data Collection). Compared to the other conifer tree species, western hemlock is more susceptible to disease, windthrow, and stem breakage.[5]

As a remnant patch of coastal forest, Stanley Park is both ecologically valuable and holds iconic status as a recreational and educational resource for residents and tourists. When established as a park in 1888,[6] it was important that the Park be managed as a recreational amenity for Vancouver residents and visitors. Natural disturbances can induce catastrophic changes to the Park; an example is the large windstorm event that hit Stanley Park in 2006, in which 30% of the forest was damaged or blown down (5-10% of all trees in the Park). Disturbance events across multiple scales will continue to impact Stanley Park into the future, as they remain part of the South Coast climate and ecology. In planning for the restoration of the looper impacted areas within the Park, it is important that restoration goals and objectives are focused on efforts that support an ecologically resilient forest that tolerates future environmental and climatic changes that may impact the Park.

[4]Green, R.N, and K. Klinka. A Field Guide to Site Identification and Interpretation for the Vancouver Forest Region. 1994. Province of British Columbia.
[5]Klinka, K., J. Worrall, L. Skoda, and P. Varga. 2000. The Distribution and Synopsis of Ecological and Silvical Characteristics of Tree Species of British Columbia's Forests. Canadian Cartographics Ltd., Coquitlam, B.C.
[6] City of Vancouver and Vancouver Park Board. 2018. Urban Forest Strategy: 2018 Update. 60 pp.

Figure 3. The extent of forested areas within Stanley Park.

2.1 HEMLOCK LOOPER OUTBREAK

Since 2019, a looper outbreak has impacted the South Coast of B.C. Looper outbreaks are cyclical, occurring every eleven to fifteen years, and typically last three to four years before natural controls lower the looper populations to endemic levels. Naturally occurring controls include parasitoids, pathogens, and summer rains during moth flights. The looper moth is native to BC and is an integral part of B.C.'s coastal forest ecology because it creates disturbances that allow for greater diversity in species and forest stand structure often reducing populations of over-represented species.

Stanley Park's western hemlock tree population has sustained light to severe amounts of damage from looper larval feeding (Figure 4). Tree defoliation, decline, and mortality is most pronounced in overstory western hemlock trees, but some damage has been observed in Douglas-fir, western red cedar, understory conifer trees, shrubs, and deciduous trees. Tree mortality will continue for several years after the infestation. Trees that survive the outbreak are at increased risk of death from other insect pests, drought stress, windthrow, parasites, and fungal pathogens.

Figure 4. Left: Typical large western hemlock killed by hemlock looper in Stanley Park. Right: Looper-killed trees along trails next to Stanley Park Drive. (B.A. Blackwell, March 2023)

Although the looper outbreak was evident in North Vancouver in 2019, 2020 was the first year of observed looper attack in Stanley Park. Observations of significant overstory tree mortality in August 2022 (see cover photo) triggered the need to assess the severity of looper impact and resulting wildfire risk in the Park. This report summarizes conditions observed in spring 2023, after three presumed seasons of looper defoliation in the Park. Light to moderate looper larvae populations have also been observed throughout the 2023 summer, indicating that the looper outbreak may continue for at least another season. Figure 5 below summarizes the life cycle of the looper.

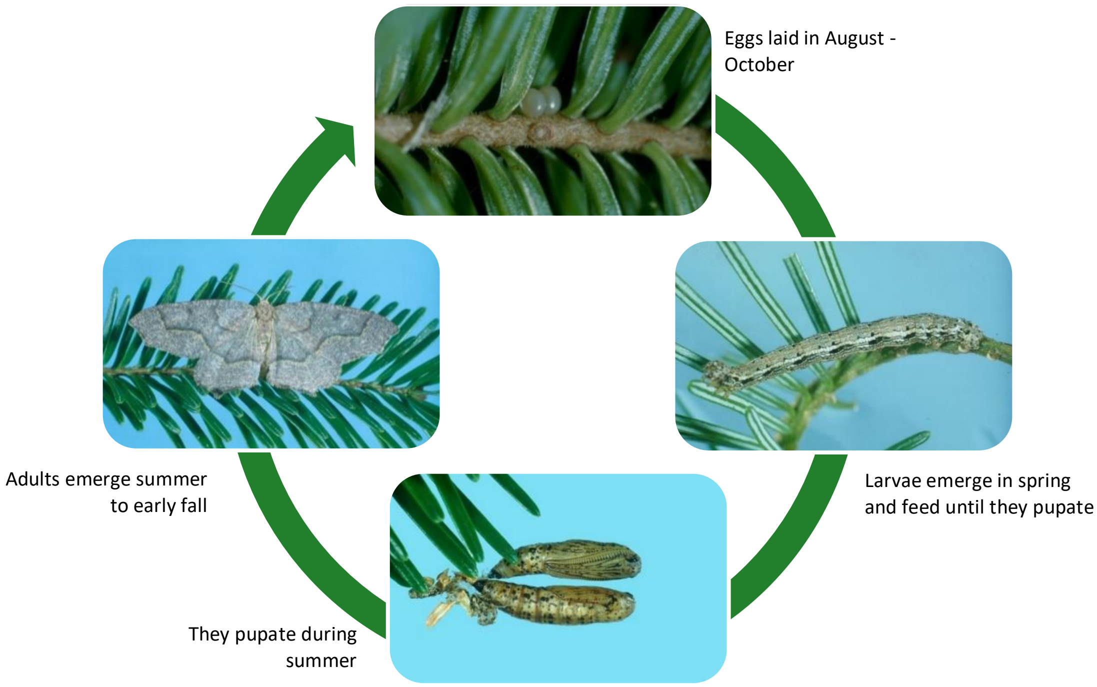

Figure 5. Western hemlock looper (*Lambdina fiscellaria*) life cycle.

3.0 ASSESSMENT METHODOLOGY

In spring 2023, estimates were made using ortho-imagery provided by the Park Board[7] to estimate areas of high, moderate, and low looper impact within the forested areas of Stanley Park (263 ha). Two hundred and eleven (211) polygons were digitized in ArcGIS based on estimated severity, forest cover data (Vancouver Park Board), and geographic boundaries (roads and trails). Based on the polygons delineated, sample plots were located throughout the Park.

Field work was conducted on multiple days between March 7 and April 5, 2023. A detailed inventory of looper impact and wildfire risk was developed using plot sampling. Tree and fuel transect data were collected in a total of 121 plots across the forested area of the Park. In addition, observations were made on understory vegetation species and cover, understory tree regeneration and health, operational constraints, invasive plant occurrences, forest composition and structure, forest health agents, and wildlife / human use.

As noted above, the spring 2023 assessment is a 'snapshot' of looper damage in the Park at the time and used to support data for this report and for next steps. Additional looper feeding in summer 2023 will likely result in additional mortality that will need to be monitored and assessed in 2024.

3.1 TREE DATA COLLECTION

Circular fixed area plot sizes were 11.28 m radius (400 m²) for >20 cm diameter at breast height (dbh) trees ('large trees') and 5.64 m radius (100 m²) for ≤20 cm dbh trees ('small trees'). Individual large tree attributes collected included dbh, species, height, decay class, percentage live crown ratio (LCR), and recommended tree treatment. Attributes for trees >20 cm dbh were collected on the Tree Form Data field form. At least one member of each

[7]The most recent ortho-imagery available was from 2022.

sampling crew had ISA TRAQ (International Society of Arborists Tree Risk Assessment Qualification) credential. Recommended treatment for each tree >20 cm was based on the TRAQ risk methodology of likelihood of impacting target and consequence of failure (Figure 6 and Figure 7 below).

Likelihood of Failure	Likelihood of Impacting Target			
	Very low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Figure 6. Matrix 1 – TRAQ likelihood matrix.

Likelihood of Failure & Impact	Consequences of Failure			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Figure 7. Matrix 2 – TRAQ risk rating matrix.

Attributes included in the 5.64 m radius plot included tree count by species and by tree layer within the overall canopy:

- Layer 4 - Regen (<1.3 m height)
- Layer 3 - Sapling (>1.3 m height – 7.5cm dbh)
- Layer 2 - Pole (7.5 – 12.5 cm dbh)
- Small Layer 1 (12.5-20 cm dbh)

Attributes for trees ≤20 cm dbh were collected on the Wildfire Data field form, including average crown base height, average height, and percent cover. General observations of looper impact, overall health and vigor, and long-term prognosis were also recorded for these small tree layers.

Based on the large (>20 cm dbh) trees sampled in the park, the species composition of the stand is as follows: western hemlock (live and dead) comprises nearly half of the large trees (50%), followed by Douglas-fir (23%), western red cedar (14%), with other species (i.e., big leaf maple, red alder, spruce, etc.) constituting the remainder (12%).

Understory tree layers (≤20 cm dbh) were even more dominated by shade tolerant western hemlock (64%), followed by western red cedar (25%). There was a small component of other species, including red alder, Douglas-fir, grand fir, and bitter cherry. Overall, one-third of sampled small trees were dead from natural suppression, looper defoliation, or other causes.

3.2 FUELS AND SITE DATA COLLECTION

Fuel type, slope, aspect, elevation, and forest floor depth were recorded on the Wildfire Data digital field form for each plot. One fuel loading transect was also conducted following established fuel management survey methodology.[8] To estimate the amount of woody debris surface loading in each plot, the line intersect sampling method (also referred to as 'fuel transect') was used. In each plot, one line intersect, 30 m in length, was laid out commencing from plot centre at 360° (due North). If this was not possible given the configuration of the polygon, the fuel transect was laid out 15 m on either side of plot centre in the same cardinal direction, or a different aspect was chosen. The number of fuel pieces in each size class were counted and tallied.

The coarse woody debris decay class for each piece of large coarse woody debris was recorded. Tree species composition was determined by percentage as it is required as input to the BC Wildfire Service's (BCWS) line intersect calculator (BCWS, 2022).

Following field work, collected data was checked for errors and omissions and compiled in Microsoft Excel. Spatial and tabular data was organized and used to create an up-to-date inventory of looper and wildfire risk areas as ArcGIS polygons. Other datasets created included fuel type, plots, wildlife features, water features, human encampments, and other observations that support future planning.

The original 211 polygons were combined or redrawn as required to reflect on-the-ground forest conditions as determined by plot sampling, ortho-imagery, and field verification to assess both the hemlock looper impact and wildfire risk. Polygons that were small and similar to neighboring polygons were not quantitatively sampled. These small polygons were combined with adjacent polygons with similar attributes. The original 211 polygons were rationalized using plot attributes and field verification to characterize each polygon in the final inventory dataset of 157 polygons (Figure 8). One of the most important plot attributes for assessing looper severity was defined as the percentage of trees in each plot recommended for removal due to risks to public safety. Trees were recommended for removal that were: a) standing dead; b) severely defoliated (<25% live crown remaining and most likely to die imminently); or c) otherwise hazardous due to various structural factors. Looper impact within polygons was categorized as follows:

- 'High Impact': 50% or more trees identified for removal;
- 'Moderate' Impact: 10-50% of trees identified for removal; and
- 'Low' Impact: <10% of trees identified for removal.

Field observations and professional judgement were used to verify all ratings and classify polygons in borderline cases.

[8] BC Wildfire Service. 2022. *Fuel Management Survey Data Collection Standard.* Tools for fuel management - Province of British Columbia (gov.bc.ca). Available online.

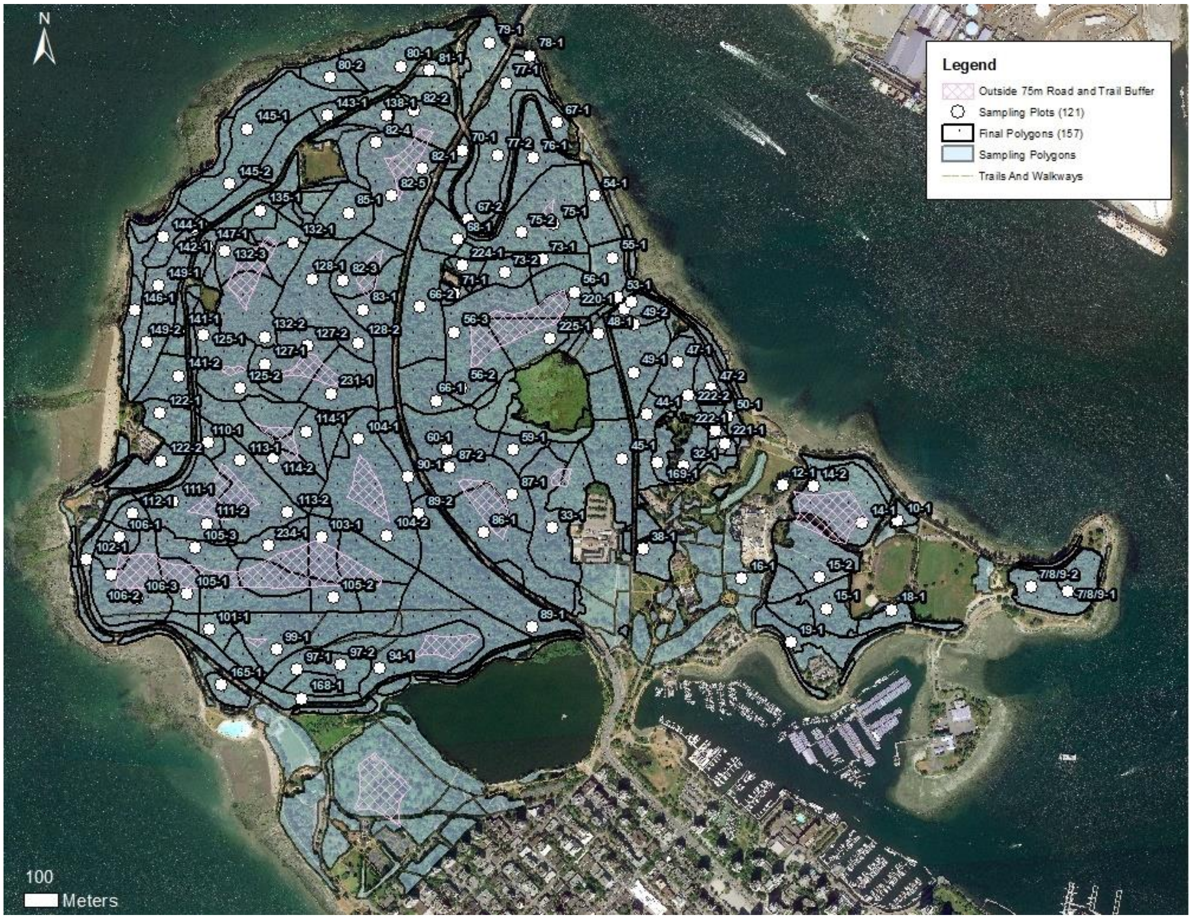

Figure 8. Field sampling strategy, including 121 sampling plots. Final polygon boundaries delineate stands with similar conditions as of March 2023.

Figure 9. Example of a Moderate Risk Polygon in Stanley Park and the potential public safety risk associated with the standing dead trees. (B.A. Blackwell, April 2023)

The resulting inventory dataset describes the severity of current looper impacts (as of spring 2023), fuel types and associated fuel loading (which are important to wildfire risk assessment), and number of tree stems per hectare in each of the final 157 polygons. Subsequently, looper impact severity classes were delineated based on geographical location and estimated percentage of looper-induced mortality. Further details on the results of the looper impact assessment are outlined in Section 4.1 Hemlock Looper Assessment.

4.0 RESULTS

4.1 HEMLOCK LOOPER ASSESSMENT

Looper severity is highly variable across individual trees, tree species, tree patches, and whole stands from the overstory to the understory. Figure 10 illustrates the overall results of the looper impact assessment by severity class and the following list depicts the extent of areas impacted in each category:

- High: >50% of trees identified for removal (**66 ha – 25% of the 263 ha of forest area**)
- Moderate: 10-50% of trees identified for removal (**118 ha - 45% of the 263 ha of forest area**)
- Low: <10% of trees identified for removal (**79 ha - 30% of the 263 ha of forest area**)

Overall, approximately 30% of the trees >20 cm in diameter (approximately 20,410 trees) have been killed by the looper in Stanley Park. An additional 36% have been moderately defoliated and should be monitored. The majority of the trees requiring removal are due to looper-related mortality of western hemlock. Douglas-fir and western red cedar have also been impacted, but to a lesser degree and have proved more resilient to the outbreak (Figure 11).

Tree that are <20 cm in diameter have also been defoliated by the looper. Their smaller size presents a lower risk to public safety, but a residual wildfire risk remains. Removal of these trees will be recommended in some units for wildfire risk mitigation (Figure 12).

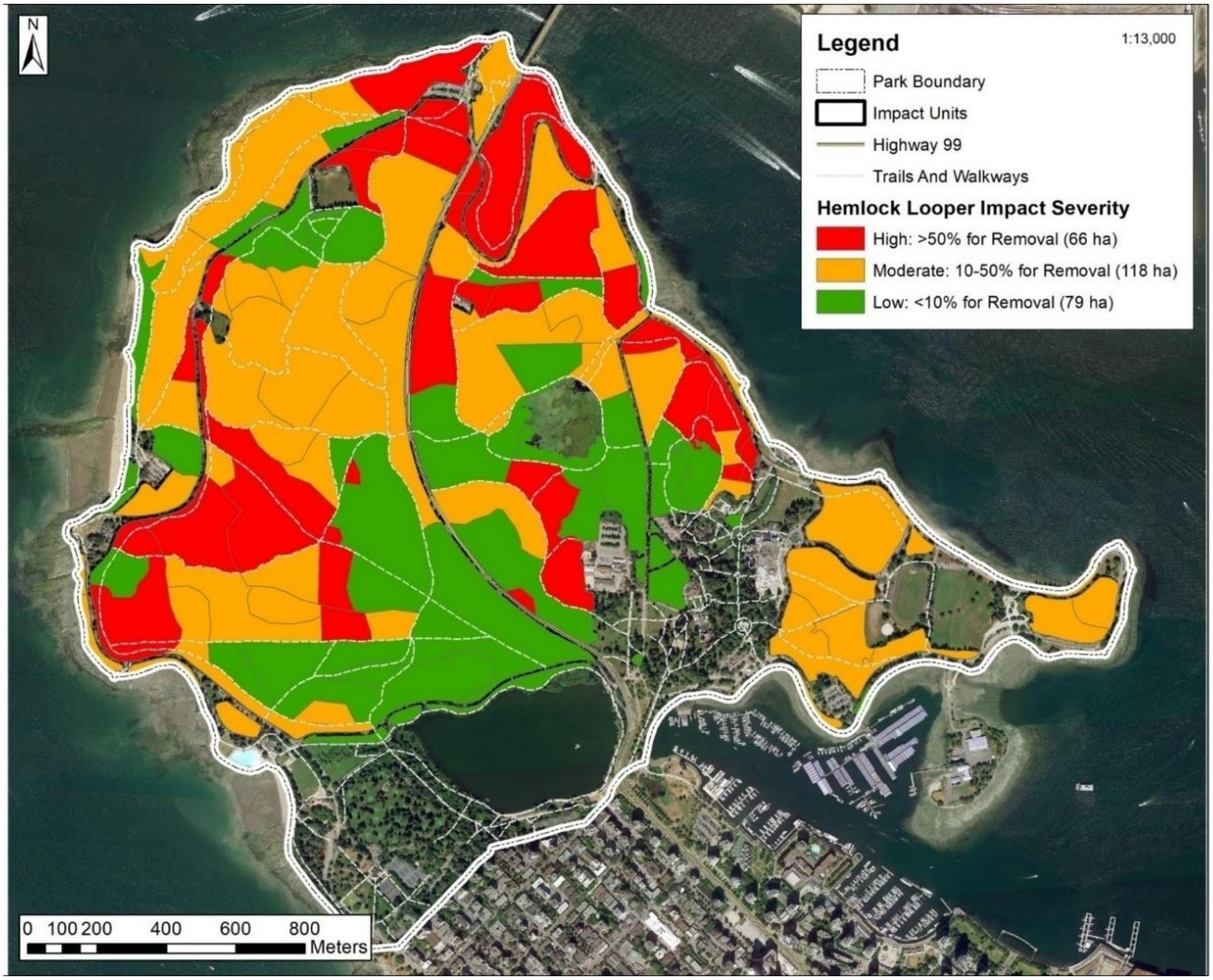

Figure 10. Stanley Park hemlock looper impact severity map (as of May 2023). The red areas have the highest proportion of looper-impacted trees, but are not necessarily the highest risk. Risk is based on occupancy rate in addition to impact.

Trees in 'Low' impact areas that have been lightly to moderately defoliated by the looper may also include trees that present an imminent hazard to an area of high use resulting in the need to prioritize these impact areas for removals in the short term. Blackwell's experience with looper outbreaks in similar urban interface areas (i.e., Lynn Headwaters Regional Park) suggests that some lightly to moderately defoliated trees will recover and survive, however, the exact proportion of future survival is unknown and depends on other factors such as drought and secondary pests and pathogens. Therefore, these trees have been placed in a 'monitor' class and should be assessed for risks to public safety in the future. Some of these trees may require treatments such as topping and pruning.

Figure 11 illustrates the average proportion and total number of trees >20 cm in diameter in Stanley Park by species and treatment recommendation (removal). Western hemlock is the species most severely impacted by the looper, followed by Douglas-fir. There are small numbers of western red cedar trees and other species recommended for removal.

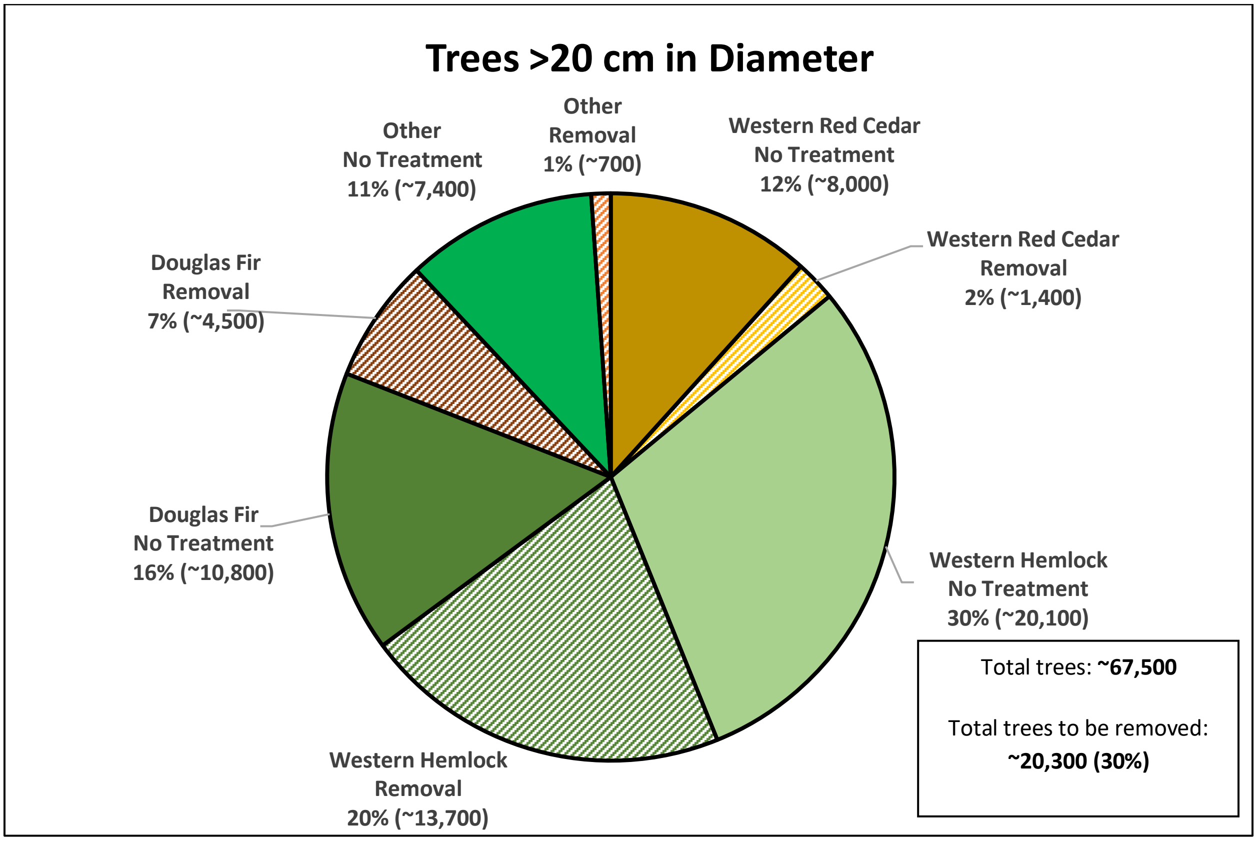

Figure 11: Average proportion and total number of trees >20 cm in diameter in Stanley Park by species and treatment recommendation.

Figure 12 below shows the approximate proportion of understory trees (<u><</u>20 cm in diameter) in Stanley Park by species. These small trees, especially western hemlock, were also impacted by the looper, although mortality and stress from other causes (e.g., shade and/or drought) was also observed during the field assessment. Many of the live trees were lightly to heavily defoliated, and it is indeterminate how much additional mortality will occur in these layers. These smaller dead trees do not pose the same risk to public safety as large trees pose, but especially in high numbers, they create a wildfire fuel hazard. The density and vigor of understory trees should continue to be monitored across the park, and removal of a portion dead and suppressed trees should be prescribed to achieve wildfire risk reduction objectives.

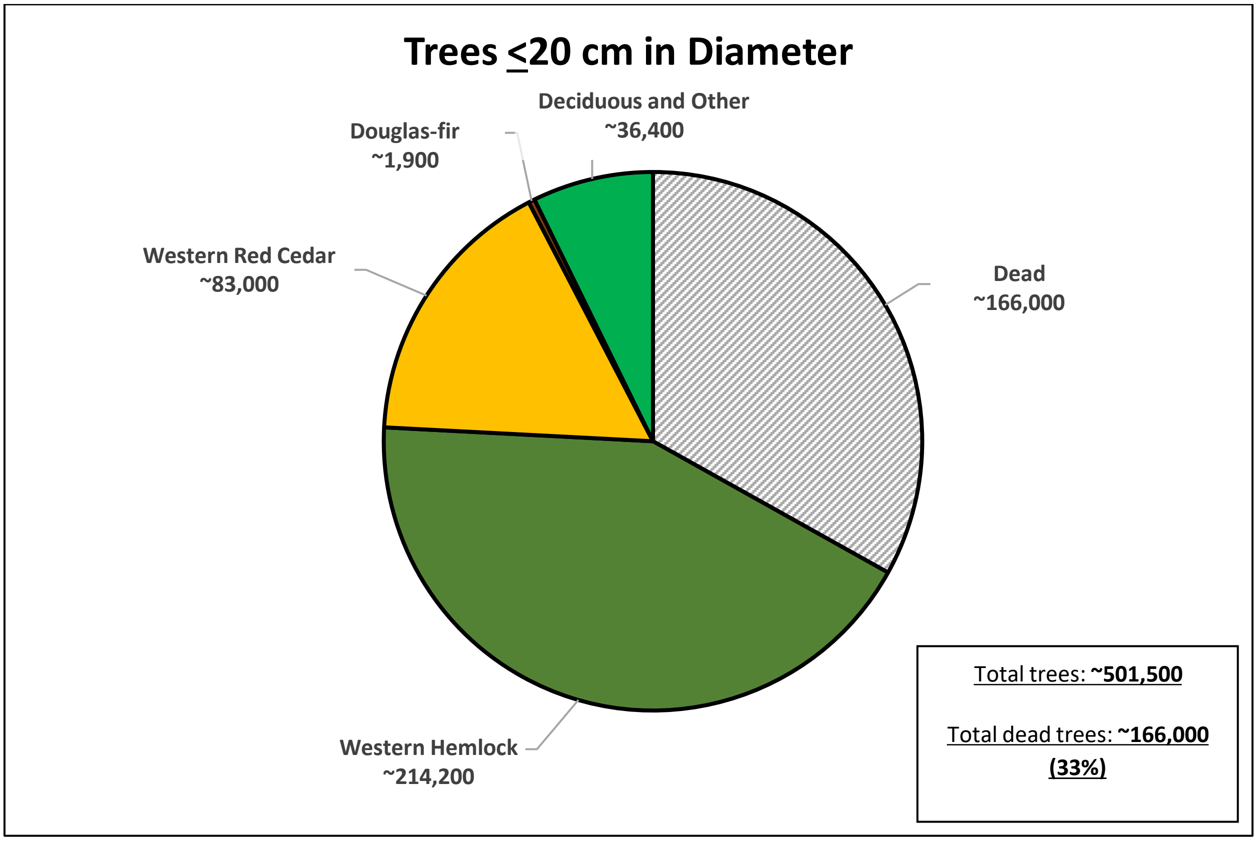

Figure 12. Average proportion and total number of trees <20 cm in diameter in Stanley Park by species.

Note: The number of trees <20 cm dbh was originally reported as 609,200 total trees and 138,200 dead trees (23%). These numbers have since been recalculated and reflect an average of the sampled area as of March 2023.

4.2 WILDFIRE RISK ASSESSMENT

Wildfire risk in Stanley Park was assessed for the current risk (Figure 13). Definitions of the term "risk" and all its derivatives (e.g., risk management, risk assessment, risk evaluation, etc.) are inconsistent in the wildfire literature, this may be a legacy of the fact that most wildfire research has been broken down into specialty topics such as fire behaviour, fire effects, and fire history/occurrence. For the purposes of this report, wildfire risk is defined as the probability and consequence of wildfire at a specified location under specified conditions. This definition is consistent with the generic definition of risk and its derivative terms adopted in many jurisdictions worldwide (Canadian Standards Association, 1997; Council of Standards Australia/New Zealand, 1999; International Standards Organization, 2002).

Figure 13. Surface fuel from one fallen western hemlock tree in Stanley Park. (B.A. Blackwell, March 2023)

Analytically, the approach used to quantify wildfire risk provides a spatial characterization of risk based on probability and consequence ratings. In other words, the model can indicate, at any given location and under specified conditions, what the probability of wildfire occurring is and, for a given wildfire behaviour, what the potential consequences on valued resources are.

Figure 14 depicts how various combinations of probability and consequence can imply basic management strategies. In practice, the implementation of this risk management approach requires a detailed spatial examination of assessment results across a full continuum from low to high ratings.

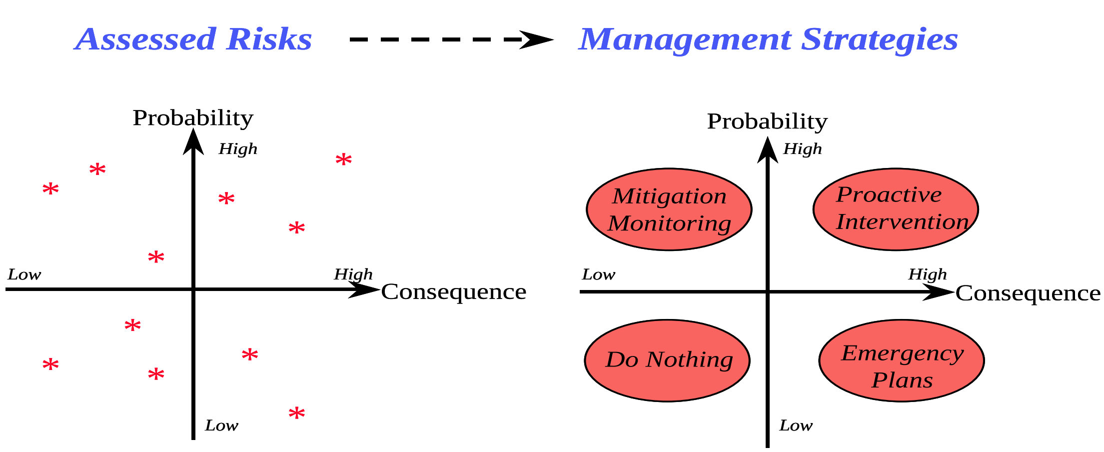

Figure 14. Conceptual representation of risk assessment/management as the resultant of two factors: Probability and Consequence.

Risk is represented as the overlay of *wildfire probability* (based on historical ignitions, fire weather, topography, and fuel type) and *wildfire consequence* (based on proximity to values at risk), where:

- ***Wildfire Risk*** is defined as the potential losses incurred to human life and or values at risk within a community in the event of a wildfire.
- ***Wildfire Consequences*** are the repercussions associated with fire occurrence in an area. Higher consequences are associated with public safety, presence of values-at-risk, critical infrastructure, etc.
- ***Wildfire Probability*** is the likelihood of wildfire occurring in an area and is expressed by the ability of a wildfire to ignite and spread, and the associated suppression difficulty. Wildfire probability is based on historical ignitions, fire weather, fuel type, and topography and the influence of suppression, if they are available.

The probability of a wildfire occurring and the consequences or impacts from wildfire were modeled to determine overall wildfire risk. The components of Probability are:

1) Probability of Ignition;

2) Fire Behaviour; and

3) Suppression Capability.

The components of Consequence represent the values-at-risk and are:

1) Urban Interface;

2) Ecosystem Integrity;

3) Air Quality; and

4) Visual Quality.

Components are composed of one or more subcomponents and are given different weightings, or values of importance, within the model framework.

Spatial and field assessment data were used to develop a wildfire risk assessment model for the Park as outlined in Figure 15. Input variables affecting wildfire risk include: local climate data; fuel type; historical ignitions; projected wildfire behavior; distance to roads and trails; and proximity to facilities. Infrastructure, roads and trails, park facilities, and other areas of human use were used to develop a wildfire consequence theme. The overall wildfire risk was calculated based on the relationship between wildfire probability and consequence. Wildfire risk was assessed with and without suppression capability (i.e., proximity to water sources, roads, helicopter arrival time, and terrain steepness).

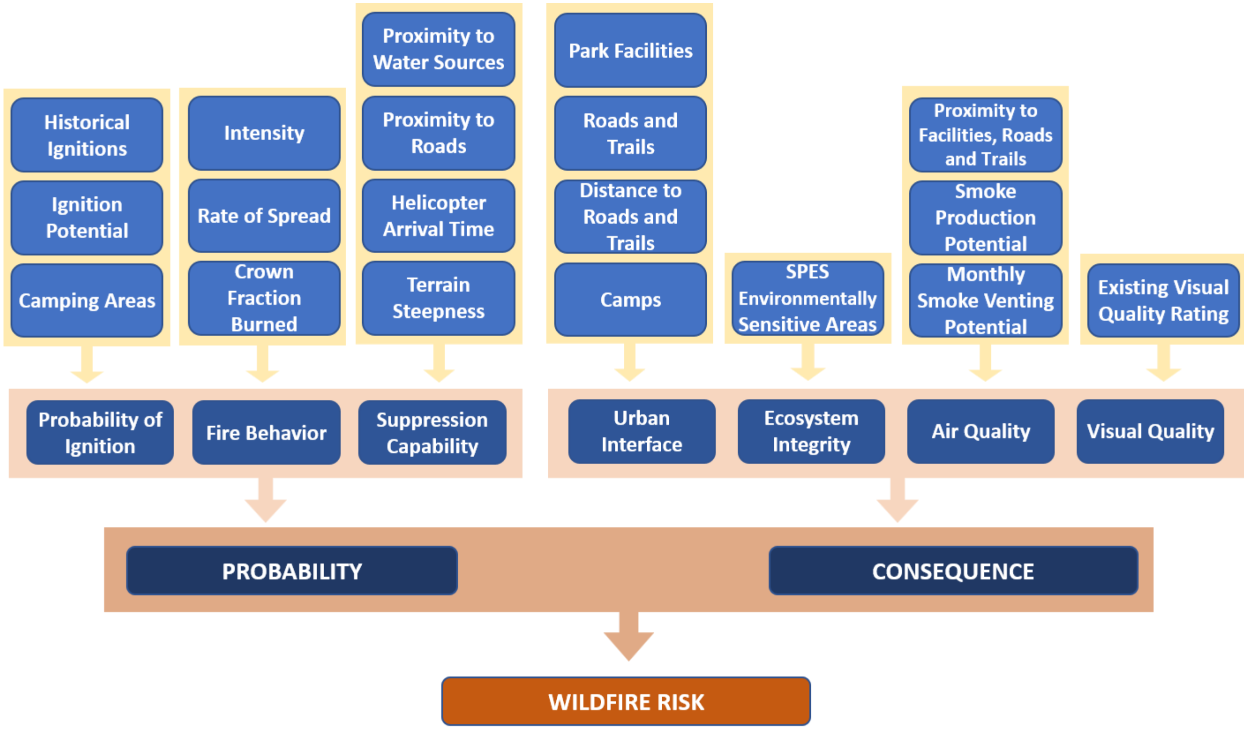

Figure 15. The wildfire risk assessment model. (B.A. Blackwell graphic)

It should be noted that dramatic changes or disturbance events (e.g., tree defoliation, tree mortality caused by the hemlock looper, and the consequent accumulation of surface woody debris) may not dramatically change overall wildfire risk in Stanley Park. An increase in the fuel hazard in the Park will increase only one of the three wildfire probability components in the model above – Potential Fire Behavior. The other two Probability components (Probability of Ignition and Suppression Capability) will remain unchanged. Each of the Consequence components will also be unchanged, as trails, roads, structures, and environmentally sensitive areas will still be present on the landscape, and therefore drive 50% of the wildfire risk. This is a limitation of the modelling and may underestimate the real risk.

4.2.1 OVERALL WILDFIRE RISK

Figure 16 and Figure 17 illustrates current wildfire risk in the Park. Areas of high wildfire risk are concentrated around Stanley Park Drive, Prospect Point, and high-use areas at the south end of the Park. Areas of very high risk are found between Prospect Point and Third Beach, north of Lost Lagoon, and near Pipeline Drive, due in part to the history of frequent human-caused fire ignitions. Risk is under-represented adjacent to the causeway because it is a highway (paved surface) and therefore classified as a non-fuel area.

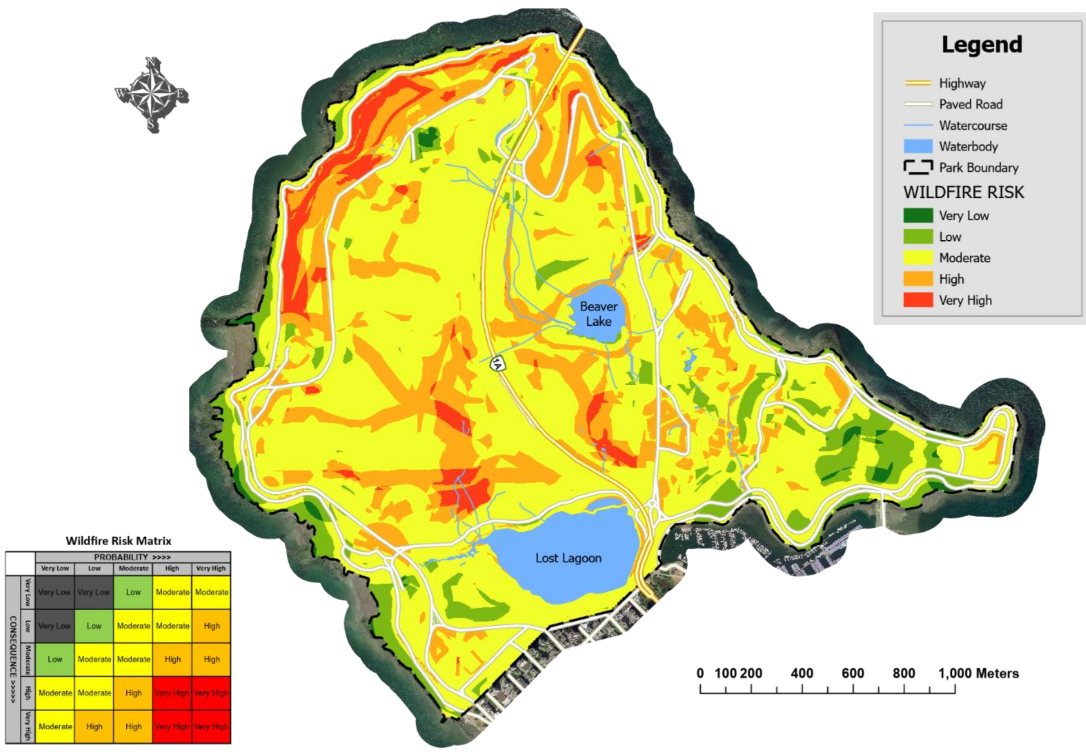

Figure 16. Current Wildfire Risk in Stanley Park, as represented as the intersection of Wildfire Probability and Wildfire Consequence.

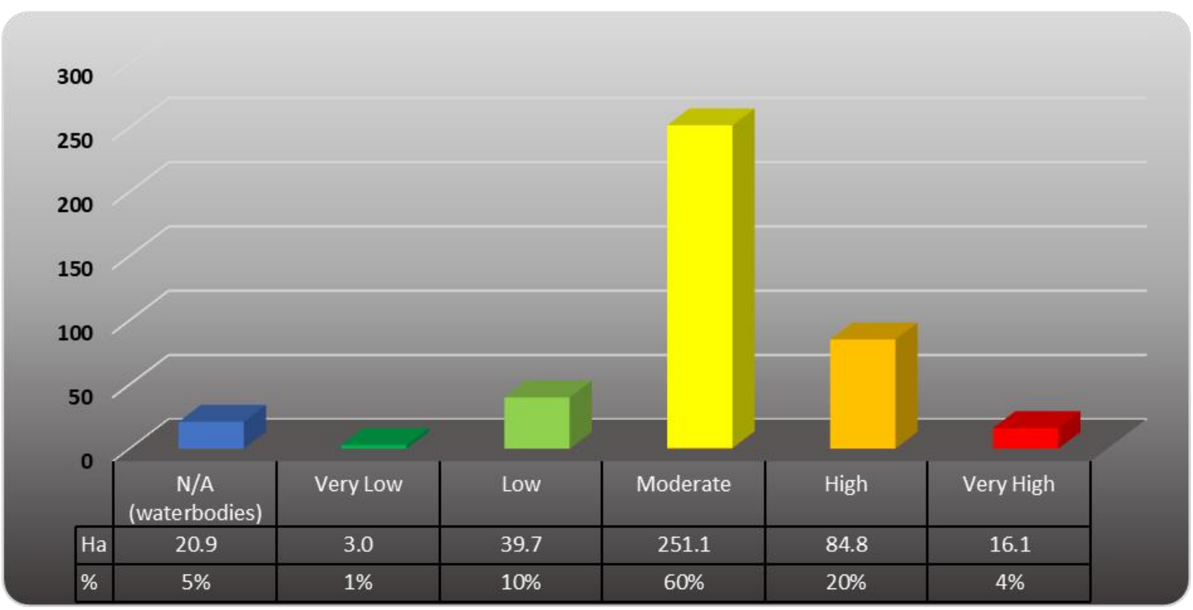

Figure 17. Current distribution of area (hectares) in each wildfire risk class in Stanley Park.

4.2.2 POTENTIAL FIRE INTENSITY

A change in the forest fuel types in Stanley Park changes the modeled wildfire behavior. As dead trees decay and lose structural integrity, components such as tops, branches, and eventually stems, fall to the ground resulting in an increase in fuel loading. Although there is a reduction in crown fire hazard as fuel moves to the ground, the resulting increase in surface fuel will lead to an increase in potential fire intensity and rate of wildfire spread across the Park. Figure 18 shows the current potential fire intensity compared to the fire intensity after mitigation of surface and overstory fuel.

Areas of red and orange have relatively high potential fire intensity under high fire danger weather conditions. If dead and downed fuel is cleaned up, the potential fire intensity is reduced to more moderate levels throughout most of the park. Felling dead trees and removing woody debris accumulations will reduce the fire intensity over 27% of the area in the highest intensity classes (4000 - 10,000 KW/m) and will shift fire intensity to the lower intensity class (2000 - 4000 KW/m). Overall fire intensity will be lower and the consequent risk to established park values will be reduced to more acceptable and manageable levels.

Areas of high potential fire intensity following tree removal (mitigation) include those areas of young dense conifers that have not been severely impacted by the looper, but still have high continuity of ladder fuel (e.g., northwest facing slope next to Prospect Point). Thinning in these young dense conifer stands, based on fuel management science, will significantly reduce the fire hazard associated with these stand types that are not treated as part of the broader looper mitigation work. Since these areas still contribute significantly to wildfire risk/intensity in Stanley Park, they are recommended for mitigation and restoration following the response to the priority looper-impacted areas. Recommended treatments would involve reducing conifer stem density by thinning from below to appropriate numbers of desired species, and pruning remaining trees.

Potential fire intensity cannot be reduced to low everywhere, as all conifer forests have some level of fire threat. Areas that received a ‘low’ rating in this model are areas that cannot support any fire (e.g., irrigated grass fields, gardens, roads, and beaches).

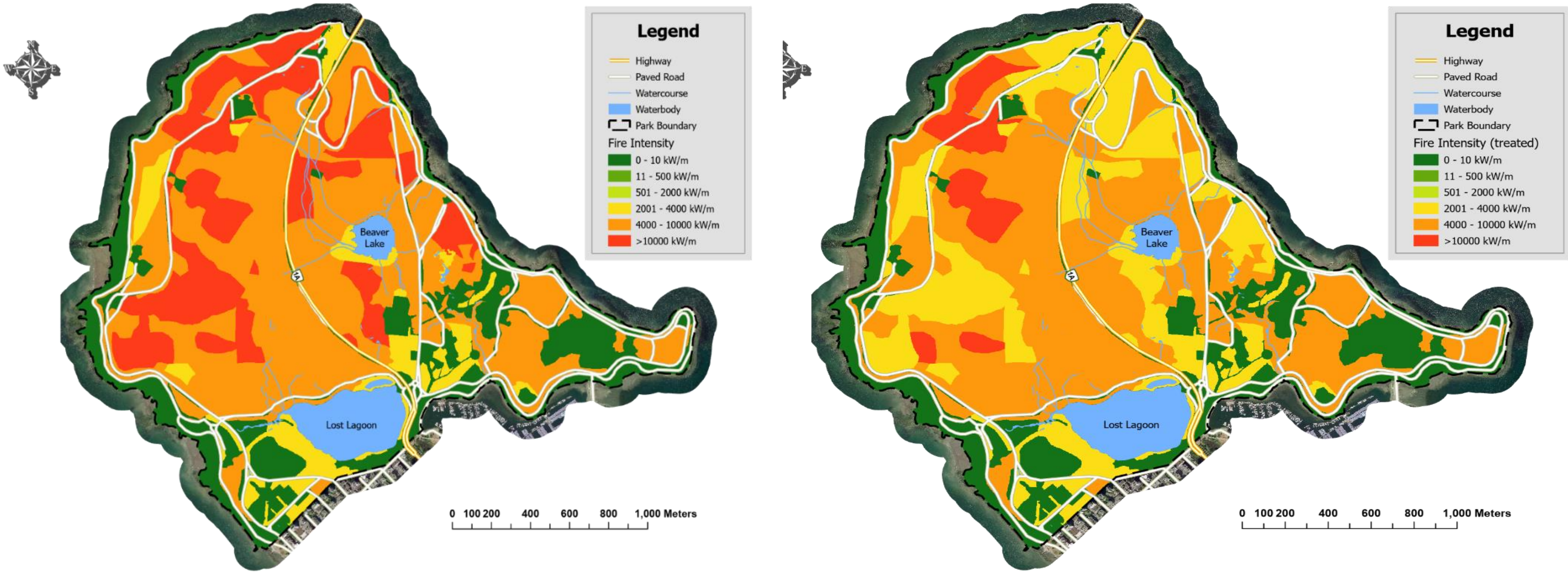

Figure 18. Potential fire intensity in Stanley Park. Left: No mitigation of looper-impacted areas. Right: Mitigation of looper-impacted areas. Potential fire intensity remains high in areas with fuel hazard unrelated to looper (e.g., areas of existing dense juvenile stands of conifer trees).

Note: Where the looper impacts were moderate or low, as described earlier in the report, tree removal does not change the standing green forest significantly enough to change the post treatment fire behaviour potential.

Figure 19. Example of an area with low fire behavior potential (B.A. Blackwell, March 2023).

4.2.3 WILDFIRE RESPONSE

Without mitigation and restoration of looper-impacted areas, the ability of fire suppression crews to address wildfire safely and rapidly in Stanley Park will decline over time. Hazard trees and surface fuels hinder both foot and vehicle access to forested areas in the Park. High concentrations of historical ignitions continue to drive present and future wildfire risk in the Park, especially north of Lost Lagoon (Figure 20). No data is available for July and August 2023, but in June alone, City of Vancouver Fire Rescue responded to ~39 human-caused fire ignitions in Stanley Park. Fortunately, forest-wetting, monitoring / reporting by Park Rangers, diligent fire response / suppression, and targeted hazard reductions have controlled fire ignitions to date.

The Canadian fire growth model 'Prometheus'[9] was used to model fire growth potential in Stanley Park. The model relies on the Canadian Forest Fire Danger Rating System (CFFDRS).[10] The CFFDRS consists of two main subsystems; the Fire Weather Index (FWI) system and the Fire Behaviour Prediction (FBP) system. With respect to fuels, vegetation must be represented, as defined by the FBP System.

Wildfire growth modeling (Figure 20) shows what could occur if there was a delay in fire detection or response, under high or extreme fire danger conditions (90th percentile weather conditions) where winds are elevated. Based on current stand conditions, a wind-driven fire has the potential to impact over 25% of the Park within twelve hours. The model also compares the potential fire growth from five other high-probability ignition points under varying

[9] http://www.firegrowthmodel.com/index.cfm
[10]http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm
http://www.firegrowthmodel.com/index.cfm
[10] http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm

wind scenarios that have the potential to significantly impact the Park under a worst-case scenario but are not included in this report.

The present-day potential impacts from a wildfire to people, property, and infrastructure are significant, but will grow substantially over the next decade if fuel from looper-killed trees is not properly mitigated. In the most severely impacted areas, the amount of fine fuel is projected to increase to a level where the rate of spread and fire intensity could be very high, and a wildfire would be difficult to control under high and extreme fire danger conditions. Given the spatial distribution of current looper impact, future wildfire risk is expected to be highest around Prospect Point, east of the Tea House and Second Beach, adjacent to the works yard, and north of the Stanley Park railway. All of these areas are priorities for looper impacted tree removal and restoration.

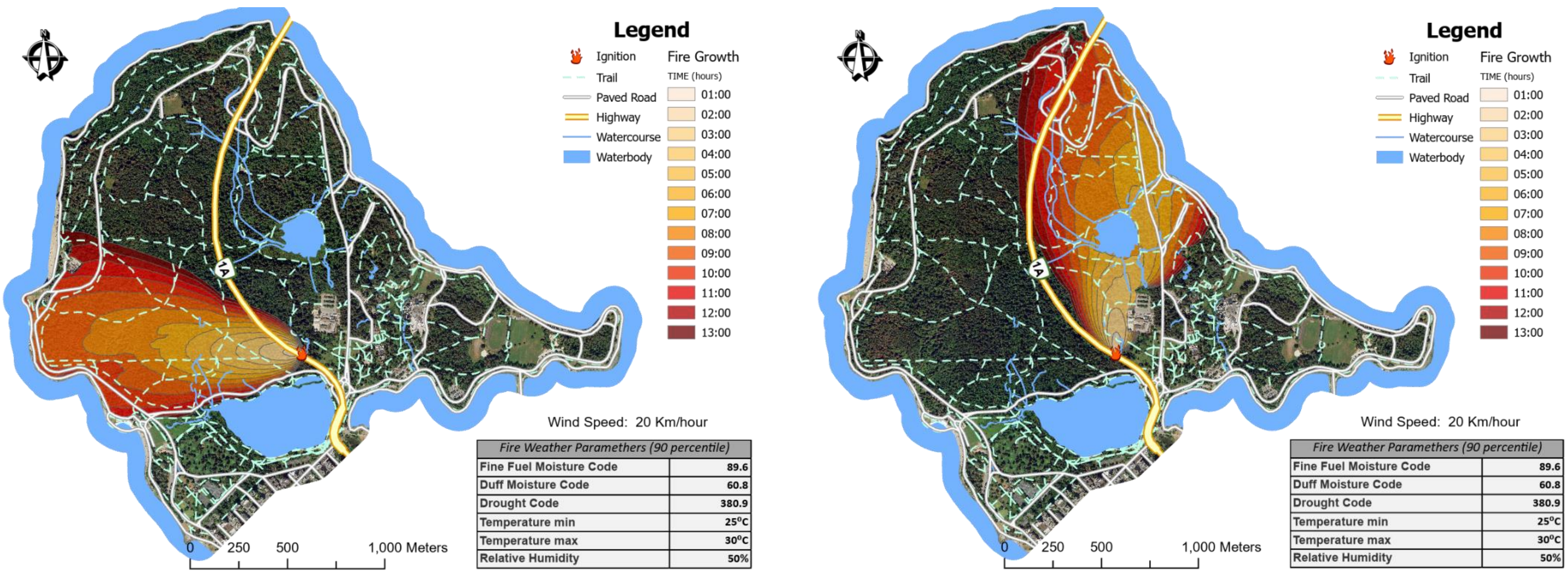

Figure 20. Twelve-hour wildfire growth modelling with an ignition from the causeway. Winds at 20 km/hr from the east (left) and south (right) winds are shown.

5.0 RECOMMENDATIONS

Areas that are selected for priority treatment should be based on severity of looper damage, human use, and consideration of risk to public safety. Treatments should commence in the highest use areas and be coordinated with biological windows to limit impacts to nesting birds, and take into consideration any required archaeological assessments and peak visitation seasons to minimize disruption to Park assets and visitors. In addition, mitigation efforts must coordinate with parallel projects, such as the Metro Vancouver Capilano 5 Water Main project, scheduled to begin in 2024.

The highest risk area based on occupancy rate is the Causeway. It is a provincial highway with very high daily traffic volume. Treatment timing will depend on coordinating road closures with the Ministry of Transportation. As Stanley Park Drive and the seawall would be considered to have high occupancy rates it is recommended that a coordinated treatment of these areas as part of the project areas may result in a shorter duration for closures.

It is recommended that treatments are carried out during fall/winter months (October to March) when there is typically decreased public use of the Park and outside the bird breeding window (March – August). The three-to-five-year timeline is an estimate and is dependent on operational requirements and weather conditions.

All treatments are intended to promote ecosystem restoration and resilience; to achieve this, some dead trees can be left or modified to serve as wildlife trees. The number of these trees will be determined based on safety, tree condition, species, and other stand structure attributes and their contribution. A portion of the dead down trees, greater than 30 cm in diameter, will be left as coarse woody debris and spread flat to the ground and separated from other pieces to ensure that the wildfire hazard is mitigated. Large diameter trees are only considered a wildfire threat when they are mixed with fine fuels (<12.5 cm), as the fine fuels provides the ignition source and has the ability to preheat the large pieces of debris.

The focus of wildfire treatments will be to reduce the fine fuels to levels that will reduce fuel ignition potential, fire spread, and fire growth potential. Fuel loadings will be reduced to limit the fire intensity. These treatment standards will improve firefighter safety and wildfire suppression success.

The focus of reforestation of the treated areas will be the re-establishment of Douglas-fir and western red cedar. It is expected that western hemlock will re-seed naturally in large numbers and will require some thinning to maintain their distribution to acceptable levels. Douglas-fir and western red cedar are the preferred species as they are longer living and more disease- and decay-resistant. A reasonable component of hardwoods (deciduous trees) is to be maintained within the reforestation species mix as deciduous trees provide biodiversity, wildlife habitat (cavity nests), and wildfire resilience.

Wherever possible, larger trees and forest stands will be retained and only removed if they pose a risk to public safety. Generally, the larger trees throughout the Park have not been as heavily impacted by the looper and do not contribute significantly to wildfire risk. Trees that have been only lightly or moderately defoliated and have a higher likelihood of survival should be monitored.

Invasive plant management is an existing challenge in the Park. The looper operational treatment prescriptions will not provide direct mitigation of existing invasive plant populations, but will be focused on limiting the spread of invasive species. However, the reforestation and subsequent brushing of reforested areas will focus on the control of invasives as part of the brushing prescription. Once the looper restoration of the Park is complete, it is recommended the Park Board continue to take into consideration recommendations in the 2013 SPES Invasive Plant Management Plan[11] to manage invasive species throughout the Park.

Treatment in Stanley Park is complicated by infrastructure that requires protection, the movement of woody debris out of the park, the human use and traffic patterns, archaeological assets, environmental conditions, the need to keep as much of park open to the public at all times, and can only be delivered based on available budget.

6.0 SUMMARY

The impact of the looper outbreak in Stanley Park has resulted in approximately 30% (approximately 20,300 trees) of the trees >20 cm in diameter killed or severely defoliated. Dead, looper-impacted trees are expected to decay and start failing (tops, branches, or whole trees) within the near-term and will continue over the next 20 years, with commensurate increase in risks to public safety and park infrastructure. This ongoing tree failure will lead to unacceptable levels of risk to people and infrastructure, and mitigation or management of at least 90% of the Park's forest areas is critical in the short-term. See Appendix A – Trends in Risk for further details.

In addition, wildfire surface fuel loading will gradually increase as trees fail. Large accumulations of surface fuels will increase the risk of wildfire, the rates of wildfire spread, and the deep burning potential of surface fires. The increase of surface fuel may damage and destabilize live trees, as well as increase fire suppression difficulty, suppression costs, and smoke production (extensive periods of smoldering).

The effects of the looper impact also poses a risk to the health of the remaining forest. Stressed trees are more likely to succumb to other forest health factors such as drought and windthrow, and are at an increased risk of mortality from secondary pests, such as ambrosia beetle (*Gnathotrichus sulcatus*). The effects of these secondary pests will continue for several years after the looper infestation collapses. Continued large-scale die-back will induce undesirable ecological impacts, such as proliferation of invasive plants, and degradation of soil-root cohesion, resulting in the potential increased risk of windthrow and slope failure in steep areas.

To mitigate and manage the looper impacted trees in Stanley Park to acceptable levels, operational treatment prescriptions must be developed as part of implementation actions stemming from this report. As most of the park overlaps high-use areas, priority areas for mitigation and restoration should be prioritized based on the frequency of use by people and in consultation with Park Board staff.

Ongoing monitoring should be a key component of addressing the hemlock looper outbreak in Stanley Park. Without the ability to identify and respond to emerging forest health factors, increased wildfire risk, spread of invasive plants, and other potential changes to the park over the near and long term, the vision of Stanley Park as a resilient and diverse coastal forest is jeopardized. Adaptive management will be key to successfully mitigating hemlock looper and wildfire risk within the Park within a context of healthy forest ecosystems and functional park assets.

[11] Stanley Park Ecology Society. 2013. SPES Invasive Plant Management Plan.

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8.0 DEFINITIONS

Crown Base Height- the height, above ground where the live tree crown of a coniferous tree begins.

Coarse woody debris decay class– a classification scheme of 5 classes to record coarse woody debris decay. Wood texture criteria is the key component of decay, with class 1 as *intact, hard* and class 5 as *many small pieces, soft portions,* other criteria are provided in the scheme as guidelines for classifying the decay. The definition and scheme are defined in the *Vegetation Resources Inventory – British Columbia Ground Sampling Procedures*, March 2018, Version 5.5, pg. 192.

Diameter at breast height (dbh)– a standard method of expressing the diameter of the trunk or bole of a standing tree as measured from 1.3 m above the ground.

Fuel Type - an identifiable association of fuel elements of distinctive species, form, size, arrangement, and continuity that will exhibit characteristic fire behavior under defined burning conditions.

Head Fire Intensity - the rate of heat energy released at the head of the fire.

Live Crown Ratio - the ratio of crown length to total tree height, or the percentage of a tree's total height that has foliage.

Hemlock Looper Risk – the possibility or likelihood of Hemlock Looper killing or infecting a tree.

Operational Constraints–site conditions that restrict forestry operations from occurring.

Percent Cover - also known as canopy cover, age, or crown cover, is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns

Tree Risk – the likelihood and consequences of failure of a tree or tree parts striking a target.

Tree Failure– a term that refers to the structural failure or physical breakage of any part of a tree, including roots, trunk, or branches.

Tree Health and Vigor - often thought of as the absence of biotic or abiotic factors that stress the tree and limit its physiological capacity**.** Stress results in less growth and an increased risk of death. Tree vigor is one way to describe aspects of tree health.

Tree Risk Assessment – a visual assessment of a tree's health by a certified arborist. It is done to determine the likelihood and consequence of failure of branches or the whole tree. The goal is to establish whether the tree poses an immediate threat to persons or property.

9.0 SIGNATURES

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APPENDIX A – TRENDS IN RISK

Figure 21 is a conceptual graph showing increasing tree and wildfire risk on the vertical axis. Note that the risk is not 'zero' at time zero: this just conceptualizes the change in risk over the next 20 years. The graph illustrates the likelihood of failure of looper-impacted trees rising sharply over the next 10 years.[12] Risk of tree failures declines within ~20 years – the point at which nearly every looper-killed tree will have already fallen or broken off.

Wildfire risk rises lags behind tree fall risk as the wildfire risk is associated with the buildup of surface fuels. This risk profile represents what would happen if trees were left to fall and fine fuels were left to accumulate, with no mitigation. The risk starts to decline slightly around year 15-20 as the majority of fine fuels decay.

With mitigation over the coming years, both trend lines shift downward, lowering risk. There remains a small rise at the ~9-year mark, assuming that there will still be a small amount of residual tree failure and wildfire risk associated with small, impacted areas. The red and grey lines at the bottom of the graphic show the trends in looper-related tree failure and wildfire risk if mitigation treatments are undertaken.

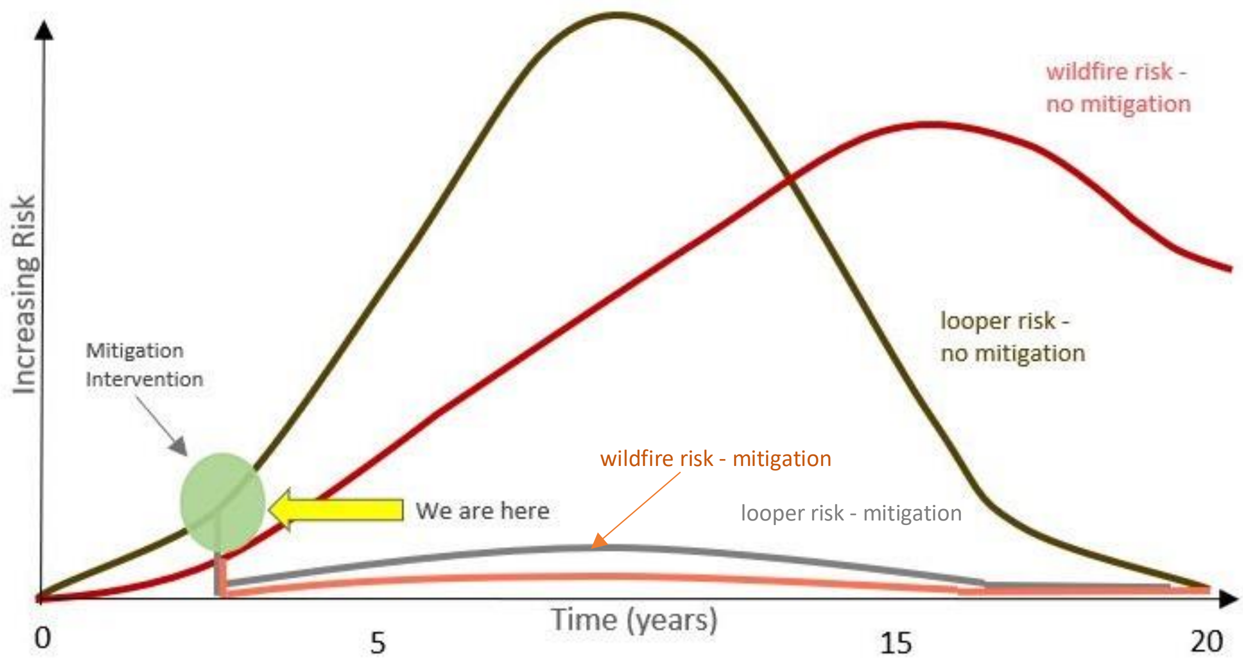

Figure 21. Trend in looper tree failure and wildfire risk over time - with and without mitigation.

[12] 9 years is the median 'persistence' time for dead hemlock trees. (Parish et al., 2010)

Examples of future forest condition in treated and untreated conditions within high and moderately impacted forest areas are shown in the figures below (Figure 22, Figure 23, and Figure 24).

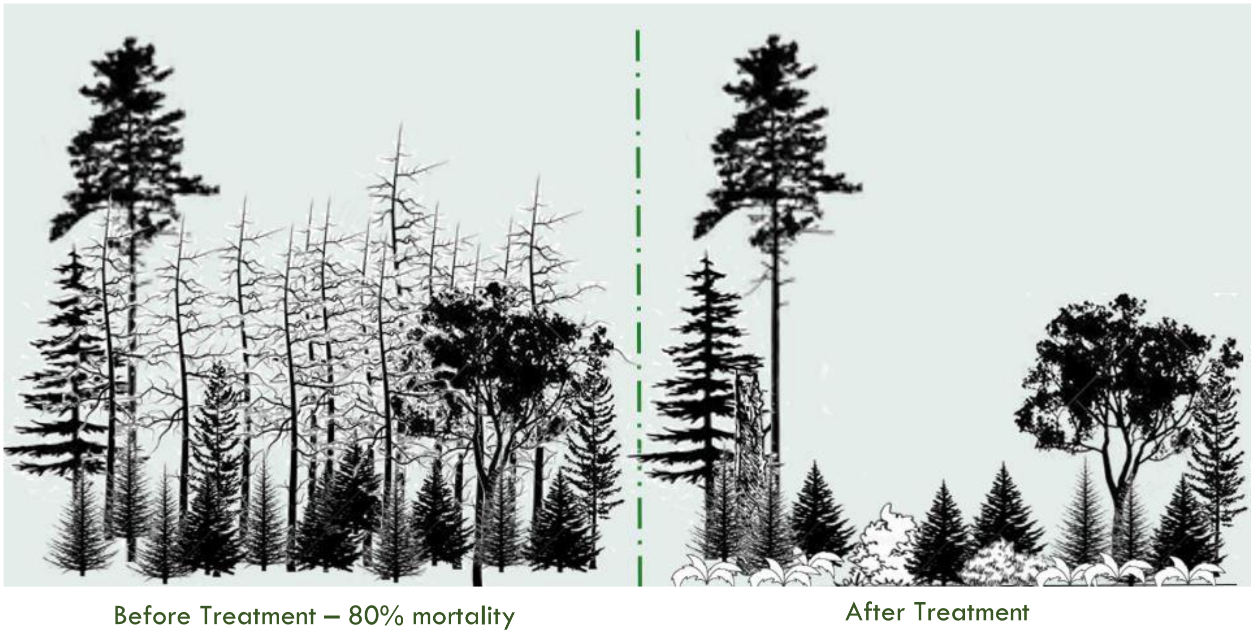

Figure 22. Example of forest change – areas with high looper impact.

Figure 23. Example of forest change – areas with moderate looper impact.

Figure 24. Example of forest change – areas with accumulation of debris from tree mortality.