British Columbia Ministry of Forests, Lands and
Natural Resource Operations and Rural Development

Forest Health Overview

2021-23 Coast Area

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Introduction

Forest health management requires knowledge of the temporal and spatial distribution of damaging forest health agents on the landscape as well as an understanding of their biological functions and ecological roles. Historically, forest health management was viewed as forest pest management and was often reactive in nature and did not acknowledge many ecological principles. Recently, more emphasis has been placed on ecosystem management and application of proactive risk management. Healthy forests are described as those which are resilient to disturbances, sustainable over the long-term and provide for a variety of resource needs and demands. This Forest Health Overview provides background and advice for forest health management in the Coast Area of British Columbia incorporating both the West Coast and South Coast Natural Resource Regions by:

- Identifying damaging agents (and their inherent hazards and risks) that have the potential to impact forest and other resources;
- Outlining the recoverable and non-recoverable losses in managed forest stands and applying them to timber supply reviews;
- Developing strategies and tactics to mitigate both short and long-term forest health risks and thereby protect and increase the adaptability of forested ecosystems; and
- Determining management priorities and the future direction of operational research activities.

These points will be consistent with information currently available in Ministry of Forests, Lands and Natural Resource Operations and Rural Development policy, Forest Health Stand Establishment Decision Aids (SEDA) and other existing forest health management practices guides and documents.

The aim and scope of the provincial forest health program is outlined in the *2019-2022 Provincial Forest Health Strategy* summarized in the section titled "Hierarchy of Government Aims regarding Forest Health".

This overview outlines the regional activities that will be pursued as part of the Ministry's business plan and is intended to inform district priorities. These activities arise from the provincial forest health strategy and local priorities. Included is a synopsis of most coast-specific pests presented as a series of pest profiles and a brief history of major pest activity by timber supply area (TSA).

Legislation on Forest Health

The *Forest and Range Practices Act* (FRPA) has altered the context in which forest management is conducted in British Columbia. The replacement of the previous "directive" regime with a "results-based" system based on the principle of professional reliance has led to significant change in the manner forest health is dealt with in the planning phase of forestry operations.

The primary tool for planning and managing public forest lands is the Forest Stewardship Plan (FSP) mandated under FRPA for all public agreement holders. Within this plan, the holder specifies results or strategies to achieve the various objectives, such as biodiversity or timber, set by government. It also includes commitments and standards for harvesting and reforestation, including stocking standards, which may directly influence forest health. Under FRPA section 26, the Minister may direct private landowners and public agreement holders to conduct remedial forest health control activities if the Minister determines that damage is being done to the provincial forest by pests.

Hierarchy of Government Aims Regarding Forest Health

The Ministry is responsible for land and resource management in British Columbia (BC). The direction for this mandate flows from both legislation and the ministry's Service Plan. The progression from overarching mandate to activities conducted at the regional level is as illustrated below (as excerpted from the Ministry's 2020/21 - 2022/23 Service Plan).

Ministry Service Plan

Forest health falls within two strategic priorities in the Ministry's Service Plan: building a strong, sustainable, innovative economy and a changing climate. These priorities are addressed through the following goals and objectives:

Goal 1: Economic Benefits for all British Columbians with Strong, Resilient Rural Communities
- Objective 1.3: Improve community resilience through proactive and collaborative natural hazard management.

Goal 3: Sustainable Natural Resource Management
- Objective 3.2: Expand and strengthen climate change mitigation and adaptation activities.

Provincial Forest Health Strategy

Forest Health Mission Statement:
"Provide evidence-based, economically rationalized management practices that prevent or mitigate the impacts of forest health agents."

Forest Health Strategic Goals:

1. Forest health factors are detected and assessed.
   New and recurring disturbances caused by forest health factors are detected, and assessments of risk and impact to forest resource values are provided.
2. Practices are adapted to accomodate known forest health risks.
   Evidence-based information is used to develop recommendations and modify forest management practices to mitigate the impacts of forest health factors.
3. Resource values are protected.
   Forest resource values are protected from forest health factor damage through appropriately applied direct management actions including treatment and monitoring. This includes the support and implementation of proactive management activities.

Coast Area Forest Health Overview

Coast Area TSA Forest Health Overview components:

a. Regional forest health activities.
b. Forest health monitoring and inventories.
c. Assessment of hazard and risk.
d. Impact assessment on timber supply.
e. Pest profiles.
f. Pest history by TSA.

Area Covered by this Strategy

This strategy covers forested crown land contained within the Coast Area (Figure 1). The Coast Area consists of two regions (South Coast and West Coast) and is composed of nine TSAs: Arrowsmith, Fraser, Great Bear Rainforest (GBR) North, GBR South, North Island, Haida Gwaii, Pacific, Soo and Sunshine Coast (Table 1). The GBR North and Pacific TSAs are shared with the Skeena Natural Resource Region. This strategy includes, but does not specifically address, parks, protected areas and Tree Farm Licence (TFL) lands within the Coast Area. Individual TFL planning documents should be consulted for local information on pest history and risks within those tenures.

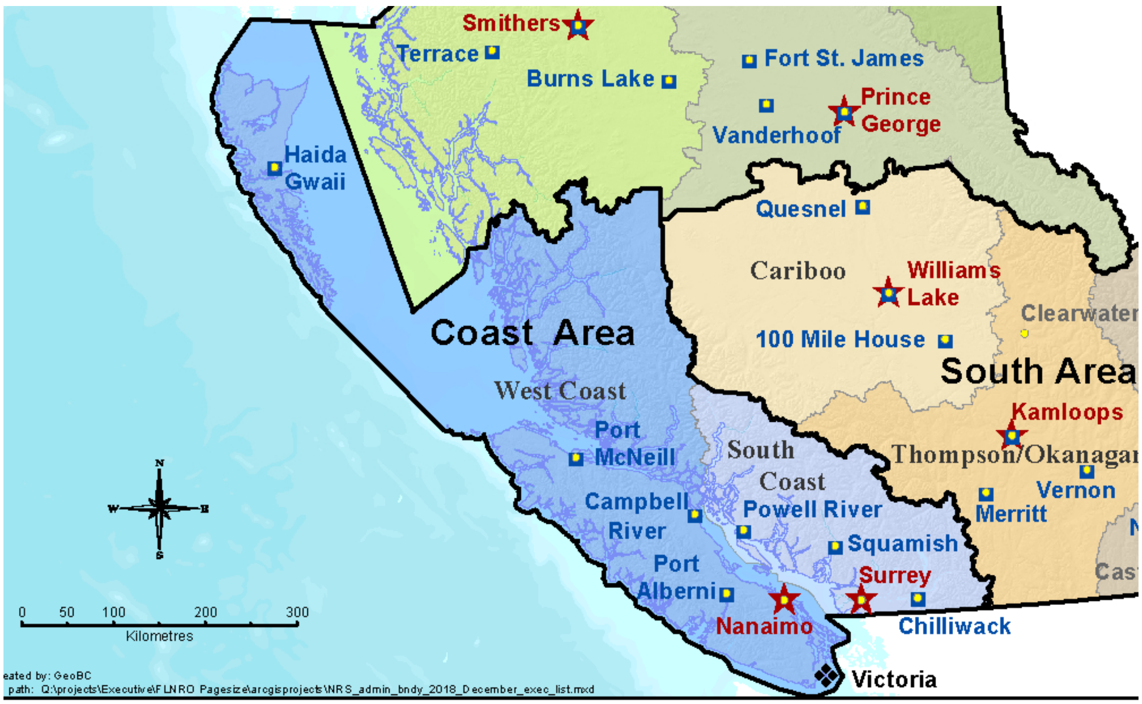

Figure 1. West Coast and South Coast Natural Resource Regions and Ministry office locations within the Coast Area.

Table 1. The nine timber supply areas within the Coast Area and their respective administrative districts

Timber Supply Area	Natural Resource District (Administrative office locations)
Arrowsmith	South Island (Port Alberni)
Fraser	Chilliwack
Great Bear Rainforest North	North Island (Port McNeill) and Coast Mountains (Terrace)
Great Bear Rainforest South	North Island (Port McNeill) and Campbell River
Haida Gwaii	Haida Gwaii (Queen Charlotte)
North Island	North Island (Port McNeill) and Campbell River
Pacific	Shared between West Coast, South Coast and Skeena Natural Resource Regions
Soo	Sea-to-Sky (Squamish)
Sunshine Coast	Sunshine Coast (Powell River)

Regional Forest Health Activities

The regional forest health program consists of three themes and 10 functions that support provincial and regional forest health goals. These functions provide context for the various activities that are conducted annually as part of the forest health program. Regional activities include district involvement.

Theme: Program Administration and Strategies

Function 1: Program Management.

- Manage budgets and projects, including performance management.
- Identify risks and set priorities for resource allocation.
- Implement and maintain internal policy and procedures.
- Develop, review and propose changes to policy and legislation.

Function 2: Administration.

- Contract management and managing partnering agreements.
- Communication, public and First Nation consultation and FOI.
- Incorporate GBA+ principles into the working environment.
- Training (internal and external).

Function 3: Development of provincial, regional and TSA strategies.

- Decide government objectives and priorities for forest health and revise strategies, policies, practices and standard operating procedures.
- Participate in the development of Integrated Silviculture Strategies for each TSA.
- Participate in the development and revision of climate-change strategies.
- Provide technical expertise to the development and implementation of best management practices and operational plans (e.g., Forest Stewardship Plans) and determination of non-recoverable pest losses.

Function 4: Participation in interagency efforts.

- Develop partnering agreements with other agencies and organizations.
- Advocate strategic government objectives to other agencies and participate in co-ordinated response planning for forest health issues.

Theme: Program delivery

Function 5: Detection, assessment and prediction of pest damage.

- Set survey and treatment standards and procedures.
- Conduct forest health inventories, including detailed aerial and ground surveys.
- Investigate new infestations.
- Assess hazard and risk at multiple scales consistent with management objectives.
- Quantify biological, economic and environmental impacts.

Function 6: Treatment of pest outbreaks and prevention of the establishment of new exotic pests.

- Define treatment and prevention standards and measures of success.
- Implement co-ordinated response to forest health outbreaks and prevent establishment of new introductions.

Function 7: Management of endemic pests during forest operations.

- Provide technical input to, and support for, the implementation of best management practices and treatment options.
- Advocate treatment and management regimes to mitigate risk from endemic pests.

Theme: Adaptive management

Function 8: Monitor forest health and management.

- Conduct Coast Area part of provincial aerial overview survey.
- Develop protocols for forest health monitoring and support surveys.
- Monitor natural and managed stands to determine pest impacts and report results.

Function 9: Professional development, training and extension.

- Maintain expert knowledge through participation in workshops, conferences and through liaison with other agencies.
- Encourage innovative approaches to forest management that promote forest health.
- Update guidebooks and reference materials.
- Identify, develop, deliver and participate in training needs for Ministry staff and others (e.g., agreement holders, stakeholders, contractors, First Nations and the public).

Function 10: Operational forest health research.

- Design and conduct operational trials to enable science-based management.
- Develop and refine hazard and risk models.
- Communicate results of operational trials, inventories, and implications of management policies and practices.
- Advocate Ministry forest health research needs and priorities to research agencies.

Forest Health Monitoring and Inventories

Damaging Agents

The list of biotic agents that cause damage to forest trees is quite extensive. Only a subset of these agents is usually significant as measured in terms of their potential to cause appreciable damage or detrimentally affect FRPA values or management objectives. A list that focuses on the agents most significant to the Coast Area is found in Appendix A of this document.

Detection

Detection, often confused with monitoring, applies to both aerial and ground surveys. The Ministry undertakes an annual aerial overview survey of the province for all detectable forest pests. This survey is usually conducted across all Crown forest land, including parks and protected areas, at a scale of 1:100,000-1:150,000. Survey standards and annual results are available from the Ministry website[1]. Aerial survey results are incorporated into the annual provincial report *Summary of Forest Health Conditions in British Columbia.*

It should be noted that due to the relative ease of mapping insect infestations from the air, especially those created by bark beetles and defoliating insects, there is dramatically more information on their incidence and severity relative to tree diseases. However, although under-reported, the overall distribution and impact of diseases in the Coast Area usually exceeds that of insects.

In areas with designated Suppression Bark Beetle Landscape Units, detailed aerial surveys are also conducted. These are conducted at a scale of 1:20,000-1:40,000, with a required horizontal accuracy of +/- 20 m. In addition, districts may conduct more detailed aerial and ground surveys when trying to assess the distribution and potential impact of some specific pests like defoliators.

Monitoring

Under FRPA the lead for monitoring within the Ministry has been the Forest and Range Evaluation Program[2] (FREP). This monitoring generates field data from inspections done on most of the values described in the FRPA, including the Timber value which encompasses forest health.

There are various forest health monitoring projects in the Coast Area. For example, the South Coast Natural Resource Region has whitebark pine monitoring plots tracking these high-elevation trees and baited traps are deployed to track Douglas-fir beetle activity following large wildfires. Both regions have plots monitoring the long-term development of blister-rust resistant western white pine and others tracking the impact of root diseases on second growth stands. There is also a network of plots in some Coastal western hemlock (CWH) subzones that monitor the impact of Swiss needle cast.

Pest Inventory

There are two main repositories for historical forest health information. The first is the provincial forest health website that has pest incidence and distribution information (back to 1999 for the Coast Area). This is based solely on the provincial annual overview survey and is best applied at a landscape-level. This data is also available as GIS layers downloadable through DataBC[3].

The second, more extensive repository is at the Pacific Forestry Centre[4] in Victoria. There the Canadian Forest Service runs an insectary and herbarium that collect insect and disease specimens from across the province and maintain a database that tracks their locations. Quite specific queries of insect pests can be made through the pest data archives while those for fungi can be accessed through the DAVFP database supported by the forest pathology herbarium. Records go back as far as 1901.

1 Web address is AERIAL OVERVIEW SURVEYS - PROVINCE OF BRITISH COLUMBIA (GOV.BC.CA).
2 Web address is FOREST & RANGE EVALUATION PROGRAM (FREP) - PROVINCE OF BRITISH COLUMBIA (GOV.BC.CA).
3 Web address is DataBC - Province of British Columbia (gov.bc.ca)
4 Web address is HTTPS://WWW.NRCAN.GC.CA/SCIENCE-DATA/RESEARCH-CENTRES-LABS/FORESTRY-RESEARCH-CENTRES/PACIFIC-FORESTRY-CENTRE/13489.

There are also minor repositories for forest health data. While large databases, like the RESULTS database run by the Ministry, cover the province, the pest data they house is sometimes incomplete, difficult to access or not specifically organized for pest enquiries. Thus, extracting useful data for large scale forest planning is often difficult or requires a certain ability with the database.

A summary of the historical information regarding pest outbreaks for each TSA in the Coast Area is available in Appendix B.

Assessment of Forest Health Hazard and Risk

The terms hazard and risk deserve attention, as they are not synonymous. Hazard is usually referred to as a "source of danger" while risk is the "probability of loss". Hazard in the literature is often used as "the favourableness of the particular site for the development of the [pest]". The key points conveyed by hazard as a source of danger are: (1) a situation in space and time; (2) driven by environmental factors of climate and host distributions; and (3) a relative indication of the likelihood and severity of infestation.

Risk fundamentally refers to the probability of an undesirable outcome. Risk adds the idea that resource values or management investments are in jeopardy because damage from pests reduces host growth, reproduction and survival sufficiently to impact economic or ecological objectives.

A first approximation of hazard for most pests in the Coast Area is provided in Section 6.6 of Land management Handbook 28 (Green and Klinka 1994)[5]. This reference can be considered the "default" value when more up-to-date information (e.g., in Ministry guidelines or other published reference) is not available for a specific pest. Note that while the section is titled "Pest Risks of Major Conifer Species", as discussed above, it is really describing hazard. Risk cannot be assessed at this scale without seeing the incidence of pests on or near the area of interest.

For certain pests (e. g., spruce leader weevil, laminated root disease), more detailed second approximation hazard ratings exist. These are usually found in Ministry guidelines like the publication *Managing Root Disease in British Columbia* (2018) or within pest-specific reference publications like the Stand Establishment Decision Aids (SEDA) published by FORREX in the *Journal of Ecosystems and Management*[6].

For use in conjunction with some host specific SEDAs, some information about hazard and risk in reforestation is provided in the *Reference Guide for FDP Stocking Standards* located on the Ministry website[7]. This guide is updated periodically to reflect changes in forest health considerations when certain species are used for reforestation in specific biogeoclimatic units.

5 Green, R.N. and K. Klinka. 1994. A field guide to site identification and interpretation for the Vancouver Forest Region. BC Ministry of Forests. Land Management Handbook 28.
6 Web address is https://jem-online.org/index.php/jem/issue/archive.
7 Web address is Stocking Standards - Province of British Columbia (gov.bc.ca).

Impact Assessment on Timber Supply

Predicted future yield is at the foundation of timber supply modelling in British Columbia. Most timber supply reviews (TSR) are based on output from three models: the Variable Density Yield Prediction (VDYP) model that predicts yield for natural stands, and the Tree and Stand Simulator (TASS)/Table Interpolation Program from Stand Yields (TIPSY) models that predict yield for managed stands[8]. These models may or may not account for the impact of damaging agents.

Non-recoverable losses (NRL), however, are not included in any of these models, and are accounted for separately in TSR. These NRLs are based on estimates developed by the Ministry. Some pest-specific forecasting models and extensions have been developed for use with TASS/TIPSY like the Spruce Weevil Attack Trial (SWAT) or the Gall Rust Impact Module (GRIM).

VDYP – Natural (Unmanaged) Stands

VDYP is used to produce yield tables for natural unmanaged stands based on measurements from extensive sampling of temporary and permanent sample plots. Decay losses are inherent to the model, while waste and breakage factors are applied to the analysis in the development of VDYP yield curves. These decay, waste and breakage estimates were developed based on sampling in different areas of the province, and therefore different factors exist for different areas.

In addition to decay, other damaging agents are accounted for in VDYP since they would have naturally occurred in the measurement plots. These include endemic levels of hemlock dwarf mistletoe, root disease, and defoliators. The caveat is that obviously pest-affected plots are discarded and no longer help form future yield curves. The consensus amongst forest health and growth and yield specialists is that VDYP accounts for endemic pest and decay losses.

TIPSY/TASS – Managed Stands

Volume estimates for single-species, even-aged managed stands are based on TIPSY which uses growth and yield tables derived from TASS. TASS is based on fully stocked, pest-free sample plots and is, therefore, considered to represent the full potential of the site. Adjustments to the model yield projections are used to reflect actual stand conditions and constraints.

Operational Adjustment Factors

Operational adjustment factors (OAF) are used to adjust the potential yields generated from TIPSY to reflect actual yields under operational conditions. OAF 1 reduces the potential yield by a constant percentage to reflect stocking gaps within stands that are incapable of growing trees (e. g., swamps, rocky areas). OAF 2 reduces potential yields to reflect losses due to tree maturity, including decay; waste and breakage, and other factors that increase with age. Therefore, OAF 1 is a constant reduction factor that shifts the yield curve down (a Type 1 response), while OAF 2 losses start at zero and increase to its full value at age 100, modifying the shape of the yield curve as time passes (a Type 2 response).

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[8] Web address is Growth & Yield Modelling - Province of British Columbia (gov.bc.ca).

The provincial default value for OAF 1 is 15% and for OAF 2 is 5%. OAF 1 values may be modified by using a survey to check the underlying assumptions for the area under question. OAF 2 is an estimate of the impact of decay, waste and breakage in second growth stands. Despite popular belief, it does not account for losses due to insects, diseases or other pests, even endemic ones, other than decay. Any impacts from these damaging agents are added to the default value of 5% and should be applied for the specific timber types, biogeoclimatic zones, and age classes as appropriate in the next TSR. Where they exist, recommended adjustments to OAF 2 values are described in the pest profiles in Appendix A.

Non-Recoverable Losses

Non-recoverable losses (NRL), or unsalvaged losses, are the amount of volume lost annually to damaging agents that is not harvested. This represents losses above and beyond those already accounted for in existing growth and yield models, often as a result of unpredictable events. These losses can be both increment loss and mortality. A NRL estimate is subtracted from yield projections. Often NRLs are the result of abiotic factors like fire or wind. Catastrophic or sustained events (e.g., prolonged defoliation) or those which are not well-suited to either OAF (e.g., drought, windthrow) may also qualify. The most recent NRL estimates for each TSA are provided in Table 2.

Table 2. Summary of non-recoverable (unsalvaged) losses by damage category and percent of AAC affected as accounted for in the most recent TSR for each TSA in the Coast Area

TSA (Effective date)	Fire m^3	Wind m^3	Pests[a] m^3	Total m^3	Current AAC m^3	% of AAC
Arrowsmith (2018)	1,067		8,038	9,109	324,580	2.8
Fraser (2019)	16,500	2,340	8,100	26,940	1,220,808	2.2
Great Bear North (2017)					803,000	
Great Bear South (2017)					830,500	
Haida Gwaii (2020)		70 ha[b]	99 ha		776,000	
North Island (proposed)	2,592		329	2,921		
Soo (2011)	30,000		4,000	34,000	466,872	7.3
Sunshine Coast (2013)	500	6,900	5,250	12,650	1,204,808	1.1
Total				118,544	8,440,168	

[a] Pests does not include losses as determined by OAF reductions but does include losses to disease, insects, animals and abiotic factors other than fire and wind.

[b] For Haida Gwaii, the unsalvaged losses were presented as non-contributing areas for use in the SELES spatial timber supply model.

Operational Research Plan

The following table outlines the key projects forming the operational research part of the Coast Area forest health program.

Project	Description	Product(s)	Timelines
Pathology (Stefan Zeglen)			
CFS Root Disease Plots	Long-term (45+ years) CFS root disease plots set up to track extent and spread of disease over time.	- Part of legacy of sites used to calibrate root disease models (oldest continuous dataset from coastal stands). - Past CFS publications.	Remeasured 2002 (Tsable) and 2003 (Campbell River). Analysis pending.
Pw Low Branch Pruning Trial	Three sets of plots – two set up in 1983, the other in 1988 – as long-term tests of unimproved white pine survival following sanitation pruning. Longest running trial of its type on the coast.	- 30-year data collected from two sites, 15-year data from another. - Internal reports in 1991 and 1994. - Results published in CJPP 2021.	Completed.
Texada Pw Outplanting Trial (Sx 94404V)	Large trial testing four seedlots of Pw (three from Texada plus control) for survival after pruning at nine locations throughout region. This is the baseline trial in a series testing resistance to WPBR found on trees from Texada Island.	- Fifteen years of continuous data. - Interim report in 2000. - Recommendations on use of Texada B+ seed and timing of pruning treatment(s).	Final evaluations in 2014. Analysis pending.
Tree Wounding & Decay Permanent Sample Trees (Sx 97802V)	Extensive long-term trial involving 25 partial cut stands across region. Each stand has 15-20 tree pairs (wounded and non-wounded) of various species damaged during harvesting activities. Only trial testing nature and extent of tree damage on standing residuals and the resulting wood products on the coast.	- No data to date as trial requires harvest of stands. - Recommendations on tolerance to tree damage as described in *Tree Wounding & Decay Guidebook*. - Quantification of volume loss due to location and size of various wounds.	Some stands being harvested 10 years following treatment. Pilot assessment of damaged trees in 2009.
Texada Pw Families Progeny Trial (Sx 98101V)	Large trial testing the survival of wild-pollinated, half-sib Pw progeny from known Texada Island families against Pw families from other sources (e.g., CFS, Dorena, Westar) at four sites. Third in a series of trials testing Texada Island Pw.	- Biennial data collection. - Recommendations on use of Texada half-sib seed for reforestation.	Last assessed in 2013.
Retrospective Evaluation of Stumped Areas	Assessment of earliest stands treated for root disease by stumping (1977-87). Stands are surveyed for presence of root diseases 15-20 years post-treatment and tree growth for treated and untreated areas (where possible) is compared using the growth intercept method.	- To date, 51 stands have been assessed. - Interim report in 1999. - Publication after data collection complete.	Last group assessed in 2014. Analysis pending.

Project	Description	Product(s)	Timelines
Whitebark Pine Monitoring Plots	Long-term monitoring plots to track health of whitebark pine. Surveys to date (Zeglen 2002) show 50% of whitebark pine in BC is dead or infected by white pine blister rust. The rate varies across the province. Monitoring is needed to find the mortality trend.	- Nine plots set up to date. - One plot destroyed by fire, another abandoned due to low tree count. - Future plots required across range of Pa.	Assess plots every 5 years following establishment.
MGR Pw Field Test	Field trial of major gene resistant (MGR) western white pine from Dorena, Oregon versus Texada seedlots. MGR trees show excellent resistance (80+%) in preliminary trials.	- Seven plots set up in 3 districts in 2002. - Biennial data collection.	Last assessed in 2020.
Stumping Disturbance Trial	In conjunction with Paul Courtin (Research Section), evaluating the effect of stumping on soil disturbance and assessing Fdc seedling growth and development.	- Five sites set up in 2007 and 2008. - Results published in CJFR 2019.	Completed.
Yellow-cedar Decline dendrochronology	Dendrochronology studies of declining stands on the north coast and Haida Gwaii testing validity of prevailing theory across the range of decline.	- Dendrochronology pilot project complete and published 2011. - UBC MSc thesis completed and results published in *Forests* 2019 and *Ecosphere* 2021.	Completed.
Septoria canker of poplar	Introduction of non-native disease threatens susceptible hybrid poplar clones and native *P. trichocarpa*.	- Risk evaluation for establishment of *Septoria* in native poplar. - Chief Forester guidance on use of poplar hybrids in BC.	Follow up survey completed in 2020.
Yellow-cedar Decline ecological succession	Collaborative work with regional research, UBC and partners on assessing ecological implications of decline sites on the north and mid-coasts.	- Research proposal funded. - Summary of pilot field season.	Pilot completed 2019. Next collection planned 2021.
Swiss needle cast	Monitoring plot network tracking the severity and impact of SNC on young Fd stands in CWH subzones. Collaborative project with SNC Co-op plot network in OR and WA states.	- Network of 43 plots set up 2017-19 across three subzones. - Initial plot data capture and analysis of tree foliage and soils and genomic profiling of disease in BC. - BCIT student projects. - MSc student at ULaval.	Annual monitoring of 14 weather station sites. Five-year assessment starts late 2021.

Entomology (there are currently no entomology research projects)

Appendix A: Pest Profiles

The following pest profiles are derived from a regional list of the most relevant damaging agents for the Coast Area, although their significance does vary between management units. Not all pests present in the region are profiled. They are grouped by common association (e.g., root diseases, defoliators) and then alphabetically within each group.

For each damaging agent a brief background is provided. Detailed information on the biology of these organisms is not presented here. There are better sources for this information. Historical information on pest occurrence by TSA is provided in Appendix B. Following this are entries on hazard and risk and impact that are adapted specifically for the coast. This includes recommendations for FSP and site plan writers and reviewers on forecasting management constraints and identifying potential implications for TSR. Similarly, a summary of current management strategies and tactics to mitigate pest damage is provided for those creating site plans in areas where risks are identified. There are references to Stand establishment decision aids (SEDA), if relevant, and other helpful reading. Finally, the relative ranking of the damaging agent in the provincial research priority matrix is given and any relevant ongoing or planned research is described.

The information supplied here is neither exhaustive nor complete for any pest or group of damaging agents. It is provided as a starting point for planners and statutory decision makers to ensure that plans and analyses incorporate and address known risks from the agents of most obvious concern to professional forest managers.

General references for field identification of damaging agents includes:

- Allen, E., Morrison, D. and Wallis, G. 1996. Common Tree Diseases of British Columbia. Canadian Forest Service, Victoria, BC. 178 pp.
- Burleigh, J., Ebata, T., White, K. J., Rusch, D. and Kope, H. Eds. 2014. Field Guide to Forest Damage in British Columbia. Can. For. Serv. and BC MFLNRO. Joint Pub. No. 17. Third Ed. 355 pp.

General references for management of some major pest groups include the Forest Practices Code guidebooks including:

- Bark Beetle Management,
- Defoliator Management,
- Management of Terminal Weevils,
- Pine Stem Rust Management,
- Tree Wounding and Decay.

Additionally, there have been revisions to guidance around managing dwarf mistletoes [Land Management Handbook 73 (2019)] and root diseases[9]

[9] FLNRORD. Managing root disease in British Columbia. 2018. Available at [Root diseases — Management - Province of British Columbia (gov.bc.ca)](gov.bc.ca).

Abiotics

Yellow-cedar Decline

Yellow-cedar decline has been a problem in southeastern Alaska for several decades but, until 2005, its occurrence and impact were poorly documented in BC. The decline can appear in small scattered patches or extend over a large area. Identification of dead or dying yellow-cedar can be difficult due to its visual similarity with western redcedar and the tendency for the two species to commingle in coastal forests. The spike-top mortality found in western redcedar can hide the dead or symptomatic crowns of yellow-cedar, especially when the latter occurs sparsely. Individual declining trees can die quickly, showing red or brown crowns, or slowly with gradually thinning crowns. Regardless of the speed of death, root systems are always in an advanced stage of deterioration with the smallest roots dying first. Necrotic lesions are often found on the lower bole under the bark. Dead trees can remain standing for decades.

Aerial assessments along the coast show over 150,000 ha of yellow-cedar stands afflicted by decline which may be constricting the future range of this species. The most noticeable areas are on Haida Gwaii and the north and mid-coasts where landscape-level occurrence can be seen quite readily. The frequency of decline decreases as one travels south and virtually disappears south of Kingcome Inlet. Individual or small group mortality may still occur south of this point but the infrequent distribution of yellow-cedar makes it difficult to detect.

Hazard and Risk

Yellow-cedar decline is a result of long-term climate change since the late 1800's. Warming winter temperatures result in declining snow levels and early snow melt leads to increased susceptibility of the shallow fine roots to sudden late season frost events where upper layer soil temperature falls below minus 5° C. As has been recently illustrated on Haida Gwaii, yellow-cedar of all ages is subject to decline given these risk factors. Indications are the decline seems to occur most strongly in the CWHvm2 variant of the north and mid-coast.

Impact

A 2019 analysis of losses detected by the annual aerial overview survey shows over 2.2 million m^3 of yellow-cedar volume has been mapped as killed by decline, primarily in the GBR North TSA. Much of this mortality is at higher elevation or outside the timber harvesting land base (THLB).

Management

Since the decline appears to be climate driven and since we do not yet understand fully the drivers involved, management options are limited. In time local guidelines may be developed around the suitability of yellow-cedar for reforestation in areas where conditions for occurrence of the decline can be predicted. Until then, a publication from Alaska (Hennon et al. 2016) may offer guidance in managing yellow-cedar on the north coast and Haida Gwaii.

Priority and Research

Dendrochronology work on the north coast and Haida Gwaii has increased our understanding of how the decline manifests in BC. Further work on the north and mid-coast is continuing and should be completed soon. A new collaborative research project exploring the recovery and ecological succession of declining stands on the north coast was started in 2019.

Further Reading

- Comeau, V.M., L.D. Daniels and S. Zeglen. 2021. Climate-induced yellow-cedar decline on the island archipelago of Haida Gwaii. Ecosphere 12(3) **https://doi.org/10.1002/ecs2.3427**
- Comeau, V.M., L.D. Daniels, G. Knochenmus, R.D. Chavardes and S. Zeglen. 2019. Tree-rings reveal accelerated Yellow-cedar decline with changes to winter climate after 1980. Forests 10: 1085 **https://doi.org/10.3390/f10121085**
- Hennon, P.E., McKenzie, C.M., D'Amore, D.V., Wittwer, D.T., Mulvey, R.L., Lamb, M.S., Biles, F.E., and Cronn, R.C. 2016. A climate adaptation strategy for conservation and management of yellow-cedar in Alaska. USDA Forest Service, Gen. Tech. Rep. PNW-GTR-917.
- Stan, A.B., T.B. Maertens, L.D. Daniels and S. Zeglen. 2011. Reconstructing population dynamics of yellow-cedar in declining stands: baseline information from tree rings. Tree-Ring Research 67(1): 13-25.
- Wooten, C.E. and B. Klinkenberg. 2011. A landscape-level analysis of yellow-cedar decline in coastal British Columbia. Can. J. Forest Research 41: 1638-1648.
- Hennon, P.E., D.V. D'Amore, S. Zeglen and M. Grainger. 2005. Yellow-cedar decline in the North Coast Forest District of British Columbia. USDA Forest Service, Research Note PNW-RN-549.

Adelgids

Balsam Woolly Adelgid

Balsam woolly adelgid (*Adelges piceae*) is a small aphid-like insect that was introduced to North America from Europe. It feeds on all species and all ages of true fir (*Abies* species) and can cause deformity, die-back and mortality. In BC, amabilis and grand firs are attacked most often. Grand fir is the most tolerant of attacks; sub-alpine fir is the most easily damaged; and amabilis is intermediate. Damage is caused by substances injected by the adelgid during feeding. These substances cause abnormal tissue growth that disrupts normal translocation processes within the tree.

The adelgid was first detected in BC in 1958 in the Vancouver area and on southern Vancouver Island. From there it continues to spread northward and eastward. Currently, its known distribution within BC ranges throughout Vancouver Island; to the Loughborough Inlet on the mainland coast; northward into the Cariboo and eastward into the Kootenays.

Hazard and Risk

Any *Abies* species within the currently infested area is potentially susceptible and may be at risk. The infested area continues to expand. It appears there is a range of susceptibilities within the *Abies* population. Some trees die within a few years of becoming infested, some survive with chronic infestations for many years, some with minimal effects, while others appear unaffected.

Impact

The affects of adelgid have not been well studied. Infestations within grand fir can be chronic for decades however the trees often succumb eventually. Their decline in vigour may be taken advantage of by the fir engraver beetle, *Scolytus ventralis*, especially following dry summers, as is common on the east coast of Vancouver Island. Affects for amabilis fir are variable; some trees will die within a few years of becoming infested while others may remain chronically affected for many years and yet others do not seem to be affected.

Information from Idaho shows sub-alpine fir appears to die after only a few years of infestation. There, 100% mortality of sub-alpine fir stands has occurred within 10 years of the stand becoming infested. In Oregon, infestation and damage were found to be most severe on good sites and at lower elevations; tree damage was most severe in the first decade; infestation and further tree killing were observed 40 years after the initial infestation. As a result, grand fir is slowly being eliminated from Oregon forests.

Management

The *Balsam Woolly Adelgid Regulation* restricted the movement of true firs within BC, with the intent to reduce the risk of spreading the adelgid beyond the quarantine zone. However, the regulation was repealed as of March 31, 2019 because the adelgid had firmly established in the interior of the province. Although nurseries no longer require a permit to grow *Abies* species, the province encourages limiting the movement of seedlings from the southern interior or coast, into the north.

Priority and Research

No research is occurring currently.

Further Reading

- Turnquist, R. and J.W.E. Harris. 1993. Balsam woolly adelgid. Forest Pest Leaflet #1. Pacific Forestry Centre, Forestry Canada, Victoria.

Bark Beetles

Douglas-fir Beetle

Douglas-fir beetle (*Dendroctonus pseudotsugae*) is endemic throughout the range of Douglas-fir where it normally breeds in trees that are stressed, recently windthrown, recently dead or dying from other causes. However, outbreaks occur periodically on the coast (about once every decade) and tend to last 3 to 4 years before subsiding.

Hazard and Risk

Douglas-fir can be attacked anywhere in the Coast Area if conditions are suitable. The beetle is often associated with trees that are stressed or have been recently killed by root disease or other agent. However, within the Coast Area, Douglas-fir beetle only becomes a significant pest within the coast/interior transition area (i.e., IDFww, CWHds1) or following large windthrow events. During outbreaks, scattered patches of healthy Douglas-fir can be killed across extensive areas. Recent large wildfires in the Fraser, Soo and Sunshine Coast TSAs have not led to a notable increase in beetle populations colonizing wildfire-damaged trees.

Impact
Endemic mortality can normally be seen on the landscape, however because it is widely scattered it may not have significant impacts. Although outbreaks do not usually build into large areas of attack on the coast, this beetle tends to attack the larger Douglas-fir in a stand and can kill substantial volumes of valuable timber when populations build.

Management
Control is via sanitation harvesting using trap trees (see *Bark Beetle Management Guidebook*). Use of the anti-aggregation pheromone MCH may be considered in certain situations. Capturing beetles in baited traps following wildfires is also recommended following large wildfire events in areas known to have beetles.

Priority and Research
No research is occurring currently.

Further Reading
- FLNRORD. 2019. A guide to managing Douglas-fir beetles in BC's coastal region. Factsheet. 3 pp. Available at A Guide to Managing Douglas-fir Beetles in B.C.'s Coastal Region (gov.bc.ca).
- Humphreys, N. 1995. Douglas-fir beetle in British Columbia. Forest Pest Leaflet #14. Canadian Forest Service, Pacific Forestry Centre, Victoria.

Mountain Pine Beetle

Mountain pine beetle (*Dendroctonus ponderosae*) is BC's most infamous forest insect. This bark beetle attacks all pine species but is primarily associated with mature lodgepole pine. Its population dynamics allow it to develop into extensive outbreaks. Fortunately, on the coast lodgepole pine is a minor commercial species, except in the coast-interior transition zone where it is more abundant. Most infestations of this bark beetle on the coast are in stands considered to be inoperable. There may however be visual, recreational or wildfire-related reasons for managing this beetle.

Hazard and Risk
Within the Coast Area, pine stands in the coast-interior transition zone have the highest hazard for attack by mountain pine beetle (i.e., IDFww, CWHds1, ds2, and ESSFmw). During outbreaks any pine stand within 10 km of currently infested trees could be at risk. The large provincial MPB epidemic ended several years ago, and for the coast populations have returned to their endemic level of occasional local attack where mature pine still exists. The *Bark Beetle Management Guidebook* supplies methods to assess hazard and risk based on stand age, density, elevation and location.

Impact
The impacts of this beetle can be extreme. During outbreaks all mature pine within an area can be killed. Immature pine can also be killed during severe outbreaks. Within the Coast Area, pine only composes small part of the timber supply. So, even though pine trees can be killed, the impact on timber supply is limited. However, this beetle can affect the scenic viewscape and may affect recreational experiences, wildlife habitat and fire hazard. The creation of fuels because of beetle-killed standing dead and downed trees should be evaluated in areas prone to wildfire.

Management
When outbreaks are at the incipient stage, single-tree treatments can be effective at controlling spread. Falling and burning individual trees, or small patch harvesting of currently infested trees, can be practical. The use of pheromone baits can help control efforts. See the *Bark Beetle Management Guidebook* for detailed procedures. However, once initial outbreaks grow and spread, control efforts can quickly become expensive and less effective.

Priority and Research
No research is occurring currently.

Further Reading

- Unger, L. 1993. Mountain pine beetle. Forest Pest Leaflet #76. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Safranyik, L., D.M. Shrimpton and H.S. Whitney. 1976. Management of lodgepole pine to reduce losses from the mountain pine beetle. Forestry Technical Report #1. Canadian Forestry Service, Pacific Forest Research Centre, Victoria.

Spruce Beetle

Spruce beetle (*Dendroctonus rufipennis*) is endemic throughout the range of spruce where it normally breeds in trees that are under stress or recently windthrown, and in freshly cut logs. Localized outbreaks occur periodically in the coast/interior transition areas (i.e., ESSFmw).

Hazard and Risk
Spruce beetle infests Engelmann, white, Sitka spruce and their hybrids if conditions are suitable. The beetle is often associated with trees that are stressed or recently killed. However, within the Coast Area, spruce beetle is only a significant pest within the coast/interior transition area. During localized outbreaks, scattered patches of healthy spruce trees can be killed.

Impact
Although outbreaks on the coast are rare and do not build into large areas of attack, this beetle tends to favour both stressed and mature spruce trees in a stand and can kill valuable timber when populations build.

Management
Control options include sanitation harvesting, salvage harvesting and trap trees (see *Bark Beetle Management Guidebook* and *Spruce Beetle Management in B.C.*).

Priority and Research
No research is occurring currently.

Further Reading

- Province of British Columbia. Spruce beetle management in B. C. Available at [Spruce Beetle Management in B.C. (gov.bc.ca)].

Western Balsam Bark Beetle

Western balsam bark beetle (*Dryocoetes confuses*) is one of the most destructive insect pests of subalpine fir and is a primary driver of succession in high elevation subalpine fir stands. The balsam bark beetle is endemic throughout the range of subalpine fir, where it causes scattered mortality over large areas of its host range.

Hazard and Risk

Western balsam bark beetle typically attacks over-mature subalpine fir, and the highest levels of attack occur in the drier and cooler ESSF subzones. Additionally, with more frequent and prolonged periods of drought due to climate change, mature (not just over-mature) subalpine fir is becoming more susceptible to attack.

Impact

Western balsam bark beetle populations are not eruptive, and they do not have outbreaks. Damage is chronic throughout mature, high elevation subalpine fir stands.

Management

Western balsam bark beetle populations are not usually managed due to its complex biology (endemic) and difficulty in harvesting access and operability. No proactive measures are appropriate and the only viable option for managed stands is to limit subalpine fir stands to a shorter rotation or target harvesting of stands with dead and dying trees (see *Bark Beetle Management Guidebook*).

Priority and Research

No research is currently occurring.

Further Reading

- Furniss, R.L. and V.M. Carolin. 1977. Western Forest Insects. Miscellaneous Publication No. 1339. U.S. Department of Agriculture, Forest Service.

Defoliators

Conifer Sawfly

The conifer sawfly (*Neodiprion abietis*) is a defoliator of amabilis fir and western hemlock on the BC coast. Outbreaks by this insect are rare and short-lived but can have significant impacts if the defoliation is severe. It is a unique defoliator in that it is from the insect Order *Hymenoptera* (wasps) rather than the usual defoliator Order *Lepidoptera* (moths). The sawfly is a wasp whose larval stage feeds on tree needles.

Hazard and Risk

A hazard rating system has not been developed; however, outbreaks appear to re-occur in the same areas involving the same stands. Outbreaks have occurred in the following areas: Philips River, Apple River, Stafford River and Paradise Creek on the mainland coast; and Kunnum Creek, Compton Creek, Memekay River and Bigtree Creek on Vancouver Island. Defoliation tends to occur on mid- to upper-slopes and at the back end of drainages at elevations ranging from 600m to 900m. The biogeoclimatic units that appear to be involved are: CWHvm1, vm2, mm1, mm2, and MHmm1, with CWHvm2 and mm2 being the most severely affected. Trees stressed by defoliation may be at risk of attack by *Pseudohylesinus* bark beetles.

Impact

Impacts have not been well quantified but can be significant in severely defoliated stands of old growth amabilis fir (15 to 20% mortality in severely defoliated stands). Mortality could potentially be worse if bark beetle populations take advantage of the defoliation stress.

Management

Control treatments have not been developed for BC. Treatments using common insecticides would be effective; however, environmental concerns will likely prevent their use. The biological control agent *Bacillus thuringiensis var. kurstaki* (*Btk*) will not affect this insect. Treatments using a nucleopolyhedrovirus (NPV) show promise on outbreaks in Eastern Canada but is still in the developmental stages.

Management actions are limited to monitoring and mapping defoliation, and quantifying impacts. Identify severe defoliation for priority salvage harvesting where necessary or possible.

Priority and Research

No research is occurring currently.

Further Reading

- Ingram, J.D. 2005. The 1995-1998 outbreak of *Neodiprion abietis* on the coast of British Columbia. Unpublished graduating essay. Faculty of Forestry, UBC, Vancouver.
- Westfall, J. 2002. Conifer sawfly outbreak, Vancouver Forest Region 1995 – 1998. Unpublished internal report. Vancouver Forest Region, Ministry of Forests, Nanaimo.

Western Blackheaded Budworm

The western blackheaded budworm (*Acleris gloverana*) is a defoliator of western hemlock. Outbreaks periodically occur on the coast of BC every eight to 15 years and last three to five years, defoliating extensive areas. The most serious outbreaks consistently occur on Haida Gwaii and on northern Vancouver Island.

Hazard and Risk

Although this budworm is found throughout hemlock forests, outbreaks on the coast are most common in the following subzone variants: CWH vh1, vh2, vm1, vm2, wh1 and wh2. However, significant impacts seem to be limited to the CWHvm1 and wh1. All age classes can be affected. Defoliation tends to reoccur in the same stands during each outbreak, thus maps of earlier outbreaks provide a good indication of the hazard of budworm defoliation.

Impact

Most impacts are minimal, and most stands recover well; however, stands that receive severe defoliation over consecutive years will have mortality and top-kill. Impacts are higher in Haida Gwaii. Severe defoliation of immature stands seems to result in higher mortality rates than in mature or old growth. Stands that have received >50% defoliation for several consecutive years can show 30% to 60% mortality.

Immature, second growth stands that have been thinned seem to be more affected by defoliation from this budworm. Following an outbreak that lasted six years on Haida Gwaii, mortality in severely defoliated immature stands averaged <10%. However, top-kill was significant and frequent (45%) with very poor recovery six years post-outbreak. It appears that growth reductions in second growth stands may be worse than originally expected.

Management
A survey method for egg mass sampling to forecast defoliation severity can be found in the *Defoliator Management Guidebook*. There is currently no operational control treatment for this defoliator. The biological control agent *Btk* will work but is not yet registered for this insect. As seen in 2001 on Haida Gwaii, thinned stands may be subject to greater mortality, due to greater exposure of the upper crown. Therefore, post-thinning density targets should allow for this in areas at risk of budworm defoliation.

Priority and Research
No research is occurring currently.

Further Reading

- Nealis, V.G., R. Turnquist, and R. Garbutt. 2004. Defoliation of juvenile western hemlock by western blackheaded budworm in Pacific coastal forests. Forest Ecology and Management 198: 291-301.
- Koot, H.P. 1994. Western Blackheaded Budworm. Forest Pest Leaflet #24. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Wood, P.M. and D.G. Heppner. 1986. Blackheaded budworm in the Vancouver Forest Region: 1985/86 situation report. Forest Service Internal Report PM-V-8. BC Ministry of Forests.

Western Hemlock Looper

The western hemlock looper (*Lambdina fiscellaria lugubrosa*) is another serious defoliator of western hemlock that occasionally reaches outbreak proportions on the coast. Seven outbreak episodes have occurred on the coast of BC since 1911. While western hemlock is the preferred host, almost any foliage including broad-leaved trees and shrubs will be fed upon during outbreaks. All ages are susceptible. A closely related sub-species of looper defoliates Gary oak.

Hemlock looper outbreaks on the coast are sporadic; however, populations can increase rapidly and quickly cause severe defoliation. Within areas of severe defoliation, 80% of hemlock trees can be killed during the second year of the outbreak. Outbreaks also decline rapidly following two to four years of defoliation.

Hazard and Risk
On the BC coast, outbreaks are most common in the Sunshine Coast and Howe Sound areas and within the Metro Vancouver watersheds (Seymour, Capilano and Coquitlam). It has also occurred on

Vancouver Island (Neroutsos Inlet and Nitinat Lake areas) and along Jervis Inlet. The CWH vm1 and CWHdm are the BEC subzone variants most at risk.

Impact
Severe mortality of western hemlock can occur following one year of moderate to severe defoliation and mortality of other hosts can occur following one or more years of severe defoliation. Drought stress and the presence of other forest health factors (i.e., hemlock dwarf mistletoe or root disease) will also affect survival. The killed trees deteriorate quickly; two years following mortality 20% of the wood will be affected with advanced decay. Beyond the second year of deterioration, radial penetration by decay fungi will increase rapidly and, as a result, the sawlog volume will be reduced below the point of economic recovery by the fifth year, with only small volumes of relatively low quality sound wood remaining in the basal logs of larger trees.

Management
Foray 48B (a commercial formulation of *Btk*) is now registered for use on western hemlock looper. Spray treatments should be applied during the spring following the first year of detected defoliation in high value stands. Delay will result in significant hemlock mortality.

Although looper populations can be monitored via egg and larva sampling and with pheromone traps; the sporadic nature of outbreaks on the coast makes them difficult to forecast. High indices of moisture stress have recently been found to be significantly correlated with looper outbreaks.

Priority and Research
No research is occurring currently.

Further Reading

- McCloskey, S.P.J., L.D. Daniels and J.A. McLean. 2009. Potential impacts of climate change on western hemlock looper outbreaks. Northwest Science 83: 225-238.
- Parfett, N., I.S. Otvos and A.V. Sickle. 1995. Historical western hemlock looper outbreaks in British Columbia: input and analysis using a geographical information system. FRDA Report 235. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Koot, H.P. 1994. Western Hemlock Looper. Forest Pest Leaflet #21. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Turnquist, R. 1991. Western Hemlock Looper in British Columbia. FIDS Report 91-8. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Engelhardt, N.T. 1957. Pathological deterioration of looper-killed western hemlock on southern Vancouver Island. Forest Science 3: 125-136.

Western Spruce Budworm

Western spruce budworm (*Choristoneura occidentalis*) is a defoliator of Douglas-fir throughout the tree's range in British Columbia. Historically, western spruce budworm has had it largest impact in the coastal-interior transitions areas of the Sea-to-Sky and Chilliwack Natural Resource Districts, particularly in the Pemberton/Birkenhead area and the Fraser Canyon area near Boston Bar. Outbreaks are periodic, occurring every decade and last 3 to 5 years.

Hazard and Risk
Within the Sea-to-Sky and Chilliwack Natural Resource Districts, defoliation often occurs in an elevational band across mountain sides, particularly on south and west facing slopes. Warm, dry sites with greater than 80% Douglas-fir are most affected. Douglas-fir is the principle host, amabilis and grand fir are secondary hosts, and spruce is occasionally fed upon. Budworm defoliation reoccurs in the same general sites for each outbreak. Stand hazard can be estimated from maps of earlier outbreaks.

Defoliation is most common in the Boston Bar area of the Fraser Canyon, the D'Arcy/Birkenhead area north east of Pemberton, and the mountain slopes on the north side of the Lillooet River, northwest of Pemberton. Defoliation occasionally expands beyond these areas, but seldom causes severe damage.

Impact
Impacts caused by this defoliator are variable and depend on the severity of defoliation and the number of years of defoliation. Defoliation reduces incremental growth and can cause top-kill and mortality. Mortality is rare on the coast but may occur after consecutive years of severe defoliation. Top-kill in immature trees can result in forks and crooks forming on the stem of the tree (i.e., within the first log).

Stand mortality, even after seven consecutive years of moderate to severe defoliation, averages about 1% of the trees. However, individual stand extremes can reach 50% mortality. Forks, crooks and creases caused by up to three previous infestations were found on 11% of all live Douglas-fir but varied from 0 to 70% across individual stands. The cumulative effect of four separate budworm outbreaks that occurred during the life of one Douglas-fir stand amounted to a loss of about 12% in radial growth. Cumulative stand volume losses following an outbreak can range as high at 19%.

Management
Re-establishing Douglas-fir in high budworm hazard areas assumes a risk of future damage from budworm defoliation. Spray treatments may be needed to meet regeneration and stand objectives. Species for reforestation are limited in high hazard areas; however, using non-host species (e.g., ponderosa pine, lodgepole pine) within a mixed planting with Douglas-fir will help reduce impact, especially along edges of mature timber. Spruce can be used at higher elevations as an alternative to Douglas-fir.

Dense stands are more susceptible; manage density to target stocking standard levels and thin stands from below to keep an even-aged structure. Ecosystem restoration treatments that thin and use prescribed fire in dense uneven-aged stands should reduce budworm populations and damage. Commercial thinning should also reduce budworm damage. Thinning and fertilization, through improving tree vigour, may help trees withstand repeated attacks and compensate for growth losses. However, these treatments are unlikely to reduce stand susceptibility.

Spray treatments are suggested for young stands of Douglas-fir when moderate to severe defoliation is predicted for the following year (as found from predictive egg sampling surveys). The biological control agent *Bacillus thuringiensis* var. *kurstaki* (*Btk*) (e.g., Foray 48B) is the product of choice for budworm control (refer to the *Defoliator Management Guidebook*).

Priority and Research
No research is occurring currently.

Further Reading

- Heppner, D. and J. Turner. 2006. British Columbia's coastal forests: Spruce weevil and western spruce budworm forest health. Stand Establishment Decision Aids. BC J Ecosystems and Management 7(3): 45–49.
- Unger, L.S. 1995. Spruce budworms. Forest Pest Leaflet #31. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- Shepherd, R.F. 1994. Management strategies for forest insect defoliators in British Columbia. Forest Ecology and Management 68: 303-324.

Dwarf Mistletoe

Hemlock Dwarf Mistletoe

Hemlock dwarf mistletoe (*Arceuthobium tsugense*) is an obligate parasitic plant that affects tree growth and leads to the production of foliar "brooms", stem deformities and occasional mortality. Breakage of branches holding brooms can supply potential entry sites for wood-decaying fungi. While the primary host is western hemlock, *A. tsugense* can also be found on mountain hemlock, Pacific silver fir, grand fir, Sitka spruce and lodgepole (shore) pine. Recent taxonomic work proposes three subspecies of *A. tsugense* based on host affinity: *A. tsugense* subsp. *tsugense* on western hemlock, *A. tsugense* subsp. *contorta* on shore pine and *A. tsugense* subsp. *mertensiana* on mountain hemlock Like most plants, dwarf mistletoes produce flowers which are pollinated by insects and produce seeds that spread within the same tree canopy (intensification) or to adjacent canopies. The infection process is slow and often difficult to see, as there may be up to a four-year lag from the time of infection until the first aerial shoots are produced. On older trees the results of prolonged infection are more readily seen.

Hazard and Risk
Land Management Handbook 73 states that all subzones within the CWH are considered high hazard to hemlock dwarf mistletoe. The risk of hemlock dwarf mistletoe typically manifests in two ways. First, the risk to susceptible regeneration growing within 10-15 m of infested mature residual trees along cutblock boundaries or next to single-tree or group reserves is high. Second, the risk to uninfected residual trees left after partial cutting is dependent on the amount of infested neighbouring trees left behind. The opening of infested canopies stimulates the formation of mistletoe aerial shoots which increases the production and spread of seeds.

Impact
Although not primarily a mortality agent, it has been estimated that for coastal BC hemlock dwarf mistletoe accounts for about 0.8 million m^3 in annual growth loss. This loss may decrease as mature stands are converted to plantations. However, poor sanitation practices when harvesting leaves regeneration susceptible to early infection when the impact is greatest. Moderately and severely infested trees have showed growth reductions of 20-40%, respectively, compared to uninfested trees. Young trees starting out under infested canopies can undergo decades of suppressed growth and creation of stem deformities (swellings) that result in unmerchantable stem form and occasionally

death. While individual tree growth effects have been quantified, currently there is no OAF reduction to account for stand-level infestation.

Management

Being obligate parasites, management of dwarf mistletoes should be easy: kill the host and you kill the parasite. For years, application of this principle formed the basis for dwarf mistletoe management in BC. Infested stands were clearcut, with straight edged boundaries and strict adherence to the "3-m knockdown rule" on the coast. This led to sanitation of large areas which were successfully regenerated to western hemlock. It is not a terribly aesthetic practice, but it is effective in controlling dwarf mistletoe. The advent of partial cutting, with its emphasis on irregular cut block shape and tree retention, has resulted in a corresponding increase in dwarf mistletoe survival in regenerating areas.

While it will be difficult to eradicate dwarf mistletoe from infested stands that are managed under a retention system, reducing the risk to regeneration and residual trees is possible. Reducing the perimeter edge of the cut block and the use natural barriers in placing boundaries helps limit exposure to infested edges. All severely and moderately (Hawksworth rating 3+) infested trees should be removed unless they are in reserves where there is little chance for their seed to disperse onto susceptible regeneration. Manage for non-susceptible tree species in the regeneration layer. Leaving infested trees, including advanced regeneration >3 m tall, in a dispersed retention system should be avoided. When opening closed canopies through commercial thinning or uneven-aged stand management, remove infested trees where possible to reduce the proliferation of new aerial shoots and consequent spread of seed within canopies. If conducting pre-commercial thinning along cut block or reserve edges, find and remove any infested young trees.

Priority and Research

A great deal of work on dwarf mistletoes was done in the 1950's through 1970's in BC. Since the biology was well understood and forest management practices at the time were effectively reducing risk, research was gradually stopped. With the implementation of variable retention systems, interest in dwarf mistletoe impact in these harvested stands has been rekindled. Questions about susceptible tree retention and regeneration in partial cut western hemlock stands and impact on stand volume still require resolution.

Further Reading

- Rusch, D., H. Kope, M. Murray, J. Yurkewich and S. Zeglen. 2019. Dwarf mistletoe management in British Columbia. Prov. BC, Victoria, BC. Land Management Handbook 73. Available at www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh73.htm.
- Muir, J.A., P.E. Hennon and R.W. Negrave. 2007. Biology, ecology and management of western hemlock dwarf mistletoe in coastal British Columbia: a synthesis of the literature. BC Ministry of Forests and Range, Nanaimo, BC. Technical Report TR-037.
- Muir, J., J. Turner and K. Swift. 2004. Coast Forest Region: Hemlock dwarf mistletoe stand establishment decision aid. BC J. Ecosystems and Management 5: 7-9.
- Unger, L. 1992. Dwarf mistletoes. Can. For. Serv., Pac. For. Centre. Forest Pest Leaflet 44.

Foliar Diseases

Cedar Leaf Blight (Keithia)

Cedar leaf blight (CLB), or *Didymascella* (formerly *Keithia*) *thujina*, is a widespread, native foliar disease of western redcedar. It infects the current year's foliage and kills these new leaflets, which produces a patchy pattern of foliar discolouration on younger material. This pattern is distinct from that of flagging (yellow branches), which results in foliage shedding (cladaptosis) of all ages of leaf material. A distinct, close-up sign of CLB is the presence of golden to dark brown pin-cushion-like fruiting bodies on the upper surface of a leaflet. These infected leaflets will die and then change to a grey colour, and then the fruiting body falls out leaving a pit or hole.

Hazard and Risk

Disease incidence tends to be highest for most CWH subzones particularly in dense stands with high humidity, although variability is high among individual trees. This disease is often a problem in nurseries where nursery culture conditions can intensify the disease on seedlings. Environmental conditions (temperature and moisture) help disease infection and spread. Seedlings infected in nurseries will carry the disease into plantations and where condition are suitable, the disease will expand. CLB could become more noticeable with a prolonged shift toward warmer and wetter weather. In some cases, use of enclosed type seedling protectors that can function as a mini "greenhouse" increases the development of CLB. This has been noted in typically wet environments like Haida Gwaii.

Impact

Impact in mature stands is minimal. The greatest impact is usually to planting stock that has been infected in the nursery. Infection and mortality of a substantial part of cedar foliage can result in rapid foliage loss and death of young trees. This is particularly clear when infected one-year old stock is planted. In the past, plantations have experienced widespread failure of planted cedar.

Management

Changes in nursery practices for growing western redcedar has made the sale of infected stock rare. On one-year old stock the disease is often not noticed until the following summer when fruiting bodies form, and leaflet mortality occurs. Infected two-year old stock will show signs of CLB and thus they should be carefully checked prior to planting.

Priority and Research

Since management practices around reducing the risk of this pest exists, its priority is low and little research is ongoing.

Further Reading

- Russell, J.H., H.H. Kope, P. Ades and H. Collinson. 2007. Variation in cedar leaf blight (*Didymascella thujina*) resistance of western redcedar (*Thuja plicata*). Can. J. For. Res. 37: 1978-1986.

Swiss Needle Cast

Swiss needle cast (SNC), *Nothophaeocryptopus gaeumannii*, is not an introduced disease but a native foliar pathogen. Its name comes because of it's first identification by Swiss researchers who were examining it on imported Douglas-fir growing in Switzerland. SNC can be found worldwide everywhere Douglas-fir grows and it is the only host for this fungus. SNC was rarely noticed in the past, usually overshadowed by another foliar disease of Douglas-fir, Rhabdocline needle cast (*Rhabdocline pseudotsugae*). However, in the 1990's Oregon began reporting large areas of Douglas-fir plantations defoliated by SNC and that trend has continued with over 250,000 ha being mapped there to date and an additional 100,000 ha mapped in Washington state. SNC ascospores infect newly flushing needles via the stomata. The fungus develops internally but causes no reaction or necrosis of tissue that would lead to visible symptoms like banding or foliar discolouration. The only visible sign is the production of black fruiting structures that block stomates starting a few months after infection. This blocking leads to lowered CO_2 uptake and hinders metabolic processes like photosynthesis. Once the leaf becomes a net liability to the tree, it is dropped, usually as two or three-year-old foliage. This premature foliar drop leads to growth loss and, occasionally, mortality.

Hazard and Risk

The occurrence of SNC is correlated to weather. During flush and early leaf development mild moist weather that promotes leaf wetness increases the chance of successful infections. Mild winter temperatures allow continued fungal development in the leaf that increases stomatal blocking and disease severity. Planting Douglas-fir into wetter coastal areas where it historically was not present encouraged the development of SNC while more inland areas remained unaffected. Since BC does not share the same coastal geography as Oregon, our increased incidence is more likely due to changing weather patterns that have increased the amount of spring moisture during some years. The area most severely affected by SNC is on the north side of the Fraser River between Stave and Harrison Lakes, but the disease can be found, at varying levels, on regenerating Douglas-fir throughout the coast. There is evidence that moving seedlots from high elevation or dry site sources to the coast can increase risk. Foliar diseases disproportionately affect genetically maladapted seed sources.

Impact

Monitoring plots in Oregon average 23% growth reductions in epidemic areas. Severely infected stands may suffer up to 60% reductions in growth. The value of this growth loss has been estimated at US$128 million annually. Mortality is rare but has been documented in stands with repeated annual infections especially on younger trees.

Management

Since there is no genetic resistance to SNC, choice of seedlots for reforestation is of limited use. Every tree can potentially be infected so the risk is tied directly to the weather. There is evidence of family tolerance to the disease, but such families are still being assessed for tree improvement purposes. Fertilization (N, Ca, P or blends) does not seem to compensate for needle loss. Infected trees respond to thinning more slowly (thin early and from below) but it does not help needle retention. There is no evidence that mixed species stands reduce infection, but loss of basal area may be compensated for by other species. Fungicides are effective, and used extensively in the Christmas tree industry, but would need to be applied one to three times during the infection window and every year that weather conditions are suitable for the disease.

Priority and Research

SNC has come to the fore in the last decade primarily because of its appearance in young stands prior to free growing. An extensive network of monitoring plots was set up starting in 2017 in the CWH dm, xm and vm subzones of the coast to collect information on stand infection and weather attributes and determine an impact estimate for the disease.

Further Reading

Ritokova, G., D. Shaw and D. Mainwaring. 2020. Silvicultural decision guide for Swiss needle cast in coastal Oregon and Washington. Swiss Needle Cast Co-operative, Corvallis, OR. Download at: http://sncc.forestry.oregonstate.edu/sites/default/files/SilvGuide_July2020.pdf

Root Diseases

Annosum Root Rot

The taxonomy of what was once referred to as the species complex *Heterobasidion annosum* (=*Fomes annosus*) has recently been redefined. What was once one species subdivided into five intersterility groups (ISG) is now five distinct species. Three species occur in Eurasia and two in North America. What was earlier referred to as the S-type ISG found in western North America that is partial to non-pine conifers like *Abies*, *Picea, Tsuga* and Douglas-fir is now called *H. occidentale*. It occurs throughout the coast except in the driest parts of the CDF zone. What was previously referred to as the P-type ISG is now called *H. irregulare*. It is more widespread in North America and prefers primarily pine hosts but is not much found in BC. Most damage is done as either a heart rot or as a root and butt rot, so detection of the disease can be difficult until the tree is cut or windthrown. The fungus is adept at invading new hosts via airborne spores and entry through fresh stump surfaces or stem wounds is common. Once colonized, growth of mycelia along root systems to neighbouring trees helps spread the disease.

Hazard and Risk

A first approximation hazard rating exists for *H. occidentale*. It reflects the most susceptible hosts (in descending order) true firs, spruce, hemlock and Douglas-fir with the level of activity proposed. In pre-commercial thinning, a high hazard for infection exists for amabilis fir and Sitka spruce but the hazard is low for western hemlock and Douglas-fir. This rating also applies for damage to residual stems caused by partial cutting. However, two other factors should be considered. For mature trees, the risk of rot caused by *H. occidentale* increases in trees >120 years old. Also, the risk for creating new infections decreases markedly if activities are performed during winter or summer when spore dispersal is inhibited by cold temperatures or dry conditions, respectively.

Impact

While *H. occidentale* spreads readily and through varied pathways and is a major mortality agent of conifers in Europe, its impact in coastal BC is less dramatic. While the disease is endemic to coastal forests, its impact in mature stands is not considered as significant as that of laminated root rot. This may be because the disease is considered more as a grade loss factor rather than a mortality agent. As such, its impact on timber supply is muted by being combined with all other decay, waste and breakage factors and its contribution to volume loss is included in these calculations.

Management

It is rare to single out *H. occidentale* for management in mature stands since it usually does not occur extensively, or it is often found with other root diseases like *Armillaria* or *Phellinus*. As such, most recommendations about the disease are preventive in nature aiming to reduce the risk of creating new infections. The following four recommendations are typical. First, manage stands, especially western hemlock and amabilis fir, to rotations of less than 120 years. When conducting forest operations like partial cutting, minimize wounding to deny entry points for spores. For pre-commercial thinning, do not worry about colonization of fresh western hemlock stump surfaces. While the incidence of *H. occidentale* can increase in thinned stands, the impact appears limited in terms of volume loss over a rotation. Finally, unlike Scandinavia where *Heterobasidion* is the major root disease of plantation forests, treatment of stumps using a liquid or powder formulation of Borax or zinc chloride appears unnecessary. Biological control agents are used in Europe but are untested and not approved for use in BC. In areas where *Heterobasidion* occurs with *Armillaria* or *Phellinus*, management strategies for those latter diseases will usually suffice as a control.

Priority and Research

Considerable work was done regarding *Heterobasidion* 20-30 years ago in western North America. However, fears that it would cause considerable losses in managed (thinned) stands did not materialize. That, combined with the reluctance to practice intensive silviculture in hemlock on the coast, has led to a lack of interest in further research of this fungus.

Further Reading

- Otrosina, W.J. and M. Garbelotto. 2010. *Heterobasidion occidentale* sp. nov. and *Heterobasidion irregular* nom. nov.: a disposition of North American Heterobasidion biological species. Fungal Biology 1: 16-25.
- Otrosina, W.J. and R.F. Scharpf (Eds.). 1989. Research and management of Annosus root disease (*Heterobasidion annosum*) in western North America. USDA For. Serv., Pac. SW For. and Range Exp. Stn. General Technical Report PSW-116.
- Morrison, D.J., M.D. Larock and A.J. Waters. 1986. Stump infection by *Fomes annosus* in spaced stands in the Prince Rupert Forest Region of British Columbia. Can. For. Serv., Pac. For. Centre. BC-X-285.

Armillaria Root Disease

Armillaria root disease is a complex of up to three dozen similar fungal species found across forest types worldwide. Up to seven species of *Armillaria* occur in Western Canada but only one, *Armillaria ostoyae* (= *A. solidipes*), is considered pathogenic on a range of hosts including conifers. The others (including *A. sinapina, A. gallica* and *A. nabsnona*) act primarily as saprophytes or are very rarely found. On the coast, *A. ostoyae* is found from the Dean Channel south to the US border. It is mostly visible in young stands or plantations <20 years old where mortality can be readily seen. In older stands its effect tends to be diluted and the occurrence of dead trees more difficult to spot, especially in stands dominated by coastal climax species. *Armillaria* is more obvious in the coast/interior transition and a more dramatic problem east of the Coast Range in southern Interior forests.

Hazard and Risk

A second approximation of disease hazard exists for *Armillaria* within BC. For the South Coast Region, high hazard subzones include the CDFmm, CWHdm, ds1, ms1, ms2 and IDFww. For the West Coast Region, high hazard subzones are the CDFmm, CWHmm1, mm2, xm1 and xm2.

This hazard rating is meant as a warning that *Armillaria* mortality can occur in juvenile stands, particularly those reforested heavily to Douglas-fir. An assessment of pre free-growing stands found that, in the CWH, *Armillaria* was a far more common cause of young tree mortality in plantations than laminated root rot (*Coniferiporia sulphurascens*) [10]. This mortality has appeared even when there was no Douglas-fir in the earlier mature stand. As such, care should be taken pre-harvest to ensure that mature tree mortality is not caused by *Armillaria* prior to prescribing reforestation options.

Impact
Armillaria root disease can cause mortality in trees of any age. However, visible mortality in stands on the coast is most pronounced by age 20-25. Quantification of impact across subzones is continuing and currently the prescribed OAF 2 of 7.5% for root disease in the CDFmm and CWH xm1 & 2 accounts for losses to *Armillaria*. More detail on this OAF can be found in the profile of laminated root disease.

Management
Guidelines for managing *Armillaria* are like those for laminated root disease with the added complication that the susceptible host list for *Armillaria* is larger, making choice of species suitable for reforestation more constrained. When *Armillaria* is identified in a preharvest walkthrough, a decision will need to be made whether a more detailed survey is warranted to quantify and map the disease prior to deciding if it is severe enough to require stratifying the stand for remedial treatment. The most common treatment is to regenerate with less susceptible species; however, *Armillaria's* extensive host list makes that difficult as most commercial conifer and even hardwood species are to a degree susceptible. More intensive treatments like stump removal are effective for reducing disease inoculum between rotations but are limited by site and machinery constraints.

Intensive treatment is suitable only for productive sites that will benefit most and that are amenable to machinery and some amount of disturbance. Chemical and biological controls have either not been registered or not proven easy to apply. Broadcast burning has no effect on buried disease inoculum. In studies, the application of nitrogen fertilizers has increased the incidence and mortality rate of *Armillaria* by enhancing cambial growth and supplying a more developed food base. Conversely, it is suggested that fertilization with potassium fertilizers may enhance resistance by stimulating root development.

Priority and Research
Armillaria is a top priority forest pathogen for research in BC. However, much of the work is being done in the southern interior. Work on the coast is limited to studies on the efficacy of stump removal as a treatment and its relationship with laminated root disease in maturing stands.

Further Reading

- Zeglen, S. and P. J. Courtin. 2019. Soil disturbance and juvenile Douglas-fir growth following stump removal on moderately coarse textured soils in southwestern British Columbia: 10-year results. Can. J. For. Res. 49: 767–774. dx.doi.org/10.1139

[10] Nevill, R., N. Humphreys and A. Van Sickle. 1996. Five-year overview of forest health surveys in young managed stands in British Columbia, 1991-1995. Canadian Forest Service and BC Ministry of Forests. FRDA Report 262.

- Cleary, M., B. van der Kamp and D. Morrison. 2008. British Columbia's southern interior forests: Armillaria root disease stand establishment decision aid. BC J. Ecosystem Management 9(2): 60-65.
- Morrison, D. and K. Mallet. 1996. Silvicultural management of Armillaria root disease in western Canadian forests. Can. J. Plant Pathology 18: 194-199.

Black Stain Root Disease

Black stain root disease (BSRD) is composed of three varieties of fungus, only two of which are present in BC. *Leptographium wageneri* var. *ponderosum* occurs on lodgepole and ponderosa pines and *L. wageneri* var. *pseudotsugae* on Douglas-fir. Only the latter is found on the coast. BSRD is also unique in that, unlike other root diseases, it neither kills the cambium nor decays roots. Instead, the fungus is brought into the host by root-feeding beetles and weevils (at least three different ones, including *Hylastes* spp., have been identified) and spreads into the sapwood, multiplying and causing a vascular wilt as it effectively blocks the flow of water to the crown. This insect-driven dispersal also makes predicting disease spread difficult.

Hazard and Risk

The unique insect-fungal mutualism makes predicting the occurrence of BSRD difficult in that not all vector insects carry spores and even spore carriers may not attack a host tree in enough numbers to cause mortality. The insects are attracted to trees stressed by a variety of agents, including human-caused activities like road building, harvesting and thinning. In areas where BSRD has been noted, the risk of attack by beetles may be stimulated along road or skid trail edges as roots are disturbed or trees damaged. Harvesting can also push emerging adults into surrounding stands or plantations in a search for suitable new habitat. Such displacement can briefly elevate the local vector population and cause an "outbreak" of mortality, especially in younger trees already suffering from other factors (e.g., competition, drought, etc.). It is possible that with climate change the occurrence of BSRD could increase in areas where Douglas-fir is a marginal species.

Impact

The impact of BSRD is usually localized and patchy in a stand unless circumstances are exceptional. The usual pattern is for the sudden appearance of killed trees in a stand followed by gradually increasing mortality over several years. The pattern of occurrence can appear random since nearest neighbours are not necessarily attacked or do not succumb to the disease. No specific net down is applied for BSRD.

Management

In areas where BSRD may be a concern, low mortality levels can be encouraged by minimizing site disturbance and avoiding tree injury associated with road building and harvesting in areas predominant to young Douglas-fir. Spread is by insect only. The survival of the fungus in stumps is short-lived and is not considered important in spreading the disease. One point to consider is that since the vectors are attracted to weakened trees other root diseases may be present on these sites.

Priority and Research

No research is occurring currently.

Further Reading

- Jacobi, W.R., S. Zeglen and J.D. Beale. 2008. Black stain root disease progression in coastal Douglas-fir in British Columbia. Can. J. Plant Pathology 30: 339-344.
- Hunt, R.S. and D.J. Morrison. 1995. Black stain root disease. Can. For. Serv., Pac. For. Centre. Forest Pest Leaflet 67.

Laminated Root Disease

Laminated root disease (LRD), caused by *Coniferiporia sulphurascens (= Phellinus sulphurascens, = P. weirii* Fd type*)*, is the most damaging root disease in coastal Douglas-fir forests. Its ability to kill primarily Douglas-fir and *Abies* species at any age makes this a most notable and economically significant pathogen. It is also an important natural disturbance agent causing long-term change to Douglas-fir ecosystems in the Pacific Northwest. The distribution of LRD on the coast follows that of Douglas-fir through the CDF and drier CWH subzones. LRD can create very noticeable mortality in coastal forests since many conifers are susceptible to some extent. Juvenile stand mortality can start as early as age 5 and continues throughout stand development, often culminating in large, obvious mortality centres filled with non-susceptible host species of trees or shrubs. LRD is also quite extensive throughout the southern Interior, but its presence is often overshadowed by that of *Armillaria*. A recent taxonomic change has relegated the name *P. weirii* to describe the related fungus that is known to occur as a butt rot of western redcedar, but this disease is rarely noted on the coast.

Hazard and Risk

A second approximation of disease hazard exists for LRD within BC. For the South Coast Natural Resource Region, high hazard subzones include the CDFmm, CWHdm, ds1, ms1, ms2 and IDFww. For the West Coast Natural Resource Region, high hazard subzones are the CDFmm, CWHmm1, mm2, xm1 and xm2.

This hazard rating indicates that there is a high risk of LRD occurring in stands that were previous predominant to Douglas-fir, particularly if they are being reforested again with Douglas-fir.

Impact

LRD can cause substantial mortality to Douglas-fir and *Abies* sp. of any age. It is estimated that 1.4 million m^3 are lost annually in BC through mortality and growth reduction. Mortality is typically seen starting at age 6-10 and continues throughout stand development culminating in the creation of large openings or gaps in stands that are filled by less susceptible species. The occurrence of LRD is closely tied to the presence of Douglas-fir. For example, while western hemlock is susceptible to LRD, infected hemlocks are rarely found in stands that aren't mixed with infected Douglas-fir. Quantification of impact across subzones is continuing and currently the prescribed OAF 2 of 7.5% for root disease in the CDF and CWH xm1 & 2 accounts for losses to all root diseases, including LRD and *Armillaria*. It is added to the default OAF 2 of 5% resulting in a cumulative OAF 2 of 12.5%.

Management

Guidelines for managing LRD are like those for *Armillaria*. The difference is the susceptible host list for LRD is shorter. Although many conifers are less effective hosts, all pines are tolerant and cedars resistant while hardwoods are immune. These species can be reliably chosen as alternates to highly susceptible species. When LRD is identified in a preharvest walkthrough, a decision will need to be made whether a more detailed survey is warranted to quantify and map the disease prior to deciding if it severe enough to require stratifying the stand for remedial treatment. The most common treatment is to regenerate with less susceptible species of which there are several choices including white pine (resistant MGR material only), red or yellow cedar and hardwoods. More intensive treatments like stump removal are effective for reducing disease inoculum between rotations but are limited by site and machinery constraints.

Intensive treatments are suitable only on productive sites that will benefit most and that are amenable to machinery and some amount of disturbance. Chemical and biological controls have either not been registered or not proven easy to apply. Broadcast burning has no effect on buried inoculum. Application of nitrogen fertilizers has no effect on disease incidence or the rate of mortality. Fertilization of mature stands can delay culmination age and extend rotation for a few years but has negligible effect on final stand volume.

Priority and Research

The biology and action of laminated root disease has been extensively studied over the last few decades. Current research is focussed on the efficacy of various treatment options (e.g., stump removal) and the search for resistant individual families in field trials.

Further Reading

- Zeglen, S. and P.J. Courtin. 2019. Soil disturbance and juvenile Douglas-fir growth following stump removal on moderately coarse textured soils in southwestern British Columbia: 10-year results. Can. J. For. Res. 49: 767-774.
- Sturrock, R., S. Zeglen, and J. Turner. 2006. British Columbia's coastal forests: Laminated root rot Forest Health Stand Establishment Decision Aid. BC J. Ecosystems and Management 7(3):41–43.
- Thies, W.G. and R.N. Sturrock. 1995. Laminated root rot in western North America. USDA Forest Service, Pac. NW Res. Stn. Research Bulletin PNW-GTR-349.

Rhizina Root Disease

Rhizina root disease, caused by the fungus *Rhizina undulata*, is primarily a mortality agent of seedlings planted after fire has occurred on a site. On the coast, *Rhizina* was a problem in CWH plantations in the late 1960's and through the 1970's but that has faded with the elimination of broadcast burning for site preparation.

Hazard and Risk

Since *Rhizina* spores require a certain amount of soil heating to stimulate germination, any occurrence of fire can cause appearance of the fungus. On the coast, *Rhizina* was confined to the CWH exclusively following fire, either wildfire or broadcast burning for site prep. As such, any use of fire may stimulate the appearance of *Rhizina* and care should be taken when planting into burned areas.

Impact

The incidence of Rhizina tends to disappear two seasons following burning. For example, a fall burn followed by a spring planting would create a risk for Rhizina. Incidence of the fungus would appear that year and persist into the next before exhausting itself by the third season. Mortality can be patchy since infection is dependent on proper heating of the soil but incidences of up to 80% have been seen in plantations.

Management

If planting into a burned area that has no history of *Rhizina*, conduct a seedling survival survey the season following planting to ensure no mortality has occurred. If the area has a history of *Rhizina*, then delaying planting for two seasons may be preferable. This will ensure that the disease has exhausted itself on the site and infection risk is minimal.

Priority and Research

No research is occurring currently.

Further Reading

- Callan, B.E. 1993. Rhizina root rot of conifers. Can. For. Serv., Pac. For. Centre. Forest Pest Leaflet 56.

Stem Rusts

White Pine Blister Rust

White pine blister rust (WPBR), caused by the introduced fungus *Cronartium ribicola*, is a devastating pathogen of five-needle pines across North America. In BC, it affects western white, limber and whitebark pines and has removed the former from its historical representation in forests. While WPBR may infect trees of any age, the greatest impact on western white pine is to young trees since the zone of highest infection incidence is the lowest two metres of the bole. Infection occurs via spores infecting through foliar stomata and mycelia progressing into the branch (or main stem in the case of direct stem needle infections) where swellings (cankers) appear after a year or two. Most cankers are conspicuous in the spring when the blisters holding masses of orange aeciospores open and spores spread to the alternate host, primarily *Ribes* spp. In the fall, basidiospores return to infect pine needles, most effectively during humid warm periods, and the cycle starts anew.

Hazard and Risk

Site hazard for WPBR is considered high in BC anywhere that five-needle pines grow. Some hazard rating systems exist in the US but to date no one has produced a reliable system for use in BC, mainly due to the problem of correlating various site and tree factors to the incidence of rust over a diverse landscape. One factor that is a reasonable predictor of potential infection is proximity to *Ribes* plants. Pines within 30 m of *Ribes* can suffer higher levels of infection. Recently, species of *Pedicularis* and *Castelleja* have been named as alternate hosts for WPBR but, so far, this has only been confirmed in areas east of the Cascades. As a rule of thumb for the coast, areas above 1000 m may be considered less hazardous. This may make them candidates for use of resistant, interior-source planting stock.

Impact

For over a century, WPBR has decimated white pine in BC forests. The high mortality rate associated with the disease had resulted in the discontinued use of western white pine in coastal reforestation due to doubt about its survival. WPBR, along with mountain pine beetle, has severely impeded the reproductive capability of whitebark and limber pines threatening the continued survival of these high-elevation species in areas of the province.

Management

Despite WPBR, western white pine is still a desirable species primarily because of its wood characteristics and its utility in replacing Douglas-fir in areas where laminated root disease occurs. Over the decades several attempts have been made to control this disease. The most significant was the widespread attempt to eradicate *Ribes* across the US from the 1930's to the 1960's. This was unsuccessful due to the impossible task of locating and eradicating all *Ribes* plants across the landscape. Some success can be obtained in controlling *Ribes* establishment by altering harvesting regimes to limit canopy openings and restrict the increase in light levels to the forest floor. Other cultural efforts have included using chemical and biological control agents (ineffective or impractical), thinning (ineffective), pruning (variable effectiveness), and scribing cankers (effective but expensive). Since the 1960's, the most actively pursued strategy is tree breeding to try and identify and reinforce whatever resistance to WPBR exists in the natural population and use the resulting offspring for reforestation.

On the coast, the most widespread practice has been to prune potential white pine crop trees to increase the odds of survival. Recent work, however, shows over the long-term sanitation pruning (treatment of older, already infected trees to increase survival) does not work. The recommended preventative pruning treatment regime is outlined in the 2009 Stand Establishment Decision Aid listed below and requires initial treatment early in the tree's development. The recent introduction of resistant stock (carrying the Cr2 or MGR gene) has opened the window on using western white pine more extensively in plantations without requiring pruning to ensure survival. Seed orchards are producing class A seed from crosses of resistant Cr2 pollen with local white pine families of superior growth. The offspring are conferred at least 50% resistance (50% chance of not becoming infected) and field tests have noted survival of over 80% depending on local rust conditions. Natural regeneration survival of native trees is 5-15% in most areas.

Priority and Research

WPBR has been studied since shortly after its discovery on the west coast. This includes 30 years of testing and breeding for resistant stock in BC and twice that long in the US. This is still a high-profile disease on the coast with ongoing projects testing cultural (i.e., pruning) and genetic (i.e., resistance) management practices. The most recent work involves evaluating the offspring of both major and minor gene resistant parents with the hope of combining both resistance attributes and genomics work on the fungus and host.

Further Reading

- Zeglen, S. and R.S. Diprose. 2021. Efficacy of delayed entry low branch sanitation pruning in preventing mortality of western white pine infected with white pine blister rust. Canadian Journal of Plant Pathology 43 DOI:10.1080/07060661.2021.1916602
- Zeglen, S., J. Pronos and H. Merler. 2010. Silvicultural management of white pines in western North America. Forest Pathology 40: 347-368.
- Cleary, M. R. Ed. 2010. Proceedings of the 3rd Western White Pine Management Conference. June 17-18, 2008. Vernon, BC. BC Min. Forests and Range, Kamloops, BC. 116 pp.

- Zeglen, S., R. Hunt and M. Cleary. 2009. British Columbia's forests: White pine blister rust Forest Health Stand Establishment Decision Aid. BC Journal Ecosystems and Management 10(1): 97-100.
- Hunt, R.S. and M.D. Meagher. 1992. How to recognize white pine blister rust cankers. Forestry Canada. Pacific Forestry Centre, Victoria, BC.

Weevils

Spruce Weevil

The spruce weevil, *Pissodes strobi*, is the major insect pest of Sitka spruce on the coast where it seriously limits the use of Sitka spruce for reforestation. Repeated weevil attack of the leading shoots of young Sitka spruce leads to suppressed height growth and stem deformities. Young Sitka spruce become susceptible at about age five and will continue to be attacked for the next three decades. Dense stands have slightly lower attack rates and less deformity.

Hazard and Risk

Weevil hazard zones are based on climate; warmer sites are more susceptible. Spruce plantations next to stands that have heavy attack are at risk. Englemann spruce is also susceptible to attack but due to the higher elevation and cooler climate of these sites, weevil attack is usually much less intense, and is usually not a concern but climate change may be altering the hazard in those areas. Spruce weevil has not been found on Haida Gwaii, but Sitka spruce originating from there has been shown to be highly susceptible to weevil attack.

Hazard zones for Sitka spruce have been correlated to biogeoclimatic subzone variants:

- High hazard: CDFmm; CWHxm1 & 2, dm, ds1 & 2, mm1, ms2, vm1; IDFww.
- Moderate hazard: CWHvh1, vm2.
- Low hazard: remaining variants within coastal zones [see page 229 of Green and Klinka (1994)].
- Hazard ratings within these variants declines as one moves north, for example in the north coast the CWHvm1 has a low hazard and the hazard in the vm2 is negligible.

Impact

Repeated attack by the weevil can result in unacceptable losses of height growth and stem deformation as lateral branches turn upward and compete for dominance. This can cause crooks and result in forked or dwarfed trees. In severe cases, little commercial volume is produced with attacked trees becoming overtopped and suppressed by competing, less valuable tree species.

Management

Manual control of established weevil infestations is not practical. The weevil's complex of predators and parasites has also been studied to develop ways to control it. Pesticide injection treatments were also tried as was overstorey shading. Unfortunately, no practical method has yet been developed to control established infestations. However, the identification of naturally resistant individual spruce, and later research trials have now brought this to the point where weevil resistant seedlings can be planted operationally.

When planting new stands having Sitka spruce, use weevil resistant planting stock. Use improved class A seed (from selected orchard grown weevil resistant trees, R+87). If seed availability is limited, up to half of the stand composition could be planted with Sitka spruce in areas considered to have moderate to high weevil hazard ratings. If class B seed is used (from naturally resistant stands, R+64), caution is recommended, and it is suggested that only about a third of the stand composition be spruce.

If weevil resistant stock is not available, plant Sitka spruce as follows:

- In low hazard areas, spruce can be planted following normal species selection guidelines. Low levels of weevil attack can be tolerated at the stand level (e.g., ≤10% stems attacked per year).
- In areas considered to have a moderate hazard, it is recommended that spruce only be planted to compose up to 20% of the stand composition.
- In high hazard areas, alternative non-host tree species should be planted, and limit spruce to 10% of the total stocking.
- Plant spruce with other tree species at higher densities (greater than 1600 stems per ha) and delay thinning (or don't thin). Weevil attack rates decline when stand height reaches 12 m.

Priority and Research

This insect has received a significant amount of research over the past three decades, starting with years of leader clipping trials trying to develop a control method. Since Class A weevil-resistant seed is now available little new research is being done with this pest on the coast.

Further Reading

- Heppner, D. and J. Turner. 2006. British Columbia's coastal forests: Spruce weevil and western spruce budworm forest health Stand Establishment Decision Aids. BC J Ecosystems and Management 7(3):45–49.
- Turnquist, R.D. and R.I. Alfaro. 1996. Spruce weevil in British Columbia. Forest Pest Leaflet #2. Canadian Forest Service, Pacific Forestry Centre, Victoria.
- McMullen, L.H. 1976. Spruce weevil damage, ecological basis and hazard rating for Vancouver Island. Canadian Forest Service, Info Report BC-X-288, Victoria.

Wildlife

Porcupine

Porcupines are primarily herbivores with a winter diet that consists almost exclusively of the cambium, phloem and foliage of woody shrubs and trees. The wounding caused by feeding ranges from small patches of bark removed to complete stripping and girdling of trees. Along with outright mortality, feeding damage can cause reduced tree growth and structural defects that lower wood quality and serve as entry points for decay fungi. Porcupines prefer different tree species in different areas of their range.

Hazard and Risk

There is a hazard that exists to second-growth, even-aged, hemlock-dominated stands on the north and mid-coast where porcupines may be present. Immature western hemlock is by far the preferred food source for porcupine on the coast with trees in the 10 to 30 cm dbh range most commonly suffering feeding damage. Small trees are rarely attacked since they are often too small to offer the porcupine protection from predators or a sufficiently high perch in the canopy. Larger trees that have developed thicker bark are less desirable as well due to the increased effort required to climb and feed higher in the canopy.

Impact

The results of a study done in the North Coast showed that while overall stand volume does not appear to be greatly affected, there is a considerable shift in stand species composition due to porcupine damage. Due to their preference for western hemlock, porcupine feeding kills, or causes to be killed by other factors (e.g., decay), or makes less valuable due to defect (e.g., crooks, scars, etc.) hemlock trees. This favours the growth of Sitka spruce, amabilis fir and western redcedar which are not preferred by porcupines.

Management

Since porcupines seem to key on openings stocked with substantial amounts of even-aged western hemlock, increasing species diversity in large openings known to be habitat for porcupine is a good risk reduction strategy. This may not lessen the amount of feeding damage, but it will ensure that enough stocking of non-host trees exists to carry stand volume expectations to rotation. Most active efforts to reduce local porcupine populations, by hunting or introducing predators, have failed to have any lasting effect.

Priority and Research

No research is occurring currently.

Further Reading

- Woods, A. J. and S. Zeglen. 2003. Impact of feeding damage by the porcupine on western hemlock-Sitka spruce forests of north-coastal British Columbia: 15-year results. Can. J. Forest Research 33: 1983-1989.

Appendix B: Pest History by TSA

2020 Aerial Overview Survey

Aerial overview surveys (AOS) have been conducted annually on the coast by the Ministry since 1998. Prior to this, the Forest Insect and Disease Survey (FIDS) unit of Forestry Canada (now the Canadian Forest Service) conducted large-scale aerial and ground surveys. The intent of these surveys is to provide an overview of forest health conditions. The AOS is not detailed enough for operational purposes but supplies a landscape-level picture of pest activity and distribution that can be useful for the early detection of outbreaks or new pest occurrences. Table 9 summarizes the 2020 results for the Coast Area. Annual updates are available on the Ministry website and through the *Summary of Forest Health Conditions in British Columbia.*

It is important to note that aerial surveys in the Coast Area are not undertaken with the same intensity as other parts of the province due to the lower level of insect activity. Note that TFL areas are neither completely nor consistently covered by the overview survey. The Pacific TSA is not recognized separately for the purposes of the AOS.

Table 9. Summary of annual average area (ha) affected by major pests and abiotic damaging agents at all severity levels in the Coast Area as reported by the aerial overview survey. Figures are 10-year averages except for GBR North, GBR South and North Island TSAs which are four-year averages.

	Timber Supply Area							
Damaging Agent	Arrowsmith	Fraser	GBR North	GBR South	Haida Gwaii	North Island	Soo	Sunshine Coast
Douglas-fir beetle	1690	1566	485	432		109	240	434
Mountain pine beetle		1544	2965		28		1125	217
Spruce beetle		1093	3581	132	134	28	185	260
Western balsam bark beetle	589	6534	64268	1169		188	9904	1649
Western blackheaded budworm					4680			
Western hemlock looper		602						654
Western spruce budworm		372					72	
Aspen leaf miner		101	3463					
Balsam woolly adelgid	9	50	4	93		1615		18
Root diseases	256	99				121	51	84
Foliar diseases			3632				19	
White pine blister rust	2122	13		13		1842		712
Bear	31	42						
Yellow-cedar decline			21997	4170	3045			
Windthrow	40	6	74		1285	57	15	3
Drought	1044	635	390	129	60	517	65	1283
Flooding	18	22	198	69	476	78	111	43
Slides		17	248	64	1230		21	6

Arrowsmith TSA

The Arrowsmith TSA is located on the southern half of Vancouver Island and borders on TFLs 44, 46, 54, 57, and 61. In contrast to other TSAs in British Columbia, this TSA is made up of many disconnected parcels of land ranging in size from a few hectares to a few thousand hectares. These parcels are interspersed with private land, TFLs, urban and sub-urban areas, rural agricultural lands, parks and reserves. The Arrowsmith TSA is administered by the South Island Natural Resource District. Although the TSA encompasses 1 574 719 hectares, the actual productive forest land managed by the district is only 122 445 hectares.

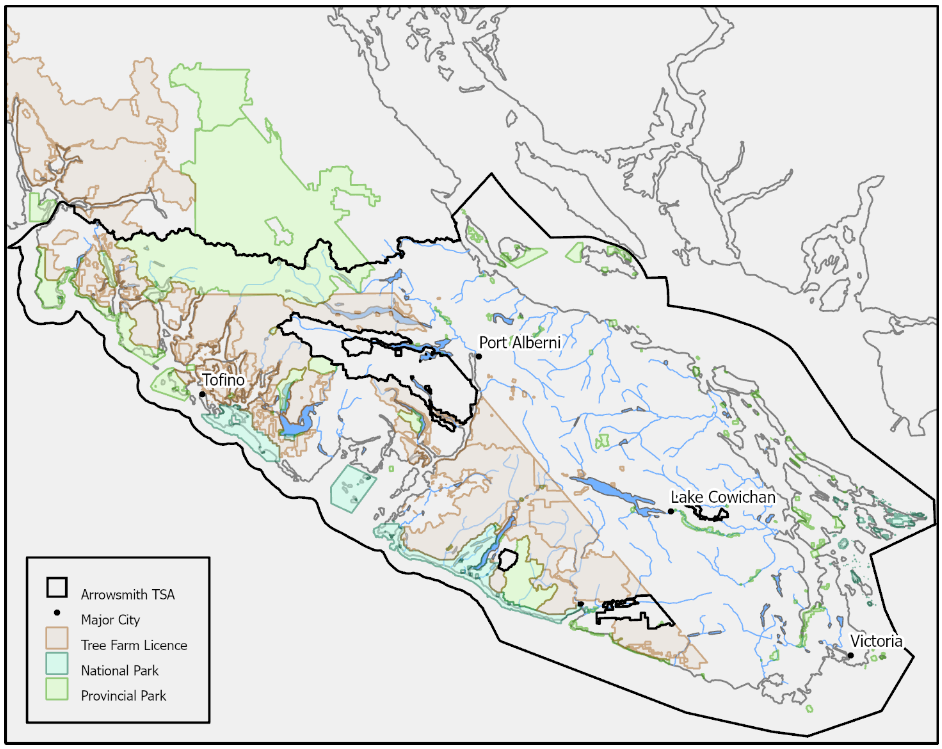

Figure 2. Arrowsmith Timber Supply Area.

Spanning southern Vancouver Island from the west to east coast, the terrain of the TSA varies from lowland valleys, with nutrient rich, moist sites to mountainous areas, with poorer, drier sites. Most of the productive forest land lies within the Coastal Western Hemlock (CWH) biogeoclimatic zone, where cool, wet summers and mild winters support stands with a sizable proportion of western hemlock. The Coastal Douglas-fir (CDF) zone occurs on the eastern side of the TSA, which is comparatively drier with gentler topography than the western part. Here warm, dry summers and cool, wet winters result in stands dominated by Douglas-fir. At higher elevations, the Mountain Hemlock (MH) zone occurs and at the highest elevations, there are isolated occurrences of Coastal Mountain-heather Alpine (CMA) zone.

The forests of the TSA are diverse, and slightly more than half of the land base contributing to timber supply is considered to have medium or good site productivity. Major tree species include Douglas-fir, western redcedar, western hemlock and true firs, while other species such as yellow-cedar, spruce, red alder, and maple also occur. The forests of the TSA have a long history of harvesting, and as a result there are rapidly maturing second-growth forests on the lower elevation sites that are accessible and highly productive. Almost half of the stands on the timber harvesting land base (THLB) are between 21 and 100 years of age.

Thirty-six First Nations have asserted and/or established Aboriginal interests within the traditional territories that overlap the Arrowsmith TSA.

Effective February 9, 2018, the new AAC for the Arrowsmith TSA is 324 580 cubic metres. This AAC is about 10 percent lower than AAC in place prior to this determination (originally set in 2009 and adjusted in 2016). This AAC is partitioned as follows:

1. Eastern Portion of the TSA: A maximum of 50 000 m^3 from the Eastern portion of the TSA (Nanaimo and Cowichan timber supply blocks);
2. The Clayoquot Sound Land Use Decision area: A maximum of 6850 m^3 from the Clayoquot Sound Land Use Decision area; and
3. The Western portion of the TSA: A maximum of 291 150 m^3 from the Western portion of the TSA, comprised of the area outside of Clayoquot Sound (Barkley timber supply block).

Douglas-Fir Beetle

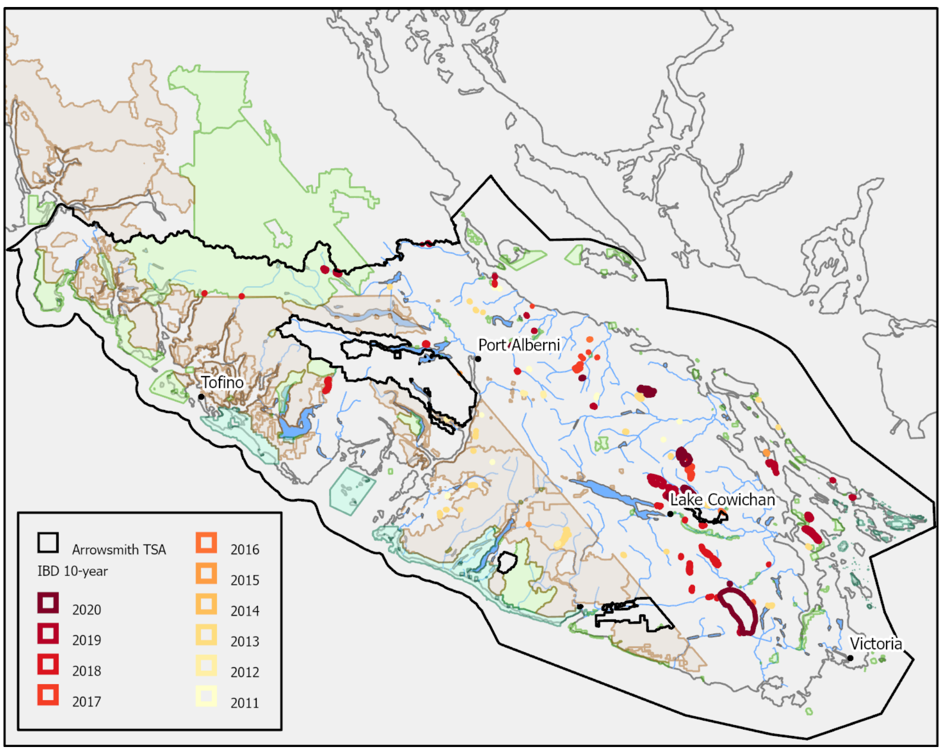

Figure 3. Annual occurrence of Douglas-fir beetle over the last decade in the Arrowsmith TSA.

Very few records of early Douglas-fir beetle activity exist for the Arrowsmith TSA. The first record was for 1914 near Cowichan Lake. In 1953, trees suffering from drought were attacked near Victoria and North Pender Island, and in some windthrow near Gordon River. In 1974, attacked trees were found near Port Alberni, East Saanich, Chemainus, and Coombs. A year later wind thrown trees were attacked in Cathedral Grove and in 1981 west of Shawnigan Lake. Douglas-fir beetle is endemic and often appears in scattered patches where mature Douglas-fir is present. It is often found associated with root diseases. It can also appear after large windthrow events when populations expand by colonizing recently killed trees. The occurrence of beetle has trended upward between 2017 and 2020 from 598 to 8995 ha a result of increased attack on drought-stressed trees.

Drought

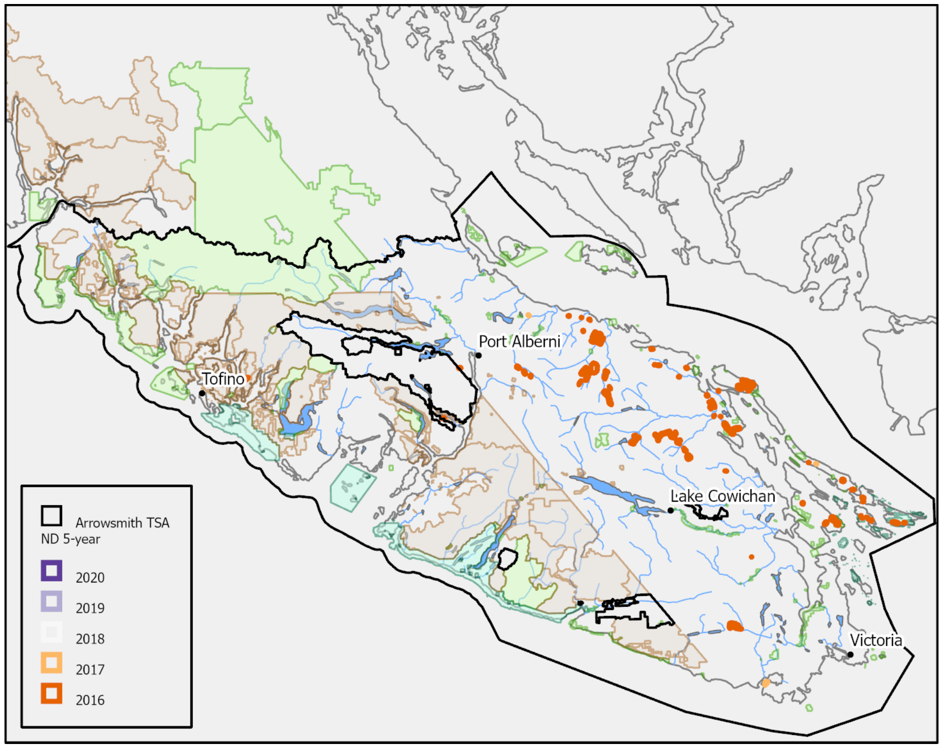

Figure 4. Annual occurrence of drought mortality in the Arrowsmith TSA.

Over the last two decades, southern Vancouver Island and the Gulf Islands have experienced occasional prolonged periods of no or little precipitation during the summer months. These dry periods are enough to cause drought stress to all ages of trees growing on shallow or coarse textured soils with low moisture holding capacity. A single, exceptional long summer dry spell with little measurable precipitation, like the ones in 1998, 2004, 2017 and 2018 can lead to significant amounts of tree decline and mortality if conditions are severe enough. Local climate shifts suggest this may occur more often. Recent drought is especially noticeable on eastern Vancouver Island and the Gulf Islands especially in areas where dead and declining western redcedar are present.

Gypsy Moth

In recent years accidental introductions of North American and Asian gypsy moths have been detected in southern British Columbia, including within the Arrowsmith TSA. The Ministry has a partnership role with the Canadian Food Inspection Agency in monitoring for this pest and a lead role in conducting aerial and ground eradication treatments, successfully preventing its establishment within the province. Baited traps are placed and assessed annually throughout the TSA to provide early detection of moths. Occasional captures are made every year, mostly in populated areas. The most recent spray applications using the biological control agent *Btk* for eradication of moths in the TSA was in 2020 at Lake Cowichan but aerial treatments have occurred at other locations in the TSA.

Mountain Pine Beetle

From 1940-1960 mountain pine beetle was recorded on western white pine near Port Renfrew, San Juan Valley, Carmanah and Englishman River areas. This infestation on Vancouver Island is estimated to have covered over 135,300 ha and killed close to 4 million trees. Since then, this beetle has rarely been reported.

Root Diseases

Losses to root diseases have been incorporated since TSR II for this TSA through adjustment of the OAF2 to 12.5% for all managed Douglas-fir leading stands in the CDF and CWHxm1 & 2 variants. The TSA has both *Coniferiporia sulphurascens* (= *Phellinus weirii* Fd-type) and *Armillaria ostoyae* acting as mortality agents of immature and mature trees, primarily Douglas-fir, in these drier subzones.

Spruce Aphid

Spruce aphid has caused defoliation to Sitka spruce at various times, mostly between Victoria and Jordan River, and on the Gulf Islands. In some years it is more noticeable than others even though it probably occurs annually in the same areas.

Western Black Headed Budworm

Outbreaks of blackheaded budworm have occurred within the Arrowsmith TSA over the past 100 years; however significant impacts have been limited. No recent occurrence of the insect has been reported recently even though outbreaks occur regularly on northern Vancouver Island.

Western Hemlock Looper

A large outbreak of western hemlock looper was recorded on southern Vancouver Island from 1945-1947, in the Cowichan and Nitinat lakes area. This outbreak was over 20,000 ha in size and mostly within the CWHvm1. It resulted in severe defoliation and mortality and later salvage harvesting.

Western Spruce Budworm

The first recorded defoliation by western spruce budworm in British Columbia occurred near Victoria (including Saltspring Island) and Duncan in 1909 and 1910 in the CDF biogeoclimatic zone. No other defoliation by this insect has been since recorded in the Arrowsmith TSA.

White Pine Blister Rust

White pine blister rust damage is not always visible during the aerial overview surveys, particularly if the infections have not killed the tree. However, surveyors often see scattered damage throughout the range that the host grows. These are often recorded as spots or small scattered polygons. In 2020, polygons totalling 11,769 ha were mapped at trace to moderate intensity throughout the TSA. Although the damage occurred primarily as scattered single trees, damage was at a high enough level that recording polygons was possible. This mortality was primarily in the drier subzones of eastern and central Vancouver Island and was mostly natural white pine regeneration.

Windthrow

There was a large wind event on December 18/19, 2019 that struck parts of southern Vancouver Island. Extensive windthrow was noted in the Whiskey Creek area, Little Qualicum Falls Provincial Park and on neighbouring private lands. Much of the material was salvaged and no uptick in Douglas-fir beetle was noted in 2020.

Fraser TSA

The Fraser TSA, located in the southern portion of British Columbia's South Coast Natural Resource Region, covers approximately 1.4 million hectares and is administered from the Chilliwack Natural Resource District office. It is the most densely populated TSA in the province, encompassing major population centres in the Lower Mainland and Fraser Valley. There are 34 communities that reside in the District, 27 communities that reside outside the TSA for a total of 61 communities that assert territories over the Fraser TSA and there are 11 tribes/councils which include a combination of the individual communities.

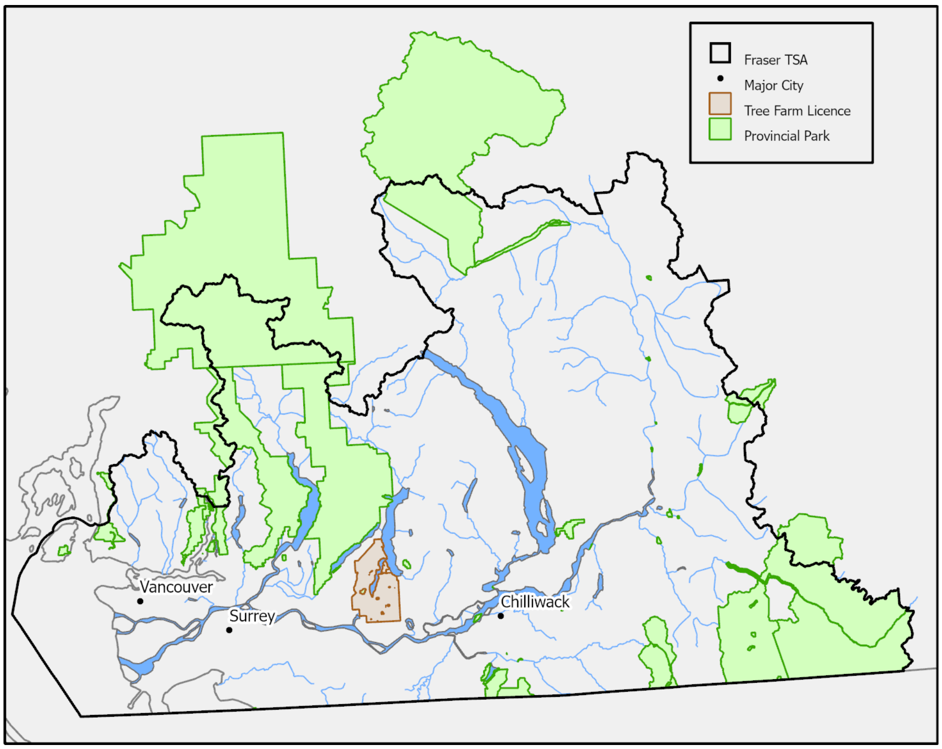

Figure 5. Fraser Timber Supply Area.

The Fraser TSA is a biologically diverse region, with five biogeoclimatic zones providing habitat for more than 300 species of resident and migratory birds, 45 species of mammals, 11 species of amphibians, and 5 species of reptiles. The TSA is bordered by the Coast Mountains to the north and to the east. Tributaries and lakes drain from this area into the Fraser River, flowing through the broad, riverine plain lying between the community of Hope to the east and the city of Vancouver to the west, on toward the extensive delta of the Fraser estuary and into the saltwater of Georgia Strait. While the coastal western hemlock zone is the most abundant zone in the TSA, the diverse landscapes support 13 commercial tree species.

The TSA includes both major urban population centres, where various service sectors combine to provide about 70 percent of the region's employment, and smaller rural communities, where primary sectors including forestry provide important sources of employment and economic activity.

Effective August 6, 2019, the new AAC for the Fraser TSA is 1 220 808 m^3.

Balsam Woolly Adelgid

This introduced pest has been found throughout the Fraser TSA. It can cause considerable damage, including mortality, to *Abies* species; however, within this TSA its impacts have not yet been found to be significant. The TSA was included within the regulated quarantine area which restricted the movement of true firs (see *Balsam Woolly Adelgid Regulation*), however, this regulation was repealed in 2019.

Douglas-fir beetle

Douglas-fir beetle is a native insect that attacks fresh wind throw or trees predisposed by other factors, such as drought, defoliation or root diseases. Instances of Douglas-fir beetle attacked root-diseased trees are common in the Fraser TSA.

Douglas-fir beetle was first recorded in 1952 in the Skagit and Anderson River Valleys. Populations continued at low levels until 1956, with no recorded damage from 1957-1959. In 1960 infestations were noted again in these areas, and by 1961 populations expanded to include small patches in the Nahatlatch River valley. In 1967 and 1968, populations increased in the Fraser Canyon, with infestations totalling, 1960 ha and 1677 ha, respectively. Small patches continued until 1972 throughout the Fraser Canyon. In 1974 dead trees were noted in the Silver-Skagit valley. Small pockets of attacked trees continued annually and sporadically throughout the TSA, until 1980 when 1300 ha were reported in the Fraser Canyon and through to Sunshine Valley. Populations have remained active since then at low levels, with a peak of 870 ha in 2000 in a large infestation near Nahatlatch River. In 2003, 250 ha were recorded in 17 separate patch infestations, three of which were near the Nahatlatch River and the rest in areas along Highway 3 between Sunshine Valley and the west gate of Manning Park. In 2004, populations increased along the Fraser Canyon corridor and Nahatlatch River with about 2590 ha infested, and in Manning Park where 155 ha were infested. Populations stayed low with 500-1500 ha reported annually from 2011-2014. A spike to 4271 ha in

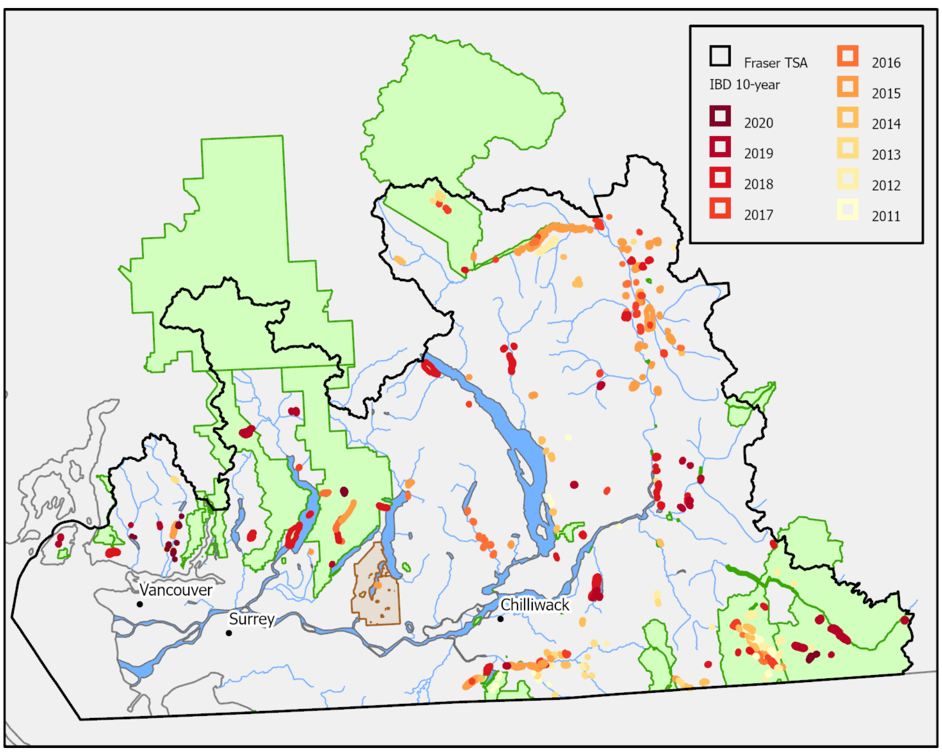

Figure 6. Annual occurrence of Douglas-fir beetle in the Fraser TSA over the past decade.

2015 was primarily in the Fraser and Nahatlatch Valleys. Endemic level mortality around the Sunshine Valley area prompted calls from the locals. Recently, the beetle has been trending down with 3603 ha found in 2018 but only 288 ha in 2020.

Douglas-Fir Tussock Moth

Douglas-fir tussock moth has caused occasional defoliation of ornamental spruce and Douglas-fir in urban areas (i.e., golf courses, boulevards, etc.). It is not considered a serious pest of managed coastal forests.

Drought

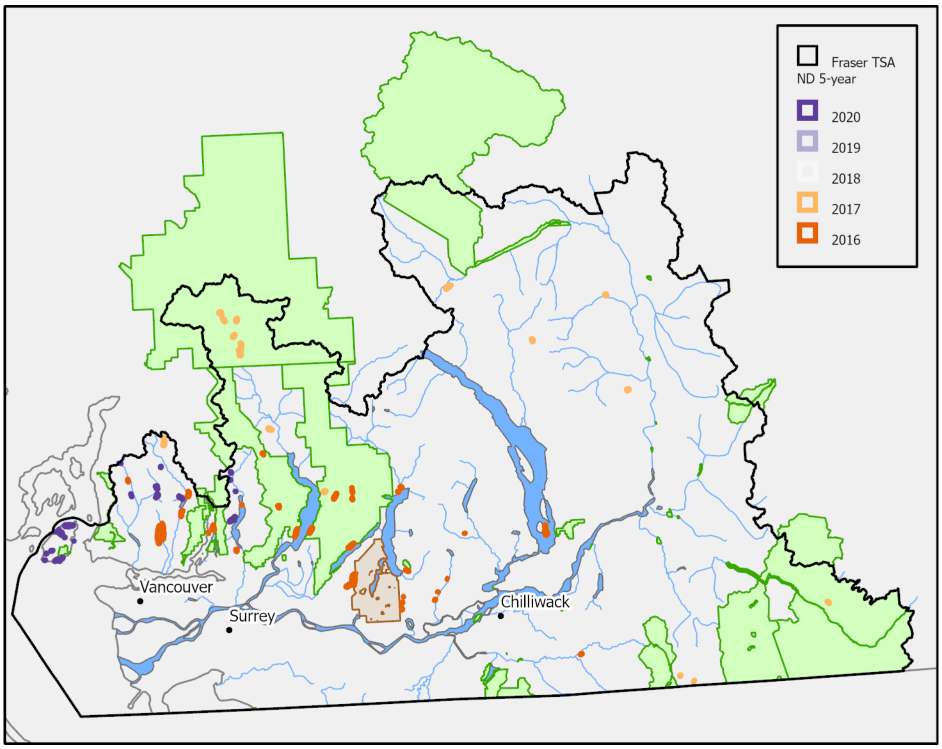

Figure 7. Annual occurrence of drought mortality in the Fraser TSA from 2016-2020.

Over the last two decades, the South Coast has experienced occasional prolonged periods of no or little precipitation during the summer months. These dry periods are enough to cause drought stress to all ages of trees growing on shallow or coarse textured soils with low moisture holding capacity. A single, exceptional long spell with no measurable precipitation, like the ones in 1998, 2004, 2017 and 2018 can lead to significant amounts of tree decline and mortality if conditions are severe enough. Local climate shifts suggest this may occur more often. Recent drought is especially noticeable in areas where dead and declining western redcedar are present.

Forest Tent Caterpillar

In 2014, this insect caused 2,205 ha of light to moderate defoliation mostly in the Cultus Lake area. While the defoliation can be unsightly due to the massive profusion of webs on trees and the migration of larvae across the landscape, it is not considered a serious forest pest and only repeated defoliation causes results in growth loss or mortality. Defoliated trees typically reflush later in the growing season or normally the following spring.

Gypsy Moth

In recent years accidental introductions of North American and Asian gypsy moths have been detected in southern British Columbia, including within the Fraser TSA. The Ministry has a partnership role with the Canadian Food Inspection Agency in monitoring for this pest and a lead role in conducting aerial and ground eradication treatments, successfully preventing its establishment within the province. Baited traps are placed and assessed annually throughout the TSA to provide early detection of moths. Occasional captures are made every year, mostly in populated areas, however, 197 moths were trapped near Cloverdale in 2014 resulting in a spray treatment in 2015. There have been several ground and aerial spray treatments within the TSA since 1984. Over the last decade, areas have been sprayed near Harrison Hot Springs (2009, 2010), Richmond (2010), Delta (2015), Surrey (2015, 2017, 2018, 2019, 2020) and Agassiz (2018). These are exclusively in urban or agricultural areas and not in managed forests.

Mountain Pine Beetle

Mountain pine beetle is a native insect that was first recorded from the 1940's to 1960's in the Skagit River Valley and side drainages of the Fraser River. In 1972 several patches were noted in Manning Park, and in 1973 in the Nahatlatch River drainage. The infestation continued in both areas in 1974. In 1975 populations near Nahatlatch decreased, while those in the Manning Park corridor remained sporadic from 1976-1998 and expanded significantly in 1999 to 1577 ha. This infestation has increased annually with about 9300 ha recorded in Manning Park and Skagit valley, and 3300 ha outside park boundaries along Highway 3, in 2004. This is an increase from 2003 when approximately 4300 infested ha were found in Manning Park and 690 ha outside the park In the Fraser Canyon small spot and patch infestations have also occurred sporadically, with slight increases from 1977-1978, 1980, 1985-1986, and 2002-2003. During the last mega outbreak, attack peaked at 31,921 ha of pines in 2007. Population levels then steadily declined to about 4000 ha in 2013 mostly in the Manning Park and Nahatlatch areas. These areas showed light to moderate severity. Since then

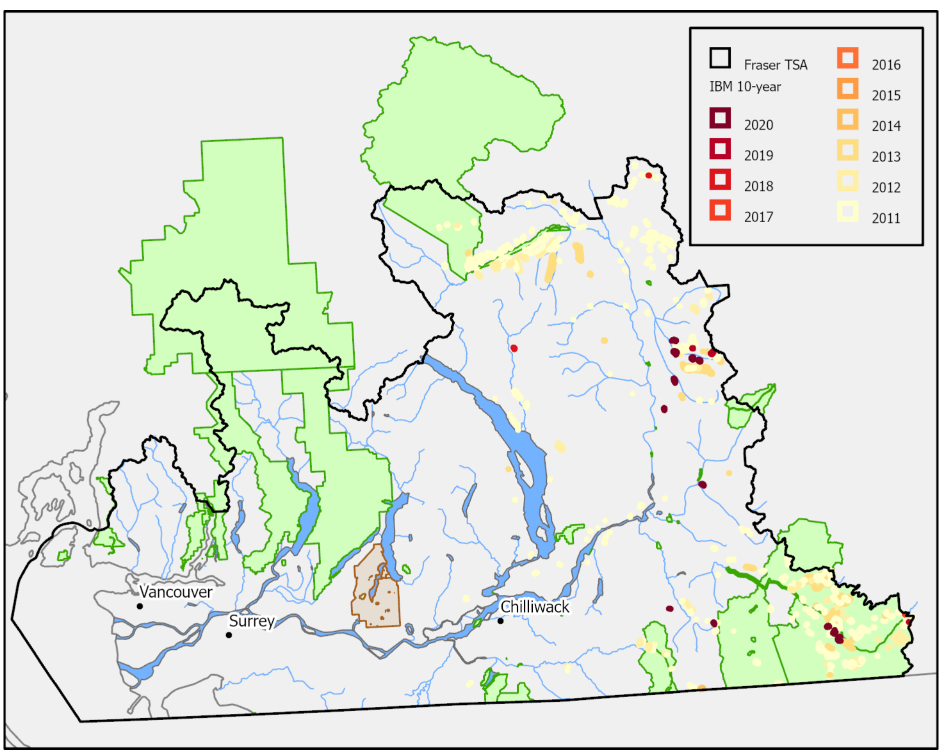

Figure 8. Annual occurrence of mountain pine beetle in the Fraser TSA over the past decade.

it has only been reported on a few dozen hectares annually, primarily in the Fraser Canyon and in the coast-interior transition zone.

Root Diseases

The TSA has both *Coniferiporia sulphurascens* (= *Phellinus weirii* Fd-type) and *Armillaria ostoyae* acting as mortality agents of immature and mature trees, primarily Douglas-fir, in drier subzones. Root disease losses have been not been accounted for in the 2016 TSR.

Septoria Canker

Septoria canker, caused by an introduced pathogen *Septoria musiva*, was positively identified for the first time in 2007 in the Fraser Valley on hybrid poplar. Foliar sampling and analysis in 2008, 2009 and 2012 confirmed the presence of Septoria canker on native black cottonwood in locations from Hatzic, east of Mission, to Othello, east of Hope. It has also been confirmed in hybrid poplar plantations found on private lands in or near the Fraser River. A follow-up survey in 2020 sampled 231 black cottonwoods in the same area as the 2012 survey. Only three samples were positive for *S. musiva*, about the same incidence as the earlier survey. Since the disease can transfer readily from hybrid to native poplar, the risk is that it will spread from native forest to plantations and back again as it expands its range. The spread rate of this disease currently is slow; however, the use of specific hybrid poplar strains should be avoided. Consult the Chief Forester's letter regarding "Guidance on the use of hybrid poplar clones for reforestation on Crown land" (April 26, 2019) for more information.

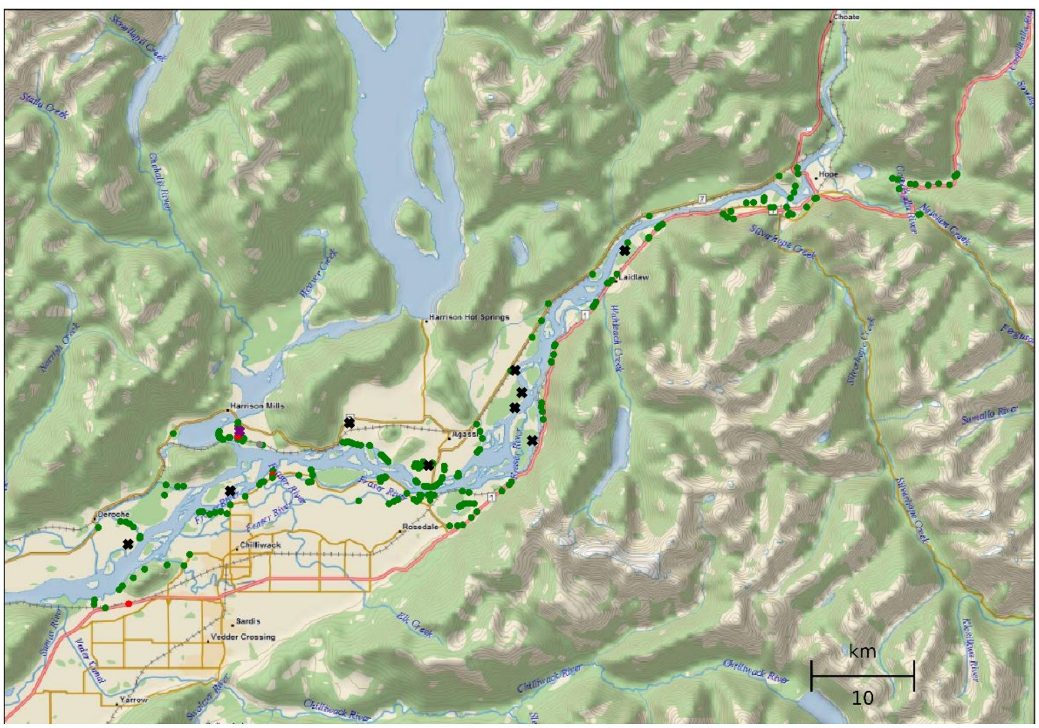

Figure 9. Distribution of sites in the Fraser Valley where Septoria canker was found (red spots) during a 2020 survey.

Spruce Beetle

Little spruce beetle activity has been noted in the Fraser TSA. In 1988, 84 ha were lightly infested in Manning Provincial Park, and in 1994-1995 about 50 ha were infested near the Coquihalla Summit. In 2002, 160 ha were reported south of Nahatlatch and Pitt rivers, and in 2003, 120 ha NE of Boston Bar and 20 ha in Manning Provincial Park. In 2004 about 55 ha of infested spruce were detected south of the Nahatlatch River. Between 2004 and 2016 areas attacked by spruce beetle increased modestly with 738 ha mapped in 2016 with the majority found in Manning Provincial Park. The area affected increased in the park between 2017 and 2019 with just under 4,000 ha detected.

Swiss Needle Cast

Swiss needle cast (*Nothophaeocryptopus gaeumannii*) and Douglas-fir needle cast (*Rhabdocline pseudotsugae*) have been found in young Douglas-fir plantations in the Fraser TSA. Douglas-fir needle cast has been found on Vedder Mountain and in the Lake Errock area and is of occasional concern. Swiss needle cast has been confirmed throughout the TSA except in the driest subzones and has had more consistent occurrence on trees since 2010. These foliar diseases thrive during damp and mild spring conditions, so their occurrence is heightened when conditions are right. Changes in weather patterns favouring damp springs has led to severe occurrences of Swiss needle cast in TFL 26 and stands around Harrison Lake. The district has installed monitoring transects in young stands to measure defoliation levels over time on both eastern and western portions of the TSA. Results show a general uptrend in foliar retention on the west side (west of Harrison Lake) from 2014 to 2020 but not consistently in all areas. The district also has 20 long-term impact monitoring plots in the CWHdm and vm subzones. Data from these plots should supply impact estimates for this disease in 2023.

Western Balsam Bark Beetle

This beetle is usually found scattered, rather than clumped, at higher elevations within the ESSFmw. Historical records do not accurately reflect populations, as often funds were not available to survey high elevation stands. From 2005 to 2009, an average of 4420 ha per year was attacked, with a low of 681 hectares in 2010 following a high of 7775 ha in 2008. Recently, beetle activity has increased

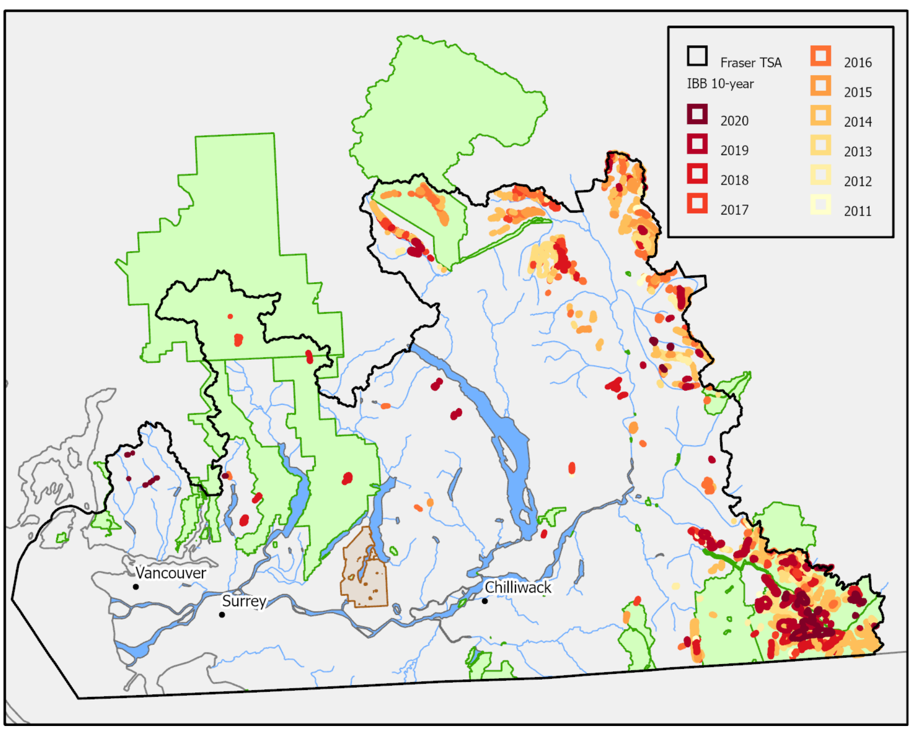

Figure 10. Annual occurrence of western balsam bark beetle in the Fraser TSA over the past decade.

with 13,506 ha mapped in 2013 and 17,826 of mostly trace and light damage mapped in 2014. A few thousand hectares have been reported annually since. It is impractical to manage this beetle on the coast.

Western Black-Headed Budworm

In 1941 light defoliation occurred from Vancouver to Surrey. In 1967, about 3000 ha of western hemlock and true fir were defoliated near Hope and the Coquihalla Valley. This population decreased by half in 1968 but increased in 1969 to over 6000 ha stretching from the North Shore Mountains to Howe Sound and Harrison Lake. Populations collapsed by 1972. In 1985 over 2300 ha near Harrison Lake were defoliated. Historically these defoliations have been light to moderate and have not had significant impacts. No detections have been recorded in recent years.

Western Hemlock Looper

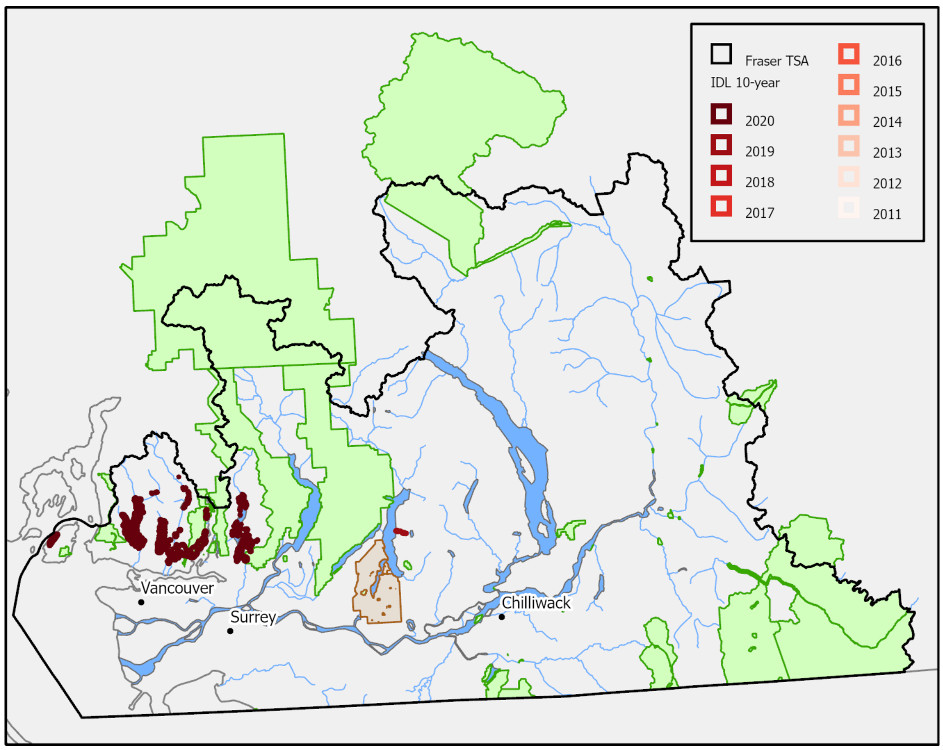

Figure 11. Annual occurrence of western hemlock looper in the Fraser TSA over the last decade.

Seven outbreaks of western hemlock looper have been recorded in the Fraser TSA. The first occurred from 1911-1913 causing severe defoliation and mortality near Stanley Park. The second outbreak occurred from 1926-1930 and covered over 4600 ha in total. This outbreak led to severe defoliation and extensive top-kill and tree mortality in the lower Fraser Valley, west of Hope, and in the Howe Sound and Port Mellon areas. From 1944 to 1947 defoliation occurred near, and in, the City of Vancouver watersheds, covering over 12,000 ha. From 1958-1959 light to severe defoliation occurred once again in Stanley Park. From 1969-1972 light defoliation was recorded near Coquitlam Lake. In 2002 defoliation was noted near Port Moody. In 2003, populations increased with about 2100 ha defoliated noted near Stave and Harrison Lakes. These populations collapsed in 2004 with only 18 ha defoliated near Stave Lake. In 2020, a new outbreak was recorded in the North Shore watersheds with 5978 ha affected. Moths were reported briefly fluttering around parts of urban Vancouver that summer.

Western Spruce Budworm

Several outbreaks of this native insect have been recorded in the Fraser TSA. The first recorded outbreak occurred from 1943-1944 along the Skaist River and defoliated about 7000 ha per year. From 1953-1958 extensive defoliation occurred along the Fraser Canyon, including Nahatlatch and Anderson Rivers. In 1971, populations began building again in the Fraser Canyon and near Hope and Tashme on the Hope-Princeton Highway. This infestation expanded annually along the Fraser Canyon and Skagit and Skaist corridors until 1977 and collapsed by 1981. In 1989-1990, small pockets of defoliation were noted near Boston Bar. From 1992-1994 populations expanded in the Nahatlatch River area but collapsed by 1995. In 2001 populations began increasing near Boston Bar and along the Nahatlatch River, with 6600 ha of defoliation recorded in 2003. Populations were down slightly in 2004 and declined further in 2005. In 2006, however, budworm populations increased to a high of 24,337 ha in 2007. Levels have declined steadily since then.

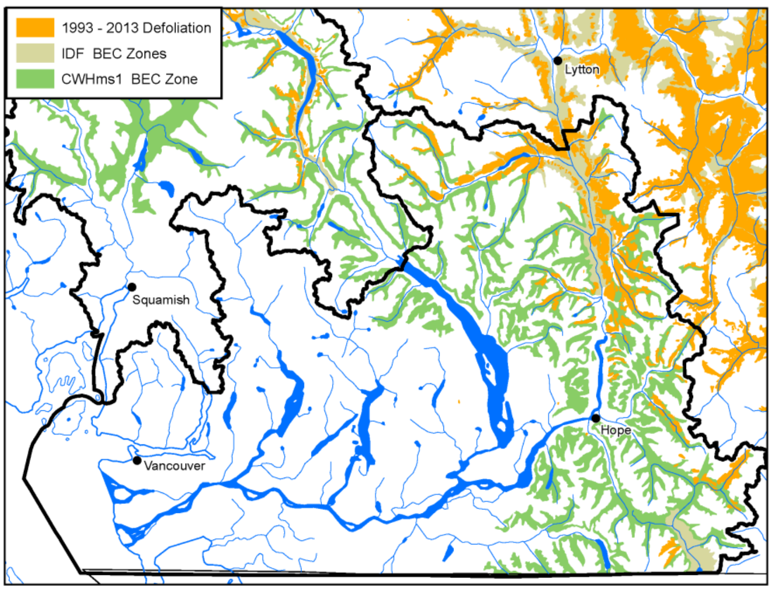

Figure 12. Areas defoliated by western spruce budworm from 1993-2013 in the Fraser TSA.

Control treatments have been conducted in 2008 and 2009 specifically targeting young Douglas-fir stands in the Fraser Canyon and Coquihalla areas. The aim of the treatments is to minimize top-kill to 20 to 60 years old trees since defects to the leader can decrease the value of the timber at harvest. In 2008 and 2009, 833 ha and 1664 ha respectively were treated with *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*). Ground sampling conducted in the fall of 2009 and spring of 2010 indicated that infestation levels were light and further control treatments were not required.

Areas which have sustained chronic infestations are found along the Nahatlatch River and south to Boston Bar, with 45% of the defoliation occurring in the CWHms1, followed by the IDFww at 28%.

Table 10. Summary of western spruce budworm defoliation in the Fraser TSA since 1943, by biogeoclimatic zone and total years of defoliation in hecatres

	Total Years of Defoliation					
	1-2	3-6	7-10	>10	Total	% of Total
IDFdk2	0	57	20	0	77	0
IDFww	10,730	21,114	5,935	579	38,358	28
CWHds1	10,075	6,317	1,134	5	17,531	13
CWHms1	34,161	24,529	6,873	118	65,681	48
ESSFmw	9,384	1,709	50	0	11,143	8
MHmm2	6,105	1,702	0	0	7,807	6
Total	70,455	55,428	14,012	702	140,597	100

Windthrow

According to TSR estimates, windthrow is estimated to account for a loss of 2340 m^3/year.

Great Bear Rainforest (GBR) North TSA

The Great Bear Rainforest North TSA is created from the former North Coast and Mid Coast TSAs effective January 1, 2017. The TSA was created under the *Great Bear Rainforest (Forest Management) Act*. The allowable annual cut for the TSA is 803,000 m^3. This includes a partition of 468,600 cubic metres limited to Crown land within the North Island Central Coast district and not within the Owikeno Lake basin. Another partition for 113,200 m^3 is attributed to western redcedar and yellow-cedar within the Coast Mountain district.

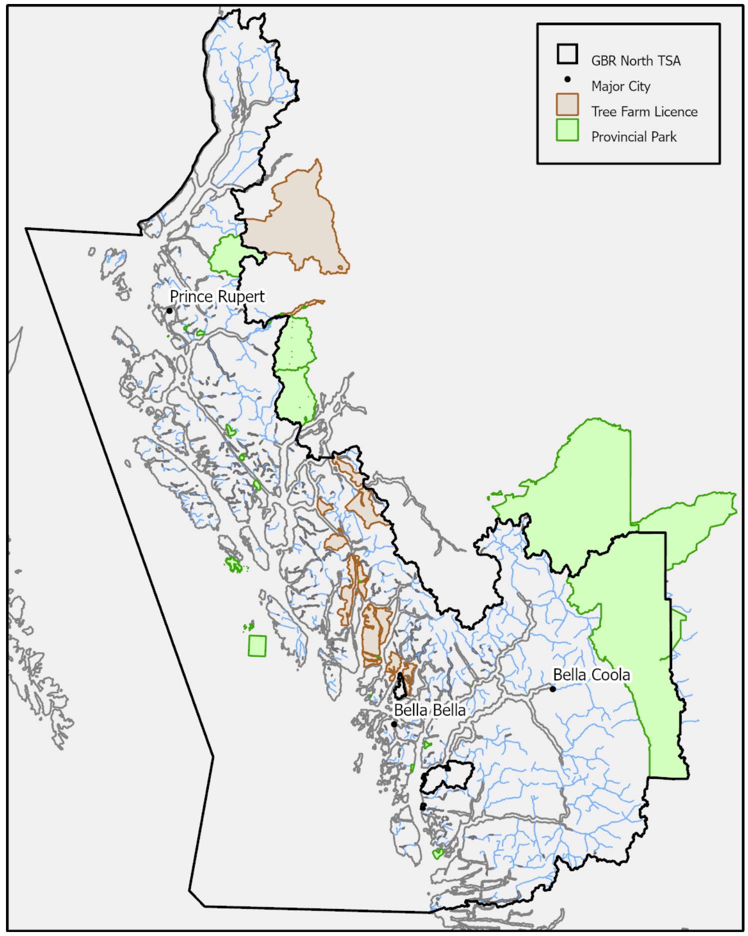

Figure 133. The Great Bear Rainforest North Timber Supply Area.

Aspen Serpentine Leaf Miner

This defoliator has been occurring more prominently in the TSA rising from 612 ha of mapped damage in 2012 to 8174 ha in 2014 with some defoliation being quite severe. In 2018 the insect appeared again on 7104 ha in the very northeast part of the TSA and 4683 ha in 2020. Due to aspen being the most common species attacked, much of the damage is confined to Tweedsmuir Park and the far eastern part of the TSA. Like most damage by defoliators, repeated attacks on the same tree will cause growth loss and, if persistent, mortality.

Douglas-fir beetle

In the late 1980's and early 1990's there was significant beetle activity in the Talchako and Atnarko drainages mostly within Tweedsmuir Provincial Park. This area has a high climatic hazard for DFB; however, much of the susceptible timber was harvested. Spot infestations were noted in 1993 near Bella Coola, and once again in 1994 with about 140 ha recorded. This outbreak decreased in 1995 with only 25 ha recorded in the Dean, Talchako, and Atnarko river valleys near Bella Coola. In 2003, 14 spots infestations were detected just southeast of Bella Coola and east of Kimsquit. In 2018, 1634 ha of mostly light attack was recorded west of Tanya Mountain.

Hemlock Dwarf Mistletoe

The incidence of dwarf mistletoe on all ages of hemlock is expected to rise as the proportion of clearcut area is reduced. Partial cutting systems now account for about half of all coastal harvesting, and Ecosystem Based Management will require leaving residual trees within cutblocks. Small clearcuts, helicopter logging, and dispersed retention are common practices in the GBR North TSA. Unavoidably, a percentage of retained trees will be infected, and the parasite will have ideal conditions to spread to the surrounding understory. Losses associated with dwarf mistletoe include growth loss, premature stem breakage and mortality, reduced lumber quality and value, and affects on regeneration.

Mountain Pine Beetle

The following describes mountain pine beetle activity outside of Tweedsmuir Provincial Park. The first record of mountain pine beetle activity covered about 700 ha, from 1975-1983 just west of Tweedsmuir Provincial Park, in the Dean River drainage. Small patch infestations were recorded from 1984 to 1986. In 1999, 391 ha were infested near the mouth of the Dean River and south of Hagensborg. In 2000, the infestation near Hagensborg collapsed but expanded to 1796 ha along the Kimsquit River, Dean River, and Dean Channel. Populations doubled in 2001 with 3774 ha infested mostly in previously infested areas, and near Hagensborg. In 2002, significant expansions occurred with about 13, 800 ha infested along the Dean and Kimsquit rivers and along the highway corridor between Bella Coola and Hagensborg. By 2003, populations decreased east of Dean Channel, with just over 8000 ha recorded. Area infested in 2004 amounted to about 3400 ha along the Bella Coola River west of Tweedsmuir to Bella Coola, south along South Bentinck Arm and North along Dean Channel. Since 2008, the mountain pine beetle has returned to endemic levels not considered problematic. Most recent occurrences have been in Tweedsmuir Provincial Park.

Table 3. Annual comparison of hectares attacked by mountain pine beetle and balsam bark beetle in the GBR North TSA

	Area Attacked (ha)			
	2017	2018	2019	2020
Mountain Pine Beetle	1317	1961	8581	11,606
Spruce Bark Beetle	344	1402	465	508
Western Balsam Bark Beetle	47,419	84,082	71,717	53,852

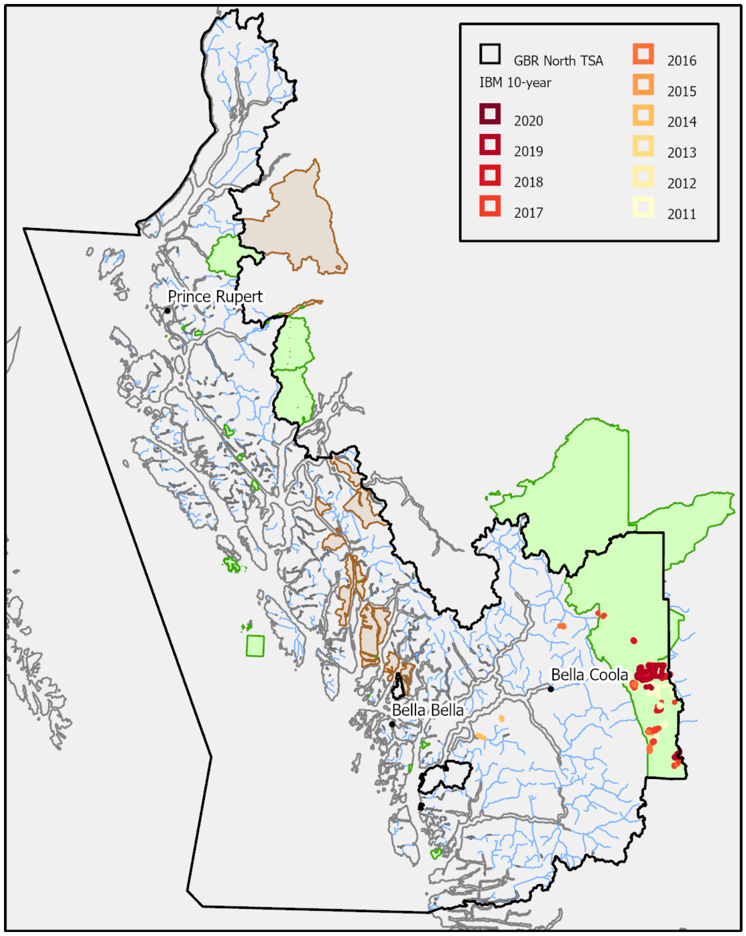

Figure 144. Annual occurrence of mountain pine beetle in the GBR North TSA over the past decade.

Spruce Beetle

Small patches of spruce beetle were recorded from 1989-1992 near Bella Coola. Populations increased to 1683 ha in 2004 with patches recorded along the shores of Owikeno Lake and scattered south to Seymour inlet, with a patch to the north near Bentinck Arm. A small peak of 1402 ha occurred in 2018 but has dropped since.

Western Balsam Bark Beetle

Western balsam bark beetle infestations are ubiquitous in stands having suitable hosts. From 1994 to 2001 the area infested fluctuated between 900-1500 ha and decreased to 580 ha in 2002. In 2003, populations increased 2384 ha (or aerial survey coverage increased) mostly south of Dean River to the TSA boundary. From 2012 incidence levels increased from around 4000 to over 12,000 ha of mostly trace levels of endemic damage. However, occurrence has exploded with tens of thousands of hectares mapped over the last five years. Most of this loss is unsalvaged.

Western Black-Headed Budworm

Defoliation by blackheaded budworm was recorded from 1973-1974 when about 8400 ha were recorded near Ocean Falls, Fiordland and Kitlope River.

Western Spruce Budworm

About 500 ha of moderate and 1000 ha of light defoliation noted in 2006 in the Knot Lakes area south of Tweedsmuir Provincial Park is suspected to be due to western spruce budworm. This defoliation was first noted in 2004.

Windthrow

The last TSR included 13,000 m^3/year of unsalvaged losses due to windthrow.

Yellow-Cedar Decline

Yellow-cedar decline extends over 200,000 hectares in Alaska and the mortality has been mapped on over 100,000 ha of coastal BC since 2006. This decline is caused by changing climatic conditions, like early snowpack melt that leaves dehardening fine roots exposed to sudden late winter frost events. Yellow-cedar is susceptible to fine root mortality earlier than most other species and trees growing on shallow soils are particularly susceptible. During a 2004 survey, yellow cedar decline was found as far south as Cypress Lake on Banks Island in the former North Coast Forest District. A follow-up aerial survey of the mainland part of the TSA in 2006 found yellow-cedar decline in the areas south of Burke Channel, including the Ambach Creek and Kilbella River areas. Further investigation has found a band of mortality running through the TSA occurring along the elevation boundary of the CWH vm1 and vm2 in the coastal maritime zone. Salvage opportunities of the dead and dying material is limited but could be undertaken where economically viable since yellow-cedar decays slowly and can stay upright and sound for decades.

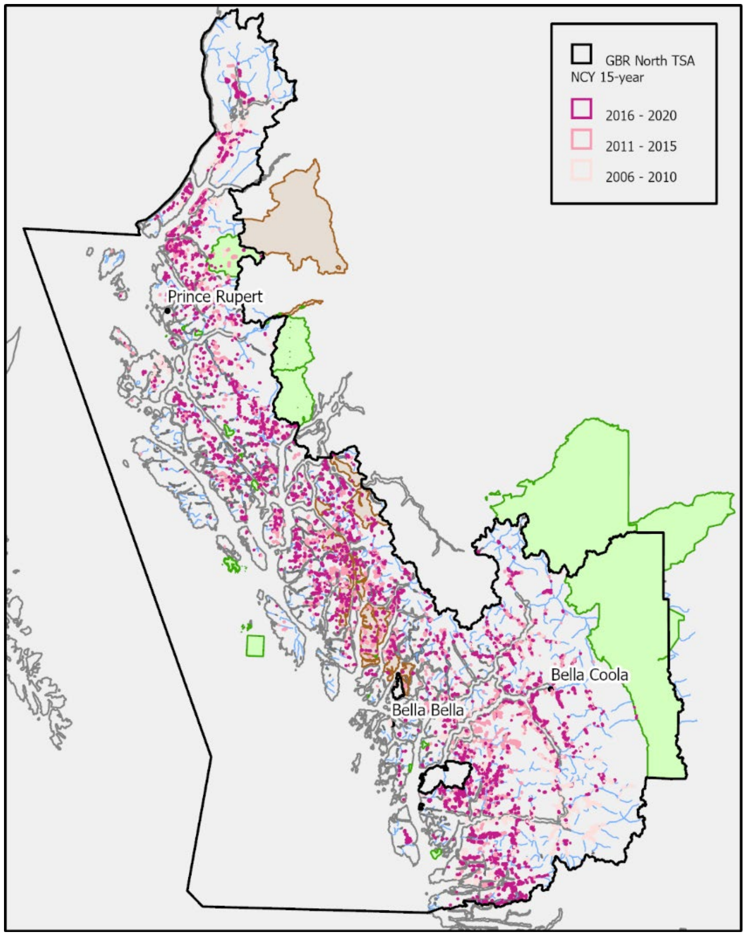

Figure 15. Occurrence of yellow-cedar decline in the GBR North TSA since 2006.

Great Bear Rainforest (GBR) South TSA

The GBR South TSA was created from the mainland portions of the former Kingcome and Strathcona TSAs effective January 1, 2017. The TSA was created under the *Great Bear Rainforest (Forest Management) Act*. The allowable annual cut for the TSA is 830,500 m^3.

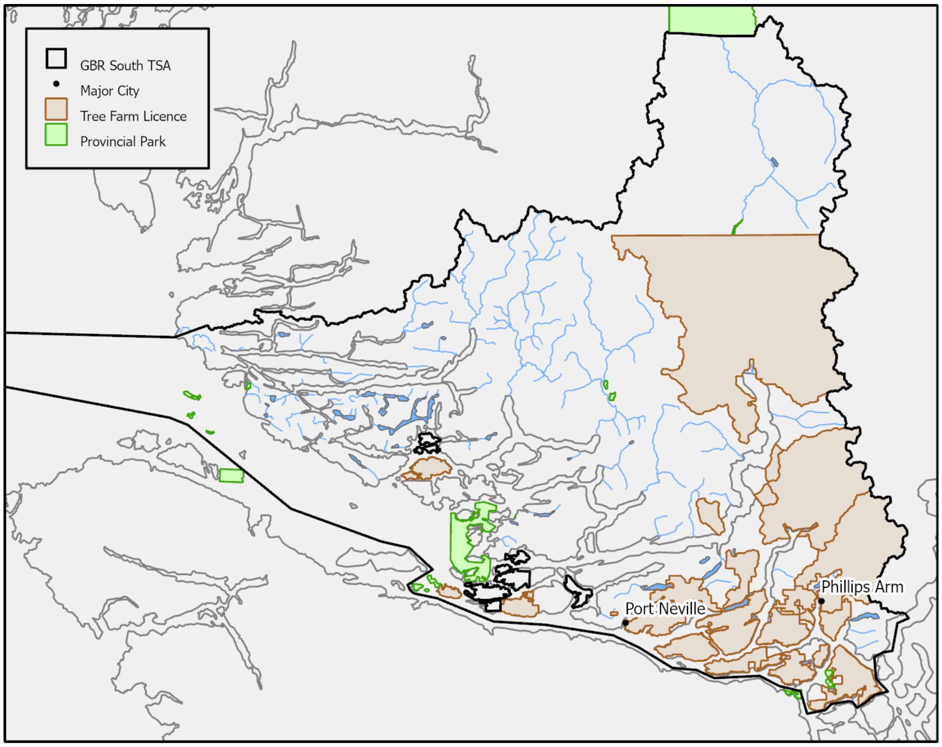

Figure 156. Great Bear Rainforest South Timber Supply Area.

Alder Sawfly

Defoliation of alder was noted in 2006 on the Klinaklini Estuary (about 40 ha) and mouth of Ahnuhati River (about 25 ha). No control action was needed.

Hemlock Dwarf Mistletoe

The incidence of dwarf mistletoe on all ages of hemlock is expected to rise as we move away from clear-cutting. Partial cutting systems now account for about half of all coastal harvesting, and Ecosystem Based Management involves leaving trees and groups of trees within cutblocks. Unavoidably, a percentage of residual trees will be infected, and the parasite will have ideal conditions to spread to the surrounding regeneration. Losses associated with dwarf mistletoe include growth loss, premature stem breakage and mortality, reduced lumber quality and value, and impacts on regeneration.

Mountain Pine Beetle

Mountain pine beetle infestations have been confined to the northeast corner of the TSA in the Klinaklini River Valley, just south of Tweedsmuir Provincial Park. The first outbreak was noticed in

1974 and continued until 1981. The latest outbreak was noted staring in 2000 and has continued throughout the last decade until ending in 2009. Infestations have increased significantly with 8,581 ha and 11,606 ha mapped in 2019 and 2020, respectively.

Spruce Weevil

The impact of spruce weevil is becoming more of a legacy problem due to the avoidance of spruce in the 1990's and the increased use of weevil resistant stock in recent plantations. Nonetheless, significant growth loss associated with the insects wide ranging destruction has been experienced in areas where spruce was a part of the plantations established in the 1970's and 1980's.

Western Balsam Bark Beetle

Western balsam bark beetle activity has been noted in the northeast corner of the TSA, just south of Tweedsmuir Provincial Park, in the upper Klinaklini River drainages including Colwell, Dorothy, and Frontier Creeks. These areas are not considered part of the timber supply due to their remote location. Recent attack has been increasingly modestly since 2013.

Yellow-Cedar Decline

Yellow-cedar decline extends over 200,000 hectares in Alaska and the mortality has been mapped on over 100,000 ha of coastal BC. This decline is caused by changing climatic conditions, like early snowpack melt that leaves dehardening fine roots exposed to sudden late winter frost events. Yellow-cedar is susceptible to fine root mortality earlier than most other species and trees growing on shallow soils are particularly susceptible. Over recent years, the AOS of the mainland part of the TSA has identified yellow-cedar decline in the several areas between Seymour and Kingcome Inlets, including the Parson Creek, Rainbow Creek and Clear River areas. In 2014, an added 2227 ha of decline was mapped in the TSA. Since then the decline has been mapped every year with over 6000 ha reported in 2017 and 2019. As the affected areas are not often suitable candidates for harvest or salvage, non recoverable losses should include an allowance for this in the next TSR.

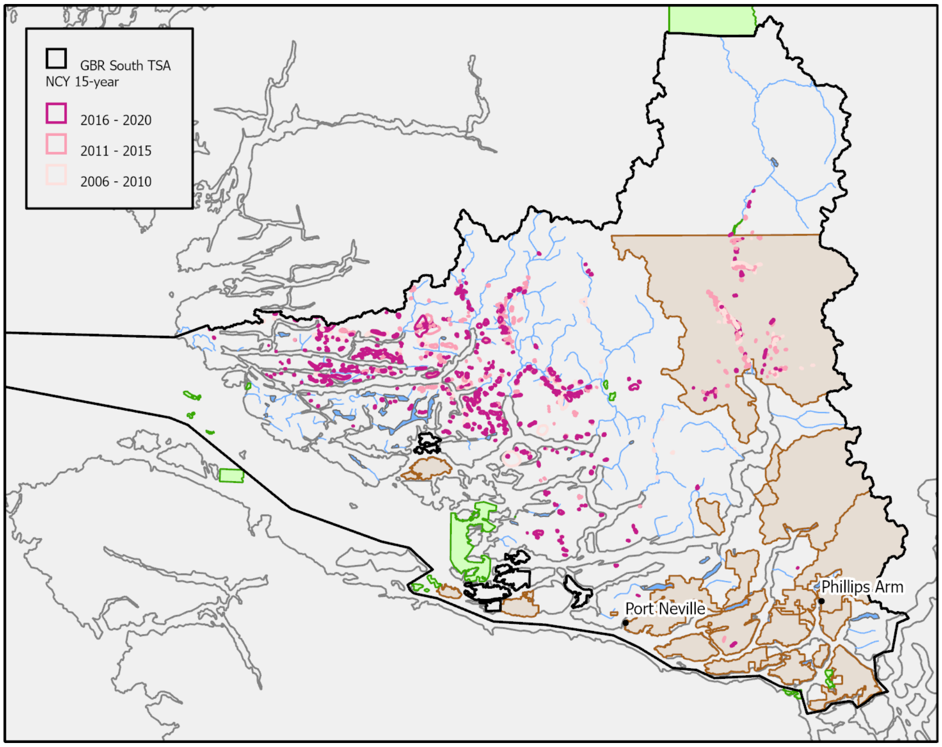

Figure 167. Occurrence of yellow-cedar decline in the Great Bear Rainforest South TSA since 2006.

Haida Gwaii Management Area

Xaadaa Gwaay, Xaaydag̱a Gway □ yaay, or Haida Gwaii ("Islands of the people") is an archipelago of more than 150 islands off the north coast of BC. The mainland north coast of BC lies 80 kilometres to the east across Hecate Strait, and the state of Alaska lies to the north across Dixon Entrance. Haida Gwaii's total landmass of just over a million hectares is situated mostly on two main islands: the larger, Graham Island, being to the north and Moresby Island to the south. The geography of the Islands is like the mainland coast of BC and the southern regions of Alaska, including mountainous terrain, deep fjords, temperate rainforests, sub-alpine forests and alpine tundra. Haida Gwaii's coastal temperate rainforests occur at lower elevations with western hemlock, western redcedar and Sitka spruce being the most dominant tree species along with lodgepole pine, mountain hemlock, yellow-cedar, western yew, and red alder. At yet higher altitudes, closed forests give way to open parkland forests and alpine meadows. About 80% of Haida Gwaii is forested.

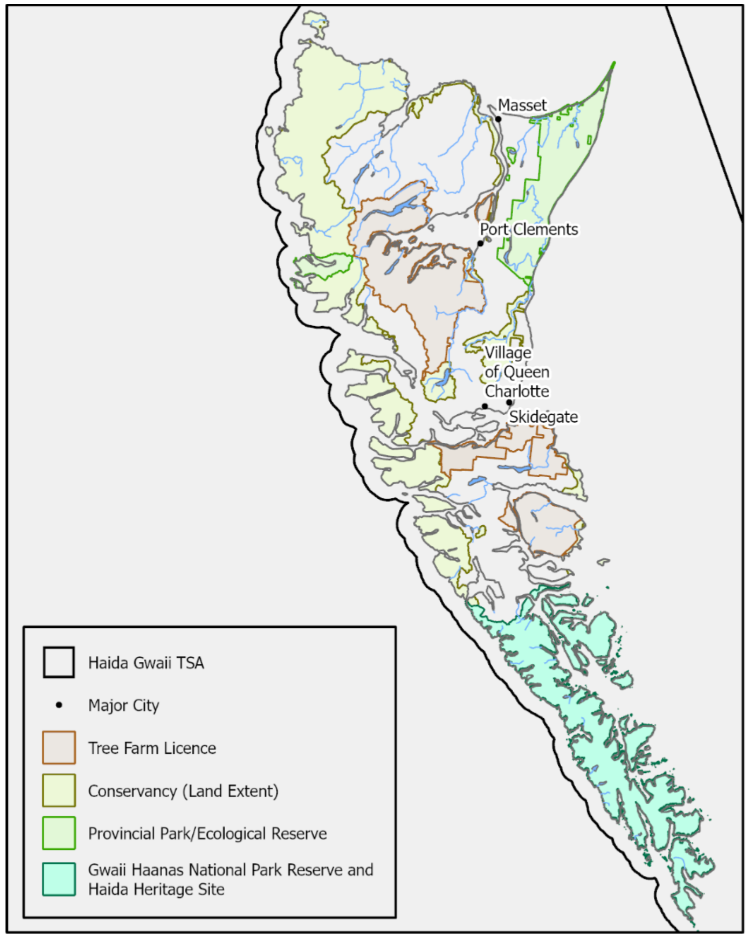

Figure 178. Haida Gwaii Timber Supply Area.

Effective October 27, 2020, the Haida Gwaii Management Area's new allowable annual cut (AAC) determination is 776,000 m^3.

Armillaria Root Disease

This root disease, caused by the pathogen *Armillaria ostoyae*, was thought to be discovered around Tlell, well outside of its previously identified range, by district staff in 1996. Genomic testing done in 2018 confirmed that the original identification was incorrect, and the disease was a related species, *A. sinapina*, a saprophyte. Saprophytic species of *Armillaria*, often quite difficult to visually differentiate from the pathogenic variety, are commonly found on dead trees. All the juvenile dead trees sampled on Haida Gwaii during 2017 and 2018 with evidence of *Armillaria* were killed by *A. sinapina* so it does pose a risk to regenerating stands on the east side of Graham and Moresby Islands.

Cooley spruce gall adelgid

This insect has been introduced to Haida Gwaii on live Douglas-fir brought to the Islands. From the imported Douglas-fir it has spread to its alternative host, Sitka spruce, however, its occurrence on spruce is still very low. Most Douglas-fir on Crown land have been removed but there are still live trees on private property.

Conifer Sawflies

Although larval counts of sawflies are often high, defoliation is not always noticeable. In 1984, however, over 200 ha of shore pine were defoliated by pine sawfly near Nadu creek. Hemlock sawfly populations typically increase with western blackheaded budworm populations however their impact during outbreaks is minor compared to blackheaded budworm.

Green-striped Forest Looper

This looper has reached outbreak populations in the past in this TSA. On Graham Island in 1963 over 14,000 ha of western hemlock and western red cedar were defoliated. This infestation moved to the west side of Masset Sound, causing further defoliation to 2430 ha. No other outbreaks have been recorded.

Mammals

Deer browse is one of the most significant and costly forest damage agents on Haida Gwaii, primarily on western redcedar and yellow-cedar in the establishment phase. Recently, the lack of prompt removal of browse protectors on cedar saplings has also resulted in increased stem defects as the protectors are not degrading quickly enough to guarantee unimpeded release of the tree. Efforts should be made to remove these protectors once trees are above browsing height (1.2 m).

Spruce Beetle

Spruce beetle has only been reported occasionally in this TSA. No extensive damage has been recorded.

Spruce Aphid

In 1961 a severe and extensive outbreak of aphid was recorded in this TSA. Infestations decreased in intensity in 1962 but caused defoliation once again in 1963. Increases in populations have occurred periodically since throughout Haida Gwaii but tends to only be significant within a fringe along the coastline. The last outbreak was mapped at 578 ha mostly around the Village of Masset and the east side of Masset Inlet. Losses to the aphid are assumed to result in a mortality rate of 10% based on Forestry Canada data.

Western blackheaded budworm

The first recorded defoliation by this pest occurred in 1931 from Lyell Island to Masset Inlet. However, blackheaded budworm outbreaks have most probably been a part of island ecology here for a long time. Outbreaks have since occurred in 1943-1944, 1952-1955, 1957-1960, 1972-1975, 1985-1988, and 1996-2001. Defoliation tends to reoccur in the same stands each outbreak episode.

Typically, the outbreaks start on the south east coast of Moresby Island and move northward in each successive year. Most stand recover from the defoliation however there is usually patchy mortality and top-kill. About 12,000 ha were aerially sprayed with DDT in 1960. An experimental application of an early formulation of Btk was also successfully conducted in 1960. The most recent outbreak started in 1996 with about 6300 ha defoliated in the southern part of the islands. In 2000, the outbreak covered over 31,100 ha and covered the mid-central to southern part of the islands. The population collapsed in 2001, with only 1500 ha mapped. It is interesting to note that juvenile stands, especially those that had been thinned, were heavily defoliated which resulted in patch mortality. The most recent outbreak cycle ran from 2008 to 2012 peaking at 37,378 ha in 2011.

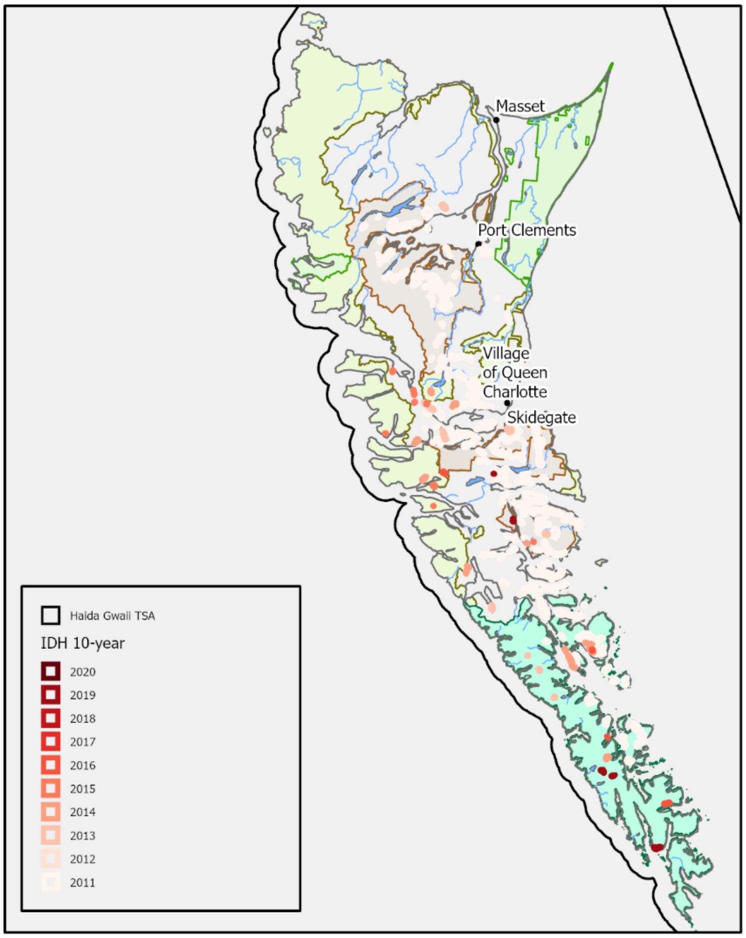

Figure 18. Occurrence of western blackheaded budworm in the Haida Gwaii TSA over the past decade.

Windthrow

Wind is a major disturbance agent in the TSA with an average of 1952 ha mapped each year from 2012-2014. However, a sizable portion of windthrow occurring on the operable land base is salvaged. A Ministry study of unsalvaged losses in the TSA estimate annual losses at 3800 m^3.

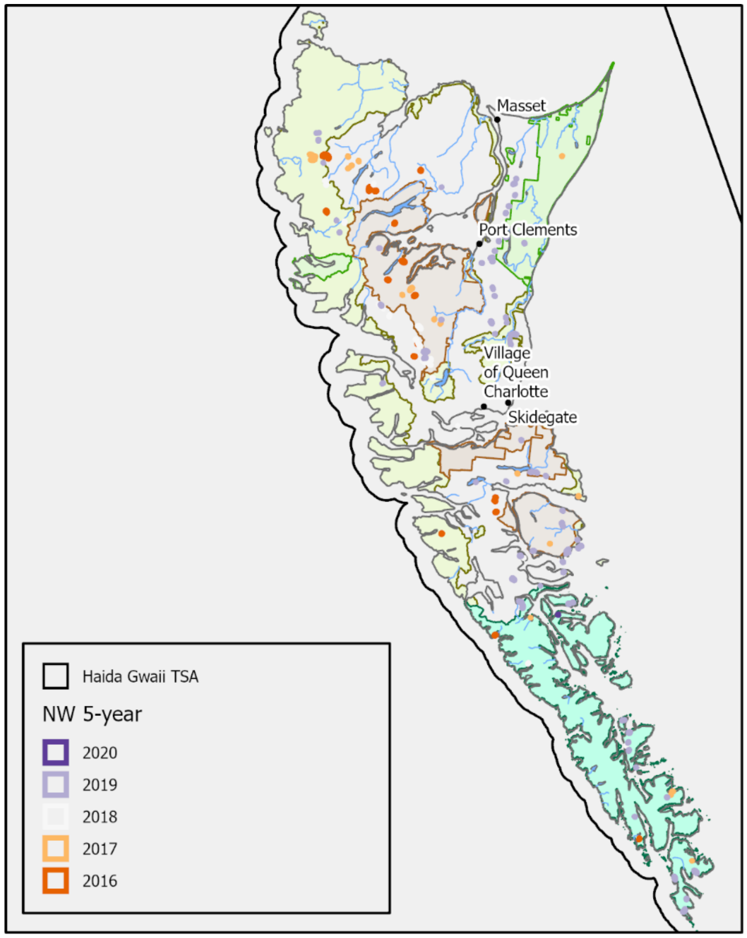

Figure 190. Occurrence of windthrow events in the Haida Gwaii TSA over the previous five years.

Yellow-Cedar Decline

Yellow-cedar decline extends over 200,000 hectares in Alaska and the mortality has been mapped on over 100,000 ha of coastal BC. This decline is caused by changing climatic conditions, like early snowpack melt that leaves dehardening fine roots exposed to sudden late winter frost events. Yellow-cedar is susceptible to fine root mortality earlier than other species and trees growing on shallow or wet soils are particularly susceptible. During a 2004 survey, yellow cedar decline was found as far south as Cypress Lake on Banks Island in the North Coast Forest District. Until 2006, the decline was not mapped on Haida Gwaii, but the 2014 survey found over 14,000 ha of trace to severe decline, mostly on the west side of Graham Island. Since then areas experiencing decline have varied widely in location and area but nearly every year yields newly mapped declining trees. Salvage opportunities of the dead and dying material is limited but could be undertaken where economically viable since yellow-cedar decays slowly and can stay upright and sound for decades. Extensive field studies of the decline have been conducted on Haida Gwaii over the last decade and results are presented in the Pest Profiles section under Abiotics.

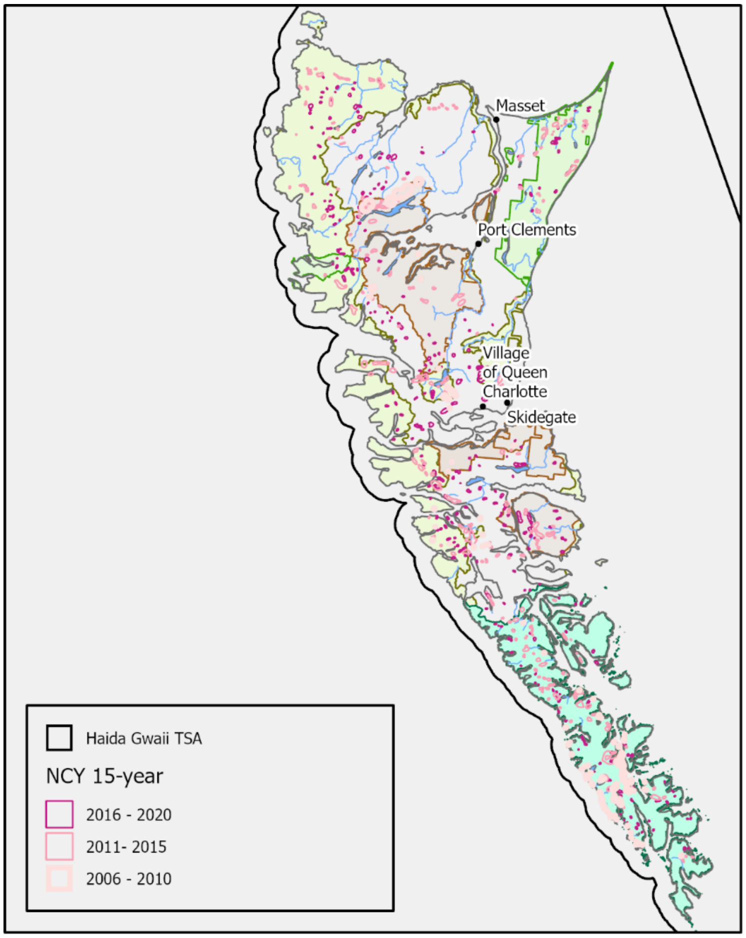

Figure 201. Occurrence of yellow-cedar decline on Haida Gwaii since first mapped in 2006.

North Island TSA

The North Island TSA, located on the northern half of Vancouver Island, was created in January 2017 when the *Great Bear Rainforest (Forest Management) Act* and regulations came into effect. Under the regulations, this new TSA was created from the Vancouver Island portions of the former Kingcome and Strathcona TSAs. Segments of the Pacific TSA are interspersed throughout the TSA, as well as TFLs 6, 19, 37, 39 and 47. The total TSA land base area is approximately 1 749 460 hectares and it is administered by the Campbell River Natural Resource District (DCR) office in Campbell River, and the North Island Central Coast Natural Resource District (DNI) office in Port McNeill.

The western and northern Vancouver Island areas are characterized with rugged marine coastlines, steep mountainous terrain, and deep river valleys and inlets that extend into the Pacific Ocean. The eastern TSA and some interior northern areas have terrain ranging from rugged mountains to poorly drained lowlands. The TSA overlaps three biogeoclimatic zones: the Coastal Western Hemlock (CWH) located between sea level and 1000 metres of elevation, and the higher elevation zones of Mountain Hemlock (MH) and Coastal Mountain heather Alpine (CMA). Dominant tree species are western hemlock (Hw) and amabilis fir (more often called balsam (Ba) – HwBa together referred to as "hembal"), western redcedar (Cw) and yellow cedar (Yc), mountain hemlock (Hm), Douglas fir (Fd) and small amounts of alder (Dr) and spruce (Ss).

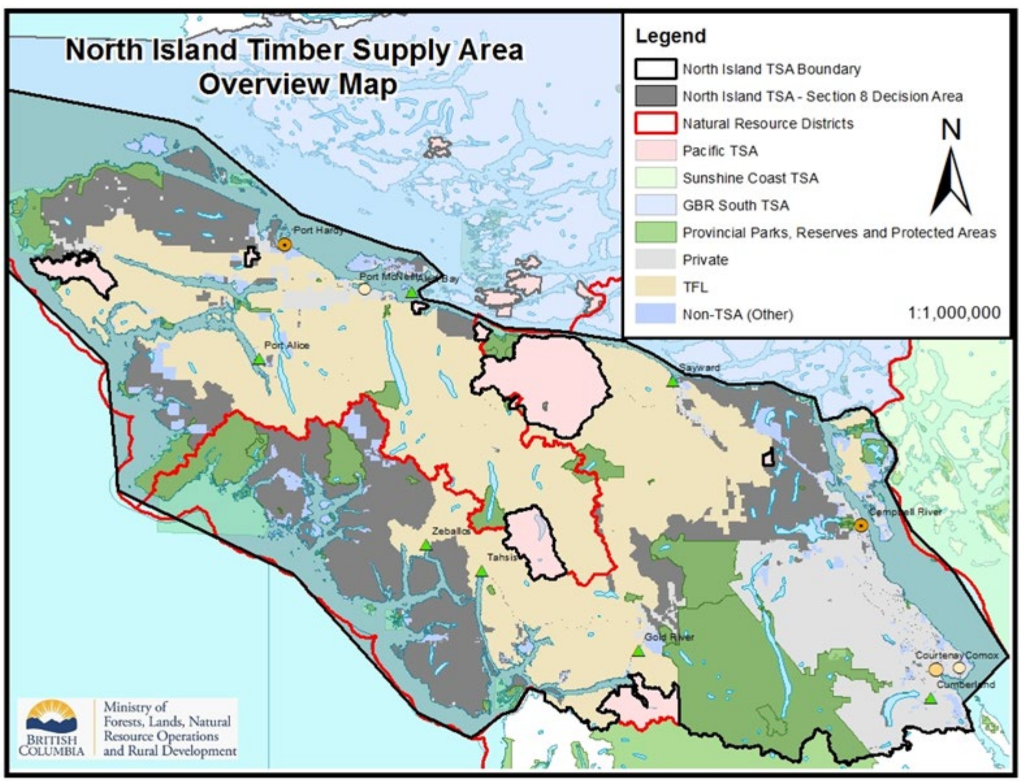

Figure 212. North Island Timber Supply Area.

Land use planning for the TSA area is guided by the Vancouver Island Land Use Plan (VILUP) approved in 2000. Twenty-five First Nations have Aboriginal Interests within the North Island TSA.

The initial AAC for the TSA was legislated and set effective on January 1, 2017 in the *Great Bear Rainforest (Forest Management) Regulation*. The allowable annual cut is 1,248,100 m^3. The *Act* specifies that subsequent (non GBR) AAC determinations must be made by the chief forester. The new AAC for this TSA is expected to be determined in 2021.

Balsam Woolly Adelgid

This introduced pest has been reported occasionally in the North Island TSA. It can cause considerable damage, including mortality, to *Abies* species; yet within this TSA its impacts have not been found to be significant. However, over the last two years, hectares mapped have increased dramatically with 1351 ha reported in 2019 and 5072 ha in 2020. The TSA was included within the regulated quarantine area which restricted the movement of true firs (see *Balsam Woolly Adelgid Regulation*), however, this regulation was repealed in 2019.

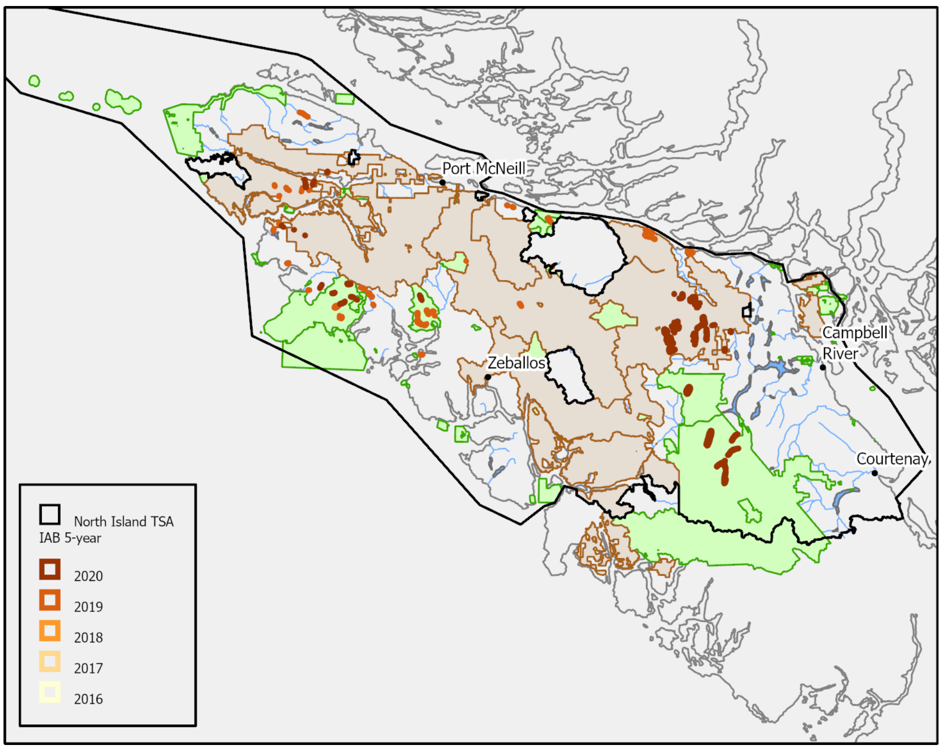

Figure 23. Occurrence of balsam woolly adelgid in the North Island TSA during the previous five years.

Conifer Sawflies

Populations of conifer sawfly (*Neodiprion* spp.) periodically reach outbreak levels within this TSA in the Adam, White and Memekay river areas and in mainland river drainages such as the Stafford and Phillips. The conifer sawfly's principle host is amabilis fir and it primarily feeds on older foliage. In severely defoliated stands, up to 20% of amabilis fir can be killed. In 1952, spot activity was noted between Salmon River and Great Central Lake. The first major outbreak recorded in the TSA occurred in 1978 – 1980 with over 4,470 ha in the Sayward area. Significant salvage harvesting followed as *Pseudohylesinus* bark beetles attacked the stressed trees. The most recent outbreak occurred in 1995 – 1998 in the same general areas. At the peak of the outbreak in 1996, about 29,445 ha were defoliated, with 38% in the CWHvm2, 34% in the MHmm1, 20% in the CWHvm1, 7% in the CWHmm2 and 1% in the CWHmm1. About 330 ha were salvage harvested.

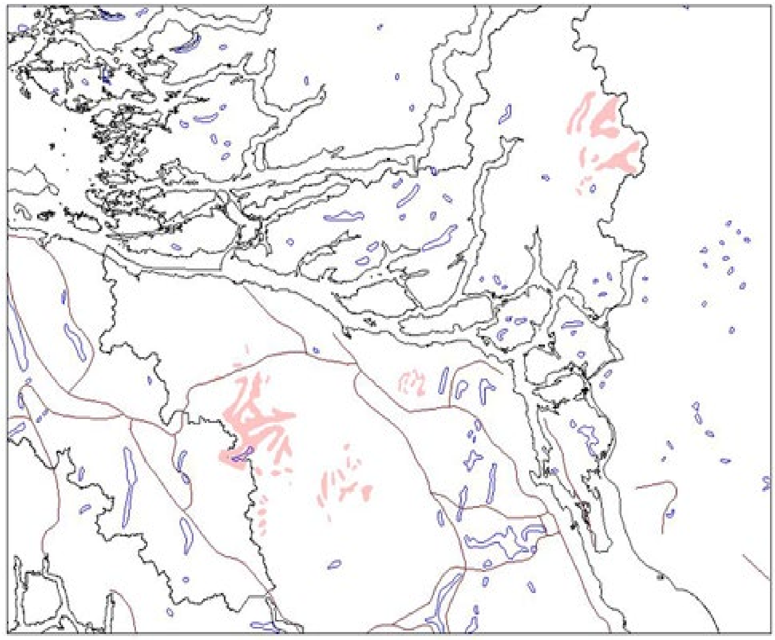

Figure 224. Area defoliated by conifer sawflies in 1996 near Schoen Lake Park and in the Phillips River drainage on the mainland.

Douglas-fir Beetle

Very few records of Douglas-fir beetle activity exist for the North Island TSA. The first recorded activity was in 1938 near Comox Lake, followed in 1953 near Cumberland, and 1954-1955 and 1974 near Buttle Lake. Beetle activity is at an endemic level, and usually associated with trees affected with root disease. However, the beetle is commonly found in trees that die due to other causes. Recently, the beetle saw a brief uptick in 2018 with 1027 ha attacked and in 2019 with 3191 ha attacked mainly west of Campbell and Buttle Lakes and north of Atluck River. This recent mortality was likely triggered by the extensive summer droughts of 2017 and 2018.

Mountain Pine Beetle

From 1940-1960 mountain pine beetle was recorded on western white pine near Buttle Lake and Forbidden Plateau. This infestation on Vancouver Island is estimated to have covered over 135,300 ha and killed close to 4 million trees. In 2006, a small patch of beetle-killed lodgepole pine was found south of Sayward but no further mortality was reported.

Root Disease

Laminated root rot occurs throughout the drier regions of the North Island TSA, primarily in young Douglas-fir stands in the Sayward forest, Quadra Island and in the Gold River area. The last TSR accounted for 11,400 m^3 of annual unsalvaged losses primarily due to laminated root rot.

Spruce Aphid

The accidentally introduced spruce aphid has caused severe damage to Sitka spruce in the Campbell River area and on adjacent islands. Although commonly found on spruce along the shoreline, it is not considered a forestry pest.

Western Blackheaded Budworm

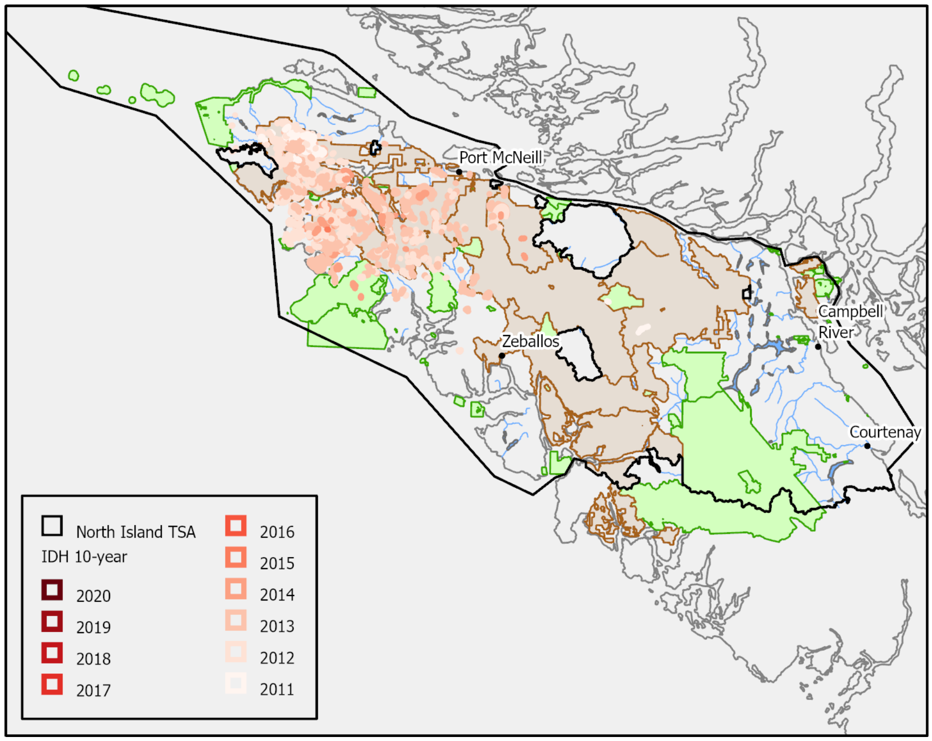

Figure 235. Area defoliated by western blackheaded budworm during the past decade on the northern Vancouver Island.

In 1944, budworm defoliation was reported near Quatsino Sound and in 1954 near Holberg. Populations expanded significantly in 1955 to 400,000 ha and doubled in 1956 to 800,000 ha. Defoliation occurred between Port McNeill and the Adam River, between Port Hardy and Holberg, north of Zeballos, and Quatsino Sound. Populations collapsed in 1957. In 1971, defoliation was noted near Victoria Lake increasing dramatically to about 35,000 ha in 1972 and included areas west of Victoria Lake to Brooks Peninsula and north to Quatsino Sound. The population collapsed in 1973, and no further defoliation noted until 1988 when about 5000 ha were infested near Port Hardy. This outbreak persisted until 1990. From 1997 to 1999, about 38,000 ha were lightly to moderately defoliated in a broad area of northern Vancouver Island extending from Brooks Peninsula to north of Holberg Inlet, and as far east as Victoria Lake. This outbreak affected old growth hemlock-balsam stands, but damage in younger regenerating hemlock was also noted. More recently, over 28,000 ha of light to severe budworm damage was reported annually in 2012 and 2013 mostly on TFL 6 and stretching as far east as Bonanza Lake. This most recent outbreak collapsed in 2014.

Western Hemlock Looper

Between 1926 and 1927 about 1500 ha were defoliated at the mouth of Neroutsos Inlet. This is the only record of western hemlock looper activity in the former Kingcome TSA.

White Pine Blister Rust

White pine blister rust damage is not always visible during the aerial overview surveys, particularly if the infections have not killed the tree. However, surveyors often see scattered damage throughout the range that the host trees grow. These are often recorded as spots or small scattered polygons. In 2010, large polygons totalling 2,328 ha were mapped at trace intensity in the TSA. Although the damage occurred primarily as scattered single trees, damage was at a high enough level that recording spot infections was possible. These disturbances were in the middle of Vancouver Island along the Nimpkish River north of Vernon Lake.

Windthrow

The last TSR estimated annual losses to windthrow at 60 000 m^3/year, with the unsalvaged part at 30,000 m^3/year. These losses are due to episodic windthrow events and are based on district windthrow records and observations.

Soo TSA

The Soo TSA closely corresponds to the drainages of the lower Squamish and Cheakamus Rivers, which flow into Howe Sound; and the Lillooet River, which flows into Harrison Lake. It is bounded on the west by TFL 38 and the Sunshine Coast TSA; on the north by the Lillooet TSA; and on the south and east by the Fraser TSA.

The total area of the Soo TSA is 909 519 hectares, of which 266 646 hectares are productive forest. The TSA includes many parks and protected areas, including nine new conservancies established since 2000 under the Sea-to-Sky Land and Resource Management Plan (LRMP). The terrain varies from rugged coastal mountains to the flat valley bottoms of the Lillooet River near Pemberton and the lower Squamish River. The major commercial tree species within the timber harvesting land base, in order of abundance, are Douglas-fir, amabilis fir (balsam), western hemlock, western redcedar, and Engelmann spruce.

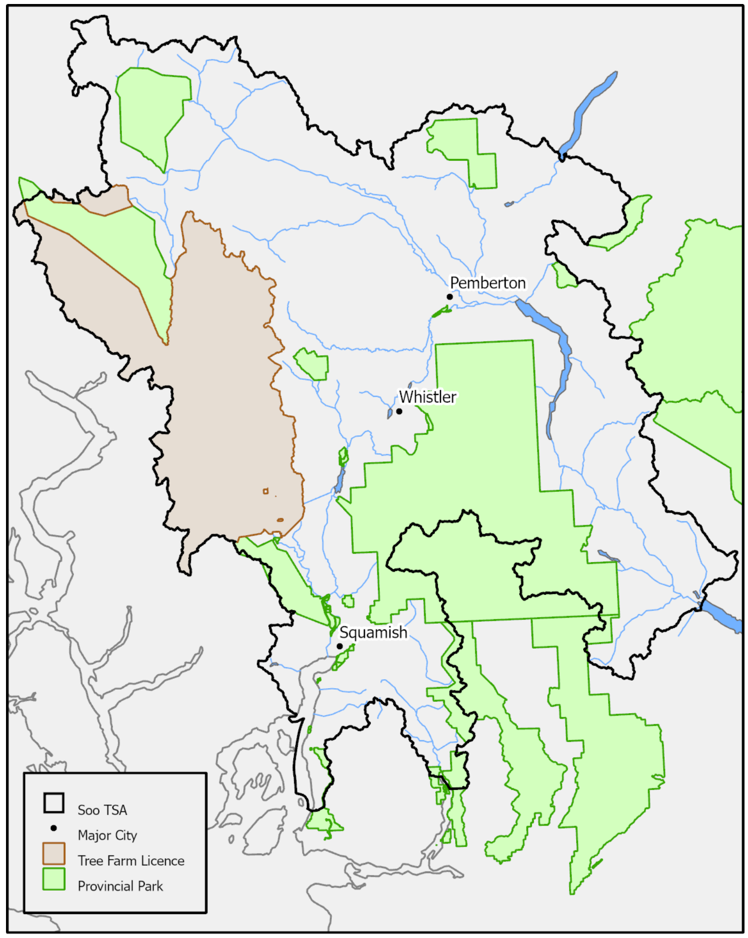

Figure 246. Soo Timber Supply Area.

The region has experienced one of the highest population growth rates in the province in recent years. One of the most significant changes in the TSA since the last timber supply review was the April 2008 approval by the provincial government of the Sea-to-Sky LRMP. This plan provides current and future direction and guidance for the development of the entire district. Seven First Nations have asserted traditional territory that includes all or a portion of the TSA.

Effective September 15, 2020 the AAC for the Soo TSA is 466 872 m^3.

Balsam Woolly Adelgid

An introduced pest, the balsam woolly adelgid has been recorded in the Whistler, Joffre and Hurley Pass areas. The TSA was included within the regulated quarantine area which restricted the movement of true firs (see *Balsam Woolly Adelgid Regulation*), however, this regulation was repealed in 2019.

Douglas-Fir Beetle

Trees previously defoliated by western spruce budworm were attacked by Douglas-fir beetle in the Pemberton Valley in 1953. Scattered attacks occurred annually until 1956, and then again in 1960, 1967, 1975-1981 and 1983-1985. In 1989, 11 separate infestations totaling 77 ha were noted on the east side of Lillooet Lake, between Billygoat Creek and Ure Creek. Douglas-fir beetle activity was noted annually until 1995 in many of the areas which had been defoliated by western spruce budworm or where laminated root disease was found. In 2004, populations increased substantially to approximately 1124 ha between Lillooet River and Pemberton, Pemberton to D'arcy, Birkenhead Lake, south between Lillooet Lake and Harrison Lake, including Snowcap Creek. Since 2004, the area affected by Douglas-fir beetle has been low with a few dozen to a few hundred hectares reported annually. A recent spike to 1068 ha in 2019 did not see similar numbers in 2020 (51 ha).

Mountain Pine Beetle

The first recorded infestations of mountain pine beetle occurred on mostly white pine in the Squamish River Valley in the 1940's, with extensive white pine mortality noted in 1960. The small spot infestations continued sporadically until the early 1970's. Larger infestations were recorded throughout the 1970's near Birkenhead and Lillooet lakes, and Haylmore and Blackwater creeks. In 1978 and 1979 white pine was attacked near Joffre Creek. Beetle populations increased in the early 1980's, specifically near Haylmore Creek and Birkenhead Lake. In 1985, populations began increasing significantly with a peak of over 58,000 trees newly attacked in the Soo TSA in 1986. The populations decreased thereafter with only 525 ha noted in 1989 near Birkenhead and Lillooet Lakes. In 1992, populations increased again in the Birkenhead and Gates rivers and the north side of Blackwater creek. Area infested declined once again from 1993-1994 but doubled in the Birkenhead River area in 1995. In 2004, about 7100 ha of mountain pine beetle were recorded along most highway corridors in the Soo TSA: from Whistler to D'Arcy, NE along Lillooet River, east along Birkenhead Lake and south of

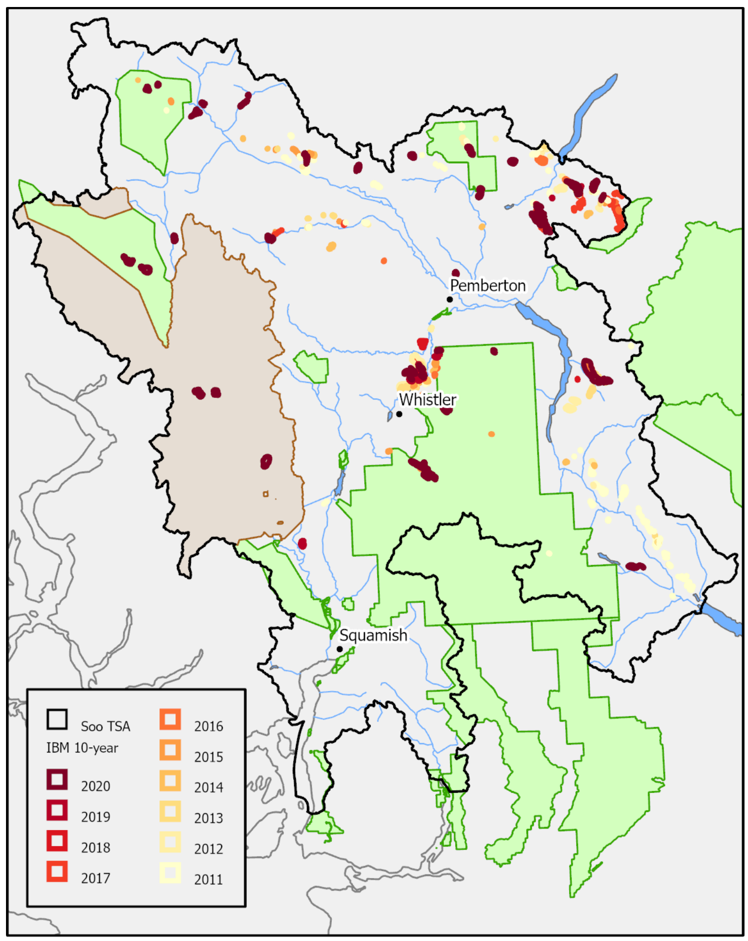

Figure 257. Annual occurrence of mountain pine beetle in the Soo TSA over the past decade.

Pemberton from Lillooet Lake to Harrison Lake. Areas affected by mountain pine beetle peaked at a high of 16,848 ha in 2007 and have decreased since. Still, several hundred hectares are mapped annually with most occurring near Whistler and in the transition areas near the northern and eastern TSA boundaries. In 2020, 4832 ha were reported, an increase from the 502 ha in 2019.

Root Diseases

The TSA has areas with extensive amounts of root disease, primarily laminated root disease of Douglas-fir and Armillaria root disease on many conifers. Root disease losses have been partially accounted for in the current TSR. The impact of root disease within transition zone forests is unclear. Stands show impacts from *Armillaria*, and some studies imply risk to future timber supply if these stands are left untreated.

Spruce Beetle

In 1995 spruce beetle mortality was noted over 5 ha in the Birkenhead River Valley. In recent years, mortality has also occurred in the Haylmore and adjacent drainages. In 2004, about 255 ha were recorded near Salamander Mountain SE of Lillooet Lake and NE of Harrison Lake. In 2006, 832 ha of attack were recorded. The attack levels have since declined to a negligible amount.

Western Balsam Bark Beetle

Western balsam bark beetle is ubiquitous throughout the range of sub-alpine fir. Upper elevation stands of spruce/sub-alpine fir generally have some activity. In 1987 infestations were first recorded in the Haylmore and Cayoosh drainages. Activity has been noted annually thereafter with a peak of 375 ha in 1991. Since then, a high level was recorded in 2007 (4545 ha) dropping to 434 ha by 2013 and rebounding to 6220 ha in 2014. Since then, occurrence has trended upward with several thousand hectares reported annually hitting a peak of 27,637 ha mapped in 2019. Attack is usually scattered throughout forested areas and often is recorded as trace levels (<1% of the trees attacked) but severity has increased along with occurrence over the last few years. Control activities are not feasible for this insect.

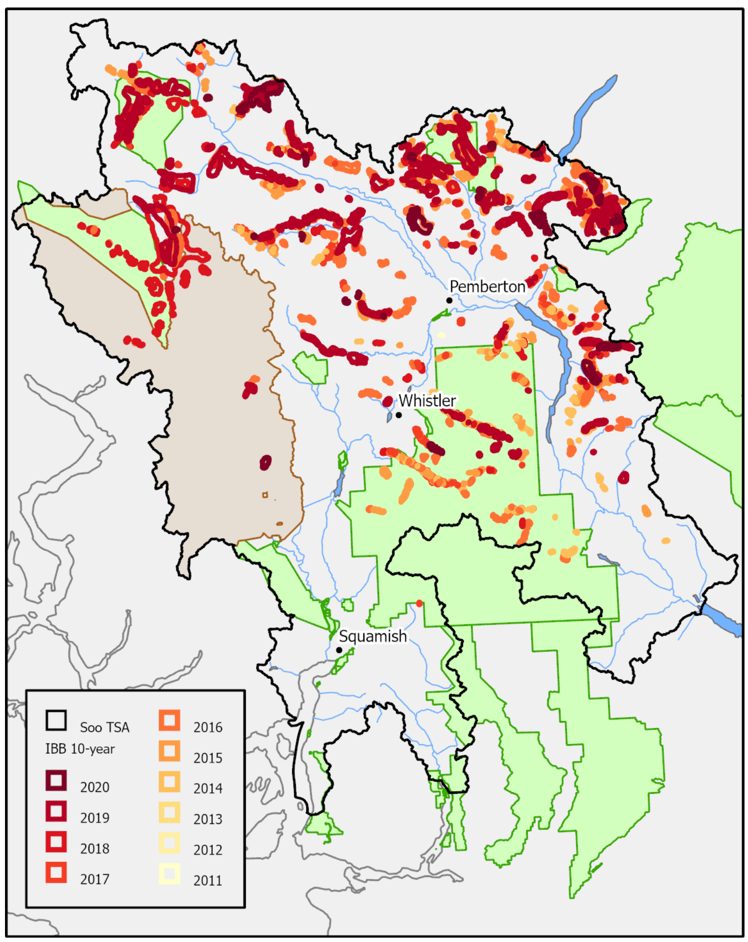

Figure 268. Annual occurrence of western balsam bark beetle in the Soo TSA over the past decade.

Western Spruce Budworm

Five outbreaks of western spruce budworm have been recorded in the Soo TSA in 1943-1944, 1953-1959, 1968-1979, 1986-1992, and most recently occurring from 2003-2008. The first record of western spruce budworm in the Soo TSA occurred in 1943 between Pemberton and Anderson Lake. In 1953 light defoliation occurred along the Lillooet River between Harrison and Lillooet lakes. Populations expanded in previously infested stands in 1954 and from Gowan Creek to Pemberton and near Haylmore Creek. The infestation continued to expand in 1955 along the Lillooet River, with new defoliation recorded between Pemberton, Birkenhead Lake and D'Arcy. Populations continued to increase in 1956 and 1957 and moved southward to Alta Lake in 1958. In 1959 populations collapsed. The next outbreak began in 1968, once again near Pemberton. This outbreak continued to increase and expanded into the Lillooet River and Lillooet Lake area until 1974 when defoliation area and intensity began decreasing. In 1976 tree mortality and top kill were noted at Rutherford and Railroad creeks. Populations continued to decline with a slight increase noted in 1977 near Lillooet and Birkenhead rivers. By 1979 populations had collapsed. An assessment conducted in 1980 found that within stands previously defoliated, up to 39% of the Douglas-fir had top kill and 28% were dead from either repeated defoliation or bark beetle attack. A small infestation was noted in 1981 near Halymore creek. The third outbreak commenced in 1986 with over 1225 ha defoliated in the Blackwater and D'Arcy creek drainages. This infestation expanded into the Haylmore drainage the following year. Populations continued to expand annually with a peak in 1992 of almost 21,000 ha defoliated. In 1993 populations collapsed. Defoliation was recorded in 2003 near D'arcy and once again in 2004 when approximately 4200 ha were defoliated.

In 2006, defoliation in the Whistler – Pemberton area (Shadow Lake Interpretive Forest) was obvious from the highway, and some egg mass sampling was done. Levels were not high enough to warrant treatment. Over 4,000 ha of impact was noted in the 2006 survey, particularly in the Haylmore and Blackwater Creek areas. The amount of area recorded increased in 2007 to 18,702 ha then declined significantly, resulting in 708 ha recorded in 2009 and to less than 100 ha since. As noted earlier, the historic elevational band ranges may change over time because of climate change. An overlay analysis of western spruce budworm defoliation since 1943 found that the CWHms1 and CWHds1 have incurred the greatest amount of defoliation, with the majority sustaining 3-10 years of defoliation. More recent defoliation has occurred primarily in the CWHms1.

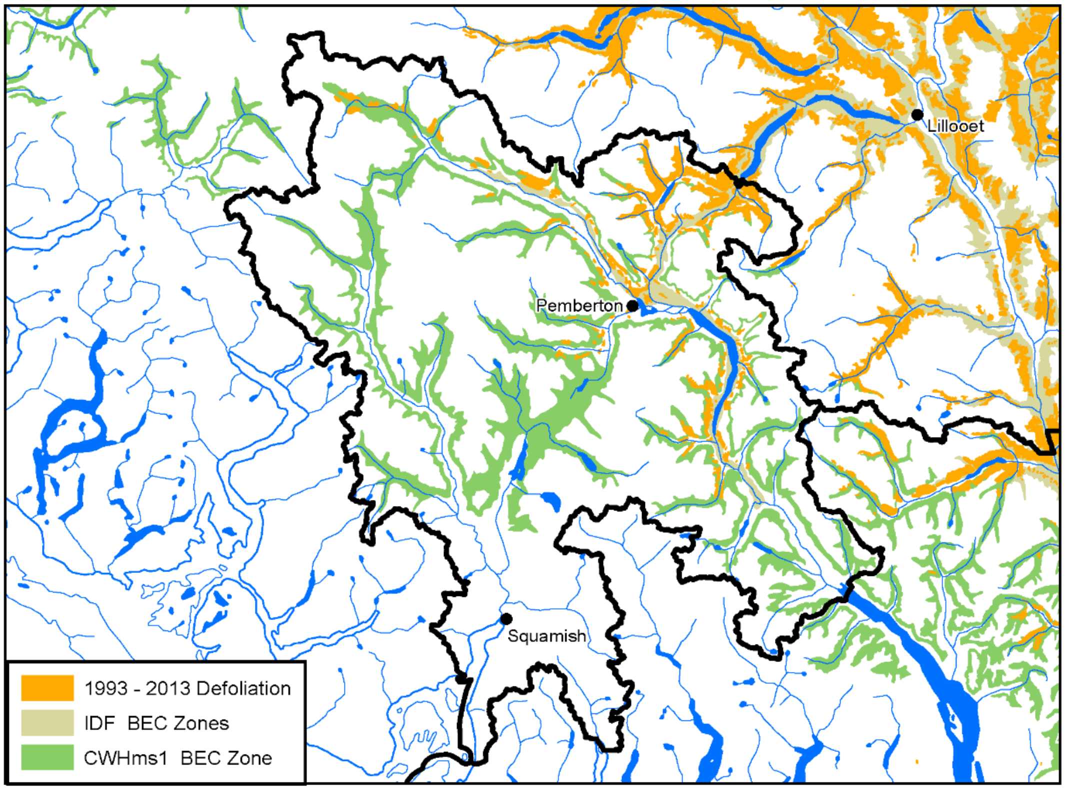

Figure 29. Area defoliated by western spruce budworm from 1993-2013 in the Soo TSA.

Sunshine Coast TSA

The Sunshine Coast TSA comprises approximately 1.5 million hectares along the southwest coast of British Columbia. The TSA is bordered by the Fraser TSA to the south, the Soo TSA to the east, the GBR South TSA to the west and the Williams Lake TSA to the north. It is also next to portions of TFL 39 and TFL 43. The landscape of the Sunshine Coast TSA is dominated by the Coast Mountains and several coastal fjords, most notably Bute, Toba and Jervis Inlets. The landscape ranges from nutrient rich, moist floodplains in the valley bottoms to alpine meadows. About 28 percent of the land base of the TSA is productive forest land managed by the Province, of which just over half is available for timber harvesting.

The forests of the TSA are diverse, and about half of the forests on the THLB are considered to have medium or good site productivity. Major tree species include Douglas-fir, hemlock and amabilis fir (balsam), while other species such as western redcedar, spruce, pine, alder, and cottonwood also occur. The forests of the TSA have a long harvesting history, and as a result there are rapidly maturing second-growth forests on the lower elevation, more accessible and higher productivity growing sites. Nearly half of the stands on the THLB are between 21 and 100 years of age.

The chief forester last determined the AAC in November 2011 and it now is set at 1,204,808 m^3 effective August 22, 2013. The AAC has a partition of 98 000 m^3 for deciduous-leading stands.

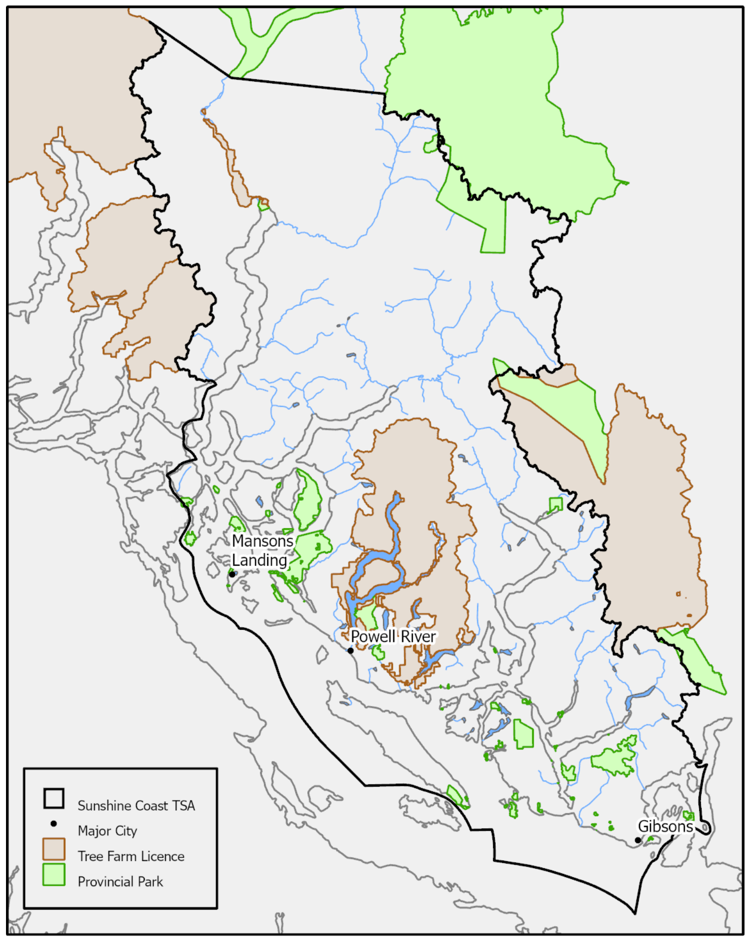

Figure 27. Sunshine Coast Timber Supply Area.

Balsam Woolly Adelgid

BWA has spread into the Sunshine Coast TSA and has been confirmed in four sites north of Jervis Inlet. The TSA was included within the regulated quarantine area which restricted the movement of true firs (see *Balsam Woolly Adelgid Regulation*), however, this regulation was repealed in 2019.

Bear

Black bear damage and volume loss has increased within the Ramsay Arm, Quatam River and lower Toba Inlet over the past 10 years. Larger diameter Douglas-fir has been damaged and killed within the Quatam River area. A flight in 2011 revealed trees of over 40 centimetres in diameter and over 25 metres in height have been killed. Damage in younger managed stands has increased and mortality levels are over 40% in some plantations. Another consideration is decay within damaged trees and long-term implications. Some of the early damaged juvenile spaced stands are showing mortality from decay. Wounding from bear damage weakens the stem, with wind and snow resulting in breakage, killing the tree, and contributing to volume loss.

Douglas-fir Beetle

In 1960, two small infestations were reported on the Sechelt Peninsula. Douglas-fir beetle populations have been increasing in recent years within TFL 39 due to recent windfall events and selective harvesting operations. In 1994, salvage harvesting of Douglas-fir beetle attacked trees occurred in conjunction with wind fall salvage in the Okeover area. From 2011 to 2014, 400 to 800 ha of damage were reported annually. Since 2011, trap tree baiting, and removal is used to reduce beetle populations near Powell River and on the Sechelt Peninsula, especially in areas having recently experienced wildfire. Still, trace and light recent attack is mapped every year across the TSA.

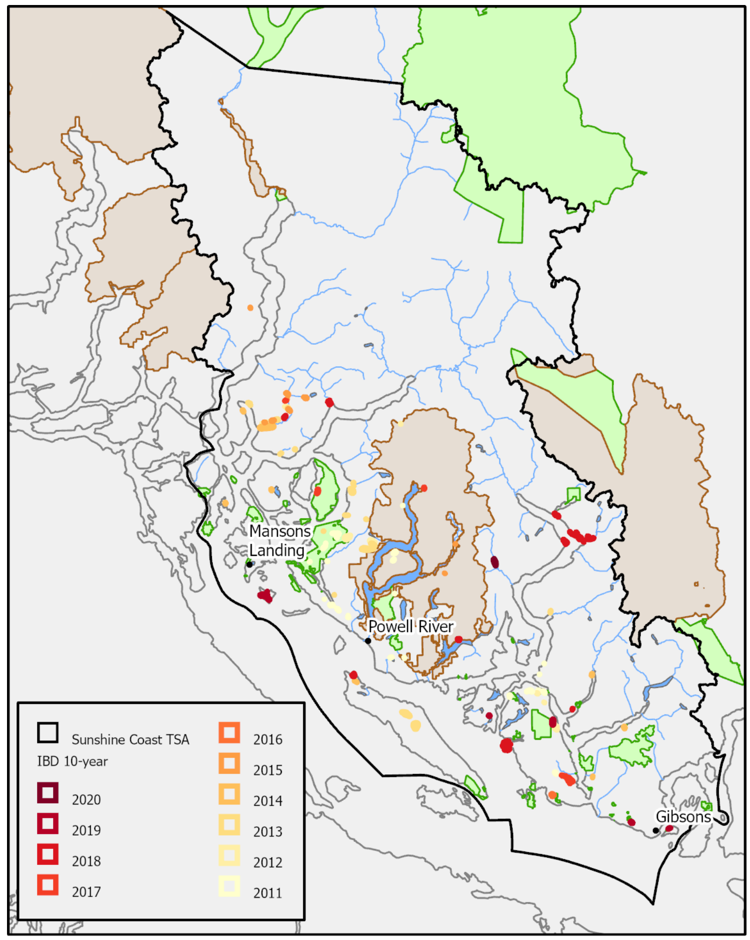

Figure 28. Occurrence of Douglas-fir beetle in the Sunshine Coast TSA over the past decade.

Mountain Pine Beetle

In 1964, a small patch of white pine was attacked at Cairn Ridge on the Sechelt Peninsula. From 1982-1988 small scattered infestations were noted in the Homathko River and at unspecified locations in the TSA. The Homathko & Southgate valleys were flown in 2006 and mountain pine beetle populations are at endemic levels, with scattered patch mortality occurring in over mature pine stands. Over the last few years some beetle attack has been mapped with 380 ha reported in 2020 mainly in the northeast portion of the TSA.

Root Diseases

Laminated root rot is the main concern with high levels of infection occurring in the Okeover Inlet area near Powell River and on the Sechelt Peninsula near Homesite Creek. Losses to root disease were incorporated into the last TSR through adjustment of the OAF2 to 12.5% for all existing managed Douglas-fir leading stands in the CDF and CWHxm1 & 2 subzones.

Spruce Beetle

In 1995, 30 ha of infestation were recorded between Powell River and Filer Creek.

Western Hemlock Looper

Defoliation by western hemlock looper was first recorded from Port Mellon to Woodfibre in 1928, and in 1946 near Sechelt. In 1969, larval counts increased from Jervis Inlet to Harrison Lake, but no defoliation was recorded. In 1987, over 90 ha of western hemlock, western redcedar and broadleaf maple were defoliated on the west side of Jervis Inlet.

Hemlock looper defoliation was noted in the Rainy River drainage in 1999 over less than one hectare. The population increased dramatically by 2002 with about 800 ha being defoliated in Rainy River and McNab Creek in Howe Sound. In 2002, Canadian Forest Products proposed salvage of about 145 ha of the most severely attacked stands containing about 87,000 m^3 of timber. Salvage operations were curtailed when Canadian Forest Products surrendered their license. Howe Sound Pulp & Paper and BC Timber Sales completed salvage of about 70,000 m^3 by 2007. A looper monitoring program was established in the Rainy River drainage in 2009 at the results to date show that the looper population remained at endemic levels until 2020.

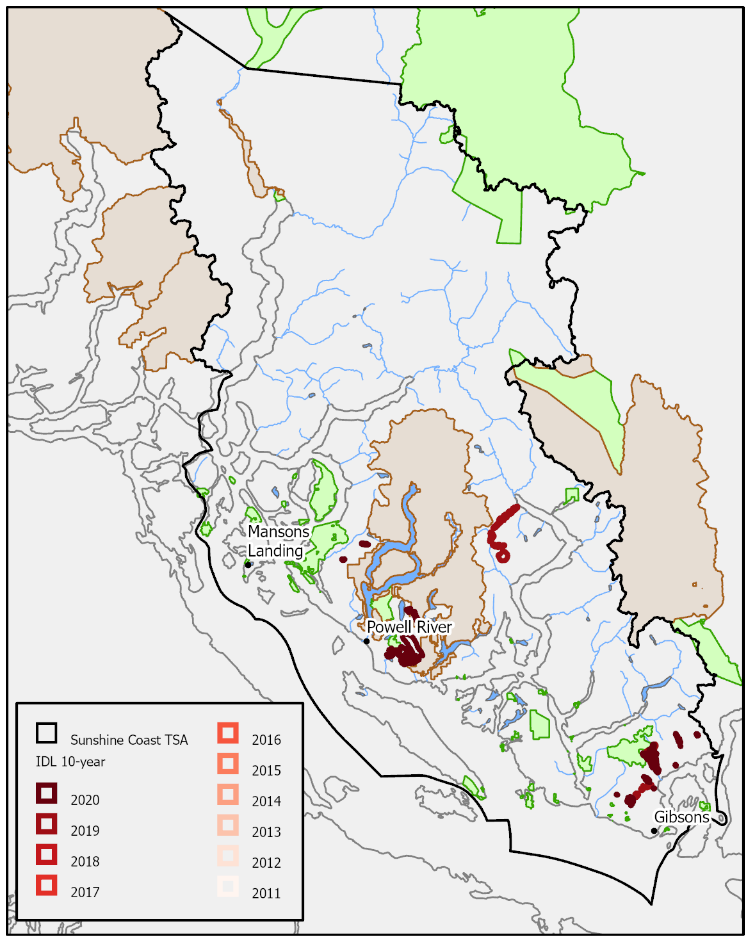

Figure 29. Occurrence of western hemlock looper in the Sunshine Coast TSA over the past decade.

In 2019, BCTS discovered a looper infestation in the Brittain River prior to canopy symptoms becoming apparent. The following year, looper was mapped also in the Rainy River area and adults were easily spotted around Powell River, Sechelt and Gibsons. This coincided with the extensive appearance of looper in the Metro Vancouver watersheds that same year. Defoliation in the TSA increased from 2,145 ha (primarily light severity) in 2019 to 4,279 ha (primarily light severity) in 2020.