SILVICULTURAL DECISION GUIDE FOR SWISS NEEDLE CAST IN COASTAL OREGON AND WASHINGTON

Swiss Needle Cast Cooperative (SNCC)
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Introduction

Swiss Needle Cast (SNC), a foliage disease caused by a native pathogenic fungus, *Nothophaeocryptopus gaeumannii (*formerly *Phaeocryptopus gaeumannii),* has emerged as a significant disease of Douglas-fir (*Pseudotsuga menziesii var. menziesii*) in the coastal Pacific Northwest since the 1990's. Swiss needle cast symptoms include: chlorotic (yellowish) foliage, low needle retention, thin crowns and reduced tree growth (Figure 1). The fungus occurs wherever its only host, Douglas fir, is grown. Disease, however, is only expressed when the fungus causes significant defoliation of two- and three-year old needles. This is an important point for managers; the fungus may be present and yet have no effect on Douglas-fir productivity.

Figure 1. Chlorotic (yellowing) and thin Douglas-fir tree crowns due to Swiss needle cast. Note the green western hemlock trees.

Nothophaeocryptopus gaeumannii lives inside the needles of Douglas-fir and only impacts needle function when fungal fruiting bodies (called pseudothecia) emerge into and plug the stomates (air pores on underside of needle), blocking gas exchange (Figure 2) When too many of the stomates on a needle get plugged, the needle dies and is cast (dropped) from the branchlet.

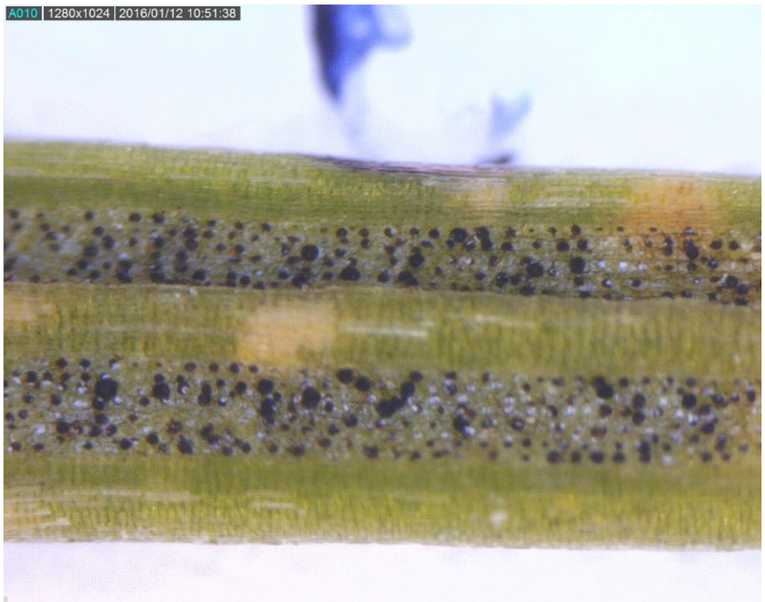

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Figure 2. Small, black pseudothecia, plugging stomates on a Douglas-fir needle.

Although first identified on Douglas-fir growing in Switzerland in the early 20th century, forest pathologists in North America found the fungus was common in native Douglas-fir stands but was not causing problems. The disease emerged in Christmas tree plantations in Washington and Oregon in the 1970s and by the 1990s, it had intensified in coastal Oregon and Washington Douglas-fir plantations. In January 1997, in response to the disease epidemic, the Swiss Needle Cast Cooperative (SNCC) was formed by private forest landowners, federal and state agencies, and the Oregon State University College of Forestry to conduct research and to address management practices. The SNCC has subsequently led research and coordinated monitoring and development of tools to assist landowners in decision-making with regards to Swiss Needle Cast disease (SNC).

The aerial detection survey for coastal Oregon (Figure 3) began in the spring of 1996 and noted 131,088 acres with obvious symptoms of SNC. By 1999, 295,000 acres (out of 2.9 million acres surveyed) of private, federal and state lands were visibly affected by SNC. From 2000 to 2015, the quantity of affected acreage displayed an increasing trend, peaking at 589,851 acres in 2015. The decreases following this peak are likely due to hotter and drier, early summer weather in subsequent years, as well as liquidation/conversion of diseased plantations to non-susceptible species in the most infected zones

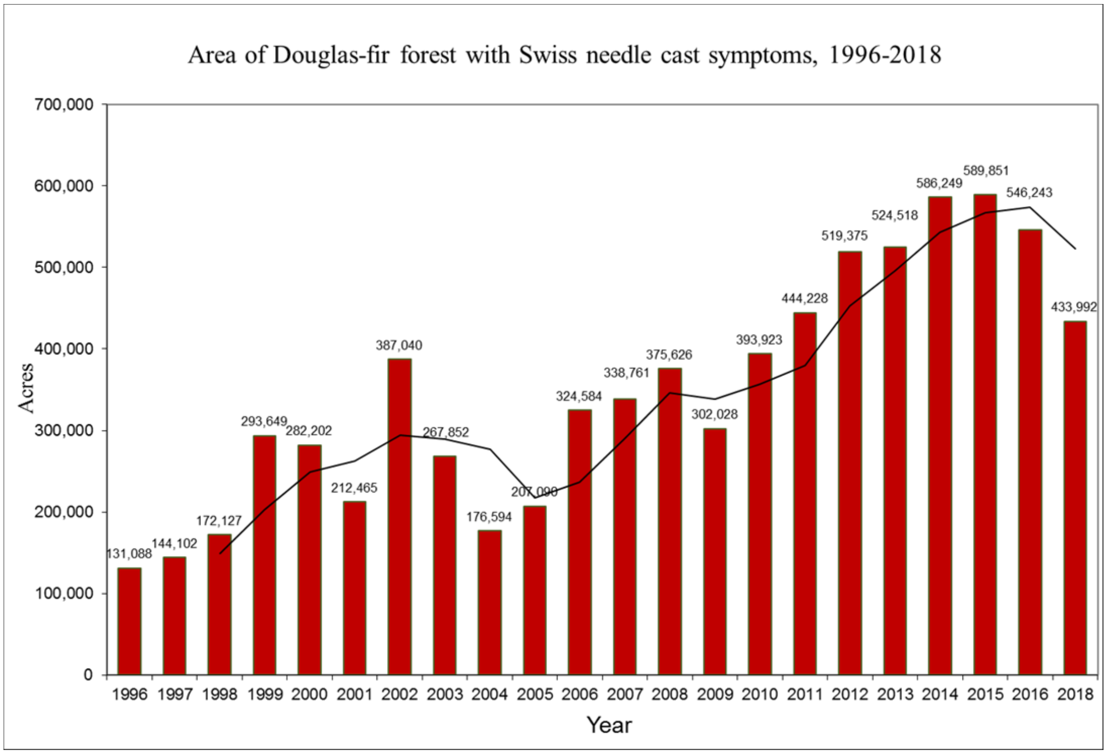

Figure 3. Area of Douglas-fir forest in western Oregon with symptoms of Swiss needle cast detected during aerial surveys conducted in April-June, 1996-2018 (2008 area estimated from partial survey consisting of 3 sample blocks). Trend line is 3-year rolling average. Coast Range, Oregon. From Oregon Department of Forestry.

Swiss needle cast is now considered one of the top threats to Douglas-fir plantation health and productivity in the Douglas-fir region of western Oregon, Washington and SW British Columbia, especially in areas near the coast. SNC causes needle loss, and there is a direct relationship between needle retention and tree growth when retention is below 3 years (Figure 4). Needle retention quantifies how many years of leaves are retained on tree branchlets. As needle retention decreases, there is a commensurate reduction in tree- and stand-level growth. This allows needle retention to be used as a proxy for disease impacts on tree growth. Diameter and height growth slow in trees impacted by SNC disease. The most heavily infected stands are estimated to be losing ~50% or more of their potential cubic volume growth. Economic losses are commensurate.

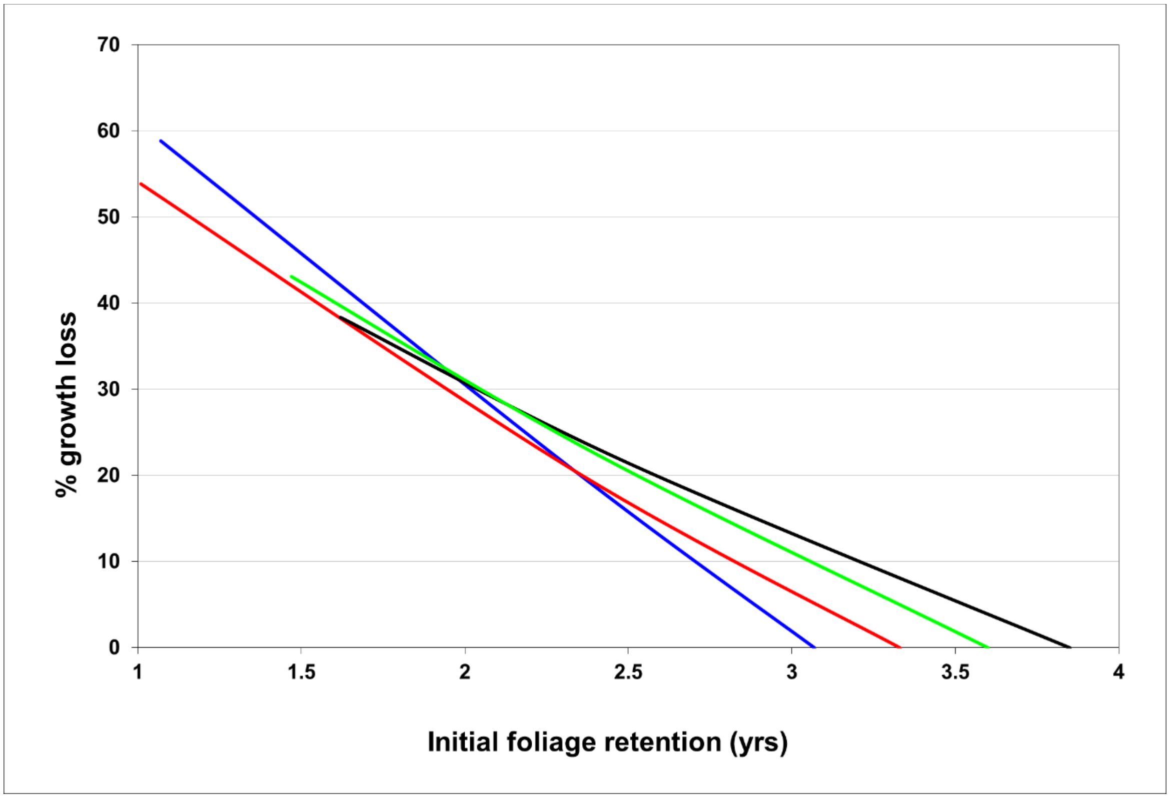

Figure 4. The percent growth losses associated with level of needle retention (From Maguire/CIPS).

Here, we synthesize our knowledge of silvicultural approaches to SNC, addressing recognition of risk. It has become abundantly clear that a one-size-fits-all approach does not work for SNC, and that management is quite nuanced and site-specific. Forest managers must consider their options and not ignore SNC.

Silviculture Decision Guide

We recommend a three-step process for deciding how to respond to SNC in forest plantations. A site hazard assessment, followed by a stand impact assessment, and finally silvicultural decisions.

1. Site Hazard Assessment

The most important climatic factors influencing disease vary with geographic location, therefore, a site hazard assessment is critical to understanding risk. Tools to assist in site hazard assessment (TABLE 1) include; aerial detection surveys, ground based plot data and our general knowledge of the relationship between disease and geographic location.

TABLE 1. Tools for site hazard assessment.

Tool	What is it?	Use
Aerial detection survey (ADS)	Surveyors fly in an airplane in spring and map location and size of stands that show visible symptoms of disease (low needle retention, yellowish, chlorotic foliage)	Provides insight into whether a location has displayed visible symptoms. may be at risk for growth impacts.
Plot data inference	On-the-ground tree measurement plots.	Plot networks allow tree growth impact monitoring, validation of ADS, as well as data on the distribution of disease severity and needle retention.
Models and Maps	Models and maps may be based on data from plot networks or predictable geographic distribution of influential variables.	Allows prediction of where disease may cause growth impacts to stands.
Geographic location	Climate and weather patterns in conjunction with topographic position and coastal influences provide clues to potential disease severity on a site.	Lower elevation and closer to the coast are most at risk. In the western Cascade Foothills, low elevation sites that receive high summer rainfall are most at risk.

ADS Data

Aerial detection survey (ADS) is a cooperative program of the Oregon Department of Forestry, Washington Department of Natural Resources, and the USFS Forest Health Protection group (https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/?cid=stelprdb5286951). The ADS group conducts a spring survey for Swiss Needle Cast. The locations of stands with visible symptoms of disease are mapped. The maps are posted on their website (Figure 5), and can be readily viewed. The data does not necessarily confer knowledge of growth impacts as much as it does the *potential* for growth impacts based on disease symptom expression. It is possible to have impacts from SNC anywhere Douglas-fir grows, but if ADS is showing visible symptoms, the likelihood is much greater. In British Columbia, the Ministry of Forests has also begun aerial detection surveys.

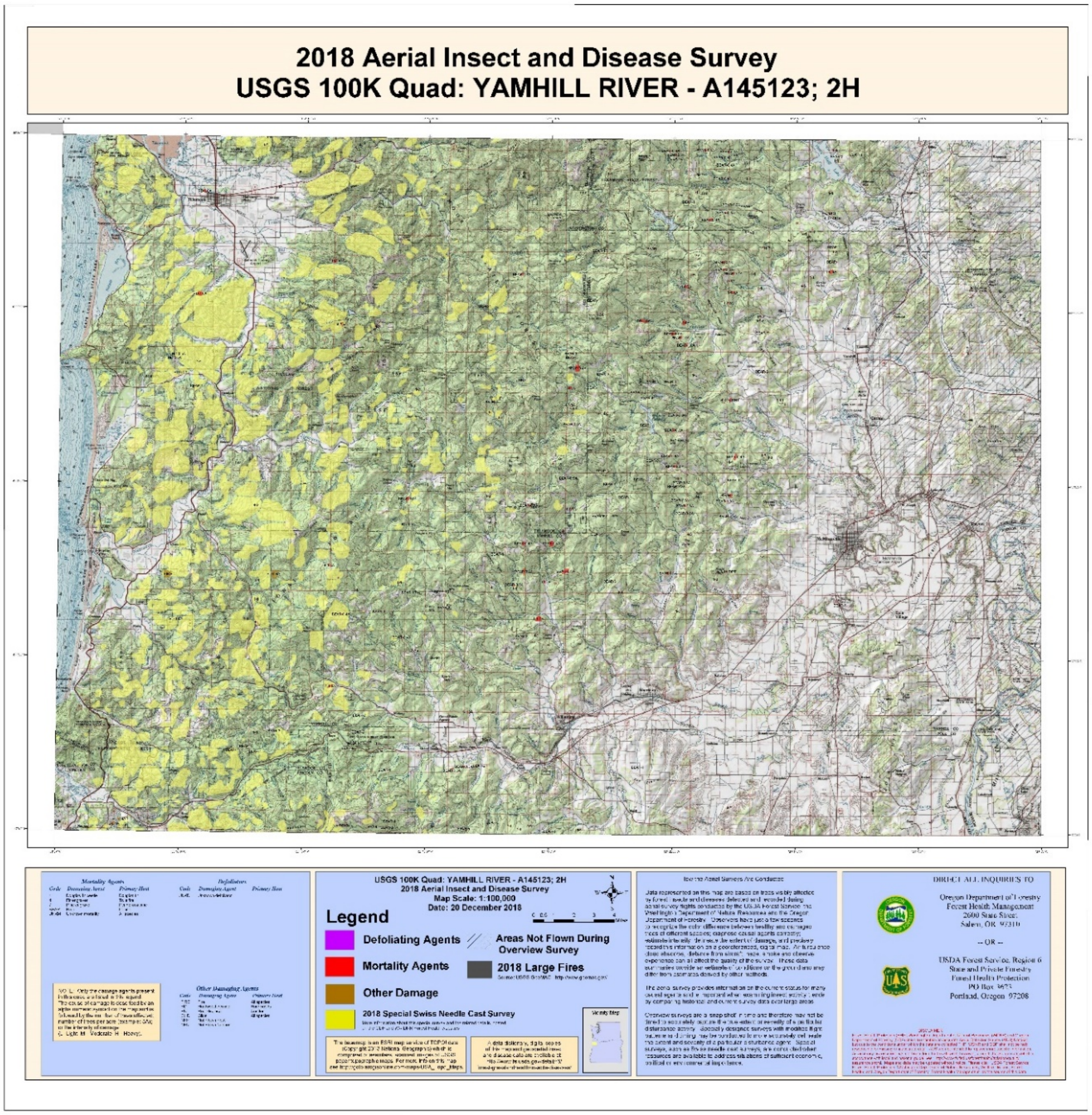

Figure 5. 1: 100,000 map with aerial detection survey data indicated. Yellow indicates areas with visible symptoms of SNC. Red indicates tree mortality, in this case mostly from bear/root rot. Maps available online at: https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/?cid=stelprdb5294941

Plot Data

Oregon, Washington, and British Columbia have each installed plot networks to monitor the disease in support of the aerial survey. The general area most at risk from growth impacts include coastal Oregon with growth impacts mostly decreasing with increasing distance from the coast. Coastal Washington is also at risk, with SW Washington perhaps most at risk. Finally, SW British Columbia has become an area of increasing concern

Maps have been produced from spatial interpolation of needle retention and disease severity ratings across 106 SNCC monitoring plots in coastal Oregon and SW Washington, providing a coarse estimate of where disease can be expected to be a problem (Figures 6,7).

Models of SNC severity and needle retention

Needle retention is associated with both disease severity and growth impacts, so maps of needle retention have been used to reflect risk of disease impacts. Several models have also been developed that use principles of disease epidemiology (http://sncc.forestry.oregonstate.edu/models).

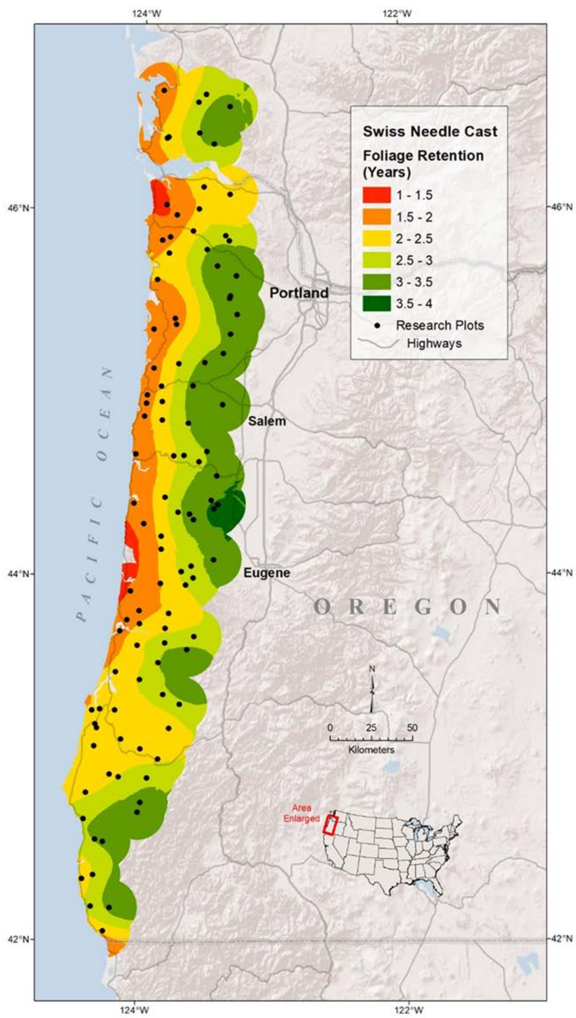

Figure 6. Douglas-fir needle retention in plantations within 35 miles of the Coast. Dots represent locations of SNCC Research and Monitoring plots.

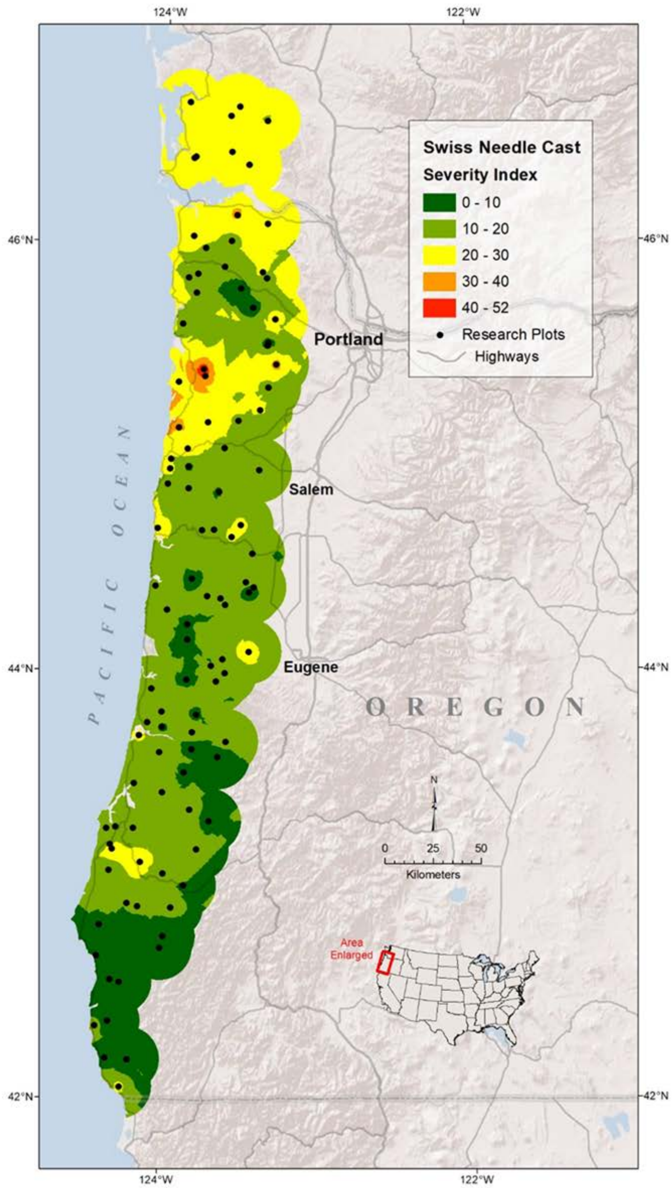

Figure 7. Swiss needle cast disease severity in coastal plantations within 35 miles of the coast. Dots represent locations of SNCC Research and Monitoring plots.

Distance from coast and elevation/geographic location

The exact factors controlling disease likely vary with geographic location, but needle wetness during May, June, and July have been found to enhance fungal germination, and warmer winter temperatures have been found to speed disease development. Evidence has shown that lower elevations with a coastal influence are more likely to experience higher SNC severity than higher elevation and inland areas.

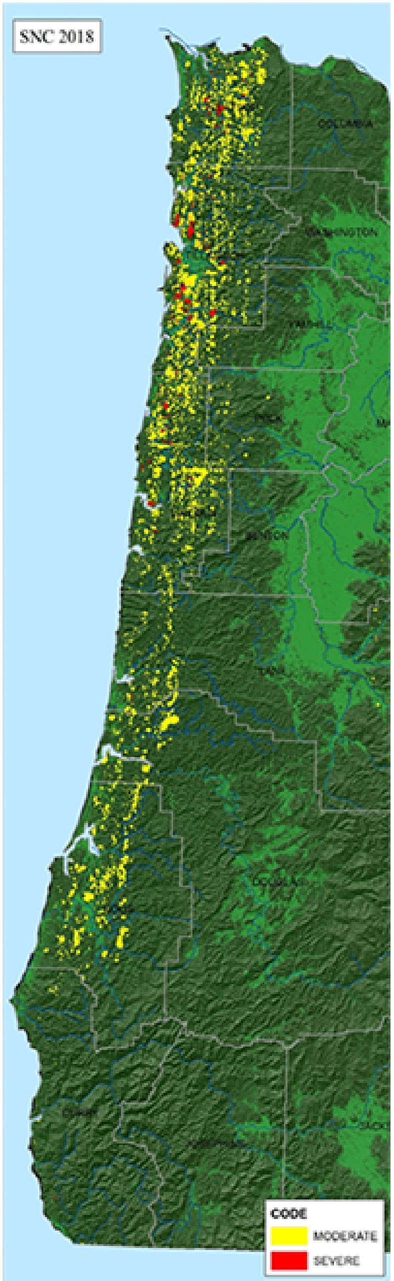

Figure 8. Oregon Aerial Detection Survey results for 2018. Note proximity to the coast. Red is severe symptoms, yellow moderate/visible.

Nevertheless, the lower elevation areas of the western Cascades Foothills in Oregon exhibit some disease. In British Columbia, the disease is also significant in the rainforest valleys on the lower elevations in the Frasier River region, especially near Chilliwack.

The site hazard assessment is a critical, but qualitative step. The geographic area of most concern is well known, providing a good basis for understanding the potential for impacts within an area.

Step 2 - Stand Impact Assessment

A quantitative assessment of stand impacts is necessary if the manager believes that deviation from standard forestry practices may be required. First, a visual assessment of stand conditions, including needle retention, stand/crown color and crown fullness, can be assessed to determine if growth losses are likely (Figure 10). If so, then confirmation of the presence of *N. gaeumannii* should be done. Once these criteria are completed, we recommend a quantitative stand assessment to clearly demonstrate if growth impacts are occurring and to what degree.

Visual Assessment of Stand Symptoms

Trees moderately to severely impacted with SNC typically show symptoms best in April and May, just before and during budbreak. Symptoms include low needle retention, yellowish crown color (chlorotic), sparse crown, and reduced growth (Figure 10, 11). Although these are most obvious in spring, severely impacted trees show symptoms all year.

Figure 10. Differences in crown characteristics of Douglas-fir impacted by SNC on left (seed source SW Oregon, and trees not impacted by SNC on right (seed source SW Coastal Washington).

Figure 11. Thin chlorotic crown with low needle retention due to SNC.

Needle retention

Estimates of needle retention should come from the mid to upper mid crown of dominant and co-dominant trees, preferably on the south side of the tree. In older stands with recessed crowns, this can be done with binoculars. Estimates can be obtained from any number of dispersed trees whose condition is judged representative of the stand.

On a mid-crown lateral branch, needle retention is estimated by summing the proportions of retention on each annual needle cohort.

In example (Figure 12b), the current year is estimated to hold 100% of its needle (proportion = 1.0), the second year is estimated to have 90% of its needles (proportion=0.9), and the third year is estimated to have 30% of its needles (proportion=0.3). The estimated needle retention for a sample branch is 1.0 + 0.9 + 0.3 = 2.2 years.

Needle retention may not be possible to estimate in young trees under 10 or 12 years old due to their lack of older side branches above DBH.

Figure 12. Examples of needle retention (NR) from top to bottom: a) NR=0.9, b) NR=2.2, c) NR=4.0 years of needles retained.

Stand/crown color

The color of a tree crown or aggregated stand is not that easy to assess, although a sickly yellow tree may seem obvious. Angle of view, sun or cloudy conditions, time of day

season all influence crown color. In general, we recommend assessing crown color in the spring prior to budbreak in April during mid-day. Trees may lose their yellowish appearance after bud break and needle shed. Do not assess the stand from the roadside, as trees adjacent the road may not represent the stand. If possible, view the stand from a high point with the sun behind you during mid-day.

Crown sparseness

Crown sparseness, a qualitative estimate, is a good indicator of foliage loss, although it can be difficult to assess, especially in older trees. However, in young trees under 10 or 12 years old, crown sparseness may provide a better estimate of the impact of disease than needle retention.

Verify presence of the fungus that causes Swiss needle cast

Crown color, crown fullness, and needle retention are influenced by SNC, but can also be influenced by soil nutrient deficiencies, other pathogens or insects, root diseases, or weather events. To be sure that SNC is the cause of the crown condition, it is important to look for signs of the fungus. The key signs are the pseudothecia that plug the stomates (Figure 13a, b). If abundant pseudothecia are present on one- and two- year old needles, then it is likely the fungus is causing disease. In particular, we use 2-year old needles as an indicator since abundant fungus on 2-year old needles leads to reduced needle retention.

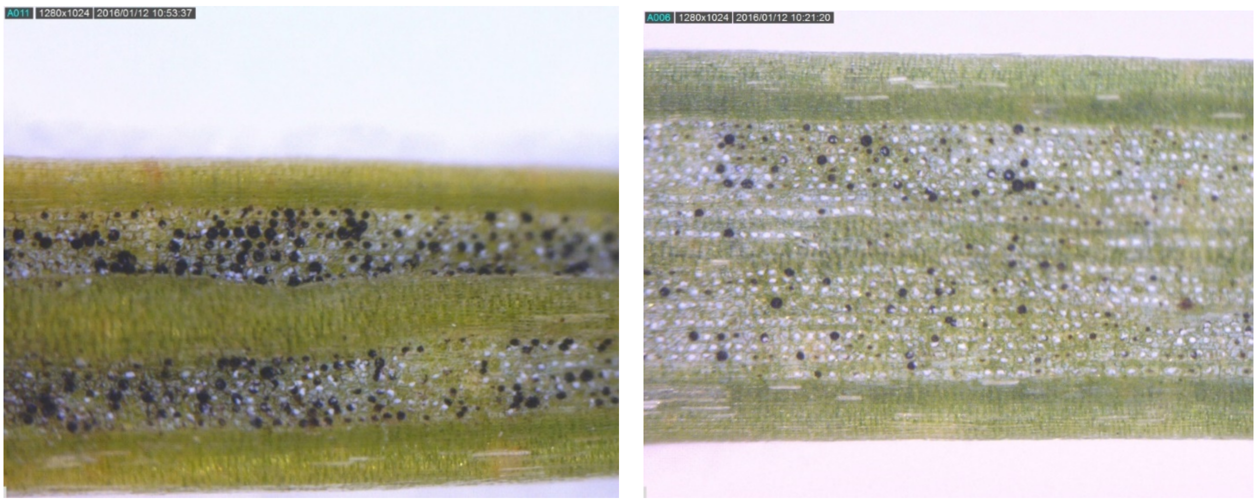

Figure 13. Underside of Douglas-fir needle with two rows of stomates separated by the midrib. Note the black fruiting bodies (pseudothecia) of Swiss needle cast. a. heavily infected. b. moderately infected.

To verify that *Nothophaeocryptopus gaeumannii* is present, look at the underside of the needle April –August to observe the pseudothecia emerging from stomates (Figure 12 a, b). This requires at least a 10x hand lens, but 20x lens may be better, especially one that has a light system. With a small hand lens, it is possible to hold the needle during a sunny day in such a way that the light on the needle shines through the needle and accentuates the black pseudothecia from behind.

Quantitative Assessment of Growth Impacts

Due to the association between Douglas-fir needle retention and stand volume growth, one method to estimate a stand’s performance is to collect a representative estimate of needle retention from dominant/codominant trees within a stand. Using this value and the relationship exhibited in Figure 4, an estimate can be made of the stand’s cubic volume growth loss relative to a healthy stand.

Analysis of infected stands has shown that despite the general association between Douglas-fir needle retention and stand volume growth, some infected stands may still be growing relatively well. Because diseased trees exhibit both height and diameter growth loss, an experienced manager may be able to assess recent height or diameter growth relative to what would be expected for the same type of stand in the absence of SNC. The SNCC has developed software to aid such an assessment.

Step 3 – Silvicultural Decisions

Disease-related silvicultural decisions are dependent on disease levels, stand age, and stand structure and composition, and are important at the time of plantation establishment or for existing stands (Table 3).

Table 3. Silvicultural treatments for Douglas-fir and the effect, SNC response, and recommendation for control.

Silvicultural Treatment	**Effect**	**SNC Response**	**Recommendation**
Alternative or mixed species management	Maintains non-susceptible species.	No response	When it makes economic sense and to avoid dependency on Douglas-fir
Vegetation Management	Improves seedling growth	No response	May be worth doing, but not to control fungus.
Thinning	Maintains longer crowns, greater needle mass per tree.	No response	Maybe worth doing, but not to control fungus
Fungicides	Protects foliage from colonization by the fungus	Can be effective. Annual application required.	Not recommended in forest plantations due to expense
Fertilization	Provides more nutrients for tree growth	May or may not impact the fungus	Not recommended due to expense, lack of positive results
Pruning	Removes lower branches/foliage	Removes healthiest and densest foliage from tree	Not recommended

Alternative or mixed species management

Choosing to plant Douglas-fir or an alternative species is a critical choice for landowners at stand establishment/regeneration. This is a decision based on disease hazard, future value, and other factors. If Douglas-fir is the preferred species, all the evidence points to local seed sources as most tolerant to disease. We recommend against moving seed from drier climates to wetter climates, or higher elevations to lower elevations. Genetic resistance to SNC has been the focus of much early research and testing. There appears to be no 'resistance' to the disease. However, there is variation in disease tolerance, as expressed in the ability to retain foliage and grow better in areas with light to moderate disease pressure. There appears to be clear gains in using improved seed stock with known tolerance to SNC in regions with moderate to low disease impacts. We recommend against planting DF stock, even if tolerant, where disease pressure is high. Tolerant stock may grow deceptively well for some years, but the trees could experience severe impacts under specific climate conditions and stop growing before they reach merchantable size at great cost.

If disease hazard is high, an alternative species is a better option. Typical alternatives to Douglas-fir include western hemlock, Sitka spruce, western redcedar, or red alder (Table 4). Each of these species has both positives and negatives associated with them and are not appropriate for every site. Sitka spruce, in particular, appears to be a poor choice anywhere but the most coastally exposed sites due to severe tip weevil incidence.

Table 4. Alternative tree species to Douglas-fir in Coastal PNW, and their pro's and con's. Value of logs/wood is not considered.

Tree Species	Pro's	Con's
Western hemlock	Fast growing alternative, can manage more trees/acre and volume/acre than DF	Wounds lead to decay (commercial thinning not recommended). Log values currently lower than DF.
Sitka Spruce	Fast growing whitewood, adapted to region.	Significant problem with tip weevil makes growing Sitka spruce outside of fog belt uneconomical.
Western redcedar	High value alternative, grows well in most sites.	Usually difficult to establish due to heavy browse from deer and elk. May not grow fast enough.
Red Alder	Fast growing, shorter rotation.	Only recommended for certain sites. Lower volume/acre than coniferous alternatives.

Mixed species stands do not diminish Douglas-fir's chances of being infected or the degree to which it becomes infected. In heavily infected stands, other species, such as western hemlock, red alder, and western redcedar will provide economic insurance against poorly performing Douglas-fir. It has been suggested that distance from coast might be a good metric for mixed species planting (see Figure 6,7,8), with no Douglas-fir in the near coast environment, and progressively mixing Douglas-fir into the planting regime as distance from coast increases and disease levels abate.

Vegetation management

There is no evidence that vegetation management decreases disease severity or improves the growth of infected trees beyond the benefits of greater resource availability due to the diminished cover of competitor species. However, the reduced yield expected for infected Douglas-fir trees may make the economic cost of vegetation management disadvantageous.

Thinning

Analyses of thinned infected stands have found that thinning does not reduce disease severity. Nevertheless, light to moderately infected stands will respond to thinning with increased diameter growth, severely infected stands may not. The response is also slower than if the stands are healthy, and the subsequent growth won't match that of healthy stands. The economics of thinning is not considered in this discussion, but in infected stands, the benefits of thinning are likely to be more structural than economic.

Because SNC negatively affects growth, thinning from below generally retains the largest and healthiest Douglas-fir trees displaying the greatest resistance. If alternative species are mixed in the stand, they can be retained as insurance for future stand viability in the event of poor Douglas-fir performance. The reduced growth rates of Douglas-fir in mixed-species stands may allow other species to grow faster and should be considered during thinning operations.

One approach for choosing between Douglas-fir and alternative species in a pre-commercial thinning has been developed by Stimson Lumber Company foresters. The “D-minus” rule involves giving a fast-growing tree such as western hemlock a size credit against adjacent Douglas-fir that may not grow as fast. Depending on disease severity at the site, a hemlock that is smaller in dbh than an adjacent Douglas-fir would be retained, and the DF would be removed because analysis has shown that the hemlock will ultimately outgrow the Douglas-fir. The diameter differential varies depending on disease severity and tree diameter.

Fungicides

Fungicide use is common in Douglas-fir Christmas tree plantations. Chlorothalonil (Bravo) and sulfur have been assessed in forestry plantations, where they have been used as a protectant. Bravo is effective, but any fungicide must be used every year to maintain needle retention because new foliage is colonized each year. Expense and toxicity, especially to aquatic animals, make general use prohibitive. Sulfur has shown marginal effectiveness and treatment is expensive and must be done in the spring when wet weather can make the application logistically difficult and potentially ineffective. Again, only current year foliage is protected. If fungicides are being considered, check the Pacific Northwest Plant Disease Management Handbook for currently registered fungicides (https://pnwhandbooks.org/plantdisease/host-disease/fir-douglas-pseudotsuga-menziesii-needle-cast-swiss)

Fertilization

There have been several studies looking at N only and N-P-K+ custom blends. Results show on average, no increase or decrease in disease severity associated with fertilization in ~20-year-old stands. One seedling study has shown an increase in disease severity associated with high N and high foliar nitrogen concentrations are already associated with SNC-infected stands across the Coast Range of Oregon. The cause-effect relationships are uncertain. Because fertilization has become expensive, it should be reserved for stands where a positive response is expected. Therefore, SNC-infected stands should be disqualified as candidates for fertilization.

Pruning

Although there have been no studies of pruning and SNC, pruning is not recommended since needle retention in the lower crown is greatest in SNC infected trees. Furthermore, capturing the cost of pruning requires sufficient diameter growth, and SNC-infected trees will not provide it.

To retain or not to retain…

Some pre-merchantable stands are performing so poorly, it is unclear whether they will reach merchantable size in an acceptable amount of time. Based on observation and anecdotal information, stands meeting this description are growing in zones where SNC pressure has been high for years, and periodic improvement in conditions seems unlikely. The authors are unaware of very poorly performing stands that “turn the corner”. This should be kept in mind when stands are being regenerated.

Published literature concerning management of Swiss needle cast:

For a complete list of publications on SNC, see the SNCC website: http://sncc.forestry.oregonstate.edu/

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