Swiss needle cast epidemiology

Environmental factors affecting disease distribution and severity

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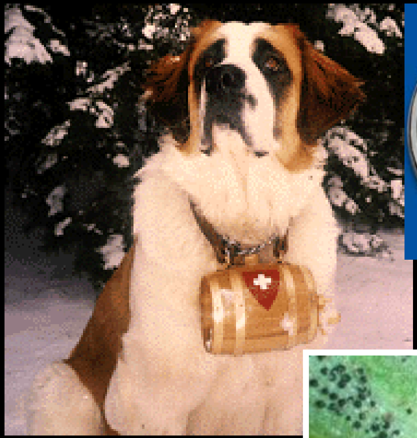
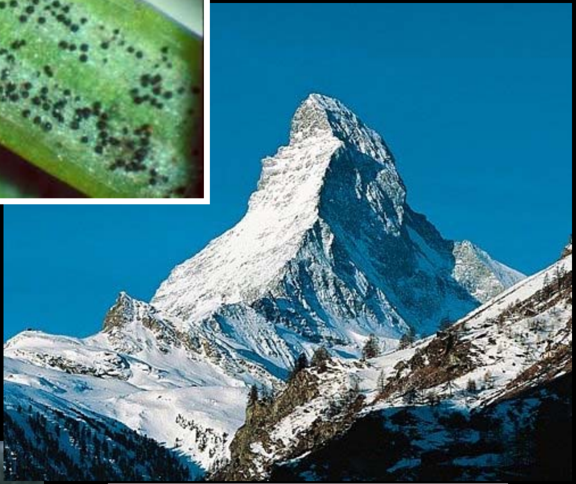
Why is it called Swiss needle cast?







SNC History

Foliage disease first observed in 1925 in Douglas-fir plantations in Switzerland; later (1931, 1934) from s. Germany and Austria. By 1940 fungus spread to Denmark, throughout Switzerland, s. Germany.

Pathogen identified as new, named *Phaeocryptopus* (=*Adelopus*) *gaeumannii*.

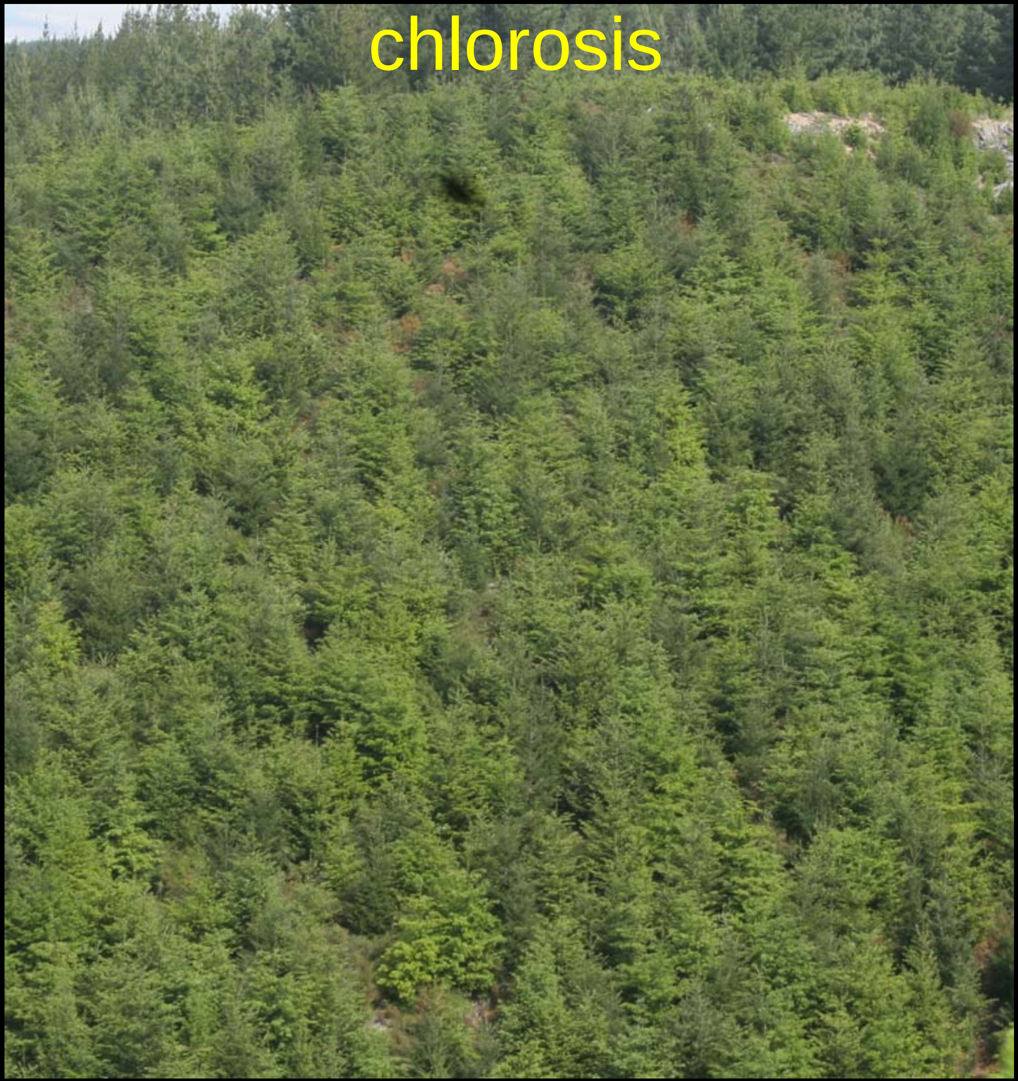
P. gaeumannii also found in British Isles, with severe disease noted in Ireland (1927, 1928).

P. gaeumannii first reported from U.S. (Connecticut) in 1938 but present prior to 1929. Widespread in New England states by 1940.

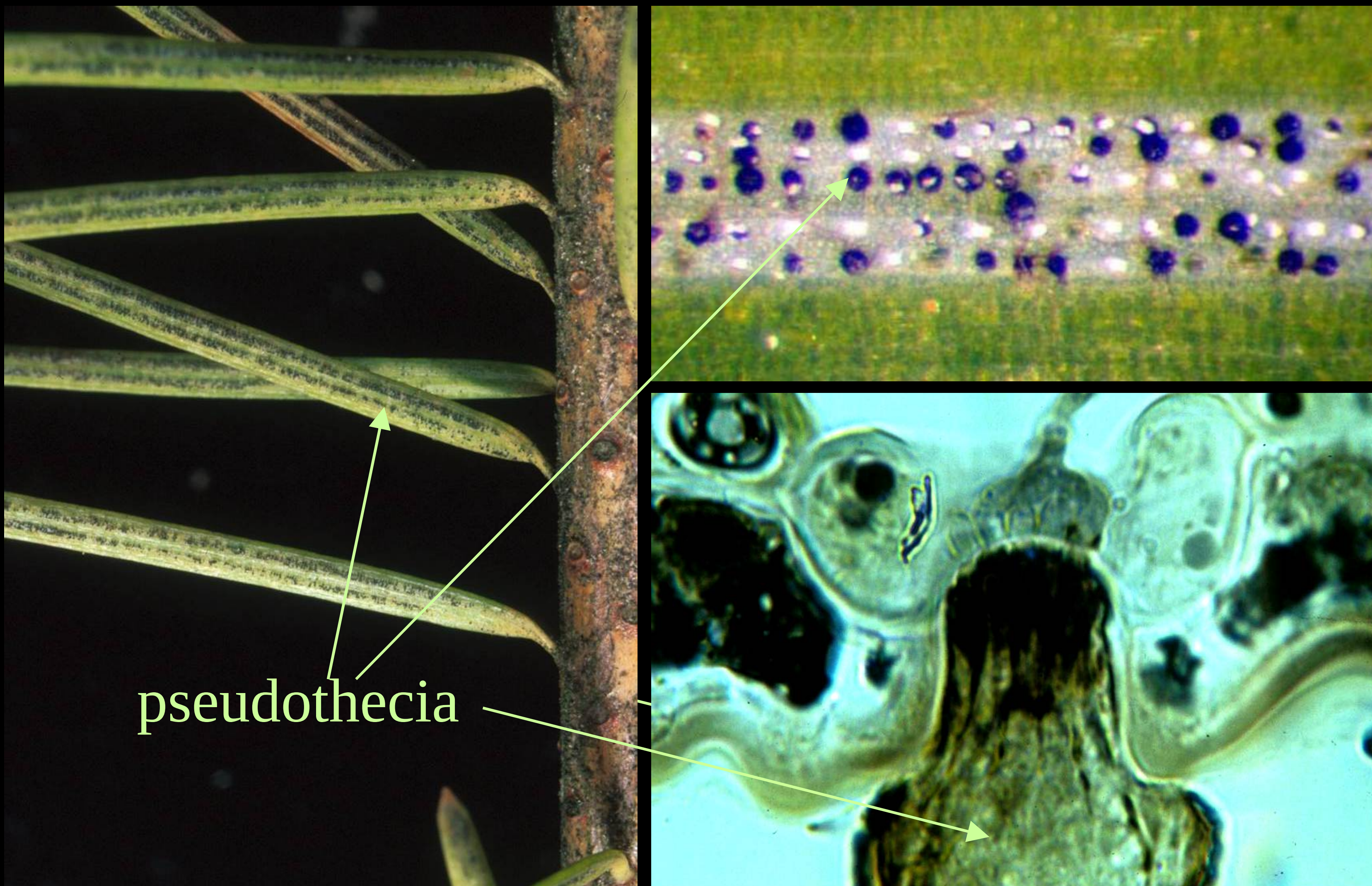
Present on herbarium specimens collected in 1916, 1921 (Oregon), and 1923 (n. California). Found throughout the Pacific Northwest and reported from native Douglas-fir in New Mexico (1939).

The pathogen has become distributed worldwide together with its host because infections can be very inconspicuous.

The disease: Swiss needle cast



The Pathogen: *Phaeocryptopus gaeumannii*



Since then the fungus has been found at such widely separated localities in British Columbia, Washington, and Oregon that it must be considered generally distributed, although harmless in the Douglas-fir region of the Pacific Coast.

In the Douglas-fir region of the Pacific Coast, even though the fungus is prevalent, it has caused no injury.

J. S. Boyce, Yale University, 1940

This is a classic case of a disease, of no importance in its native haunts, which has become damaging when transported to other areas.

T. R. Peace, British Forestry Commission 1962

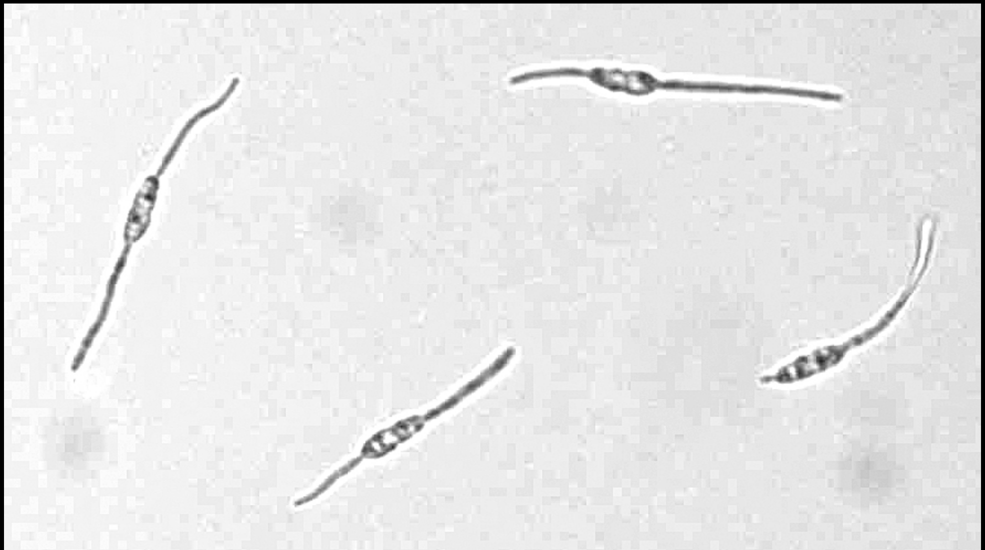
What changed, and why?

- **Swiss needle cast currently affects 400,000 acres in western Oregon**
- **Cubic <u>volume growth loss</u> in the area affected ranges from 20 – 50%[A]**
- **Volume losses average 21% for 2004 - 2007[B]**
- **Growth loss = 8.6 million cu ft or 34 million board-feet per year**

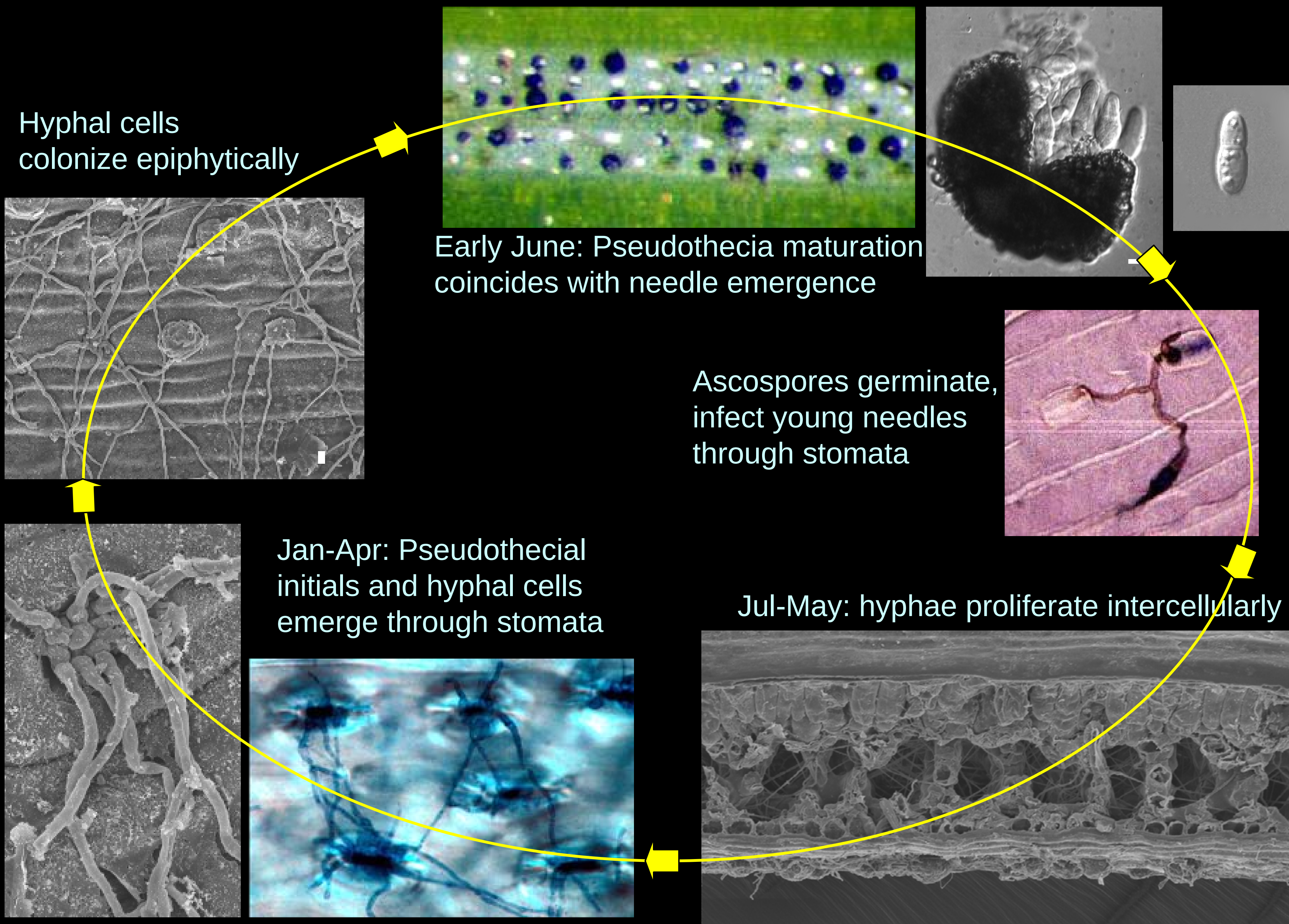

[A] Maguire et al. 2002 Western Journal of Applied Forestry 17: 86-95
[B] Mainwaring et al. SNCC Annual Report 2008, pp. 13-17.

Pathogen biology

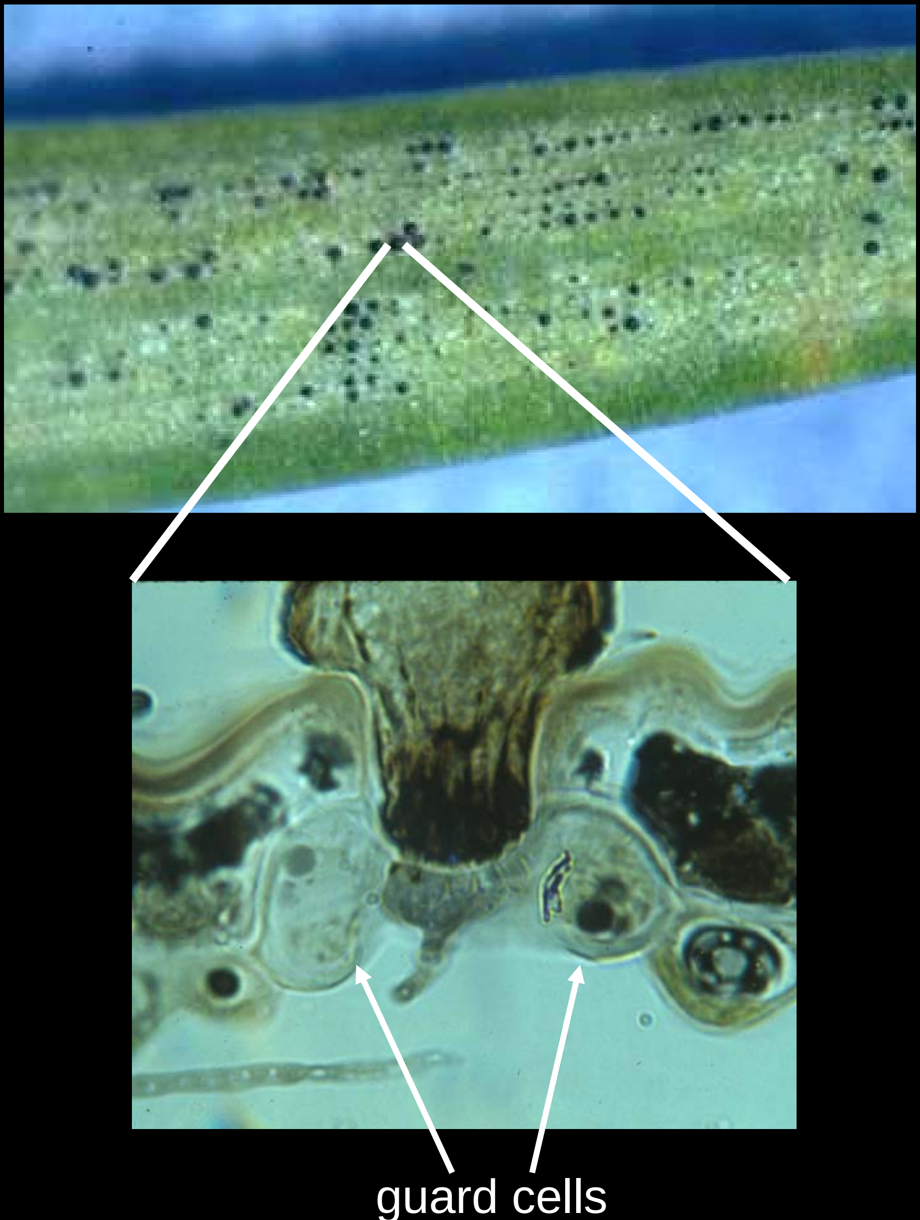
- Douglas-fir is the only host
- Reproduction, infection by ascospores, one cycle per year
- Ascospore release, new infection coincides with needle flush
- Only found in living needles
- Colonization of needles <u>intercellular</u> only
- Does not colonize vascular tissue, restricted to needles
- Pathogen does not persist on dead needles



Infection cycle: 12 months from spore to spore



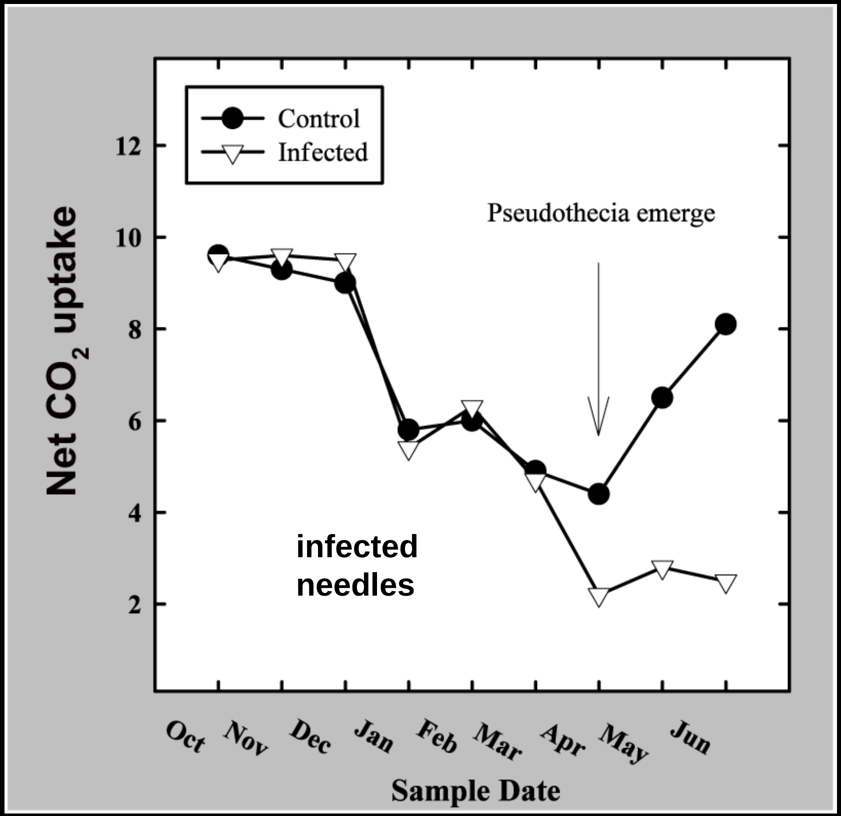
Disease is caused by occlusion of stomates



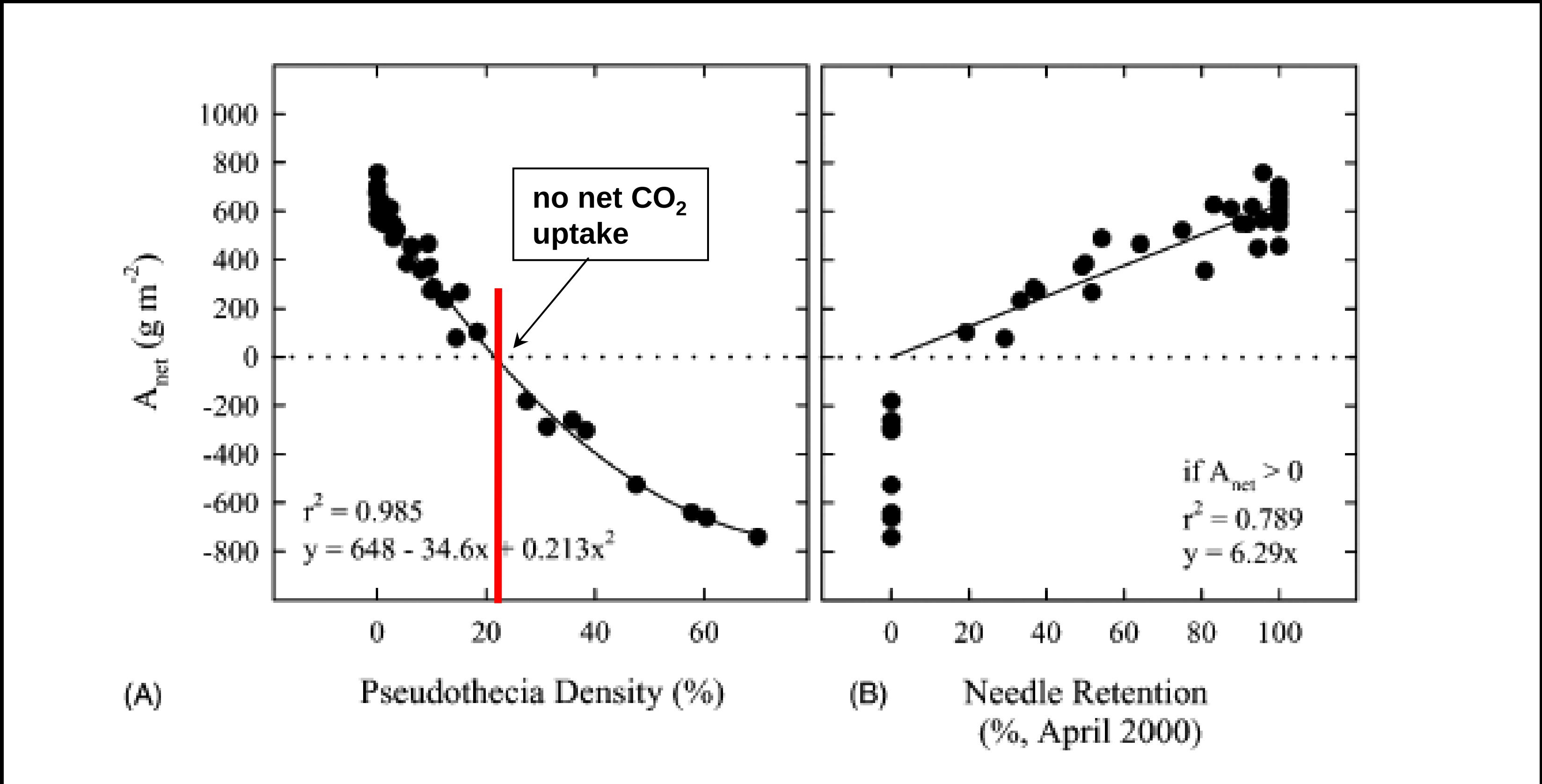
Fruiting bodies, pseudothecia, of the fungus block stomates

Gas exchange is impaired, reducing net CO_2 assimilation

Reduced CO_2 uptake coincides with emergence of pseudothecia in spring



Relationship between proportion of stomata occluded, CO_2 uptake and needle retention



CO_2 uptake decreases as the number of pseudothecia increases
Foliage retention decreases as CO_2 uptake decreases

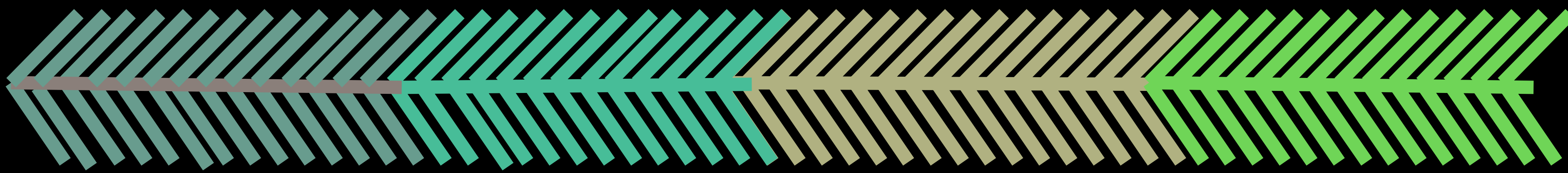
If about 25% of stomates are blocked, net CO_2 uptake is zero.

Manter et al. 2003 Ecological Modelling 164: 211-226

The less foliage on the tree, the less the volume growth

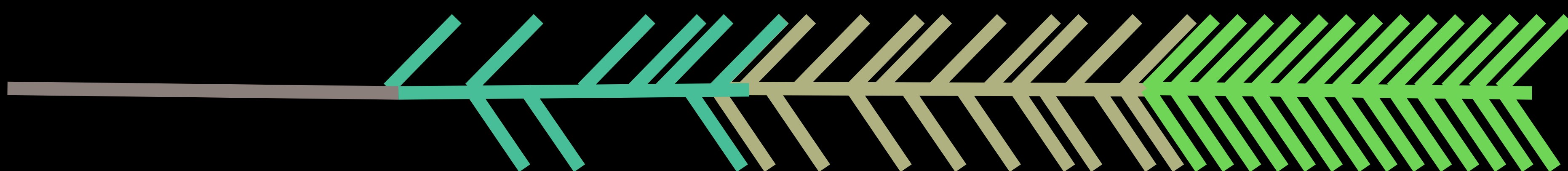
Effect of SNC is premature loss of older needles

Normal needle retention, 3.9 years



2.5 years of foliage, volume growth reduction of up to 14-30%

1.6 years of foliage, volume growth reduction of 30-50%



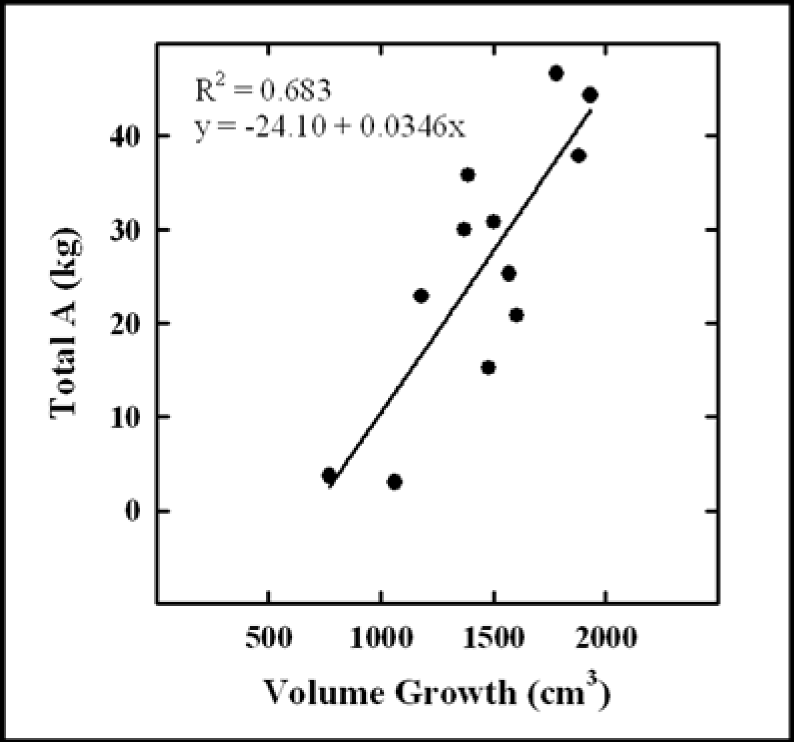
Maguire et al. 2004, Swiss needle cast cooperative annual report

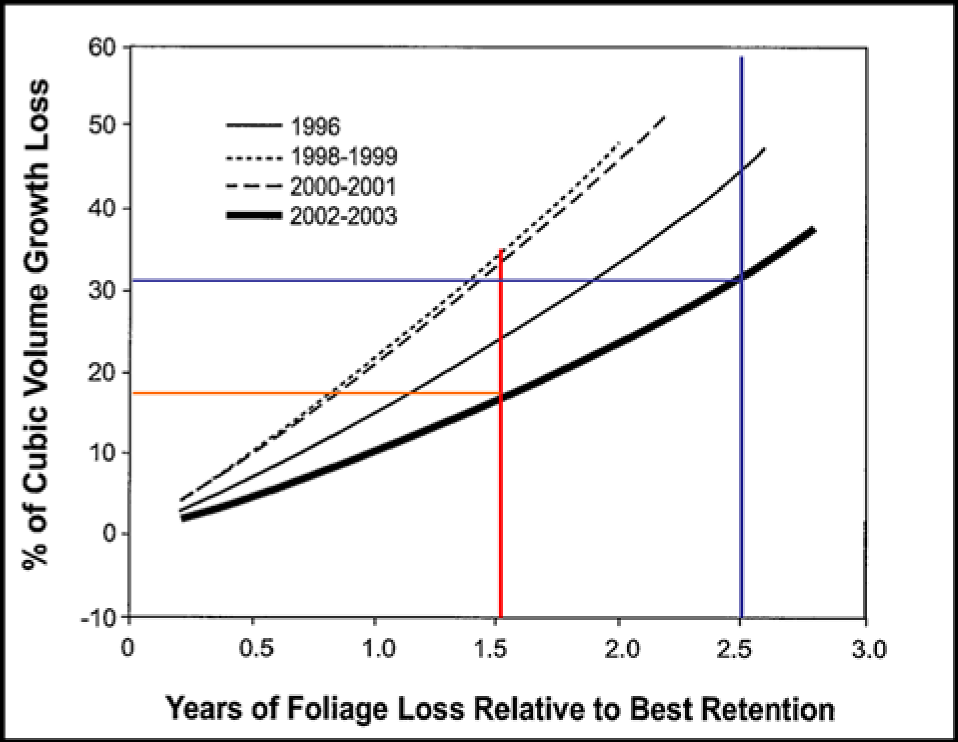
Relationship between % volume loss and foliage retention

20% growth loss at average 2.5 years needle retention

Mainwaring et al. SNCC Annual Report 2008, pp. 13-17

Relationship between Anet, foliage retention and volume growth





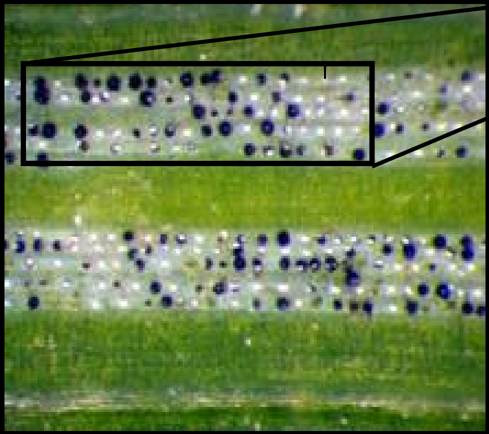
Less photosynthesis means there is less sugar produced to build wood volume

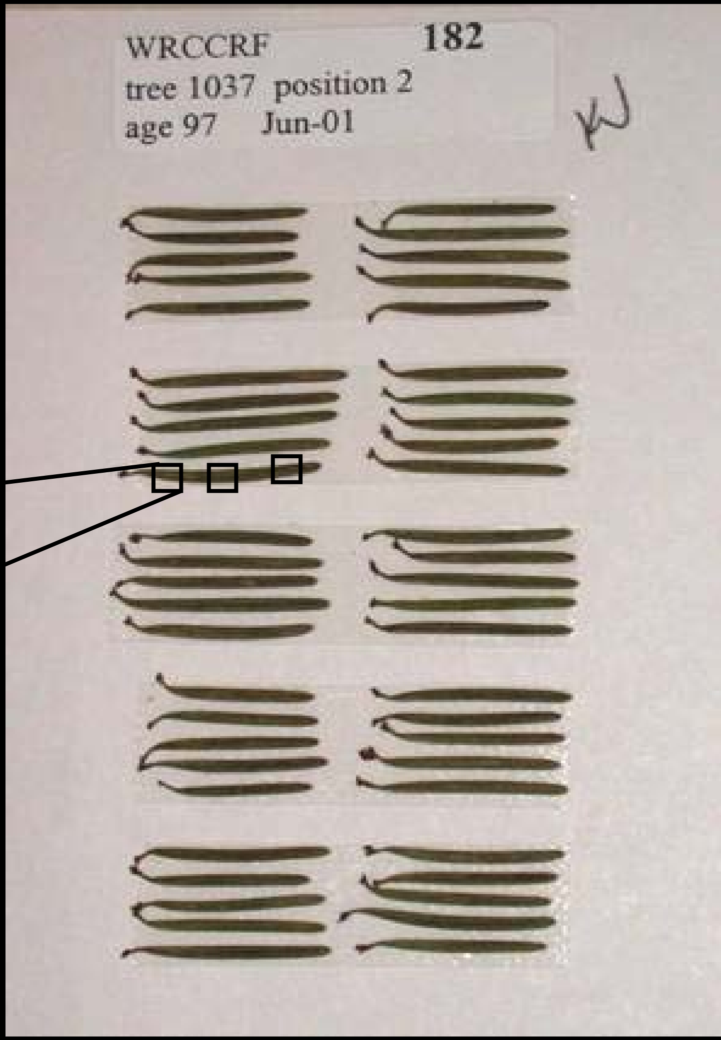
Trees bearing 2.5 yrs foliage: growth loss of 15-30%
Trees bearing 1.5 years of foliage: growth loss of 30-50%

Maguire et al. 2004, Swiss needle cast cooperative annual report

Phaeocryptopus gaeumannii quantification

Because the proportion of occluded stomata is directly related to disease, it is a good response variable for comparing environmental effects on disease severity.





Pseudothecia counts:

Incidence = # infected / 50 needles

Severity = avg # $\frac{\text{pseudothecia in area}}{\text{total stomata in area}}$

colonization index = incidence x severity x 100

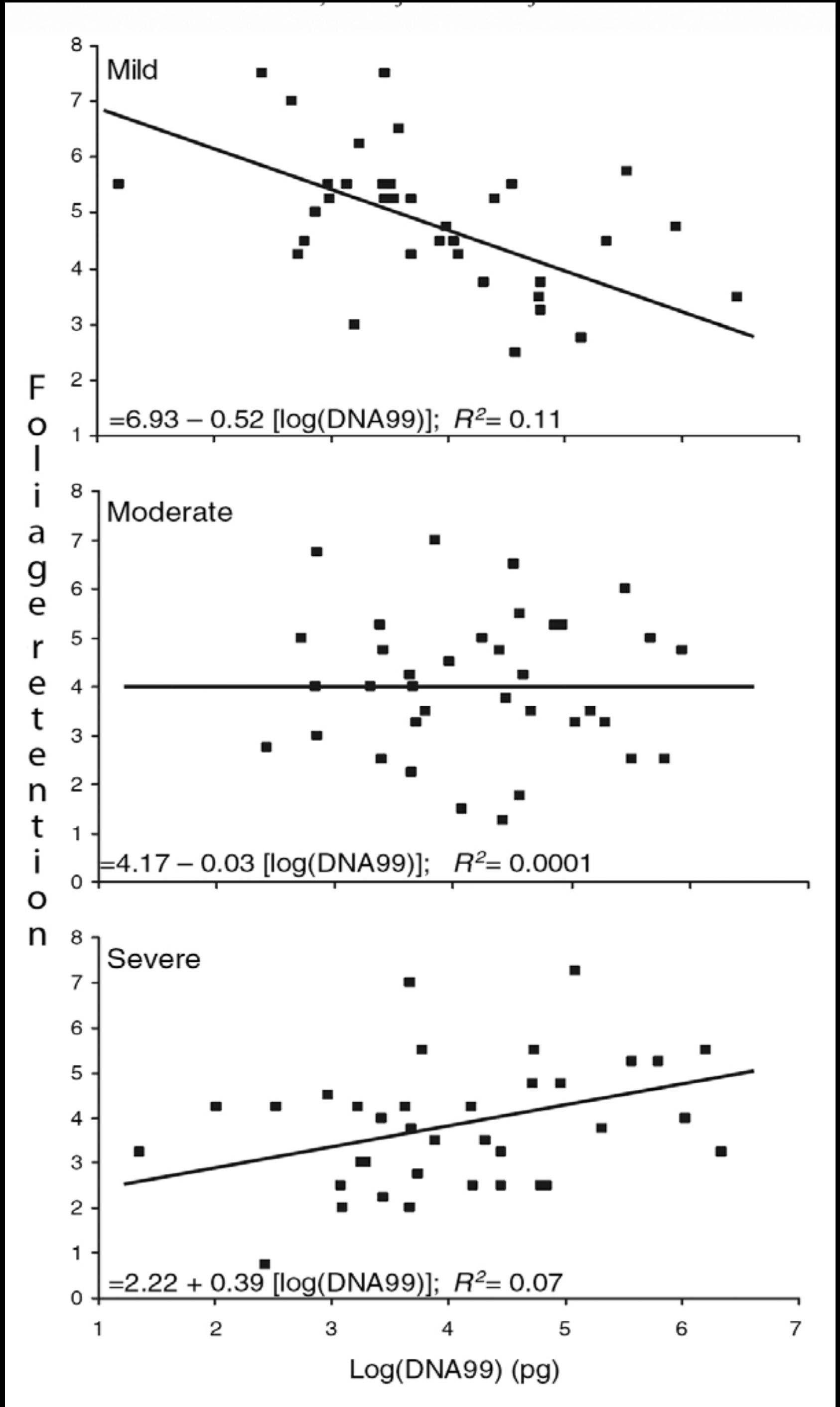
Variation in Douglas-fir genotypes with respect to foliage retention and *P. gaeumannii* abundance

Douglas-fir families characterized as displaying mild, moderate or severe symptoms under comparable disease pressure.

There is wide variation in foliage retention across Douglas-fir families.

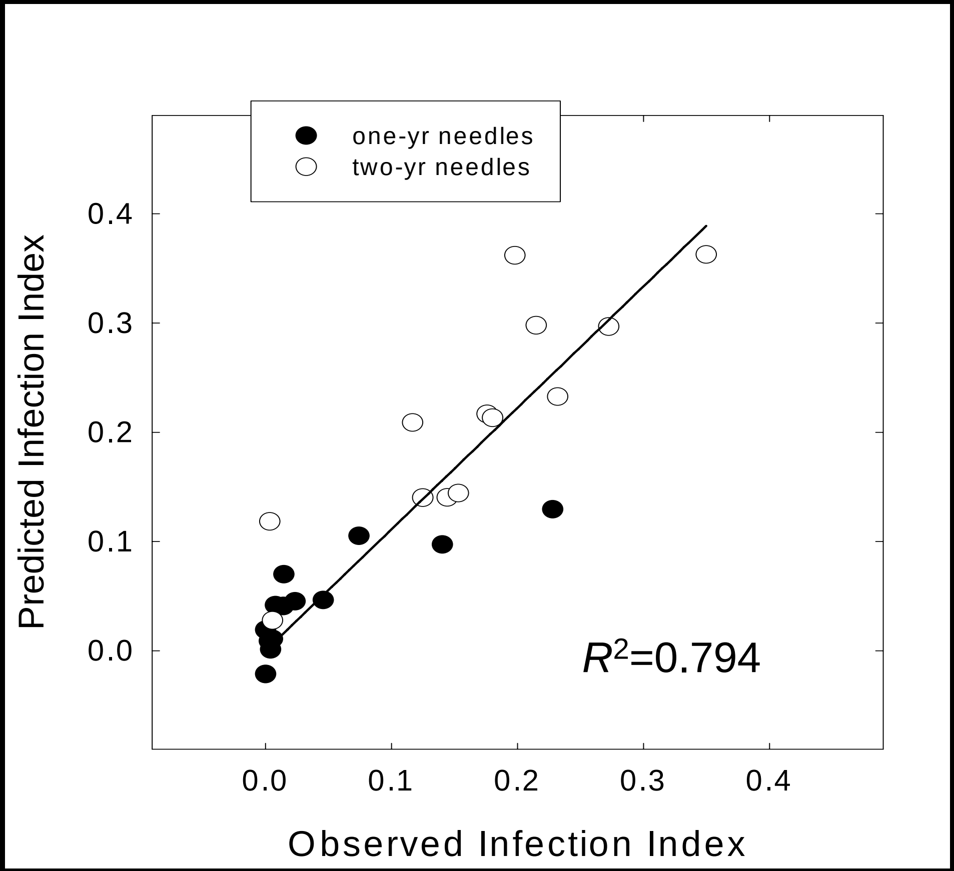
All genotypes are susceptible to infection but vary in degree of defoliation with amount of pathogen.

Families expressing more severe symptoms lose foliage with smaller amount of pathogen



Predicting Swiss Needle Cast Severity

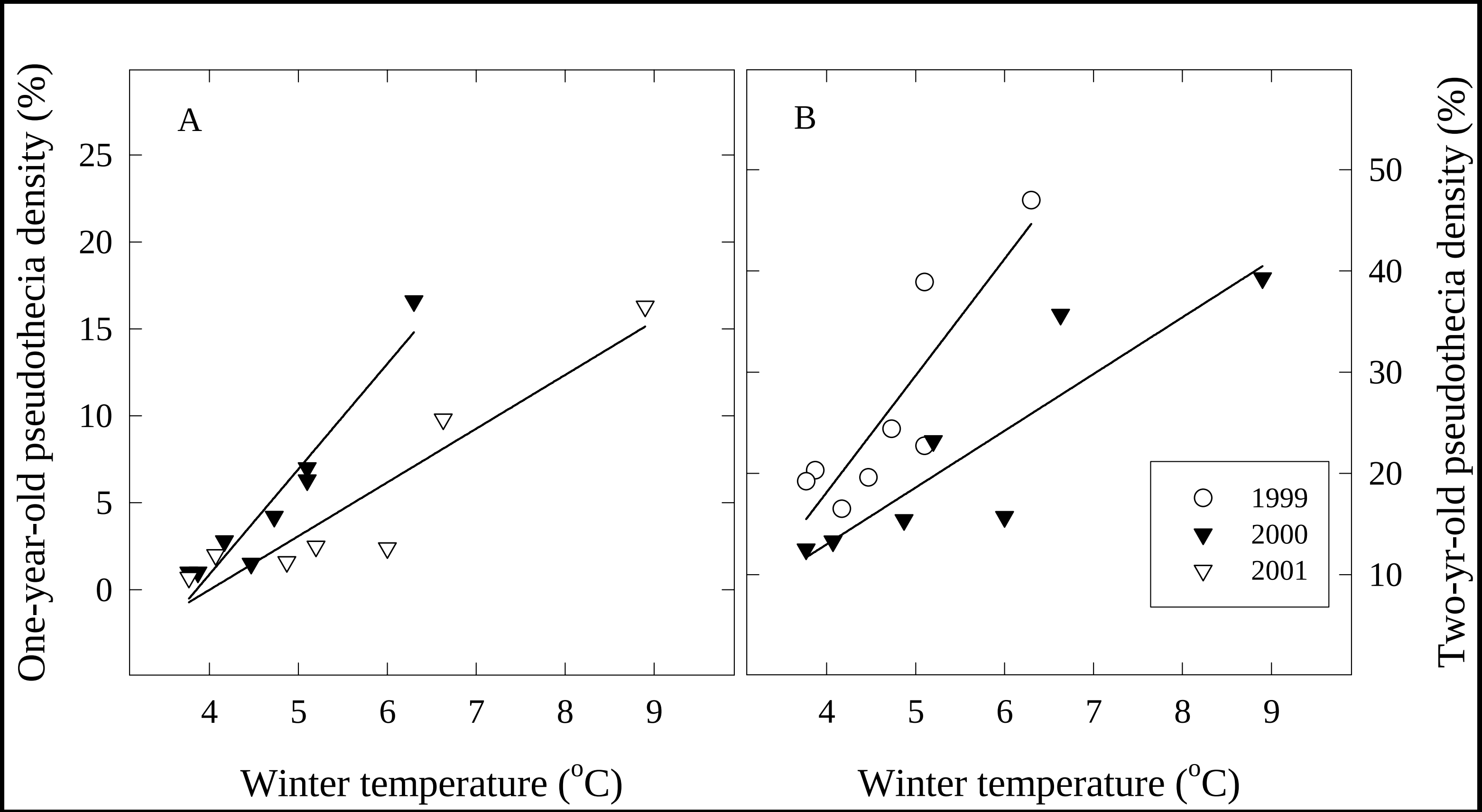
The best predictors of disease severity in Oregon coastal study sites are mean daily winter temperature and spring leaf wetness, because of their effects on infection and pathogen growth



Climate-only model:

Predicted vs. observed values for numbers of pseudothecia on one- and two-year-old needles for sites in the Coast Range, based on winter (Dec-Feb) average daily temperature, spring leaf wetness.

Regression between *Phaeocryptopus gaeumannii* pseudothecia values for (A) one- and (B) two-year-old needles and average winter temperatures.

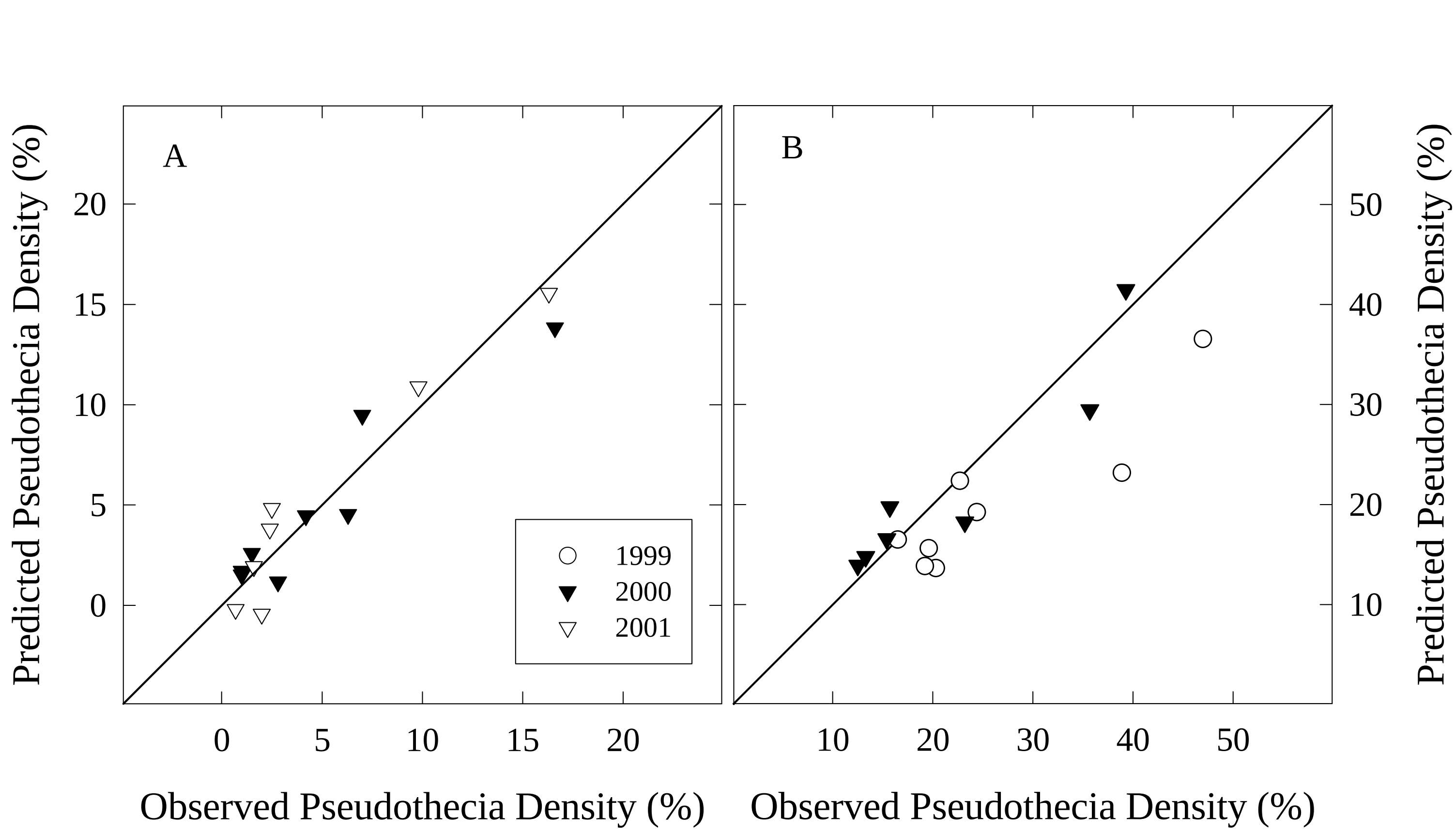


If winter temperature is only term, slope varies by year:

**current year disease levels are not independent of previous year

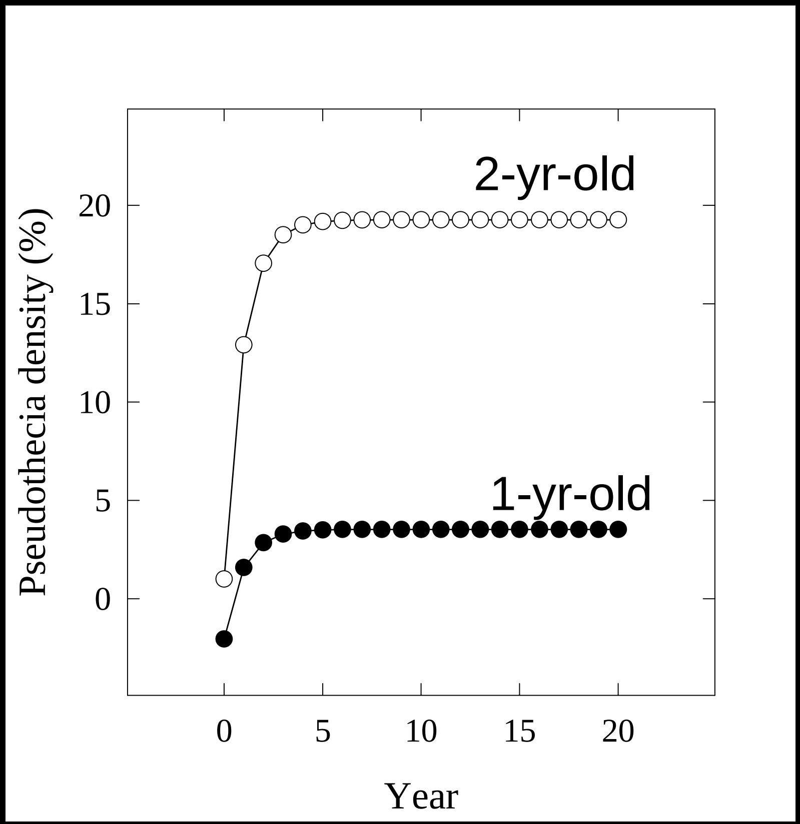
Manter et al. 2005. Phytopathology 95: 1256-1265

Adding terms for preceding year colonization allows prediction of disease levels independent of year with winter temperature only

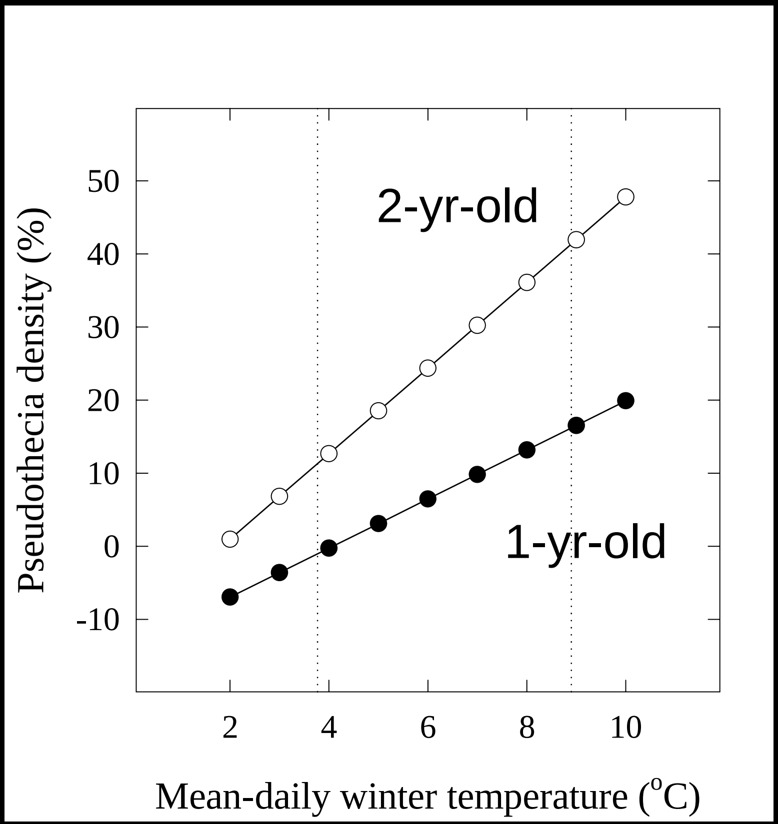


Observed vs. predicted *Phaeocryptopus gaeumannii* pseudothecia abundance using the best two predictors - winter temperature and previous year colonization index - for (Panel A) one-year-old and (Panel B) two-year-old needles.

Manter et al. 2005. Phytopathology 95: 1256-1265

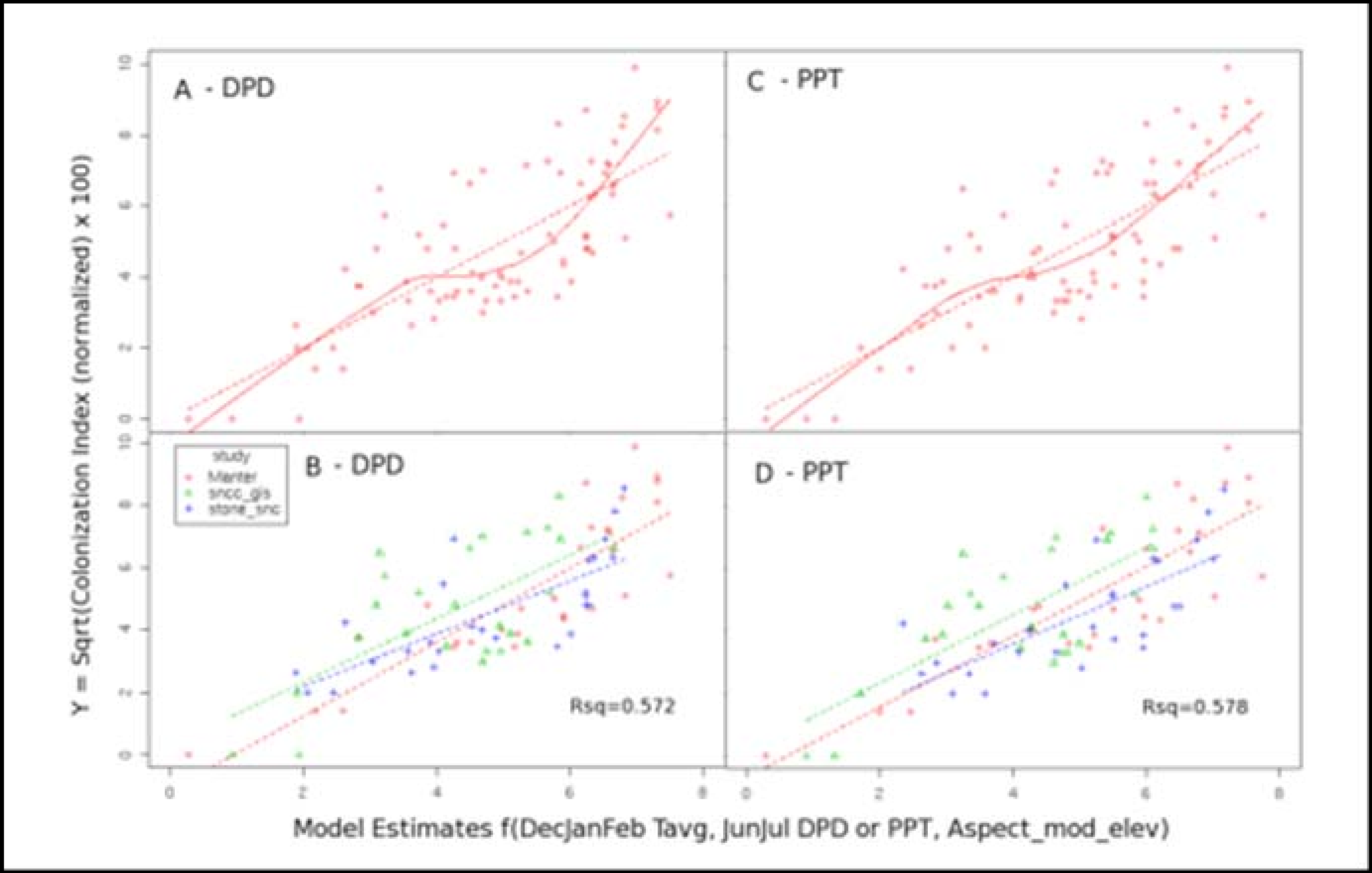


Simulation of *Phaeocryptopus gaeumannii* pseudothecia abundance over time for one-year-old and two-year-old needles. Mean-daily winter temperature was held constant at 5.13 ºC and the initial colonization index was set to 1.0 %.



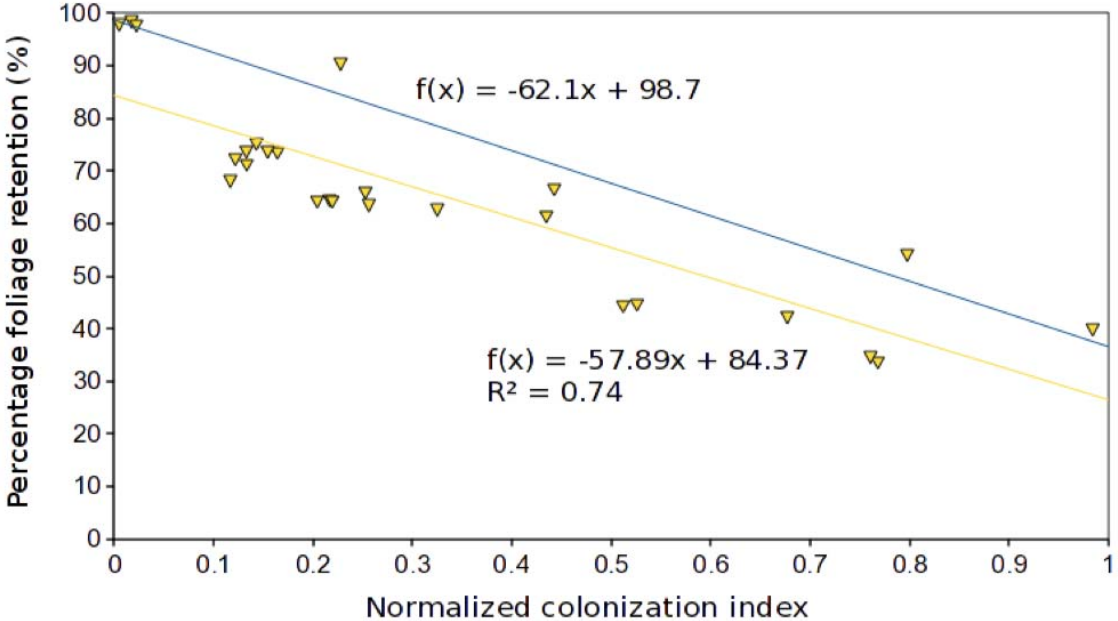
Simulated final *Phaeocryptopus gaeumannii* colonization index for one-year-old and two-year-old needles over a range of constant winter temperatures. Vertical lines represent the high (8.90 ºC) and low (3.77 ºC) mean-daily winter temperatures observed from coastal study sites.

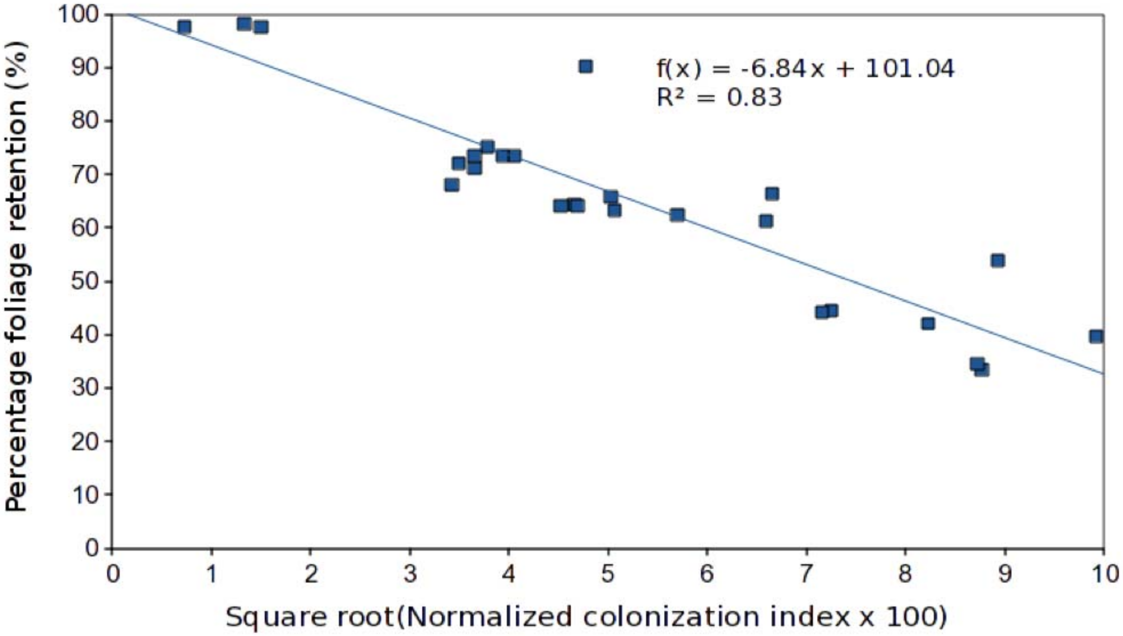
Refined models include average winter temperature and June-July dewpoint deficit or total precipitation



Dewpoint deficit (DPD) = avg temp - dewpoint, an estimate of free water availability

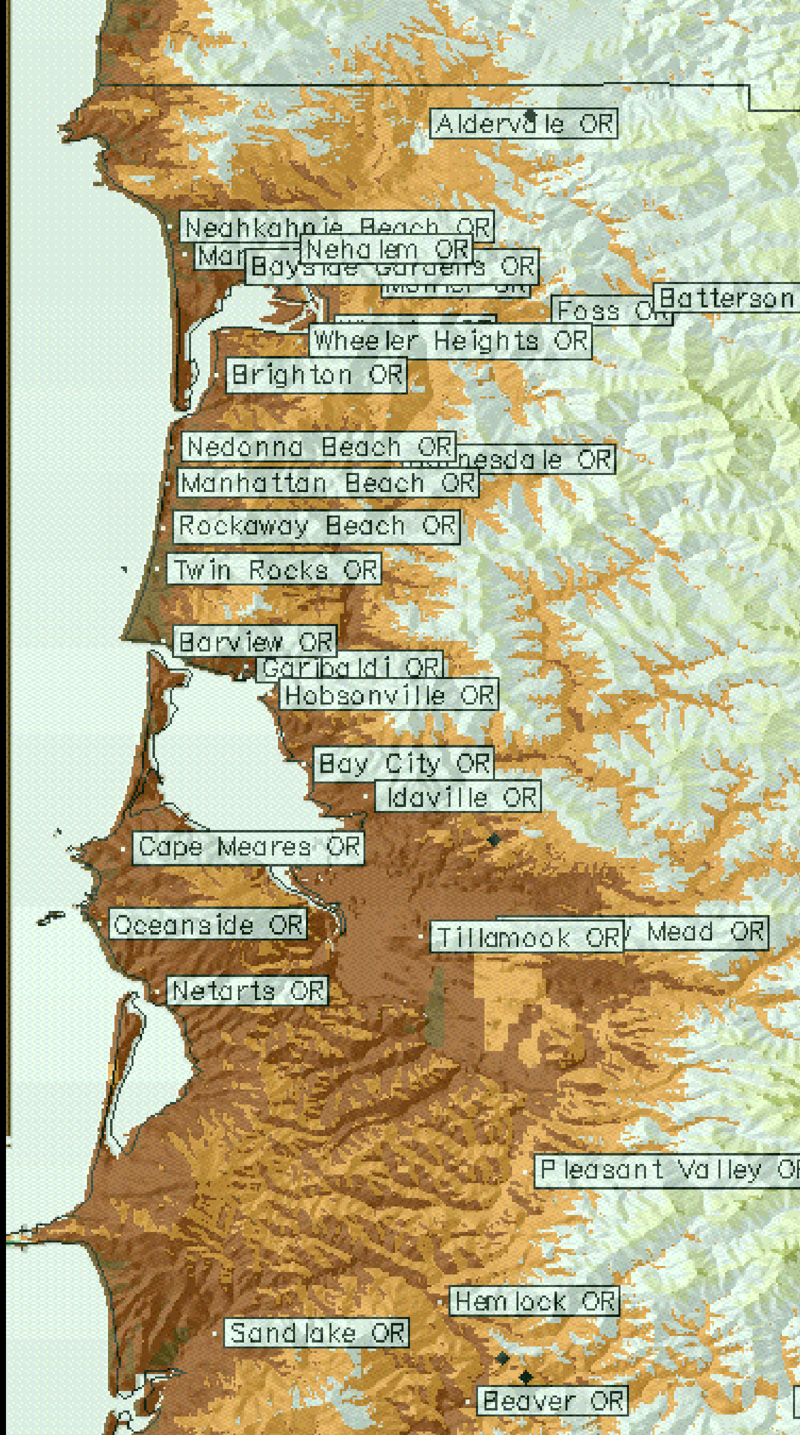
Both model forms predict distribution of SNC under current climate

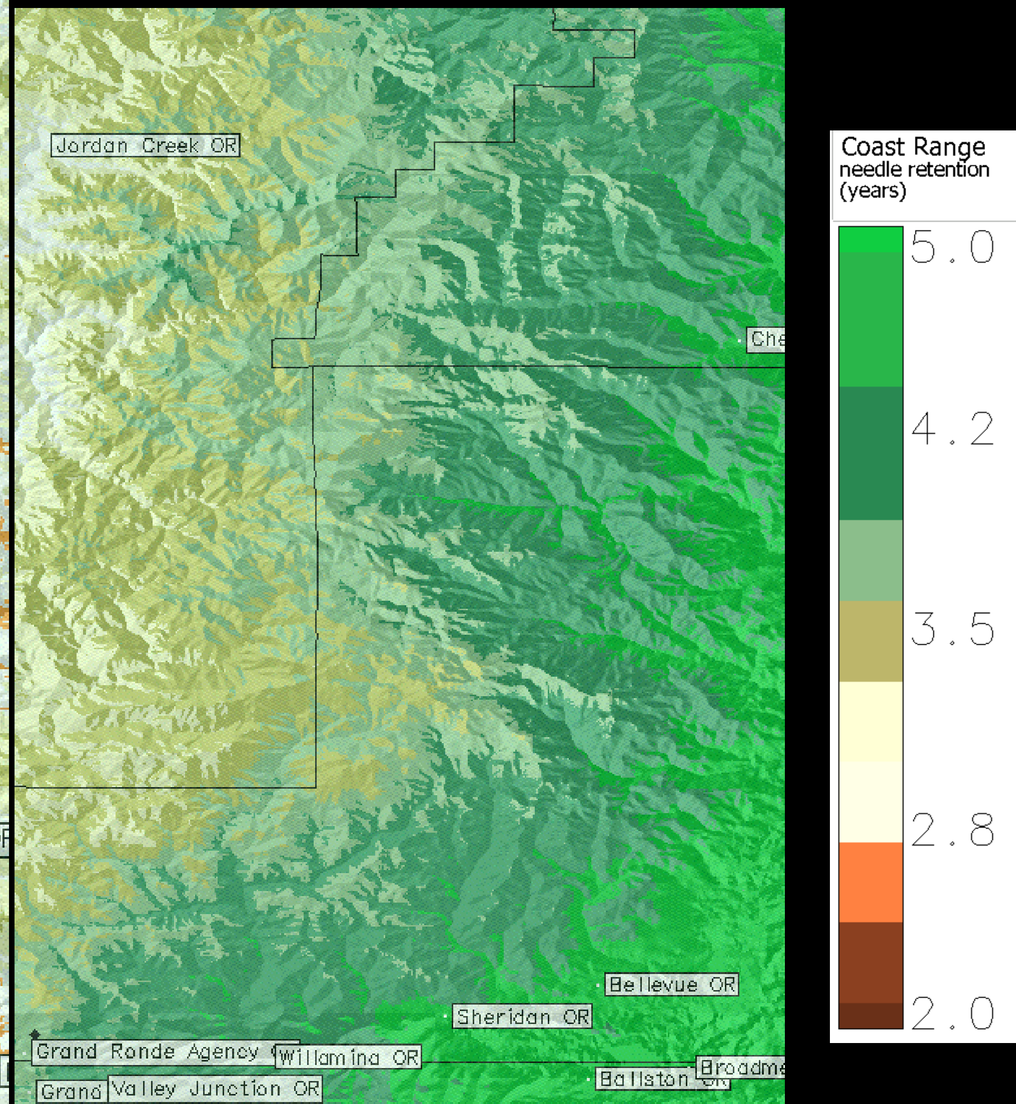




Models for conversion of abundance of P. gaeumannii pseudothecia and foliage retention

Climate based models for disease severity can be used to generate spatial models of disease severity based on high resolution climate models





Swiss needle cast in New Zealand

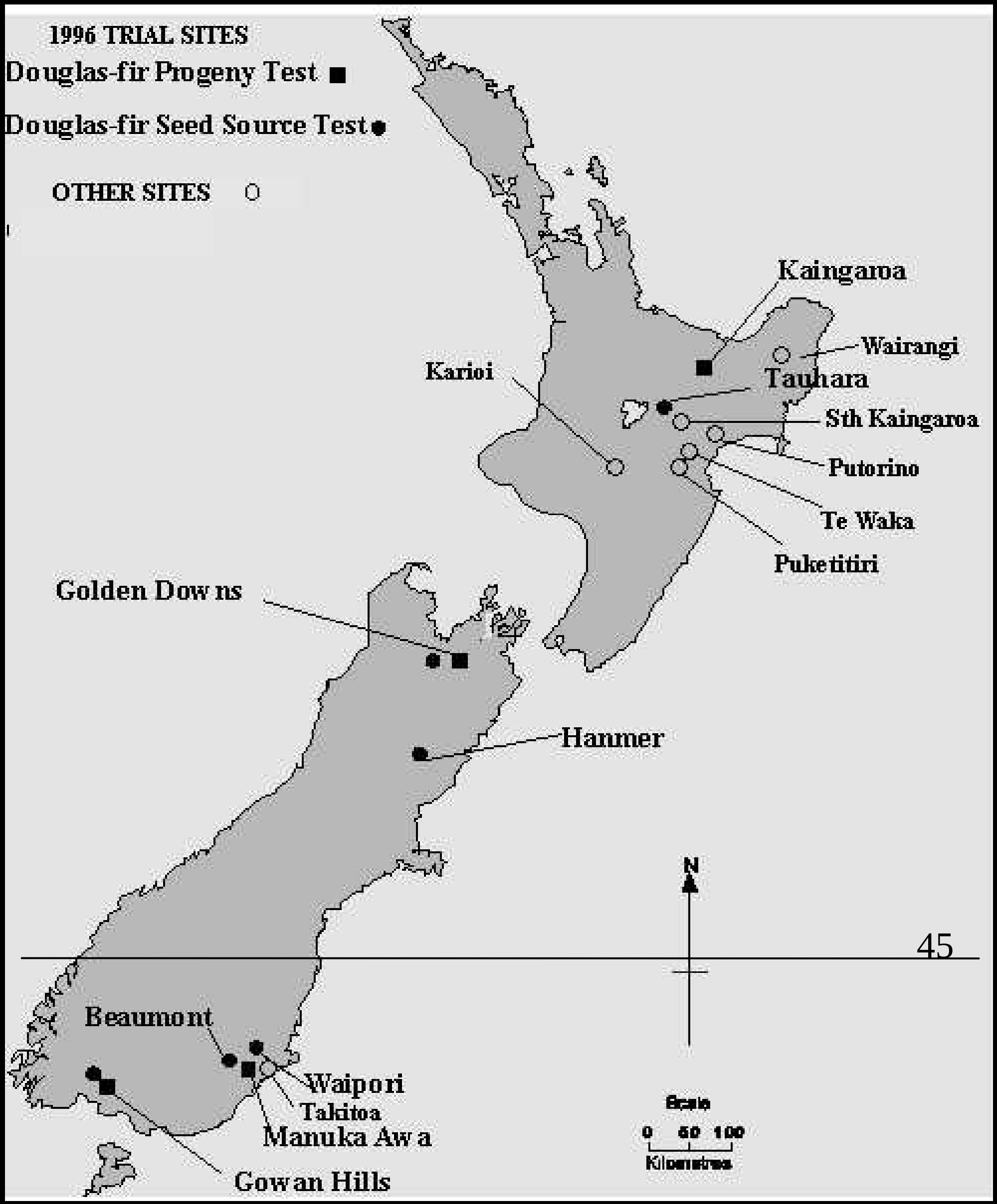
Douglas-fir grown as an exotic
***P. gauemannii*/Swiss needle cast present since ~1959**
Can be used to test climate models for Oregon

Growth impact of SNC in New Zealand

In the first 15 years following its detection in New Zealand SNC caused an average reduction of 30% of stem volume (CAI, current annual increment)

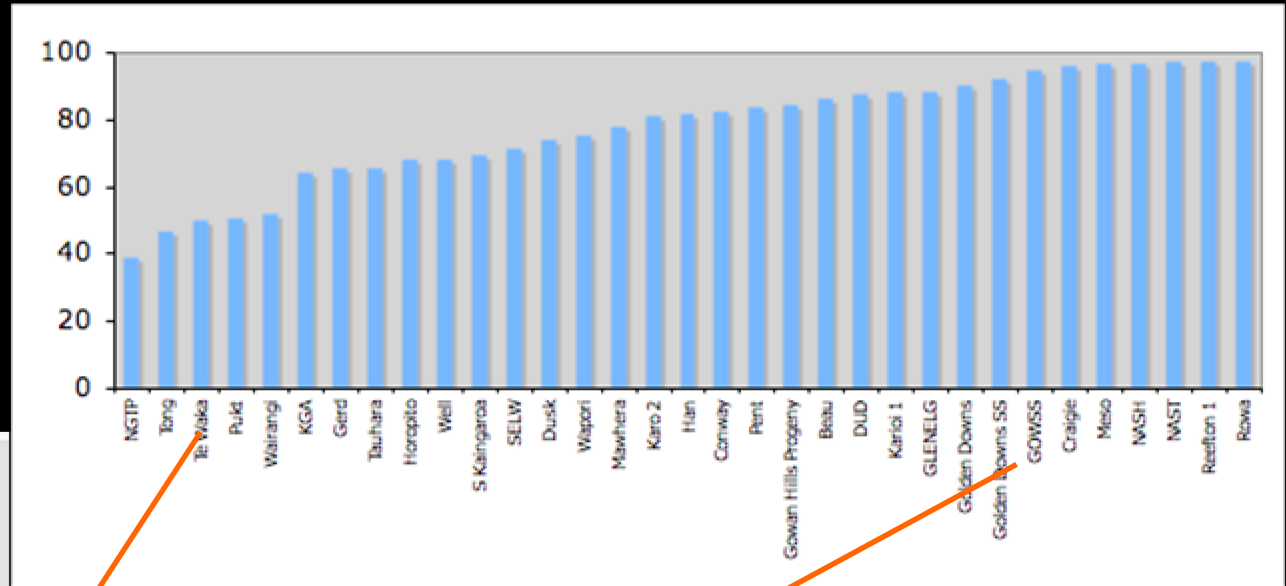
Kimberley et al. 2010. Phytopathology (in press)

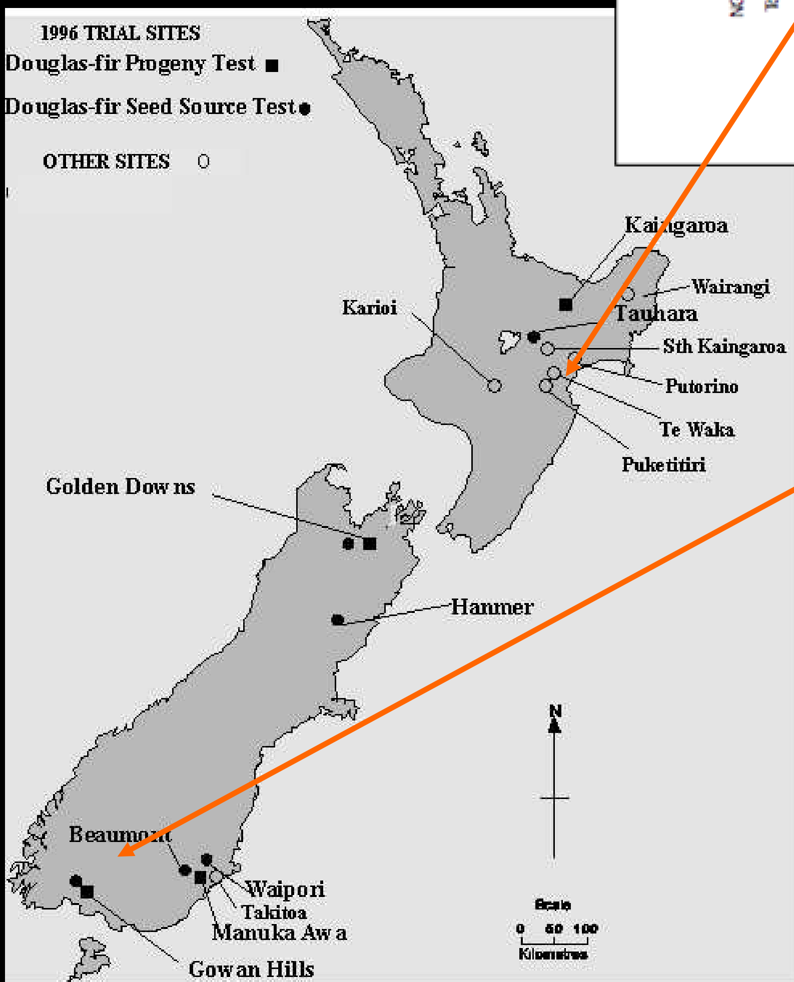
Distribution of SNC in New Zealand also is strongly correlated with climate factors affecting abundance of *P. gaeumannii*



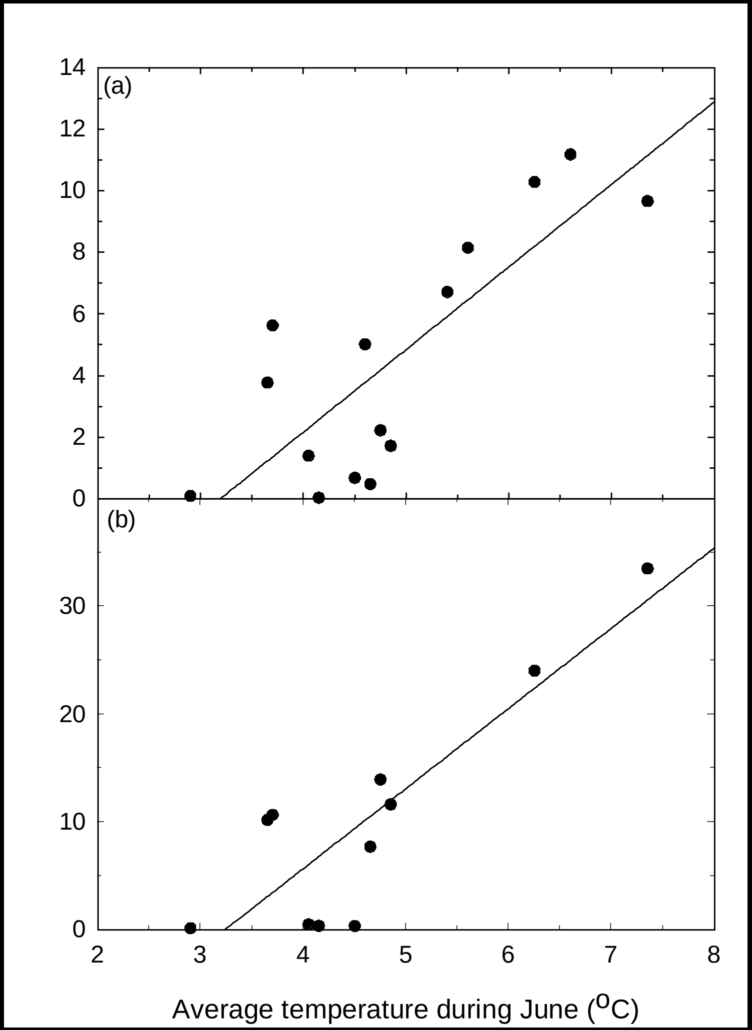
New Zealand Plantations sampled in 2006

Average needle retention for New Zealand sites





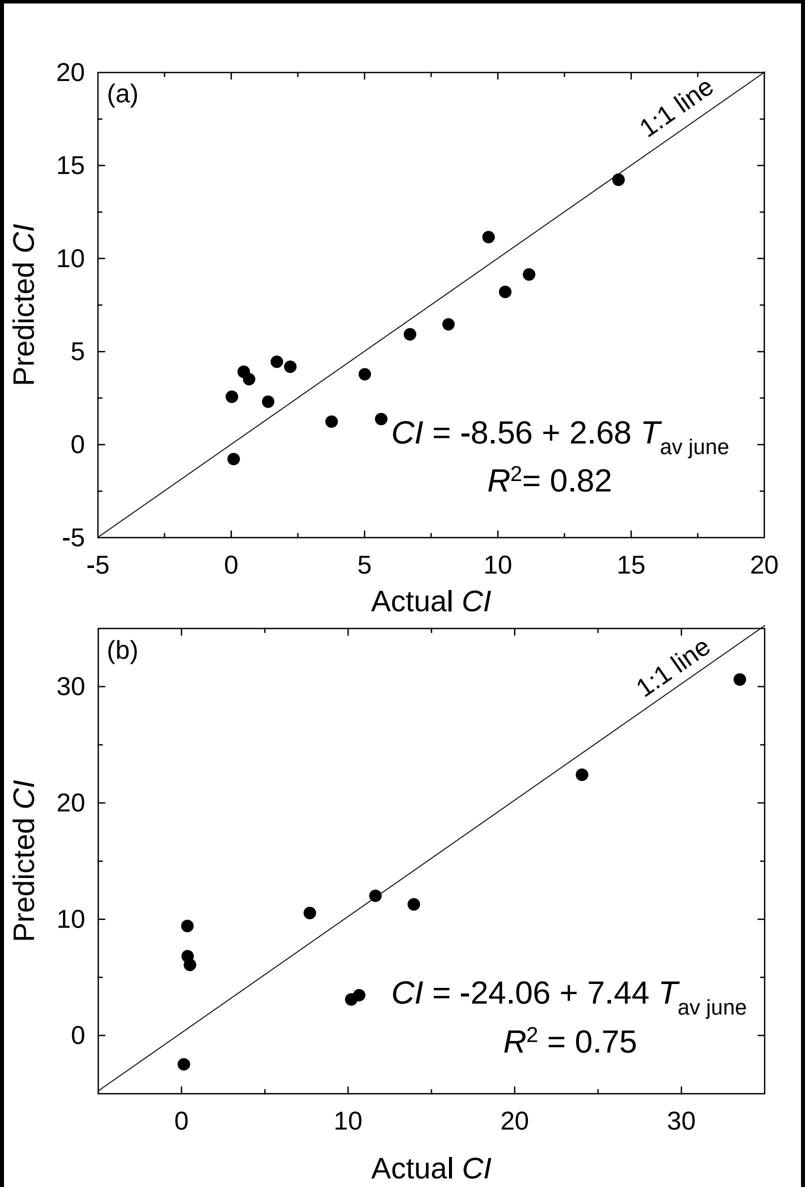
Best predictor of *P. gaeumannii* abundance and foliage retention in New Zealand is winter (June) mean temperature



Relationship between *P. gaeumannii* abundance and foliage retention

Stone et al. 2007. Australasian Plant Pathology 36:445-454.

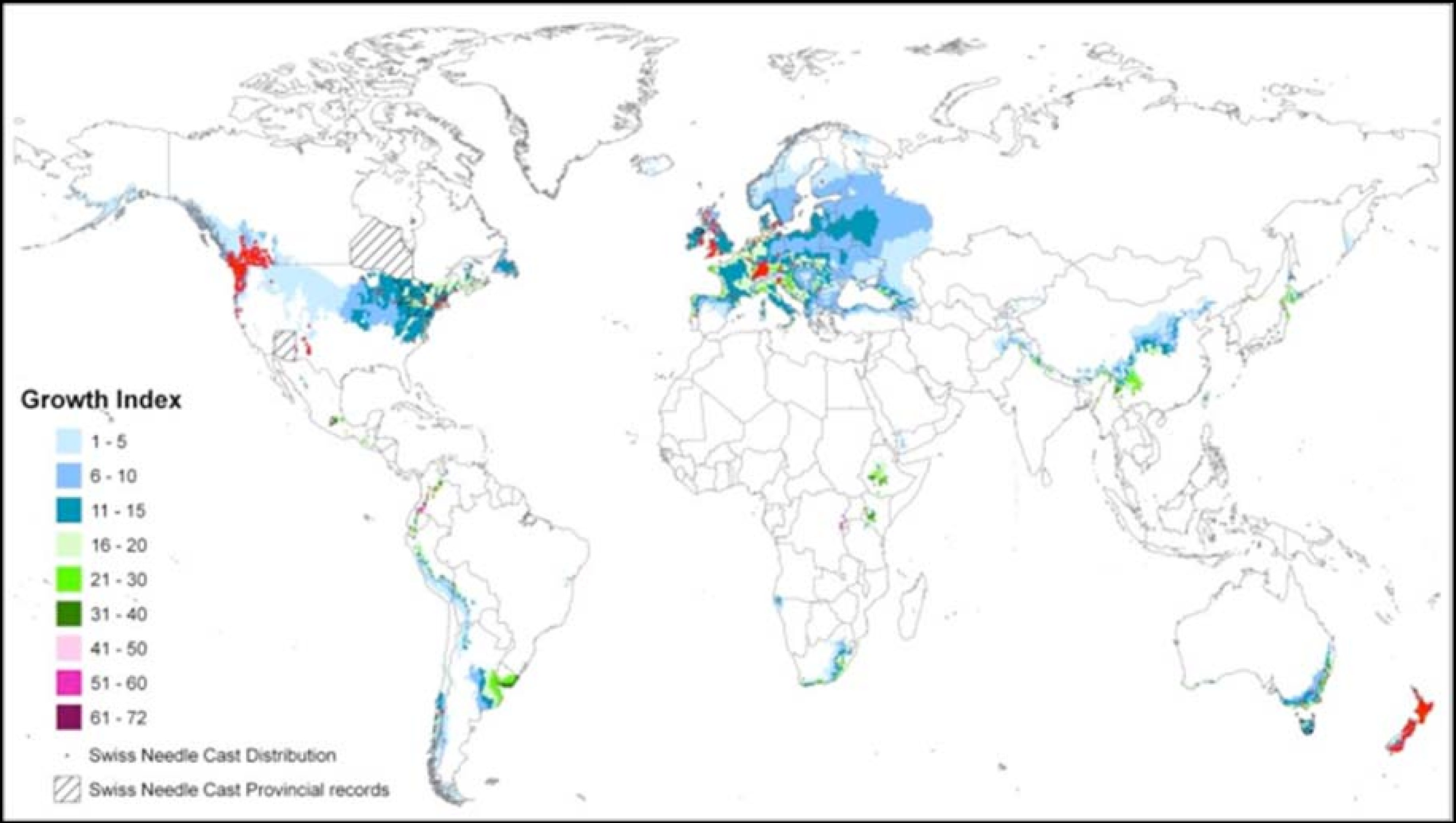
Relationship between predicted and actual colonization index (*CI*), NZ sites



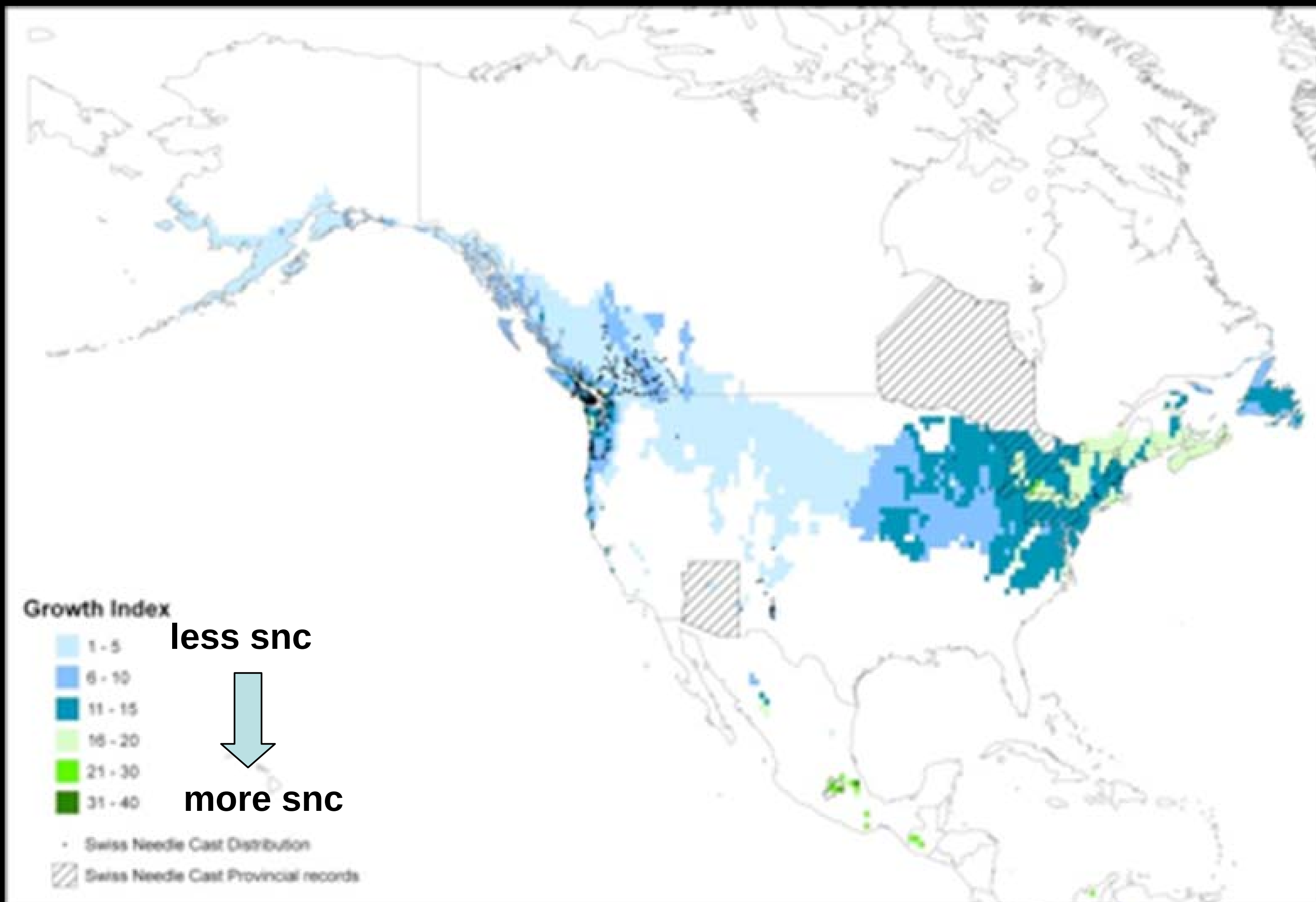
Relationship between model prediction and observed pseudothecia abundance (*CI*) for one-year-old needles

Relationship between model prediction and observed pseudothecia abundance (*CI*) for two-year-old needles

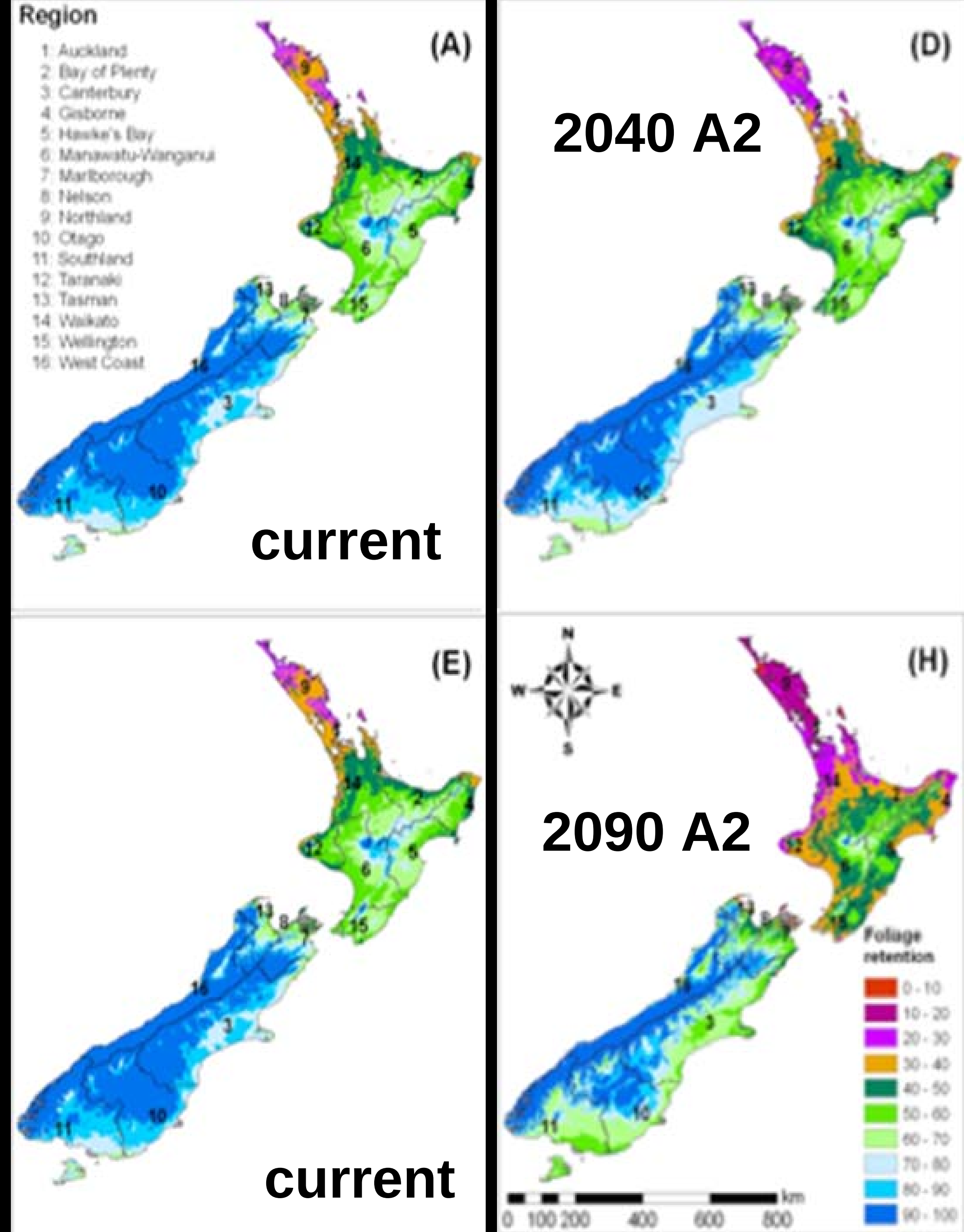
Using current/historical records of SNC to generate a worldwide map to predict its potential distribution



Potential distribution of *P. gaeumannii* includes all areas where Douglas-fir occurs naturally, or where climate is suitable, and agrees with records of distribution

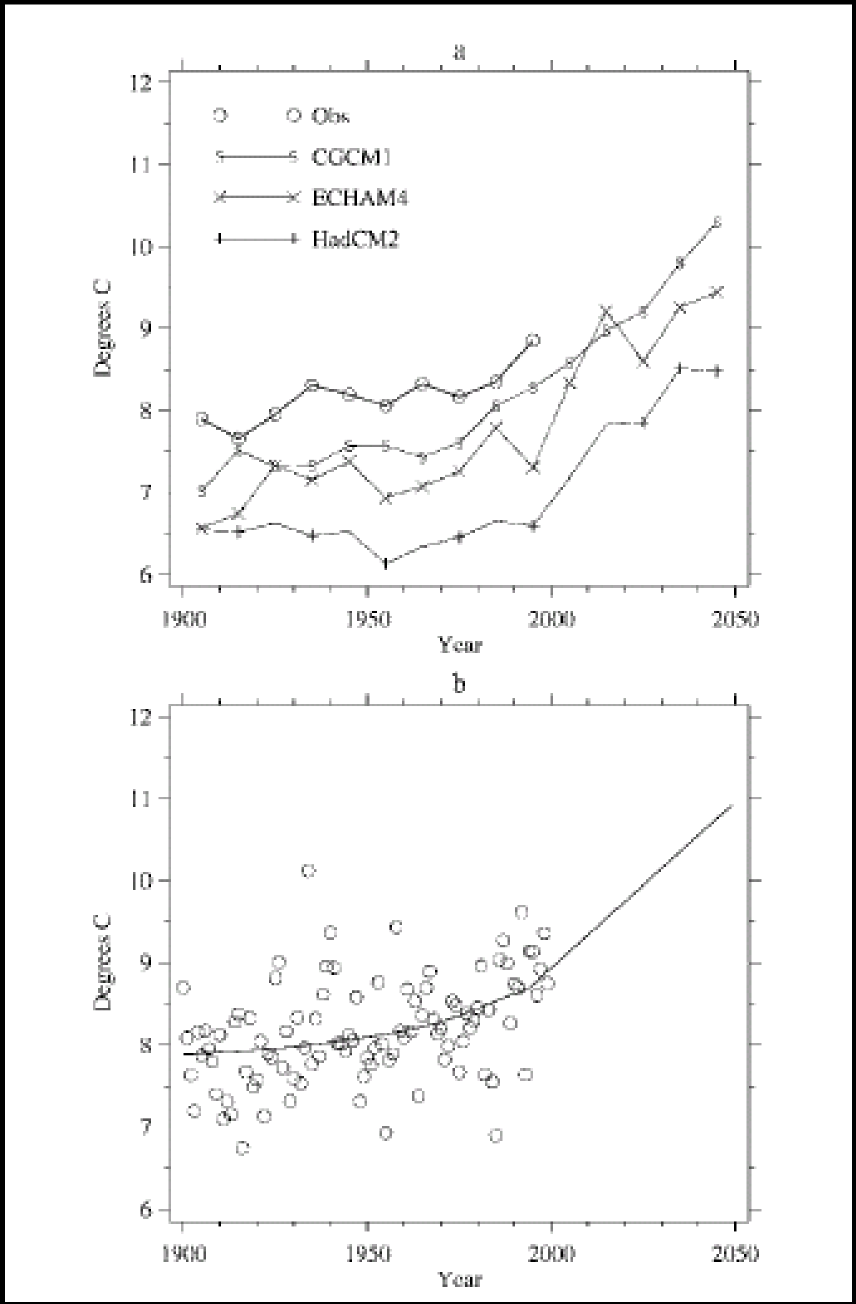


Predicted changes in Douglas-fir needle retention by 2040 and 2090



By 2090 all areas of the North Island predicted to have less than 60% foliage retention

Watt et al 2010. Forest Ecology & Management (in press)



Climate predictions for The Pacific Northwest: 2020

Average increase of 0.9 °F (0.5 °C) per decade

Average increase in precipitation April – Sept of +2 – 4%

Increasing Swiss needle cast severity and area affected, expansion of area affected by Swiss needle cast

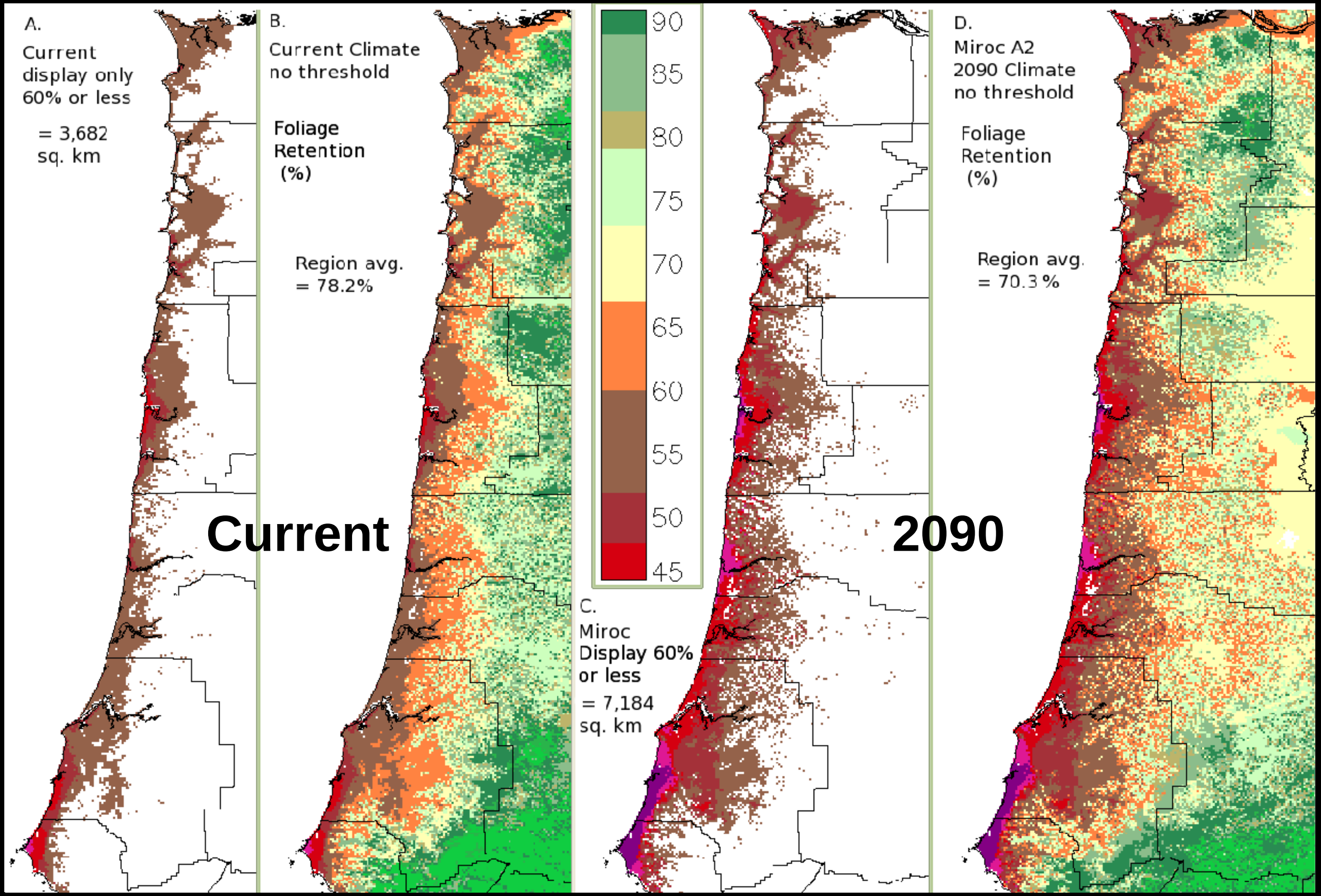
Mote et al. 2003 Climatic change 61: 45-88

Current and future SNC distribution in western Oregon based on MIROC A2 climate model

Within the area of western Oregon covered by aerial survey:

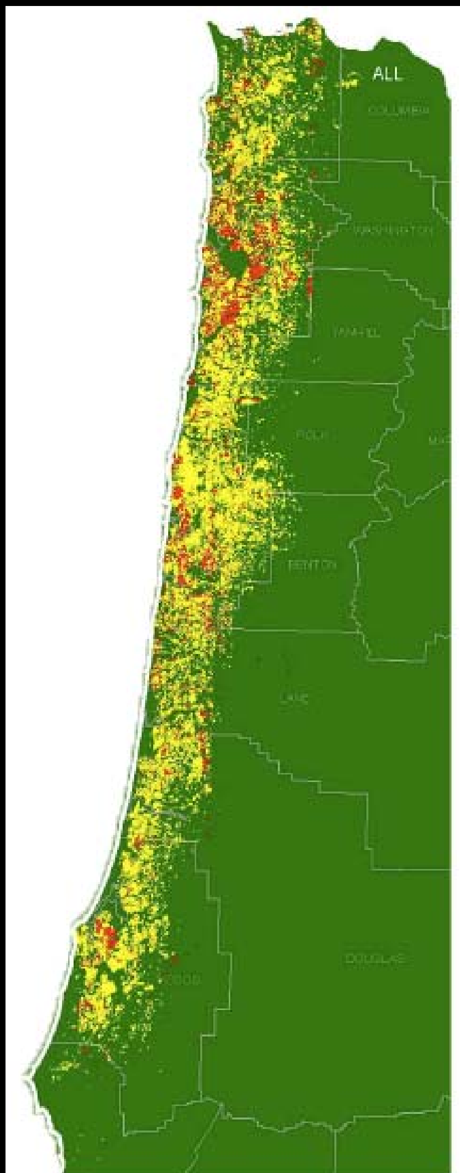
Average foliage retention decrease from 78% to 70 by 2090

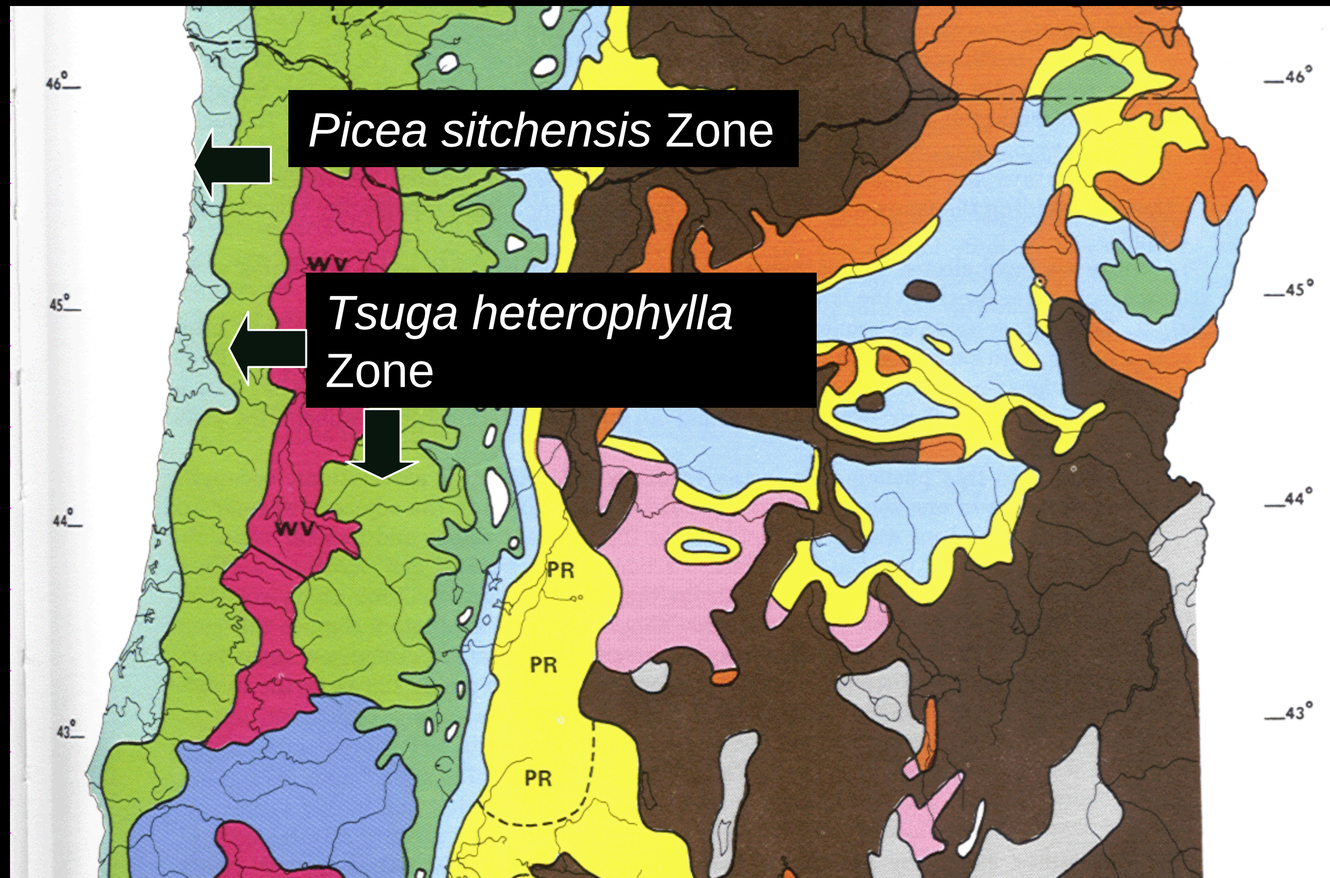
Area with <60% foliage retention increase from 3700 km^2 to 7200 km^2



Why is severe SNC only found on the west side of the Coast Range?

Distribution of Swiss needle cast coincides with the Sitka spruce natural vegetation zone



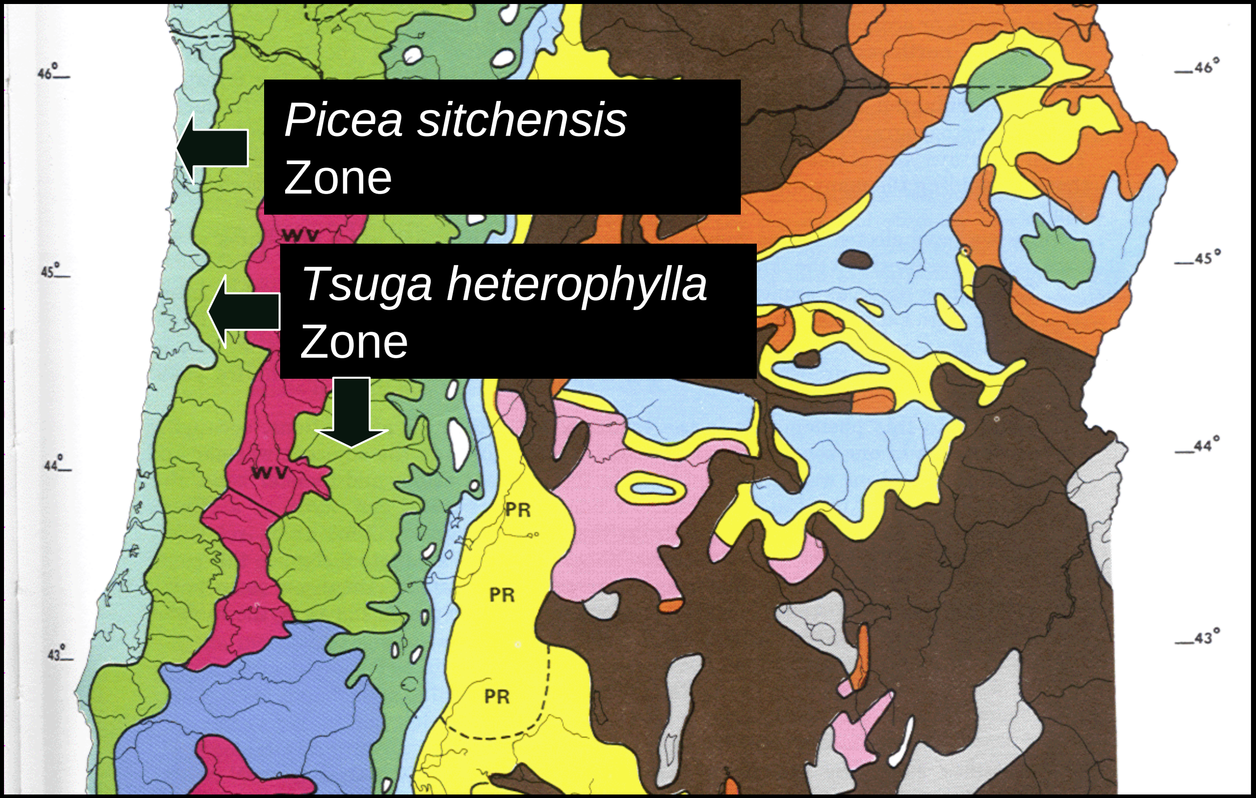


Picea sitchensis Zone - Characterized by proximity to coast, low elevations, climate wet, temperatures mild, frequent fogs. Dominant species are western hemlock, Sitka spruce, lodgepole pine, and red alder. Douglas-fir is a minor species.

Franklin and Dyrness 1973 Natural Vegetation of Oregon and Washington

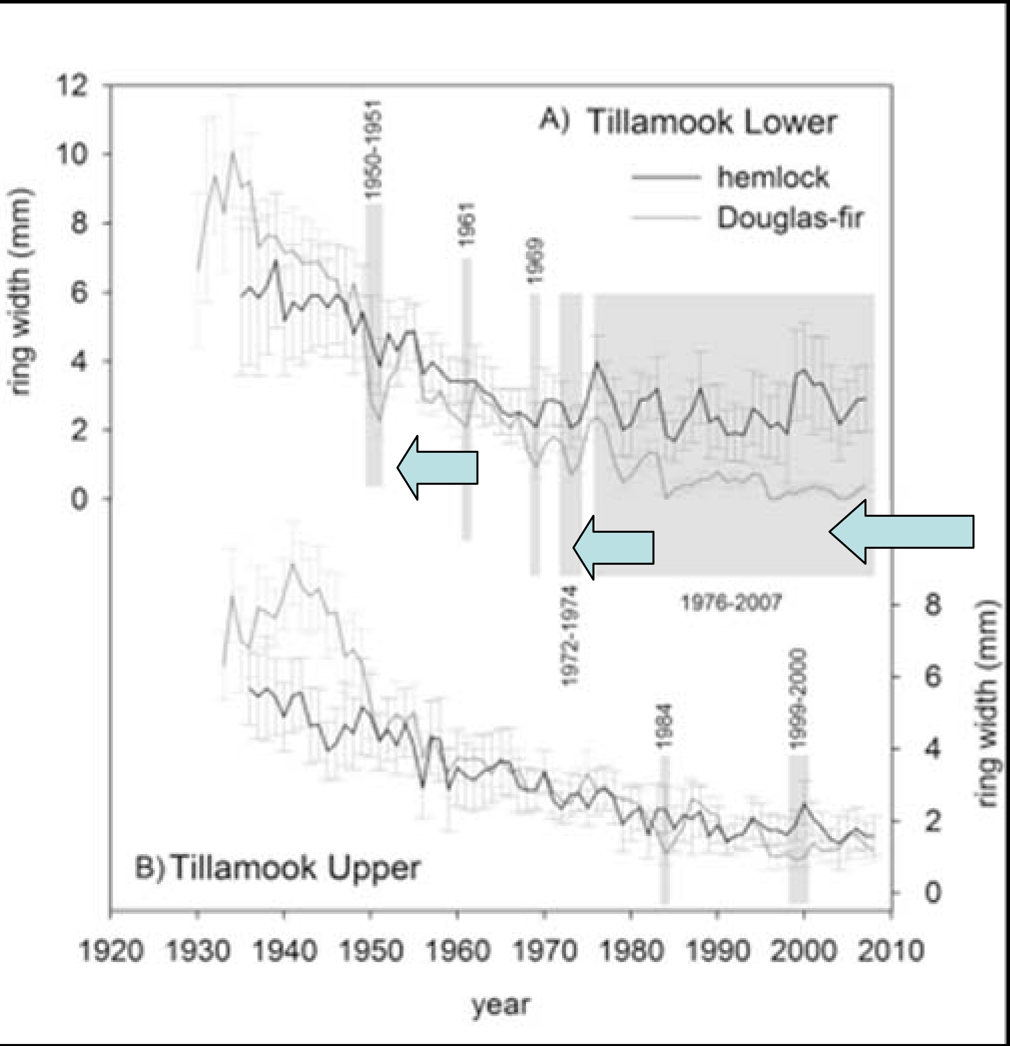
Vegetation zones reflect historical interactions between plants and climate – also plants, <u>pathogens</u> and climate

Spruce zone is where conditions are optimal for growth and reproduction of *P. gaeumannii*

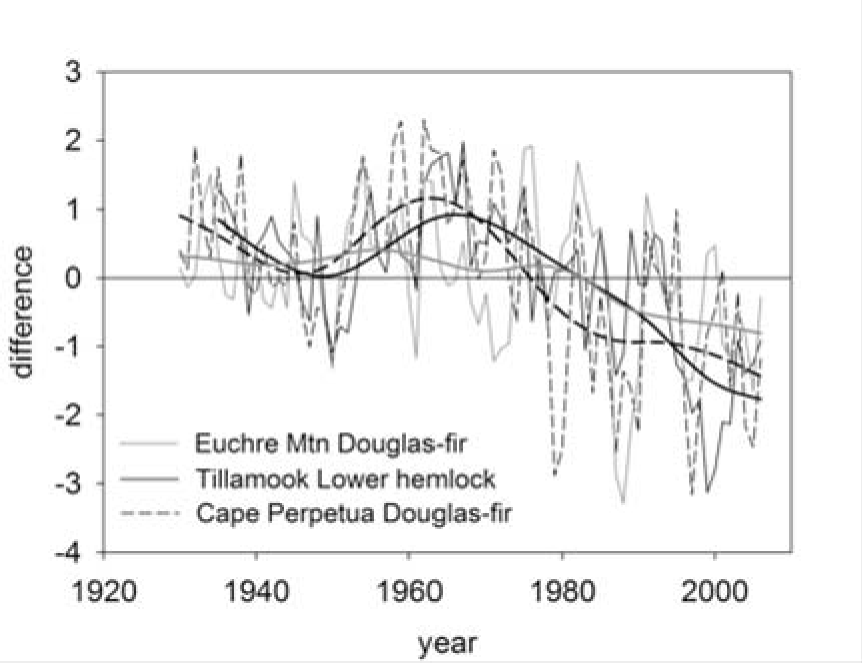


P. gaeumannnii **probably one of the determinants of the vegetation composition of the** ***P. sitchensis*** **zone**

How long has SNC been affecting Douglas-fir in western Oregon?



Suppression of Douglas-fir relative to hemlock increased after 1976

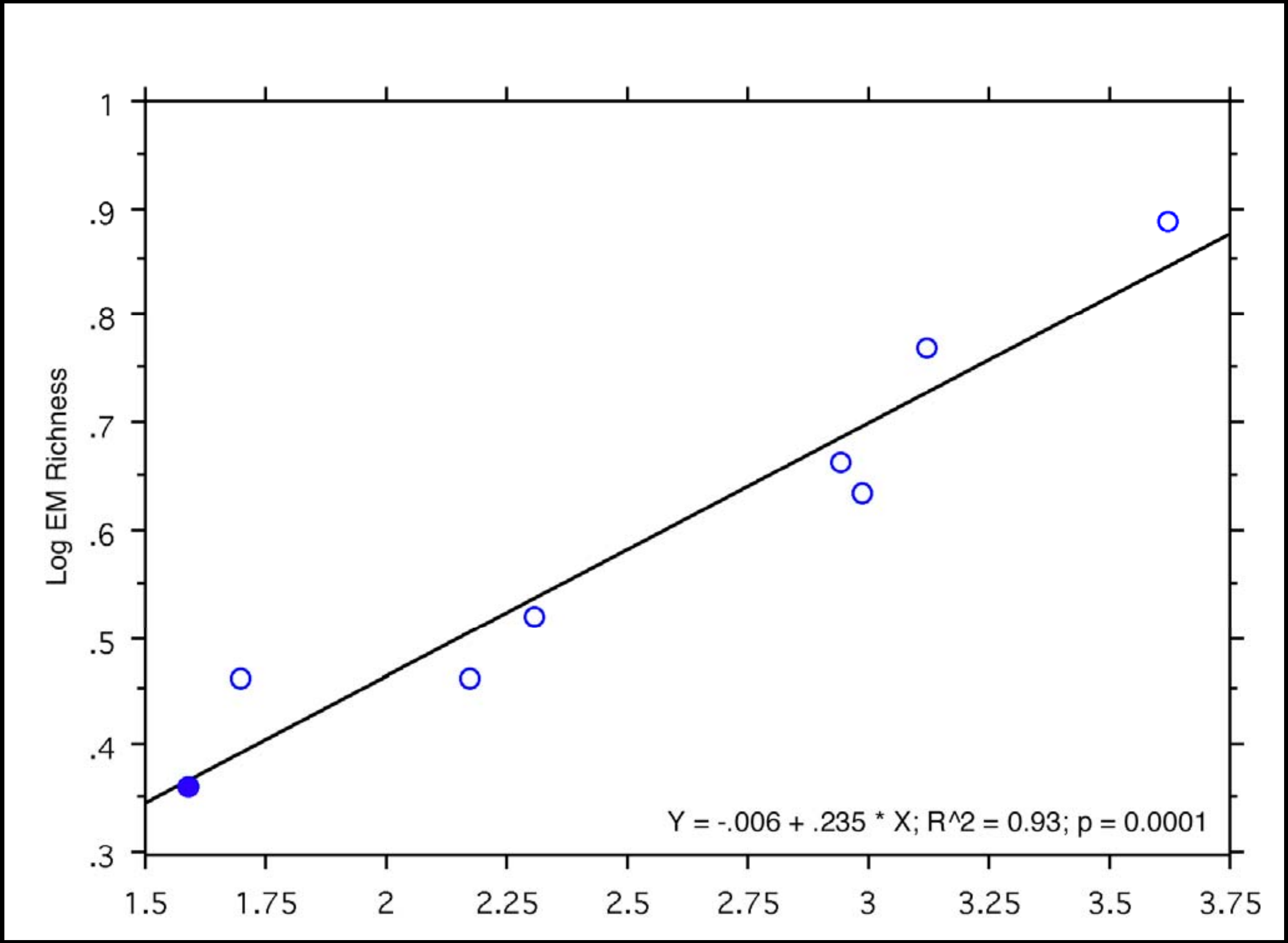


Black et al. 2010, Forest Ecology and Management 259:1673-1680

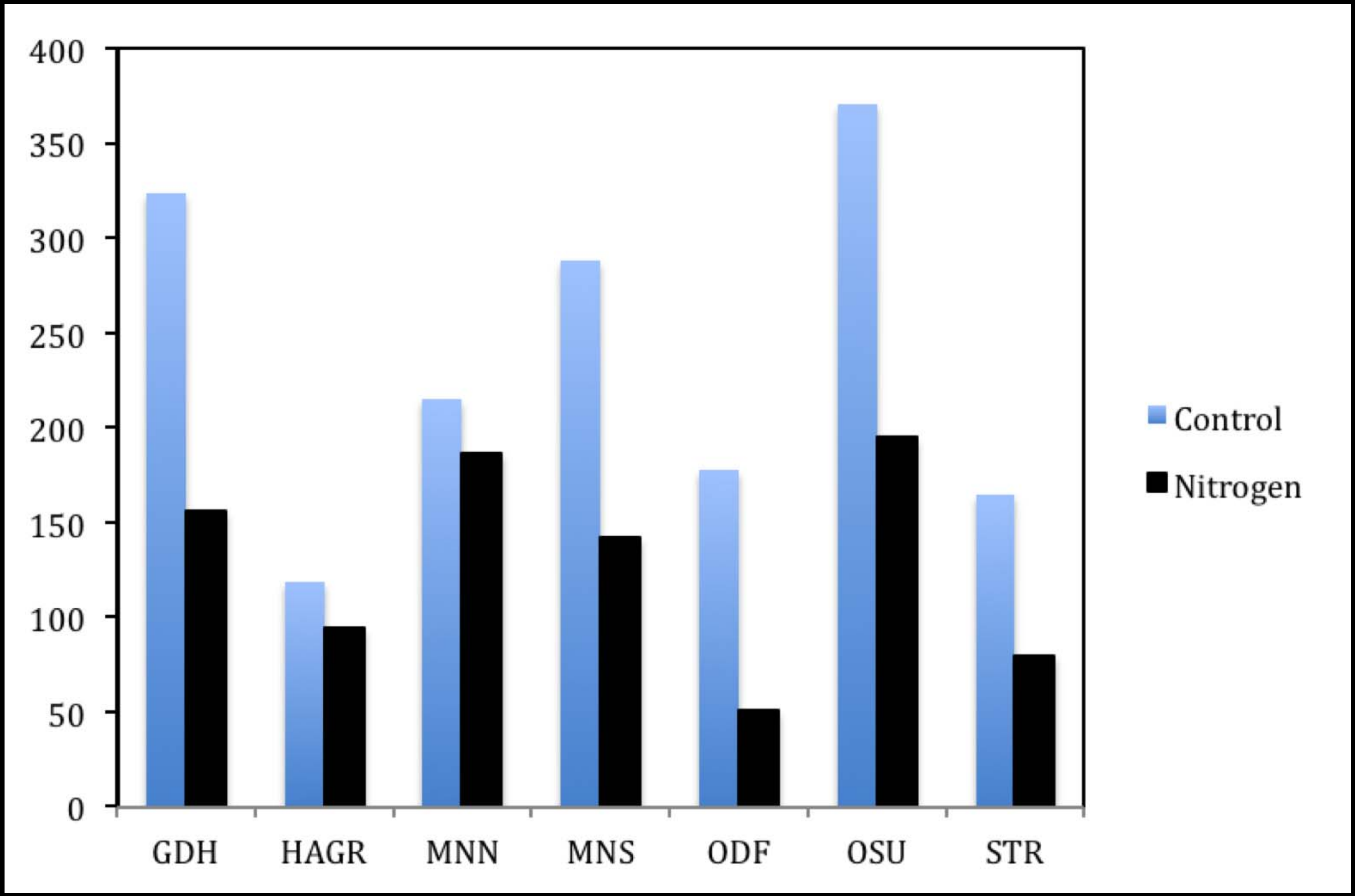
Other impacts of SNC on forest health: mycorrhizae

The *Lactarius luculentus* EM type on Douglas-fir roots

EM Species Richness vs. Needle Retention



Regression plot of mean ectomycorrhiza root density (log transformed) against mean years needle retention ($p = 0.0001$, $n = 10$). The solid fill symbol represents data from the 2008 sample, other data are from the 2007 effort. The two left-most points represent the Green Diamond, Hemlock site.



Variation in feeder root density (mean # of ectomycorrhizal root tips/soil core) by treatment across study sites (blocks). The treatment means were different across blocks ($p = 0.06$, $n = 5$). Mean root density was not different among blocks ($p = 0.16$).

Conclusions

Swiss needle cast, *P. gaeumannii* have long been a part of the Oregon Coast Range forest, but recently causing significant growth reductions

Recent climate trends that favor growth, reproduction of *P. gaeumannii*, have contributed to increased disease pressure

SNC disease impacts have multiple effects on forest health

Predictions for winter warming, increased spring precipitation through 2090 suggests increasing favorable conditions for SNC in the Coast Range

Area affected by severe disease predicted to double by 2090 but relatively little effect in Cascades