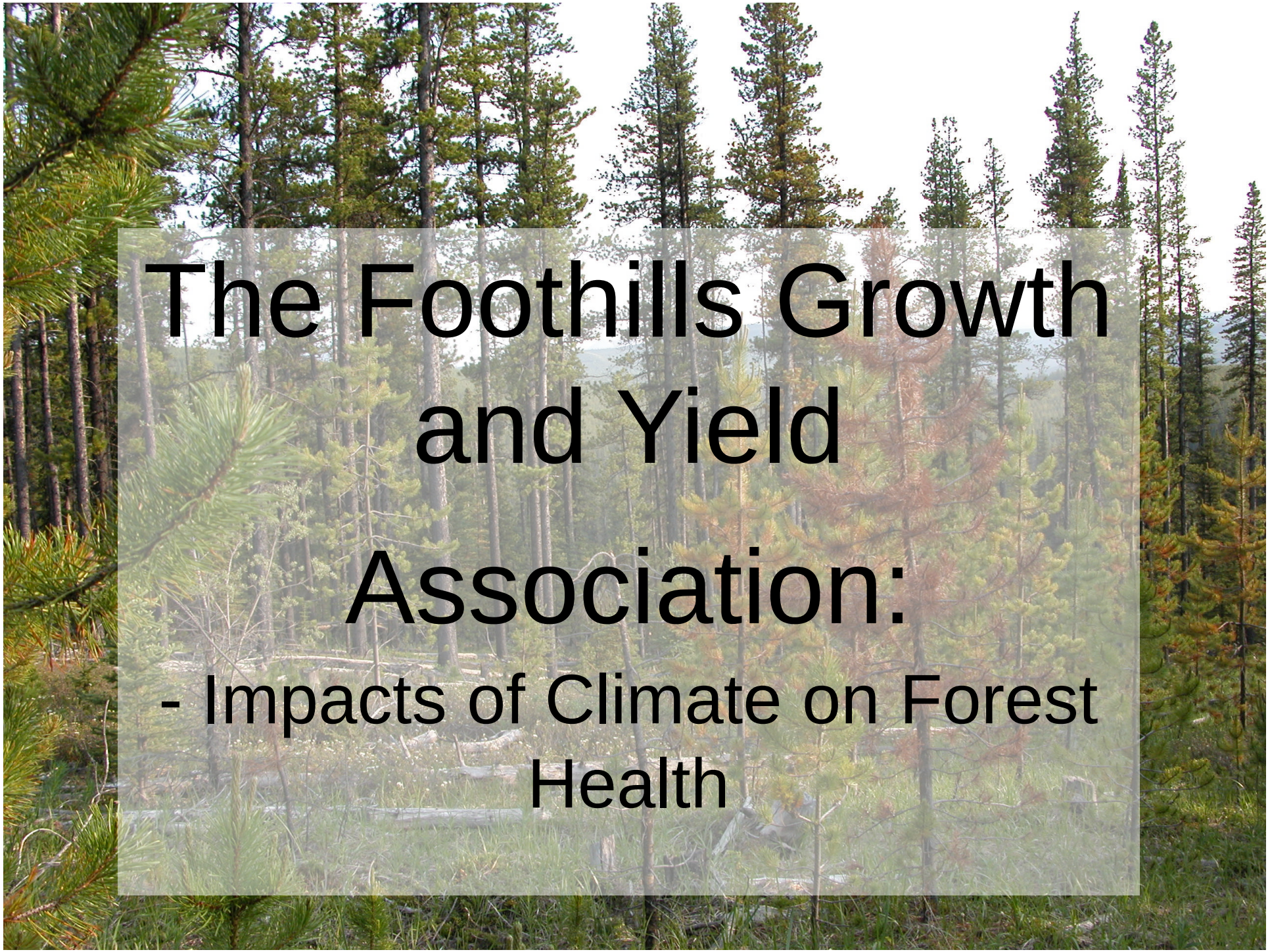


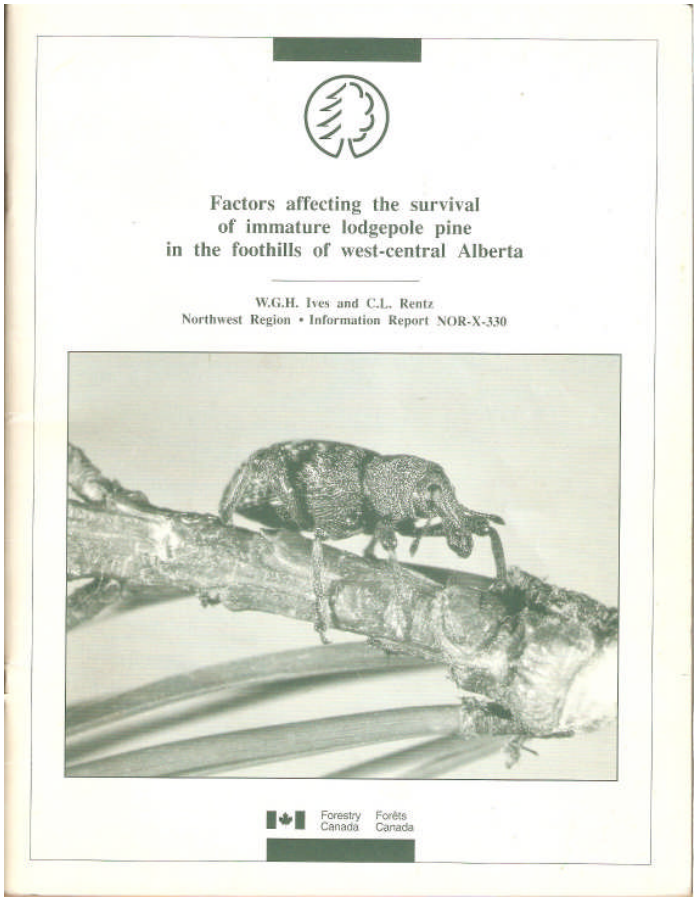
The Foothills Growth and Yield Association:

- Impacts of Climate on Forest Health

Data Sources:
Regenerated Lodgepole Pine ("RLP") Trial

- Established between the summer of 2000 and the spring of 2002; ongoing.
- Designed to monitor stand development of harvest-origin lodgepole pine in relation to site, initial spacing of planted stock, vegetation control (weeding) and density regulation (pre-commercial thinning).
- 102 one-hectare plot clusters distributed primarily throughout Lower and Upper Foothills sub-regions.

Data Sources: Ives

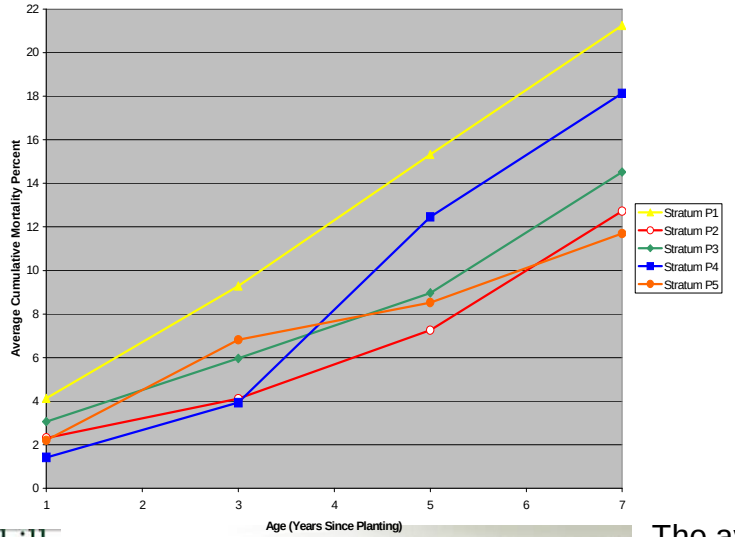


- Plots established to monitor survival of immature lodgepole pine in Sub-alpine and Foothills sub-regions.
- Over 70 cutover areas sampled.
- Conducted between 1981 and 1990.
- 3-year survival rates spanning 9 year period.
- Mostly thinned natural regeneration, 6 to 30+ years since harvesting.

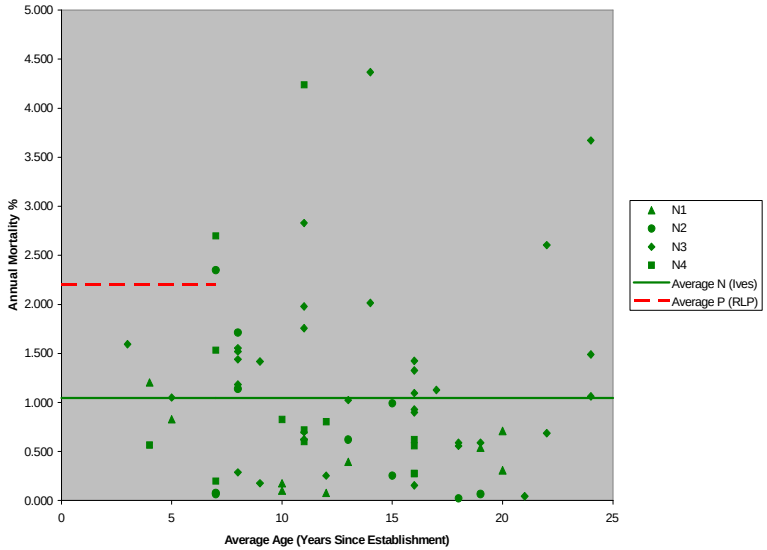
Stratification of Data

Data Set	Period	EcoClass	Moisture	Nutrient	Vegetation	Stratum
Ives and Rentz (**N**atural regeneration)	1981-1990	1	submesic	medium - poor	non-*Ledum*	N1
		2	mesic	poor	*Ledum*	N2
		3	mesic	medium	non-*Ledum*	N3
		4	subhygric	rich	non-*Ledum*	N4
RLP (**P**lanted stock)	2001-2006	1	submesic	medium - poor	non-*Ledum*	P1
		2	mesic	poor	*Ledum*	P2
		3	mesic	medium	non-*Ledum*	P3
		4	subhygric	rich	non-*Ledum*	P4
		5	hygric	poor	*Ledum*	P5

The Concern: High Non-declining Mortality in Planted Stock (FGYA Regenerated Lodgepole Pine Trial) .....



..... and Previous Reports of Lower but Persistent Mortality in Natural Regeneration (Ives)



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Foothills Growth and Yield Association

The average rate of mortality during the first 7 years since establishment by planting of the RLP study was double that indicated by the Ives data (see "average P" line). It has been variously speculated that the higher rates were attributable to sample tree selection (RLP tree selection was randor - Ives confined monitoring to "crop" trees), drought conditions shortly afte RLP planting, stress resulting from out-planting, poor planting practices, c inappropriate seed-lot allocation.

Most of the Ives points graphed are based on observed mortality over a 9-year period, though a few are based on 6 or less years. At a 3 year return interval

Establishment of natural regeneration in the Ives study was assumed to have occurred 6 years after harvest. Ives attributed the observed mortality to biotic factors rather than normal self-thinning.

The data demonstrated no relationship between stand age and rate of mortality. Although the average rate of mortality was low, Ives expressed concern a the sustained level of mortality resulting from biotic damage.

Tool Used for Climate Analysis: ClimateAB

- Computer program integrating climate normals and historical data for genecology and climate change studies in Alberta.*
- Calculates seasonal and annual climate variables for point locations based on weather-station data adjusted for latitude, longitude and elevation.
- Reports historical monthly, seasonal and annual climate variables for individual years and periods between 1901-2006.
- Also predicts future climate using various global circulation models.
- Output includes both directly calculated and derived climate variables.

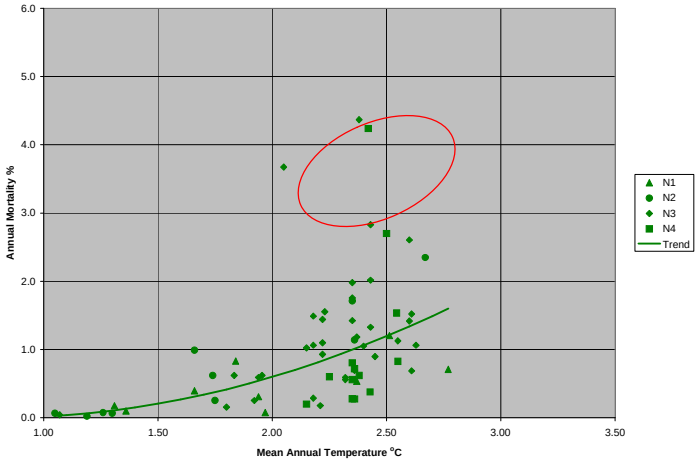
- Wang, T., Hamann, A., Spittlehouse, D., and Aitken, S. N. 2006. Development of scale-free climate data for western Canada for use in resource management. *International Journal of Climatology*, 26(3):383-397.

Analytical Approach

- Using FGYA data for period 2001-2006, explored correlations between periodic mortality rates (regardless of apparent cause) and climate variables extracted for each sample location by ClimateAB.
- Many climate variables showed significant correlations to mortality and each other. Mean annual temperature (MAT) most consistent.
- Analysis of mortality-MAT relationship extended and compared to Ives-Rentz periodic survival data (1981-1990).
- Arc sine transformation normalized distribution of percent mortality.
- Transformed periodic mortality was tested for relationship to MAT, and differences between strata and between datasets, using least-squares regression and analysis of variance / covariance.

Results

Mortality and MAT: All Ives ("N") Strata

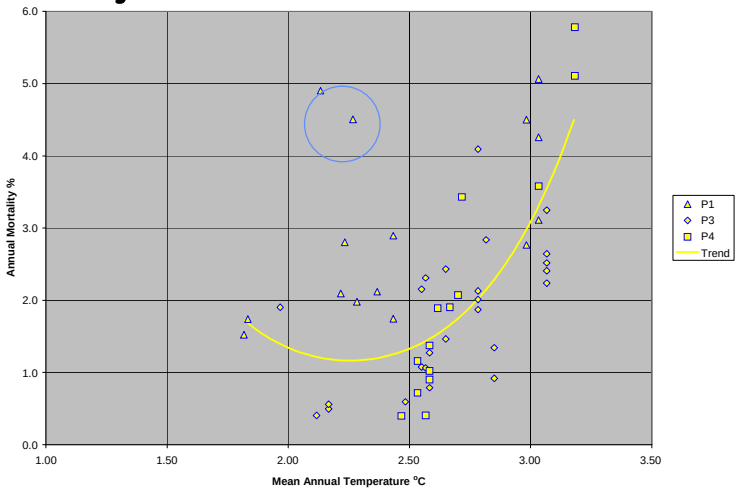


The 3 sites circled in red were all recorded as having endured sustained rodent damage throughout the 9 year study period, and excluded from compilation of the trend line. Both the average rate of mortality and mortality variation increase with temperature.

R-square = 0.50; p = <0.0001. I.e. 50% of observed variation in mortality explained by MAT; less than 1 chance in 10,000 that trend occurred by chance

Ecosite data were available for only 28 of the 71 study areas. For areas lacking ecosite information, strata were inferred from Ives' records of site productivity and drainage. The effect of stratum is only marginally significant.

Mortality and MAT: RLP Non-*Ledum* Strata



Extreme outliers circled in blue – one had severe horse browsing, other may have had planting problems (J rooting noted). Both are on poor-dry sites.

The level of mortality at a given temperature tends to be higher on poor-dry sites (stratum P1). The majority of upper outliers belong to this stratum. Operationally this stratum would not usually be planted, and it typically regenerates naturally at high densities.

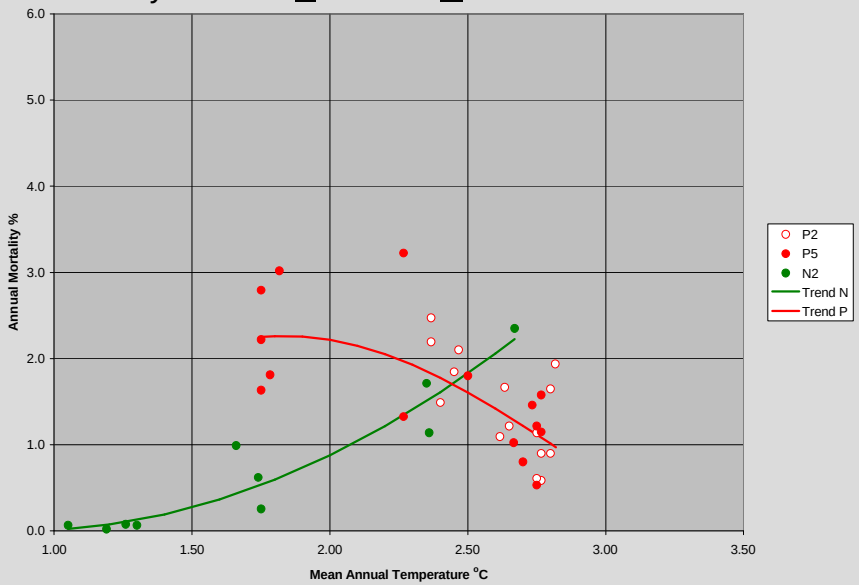
Extreme outliers were omitted from computation of the trend line.

R-square = 0.49; p = <0.0001.

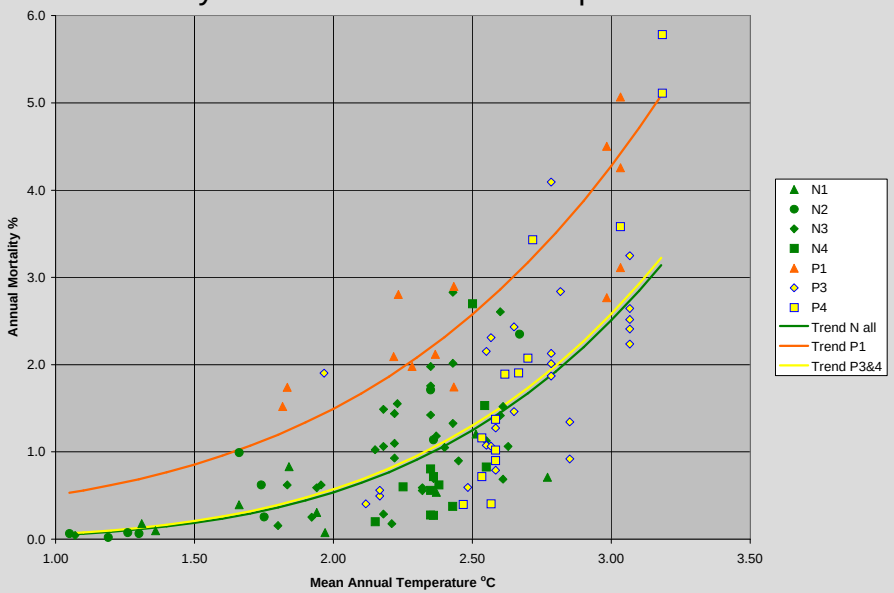
The upper mortality values at lower temperatures, again predominantly in the P1 stratum, disrupt the otherwise consistently upward trend of mortality with temperature.

Results

Contrary Trend in Planted v. Natural *Ledum* Strata



Mortality and MAT: All Strata Except RLP *Ledum*



The trend of decreasing mortality with temperature in planted stock on *Ledum* (Labrador Tea) sites (strata P2 and P5) is opposite in direction to that shown by all other strata. Some indication that strength of relationship is declining with time.

R-square (for red line) is 0.48; p = <0.0001.

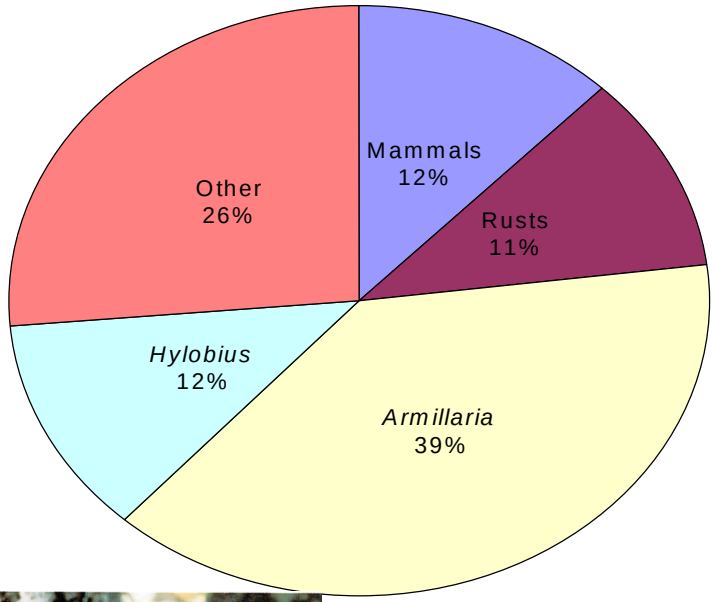
P5 (hygric-poor) ecosites are not represented in the Ives study and are marginal for natural regeneration of lodgepole pine. Such sites are difficult to successfully plant with pine because of their cold wet soils.

R-square of combined covariance-regression model is 0.67.

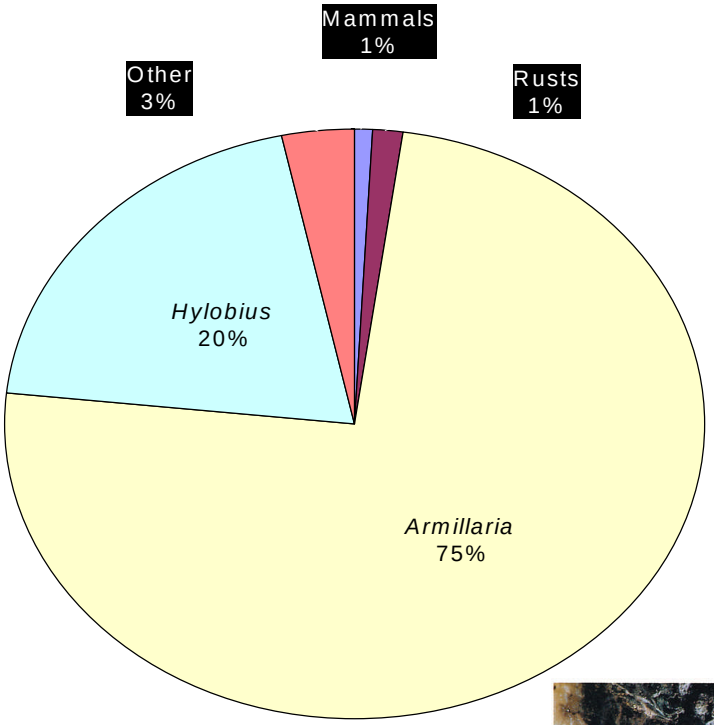
The model indicates almost identical trends on Ives naturally regenerated sites (all "N" strata) and RLP planted medium-good sites (strata P3 and P4). Only planted stock on dry sites (strata P1) shows a significantly different (higher) mortality trend.

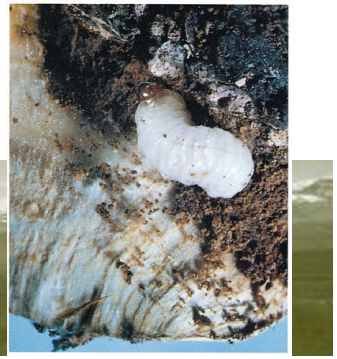
Mortality Causes during 1st Decade after Establishment

Ives – Natural Regeneration



RLP – Planted Stock





Implications

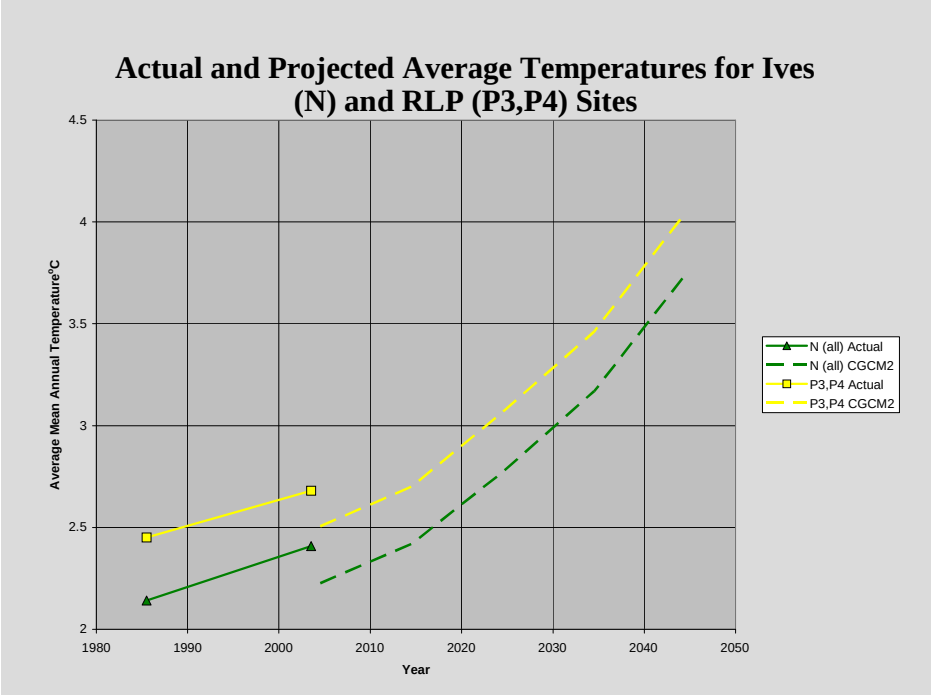
Ives and FGYA data show similar trends between mortality and climate:

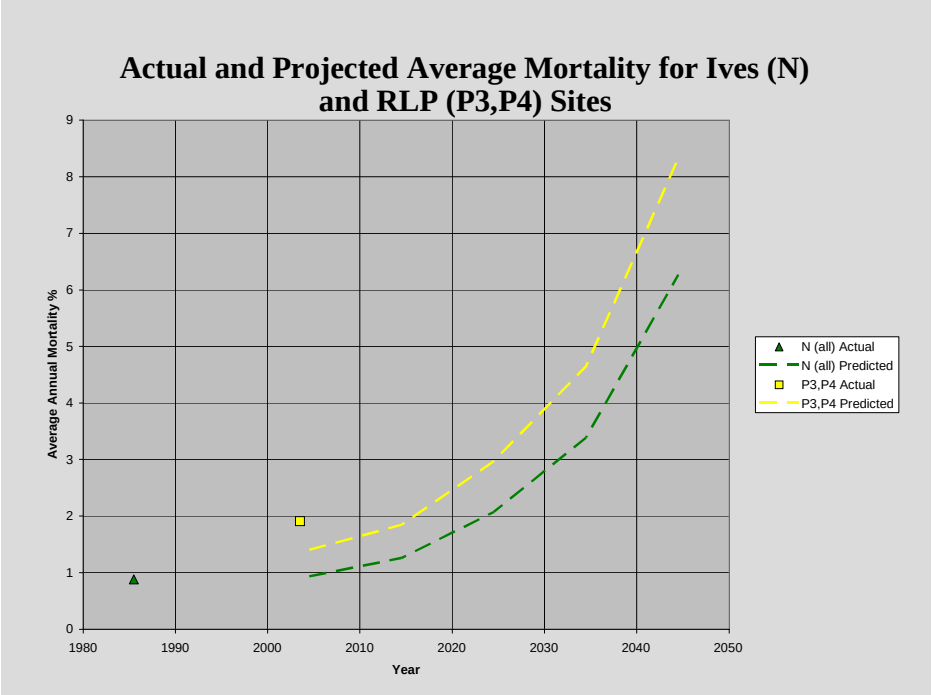
- Increased mortality with increasing mean annual temperature;
- Correlation is strong;
- Mortality factors are primarily biological pathogens rather than direct climate injury;
- Exceptions to the common trend are on experimentally planted sites that would not normally be planted with pine.

We don't yet know, and need to find out, whether and to what extent:

- Trends between mortality and temperature observed across the landscape will translate into increases in mortality with climate change over time;
- Pathogen-related mortality observed in stands up to about 30 years is persisting in older post-harvest stands;
- Increased mortality could be offset by increased growth.

Temperatures and Mortality Are Both Predicted to Rise





Implications

The observed trends and their possible implications need to be considered from the perspectives of:

- Reforestation strategies and standards;
- Yield forecasting;
- Integrated pest management.

Similar work is urgently required on other species.

For Further Information Contact:
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