Vulnerability of White Spruce Tree Growth in Interior Alaska in Response to Climate Variability: Dendrochronological, Demographic, and Experimental Perspectives

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Key Question of the Study

What is the vulnerability of white spruce tree growth to continued warming in interior Alaska?

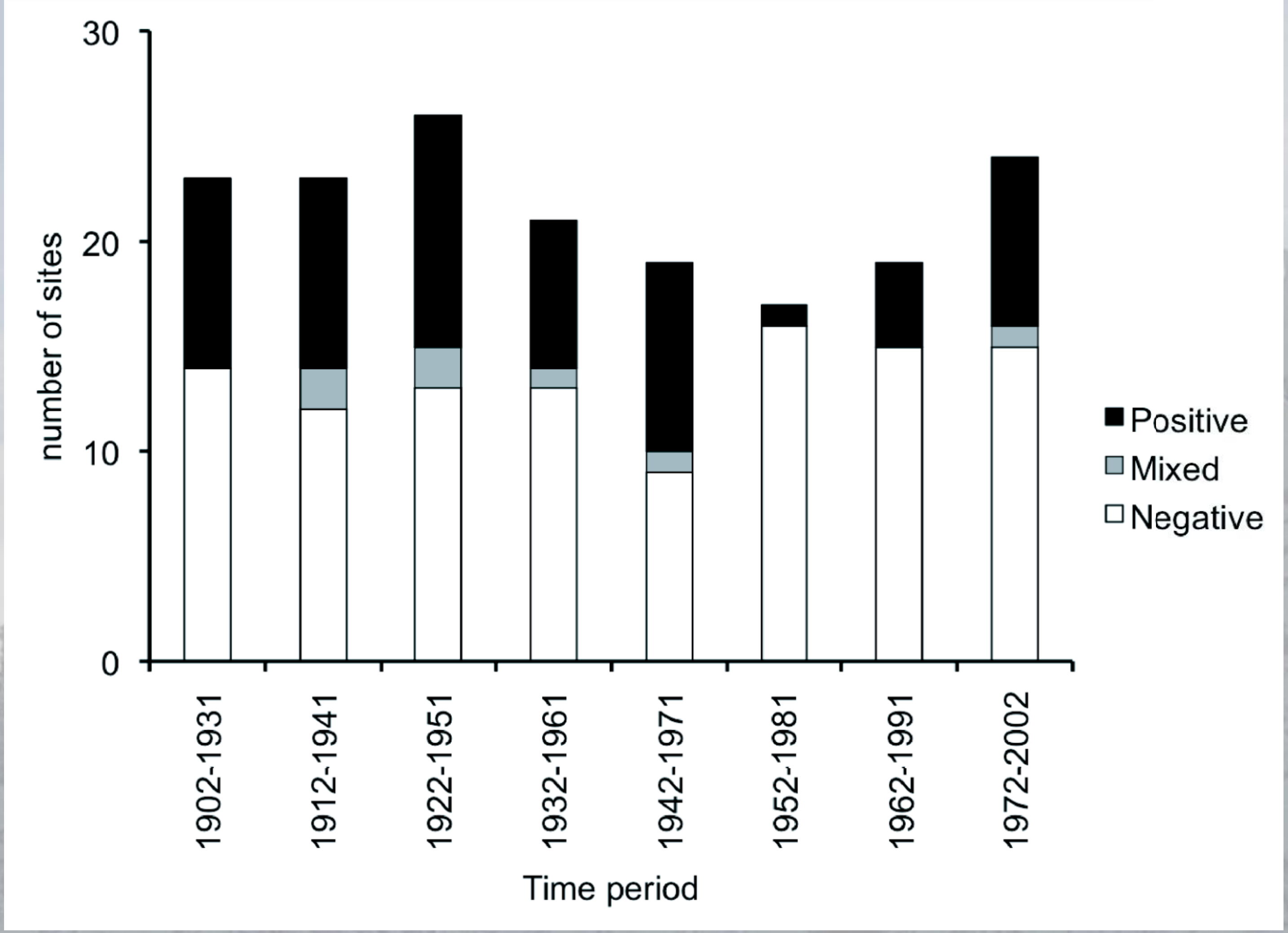
Vulnerability is the degree to which a system is likely to experience harm due to exposure and sensitivity to a specific hazard or stress and its adaptive capacity to respond to stress.

Approaches used to understand vulnerability include tree ring studies, long-term monitoring of growth, and experiments.

Dendrochronological Approach

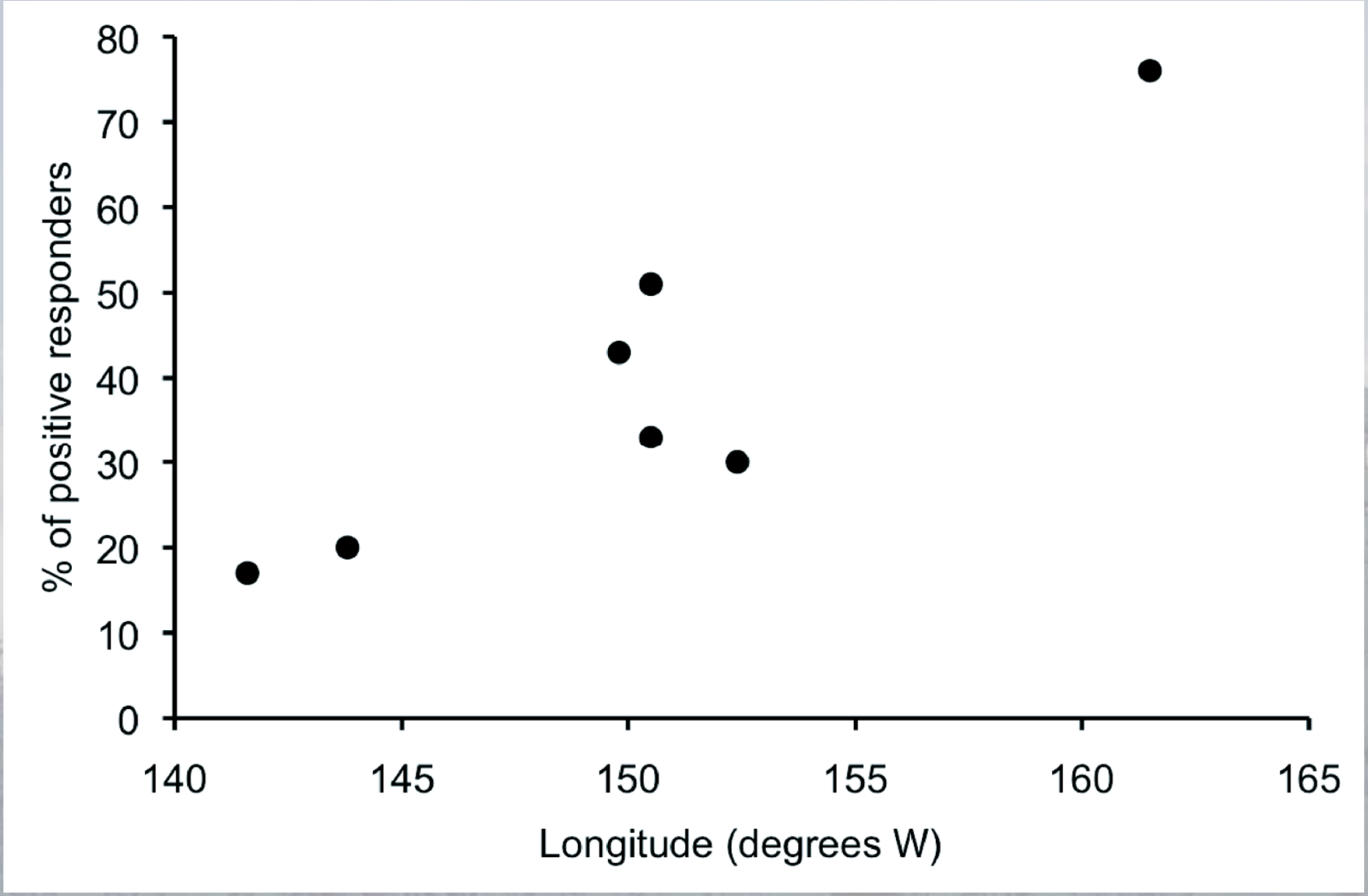
- 25 sites in all regions of Alaska
- Only 5 sites showed consistently positive responses to temperature (two in western Brooks Range, two in southern Alaska range, one at treeline in White Mountains of interior Alaska)
- Growth at one site showed a mixed response to temperature
- Negative responses to temperature at other 19 sites
- No difference in precipitation between positive and negative responding sites
- Tree growth significantly correlated with precipitation at 12 of the sites
- Tree growth at negatively responding sites negatively correlated with previous July temperature

Dendrochronological Approach



The role of temperature has changed in recent decades: negative responses to temperature are more prevalent in late 1900s than in early 1900s.

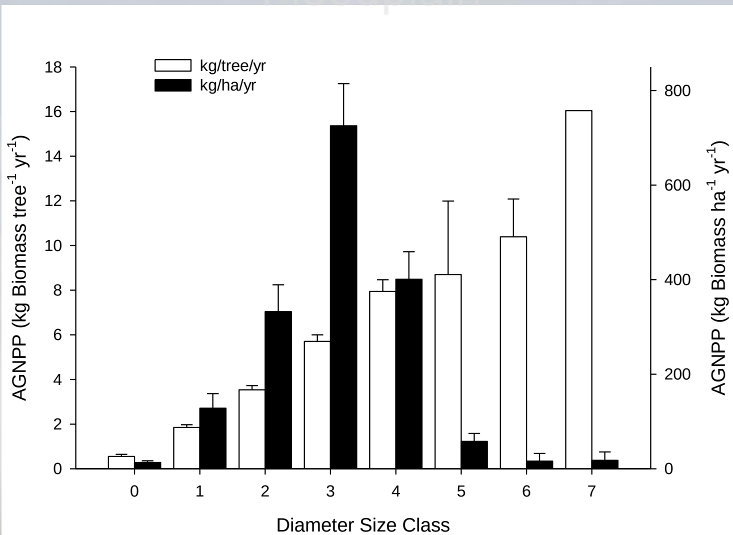
Dendrochronological Approach



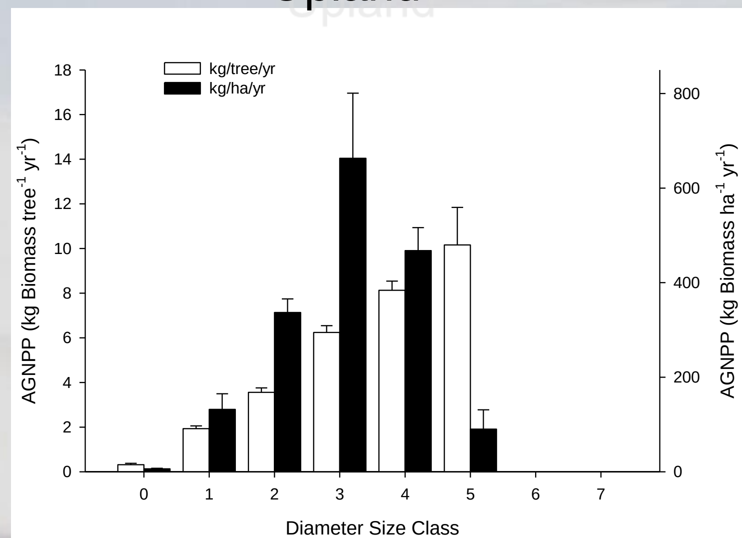
The prevalence of negatively responding trees was signficantly greater in warmer sites than in cooler moister sites

Demographic Approach: Stand Structure and ANPP

Floodplain



Upland



White spruce trees of a given size class in late-successional stands grow at similar rates in floodplain and upland stands

Demographic Approach:
Stand Structure and ANPP

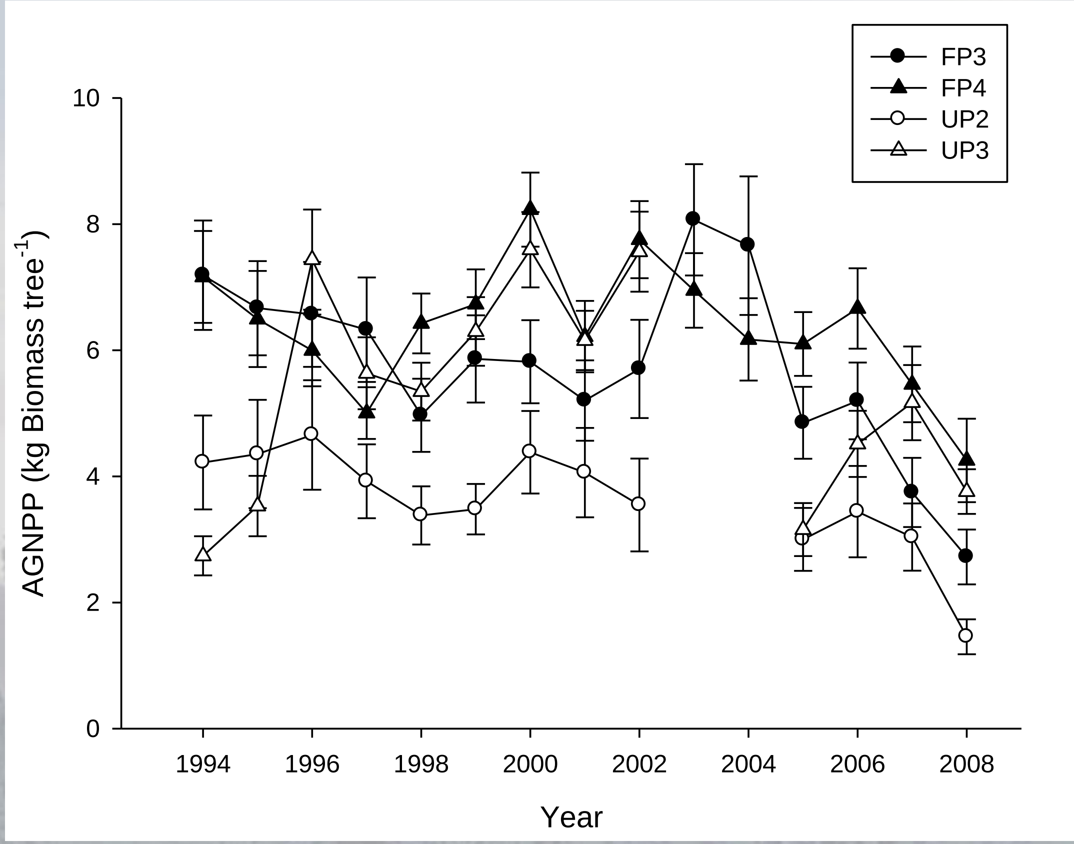
Stand	Density (# ha^{-1})	Basal Area (m^2 ha^{-1})	ANPP (kg Biomass ha^{-1} yr^{-1})
Upland			
mid-succession	576 93b	3.6 0.6c	842 338
late-succession	354 22b	26.8 0.8a	1696 144
Floodplain			
mid-succession	1684 503a	17.6 1.6b	2696 694
late-succession	370 21b	27.7 1.0a	1692 191

Stand-level ANPP varies significantly between upland and floodplain mid-successional stands, but not between upland and floodplain late successional stands

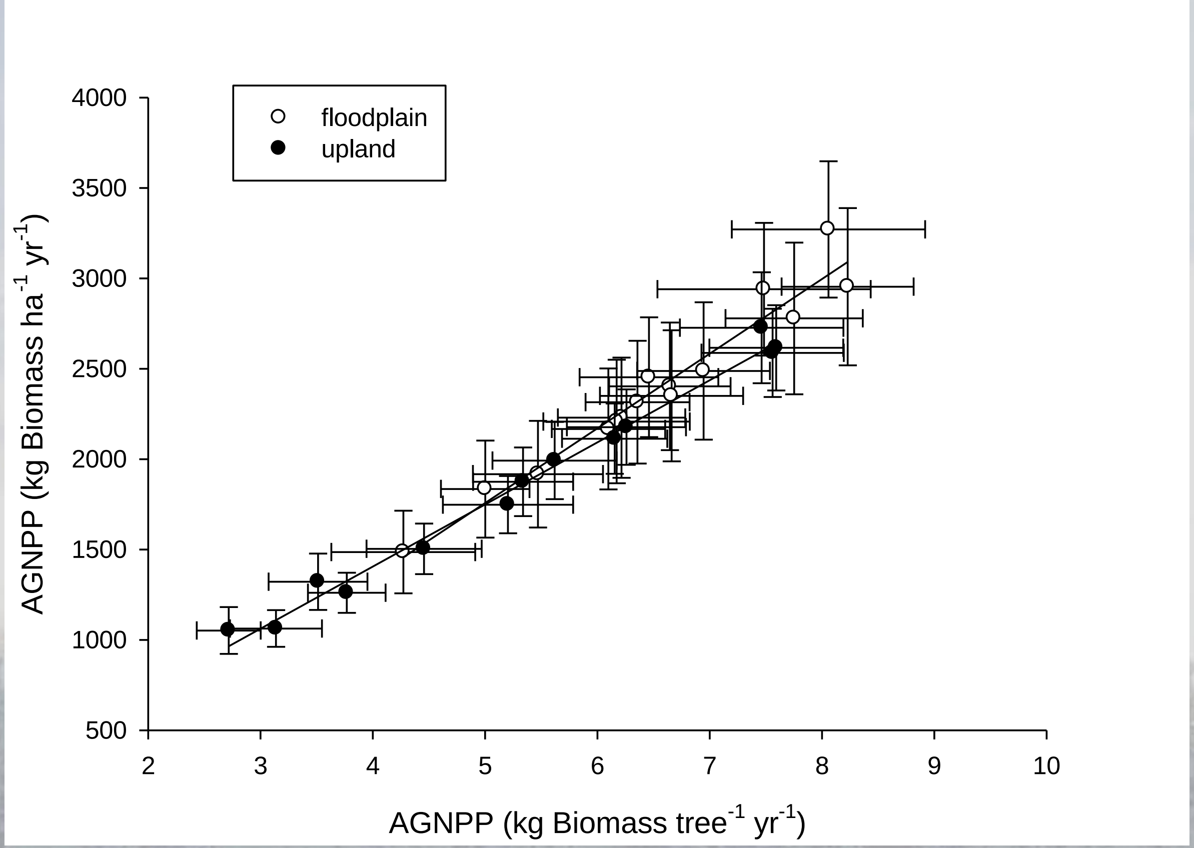
Demographic Approach: Interannual Variation in Tree Growth

Average rates of tree growth were positively correlated among replicate stands across years in mid- and late successional (FP3 and FP4) floodplain and upland (UP2 and UP3) stands.

Tree growth rates strongly correlated between upland and floodplain mid-successional stands (UP2 and FP3), but not for late successional stands between uplands and floodplains (UP3 and FP4).



Demographic Approach: Interannual Variation in Tree Growth



Over the 15 year period, stand-level ANPP is controlled by tree growth and not by stand demography.

Demographic Approach:
Climate Sensitivity of White Spruce Tree ANPP

Take-Home Messages from Step-Wise Regression Analyses

- Negative relationships to June temperature in late-successional forests, but not mid-successional forests

- Soil moisture negatively correlated to June temperature

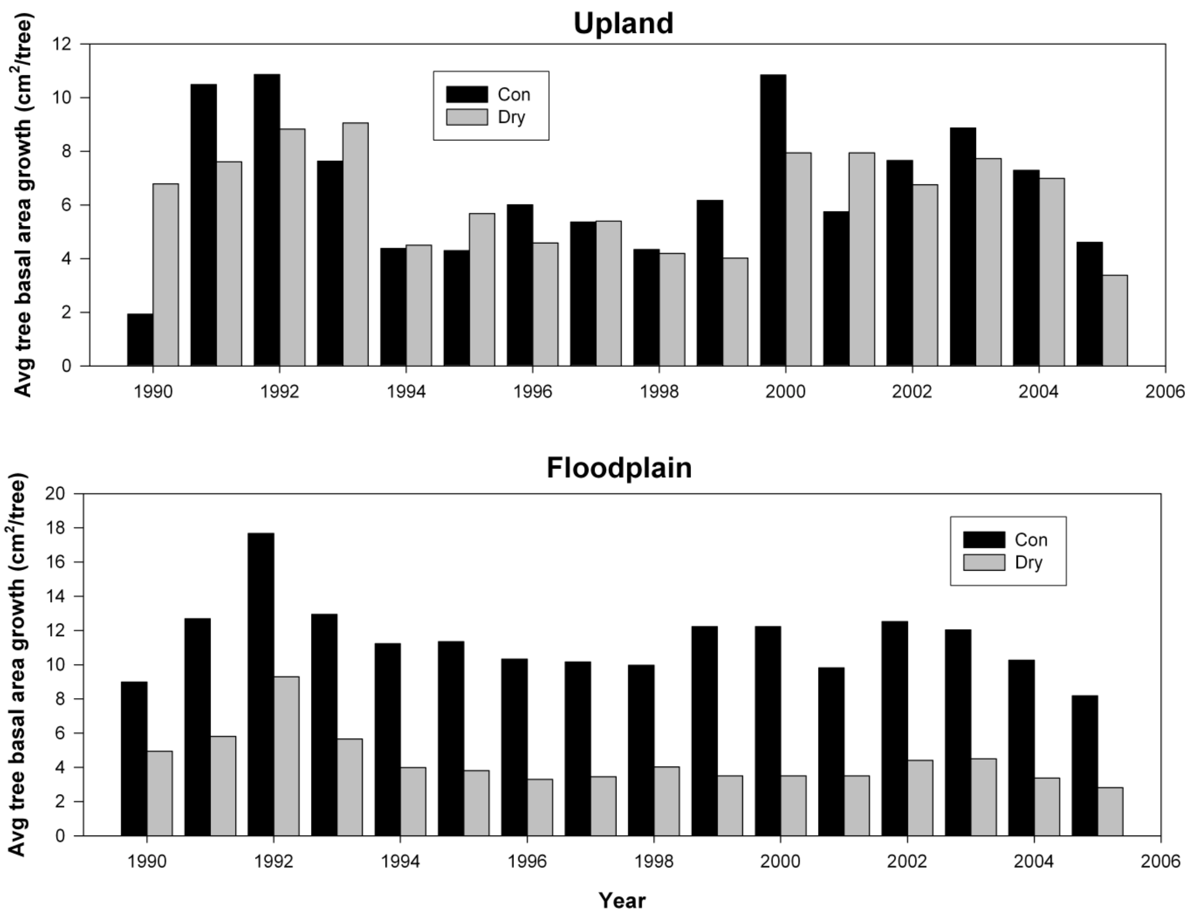
- Gauge height predictor of ANPP in both floodplain and upland stands

- Gauge height more important in late-successional floodplain stands than in mid-successional floodplain stands

- Previous August PDSI important in mid-successional floodplain stands

- July precipitation important in upland mid-successional stands

Experimental Approach:



Upland tree growth not affected by drought treatment
Drought treatment decreased floodplain tree growth

Summary

1. Dendrochronological and demographic results are generally consistent with each other in indicating negative responses to warming because of warming-induced drought.
2. Both dendrochronological and demographic results indicate that the response to temperature depends on the landscape position.
3. Dendrochronological results also indicate that the response depends on prevailing climate.
4. Experimental and demographic results generally not consistent.
5. The linkage between previous year's climate and ANPP may indicate that moisture available at the end of the season translates into moisture availability at beginning of the season – currently being tested with the experimental approach.
6. Overall, the approaches indicate that white spruce tree growth is vulnerable to warming, and many areas in Alaska may have passed a critical threshold between positive and negative responses to warming.