The influence of soil on whitebark pine (Pinus albicaulis) cone production in the Greater Yellowstone Ecosystem

by Adam Walker Morrill

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Sciences
Montana State University

Abstract:
This research examined the relationships between whitebark pine (Pinus albicaulis) cone production and soil properties and foliar nutrient levels. Cone count data were collected by the Interagency Grizzly Bear Study Team from plots across the Greater Yellowstone Ecosystem (1980-1999). The data used in this study came from 8 of those plots (78 trees) and covered the years of 1989-1997. Soil properties measured included: electrical conductivity (EC), pH, percent coarse material, texture (% sand, % silt and % clay), percent organic matter and depth. Foliar nutrient levels were determined for the following nutrients: boron, calcium, copper, iron, potassium, magnesium, manganese, molybdenum, nitrogen, phosphorus, sulfur and zinc. These variables were regressed against cone production to determine their influence and significance. EC and pH both had significant positive correlations with cone production, and percent coarse material had a significant negative correlation with cone production. EC is a measure of the concentration of ions in solution, and in whitebark pine environments it can be used as an approximation of the amount of available nutrients. When soil pH levels approach neutral more nutrients necessary to plants become available. Percent coarse material limits the amount of surface area on which nutrients or water may be held, and thus limits productivity. All other variables had no significant relationships with cone production.

A multiple regression model using EC and pH significantly explained 38% of the variation in cone production. Percent coarse material was insignificant in the model because of its covariance with EC and pH, suggesting that it affected soil chemistry rather than water availability. A second multiple regression model, which used crown volume (Spector, 1999) and EC, significantly explained 59% of the variation in cone production. Soil pH was not used because of its correlation with EC, and because EC had more predictive power. The information gained from this study could be used to assist in site selection for planting of whitebark pine, and in developing other management strategies that increase whitebark pine cone production and provide better wildlife habitat.

THE INFLUENCE OF SOIL ON WHITEBARK PINE (*PINUS ALBICAULIS*) CONE PRODUCTION IN THE GREATER YELLOWSTONE ECOSYSTEM

by

Adam Walker Morrill

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Earth Sciences

MONTANA STATE UNIVERSITY-BOZEMAN
Bozeman, Montana

August 2000

APPROVAL

of a thesis submitted by

Adam Walker Morrill

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. Katherine Hansen — Katherine Hansen — 6-15-00
Chairperson, Graduate Committee — Date

Approved for the Department of Earth Sciences

Dr. James Schmitt — James Schmitt — 7-18-00
Head, Major Department — Date

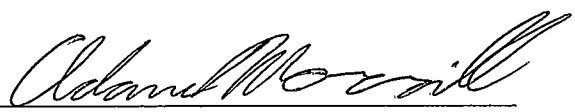
Approved for the College of Graduate Studies

Dr. Bruce McLeod — Bruce R. McLeod — 7-21-00
Graduate Dean — Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for the master's degree at Montana State University-Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature 

Date 7/16/00

ACKNOWLEDGEMENTS

I would like to thank the members of my committee, Dr. Katherine Hansen, for her continuous advice and hours of editing, Dr. William Locke, for his assistance with my almost daily questions, Dr. Ward McCaughey from the U.S.D.A., Forest Service, Rocky Mountain Research Station, for his advice, logistical support and use of equipment, and Dr. Charles Schwartz for his input and for allowing me to use the Interagency Grizzly Bear Study Team's cone data, which is the foundation of this project. I would also like to thank the Interagency Grizzly Bear Study Team, the Department of Earth Sciences, and the Biogeography Specialty Group of the Association of American Geographers for their financial contributions to this project. I also thank Ann Rodman, Soil Scientist for Yellowstone National Park, for allowing me use of her soil maps and the staff of the Soil Analytical Lab at Montana State University, Bozeman for assisting me with my soil analyses. I would also like to thank my field assistants Matt Menge and Michael Blahut. Additionally, I would like to thank my family and friends back in California and my fellow graduate students for their support the last two years. Most of all I would like to thank the person without whom this project would not have been possible, my future wife, Nicole Blahut, for her help in the field and for her endless support, patience and love throughout the entire process.

TABLE OF CONTENTS

TABLE OF CONTENTS – Continued

TABLE OF CONTENTS – Continued

LIST OF TABLES

LIST OF TABLES – Continued

LIST OF FIGURES

LIST OF FIGURES – Continued

LIST OF FIGURES – Continued

ABSTRACT

This research examined the relationships between whitebark pine (*Pinus albicaulis*) cone production and soil properties and foliar nutrient levels. Cone count data were collected by the Interagency Grizzly Bear Study Team from plots across the Greater Yellowstone Ecosystem (1980-1999). The data used in this study came from 8 of those plots (78 trees) and covered the years of 1989-1997. Soil properties measured included: electrical conductivity (EC), pH, percent coarse material, texture (% sand, % silt and % clay), percent organic matter and depth. Foliar nutrient levels were determined for the following nutrients: boron, calcium, copper, iron, potassium, magnesium, manganese, molybdenum, nitrogen, phosphorus, sulfur and zinc. These variables were regressed against cone production to determine their influence and significance. EC and pH both had significant positive correlations with cone production, and percent coarse material had a significant negative correlation with cone production. EC is a measure of the concentration of ions in solution, and in whitebark pine environments it can be used as an approximation of the amount of available nutrients. When soil pH levels approach neutral more nutrients necessary to plants become available. Percent coarse material limits the amount of surface area on which nutrients or water may be held, and thus limits productivity. All other variables had no significant relationships with cone production. A multiple regression model using EC and pH significantly explained 38% of the variation in cone production. Percent coarse material was insignificant in the model because of its covariance with EC and pH, suggesting that it affected soil chemistry rather than water availability. A second multiple regression model, which used crown volume (Spector, 1999) and EC, significantly explained 59% of the variation in cone production. Soil pH was not used because of its correlation with EC, and because EC had more predictive power. The information gained from this study could be used to assist in site selection for planting of whitebark pine, and in developing other management strategies that increase whitebark pine cone production and provide better wildlife habitat.

INTRODUCTION

Whitebark pine grows in the western mountains of North America (Figure 1). It is generally found between the high elevation forests and upper treeline. Until recently little research attention has been given to the species due to its low timber value. However whitebark pine is important for wildlife, microclimates, snowmelt accumulation and ablation, and for reduced erosion in the upper parts of watersheds.

Whitebark pine is currently in danger from an introduced disease, white pine blister rust (*Cronartium ribicola*). This disease is moving into the Greater Yellowstone Ecosystem (Figure 2) from the Pacific Northwest (where it was accidentally introduced in 1910) (Hoff and Hagle, 1990). Whitebark pine is of great value to grizzly bears (*Ursus arctos horribilus*) because the cones contribute to part of the bears' diet (due to the high fat content of the seeds) (Kendall and Arno, 1990; Mattson and Jonkel, 1990; Baskin 1998). This large supply of high fat and easily accessible food serves to keep the bears foraging in higher elevations. Without an adequate seed supply the bears will increase the geography of their search for other food sources. Unlike the area around Glacier National Park, Montana where the bears have an alternative food in the higher elevations (e.g. huckleberries, *Vaccinium globulare*), the bears of the Greater Yellowstone Ecosystem lack alternate sources of plant-derived food in the higher elevations (Baskin, 1998). As a result, when the whitebark pine cone crop declines, bears leave the higher elevations in search of other types of food (such as elk or bison) (Kendall and Arno,

Figure 1: Distribution of whitebark pine across North America (from Arno and Hoff, 1989).

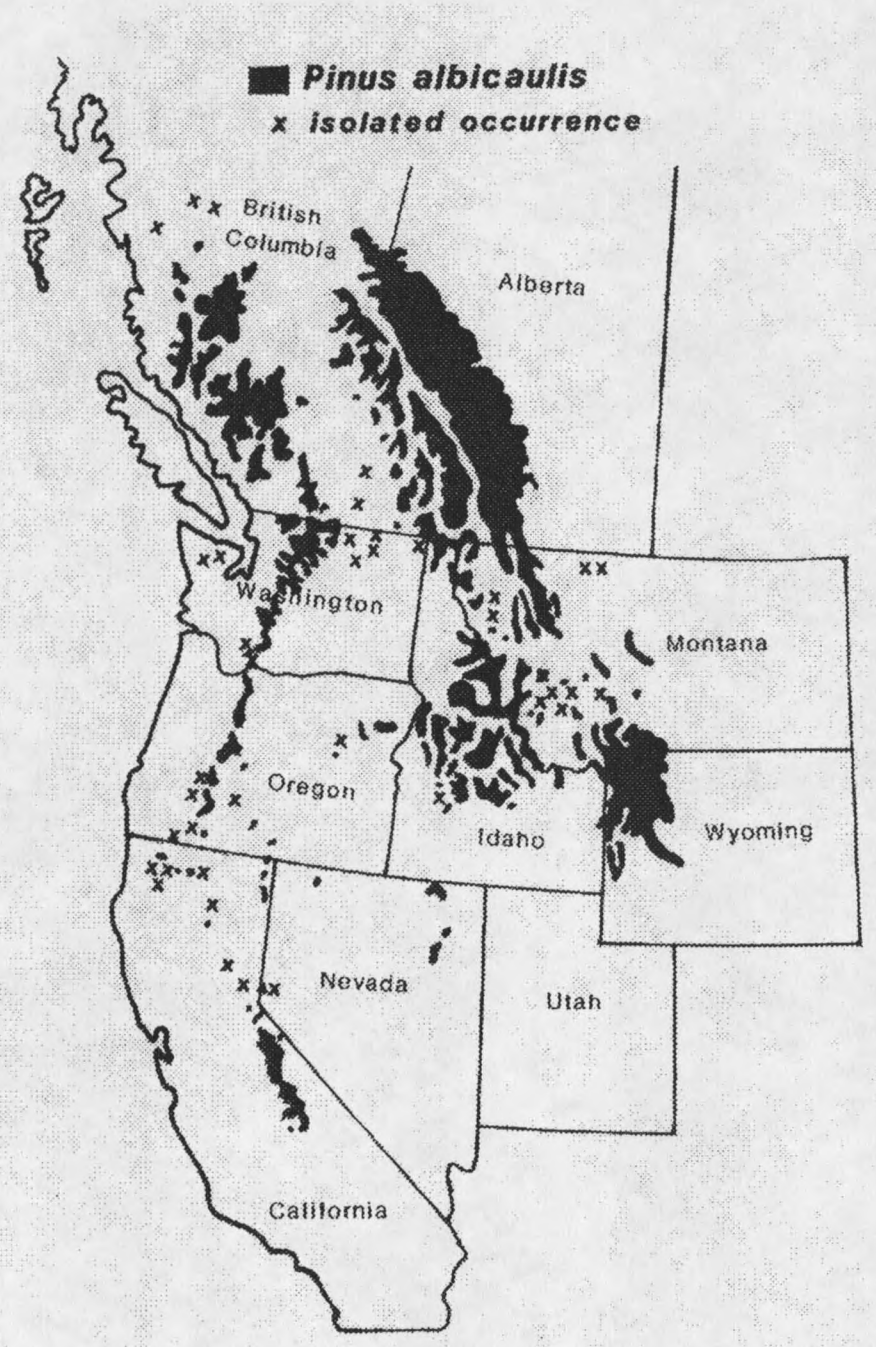
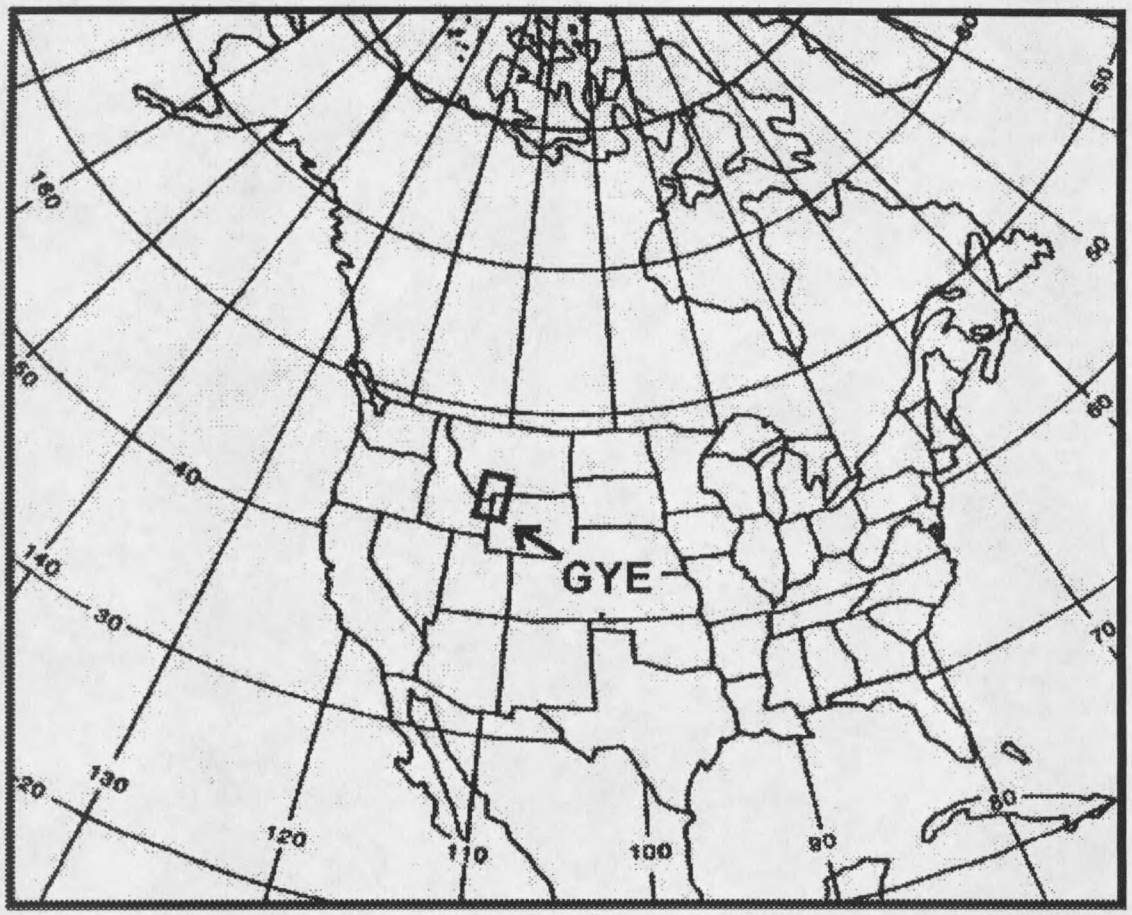


Figure 2: Location of the Greater Yellowstone Ecosystem (GYE).



1990) which may result in increased numbers of bear/human interactions (Blanchard, 1990; Kendall and Arno, 1990; Mattson and Jonkel, 1990). It has been documented that bear mortality (especially human-caused mortality) increases in years of low whitebark pine cone production (Mattson, 1998).

In 1980, the Interagency Grizzly Bear Study Team began collecting whitebark pine cone counts from sites around the Greater Yellowstone Ecosystem (Figure 3) in order to better understand whitebark pine cone production. Many factors, such as soils, climate, disease, ecology and genetics, may influence whitebark pine cone production, but to date there have been no studies that have examined the effects of soil on whitebark pine cone production (Arno, pers. comm.; Callaway, pers. comm.; Keane, pers. comm.; Montagne, pers. comm.).

Objectives and Hypotheses

The objective of my research was to determine if various soil properties affect whitebark pine (*Pinus albicaulis*) cone production in the Greater Yellowstone Ecosystem. There is a need to better understand what factors in the environment affect the cone production of whitebark pine. Soil properties studied included electrical conductivity, pH, texture, depth, and percent organic matter. Foliar nutrient concentrations were also studied, as a method of determining the use of soil nutrients by the tree. Soil properties should affect cone production because they strongly influence the potential productivity of a site (Powers et al., 1998).

The hypotheses of this study, based on previous literature, were: