Appendix B

Vegetation Module

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Background

Ecosystem science can help evaluate current forest management by examining how silvicultural practices follow or depart from historic disturbance regimes. The central axiom of ecological forestry is that forest management practices should occur "within limits established by natural disturbance patterns prior to extensive human alteration of the landscape" (Seymour and Hunter 1999). Disturbance regimes can be characterized by three general criteria: 1) return interval or time between disturbances, 2) area and spatial pattern, and 3) quality or severity of disturbance including biological legacies of the disturbance (Pickett and White 1985). If a forest, however, is already outside of its range of historical variability, restoration may require management practices that do not directly mimic historical disturbance patterns. These management practices are means to an end and should be evaluated by their ability to move stand structure and composition toward a desired condition.

The heterogeneity of Sierran mixed conifer forests is remarkable. Vegetation composition and structure within these forests varies considerably as a function of aspect, slope, position within a watershed, elevation, latitude, as well as many other physical and biological factors. Forest managers are engaging in silvicultural treatments intended to return forest conditions more within the range of natural variation with respect to fire extent and severity, composition, and structure. While employing treatment strategies across entire landscapes, attention to local conditions cannot be overlooked. Better understanding of site specific variation in tree response to treatments and resulting environmental conditions is important information for management.

There is particular concern for how forest management activities are going to enable the regeneration of shade-intolerant tree species, including ponderosa pine, sugar pine, Jeffery pine, and black oak. Use of group selection silviculture is one method that is being explored. Collectively, past research suggests that shade-intolerants can seed into, become established, and grow rapidly in larger group select openings. Based on the literature reviews we believe that group selection may favor shade-intolerant regeneration but that the resulting distribution and age structure of groups may differ from pre-settlement forest conditions. There are several parts of the puzzle, however, which need research. First, there are few reconstructions of historical disturbance regimes and stand structures for the northern Sierra Nevada; although it is unlikely that fire dynamics differ greatly from elsewhere in the mixed-conifer belt (Skinner and Chang 1996), an investigation of the fire history of this area would be helpful.

Studies in the Pacific Northwest have shown tree growth in gaps is affected by tradeoffs between increased light, temperature and soil moisture (from both increased throughfall and reduced transpiration). The interaction of these factors varies depending on seedling location within the gap and gap size (Gray and Spies 1997; Gray et al. 2002). What the studies do not address is the light, moisture and soil conditions favorable to different species, information we are now collecting which can be used to determine how group size should vary with local conditions such as aspect, slope and soil texture.

It is not known how retention of large trees in canopy openings created by group selection will affect tree regeneration. Large trees may facilitate seedling establishment by reducing soil surface temperatures and increasing near-surface soil moisture through hydraulic lift (Dawson 1996). As seedlings become established, however, large trees may reduce sapling growth by casting shade or competing for soil moisture and nutrients. Research is needed on the effects of size and density of retained tree on regeneration establishment and growth.

The competitive or facilitative dynamics of shrubs and tree regeneration are not well understood and may play an important role in seral development of group selects. Although some silviculturists have sometimes worked to eliminate shrubs on harvest sites, as a source of nitrogen, shade and wildlife cover they have important ecological functions. Research is needed to understand tree/shrub interactions and develop guidelines for shrub abundance and composition.

Finally, research should also examine group selection effects on small mammals. Although effects on individual owl pairs may be difficult to detect, changes in prey abundance, particularly density and abundance of the northern flying squirrel, could indicate more subtle, long-term effects on owl habitat ‘quality’.

Objectives

The vegetation module of the Plumas-Lassen Administrative study is focused on studying how changes in the forest canopy affect ecosystem functioning. Aspects of ecosystem function studied include understory microclimate, growth and competition of shrubs and juvenile trees, and growth of retained mature trees. A variety of approaches are used for studying tree canopy structure including 1) locating existing stands with different levels of canopy openness, and 2) carrying out manipulative experiments to change canopy openness. A second overarching objective is to assist other research modules of the Plumas-Lassen Administrative Study in achieving their vegetation-sampling objectives.

Accomplishments

Canopy cover and microclimate experiment. During the 2003 field season we established a medium-scale field experiment with the cooperation of the small mammal module researchers, and the ecosystem management team of the Mount Hough Ranger District. The experiment comprises nine 22-acre stands grouped in three areas (blocks) in mixed-conifer forest (Table 1). One stand in each block will serve as a control and the other two will undergo different levels of thinning, likely in the autumn of 2004, according to prescriptions established for use elsewhere on the National Forests. Trapping for small mammals is being done in all the stands by the small mammal research module.

Measurements of canopy structure were done in all the stands. In each stand a grid of 9 points at 50 m spacing was established where canopy-openness measurements were taken with an array of instruments: hemispherical-lens camera, moosehorn, spherical densiometer, and densitometer. Microclimate sensors were installed at a subset of points in each stand in fall 2003 and have been in continuous operation since then. The shrub community of the stands was assessed in conjunction with the small mammal researchers, which involved going to >100 points in each stand, identifying and measuring the shrubs present, and taking canopy photographs to assess canopy openness.

Table 1. Canopy cover (%) prior to treatment of nine 22-acre stands in experiment on thinning effects on microclimate. Cover was assessed with vertical sighting tube (i.e., canopy densitometer: 400 observations per stand).

Treatment	Location of block		
	Snake	Deane’s Valley	Waters
control	83	76	74
thin	63	70	60
thin	72	78	64

Mixed-conifer regeneration along natural gradients. A 20-mile long west-to-east transect was established to study regeneration of tree species of mixed-conifer forest. Field sampling for a study of sapling growth was completed: measurements of environmental variables (radiation interception and soil depth) and growth rate were done on 40 trees each of ponderosa pine, Jeffrey pine, sugar pine, white fir, incense cedar, and Douglas-fir (Figure 1). In addition, a suite of plant and soil variables are being analyzed in the lab. Growth ring analysis is underway in the Pacific Southwest Research Station dendrochronology lab (Figure 2), and carbon isotopic composition (an integrative measure of plant water status) will be analyzed in collaboration with Will Horwath of the U. C. Davis Department of Land, Air and Water Resources. Soil variables to be analyzed include pH, texture, nitrogen mineralization, extractable phosphorus, and magnesium-to-calcium ratio.

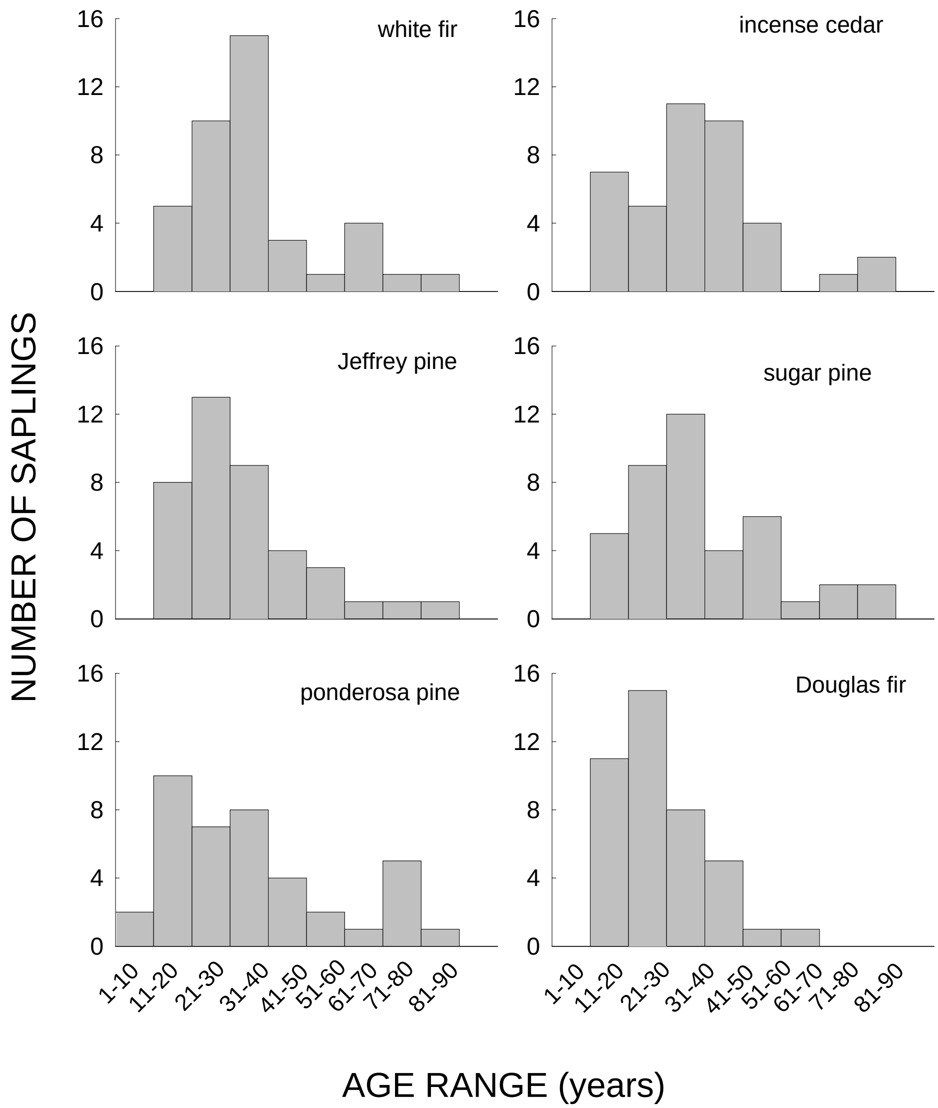


Figure 1. Age distribution of conifer saplings (0.5 - 3 m height) studied. Note the ability of all species to persist in the pre-reproductive state for many decades.

A companion study was established along the same 20-mile transect to examine survival along environmental gradients: 80 seedlings of the same species were tagged and measured, their survival will be monitored for an additional two years, and the same suite of environmental and plant variables will be measured. This same 20-mile transect may prove useful for understanding the conditions under which common shrub species thrive and hence compete with regenerating trees. A grant proposal was submitted to the Pacific-Southwest Research Station's Internal Competitive Grants program to apply the methods used in the regeneration study to the shrub community (Appendix 1).

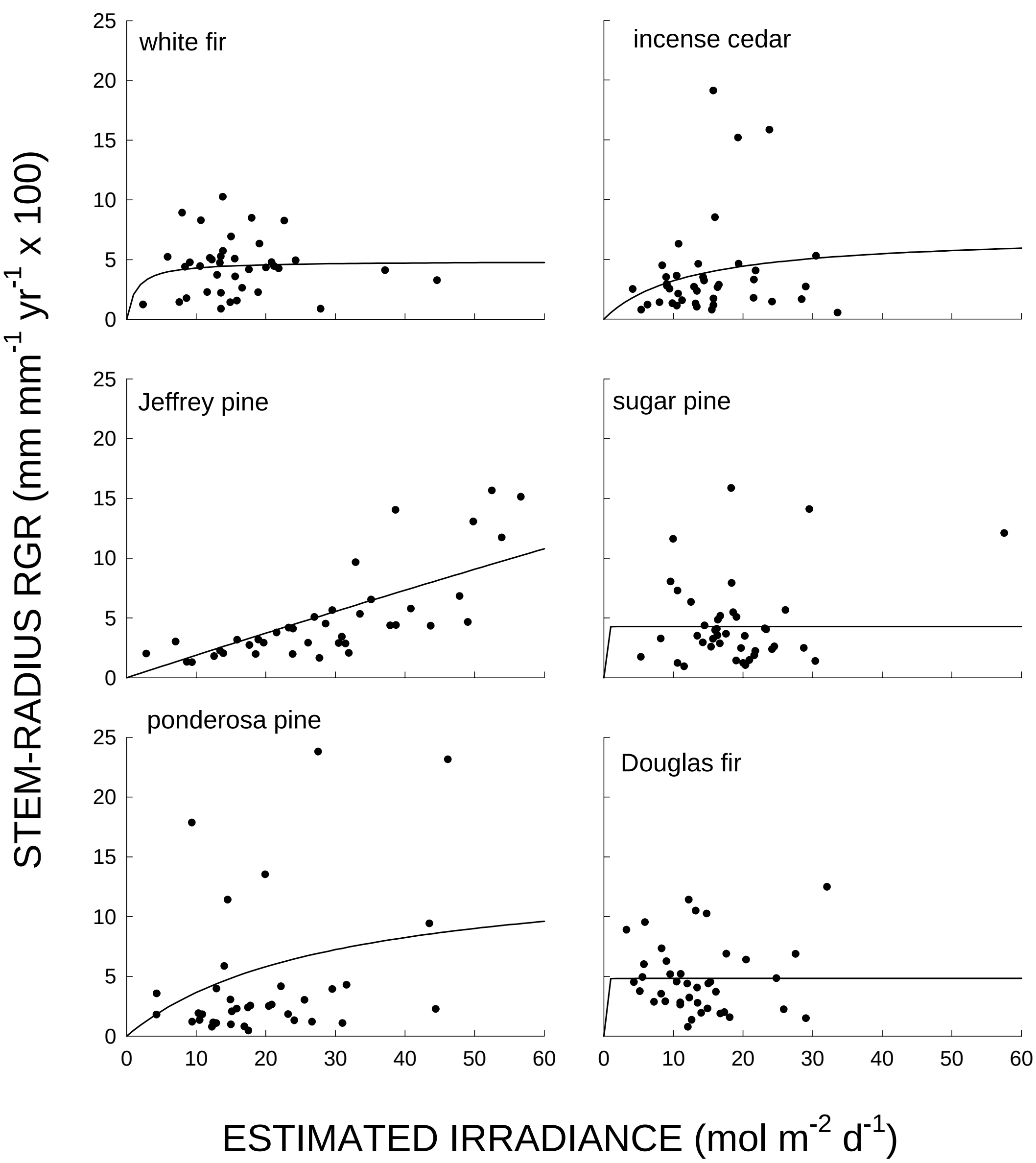


Figure 2. Relative growth rates of conifer saplings with respect to light. Ponderosa and Jeffrey pine saplings show typical shade-intolerant pattern of very low growth at low light, and high growth at high light. White fir exhibits a trade-off: high

growth rates at low light, but inability to grow rapidly at high light. Incense cedar, sugar pine, and Douglas fir show shade-tolerant behavior in this system.

Collaborative studies. Vegetation module personnel also designed an integrated scheme for sampling vegetation at scales appropriate to focal organisms and processes in the Administrative study (Appendix 2). Other collaboration (in addition to the above-described efforts with the small mammal research module included design of a menu-driven data-entry program for personal digital assistant using the Pendragon Forms program. The program allows direct field entry of data collected from releve (ocular macroplots) and fuels-module plots. The program interfaces with a Microsoft Access database. Personnel from the Terrestrial Bird module were trained in use of the data-entry program and in plot-assessment techniques. Vegetation module staff spent one month establishing plots for the Fire and Fuels research module.

Outreach. Vegetation module personnel participated in a presentation to community members and students from the U. C. Berkeley forestry camp at the Meadow Valley Schoolhouse, and also took part in a research presentation to the Quincy Library Group. Personnel also attended a field workshop on group selection silviculture organized by the Mt. Hough ranger district; and conducted a literature review of studies pertaining to the ecological basis of group selection silviculture in the northern Sierra Nevada.

Appendix 1. Research proposal submitted to PSW Internal Competitive Grants Program.

FROM CLOSED- TO OPEN-CANOPY FOREST: ANTICIPATING UNDERSTORY RESPONSE

Principal Investigators

Seth Bigelow, Pacific Southwest Research Station
William Horwath, University of California at Davis.

Introduction/Problem Statement

A central challenge facing forest managers in the Sierra Nevada range and throughout the American west is to alter the trajectory of forest development from dense, closed-canopy forests with infrequent but catastrophical fire regimes, towards open-canopy forests dominated by crown-fire-resistant species that tolerate and thrive on low-intensity surface fire. The means of effecting this change in trajectory, however, is not clearly known. Several outcomes of management interventions are possible including establishment of an alternate ecosystem state of shrublands dominated by a crown-fire regime. Silvicultural research in plantations has focused on controlling shrubs to establish regeneration, but little is known about tree-shrub interactions in the context of uneven-age management. Understanding of the early successional plant communities that form after disturbance has been identified as a key research need (McDonald 1999).

The plant communities that form after large canopy opening from logging disturbance are often determined by priority effects: whichever plant arrives first preempts growing space making it difficult for subsequent plants to become established. Shrub communities are resistant to invasion by trees (Hill et al. 1995) and the communities of the northern Sierra Nevada/southern Cascades are no exception. Common shrubs of the northern Sierra Nevada have a soil seedbank, so in the absence of a good tree seedfall year, the shrub community establishes a dominant presence at a site (Helms and Tappeiner 1996). Studies of openings in which no replanted was done (and which had site disturbance) showed that 5 years after disturbance, shrubs contributed over 50% of canopy cover, with grasses and forbs taking over much of the remaining cover (McDonald 1999).

Once established, trees are still susceptible to severe competition from shrubs. Experiments have demonstrated competition between Sierra trees and shrubs, and several studies have have examined the mechanisms of tree-shrub competition. High shrub densities considerably reduce ponderosa pine (*Pinus ponderosa* Laws) productivity (McDonald and Abbott 1997), and experiments with greenleaf manzanita (*Arctostaphylos patula* E. Greene) have linked this effect to competition for soil moisture (Shainsky and Radosevich 1986). The suite of tree species in the mixed-conifer forest respond differently to shrub competition: ponderosa pine is more sensitive than white fir or sugar pine to canopy volume of neighboring shrubs (Lanini and Radosevich 1986), and total cover of all woody plants within a 2 m radius is the best predictor of growth of Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) growth (Wagner and Radosevich 1991). One study, of competition between ponderosa pine and greenleaf manzanita varied the conditions under which the experiment was conducted (i.e., at different levels of soil moisture; Anderson and Helms 1994), but in general little is known about how environment changes the competitive balance between trees and shrubs.

Interactions between trees and shrubs in mixed-conifer forest should not simply be viewed as characterized by competition: there is substantial reason to believe that shrubs influence and even facilitate establishment of tree communities. Douglas-fir seedling establishment is limited by mycorrhizal inocula, but ericoid shrubs (e.g., *Arctostaphylos* sp.) can lifeboat inocula while sites are devoid of conifers (Hagerman et al. 2001). Perhaps more importantly, small mammals have been shown to be key dispersers of the seeds of one species, Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.), to sites favorable for germination, and there is a tendency to bury seeds under the cover of shrubs to reduce risk of predation (Vander Wall 1993, Vander Wall et al. 1999). Although Jeffrey pine has been most intensively studied in this regard, other species of mixed-conifer forest have similar adaptations for secondary seed dispersal by rodents. Finally, in particularly harsh sites, shrubs can ameliorate abiotic conditions resulting in enhanced establishment of tree seedlings. *Arctostaphylos* plants in coastal California scrub facilitate first-year establishment of invading Douglas-fir trees (Dunne and Parker 1999), and other shrubs perform a similar role in the southern Sierra Nevada (Gray et al. *unpublished manuscript*), although they competed with the saplings. (Understory shrubs maintain site quality: Busse et al. 1996.

Shrubs in Sierra Nevada ecosystems, and the potential of shrub communities to serve either as a seral stage that facilitates the establishment of tree communities or an climax state (dysclimax?) the time is ripe for further investigation into management of shrub communities and in particular, the contingencies of tree-shrub competition.

Objectives

We plan to characterize the growth rates of three common shrubs in the northern Sierra/southern Cascades province: Deerbrush (*Ceanothus integerrimus* Hook. and Arn.), greenleaf manzanita, and whiteleaf manzanita (*Arctostaphylos viscida* C. parry) with respect to light availability, neighborhood density, and growth resources. We wish to know under what conditions of light and soil resource availability the competitive relationships between common shrub and tree species are likely to be reversed. We will do a one-time sampling of soil and light conditions and water status of three common shrubs of the northern Sierra Nevada ranges. From these data we will determine growth optima (conditions for best growth) for each species, the range of growth conditions, and the most-limiting soil nutrients. We will develop equations for each species of growth as a function of light and most-limiting soil factor. We will compare these equations to ones already being developed for common trees of mixed-conifer forest: ponderosa, Jeffrey, and sugar pines; red and white fir; and incense cedar. We will look for areas of shifting competitive dominance. 0

Research Approach

Experimental Design and Methods

Naturally established individuals of the two most locally common shrubs-deerbrush and whiteleaf manzanita--will be located in a variety of light and soil environments of the northern Sierra Nevada/southern Cascades region (Plumas and Lassen National Forests). Sampling will be stratified by four prevalent parent material types: basalt, andesite, serpentinite, and granodiorite. On soils developed *in situ* from each parent material type, eight individuals of each species will be located in each of three canopy-openness classes: <33%, 33-66%, and >66% (field estimates of canopy openness to be obtained with a spherical crown densiometer; Lemmon 1957). Total sample size will be 192 shrubs: 2 species × 4 parent materials × 3 canopy openness classes × 8 individuals. Measurements of growth rate, age, and light and soil environments will be done on each shrub.

Plants will be sampled in circular plots of radius 0.56 m (1 m^2), because greenleaf manzanita has dense clonal growth and individual deerbrush plants are difficult to discern. All stems within the plot will have their diameter measured at 8 cm above the root collar (Hughes et al 1987), and the length of the five longest stems will be measured, as well as the height of the tallest plant in the plot. A section of the largest sound stem will be removed for ring width analysis (Keeley 1993) in the laboratory using a microscope and computerized stands. Age of the stem will be determined, as well as width of the growth rings of the three past years.

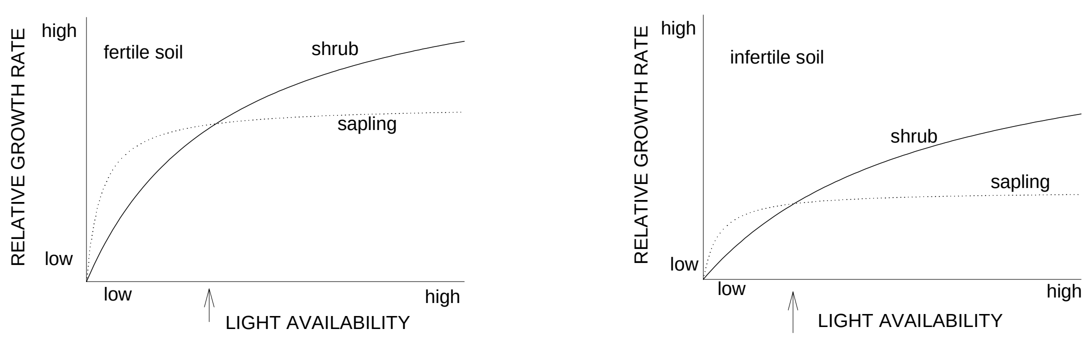
The annual photosynthetic photon flux density to each shrub will be estimated from a hemispherical-lens photograph taken of the tree canopy directly overhead using GLA software (Frazer et al. 2000). Three soil samples (0 to 20 cm depth) will be taken from around the base of each shrub and mixed together in the field. Soil will be analyzed for nitrogen mineralization rate (seven-day anaerobic incubation), exchangeable phosphorus (0.5 M HCl-1 M NH_4F extraction), exchangeable cations (1 M NH_4Cl extraction; Johnson 1995), and pH (0.01 M $CaCl_2$). Samples will be sealed in the field for gravimetric analysis of water content. Wood from the three most recent stem growth rings will be ground, purified, and tested for C13/C12 ratios to determine moisture stress.

Analysis

There will be three stages to the analyses. The first is to address how soil factors vary among the four parent materials and the two shrub species. The statistical approach is a multiple analysis of variance, with soil chemical and physical factors (including $^{13}C/^{12}C$ ratio in stem tissue and Ca: Mg ratio as a serpentine soil indicator) as response variables, and parent material, shrub species, and their interaction as main effects.

The second step is to select the best growth curve for the light response, then to test for limiting soil factors. An asymptotic curve is often used to describe tree growth (Pacala et al 1993) but this approach has not yet been used for shrubs, and it will be important to test whether a simpler formulation (e.g., a linear increase in growth rate in response to light) is appropriate. A maximum likelihood approach will be used, in which more complex models (e.g. curved compared to straight lines) are penalized in proportion to the additional numbers of parameters it takes to describe them mathematically (AIC?? Is so why not state it) (Hillborn and Mangel 1997). Once the appropriate light-response curve has been determined, we test for improvements in fit by modifying parameters of the light-growth equation according to soil chemistry, again using a maximum likelihood approach. This is a powerful, novel method for relating plant performance to soil chemistry (Bigelow and Canham 2002).

The final stage is to superimpose shrub light-growth curves on similar curves currently under development for saplings of mixed conifer species (see figure).The idea will be to search for points at which there is a switching of competitive performance so that we can predict canopy openness levels at which growth of sapling will exceed that of shrubs – such that the sapling are competitively dominant. Finally, we will introduce the concept of soil modulation of competitive relationships.



Hypothetical comparisons of shrub and sapling performance on fertile (left panel) and infertile (right panel) soils. Arrows denote light levels at which relative growth rate is equal between the two life forms: note shift to left at low soil fertility.

Research Timetable
Fieldwork will be carried out during the summer of 2004. Lab work will take place in the fall 2004, and data analysis and write-up will be done in spring of 2005.

Pitfalls/Limitations

The study will measure growth response of shrubs integrated over three years, but the plant's environment may have changed during that time. In particular, tree-falls or growth of tree crowns can change canopy openness, so there is an unavoidable degree of uncertainty in the measurement of light availability. Soil chemistry is likely to change more slowly, but inferences made with soil chemistry data bear the caveat that plants have the ability to change the soil that they grow in over time. Also, the degree of clonal integration of the plants is unknown. If greenleaf manzanita transports carbohydrates and other internal resources among stems, precise measurements of environment around one part of a plant may not accurately predict growth if the environment is patchy at the scale of a single clone. Finally, although the results will be used to predict the ability of plants to change growth rates given a change in canopy openness and/or soil conditions, the plasticity of growth rates is unknown. There is no substitute for manipulative experiments followed over time.

Expected Outcomes and Future Direction of Proposed Study

The study's outcome will be a research paper published in the peer-reviewed literature that 1) establishes growth-light relationships of two common Sierra shrubs, 2) compares them to growth-light relationships of saplings of six tree species of the mixed-conifer forest, 3) explores how growth-light relationships are contingent upon soil moisture, parent material, and other site factors, and 4) discusses implications for forest management practices of thinning and green-tree retention. The next stage of this research will be to test the predictions of the study by measuring response of shrubs and saplings to manipulations of overstory vegetation. Implementation of this experiment is already underway in the northern Sierra Nevada: experimental sites have been identified and agreements with forest personnel have been made. Treatments will include two levels of thinning, and complete canopy removal. Results of these experiments will provide needed guidance for policy makers and forest managers who are formulating forest harvest guidelines with the aim of restoring forests while preserving wildlife and restoring a historic fire regime and providing for harvest of timber.

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Seth Bigelow received his B.A. (1988) from the Department of Biology at the University of California, Santa Cruz and his M.S. (1992) and Ph.D. (1998) from the Department of Botany at the University of Florida, where his research concerned nutrient cycling in humid tropical forests. Since then he has studied tree-soil relationships in northern hardwood and western mixed-conifer forests as a post-doctoral researcher at the Institute of Ecosystem Studies (Millbrook, New York) and the Sierra Nevada Research Center.

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Will Horwath received his B. S. in Forestry and Environmental Impact Assessment from Southern Illinois University, and his Ph. D. in Crop and Soil Science and Forest Ecology from Michigan State University. His research interests are in soil fertility and sustainability of managed and natural ecosystems; roles of soil organic matter in global climate change and soil C sequestration; and carbon and nitrogen cycling processes, soil organic matter dynamics, and microbial-plant interactions using stable isotopes.

Responsibilities and time.

Bigelow will hire and manage the field crew, provide criteria for selection of field sites, supervise lab activities, and manage, analyze, and write-up data. (20% of year). Horwath will provide facilities and technical assistance for conducting laboratory analyses, and will consult in data analysis and write-up (2%).

Selected Recent Publications-Bigelow

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Potential Neutral Referees

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Appendix 2. Integrated Sampling Scheme for Plumas-Lassen Administrative Study

I. **PLUMAS VEGETATION SAMPLING: A 3 TIERED, INTEGRATED PROTOCOL**

Objectives:

Provide a common protocol to all modules in the Plumas Lassen study that 1) facilitates data integration and cross-discipline analysis; 2) provides for different sampling intensities and time limitations; and 3) is nested around a set of common methods and protocols with additional measurements added at each higher level.

Approach:

We have focused on 3 perceived levels of detail desired by different studies:

- Bird Module: need for rapid assessment of forest structure with many plots to be widely distributed across the landscape along bird census grids
- Fire Module: need for more detailed information on fuels, forest structure and shrub cover with targeted plot locations in fuel treatment zones
- Spotted owl & small mammal module: need for intensive quantification of old-growth and canopy attributes in specific use areas

Strategy:

All three sample plots are organized around a common set of measurements and categories which will be standardized between crews through common training by the vegetation module. Field technicians will enter and store data in PDAs with the same fields and categories.

Bird Module

Plot Layout: Point centered, variable radius plot

Physiography: Record UTMs, slope, aspect, distance to water, road distance, forest type.

Trees and Snags: Using a 10 BAF prism in a Panama Angle Gauge, count how many trees (by species) and snags are “in”. Include how many tallied trees have limbs at ≤ dbh height. Record canopy cover with a spherical densiometer.

Shrubs and Fuels: Secure the middle of a 50 m tape to the gridpoint and stretch out the tape 25 m each way (90^0 apart). Along each section of the tape tally shrub cover by species and Browns fuel classes.

Approximate time: 15-20 minutes

Fuels Module

(*italics are additions*)
Plot Layout: *1/20 ha fixed radius*

Physiography: Record UTMs, slope, aspect, distance to water, road distance, forest type, *litter depth*.

Trees and Snags: *All trees with 12.6 m of plot center are measured for diameter and species (trees) or decay class (snags). For each live tree, the height to the base of the live crown is visually estimated.* Include how many tallied trees have limbs at ≤ dbh height. Record canopy cover with a spherical densiometer *and moosehorn*.

Shrubs and Fuels: Secure the middle of *two* 50 m tapes to the gridpoint and stretch out the tape 25 m each way (90^0 apart). Along each section of the tape tally shrub cover by species, *in 3 height class (<0.5 m, 0.5-2 m, 2-4 m)* and Browns fuel classes.

Logs: *A visual estimate of the large and small diameter (nearest 10 cm), length, decay class*

Time estimate: 2 hours/plot

Spotted Owl and Small Mammal Modules

(*italics are additions*)
Plot Layout: *3 concentric fixed radii plots, different cutoffs for each size*

Physiography: UTMs, slope, aspect, distance to water, road distance, forest type, litter depth, *general description*.

Live tree: species, dbh, *canopy class (emer., dom., co-dom., inter., sup.) and a Hawksworth mistletoe rating*

Snags: dbh, *height (visual estimate)*, decay class and *number of visible cavities ≥ 10 cm diam.*

Logs: [volume]—large and small diam (near 10 cm), length, decay class

Shrubs, Fuels and *Logs*: *Secure* the middle of *two* 50 m tapes to the gridpoint and stretch out the tape 25 m each way (90^0 apart). Along each section of the tape tally shrub cover by species, in 3 height class (<0.5 m, 0.5-2 m, 2-4 m) and Browns fuel classes. *Also along the tape tally log cover by decay class.*

Canopy openness: Hemispherical photograph taken at plot center

Canopy structure: For all trees in the 0.1 ha plot, 4 measurements are taken: total height, height to the beginning of ladder fuels, height to the base of the live crown,

crown diameter (avg of 2 cross diam.) and crown shape (i.e., cone, cylinder, truncated ellipse, umbrella).

<u>Plot layout</u>

The principal plot is 3 nested circles:

B: 12.6 m radius (0.05 ha). All trees and snags ≥ 10 cm dbh are measured

C: 17.8 m (0.1 ha). All trees and snags ≥50 cm dbh. All logs ≥20 cm diam and 2 m long.

D: 56.4 m (1 ha). All trees and snags ≥80 cm dbh