THE RESTORATION OF NATIVE FLORA FOLLOWING EUCALYPTUS GLOBULUS REMOVAL IN THE EAST BAY HILLS OF NORTHERN CALIFORNIA

Stephanie Lin

College of Letters & Sciences
Department of Integrative Biology
University of California, Berkeley
Berkeley, CA

Submitted on May 11, 2009 in fulfillment of the requirements of the Integrative Biology Honors Program

THE RESTORATION OF NATIVE FLORA FOLLOWING EUCALYPTUS GLOBULUS REMOVAL IN THE EAST BAY HILLS OF NORTHERN CALIFORNIA

STEPHANIE LIN

Integrative Biology, University of California, Berkeley, California 94720 USA

Abstract. Management efforts in the East Bay Hills of Northern California have dealt with the invasive species, *Eucalyptus globulus*, through stand removal in attempts to reduce fire risks associated with *E. globulus* stands as well as facilitate the restoration of native habitat. This study assessed the restoration of native flora following *E. globulus* removal over time and found that post-removal time did not correlate with grass, brush, or seedling density and composition. However, the number of brush species increased and the proportion of California native plants decreased with post-removal time. Of all brush surveyed, 59% were California native species. 90% of tree seedlings surveyed were California native species. The presence of *E. globulus* chips as groundcover correlated with fewer grasses and was not found to favor native species over non-native species. Findings suggest that the management methods used in *E. globulus* stand removal were overall effective in reducing fire risk and restoring some native habitat. However, the aggressive emergence of non-native brush species may be prevented through continued management. In addition, the landscape of the East Bay Hills may be managed with specific regards to disturbance regimes to meet management goals.

Key words: Eucalpytus globulus, invasive species management, native flora restoration

INTRODUCTION

Invasive species pose a threat to the biodiversity and ecological structures of native habitats (Schei 1996). The removal of invasive vegetation is a common method of mitigating such effects, along with native species planting (Bean & Russo, 1986, California Department of Parks and Recreation, 1988). In the coastal hills of the East Bay, once typified by perennial grassland and oak woodland, expanding populations of introduced species have altered native ecosystem characteristics, including habitat structure, species composition, and disturbance regimes (Mack and D'Antonio, 1998).

First introduced to California in 1853 (McBride et al., 1988), *Eucalyptus globulus* has since been listed as one of the top invasive species in California and is a common target of vegetation management plans (National Park Service, 2006). In general, *E. globulus* is known to increase fire intensities, decrease wildlife diversity, and displace native flora populations (Cal-IPC, 2004). For example, compared to California native Coast Live Oak, *E. globulus*, tends to produce three times the mass of dead woody debris, which in turn causes invaded areas to accumulate greater fuel loads (National Park Service, 2006). Eucalyptus also grows quickly relative to native species, up to ten feet of growth per year, and has the potential to out-compete native populations and displace grasslands and oak woodlands with tall, dense monospecific stands. Furthermore, Eucalyptus has known allelopathic effects on soil chemistry that prevent the germination and establishment of competing species (Molina et al., 1991, Cal-IPC, 2004). As such, Eucalyptus stand removal is used to restore native habitats in California (California Department of Parks and Recreation, 1988, National Park Service, 2006).

The University of California, Berkeley has attempted to control the growing population of *E. globulus* on University property situated in the East Bay Hills through the mechanical removal of dense *Eucalyptus* stands (Safe Solutions Group, 2003). According to University management plans, "the management strategy promotes a forest conversion: the emerging native forest of California Bay, Oak, Maple, and Hazelnut will be retained and the existing eucalyptus dominated exotic canopy forest will be eradicated… The protection of the native species, and ongoing management after project completion, will ensure a successful conversion protective of natural and

recreational resource values, including but not limited to habitat, hydrology, soils and geology, aesthetics and air quality." The stated priorities of the University's management efforts in the East Bay Hills include both fire risk mitigation and native habitat protection (Safe Solutions Group, 2003). Since the area of interest lies in a wildland urban interface with a known wildfire history of 15 major wildfires over the past 70 years, fire safety is a major concern within the community. Over the span of eight years, University management efforts have removed over 18,000 individuals at 15-yr and 30-yr age classes across 147 acres. This management effort can be framed as a natural experiment to test native species responses, with management technique, macroclimate, geographic situation, and historic natural plant communities as controlled variables (See Table 1) (Klatt, 2008).

In this particular management effort, the University exclusively removed *E. globulus* between 1999 and 2007 with special efforts to retain all other tree species (Klatt, 2007). All Eucalyptus stumps were immediately treated post-cut with herbicide (Garlon 4) to prevent from re-sprouting. Most of the cut logs were scattered on site as chips and whole logs to mitigate soil erosion and herbicide diffusion (Safe Solutions Group, 2003).

In this study, I surveyed the managed landscape as a model for native flora restoration following invasive vegetation removal. Through the winter and spring seasons of 2009, I surveyed five sites, each of which had been cleared of Eucalyptus between one and seven years before surveying. This study sought to capture a successional view of native flora response to renewed availability of resources following the removal of non-native competition. The main objective of this study was to survey the establishment of vegetation following management and find trends in native and non-native grass, brush, and seedling species establishment over time to give insight into future vegetation management plans with respect to native habitat restoration.

METHODS

Study Sites

The East Bay Hills are located east of the San Francisco Bay in Northern California. This study was conducted in the northern Oakland Hills, specifically in the areas of Claremont Canyon and Chaparral Hill, between elevations of 900 and 1700 feet. The five sites I surveyed represented various areas of Eucalyptus removal bounded by University management plans and property lines.

Site Name	*Date of Vegetation Removal*	*# Of Stems Removed*	*Age Class*	*Acres*
Claremont 1	September 2001	230	30 yr.	3
Claremont 4	October 2004	900	30 yr.	12
Claremont 5	August 2005	1000	30 yr.	5
Claremont 6	October 2006	3200	30 yr.	14
Chaparral Hill	July 2007	700	15 yr.	4

Table 1: Survey Sites

Vegetation Surveys

In each site, I surveyed 15 randomly selected plots, with the exception of Claremont 1 at which I surveyed only 10 plots due to the inaccessible nature of the site. Sites were surveyed one at a time between December and April of 2009. Each circular plot was 30 feet in diameter and was randomly selected using GIS software. I navigated to each plot using a handheld GPS device and surveyed the plot area for vegetation to quantify grasses, brush, and tree seedlings, in addition to site characteristics. For every plot, I determined aspect and slope with a compass, elevation using a GPS device, and groundcover through observation. I quantified presence of grasses at every foot mark within a 30-foot diameter oriented at a randomly chosen direction. Using the point-intercept method, I quantified brush intercept lengths and species. Lastly, I recorded all seedling species and their heights within each plot area. Seedlings were defined to be less than seven feet in height, depending on the post-removal time attributed to the location of the plot in which the seedling was found. In total, I surveyed 70 plots in representation of 38 acres of treated hillside.

Data Analysis

Trends were analyzed using simple statistics, ANOVA, and regression analysis using statistical software (JUMP 7.0).

RESULTS

Species Composition

Of all brush surveyed, 59% were California native species. Native brush was composed of 38% *Rubus ursinus* (California Blackberry), 26% *Baccharis pilularis* (Coyotebrush), and 17% *Toxicodendron diversilobum* (Poison Oak). Non-native brush was composed of 75% *Silybum marianum* (Milk Thistle) and 18% *Genista monspessulana* (French Broom). Of all tree seedlings surveyed, 90% were California native species, consisting of 40% *Umbellularia californica* (California Bay), 33% *Quercus agrifolia* (Coast Live Oak), and 23% *Sequoia sempervirens* (Coast Redwood). Although surveyed grasses were not identified, I observed few perennial bunchgrasses relative to annual grasses.

Effect of Post-Removal Time on Vegetation

The effect of post-removal time did not correlate with grass, brush, or seedling density and composition. However, the number of brush species present increased significantly with time since *Eucalyptus globulus* removal (P-value=0.0021, R^2=0.14, n=68). The proportion of California native plants significantly decreased with post-removal time (P-value=0.0003, R^2=0.05, n=280).

Effects of Elevation, Slope, and Aspect on Tree Seedling Composition

Tree seedling densities were significantly higher in areas of greater slope (P-value=0.0072, R^2=0.10, n=68) and significantly higher in areas of lower elevation (P-value=0.0003, R^2=0.18, n=68). Similarly, the number of seedling species present was significantly higher in areas of greater slope (P-value=0.0258, R^2=0.07, n=68) and significantly higher in areas of lower elevation. Seedling height increased with increasing aspect (P-value=0.03, R^2=0.03).

Effect of Chips on Vegetation

Chips as groundcover were found on 49% of all surveyed plots (n=68). The presence of chips as groundcover did not significantly affect brush cover, tree seedling density, seedling height, or favoring of native or non-native species. However, grass cover was significantly lower in areas with chips present (P-value=0.05, R^2=0.05, n=68). The number of brush species present per plot was significantly lower in plots with chips (P-value=0.0132, R^2=0.09, n=68). Additionally, *Umbellularia californica* seedlings were found in plots with chips as groundcover only 29.23% of the time.

Interspecific Competition

Plot areas with greater tree seedling densities also exhibited greater number of tree species (P-value<0.0001, R^2=0.56, n=68). Similarly, plot areas with greater brush cover also exhibited a greater number of brush species (P-value=0.0322, R^2=0.07, n=68).

DISCUSSION

Species Composition

The most commonly found species, *Rubus ursinus*, *Baccharis pilularis*, and *Toxicodendron diversilobum* made up 82% of native brush surveyed. *R. ursinus* typically establishes on sites following disturbances such as logging or fire and is often suppressed by the canopy closure of mature forests (Tirmenstein, 1989). *T. diversilobum* is one of the most widespread shrub in California (Howard, 1994). These native brush species commonly occur in seral woodlands and generally respond well to disturbances.

In addition, non-native brush has a strong presence, making up 41% of all brush species surveyed. 93% of the non-native brush surveyed consisted of only two dominant brush species: *Silybum marianum* and *Genista monspessulana*. Dense *S. marianum* stands are known to lower species diversity through resource competition and the shading of nearby vegetation. However, the aggressive spread of *S. marianum* often requires disturbance on nutrient-rich sites, offered by fire or intense management (Gabay et al., 1994, Cal-IPC, 2004). In California, the overall invasiveness of *S. marianum* is considered to be "limited" (Cal-IPC, 2004). In contrast, the invasiveness of *G. monspessulana* is considered to be "high" (Cal-IPC, 2004) since the species is known to increase fire intensity, out-compete native vegetation on all soil types, change microclimate conditions, and produce seeds toxic to humans and wildlife (Cal-IPC, 2004). The population of these two exotic brush species may dominate and overcrowd the East Bay Hills over time if they are not monitored and managed accordingly.

E. globulus removal has left the managed sites with a strong native tree seedling population dominated by *U. californica, Q. agrifolia*, and *S. sempervirens*. This is at least partially due to on-going management efforts that have deliberately planted *S. sempervirens* seedlings in some managed sites.

Effect of Post-Removal Time on Vegetation

The number of brush species may have increased while the proportion of native plants decreased over post-removal time due to the additional establishment of non-native brush species, mainly *S. marianum* and *G. monspessulana,* following *E. globulus* removal. The removal may have created suitable conditions for exotic brush establishment, including growing resource availability from disturbed areas.

Effects of Elevation, Slope, and Aspect on Tree Seedling Composition

Seedling densities and species richness may have increased with greater slopes and lower elevations since such conditions may provide better microhabitats for seedling recruitment. Increasing seedling height may correlate with increasing aspect since light availability is higher in south and southwest facing slopes (White and Harrod, 1997).

Effect of Chips on Vegetation

The management technique of chip distribution across project sites is intended for the economic use of removed biomass for erosion prevention and exotic species suppression. Although this method may significantly mitigate erosion, this study found that scattering chips did not effectively suppress non-native vegetation relative to native vegetation. Instead, the scattering of chips may have suppressed grasses and inhibited the restoration of grassland in favor of brush and tree seedling emergence. Overall, the consequences of management techniques are still somewhat consistent with the management goals in reducing fire risk and restoring native habitat in some form.

Study Limitations

This study was able to take advantage of an existing management project to assess native flora restoration following *E. globulus* removal. However, the natural scope of the project was limited to a small distribution of sites with limited management methods available for assessment. Further study of sites with a broader distribution of geographic characteristics and post-removal time is needed to thoroughly analyze the restoration of native flora succession following *E. globulus* removal in Northern California, including control sites consisting of mature eucalyptus forests. This study may also expand to include all sites managed by the University and other managed regions which have undergone *E. globulus* removal, including Angel Island State Park, East Bay Regional Parks, Point Reyes National Seashore, and Golden Gate National Recreation Area (National Park Service, 2006). Further study may also survey grass populations later in the spring when grasses exhibit defining characteristics. The small number of five sites that were surveyed limited this study in terms of analyzing the effect of post-removal time on vegetation.

CONCLUSION

The findings suggest that the management methods used in *E. globulus* stand removal were overall effective in immediate fire risk mitigation and native habitat improvement. The native tree seedling population has generally responded well to management efforts, in line with the management goal of native forest conversion. In addition, *E. globulus* re-sprouts have successfully been suppressed. Native grassland restoration needs to be considered in deciding how to appropriately distribute chips as groundcover.

The brush species emerging in response to *E. globulus* removal tend to be those that thrive upon disturbance. The aggressive emergence of non-native brush species in response to additional resources made available by *E. globulus* removal may be addressed through exotic brush removal and native flora planting to ensure a seed source for favored species, not only those that respond well to disturbance.

In addition, the landscape of the East Bay Hills may be managed with specific regards to disturbance regimes in facilitating or preventing the formation of certain landscape types to meet management goals, specifically native flora restoration. Management efforts may have longer-term

outcomes upon continued management and assessment to work toward "a successful conversion protective of natural and recreational resource values."

ACKNOWLEDGMENTS

I thank my thesis advisor, Professor Joe McBride for his good advice, teaching, and encouragement. I also thank Dr. Andrea Swei, Dr. Joel Abraham, and Dr. Allison Kidder for their guidance and support in developing the capacity necessary for the completion of this project. Special thanks to Tom Klatt, former manager of UC Berkeley's Office of Emergency Preparedness, for his dedication to fire mitigation in the Hills and for sharing many helpful documents. Lastly, thanks to Melissa Chun and Shee Zhi Qiang for forming the Joe Thesis Group (JTG).

LITERATURE CITED

Bean, C. and M.J. Russo. 1986. The Nature Conservancy. Element Stewardship Abstract for Eucalyptus globulus (Tasmanian blue gum).

Cal-IPC (California Invasive Plant Council). 2004. Plant Assessment Form for *Eucalyptus globulus*. Cal-IPC Invasive Plant Inventory.

Cal-IPC (California Invasive Plant Council). 2004. Plant Assessment Form for *Genista monspessulana*. Cal-IPC Invasive Plant Inventory.

Cal-IPC (California Invasive Plant Council). 2004. Plant Assessment Form for *Silybum marianum*. Cal-IPC Invasive Plant Inventory.

California Department of Parks and Recreation. 1998. Focused Environmental Study: Restoration of Angel Island Natural Areas Affected by Eucalyptus.

Gabay, R.; U. Plitmann; A. Danin. 1994. Factors affecting the dominance of *Silybum marianum L.* (Asteraceae) in its specific habitats. *Flora*. **189**: 201-206.

Howard, J.L. 1994. Toxicodendron diversilobum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2009, May 11].

Klatt, T. 2007. Mitigation Monitoring Reporting Table, 3rd Quarter 2007. University of California, Berkeley, Facilities Services, Physical and Environmental Planning.

Klatt, T. 2008. Fire Mitigation Program – Cost Accounting Summary – Cumulative 1999-2008.

Mack M. C., C. M. D'Antonio. 1998. Impacts of biological invasions on disturbance regimes. *Trends in Ecology & Evolution* **13**:195-198.

McBride, J.R., Sugihara, N., and D. Amme. 1988. History of Eucalyptus on Angel Island. In: Focused Environmental Study: Restoration of Angel Island Natural Areas Affected by Eucalyptus: 23-24.

Molina, A., M.J. Reigosa, and A. Carballeira. 1991. Release of allelochemical agents from litter, throughfall, and topsoil in plantations of Eucalyptus globulus Labill in Spain. *Journal of Chemical Ecology* **17**: 147-160.

National Park Service, U.S. Department of the Interior, Fire and Fuels Management. 2006. Eucalyptus.

Safe Solutions Group. 2003. UC Berkeley 2020 Hill Area Fire Fuel Management Program. UC Berkeley Fire Mitigation Committee.

Sax, D.F. 2002. Equal Diversity in disparate species assemblages: a comparison of native and exotic woodlands in California. *Global Ecology and Biogeography*. **11**:49-57.

Schei, P.J. 1996. Conclusions and recommendations from the UN/Norway conference on alien species. *Scientific International* **63**:32-36.

Tirmenstein, D. 1989. Rubus ursinus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2009, May 10].

White, P.S., and J. Harrod. 1997. Disturbance and Resource Availability. In: Wildlife and Landscape Ecology.