University of California, Santa Barbara
Donald Bren School of Environmental Science and Management
MESM Group Project

A Dynamic Strategy for Conserving Southern Sierra Blue Oak Woodland

A Group Project submitted in partial satisfaction of the requirements for the degree of Master's in Environmental Science and Management for the Donald Bren School of Environmental Science & Management

By:
Zachary Bradford
Ryan DiGiondomenico
Sarah Graber
Stephanie Hsia
Nathan Snider

Committee in charge:
Lee Hannah

May 2007

A Dynamic Strategy for Conserving
Southern Sierra Blue Oak Woodland

As authors of this Group Project report, we are proud to archive it on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Donald Bren School of Environmental Science & Management.

Zachary Bradford

Ryan DiGiondomenico

Sarah Graber

Stephanie Hsia

Nathan Snider

The mission of the Donald Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the school is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions. The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) program. It is a four-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

Faculty Advisor: Lee Hannah

Dean of the Donald Bren School: Ernst Ulrich von Weizsäcker

May 2007

Acknowledgements

We would like to thank the following people who assisted us by generously sharing their knowledge, time, and energy: Chang Wan Seo of Seoul National University, South Korea; Jim Thorne of University of California, Davis; Alex Mas, Dick Cameron, and Mark Reynolds of The Nature Conservancy; Theresa Syzmanis and Mike Hickey of Tulare County; Hilary Dustin of Sequoia Riverlands Trust; Harold Werner of Sequoia National Park; Ian Davies of Australian National University, Canberra; Guy Midgley of South African National Biodiversity Institute; Wilfried Thuiller of Laboratoire d'Ecologie Alpine; Robert Hijmans of Rice Research Institute, Philippines; and Allan Hollander of University of California, Davis.

We would like to extend a special thanks to our faculty advisors for their invaluable guidance: Lee Hannah, Visiting Professor, Donald Bren School of Environmental Science & Management and Senior Research Fellow, Conservation International; Frank Davis, Professor, Donald Bren School of Environmental Science & Management; David Stoms, UCSB Biogeography Lab Manager, Donald Bren School of Environmental Science & Management; and Chris Costello, Associate Professor, Donald Bren School of Environmental Science & Management.

Finally, we are grateful to our friends and family who were extremely supportive throughout this process.

Table of Contents

Abstract xi
Executive Summary xiii
Introduction 1
Background 1
Statewide and Strategic Context 3
Part I: Selection of Priority Areas 11
Background 11
Methods 13
Results 14
Part II: Threats to Blue Oak Woodland in Tulare County 19
A. Development Threats to Blue Oak Woodland 19
Background 19
Impacts of Development on Blue Oak Woodland 20
Current State of Blue Oak Woodland in Tulare County 23
Potential Development in the Foothill Region 27
Modeling Future Development Scenarios 30
B. Climate Change 41
Background 42
Bioclimatic Envelope Modeling 43
Dynamic Species Modeling 49
Discussion 52
C. Threat Synergy 54
Methods 54
Results 54
Comparison to a Previous Assessment 57
Discussion 59
Recommendations 61
References 67
Appendices 73
Appendix I: Conserving the Blue Oak Woodland Community 73
Appendix II: Selecting Appropriate Reserve Size 81
Appendix III: Managing Blue Oak Woodland 85
Appendix IV: Tulare County General Plan Synopsis 91

Figures

Figure 1.1: Counties in the Sierra Nevada and northern Central Valley containing significant amounts of blue oak woodland (shown in blue)....4

Figure 1.2: Suitable habitat ranges for BOW vertebrates....8

Figure 1.3: Statewide BOW range as predicted by four climate change scenarios....9

Figure 2.1: Clockwise from top left, the top 33% of watersheds are selected in green for riparian habitat, threatened and endangered plants, CNDDB vertebrates, elevation range, and fragmentation/intactness....15

Figure 2.2: Priority areas that contain the highest ecological value 16

Figure 2.3a-c: Left to right, watersheds with a 20%, 25%, and 33% cutoff 18

Figure 3.1 a-b: All of Tulare County's cities are located on the valley floor. The foothill region contains two communities and several major roadways (left figure). The range of blue oak woodland exists primarily within the foothill region (right figure) 24

Figure 3.2. Blue oak woodland in Tulare County mainly occurs on private lands. Most of blue oak woodland that falls on public lands occurs within the Tule River Indian Reservation....25

Figure 3.3: Intact blue oak woodland (green) and intact blue oak-foothill pine (brown) in Tulare County (left), and fragmentation effects on blue oak woodland and blue oak-foothill pine (right) 26

Figure 3.4: Potential developments—Yokohl Ranch, Sequoia Ranch, and the Foothill Development Corridor....27

Figure 3.5: The Foothill Development Corridor and the Yokohl Ranch Project exist in areas where slopes are less than 30%....28

Figure 3.6: The Yokohl Ranch Project falls on low to high priority areas identified by the multi-criteria analysis....30

Figure 3.7: Build-out map and fragmentation map for Scenario 1 33

Figure 3.8: Build-out map and fragmentation map for Scenario 2 34

Figure 3.9: Build-out map and fragmentation map for Scenario 3 35

Figure 3.10: Build-out map and fragmentation map for Scenario 4....36

Figure 3.11: Build-out map and fragmentation map for Scenario 5....37

Figure 3.12: Build-out map and fragmentation map for Scenario 6....38

Figure 3.13: Build-out map and fragmentation map for Scenario 7....39

Figure 3.14: Priority area E is predicted to be the most heavily impacted by development under the Roads-driven Scenario....41

Figure 4.1. These histograms show the range of bioclimatic conditions occupied by blue oaks relative to the overall range of conditions statewide. The bioclimatic variables displayed here are those used in the BioMOD envelope modeling. The green area of the histogram represents the vegetation survey plots classified as "present," while the blue area represents those classified as "absent" 45

Figure 4.2: The bioclimatic envelope produced by the GBM. Red points denote vegetation plots in which blue oaks were present, and black points denote plots in which blue oaks were absent. The black outline shows the range of the blue oaks as determined by the California Department of Forestry's Fire and Resource Assessment Program (CDF FRAP)........ 47

Figure 4.3: The predicted distribution of lost (red), gained (green), and stable (blue) range for the blue oaks for two GCMs and two emissions scenarios. These values were produced by taking the difference between the current modeled range of the blue oaks and their predicted range in 2080 according to each scenario 48

Figure 4.4. Impact on the total area of blue oak habitat in Tulare County under climate change, according to two GCMs and two emissions scenarios. The CCM model predicts a relatively constant rate of decline for both emissions scenarios, with range being reduced by about 25% for both emissions scenarios. The Hadley Centre model predicts a more drastic reduction in range, with declines accelerating until 80 – 95% of the current habitat has been lost........ 49

Figure 4.5. Dispersal functions for local and long-distance dispersal in the blue oaks Biomove model........ 51

Figure 4.6. Mature tree abundances from the Biomove dynamic simulation........ 52

Figure 4.7. Overlap of the BioMOD envelope results for the year 2080. The areas of highest agreement are shown in dark blue, while the areas of lower agreement are shown in varying shades of green. Thick, black outlines show priority areas as identified in Part I. Thin, dashed lines show current range of blue oak woodland as determined by FRAP........ 53

Figure 5.1: This map depicts the combination of development and climate change threats within blue oak woodland in our study area, as predicted by our analyses for 2080. Colors show the level of blue oak persistence while hatch marks show development classifications........ 56

Figure 5.2: This map shows the distribution of development impact within areas of likely persistence for blue oak woodland in the year 2080, along with the priority areas from our multi-criteria analysis. 57

Figure 5.3: The graph shows the percent of current blue oak woodland that will be made climatically unsuitable by climate change (gray), suitable habitat that may be impacted by development (orange), and unthreatened habitat (green) within the priority areas from our multi-criteria analysis. In the bar graphs, the left-to-right order of sites corresponds to a north-to-south order on the map in Figure 5.2........ 58

Figure 6.1: Bands of high persistence (shown in blue) may be used to guide the creation of a corridor system between conservation priority areas 63

Figure 6.2: An overlay of the Wildland Linkage Corridor (Shilling *et al.* 2002) shows high correspondence to bands of high-persistence habitat between conservation priority areas........ 64

Tables

Table 1.1: Area statistics (area in acres) 5

Table 1.2: Population statistics 6

Table 1.3: Population growth statistics 6

Table 1.4: Housing statistics 7

Table 2.1: CNDDB vertebrates found in Tulare County blue oak woodland 12

Table 2.2: Descriptions of each priority area 17

Table 2.3: List of CNDDB vertebrates found within our six conservation priority areas 17

Table 3.1: California Department of Finance population projections for Tulare County and California 20

Table 3.2: Current assessment of development impacts on blue oak woodland 26

Table 3.3: The percentage of parcels affected by a 200-m disturbance zone 31

Table 3.4: The impact of future development scenarios on blue oak woodland 32

Table 3.5: The impact of future development on priority areas differs greatly 40

Table 4.1: Demographic parameters used in Biomove model of blue oaks 50

Table 5.1: This table describes the condition of the current range of blue oak woodland in 2080 as predicted by our climate change and development analyses 55

Table A1: RTE species in blue oak woodland and blue oak-foothill pine as determined by CA WHR 76

Table A2: List of all CNDDB species found within the Calwater planning watersheds of Tulare County blue oak woodland and blue oak-foothill pine (sorted by global rarity—GRANK) 78

Table A3: Threatened/endangered species in Tulare County blue oak woodland/blue oak-foothill pine 80

x

Abstract

Blue oak woodland is a signature landscape of California. Endemic to the state, blue oaks are the dominant species in a habitat that contains high floral and faunal diversity. Less than 5% of blue oak woodland is protected by reserves, making it one of the most threatened ecosystems in California. We design a dynamic strategy for protecting blue oak woodland in Tulare County. Using a multi-criteria analysis, we identify areas of high ecological value within Tulare County blue oak woodland. We then analyze threats presented by development and climate change. We model how blue oak range will shift with climate change and identify patches that are likely to persist as good-quality blue oak woodland under a changed climate. We present development scenarios that depict the potential progression of growth in the Tulare County foothills and identify patches of blue oak woodland that are under immediate threat of development. Finally, we merge the results of these three models in an effort to provide information for conservation priority setting for Tulare County blue oak woodland. Our methods may be used by conservation planners to identify and prioritize conservation areas at multiple time scales. We also provide qualitative assessments of the minimum area required to support various woodland species, and recommendations for land management strategies to encourage blue oak regeneration.

Executive Summary

Blue oak (*Quercus douglasii*) is a conspicuous and charismatic California endemic. Blue oak woodlands host an array of native understory vegetation and provide important habitat for wildlife. This habitat also occupies a large quantity of valuable real estate, making it one of the more threatened California biomes. Historic threats such as habitat fragmentation, invasive species, altered waterways and ubiquitous pollution are compounded by climate change. In an effort to conserve remaining blue oak habitat, conservation organizations are purchasing lands in sensitive areas and negotiating conservation easements with private land owners.

We provide conservation planners with a dynamic strategy for conserving blue oak woodland in Tulare County, which is located in the southern portion of the blue oak range. This report identifies areas of high ecological importance and provides a spatial and temporal analysis of climate change and development threats.

To provide a well rounded strategy for protecting Tulare County blue oak woodland, we examine several components of blue oak woodland conservation, including the identification of quality habitat, a threat analysis, and strategies for multi-species management within protected areas.

1. **Priority conservation areas**
   Conservation priority areas are core areas of habitat that contain the highest measurable habitat heterogeneity and biodiversity within Tulare County blue oak woodland. We are interested designing a strategy to conserve both blue oaks and the blue oak woodland community. We therefore identify parts of Tulare County blue oak woodland that are likely to contain high quality habitat for woodland plant and animal species. In order to do this, we identify coarse-scale landscape features that represent habitat heterogeneity or act as indicators of high species biodiversity. Using a multi-criteria analysis, we rank watersheds within Tulare County blue oak woodland according to: (a) the amount of riparian habitat; (b) elevational range; (c) threatened and endangered plant species richness; (d) number of recorded vertebrate species; (e) degree of intactness. We identify six conservation priority areas based on the highest ranking watersheds or conglomeration of high-ranking watersheds. Our conservation priority areas comprise 21% of Tulare County blue oak woodland (208 sq. miles), and contain 123 square miles of privately held blue oak woodland. We believe this is an ambitious, but attainable, conservation goal.

2. **Threat from development**
   Tulare County's population has been growing at an average rate of 2% per year, with new development occurring in the foothill region of the county. The majority of blue

oak woodland currently falls under private ownership and was historically used primarily as land for grazing. The decline in profitability of cattle ranching in California along with rapidly increasing land prices is putting unprecedented pressure on landowners to develop. Tulare County's foothills still form a relatively contiguous, unfragmented band of habitat, but commuters into the Valley's rapidly growing urban centers and retiring baby boomers looking for a rural lifestyle are beginning to develop the foothills. People bring with them homes, roads, pets, and invasive species, all of which present a threat to the native flora and fauna that live in blue oak woodland and to the oaks themselves. Studies have shown that oak woodland fragmentation affects tree regeneration rates, lowers biodiversity, and results in the extirpation of sensitive species. Efficient conservation will need to identify which patches of blue oak woodland are under the most immediate pressure from development.

We evaluate current development in Tulare County blue oak woodland. Presently less than 15% of Tulare County blue oak woodland is impacted by development. We provide development scenarios that depict a likely progression of development in the southern Sierra foothills and calculate the subsequent impact on the county's blue oak woodland. For example, we show that a complete build-out under Tulare County's current General Plan would directly impact 21% of the county's blue oak woodland; increased fragmentation by roads and rural residences would degrade an additional 57% of the blue oak woodland.

3. Climate change

Climate change will compound traditional threats such as habitat fragmentation, invasive species, altered waterways, and pollution that come with development. This synergy of threats has the potential to change natural blue oak woodland habitat in unprecedented ways. Driven largely by climatic requirements, blue oaks' current distribution covers a well-defined elevational band in the foothills encircling the Central Valley of California. Increases in temperature are expected to shift the distribution of suitable habitat for blue oaks northward and upslope, resulting in decreased range size. Existing research has found that the potential range of blue oaks is likely to shrink to 59% of the current range statewide over the next 100 years.

We evaluate the potential impacts of multiple climate change scenarios on blue oak woodland in Tulare County using both statistical modeling of suitable habitat and dynamic simulations of the blue oaks' response to a changing environment. Based on our model results, we develop a simple metric for assessing the likely persistence of blue oak woodland under climate change. Our models predict that climate change will reduce the range of suitable habitat for blue oaks in Tulare County by 25-95%. Because mature blue oaks are hardy and long-lived, the actual shifts in the distribution of the species will lag significantly behind shifts in habitat suitability. We identify which parts of the current range of Tulare County blue oaks are likely to disappear as suitable habitat, which parts are likely to persist, and which are likely to emerge as newly suitable habitat. We use these results in conjunction with development predictions to evaluate the threat patterns within conservation priority areas.

4. Threat synergy

Conservation planning that aims for long-term blue oak persistence will have to protect blue oak woodland from the immediate threat of development, while planning for an eventual range shift due to climate change. We examine the relative effects of development and climate change on Tulare County's blue oak woodland in 2080, which we believe to be a reasonable time horizon for conservation planning. We divided Tulare County's blue oak woodland into 2500 m^2 pixels, then determine the relative quality of blue oak habitat under a 2080 climate and associated level of development potential for each pixel.

Our findings show that, in 2080, more than half of the current range (60%) of blue oak woodland will become unsuitable due to climate change. The suitable habitat that will remain is scattered through the range, and contraction to the upper-middle elevations of the current range occurs. Within remaining suitable habitat, we evaluated the potential for development. We then identified and mapped areas that have both high persistence under a 2080 climate and a high likelihood of development. We believe this information could be used by planners to prioritize areas for conservation.

5. The blue oak community

We conducted our multi-criteria analysis and subsequent identification of conservation priority areas at the scale of Calwater planning watersheds, which average approximately 8500 acres. Conservation site selection, however, will likely be done at a smaller scale – possibly through the purchase or easement of private parcels. Fine-scale landscape features can be used to further identify and prioritize sites within conservation priority areas. Targeted wildlife species may require specific landscape features such as ponds, rocky outcrops, or mature trees. We provide a brief overview of blue oak woodland wildlife species and associated status on federal and state endangered species lists. We address the minimum size required to maintain viable populations of various woodland species. An appropriate reserve size depends both on the species targeted and the management of land outside of protected reserves. We therefore provide a tiered approach to determining reserve size; we offer guidelines for the protection of wide-ranging woodland species down to areal requirements of smaller species within blue oak woodland. Mountain lions, for example, have home ranges of almost 10,000 acres and use a wide range of habitats, including blue oak woodland; reserves designed to accommodate this species will need to be large and interconnected to other foothill reserves and public parks.

6. Optimizing blue oak recruitment

Our models assume that blue oaks would persist indefinitely under current land use and climate conditions. There is evidence, however, that blue oaks are not

regenerating over much of their range, including Tulare County. The reasons for lack of recruitment and seedling survivorship are varied, and include: grazing, invasive species, altered disturbance regimes, fragmentation, herbicides, and tilling. We review the debate over the "regeneration problem" and offer strategies for managing blue oak lands in order to optimize the chance of successful recruitment and survivorship. We suggest the use of wire cage enclosures to protect emergent seedlings from grazing in areas where deer and cattle have access and root-cages where rodent damage is a problem. We recommend that grazing be kept to 10-20 acres per cow per year and pastures allowed to rest in the spring and summer. Mulching and weed control around emergent seedlings can reduce water and light competition. These techniques will likely increase blue oak regeneration in managed areas.

Blue oaks are an integral component of the California landscape. We offer a strategy for blue oak conservation in a dynamic landscape. We provide both methods and information for (a) prioritizing sites for limited-budget conservation, and (b) reconciling protecting lands from the immediate threat of development with planning for the long-term change caused by a warming climate. We suggest wildlife species that may be used for fine-grain conservation. Finally, we offer suggestions for the management of blue oak woodland in order to ensure that these magnificent trees are around for centuries to come.

Introduction

Background

Problem statement
Blue oak woodland is one of the most recognizable landscapes in the state of California. In recent years, however, blue oak woodland has come under pressure; changing demographics and a growing population are putting unprecedented development pressure on this important community. Climate models predict a significant reduction of current blue oak habitat, while blue oaks' limited dispersal ability may stymie migration into more suitable climes. These changes jeopardize the long-term persistence of blue oaks themselves and the associated woodland community. This project focuses on the conservation of blue oak woodland in Tulare County.

Significance of blue oak woodland
Blue oak woodland comprises one of the most diverse communities in North America, supporting more than 1,400 species of flowering plants, 29 species of amphibians and reptiles, 57 species of birds, and 10 species of mammals (Ritter 1998). Seventy-five percent of blue oak habitat falls under private ownership, most of which was traditionally used for grazing livestock (Davis *et al.* 1998). Modern day economic pressure, however, is pushing landowners to develop. Over 30,000 acres of oak woodlands are converted each year for residential and commercial uses (Standiford and Scott 2001), making it one of California's most threatened habitats. This urban expansion affects more than just trees; 14 percent of foothill terrestrial species are suffering from declining populations (University of California; SNEP Science Team and Special Consultants 1996).

Development pressures
Blue oak woodland historically enjoyed an extensive range encircling the Central Valley of California. Early European settlers reduced the area of California's oak woodland via agricultural conversion, fuelwood harvesting, and water diversion (McCreary 2004a). In the last century, oak woodland was further reduced to make room for residential developments, commercial infrastructure, and agriculture. The majority of remaining blue oak woodland (75%) falls under private ownership, and is used primarily for grazing (Davis *et al.* 1998); the land is therefore susceptible to development. Development pressures are fueled by a growing population of baby boomers looking for retirement homes, by people attracted to opportunities in Tulare County's expanding urban areas, and by general population growth in California (University of California; SNEP Science Team and Special Consultants 1996). With this development, Tulare County's traditional agricultural lands are now becoming more urban and industrial.

Climate change
Climate change adds a twist to an already uncertain future for blue oaks. The extent of suitable blue oak habitat is controlled by temperature, precipitation and soil types. Driven largely by these climatic requirements, blue oaks' current distribution covers a well-defined elevational band in the foothills that encircles the Central Valley of California. Climate change will cause blue oak range to shift northward and upslope, likely resulting in a decrease in the total range of the species, as slopes become steeper at higher elevations. Using a regional climate model, Kueppers *et al.* (2005) found that the potential range of blue oak is likely to shrink to 59% of the current range statewide over the next 100 years. Climate change has the potential to compound traditional threats such as habitat fragmentation, invasive species, altered waterways, and pollution, which come with development. This synergy of threats may change natural blue oak woodland habitat in unprecedented ways.

Furthermore, the potential range of a species does not necessarily reflect the range that it will be able to attain under real-world conditions. The extent of blue oak woodland at any given point in time will depend on the rate at which blue oaks are able to colonize newly-suitable habitat and the rate at which extant populations in unsuitable habitat die. There is evidence that oak woodlands have undergone large historical range shifts in response to climate. Pollen records show that as climatic conditions have warmed since the last ice age, some oak species have expanded their range over vast distances, with some populations in the eastern United States expanding at rates of up to 25 km per 100 years (Davis 1981). While the rate of dispersal for blue oaks in California is likely to be slower, dispersal dynamics should nevertheless be accounted for in modeling blue oak range shifts.

Blue oaks and the blue oak woodland community
The conservation of Tulare County blue oak woodland consists of more than the protection of blue oaks alone. Tulare County blue oak woodland and blue oak foothill pine communities contain 44 sensitive species, including 4 reptiles, 4 amphibians, 11 mammals, and 25 birds (Table A1 in Appendix I). All of these species depend on blue oak woodland for cover, reproduction, and food. Oak acorns are an important diet item of the California ground squirrel (*Spermophilus beecheyi*), pocket gopher (*Thomomys bottae*), scrub jay (*Aphelocoma californica*), yellow-billed magpie (*Pica nutalli*), acorn woodpecker (*Melanerpes formicivorus*), mule deer (*Odocoileus hemionus*), and American black bear (*Ursus americanus*) (Howard 1992). Many woodland species, including mountain lion (*Felis concolor*), mule deer (*Odocoileus hemionus*), and raptors, also depend on a large, interconnected ecosystem to maintain viable populations (Huntsinger *et al.* 1997). Some species, including the scrub jay, badger, and California ground squirrel, play key roles in the dispersal and burial of blue oak acorns.

Blue oaks themselves may also require more hands-on management to ensure long-term persistence. Evidence indicates that blue oaks are not regenerating over much of their range (Bartolome *et al.* 2001; Bolsinger 1988; McClaran 1983), including Tulare County. Tree core samples taken in the early 1980s indicate that blue oak establishment had been lacking for at least 60 years (Baker *et al.* 1981; McClaran 1983). Grazing, invasive species, and altered disturbance regimes may all contribute to low levels of blue oak recruitment.

Conservation strategy

The strategy for conserving blue oak woodland provided in this paper is based on a coarse-scale analysis of Tulare County blue oak woodland. We examine the effects of development and fragmentation on blue oak woodland in general, but our analysis does not include effects on specific woodland species. Our climate change analysis looks at how blue oaks will react to a changed climate, but does not consider potential range shifts of other members of the blue oak woodland ecosystem. This strategy is therefore designed to complement or guide conservation work currently being done in Tulare County. Appendices I and II offer a closer look at the blue oak woodland community and provide details about the species that comprise Tulare County's blue oak woodlands. Appendix III examines, in detail, the possible causes of poor blue oak regeneration and provides suggestions for land management strategies to optimize blue oak recruitment.

A note on habitat types

The analysis described in this paper generally treats blue oak woodland and blue oak-foothill pine as the same habitat. We use blue oaks as a proxy for the habitat and community types associated with these trees. Thus, we combine the two habitat types in our analysis. References to blue oak woodland include both blue oak woodland and blue oak-foothill pine, unless stated otherwise.

Statewide and Strategic Context

This section compares Tulare County with other counties in the Sierra Nevada and northern portion of the Central Valley that contain significant amounts of blue oak woodland (Figure 1.1).

County-wide comparison of blue oak woodlands

We use a combination of California Department of Finance and U.S. Census Bureau population and housing data to examine the proposed project area in a state-wide context. The tables below represent the synthesis of GIS analysis, calculations, and data provided from sources listed above. Statistics are provided for those counties in the Sierra Nevada and northern Central Valley containing significant amounts of blue oak woodland or blue oak-foothill pine; these counties are identified in Figure 1.1. These statistics provide context for blue oak conservation efforts within Tulare County.

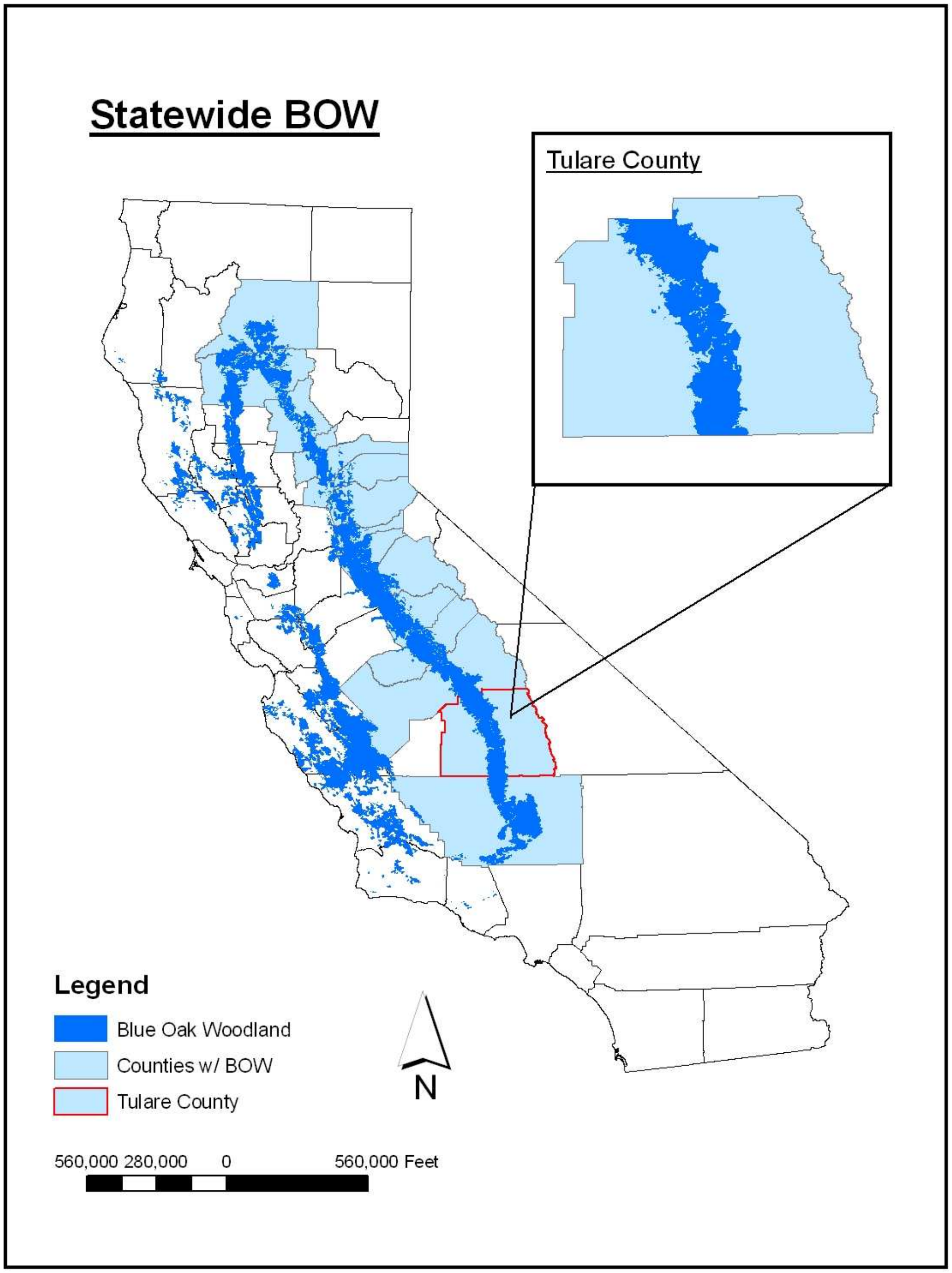


Figure 1.1: Counties in the Sierra Nevada and northern Central Valley containing significant amounts of blue oak woodland (shown in blue).

Tulare County contains approximately 550,000 acres of blue oak woodland (Table 1.1). In terms of total area of blue oak woodland, Tulare ranks third in the region, behind Kern, Fresno, and Tehama Counties.

Relative to the other counties in the region, Tulare County has a smaller percentage of its land area falling under private ownership, at 48.77%. In fact, only Tuolumne County contains less private land than Tulare, at 24.51%. However, just 22% of blue oak woodland in Tulare County falls under federal jurisdiction or in conservation easements.

Although Tulare County presently contains a low median housing density (0.04 units per acre), it had one of the fastest growing populations in the region between 2000 – 2005 and one of the highest projected growth rates between 2005 – 2020. Tulare County also contains one of the lowest median values for housing in the region, which is often indicative of low land prices.

These data suggest that Tulare County presents opportunities to developers and conservationists alike. Affordable land prices combined with a rapidly expanding population increase Tulare County's vulnerability to large-scale land conversion. Conversely, Tulare County contains one of the largest stretches of relatively intact blue oak woodland in the region, most of which is adjacent to public land, providing opportunities for large-scale conservation for relatively little expense.

Table 1.1: Area statistics (area in acres).

County	Blue oak woodland	Total Area*	Land Area*	Water Area*	% Public	% Private
Tulare	552,249	3,097,018	3,087,341	9,677	51.23%	48.77%
Kern	702,999	5,223,309	5,210,214	13,094	28.33%	71.67%
Fresno	556,002	3,851,149	3,816,147	35,008	39.97%	60.03%
Madera	286,000	1,378,125	1,366,950	11,174	36.99%	63.01%
Mariposa	354,750	936,186	928,717	7,469	52.20%	47.80%
Tuolumne	272,000	1,455,578	1,430,662	24,915	75.49%	24.51%
Calaveras	385,750	663,578	652,826	10,758	20.64%	79.36%
Amador	192,000	387,002	379,501	7,507	23.33%	76.67%
El Dorado	199,750	1,144,384	1094944	49,440	47.63%	52.37%
Placer	103,250	961,779	898,797	62,982	40.15%	59.85%
Nevada	130,250	623,674	612,870	10,803	32.80%	67.20%
Yuba	102,000	411,987	403,642	8,346	22.05%	77.95%
Butte	244,750	1,073,350	1,049,274	24,077	20.00%	80.00%
Tehama	681,750	1,895,853	1,888,634	7,219	26.47%	73.53%
Shasta	311,250	2,462,362	2,422,522	39,834	41.00%	59.00%

* = Census 2000 Summary.

Table 1.2: Population statistics.

County	Population (2000) †	Population (2005 estimate) †	Projected population (2020) ‡	Population density (2005, per acre) †
Tulare	368,021	410,874	570,900	0.13
Kern	661,645	756,825	1,088,600	0.15
Fresno	799,407	877,584	1,134,600	0.23
Madera	123,109	142,788	229,200	0.10
Mariposa	17,130	18,069	24,300	0.02
Tuolumne	54,501	59,380	77,200	0.04
Calaveras	40,554	46,871	62,200	0.07
Amador	35,100	38,471	41,300	0.10
El Dorado	156,299	176,841	252900	0.16
Placer	248,399	317,028	406900	0.35
Nevada	92,033	98,394	133200	0.16
Yuba	60,219	67,153	81900	0.17
Butte	203,171	214,185	308,900	0.20
Tehama	56,039	61,197	85,100	0.03
Shasta	163,256	179,904	231,000	0.07

† = US Census Bureau 2007. ‡ = *Interim County Population Projections*.

Table 1.3: Population growth statistics.

County	Pop. growth (2000-2005)	Pop. growth rank (2000-2005)	Pop. growth (2000 - 2020)	Pop. growth rank (2000 -2020)
Tulare	11.64%	6	38.95%	5
Kern	14.39%	4	43.84%	2
Fresno	9.78%	9	29.29%	10
Madera	15.99%	2	60.52%	1
Mariposa	5.48%	14	34.48%	11
Tuolumne	8.95%	12	30.01%	12
Calaveras	15.58%	3	32.70%	6
Amador	9.60%	10	7.35%	15
El Dorado	13.14%	5	61.81%	4
Placer	27.63%	1	63.81%	3
Nevada	6.91%	13	44.73%	9
Yuba	11.51%	7	36.00%	14
Butte	5.42%	15	44.22%	7
Tehama	9.20%	11	39.06%	8
Shasta	10.20%	8	28.40%	13

Table 1.4: Housing statistics.

County	Housing units (2005) +	Housing density (2005, units per acre) +	Median value housing (2000, $) +
Tulare	129128	0.04	97800
Kern	254226	0.05	93300
Fresno	292733	0.08	104900
Madera	45498	0.03	118800
Mariposa	9478	0.01	141900
Tuolumne	29848	0.02	149800
Calaveras	25864	0.04	156900
Amador	16732	0.04	153600
El Dorado	80,279	0.07	194,400
Placer	137,086	0.15	213,900
Nevada	48,499	0.08	205,700
Yuba	25,437	0.06	89,700
Butte	92187	0.09	129800
Tehama	25216	0.01	103000
Shasta	74219	0.03	120800

+ = US Census Bureau 2007.

Species comparison (vertebrate)

We used habitat suitability maps developed by the UCSB Biogeography Lab to examine statewide distribution of the following species in relation to blue oak woodland: bald eagle, golden eagle, black bear, mountain lion, mule deer, San Joaquin kit fox, western pond turtle, and California tiger salamander (Figure 1.2).

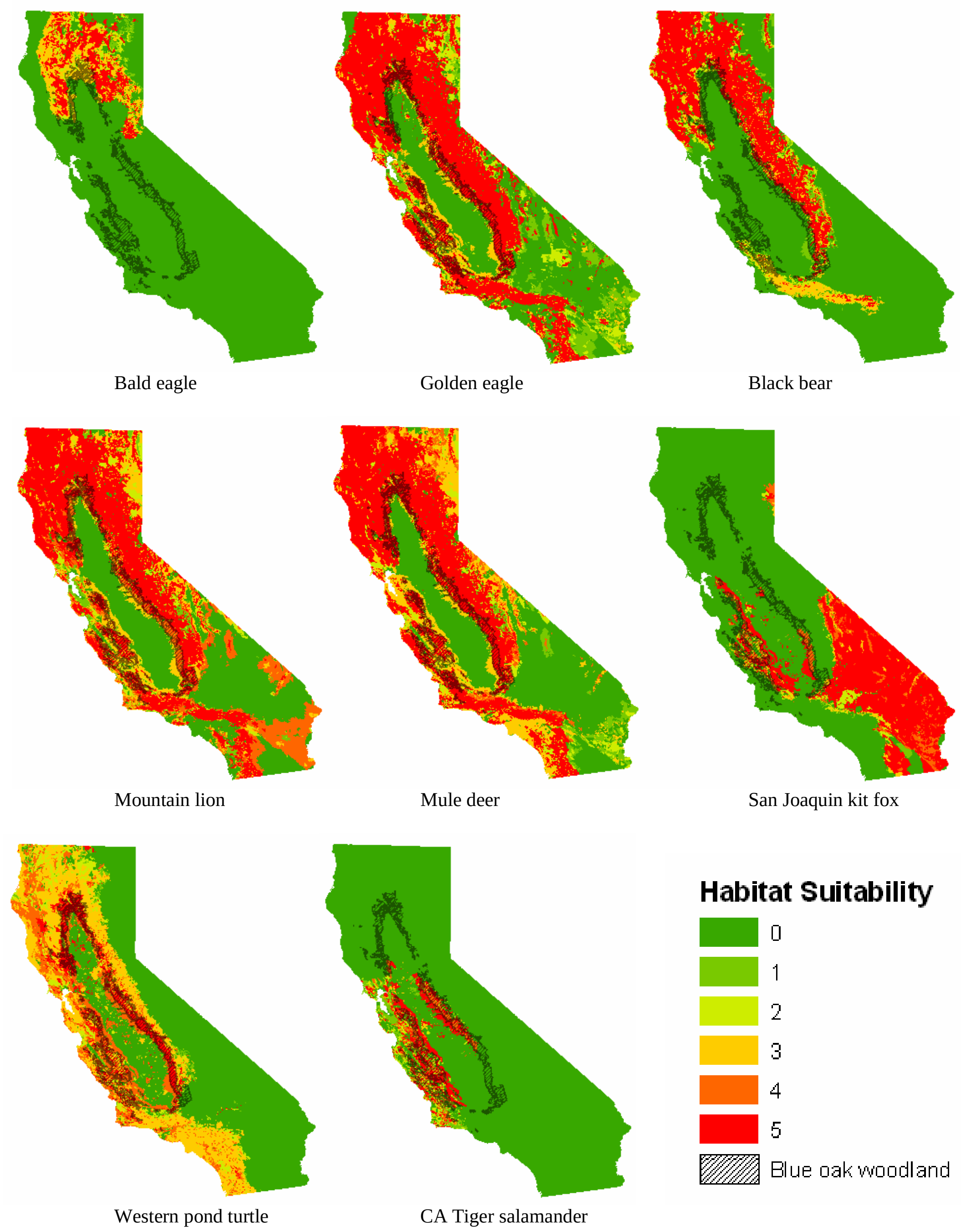


Figure 1.2: Suitable habitat ranges for BOW vertebrates.

Widespread generalist species such as the golden eagle, mountain lion, mule deer, and western pond turtle can be found throughout of most of the Sierra Nevada blue oak woodland range. Suitable habitat for the bald eagle is found only in the northern-most reaches of the blue oak woodland range. The opposite is true for the San Joaquin kit fox, with the most suitable habitat found in the southern-most portion of the Sierra Nevada. The most suitable habitat for the CA tiger salamander falls mostly in the center of the Sierra Nevada blue oak woodland range. For the most part, suitable black bear habitat seems to fall largely outside of the blue oak range. While we recognize that several of these species have suitable habitat in Coast Range blue oak woodland, we focus here only on the distributions of species in the Sierra foothills.

Statewide effects of climate change on blue oak woodland

While the above assessment provides a useful gauge of the current status of blue oak woodland statewide, climate change will alter the distribution of suitable blue oak habitat. Figure 1.3 shows the predicted suitable range from a combination of four different climate change scenarios (as described in Part IIB) for the year 2080.

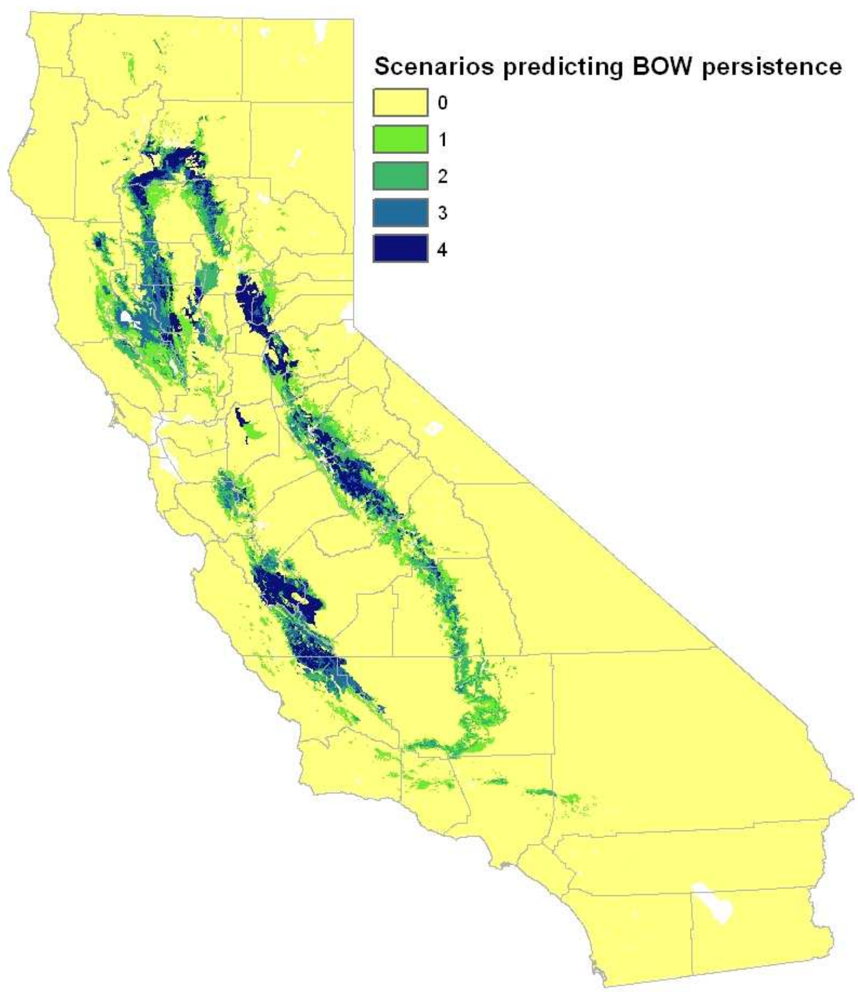


Figure 1.3: Statewide BOW range as predicted by four climate change scenarios.

Based on the agreement between scenarios, there are discernible statewide trends in persistence. In the southern Sierra Nevada, fewer scenarios predict the persistence of blue oak as compared to the northern Sierra Nevada, which contains larger areas with higher persistence. In the northern half of the blue oak range there are three distinct areas where blue oak persistence is predicted to be high (i.e., agreement between all four scenarios). The first such area is falls within Shasta and Tehama counties; the second falls within Yuba and Nevada counties; and the third area falls predominantly in Mariposa County. Thus in terms of long-term conservation efforts, these areas offer perhaps the "safest" opportunities and should be given consideration when examining blue oak woodland conservation on a long-term, statewide scale. In our study, however, we suggest areas within Tulare County that may minimize the effects of southern range loss on blue oak conservation.

Part I
Selection of Priority Areas

Background

In our development of a dynamic strategy for Tulare County blue oak woodland we identify areas of particularly high ecological value, which we call priority conservation areas. We identify priority conservation areas using a systematic approach that can be both manipulated and replicated by conservation planners.

To determine these priority conservation areas, we used a multi-criteria scoring approach to select areas of high resource quality and habitat heterogeneity. We selected criteria that (a) act as a surrogate for increased biodiversity or (b) directly target plant and vertebrate species richness. Although we recognize that cost considerations are important in the selection and acquisition of land, economic forces operate on a different time and spatial scale than other elements of our study and a comprehensive cost analysis is beyond the scope of this project. A list and a brief explanation of our selection criteria are described below.

1. Riparian habitat

We used the amount of riparian habitat in each watershed as a surrogate for biodiversity and habitat quality. The riparian corridor is generally defined as a narrow strip of land, centered on a stream, which includes the floodplain and contiguous band on either side of the flood plain, and supports plants that require saturated soils during all or part of the year. Riparian corridors possess a particularly diverse array of species and environmental processes. In a 1993 paper, Naiman *et al.* stated that "…riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth." This is largely due to the fact that riparian zones act as an interface between the terrestrial and aquatic environment. Riparian zones are characterized by variable flood regimes, geomorphic channel processes, altitudinal climate gradients, and upland influences on the fluvial corridor. These processes result in a variety of life history strategies as organisms adapt to disturbance regimes over broad spatio-temporal scales (Naiman *et al.* 1993).

2. Threatened and endangered plant habitat

Threatened and endangered plant habitat and CNDDB vertebrate sightings (criterion 3, described below) provide additional measures of biodiversity in Tulare County blue oak woodland. To capture the threatened and endangered plants within our planning area, we use the CalJep database of plant distributions. CalJep is a database that intersects distribution information from the CalFlora and Jepson plant distribution list. This database provides a spatial distribution repository that can be used to examine patterns of plant diversity and distribution ranges of individual plant taxa (Viers *et al*. 2006). This criterion is included in our model in order to capture plants identified as threatened and endangered that might otherwise be overlooked in the analysis.

3. CNDDB vertebrates

To integrate vertebrate species richness, we used the California Natural Diversity Database (CNDDB). CNDDB is a "natural heritage program," which provides the location and natural history information for plants, animals, and natural communities. Although CNDDB is not a comprehensive inventory of all species, it provides the most thorough species data available for the scale used in this analysis. Table 2.1 shows the CNDDB vertebrate species found in Tulare County blue oak woodland.

Table 2.1: CNDDB vertebrates found in Tulare County blue oak woodland.

Scientific name	Common name	Federal list	California list	Global distribution*
Gymnogyps californianus	California condor	Endangered	Endangered	G1
Batrachoseps regius	Kings River slender salamander	None	None	G1
Ambystoma californiense	California tiger salamander	Threatened	None	G2G3
Rana boylii	Foothill yellow-legged frog	None	None	G3
Spea (=Scaphiopus) hammondii	Western spadefoot	None	None	G3
Emys (=Clemmys) marmorata	Western pond turtle	None	None	G3G4
Cypseloides niger	Black swift	None	None	G4
Gulo gulo	California wolverine	None	Threatened	G4
Myotis thysanodes	Fringed myotis	None	None	G4G5
Vulpes macrotis mutica	San Joaquin kit fox	Endangered	Threatened	G4T2T3
Taxidea taxus	American badger	None	None	G5
Accipiter cooperii	Cooper's hawk	None	None	G5
Myotis evotis	Long-eared myotis	None	None	G5
Accipiter gentilis	Northern goshawk	None	None	G5
Martes pennanti (pacifica) DPS	Pacific fisher	Candidate	None	G5
Antrozous pallidus	Pallid bat	None	None	G5
Myotis ciliolabrum	Western small-footed myotis	None	None	G5
Empidonax traillii	Willow flycatcher	None	Endangered	G5
Eumops perotis californicus	Western mastiff bat	None	None	G5T4

*For global distribution, species with a lower rank are rarer.

4. Intactness/fragmentation

Empirical studies show that fragmentation has a strong, negative effect on biodiversity (Glanzig 1995; Hansen *et al.* 2005; Maestas *et al.* 2003). The definition of habitat fragmentation implies four effects on the landscape: (1) reduction in habitat amount; (2) increase in the number of habitat patches; (3) decrease in sizes of habitat patches; and (4) increase in isolation of patches (Fahrig 2003). The negative effects of fragmentation are likely due to an increase in the number of patches of habitat too small and too isolated to sustain local populations (Fahrig 2003). Furthermore, a fragmented landscape contains more edge for a given amount of habitat. Edge effects include physical changes to the border region such as altered temperature and precipitation and increased vulnerability to invasion by exotic species (Glanzig 1995). Any one or a combination of these factors may result in increased mortality or reduced reproduction for local species and a consequent decline in biodiversity. We assume less-fragmented woodland will be higher quality habitat; we therefore include degree of intactness as a criterion.

5. Elevation range

We include this criterion as an indicator of habitat heterogeneity and a surrogate for increased biodiversity. A 1990 study found elevational variance to be a strong, positive predictor of species richness for almost all mammals (Owen 1990). Research conducted in Glacier National Park established that elevation was an important environmental variable affecting the distributions of bird and butterfly species (Debinski and Brussard 1994). Additionally, a recent study in China used elevational range as a surrogate of habitat heterogeneity to investigate the variation in plant species richness in China's nature reserves. The authors found elevational variance to be strongly associated with plant richness in all regions (Zhao and Fang 2006).

Methods

Planning units

We used Calwater planning watersheds as our units for selecting conservation priority areas, as they are geographically-defined hydrologic units that appeal to planners. Watersheds in our project site, which ranged 1,500 – 20,000 acres, are an appropriate size to capture viable populations of many species. The boundaries for these watersheds were obtained from the California Department of Forestry and Fire Protection. Watersheds in which more than 75% of the area was on public lands and watersheds with less than 25% blue oak woodland coverage were not considered in this analysis. Because private conservation organizations can not implement conservation actions on public lands, we left out watersheds in which a majority of the land was on public property. We evaluated a total of 70 watersheds that averaged a size of 7,500 acres.

1. Riparian habitat

For evaluating riparian habitat, a stream layer was obtained from Census 2000 TIGER/Line. We buffered rivers by 50 meters to represent riparian habitat, and calculated the percentage of the watershed that was covered by this area. Watersheds with a higher percentage offered the greatest amount of riparian habitat, and we made the assumption that all riparian habitat is of equal quality. While we realize that some of the riparian areas surrounding larger rivers such as the Tule River may be more valuable habitat than areas around streams and creeks, we did not differentiate between them due to a lack of appropriate spatial data.

2. Threatened and endangered plant habitat

To measure the conservation value of plant species, we obtained a map of species richness of 288 threatened and endangered plants (compiled from 2006 state and federal listings) for California. The data were derived from CalJep species ranges at a 1-km grid resolution. The species richness for grid cells in our study area ranged from one to five. We used the mean richness per area for each watershed as our selection criterion.

3. CNDDB vertebrates
To obtain an estimate of vertebrate species richness, we counted the number of CNDDB species within each watershed. We decided to use the CNDDB polygon occurrences rather than point occurrences to account for the uncertainty in the location of the species. Additionally, species ranges may overlap with several watersheds, and using polygon occurrences would better capture this aspect.

4. Intactness/fragmentation
To assess the intactness of blue oak woodland, we quantified the level of fragmentation within each watershed. We calculated a fragmentation index for each watershed by determining the average distance of blue oak woodland to the nearest roadway or urban area. We buffered highways by 100 meters to show that the ecological impact of a highway is greater than that of a local road. In our results, a greater number indicates a higher level of intactness.

5. Elevation range
Spatial data for elevation was obtained from the Seamless Data Distribution System provided by the US Geologic Survey. A range was calculated by subtracting the lowest elevation by the highest elevation for each watershed. We assume a higher number to be indicative of greater species diversity.

Process
ARCGIS 9.1 was used to assemble layers for each criterion and to create a map that showed values for each watershed. Using Microsoft Excel, we looked for watersheds that fell in the top 20%, 25%, and 33% for all of the criteria, four of the criteria, three of the criteria, and so on. We chose this approach to avoid the pitfalls of a ranking system. (In a ranking system, a very high score in one criterion could cause a watershed to stand out, even though it may have scored poorly in other criteria.) By implementing a cut-off method, we ensured that our selected watersheds ranked high in as many criteria as possible.

After running our analyses, we selected areas that fell within the top 33% for the most criteria and determined them to be our "priority areas." Selected watersheds that were adjacent to one another were considered a single priority area. We then calculated total area and the percentage of current development for each priority area.

Results

A few trends were seen when picking the top 33% watersheds for each criterion (Figure 2.1). The most amount of riparian habitat occurred in the northern and central parts of the county. Threatened and endangered plants were mostly found along the western edge of the foothills while high vertebrate richness was found mostly in the center of the county. Watersheds with high intactness were scattered throughout the region, and watersheds adjacent to the public lands east of the foothill region had the largest elevation range.

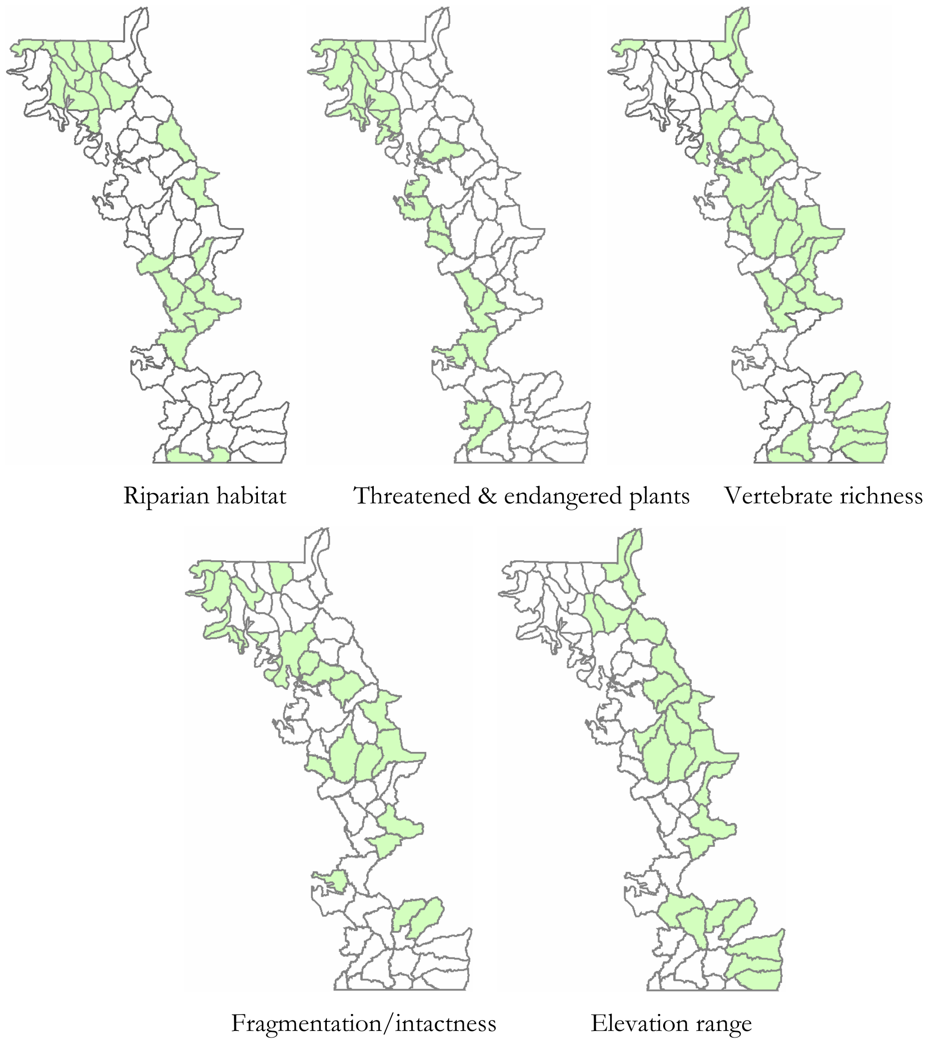


Figure 2.1: Clockwise from top left, the top 33% of watersheds are selected in green for riparian habitat, threatened and endangered plants, CNDDB vertebrates, elevation range, and fragmentation/intactness.

Figure 2.2 illustrates the aggregation of the criteria and the resulting selection of priority areas. None of the watersheds ranked in the top 33% for all criteria, and two watershed (indicated in red) ranked in the top 33% for four criteria. Twelve watersheds (orange) ranked in the top 33% for three criteria; seven watersheds did not rank in the top 33% for any of the criteria; and the majority of the watersheds ranked in the top 33% for only one or two criteria. We aggregated the 14 watersheds that ranked in the top 33% for three or four criteria into six priority areas. When examining those 14 watersheds closely, we found different combinations of criteria in which they ranked in the top 33%. Therefore, our priority areas represent a good suite of different quality criteria, and no one criterion is over-represented. All but two priority areas are adjacent to public lands.

The priority areas are labeled A – F in Figure 2.2 and are named by a characteristic geographic feature in the priority areas. Table 2.2 describes the size, the amount of blue oak woodland, and the current level of development within each priority area. In total, the priority areas cover approximately 208 sq. miles and contain 184 sq. miles of blue oak woodland. Sixty-seven percent of the blue oak woodland in these priority areas occurs on private land (123 sq. miles), so currently the majority of blue oak woodland in these priority areas falls on private lands. Table 2.3 provides a list of 12 CNDDB vertebrates for which there is a recorded occurrence within these six conservation priority areas.

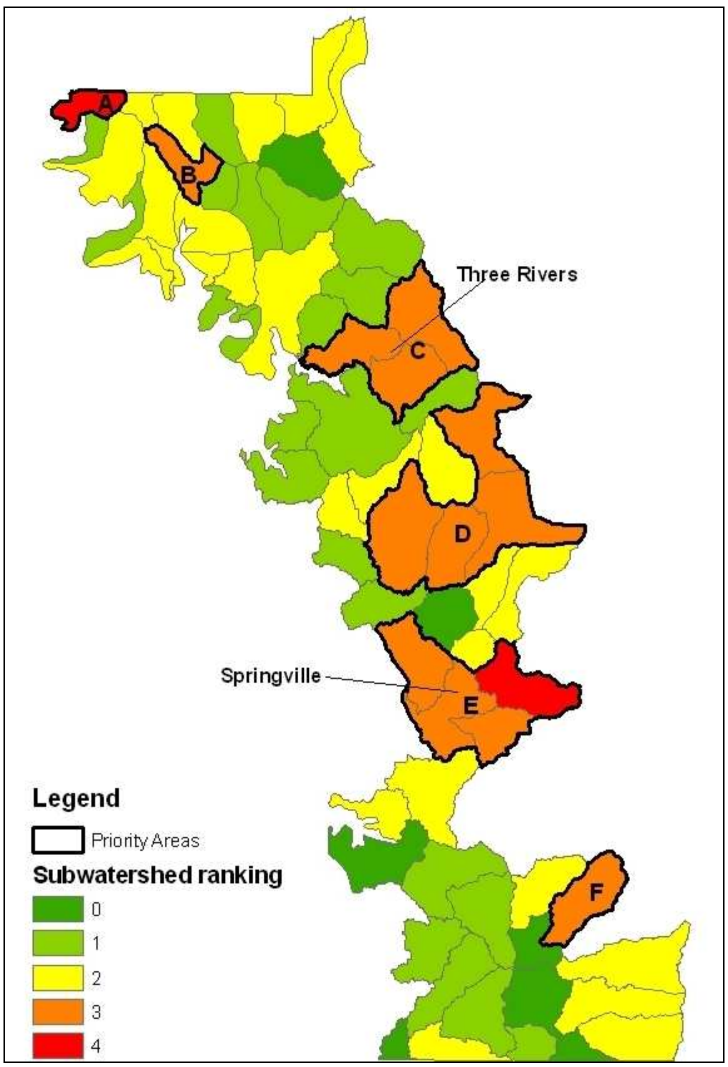


Figure 2.2: Priority areas that contain the highest ecological value.

Table 2.2: Descriptions of each priority area.

Watershed	Area (acres)	Blue oak woodland	Blue oak woodland on private land	Current public land
Hoffman Point (A)	4179	75%	100%	0%
Sand Creek (B)	5797	100%	99%	1%
Three Rivers (C)	28423	91%	79%	26%
Devil's Canyon/Blue Ridge (D)	48711	94%	61%	43%
Springville (E)	36399	83%	58%	25%
Cold Springs Canyon (F)	9667	72%	56%	60%

Table 2.3: List of CNDDB vertebrates found within our six conservation priority areas.

Scientific name	Common name	Federal list	California list	Global distribution*
Gymnogyps californianus	California condor	Endangered	Endangered	G1
Ambystoma californiense	California tiger salamander	Threatened	None	G2G3
Rana boylii	Foothill yellow-legged frog	None	None	G3
Spea (=Scaphiopus) hammondii	Western spadefoot	None	None	G3
Emys (=*Clemmys*) *marmorata*	Western pond turtle	None	None	G3G4
Cypseloides niger	Black swift	None	None	G4
Gulo gulo	California wolverine	None	Threatened	G4
Myotis thysanodes	Fringed myotis	None	None	G4G5
Martes pennanti (pacifica) DPS	Pacific fisher	Candidate	None	G5
Myotis ciliolabrum	Western small-footed myotis	None	None	G5
Myotis evotis	Long-eared myotis	None	None	G5
Eumops perotis californicus	Western mastiff bat	None	None	G5T4

We also investigated how our selected priority areas would change using a more exclusionary ranking. Figure 2.3a and 2.3b show a cutoff of 20% and 25%, respectively. The results are very similar with the major difference being two additional watersheds selected with the 25% cutoff. By extending the top-ranking delineation to 33%, nine more watersheds are selected (Figure 2.3c). Interestingly, two watersheds progress from scoring in the top tier for only one criterion with the 20% cutoff, to scoring in the top tier for three and four of the criteria with the 33% cutoff. Therefore, it appears that the ranking percentage is an important determinant of which watersheds appear to contain high quality habitat—while many of the watersheds consistently appear as priority areas, a few watersheds jump from being areas of very low to areas of high ecological value with a shift in the scoring cutoff.

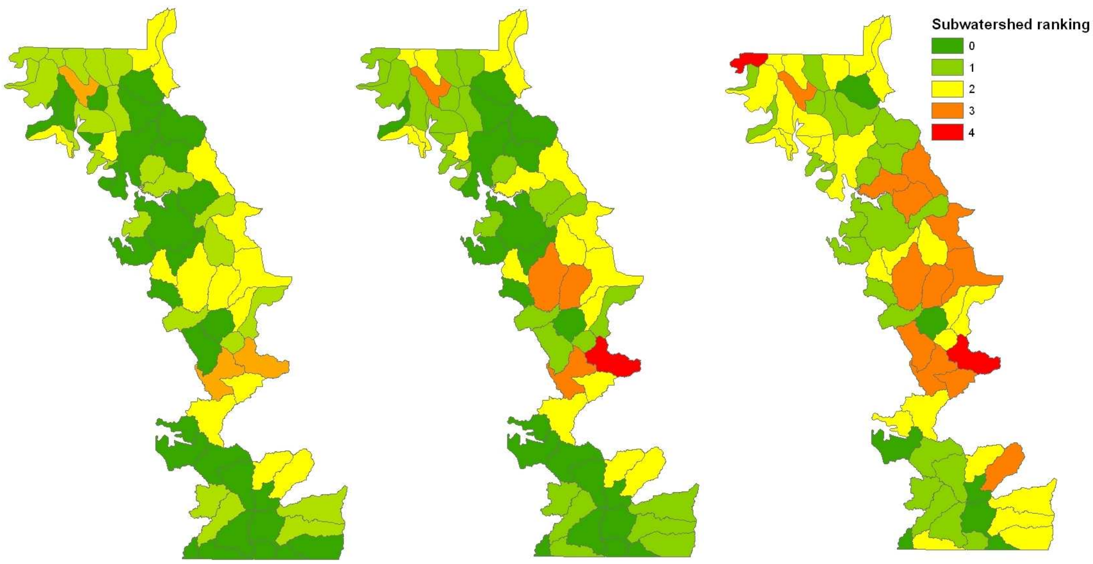


Figure 2.3a-c: Left to right, watersheds with a 20%, 25%, and 33% cutoff.

In Part II of this report, we describe the threat analysis performed on the range of blue oak woodland, with a focus on these priority areas.

Part II
Threats to Blue Oak Woodland in Tulare County

A. Development Threats to Blue Oak Woodland

This section provides a narrative on current and future population growth in Tulare County and its implications for blue oak woodland. It includes an overview of development pressures in the county, explains why we are concerned about development and how it impacts the ecology of blue oak woodland, evaluates the current state of blue oak woodland, and lastly, investigates alternative scenarios of growth. An analysis of Tulare County's General Plan can be found in Appendix IV.

Background

The California Department of Finance projects California's population to increase from about 36 million in 2005 to over 45 million by 2020 (State of California, Department of Finance 2004). The distribution of California's population is also changing, with more people moving to the edge of urban areas and the historically lower-density Central Valley and Sierra Nevada foothills (Saving & Greenwood 2002). Driven by quality of life factors, people are choosing to live near natural amenities and where recreational activities are abundant (Masnick 2001). Additionally, technological advances in communication and transportation have made it possible for people to work from home or to travel from home to work easily, thus enabling them to live away from urban centers. The Sierra Nevada region is an attractive location for those looking for a retreat away from urban areas along the coast. Growth in this region is fueled by a growing population of baby boomers looking for retirement homes, by people attracted to economic opportunities in expanding urban areas, by general population growth in California, and by those attracted to the natural amenities of the area (University of California; SNEP Science Team and Special Consultants 1996). The eastern half of most counties in the western Sierra Nevada is public land; the majority of growth is therefore occurring in the low-elevation foothills, most of which is hardwood rangeland.

Low-density, rural home development is the primary pattern of land use change that is occurring on California's hardwood rangelands. This type of growth (termed "exurban development") not only consumes natural habitats, but leaves nearby natural areas fragmented and degraded (Hansen *et al.* 2005). The entire Sierra Nevada region is expected to grow from 1.5 to 2.4 million residents by 2040. Tulare County's population growth rate is also relatively rapid, averaging 2% per year over the last few years (University of California; SNEP Science Team and Special Consultants 1996); the county's population is predicted to double in the next 30 years (Table 3.1). As a result of development pressures, oak woodland communities of the western Sierra Nevada foothills are the most vulnerable widespread vegetation type (University of California; SNEP Science Team and Special Consultants 1996). It is predicted that, statewide, an additional 12% of blue oak woodland and 15% of blue oak-foothill pine will be impacted by development by 2040 (using a housing density of one or more units on 20 acres) (FRAP 2003).

Table 3.1: California Department of Finance population projections for Tulare County and California.

	2000	2010	2020	2030	2040	2050
Tulare	369,355	447,315	543,749	650,466	754,790	867,482
California	34,043,198	39,246,767	43,851,741	48,110,671	51,538,596	54,777,700

A large portion of rangeland development is due to the division and conversion of once-expansive ranches. In a survey of California hardwood rangeland landowners, 9% claimed to have subdivided all or part of their land between 1987 and 1992; most of this rangeland is converted to housing or other developments (Huntsinger *et al.* 1997). This trend is echoed by a 2004 re-survey conducted by the Integrated Hardwoods Rangelands Management (IHRM). The study found a decline in large ranch landowners, a decrease in ranching as a major source of income, and an attitude shift towards conservationist values—ranchers are planting more oaks and destroying fewer oaks. Generally, ranchers no longer see their ranches simply as productive lands but as beautiful and wild landscapes. Nevertheless, ranchers often feel pressured to sell because land values in many woodland areas are much higher than those justifiable by range livestock production. Data on land values from California's Central Coast show that grazing may return as little as 10% of the economic value for the same land planted for wine grapes, or less than 1% of its value for residential development. Similarly, land values for grazing may be less than 20% of the current land value in the Sierra Nevada for development (Giusti *et al.* 2004). Large property owners surveyed in the central Sierra Nevada tended to believe that high land values and their associated taxes, along with sporadic and low investment return from ranching, are major obstacles to the long-term future of ranching in areas with high property values (Huntsinger *et al.* 1997).

Impacts of Development on Blue Oak Woodland

Oak woodland runs through most of California, covering a vast, relatively uninterrupted landscape. The woodland ecosystem also provides a home to many species, including mountain lion (*Felis concolor*), mule deer (*Odocoileus hemionus*), and raptors, which depend on a large, interconnected ecosystem to maintain viable populations (Huntsinger *et al.* 1997). Livestock grazing has been the primary land use within oak woodlands since European settlement—a land use that helped maintain landscape continuity across the state. Development threatens to fragment this ecosystem.

Underlying the rationale for non-profits and government agencies to work for conservation easements on ranchlands is the notion that ranches preserve biodiversity better than rural residential land use. Most ecological studies in human landscapes focus on urban areas and the gradient from urban to rural around cities (Hansen *et al.* 2005), but only recently has there been research conducted on the ecological consequences of converting ranchland to rural residential development (Maestas *et al.* 2003).

One recent study compared avian, mesopredator, and plant communities on nature reserves, cattle ranches, and rural residential development (ranchettes) in Larimer County, Colorado (Maestas *et al.* 2003). The study found that ranches are important for protecting biodiversity and concluded that future conservation efforts may rely less on reserves and more on private lands. Rural residential development was found to support greater densities of tree-nesting and human-commensal bird species and elevated numbers of domestic mammalian predators, while reserves and ranches had increased densities of ground and shrub-nesting bird species (including songbird species of conservation concern) and virtually no domestic mesopredators. Ranchlands contained a smaller proportion of non-native species and a higher proportion of native species richness compared to the other land use types (Maestas *et al.* 2003). Additionally, percent cover of non-native plants was significantly lower on ranches than on ranchettes and in protected areas. While the results of this study could not be extrapolated past this watershed, a generalization that rural residential development promotes non-native and human-commensal species could be made. Thus, our project assumes that continuing the ranching characteristics of the foothills is preferable to rural development for biodiversity.

The effects of rural residential development on plant and wildlife communities include the destruction, alteration and fragmentation of habitat, the introduction of non-native species, erosion and compaction of soil, and increased runoff, fire probability, and human presence.

Habitat alteration

The most visible impact of development is the destruction and alteration of the natural environment. Oaks and other vegetation are cleared to make way for homes and roads, and oaks are thinned around structures. Our assessment of the current status of blue oak woodland in Tulare County found that 5.1% of blue oak woodland and 3.3% of blue oak-foothill pine ranges have been directly altered by homes and roadways.

The impact from structures and roadways are felt far beyond their physical location. Native species have reduced survival and reproduction near homes (Hansen *et al.* 2005) and an impact of 200 – 800 meters from houses has been documented for a range of species (Theobald 1997). An alteration in the composition of plant and wildlife communities on ranchettes in Pitkin County, Colorado, was found 180 – 330 meters away from structures (Odell and Knight 2001). Large mammals have lower densities 100 – 200 meters away from roads and the most sensitive species showed avoidance of roadside areas 300 – 900 meters away, depending on traffic density (Foreman and

Alexander 1998). Another study by Stralberg and Williams (2001) found some woodland bird species to be sensitive to habitat changes as far away as 4,000 meters. The zone from which an ecological impact of houses and roads is seen on plant and wildlife communities is termed the "disturbance zone" (Theobald and Hobbs 2002). When including disturbance zones in the calculation for development impacts, the area of impact increases greatly. Additionally, the sparse development pattern of rural residential development maximizes the impact of individual homes on biodiversity (Lenth *et al.* 2006).

Fragmentation

The fragmentation and development of hardwood rangeland will alter the woodland ecosystem, largely to the detriment of resident organisms. Oaks themselves are likely to suffer; there is evidence that fragmentation and thinning of oak woodland may limit pollen availability, restricting oak reproduction (Sork *et al.* 2002). Knapp *et al.* (2001) found a significant positive association between number of pollen-producing neighbors and acorn production. Trees contained within larger neighborhoods are less likely to be genetically related and therefore less likely to share incompatibility alleles. Relatedness may reduce pollen efficiency and eventually affect overall fecundity.

Other woodland species are also affected by fragmentation. A Sonoma County study found that exotic plants were more common on rural residential lots 10 – 40 acres in size than on relatively undeveloped larger properties (Merenlender *et al.* 1998). A study examining the effects of exurban development on biodiversity outside of Seattle, Washington, found that native species richness tends to drop with increased exurban densities, while exotic species, some human-adapted native species, and species from early successional stages often increase with exurban development. The researchers found that the relationship between these elements of biodiversity and intensity of exurban development was often nonlinear, with sharp thresholds in biodiversity response with incremental increases in exurban intensity. They also found that biodiversity response to urbanization may continue to intensify for several decades after development. Thus, the full effects of recent developments are unlikely to have manifested themselves fully and native biodiversity will continue to erode for decades to come (Hansen *et al.* 2005).

Effect on blue oak woodland species

Development does not affect all species similarly, as invasive and human-adapted native species generally benefit at the expense of other native species. Species such as raccoons, house sparrows, and bobcats are able to take advantage of new food or shelter resources, while other species suffer from a reduction of suitable habitat. Human-commensal bird species respond to resources such as bird feeders and artificial nest boxes, and deciduous trees used for landscaping provide tree-nesting species with habitat that would otherwise be missing from a shrub-grassland habitat (Barrett 1998). Human garbage also provides food for some birds and mammals. Exurban development often favors birds that are habitat generalists (Fratterigo and Wiens 2005).

Suburban woodlots in Maryland experience significantly higher rates of nest predation than rural woodlots, likely as a result of higher densities of nest predators, which may become abundant near houses due to subsidized food sources (Wilcove 1985). Top carnivores may be reduced even at low home densities because of expanding roads and human disturbances (Hansen *et al.* 2005). A reduction in dominant predators may allow for the increase of mesopredators, which in turn are responsible for the reduction of their avian prey (Crooks & Soule 1999).

The introduction of non-native species can be accidental or deliberate; for example, the plantings of non-natives in landscaping and the introduction of pets. Homes bring domestic mammalian predators to the landscape, and free-ranging domestic cats have an especially severe effect on small mammals, invertebrates, and songbirds (Coleman & Temple 1993; Crooks and Soule 1999). Ornamental plant species used for landscaping can also have detrimental affects on native species; for example, English ivy kills native trees through competition for light (Reichard 2000). Roads and trails are often corridors for the spread of non-native flora (Foreman and Alexander 1998). The presence of people and their pets can directly displace native species (Hansen *et al.* 2005).

Current State of Blue Oak Woodland in Tulare County

Tulare County encompasses over 4,661 square miles and has a population of about 400,000. Located in the San Joaquin Valley, the county stretches from the valley floor to the higher elevations of the Sierra Nevada. Tulare County contains three eco-regions that trend generally north-south (Mintier & Associates 2006) (Figure 3.1a). The majority of the western portion of the county comprises the Great Valley Section; most of the eastern portion of the county falls in the Sierra Nevada Section; and a band between these two sections comprises the Sierra Nevada Foothill Section. Fifty-two percent of Tulare County is public land; the entrances to Sequoia and Kings Canyon National Parks, Sequoia National Monument, and Sequoia National Forest all fall within county boundaries. Agriculture, including row crops, orchards, dairies, and grazing land on the valley floor and in the foothills comprise another 43% of the county. The majority of blue oak woodland occurs in the foothills (Figure 3.1b). The rest of the county is devoted to urban uses such as cities, communities, hamlets, other unincorporated urban uses, and infrastructure (Mintier & Associates 2006).

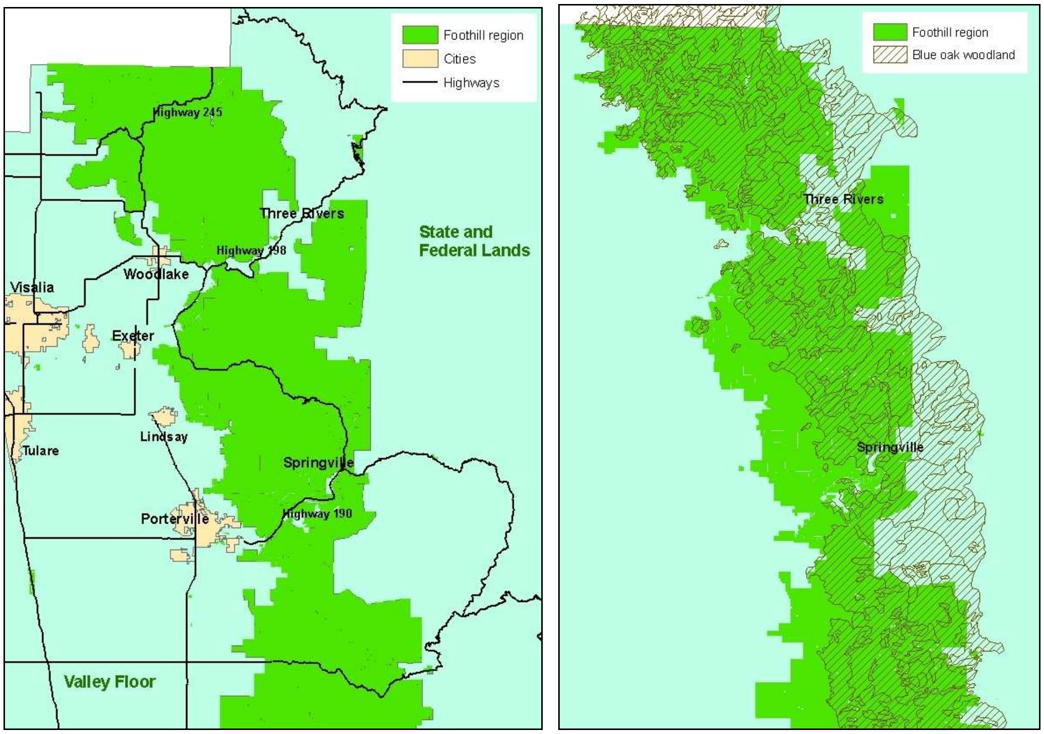


Figure 3.1 a-b: All of Tulare County's cities are located on the valley floor. The foothill region contains two communities and several major roadways (left figure). The range of blue oak woodland exists primarily within the foothill region (right figure).

Blue oak woodland and blue oak-foothill pine in Tulare County exists in an elevation range of 122 – 2,232 m, with the majority falling on private lands (72%) (Figure 3.2). The greatest amount of publicly-held blue oak woodland exists within the Tule River Indian Reservation. To evaluate the current state of blue oak woodland in Tulare County, we evaluated the impact of development using three measures: (1) the percentage of oak woodland that is directly impacted by urban areas and roadways; (2) the percentage of oak woodland that is ecologically affected by urban areas and roadways; and (3) a fragmentation index. In the current assessment analysis, we distinguish between blue oak woodland, and blue oak-foothill pine. For all other analyses, we use blue oak woodland to represent both blue oak woodland and blue oak-foothill pine.

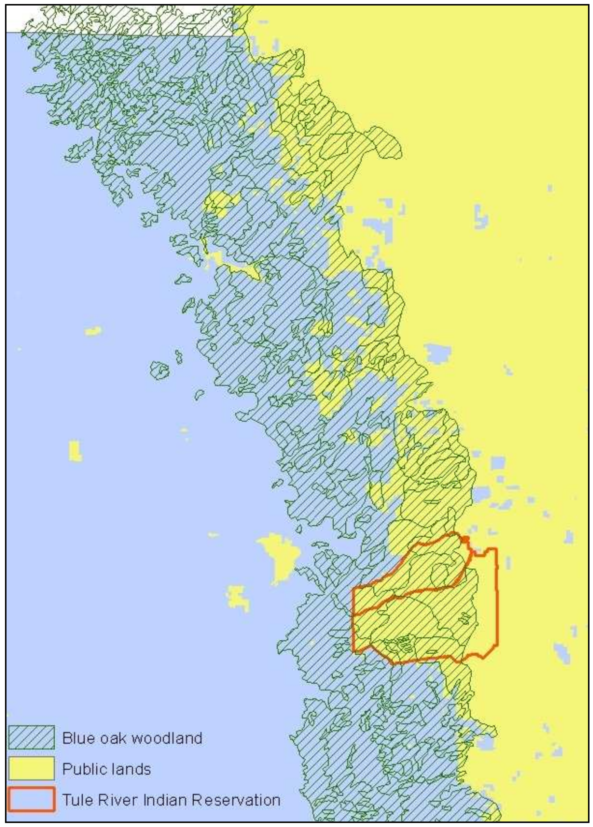


Figure 3.2. Blue oak woodland in Tulare County mainly occurs on private lands. Most of blue oak woodland that falls on public lands occurs within the Tule River Indian Reservation.

Methods
Our first measure of development impacts is calculation of the direct amount of blue oak woodland converted to urban areas or roadways. We obtained a map depicting urban areas in Tulare County from the Farmland Monitoring and Mapping Project (FMMP) (California Department of Conservation) and a map depicting local roads and state highways from the TIGER Census (U.S. Census Bureau). For our second measure, we buffer urban areas and highways by 200 m and roadways by 100 m to describe the ecological impact of development.

Our last measure assesses the amount of fragmentation caused by roadways and homes. Less fragmented oak woodland is considered higher quality habitat as it can support a greater assemblage of species and large-ranging species. To quantify fragmentation, we calculated the average distance of blue oak woodland to the nearest roadway or urban area. This provides us with an index with a lower number representing a more fragmented oak woodland and therefore lower quality habitat. Fragmentation is the only degrading factor considered here; we assume that all privately owned blue oak woodland is managed in a similar manner and that woodland habitat quality is equal throughout the region.

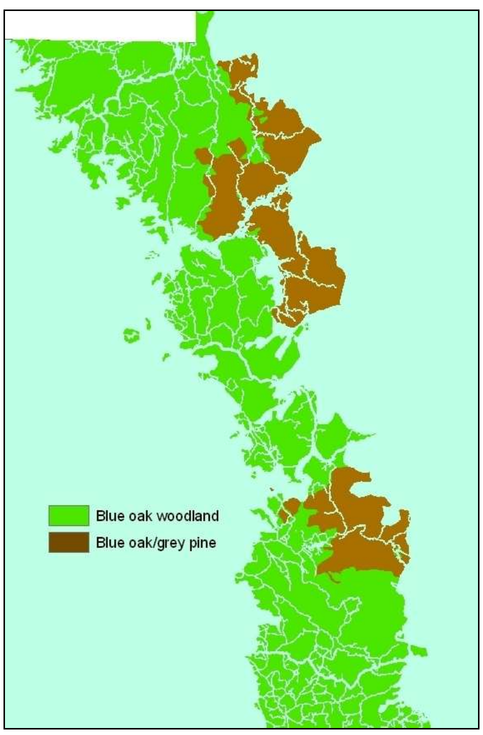
Results

The effect of development is significantly greater on blue oak woodland than on blue oak-foothill pine (Table 3.2). This is likely due to the geographic range that each habitat type occupies; blue oak-foothill pine exists in higher elevation and on steeper slopes than blue oak woodland in Tulare County, which makes the area hard to develop. Additionally, the majority of blue oak woodland lies on private lands (89%), while the majority of blue oak-foothill pine lies on public lands (58%). Blue oak-foothill pine habitat is also less fragmented than blue oak woodland. Roadways, not urban areas, are the major cause of fragmentation in Tulare County blue oak woodland.

Our results indicate that most blue oak woodland in Tulare County is currently in good condition. While the maps (Figure 3.3) may seem to indicate a large amount of fragmentation by roads, most of these roads are lightly traveled and thus their impact is minimal (A. Mas, personal communication 2007).

Table 3.2: Current assessment of development impacts on blue oak woodland.

	Direct Impact	Ecological Impact	Fragmentation Index
Blue Oak Woodland	5.2%	16.1%	706 m
Blue Oak/Foothill Pine	3.3%	10.3%	1035 m
Combined	4.6%	14.8%	782 m



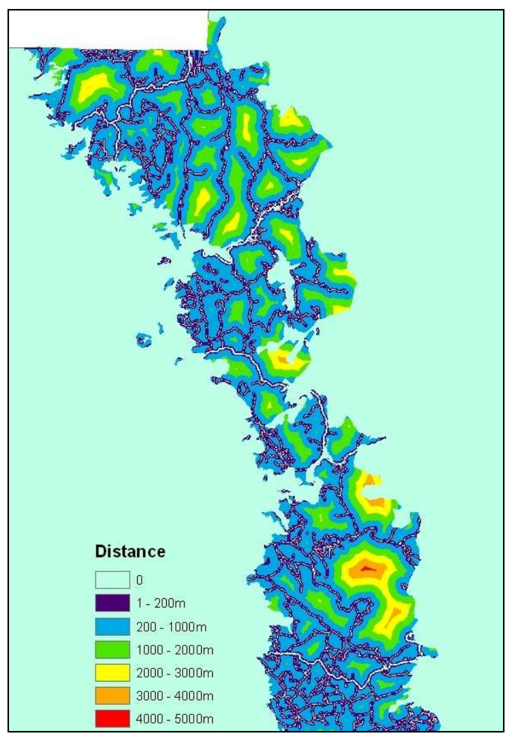


Figure 3.3: Intact blue oak woodland (green) and intact blue oak-foothill pine (brown) in Tulare County (left), and fragmentation effects on blue oak woodland and blue oak-foothill pine (right).

Potential Development in the Foothill Region

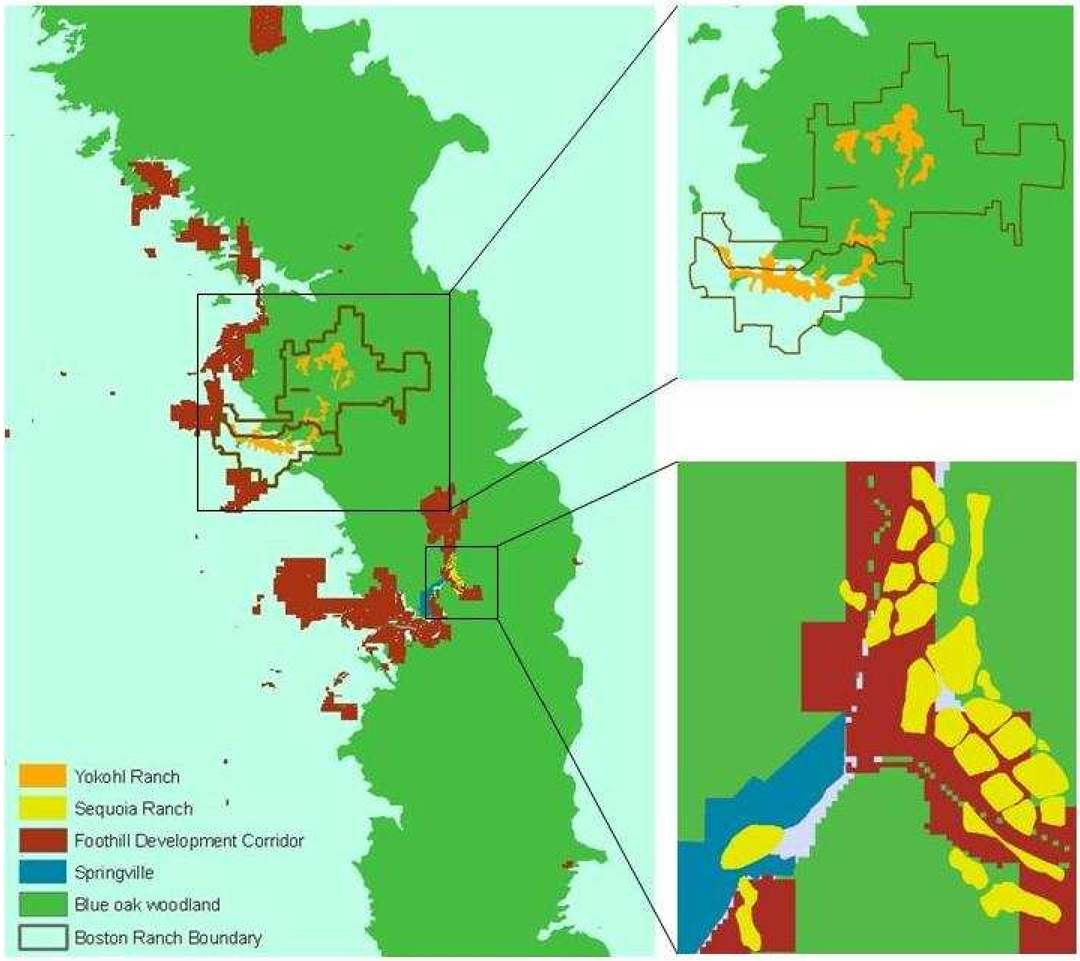


Figure 3.4: Potential developments—Yokohl Ranch, Sequoia Ranch, and the Foothill Development Corridor.

Foothill Development Corridor

In order to accommodate new growth and to drive development away from prime agricultural soils on the valley floor, the county plan delineates over 54,000 acres in the foothills as the "Foothill Development Corridor" (Figure 3.4). The corridor exists on slopes less than 30% along the western edge of foothills (Figure 3.5) and around the Springville and Badger areas. About 17,750 acres of this corridor coincides with blue oak woodland. The county has an implementation measure stating that it shall protect oak trees throughout the foothill and mountain areas. Preservation methods may include agreements with the owner, conservation easements, and purchase of the property by the county or other conservation organizations. The county also does not allow oaks with a diameter at breast height (DBH) of six inches or greater to be cut down without appropriate mitigation.

There are two types of zoning for residential use within the Foothill Development Corridor: foothill mobile (PDFM); and mountain residential (PDMR-217). There is no parcel size limit for areas zoned as PDFM and the size is determined when the owner applies for a building permit. However, setback requirements have to be satisfied, enough buildable area must be determined, and the parcel size is limited by services. If the property has a septic tank and well, the minimum size is one acre; if community water and septic tank are available, the minimum size is 12,500 square feet; and if community water and sewer are available, the county will allow division to 6,000 square feet (F. Mendocino, personal communication). Our analysis of areas zoned for PDFM, assumes a minimum parcel size of one acre. Properties zoned for mountain residential can be divided into five-acre parcels.

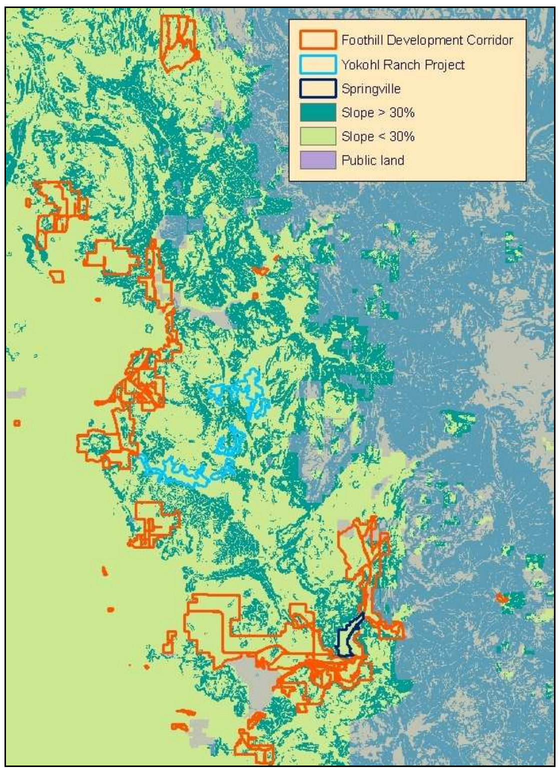


Figure 3.5: The Foothill Development Corridor and the Yokohl Ranch Project exists in areas where slopes are less than 30%.

Yokohl Ranch

While large-scale development projects are generally not economically viable in Tulare County's foothills, one project has been proposed that has the potential to significantly alter portions of the county's blue oak woodland. The Yokohl Ranch Project is a 36,000-acre development project proposed by The Yokohl Ranch Company that seeks to add a new community to the foothills. The proposed site is located on a property called Boston Ranch and is owned by J. G. Boswell. The company's vision is a self-contained, master-planned community with residential, neighborhood commercial, resort lodge enclave, recreation, open space, and ranch uses. The two main developments are a village located in the southwest part of Yokohl Valley and a resort lodge located in the northeast part. Yokohl Village would contain residential areas, a town center, schools, a lake, and recreational areas, while Yokohl Resort would contain a lodge, community center, and several golf courses. Overall, 10,000 homes could be added to the area (Valley Voice, September 2005). Water availability is not a limiting factor to development in this case as water would be provided by the Yokohl Ranch Company. The current plan maintains that 60% of the property (21,600 acres) would remain as untouched open space and ranchlands (Resource Management Agency Agenda Item, February 2006).

The impact of Yokohl Ranch on blue oak woodland would be significant. Depending on where the open space is located and how it is managed, the project has the potential to divide the current range of blue oak woodland into two fragments, disrupting the north-south gene flow of blue oaks (Figure 3.4). According to the results of the multi-criteria analysis performed in the previous section, the eastern portion of Boston Ranch falls within a conservation priority area. It is possible that actual construction within Yokohl Ranch would fall outside of priority conservation areas, but completion of this project will provide public access to portions of Yokohl Ranch that are currently inaccessible.

The project is still in the early stages of being approved by the county and faces stiff opposition by county residents. On February 7, 2006, the Tulare County Board of Supervisors unanimously approved (5:0 vote) The Yokohl Ranch Plan General Plan Amendment Initiation, which permits The Yokohl Ranch Company to proceed with its formal application for a General Plan Amendment. Because the county's General Plan does not allow the creation of new communities, an amendment to the Tulare County General Plan and Foothill Growth Management Plan to designate Yokohl Ranch as "Planned Community Area" would have to occur. If the project were to pass, planning and implementation is estimated to continue for 20 – 30 years (Resource Management Agency Agenda Item, February 2005). An Environmental Impact Report (EIR) prepared by The Yokohl Ranch Company will be available in about a year. Formal public hearings with the Planning Commission and Board of Supervisors are expected to be held in late 2007, and at that time the Board of Supervisors will decide whether the project will be approved. As the probability of the project going forward is likely, we have included the Yokohl Ranch Project in our scenario analysis. Updates on the project can be found at www.yokohlranch.com.

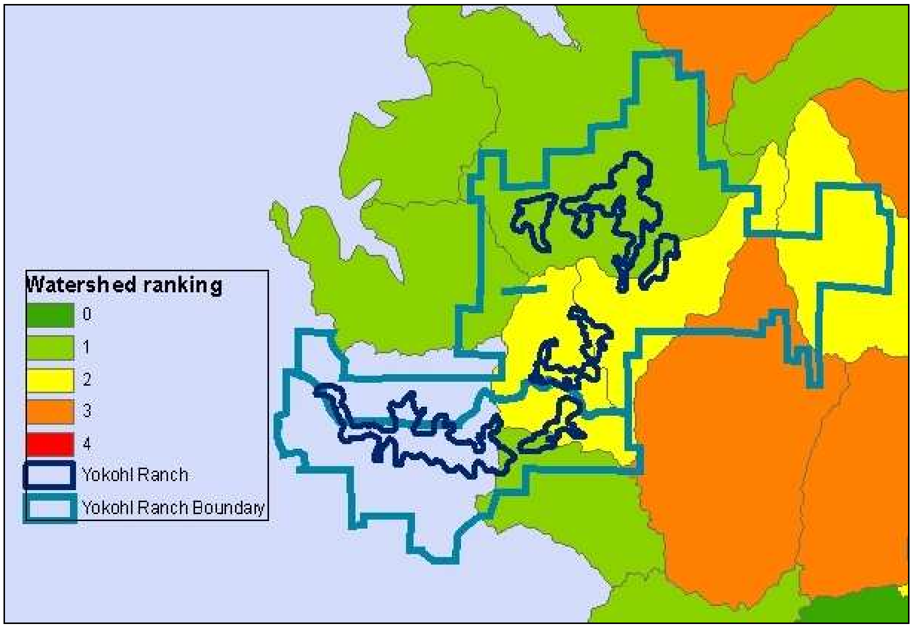


Figure 3.6: The Yokohl Ranch Project falls on low to high priority areas identified by the multi-criteria analysis.

Sequoia Ranch Project

The Sequoia Ranch Project aims to create Tulare County's first retirement community, northeast of Springville (Figure 3.4). It will cover 1,400 acres and support a population of 1,100 adults. An information session was given to the public and no public opposition to the project was expressed at this meeting. The company has not yet filed a formal application (D. Byrant, personal communication, January 2007).

Modeling Future Development Scenarios

To investigate the threat of development on blue oak woodland, we simulated alternative scenarios of development in the foothills. We investigated how development would look if we built-out the foothills under the current zoning ordinance. The current General Plan is used so this analysis is applicable if there are no major changes for the foothill region in the General Plan Update. Under current zoning, extensive agriculture, agriculture zone, commercial, manufacturing, and residential can subdivide to five acres or less. Recreation and exclusive agriculture can divide into 20 – 80 acre parcels, and the foothill agriculture region can divide into 160 acres. Because the General Plan allows for additional residences for every 40 acres for the foothill agriculture region, we assumed that the region could be subdivided into 40 acres. These scenarios also assume that development will occur only on private property. Tulare County is running their own development scenario using a model called UPlan, and their GIS department can be contacted for their results.

Methods
The program ARCGIS 9.1 was used in our analysis of the development threat to create maps that show how development will look under different build-out scenarios. GIS layers were obtained from Tulare County's GIS department and state and federal agency websites. We obtained potential locations of residences for Yokohl Ranch and Sequoia Ranch projects through promotional material provided by the projects. A GIS layer showing the current zoning for Tulare County was used extensively in this analysis. To evaluate the impact of a house on different-sized parcels we found the percentage that a 200-meter disturbance zone around a house would affect a parcel. Summarized in Table 3.3, we assume the following:

- The impact of one house extends beyond parcels of five acres or less. Those parcels are considered entirely impacted and an additional 100-meter buffer was applied to those areas.
- 10-acre parcels are entirely impacted by the development of a house but no buffer was applied.
- Parcels of 20 – 80 acres were significantly affected by the development of a house (20 – 79%).
- The impact of one house on a parcel size of 160 acres is 10%. This is our threshold of what we consider negligible impact. Thus, any parcels 160 acres or above are considered good blue oak woodland habitat.
- Yokohl Ranch and Sequoia Ranch projects are expected to have clustered housing. A 200-meter buffer is applied to both projects.

Parcel sizes of 10 acres or less are considered "intensively developed," while parcel sizes of 20 – 80 acres are considered "degraded habitat."

Table 3.3: The percentage of parcels affected by a 200-m disturbance zone.

Size of parcel (acres)	Percent affected by 200m disturbance zone
5	100%
10	100%
20	79%
40	39%
80	20%
160	10%

To calculate the fragmentation index, we followed the methods used in the "Current Assessment" section of this report. We did not include "degraded habitat" in our fragmentation index calculations. Our scenario descriptions are provided in the results section. Additionally, we investigated what development will look like within our priority conservation areas for one scenario.

Results
Table 3.4 summarizes the percent of blue oak woodland impacted ecologically and the fragmentation index.

Table 3.4: The impact of future development scenarios on blue oak woodland.

Scenario	% impacted by intensive development	% of degraded habitat	Fragmentation index
Current	14.8%	0.0%	782
1	18.3%	0.0%	683
2	19.4%	0.0%	673
3	18.3%	26.0%	683
4	19.4%	25.1%	673
5	20.7%	57.3%	661
6	22.0%	56.0%	653
7	29.8%	48.2%	512

The Foothill Development Corridor consists mainly of parcels zoned for residential, commercial, and recreational uses. Build-out within the Foothill Development Corridor increases the percent of blue oak woodland impacted and causes additional fragmentation. Especially vulnerable is the area around Springville; the Foothill Development Corridor cuts horizontally through blue oak woodland and if built-out will further increase the gap between oaks in the northern and southern parts of the county.

Under the roads-driven scenario (Scenario 3), the area ecologically-impacted by development more than doubles. Under the complete build-out scenario (Scenario 5), the area impacted increases four times. All private lands are subdivided into parcels of 40 acres or less, thus the majority of blue oak woodland is considered degraded habitat. In this scenario of extreme human impact, good quality habitat would only occur on public lands.

The expansion of urban areas scenario (Scenario 7) offers a look at how poorly planned growth could be catastrophic to blue oak woodland. Large patches of blue oak woodland no longer exist, and blue oak woodland is clearly the most fragmented of all the scenarios.

Based on the digitization of promotional photographs, the Yokohl Ranch Project designates 4,500 acres and the Sequoia Ranch Project designates 1,250 acres to be converted for residential and recreational uses. However, only parts of both projects intersect with blue oak woodland. The total ecological effect (applying a 200 meter buffer) of Yokohl Ranch is 5,830 acres and the effect of Sequoia Ranch is 1,400 acres. Most of Sequoia Ranch falls in the Foothill Development Corridor, so its additional contribution to the conversion of blue oak woodland is not significant.

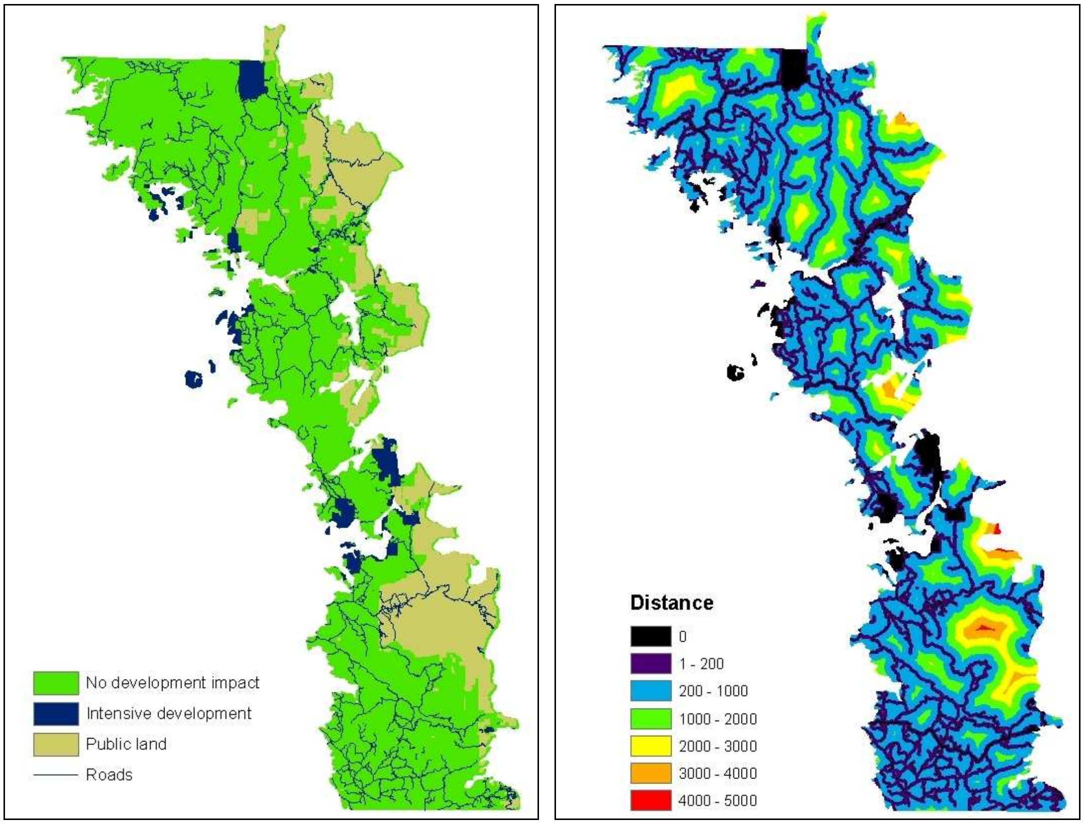


Figure 3.7: Build-out map and fragmentation map for Scenario 1.

<u>Scenario 1</u>: Foothill development corridor build-out

Tulare County has specified a development corridor in the foothills to drive development away from the valley floor and prevent rural residential development. In this optimistic scenario, we assume that development will only occur in this corridor. No subdivision outside of the development corridor occurs.

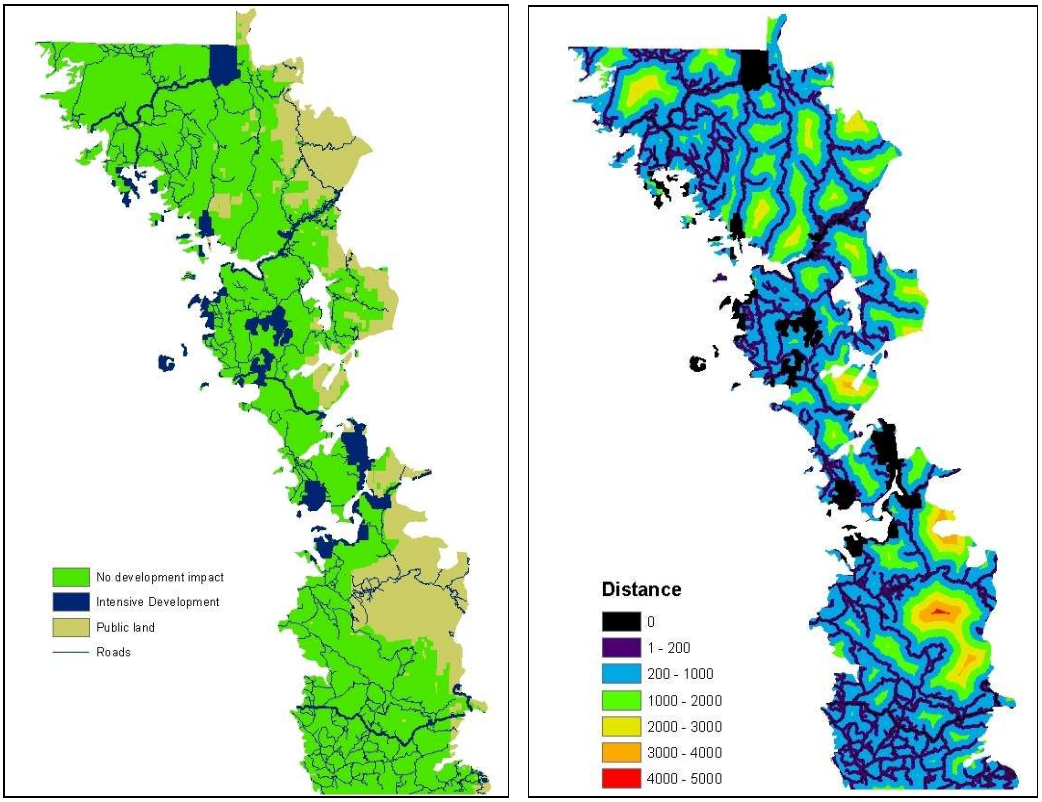


Figure 3.8: Build-out map and fragmentation map for Scenario 2**.**

<u>Scenario 2</u>: Foothill development corridor build-out with large development projects

This scenario follows Scenario 1 with the addition of the Yokohl Ranch and Sequoia Ranch projects.

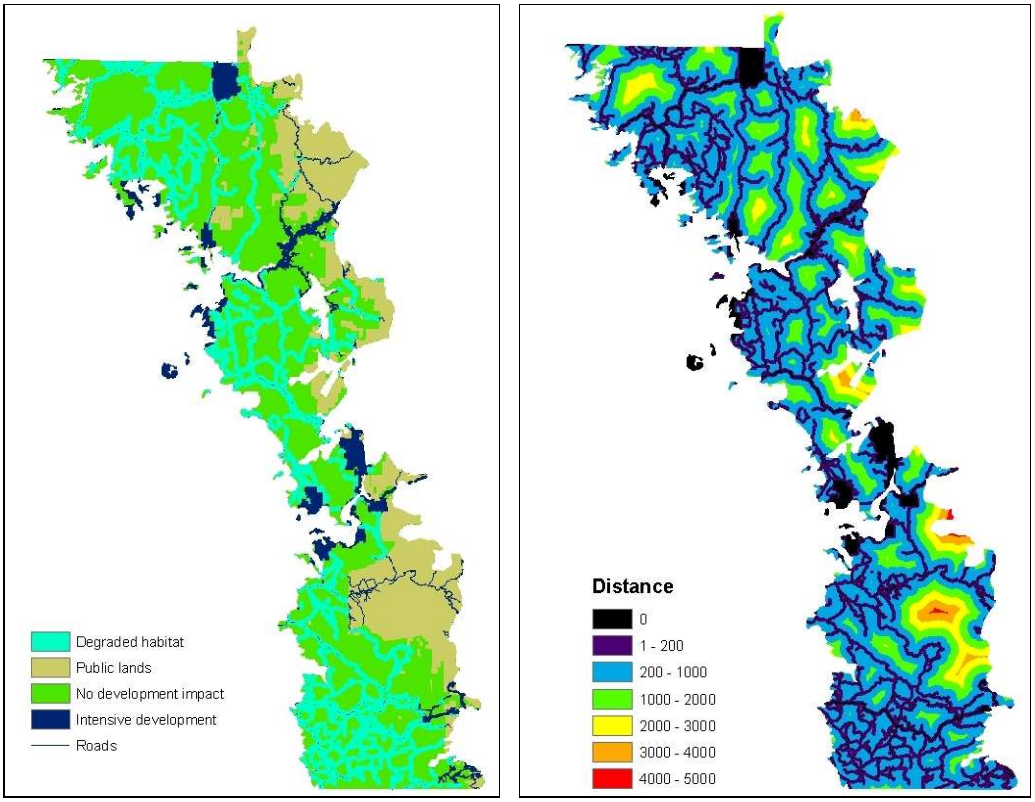


Figure 3.9: Build-out map and fragmentation map for Scenario 3.

<u>Scenario 3</u>: Road-driven expansion

In this scenario, the development corridor is built-out and subdivision occurs on properties adjacent to roads in the foothills. Currently, for lands zoned as Foothill Agriculture (AF), a single residence is allowed per 160 acres, with additional residences allowed for each 40 acres of property. We buffered local roads by 300 meters and highways by 500 meters to express the subdivision of properties along transportation corridors. Many properties in the foothills are remote with steep slopes, and roads would have to be built in order to allow for subdivision. As roads are expensive to build, properties near existing transportation corridors would be the most practical for development.

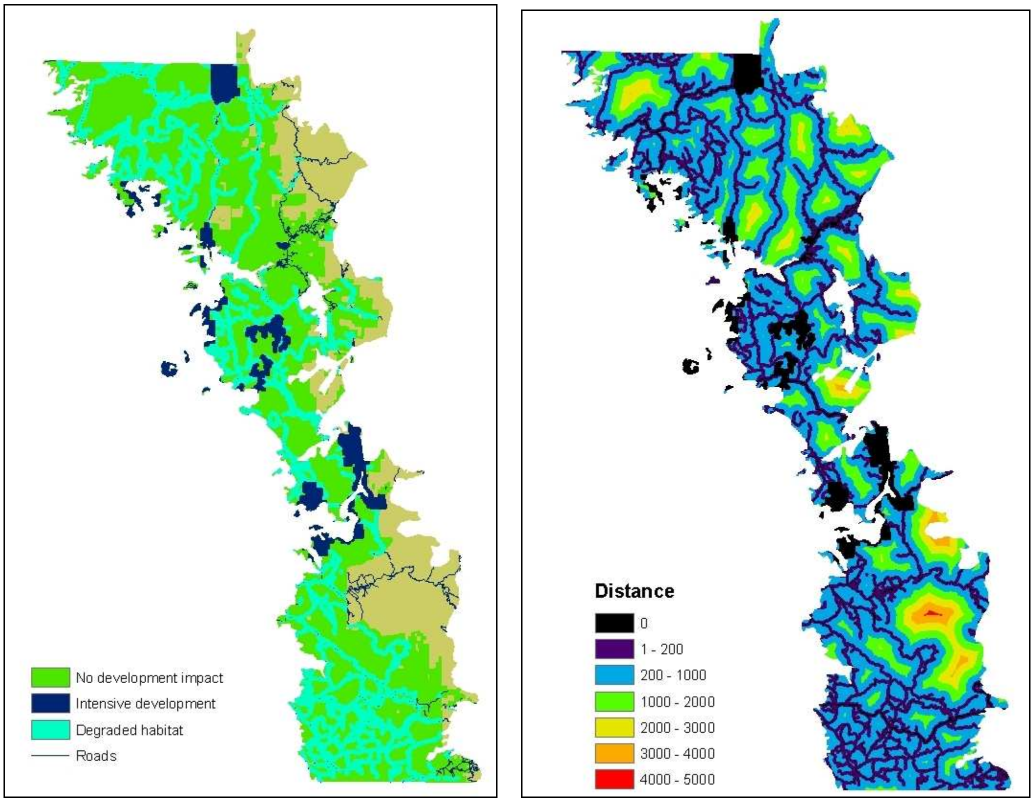


Figure 3.10: Build-out map and fragmentation map for Scenario 4.

<u>Scenario 4</u>: Road-driven expansion with planned development projects

This scenario follows Scenario 3 with the addition of the Yokohl Ranch and Sequoia Ranch projects.

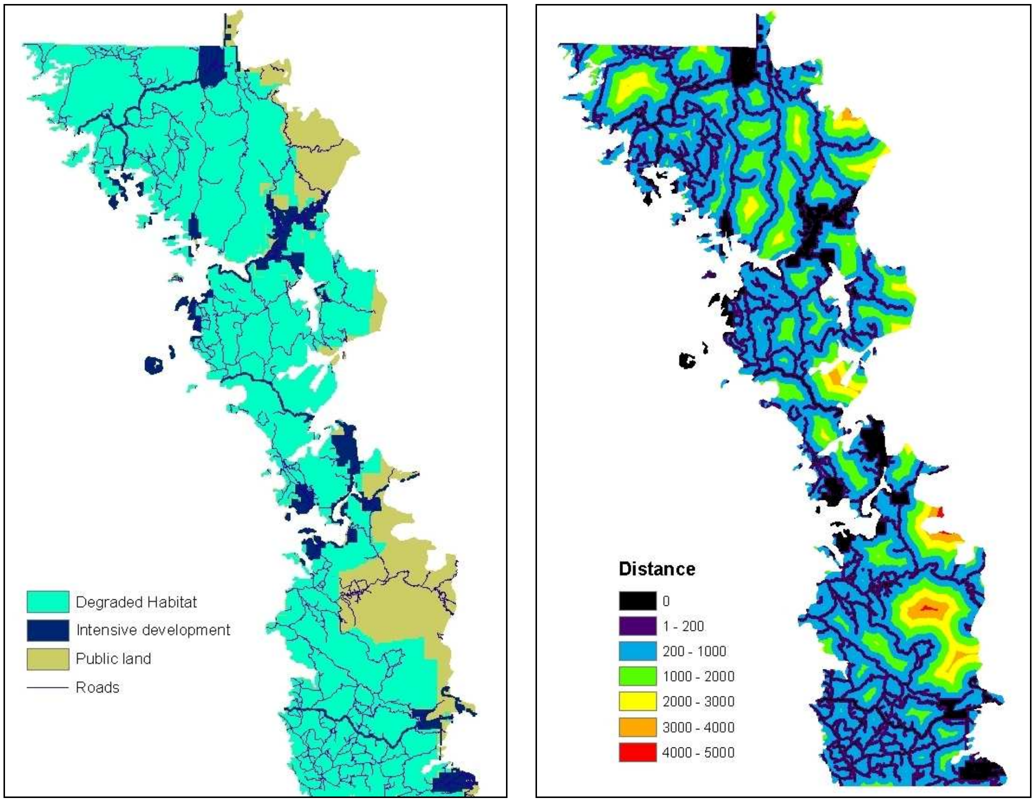


Figure 3.11: Build-out map and fragmentation map for Scenario 5.

<u>Scenario 5</u>: Complete foothill build-out

This scenario investigates the full development of the foothills. Subdivision occurs in the development corridor and in the foothills. This scenario represents an extreme level of human impact.

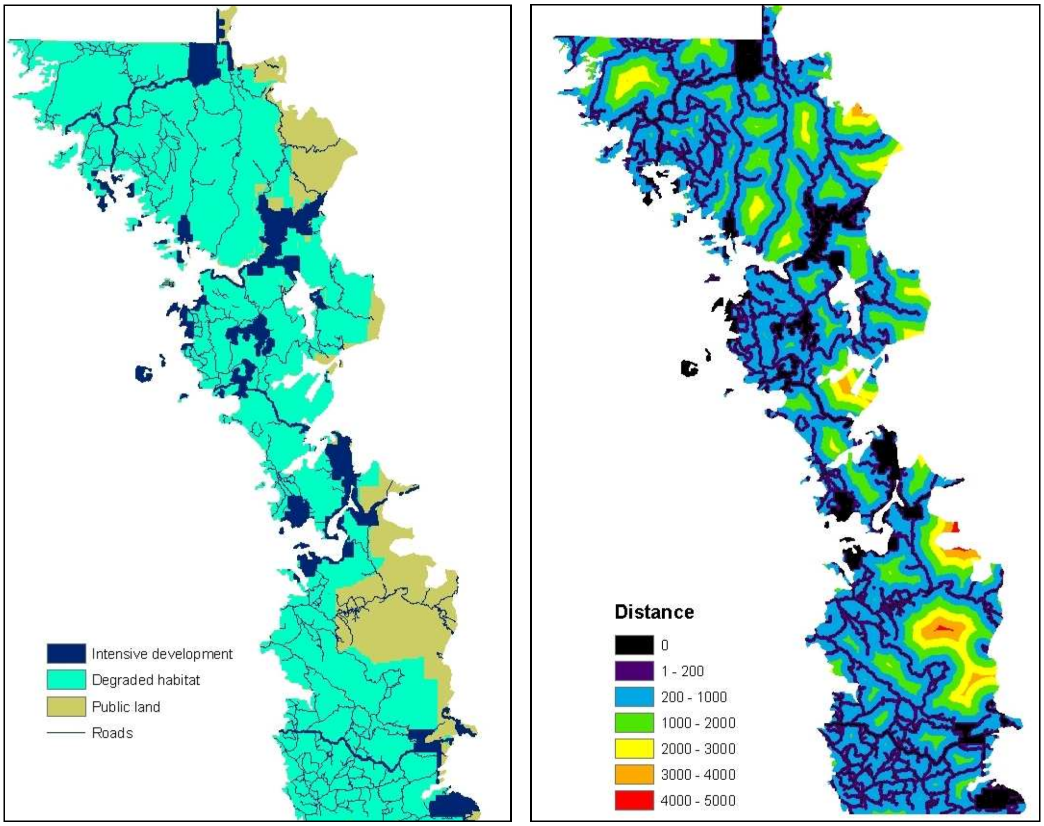


Figure 3.12: Build-out map and fragmentation map for Scenario 6.

Scenario 6: Complete foothill build-out with large development projects

This scenario follows Scenario 5 with the addition of the Yokohl Ranch and Sequoia Ranch projects.

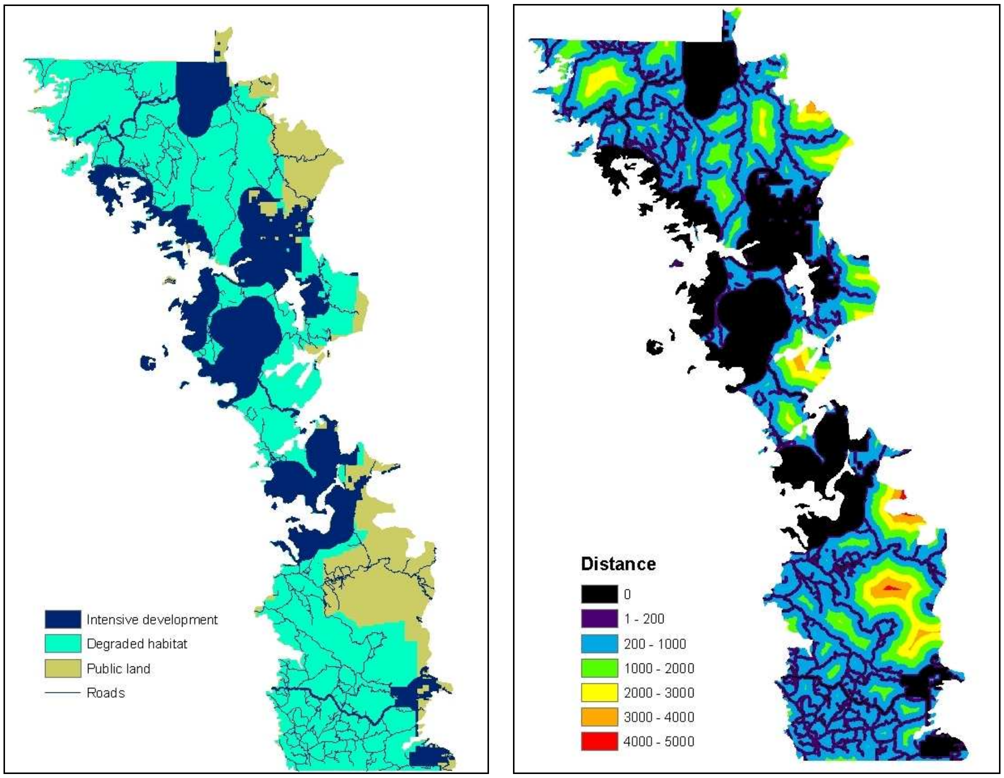


Figure 3.13: Build-out map and fragmentation map for Scenario 7.

<u>Scenario 7</u>: Expansion of urban areas

This scenario assumes complete foothill build-out, the development of the Yokohl Ranch and Sequoia Ranch projects, and the expansion of urban areas. In this scenario, we consider the development corridor and the Yokohl Ranch and Sequoia Ranch projects to be urban areas. Future existing urban areas will be attractive for urban expansion and sprawl. To account for this possibility, we apply a buffer of 2,000 meters to intensively-developed areas.

Discussion

The maps from the scenarios illustrate spatially what development could look like under the current zoning ordinance. Areas most threatened by development occur along the western edge of blue oak woodland habitat and around Springville. Both areas are zoned as the Foothill Development Corridor. Interviews with real estate agents have verified that the area around Springville has been and will continue to experience growth (Quinn Apherton and Mike Bennet, personal communication, November 2006). Development around Springville will have a large impact on blue oak woodland because it will increase the split between northern and southern blue oak woodland in Tulare County.

Based on interviews with county planners and local real estate agents, we believe that the most likely growth scenario will involve the build-out of the Foothill Development Corridor with some subdivision of ranches along roads. As development pressures increase and the ranching lifestyle becomes economically nonviable, ranchers will feel pressured to sell. The majority of the area surrounding the roads in the foothills has slopes of less than 30% and will most likely develop first. The rest of the foothills are too remote and steep to be economically viable to subdivide properties into smaller ranches. Additionally, the Foothill Growth Management Plan (1981) of Tulare County's General Plan contains language that allows for the expansion of the Foothill Development Corridor designation given the requirements of certain criteria. The zone has the potential to expand as the majority of the corridor is surrounded by lands with slopes less than 30% and is held in private ownership.

Areas with low development potential include Dry Creek, south of Springville, and areas north of Three Rivers with the exception of the small community of Badger. We assume that blue oak woodland in public lands would remain undeveloped. The largest patch of blue oak woodland habitat that falls on public lands occurs within the Tule River Indian Reservation.

Development within our conservation priority areas

We believe the foothills of Tulare County is likely to experience growth similar to the roads-driven scenario over the next 75 years or so (Scenario 3). This scenario predicts that an additional 4.6% and 25.1% of blue oak woodland will be impacted by intensive and low-density development, respectively (Table 3.4). Priority areas C-F are adjacent to public lands and a significant portion of these areas exists on public lands (Figure 3.14). Priority area E has the highest potential for intensive development (Table 3.5). The community of Springville and a large portion of the development corridor falls within priority area E. Priority area C is also expected to experience some intensive development as the community of Three Rivers is located in the area. Intensive development in priority areas A, B, and F is unlikely, but these areas may experience degradation of habitat due to development along roadways.

Table 3.5: The impact of future development on priority areas differs greatly.

Watershed	Directly impacted by development	Ecological impact of development	Future intensive development in BOW	Future degraded BOW habitat
Hoffman Point (A)	3%	8%	0%	28%
Sand Creek (B)	3%	1%	0%	32%
Three Rivers (C)	6%	17%	2%	27%
Devil's Canyon/Blue Ridge (D)	3%	10%	<1%	18%
Springville (E)	7%	21%	13%	22%
Cold Springs Canyon	<1%	3%	0%	33%

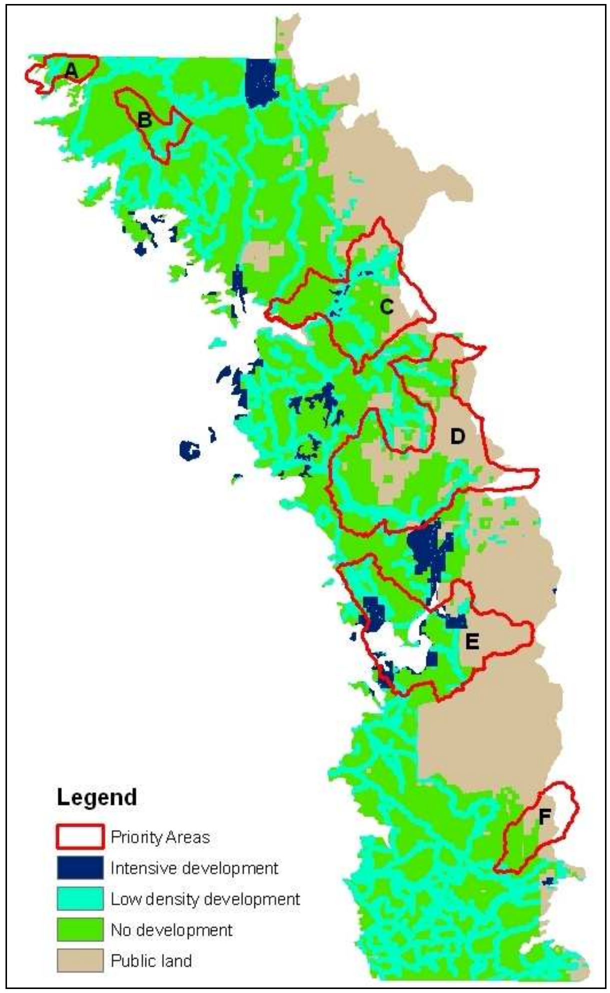


Figure 3.14: Priority area E is predicted to be the most heavily impacted by development under the Roads-driven Scenario.

These results will be combined with climate change in Part IIC to investigate synergistic threats to blue oak woodland.

B. Climate Change

In this section, we evaluate the potential impacts of multiple climate change scenarios on blue oak woodland in Tulare County. First, we use current climate and vegetation plot data to build a statistical model that predicts how blue oak habitat suitability varies with climate. Using downscaled climate results from General Circulation Models, we then predict the spatial distribution of blue oak habitat for the years 2050 and 2080. In order to evaluate the dynamic response of the blue oaks to these changes in habitat suitability, we use a dynamic simulation model incorporating species life-history, dispersal, and competitive interactions in a changing landscape. Finally, based on our model results, we develop a simple metric for assessing the likely persistence of blue oak woodland under climate change. These results can be combined with development predictions to evaluate the threat patterns within conservation priority areas.

Background

The current range of blue oaks forms a well-defined elevational band encircling California's Central Valley, limited primarily by climatic factors. Over the next century, global climate change will drastically alter climatic conditions, causing shifts in the range of suitable habitat for species across the globe. In general, these shifts will be northward and upslope. Our study area lies near the southern end of the blue oaks' current range, where the range of suitable habitat can be expected to contract as temperatures rise. Regional climate modeling work by Kueppers *et al.* (2005) has predicted that by 2100, the range of suitable habitat for blue oaks will decline by 41% statewide, with an almost-complete disappearance in Tulare County. A long-term conservation plan for blue oak woodland in Tulare County thus clearly requires that these range shifts be taken into account.

Range shifts are a dynamic process, dependent on species biological characteristics as well as changing habitat suitability over time. Shifts in the actual distribution of blue oaks will be determined by the species' ability to colonize new habitats and persist in unsuitable habitats. The rapid, large-scale shifts expected from climate change do not have any historical analogue within the human observational record. Pollen records have shown, however, that some oak species in the eastern United States were able to rapidly colonize new territory at very rapid rates (up to 25 km per 100 years) following the last glacial epoch (Davis 1981). While these dispersal rates cannot be generalized to blue oaks in California, they emphasize the importance of accounting for dynamics in species range shifts.

Climate change presents a serious threat to the long-term persistence of blue oaks in our planning area, requiring innovative strategies for conservation. Because the time horizons for a great majority of conservation plans are on the order of 3 – 10 years, they are unable to account for long-term threats such as climate change (Hannah *et al.* 2002). To capture the effects of climate change, a time horizon of 30 years or more is necessary. Our project models how the range of the blue oaks will shift under a changing climate over the next 100 years, and integrates these changes with threats from development. This effort will provide valuable information to conservation planners for use in a dynamic conservation plan for the southern Sierra foothills, and could have significant implications for future planning of the southern Sierra Nevada.

Bioclimatic Envelope Modeling

Methods
We use a bioclimatic envelope model to predict the range of suitable habitat for blue oaks in California. In this approach, a predictive model of species occurrence is first built using spatial data of species occurrence and current environmental conditions, and the model is then applied to future conditions to predict the future distribution of the species. BioMOD (Thuiller 2003) incorporates a suite of modeling methodologies into a single framework. Using the same input data, different model types can produce very different predictions, and running several models at once allows one to compare the success of each model in predicting the current, known distribution of the target species. Typically, the model with the best performance in reproducing the current range is selected as the most accurate model for predicting future habitat ranges.

Source data
To build our bioclimatic envelope model, we use presence/absence data from 16,273 vegetation plot surveys throughout California. To ensure a consistent scale across the modeling domain, these data have been re-sampled using a 1 km grid, aggregating plots that fall into the same grid cell together and classifying those that contained at least one plot with blue oaks as a presence and classifying all others as absences. Blue oaks are present in 803 plots and absent in 15,470 plots.

We obtained current and future climate data from Worldclim (Hijmans *et al.* 2005), which uses interpolated data from weather stations across the globe to produce downscaled climate surfaces at 30 arc-second (roughly 1 km) resolution. These downscaled data are available for current conditions as well as for a variety of General Circulation Models. We use the Hadley Centre Coupled Model, version 3 (HADCM3), and the Canadian Centre Coupled Global Climate Model (CCM). Each model has been run for two IPCC (Intergovernmental Panel on Climate Change) CO_2 emissions scenarios: the A2 scenario, which presents a "business as usual" approach with continued increases in emissions through the end of the century; and the B2 scenario, which assumes that technological and political conditions will lead to considerable emissions reductions. We extract 19 bioclimatic variables from these models and choose eight for use in envelope modeling:

- Annual maximum temperature
- Annual minimum temperature
- Temperature annual range (maximum – minimum)
- Mean temperature of the wettest quarter (contiguous three-month period) of the year
- Mean temperature of the driest quarter of the year
- Mean temperature of the warmest quarter of the year
- Precipitation of the wettest quarter of the year
- Precipitation of the warmest quarter of the year

We choose these variables because they are biologically relevant to plant species and because they exhibit low correlation with one another; high correlation (or collinearity) of predictive variables should generally be avoided because it introduces bias into the results of some models. Figure 4.1 indicates where blue oaks fall within the overall range of bioclimatic conditions statewide.

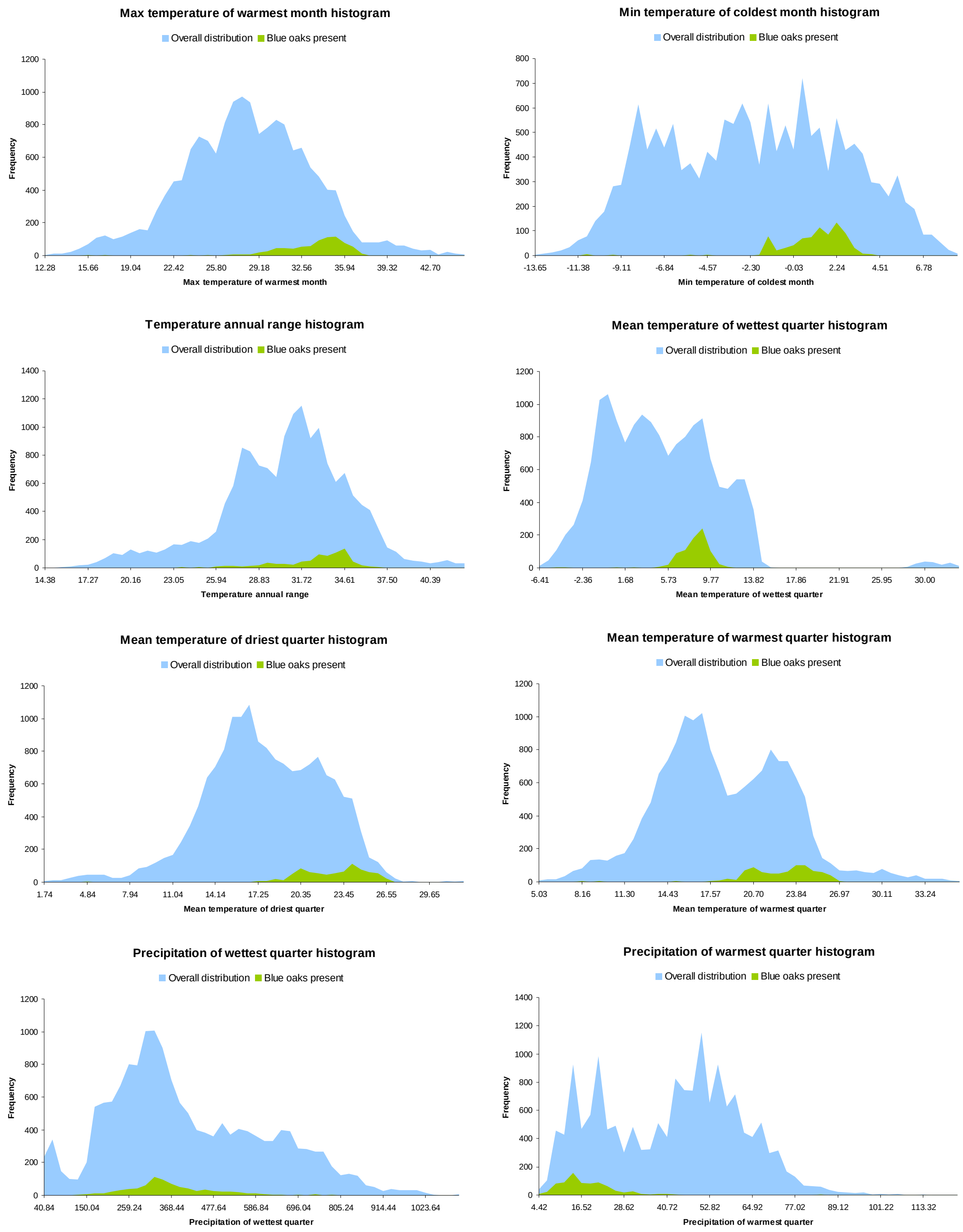


Figure 4.1. These histograms show the range of bioclimatic conditions occupied by blue oaks relative to the overall range of conditions statewide. The bioclimatic variables displayed here are those used in the BioMOD envelope modeling. The green area of the histogram represents the vegetation survey plots classified as "present," while the blue area represents those classified as "absent."

Model application and evaluation

Using the vegetation survey data in conjunction with the bioclimatic variables for current climate conditions, we produce six different statewide envelopes for blue oaks in BioMOD. We incorporate soil types into our bioclimatic envelopes by using data from the U.S. General Soils Map (STATSGO) to produce envelopes using only soils data. The probabilities of the climate and soils envelopes are then integrated using a Bayesian approach, which allows one to combine probabilities (in this case, probabilities of oak occurrence) from independent lines of evidence (in this case, soil and climate conditions) to produce a single probability. We then combine the results of all six Bayesian models into a single "consensus" model using a principle component analysis (PCA), with the first principle component taken as the new probability for modeling purposes.

In order to choose the most appropriate model for our analysis, we compare the performance of all models produced throughout the modeling process. To make the probability maps produced by each model comparable to the original vegetation survey dataset, we reclassify them as presence/absence by applying a threshold to the probabilities. We then adjust the thresholds of each model to minimize the number of false-presences and false-absences as compared to a subset of the original vegetation survey dataset. The model that produces the fewest errors at the optimum cutoff point is taken as the best model for predicting the range of the blue oaks.

Using the downscaled GCM results from Worldclim, we model the shifts in potential range of blue oaks up to the year 2080 for the CCM and HADCM3 models under the IPCC A2 and B2 scenarios. From this, we can predict the spatial distribution of lost and gained habitat statewide and within our study area. The envelope results can also be used for dynamic modeling to predict the actual range that the species will be able to achieve.

Results

The model with the best performance in predicting the range of blue oaks in BioMOD is the Generalized Boosting Model (GBM). The GBM is a form of additive logistic regression that uses a base learning algorithm to optimize its classification of areas that are difficult to classify correctly. We expected the consensus model to provide a more robust prediction, since it incorporated multiple models and a higher performance than all models except the GBM. However, it consistently over-predicted the range of the blue oaks in our study area, producing ranges that extended unrealistically onto the floor of the Central Valley. This may be due to a paucity of vegetation plot data for the valley floor, which has not been the target of many vegetation surveys since it has been covered by agricultural fields. Figure 4.2 shows the occurrence probabilities predicted by the GBM for current climate conditions. The modeled habitat range fits the vegetation plot data well, and they are also generally in good agreement with the range of the species as determined by the California Department of Forestry's (CDF) Fire and Resource Assessment Program (FRAP). There are some noticeable differences between the model results and the FRAP data. At lower elevations, the model over-predicts the current range. At the upper elevations near the center of the county, there is another mismatch that may be due to either misclassification in the FRAP data or over-prediction by the model. Since this corresponds to an area where we have observed blue oaks during a field visit, we believe that this is an error in the FRAP classification.

Using the GBM model results with the optimal threshold applied (as described above), we can produce maps of lost, gained, and stable range for the blue oaks for a variety of climate change models and scenarios. Figure 4.3 shows the predicted range shifts for the year 2080, while Figure 4.4 provides a statistical summary of the change in habitat area over time for the various climate models. The impacts are most severe under the Hadley Centre model. There is little upslope expansion of the range in any of the scenarios except the CCM B2 scenario.

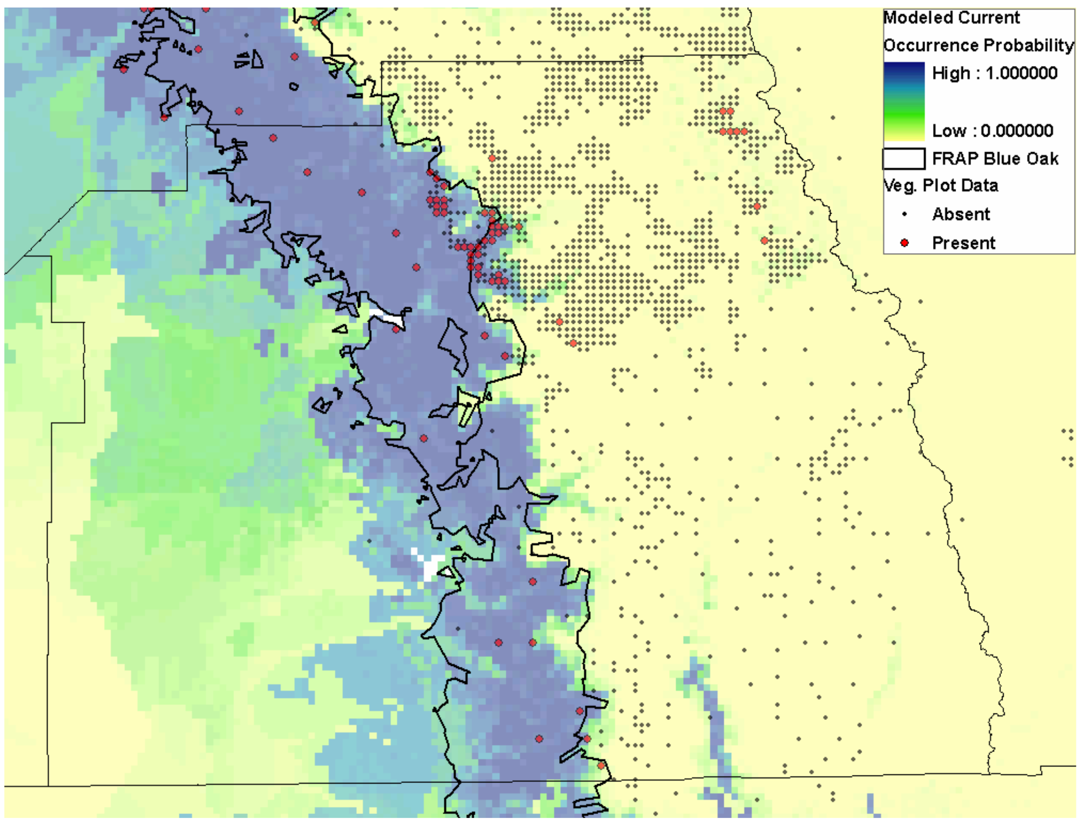


Figure 4.2: The bioclimatic envelope produced by the GBM. Red points denote vegetation plots in which blue oaks were present, and black points denote plots in which blue oaks were absent. The black outline shows the range of the blue oaks as determined by the California Department of Forestry's Fire and Resource Assessment Program (CDF FRAP).

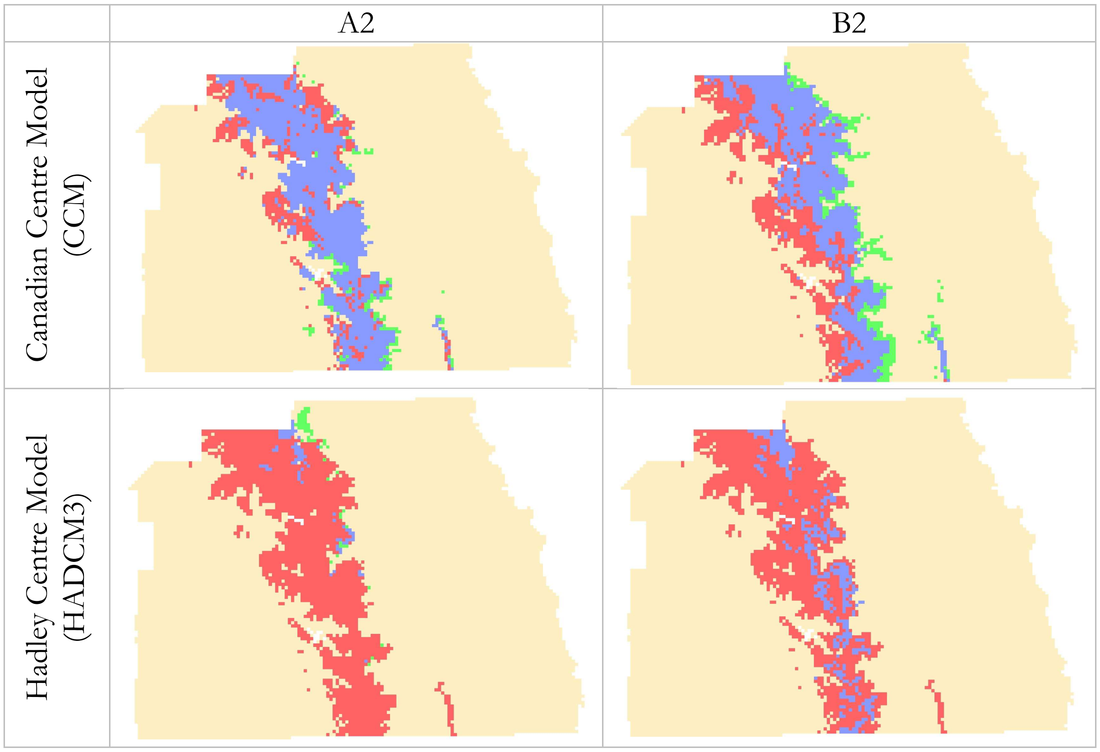


Figure 4.3: The predicted distribution of lost (red), gained (green), and stable (blue) range for the blue oaks for two GCMs and two emissions scenarios. These values were produced by taking the difference between the current modeled range of the blue oaks and their predicted range in 2080 according to each scenario.

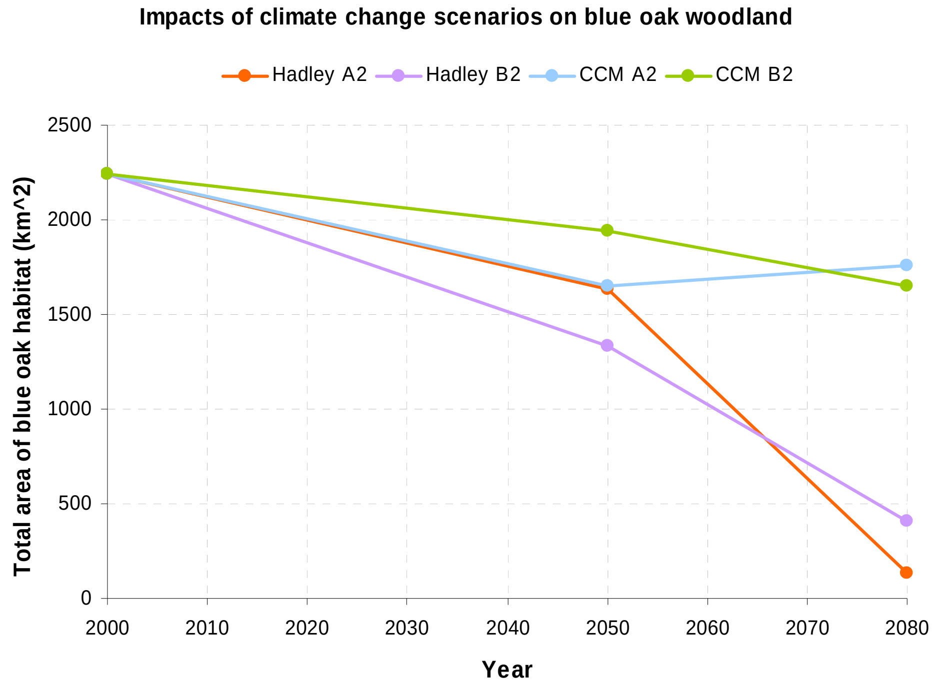


Figure 4.4. Impact on the total area of blue oak habitat in Tulare County under climate change, according to two GCMs and two emissions scenarios. The CCM model predicts a relatively constant rate of decline for both emissions scenarios, with range being reduced by about 25% for both emissions scenarios. The Hadley Centre model predicts a more drastic reduction in range, with declines accelerating until 80 – 95% of the current habitat has been lost.

Dynamic Species Modeling

Methods

We use a dynamic species model to predict the response of the blue oaks to shifting habitat suitability under climate change. BIOMOVEII (Biomove) is a dynamic species model that incorporates species life-history characteristics, dispersal ability, competition, and disturbance as well as shifting ranges over time. We incorporate the bioclimatic envelopes from BioMOD as habitat suitability maps which impact the mortality of blue oak seedlings and saplings.

Life-history

At the core of Biomove is a spatially-explicit age-structured population model. The landscape is divided into a grid, and each cell contains a population consisting of many cohorts (year-by-year age classes). The cohorts are divided into seedling, immature (sapling), mature, and senescent classes by user-specified age breaks. Each of these broader age classes has user-specified demographic characteristics, including mortality, effective fecundity, and sensitivity to climate conditions. We used the demographic characteristics shown in Table 4.1.

Table 4.1: Demographic parameters used in Biomove model of blue oaks.

	Seedlings	Saplings	Mature Trees	Senescent Trees
Age range	1-7 years	8-30 years	31-300 years	301-400 years
Annual mortality	50%	5%	0.1%	2.5%
Effect of envelope	Strong	Weak	None	None
Effective Fecundity	0	0	5 seeds/yr	3 seeds/yr

Mortality in Biomove is specified by the user as mortality over the length of the age class. However, mortality in the ecological literature (and indeed in most demographic models) is given as an annual value. In Table 4.1, the Biomove parameter values have been converted to annual mortalities. Blue oaks are a long-lived species with high seedling mortality and low adult mortality. Allen-Diaz and Bartolome (1992) found blue oak seedling mortality to be approximately 50% per year under natural field conditions. Swiecki *et al.* (1993) found adult mortality to be in the range of 2 – 4% per decade (equivalent to 0.1 – 0.2% per year). Fewer data are available for seedling and sapling mortality, but the sapling mortality of 5% used here is taken simply as a mid-range value between seedling and mature mortality rates. The rate of senescent mortality is set automatically in Biomove and cannot be changed by the user.

Envelopes in Biomove are continuous values from zero to one representing habitat suitability. We have assumed that the occurrence probabilities produced by BioMOD can be converted directly to Biomove envelope values without any scaling. By default, the effect of the climate envelope is simply a linear function applied to survival rates, with an envelope value of one having no effect, a value of 0.5 reducing survival by 50% and a value of zero causing total mortality. The level of impact on survival can be changed by specifying an exponent to be applied to the envelope value. The effect of climate on mature blue oaks is likely to be negligible, since they have deep tap roots that provide them with reliable sources of water. Seedlings and saplings, however, are likely to be more strongly impacted by moisture availability at the surface, and thus an exponent of one is applied to the climate envelope for saplings, and an exponent of five has been applied to the envelope for seedlings.

Reproduction and dispersal

When reproduction occurs in Biomove, seeds are dispersed randomly into the neighborhood of the parent grid cell according to an exponentially-weighted probability function, as shown in Figure 4.5. Dispersal occurs at both local and long-distance scales. Local dispersal accounts for 99.9% of all dispersal and has a mean "throw" distance of 100 m, while long-distance dispersal accounts for the remaining 0.1% of dispersal with a mean distance of 650 m. Since the cell size of the model is 1 km, local dispersal results in very little migration to neighboring cells, and thus any rapid (decadal time-scale) shifts in distribution must occur due to rare long-distance events.

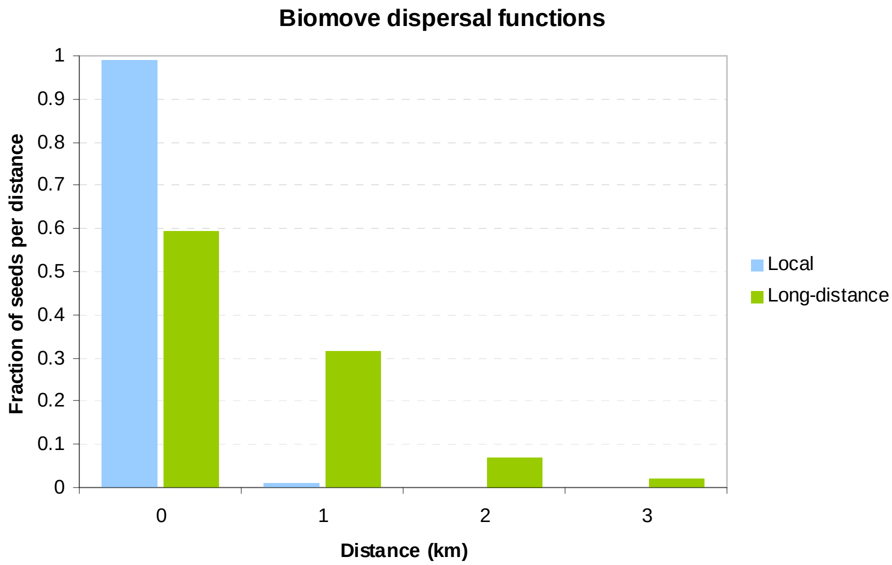


Figure 4.5. Dispersal functions for local and long-distance dispersal in the blue oaks Biomove model.

Competition

While there is evidence that blue oak seedling growth is facilitated by shade (Callaway 1992), saplings and mature trees are relatively shade-intolerant (Swiecki and Bernhardt 1998), and the species' upper-elevation range limit is governed partly by competition with conifers. In Biomove, we model competition with a pine plant functional type whose distribution is controlled by the envelope of sugar pine (*Pinus lambertiana*) as modeled in BioMOD. Inter-specific competition for light in Biomove is accomplished by specifying a response curve of the pine to light and the allocation of different age classes to different strata. The pine plant functional type impacts the blue oak through shading, but is not itself impacted by the oak. Intra-specific competition occurs via a thinning routine, which removes individuals randomly across all cohorts when the population rises above carrying capacity; there is no competition for light among the age classes of the oak species.

Simulation

Starting with an initial distribution that followed the shape of the current envelope for blue oaks, we ran a 1000-year simulation to bring the species distribution to equilibrium. We then ran a 300-year simulation starting with the current envelope at year 0 and applying the climate envelopes for 2050 and 2080 after 50 and 80 years, respectively. We ran one simulation for each combination of GCM and emissions scenario.

Results

In the dynamic simulation, there was little noticeable change in the blue oak's distribution by the year 2100. Overall, species abundances began to decline in 2080, when declining habitat suitability led to higher mortality. However, the spatial distribution of trees remained essentially unchanged. Figure 4.6 shows the overall trends in blue oak abundance for each climate scenario up to the year 2300. The declines are due to the gradual death of mature trees that have remained in unsuitable habitat. As the trees in unsuitable habitat die out they are not replaced, making the remaining distribution of blue oaks more closely reflect the envelopes in 2080.

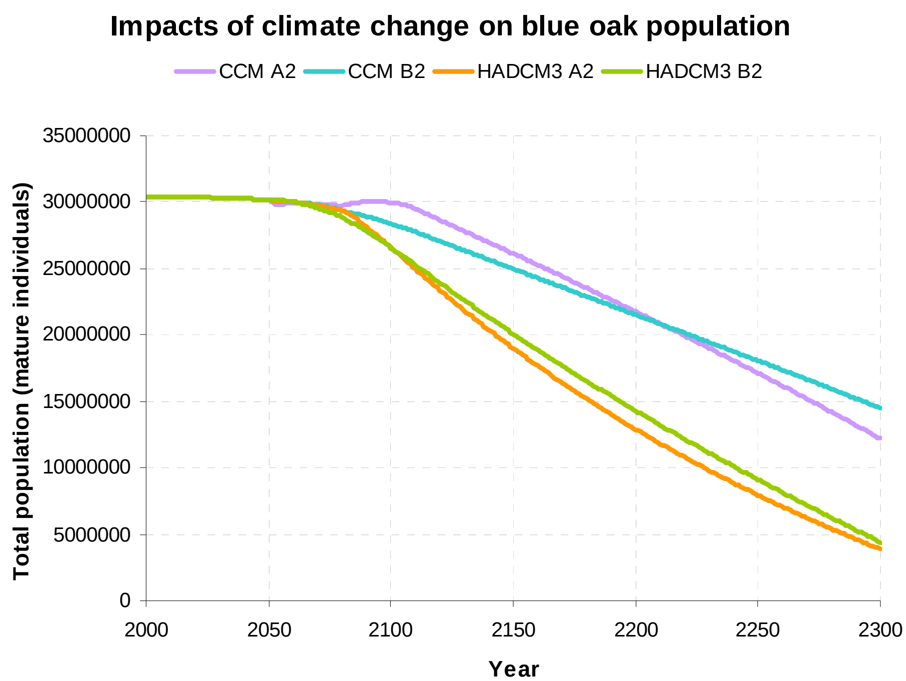


Figure 4.6. Mature tree abundances from the Biomove dynamic simulation.

Discussion

The goal of incorporating the climate change results into this conservation plan is to highlight areas of persistent blue oak woodland within our selected priority areas. We believe a long-term planning horizon of approximately 100 years to be a reasonable conservation goal. Since the distribution of blue oaks at 2100 remains essentially unchanged from the current distribution, the dynamic simulation results do not provide a basis for prioritizing any sites within the 100-year time horizon. This could be considered a result in itself, but it is prudent to consider climate change threats based on the available information. The BioMOD envelope results for the different climate scenarios have different spatial distributions, and the areas where the predicted distributions overlap can be taken as a "best bet" for future conservation of blue oak woodlands. Figure 4.7 shows the level of overlap between all four models for the year 2080, which we use as a measure of overall future habitat quality. This approach is meant to identify the areas where blue oaks are likely to persist for the longest period of time, based on available climate models.

Here, we have classified persistence into named categories based on the number of climate scenarios in which blue oaks are predicted to be present; areas selected zero to five times are considered "very low," "low," "medium," "high," and "very high" persistence, respectively. The areas of greatest blue oak persistence predicted by our climate change models are concentrated toward the upper elevations of the current range of blue oak woodland as determined by FRAP (dashed lines in Figure 4.7). Comparing these results to the current range predictions (shown as probabilities in Figure 4.2), the areas where the envelope model over-predicted the current species range in the lower elevations have largely contracted, while the upper-elevation mismatch with the FRAP data remains highly persistent. There are no discernable patterns of either high or low persistence within the priority areas identified by our multi-criteria analysis. The Sand Creek watershed (Area A) has almost no persistent blue oak, while the Devil's Canyon watershed (Area C) has high persistence throughout. The threat synergy section (Part IIC) includes a more quantitative comparison of persistence within the priority areas.

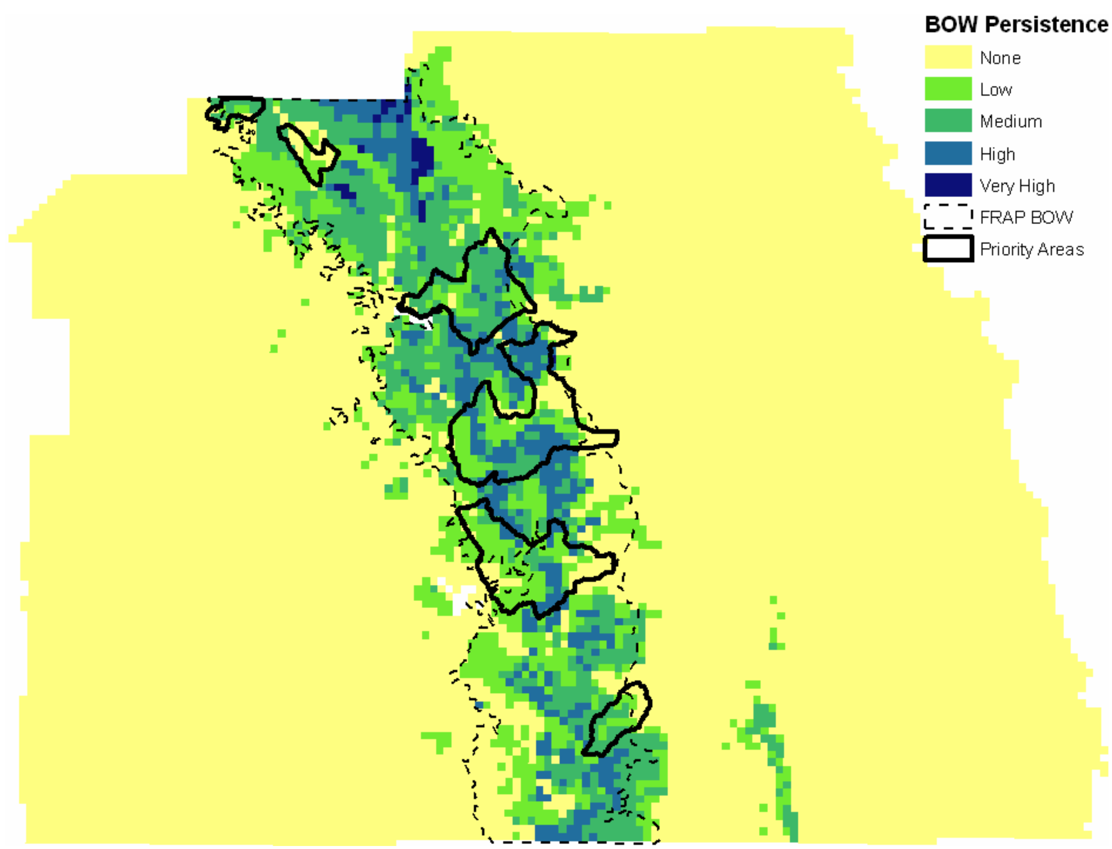


Figure 4.7. Overlap of the BioMOD envelope results for the year 2080. The areas of highest agreement are shown in dark blue, while the areas of lower agreement are shown in varying shades of green. Thick, black outlines show priority areas as identified in Part I. Thin, dashed lines show current range of blue oak woodland as determined by FRAP.

C. Threat Synergy

In this section, we evaluate the impacts of development and climate change within the conservation priority areas. For our approach to blue oak woodland conservation in Tulare County to be useful for conservation planners, the multiple aspects of this project are combined into a comprehensive set of results and recommendations. In this section, we synthesize our multiple analyses to produce a spatial evaluation of where blue oak woodland will persist and where blue oak is most threatened.

Methods

In Part I, we conducted a multi-criteria analysis to determine priority areas for conservation. Six priority areas comprised of 12 watersheds were selected. In Part IIA, we generated several GIS maps depicting different scenarios of development threat to blue oak woodland. In Part IIB, we produced multiple maps of possible blue oak woodland range shifts in response to climate change over different time spans.

Long-term conservation plans often operate on a time span of a hundred years; thus, we modeled threat synergies in the year 2080. To synthesize our threat analyses, we selected one development scenario and one climate change result to integrate spatially (Figure 3.14 and Figure 4.7). We selected the "road-driven expansion with planned development projects" scenario (Scenario 4) because this build-out scenario is a realistic estimate of where development in Tulare County will occur. We used the overlap of the BioMOD envelope results because, given future uncertainty, this provides the most robust prediction of where blue oaks are likely to persist in the long term.

To evaluate our priority conservation areas, we determined areas of high persistence and high threat. Our 2080 climate change projections produced 5 categories of persistence: very low, low, medium, high, and very high. Using ARCGIS 9.1, we separated blue oak woodland into two categories based on the climate change results. Areas where two or more models predicted oak persistence in 2080 were classified as persistent, while all other areas were classified as not-persistent. We applied the results of the development scenario to evaluate the threat to the high persistence regions. Areas predicted to be either intensively developed or degraded with low-density residential area are assumed threatened. Using Microsoft Excel, we calculated how much of each priority area contains persistent blue oak woodland, and how much of that is threatened and unthreatened. This analysis provides information about which priority areas have the highest percentages of persistent and threatened blue oak woodland.

Results

When we look at the threats in isolation, climate change poses a greater threat to blue oak woodland than development. If we assume that areas of very low to low persistence of blue oak woodland are threatened, then about 48.8% of the current range would be threatened by climate change by 2080, with about 31.1% becoming areas of very low persistence. High and medium persistence habitat is scattered throughout the range and about half of the current range of blue oak woodland remains in medium persistence or higher. The areas with the highest persistence occur in the northern range of blue oak woodland in Tulare County, near the community of Badger. The majority of the least persistent habitat occurs along the southeastern edge of the current range, with some occurring along the western edge. In 2080, contraction of blue oak suitable habitat to the upper-middle elevations of the current range occurs. None of the priority areas contain the locations with the highest persistence.

Currently, 4.6% of blue oak woodland in our study area is directly displaced by development. In 2080, 26.3% of the current range of blue oak woodland will be impacted to some degree by development. The result of the spatial integration of climate change and development is illustrated in Figure 5.1. This figure can be used to identify the degree of persistence and the threat level of individual sites. Table 5.1 provides a detailed description of the area and percentage of blue oak woodland at varying threat levels. Assuming that areas of intensive development or no to low persistence constitute habitat losses, 59.5% (330,006 acres) of blue oak woodland will be lost by 2080. Low density development will be responsible for degrading 27.0% (198,856 acres) of blue oak woodland. The remaining blue oak woodland (35.9%) would contain good quality habitat and is unlikely to be threatened by development.

Table 5.1: This table describes the condition of the current range of blue oak woodland in 2080 as predicted by our climate change and development analyses.

a) area in acres

BOW Persiste		Development Type				
		Intensive	Low-density	None	Public	Total
	None	3,164	26,231	29,017	38,702	97,114
	Low	9,819	47,508	57,344	58,891	173,562
	Medium	5,300	49,721	85,179	37,039	177,239
	High	2,719	24,115	52,439	19,853	99,126
	Very High	919	2,057	3,905	440	7,321
	Total	21,921	149,632	227,885	154,925	554,363

b) percentage

BOW Persiste		Development Type				
		Intensive	Low-density	None	Public	Total
	None	1%	5%	5%	7%	18%
	Low	2%	9%	10%	11%	31%
	Medium	1%	9%	15%	7%	32%
	High	0%	4%	9%	4%	18%
	Very High	0%	0%	1%	0%	1%
	Total	4%	27%	41%	28%	

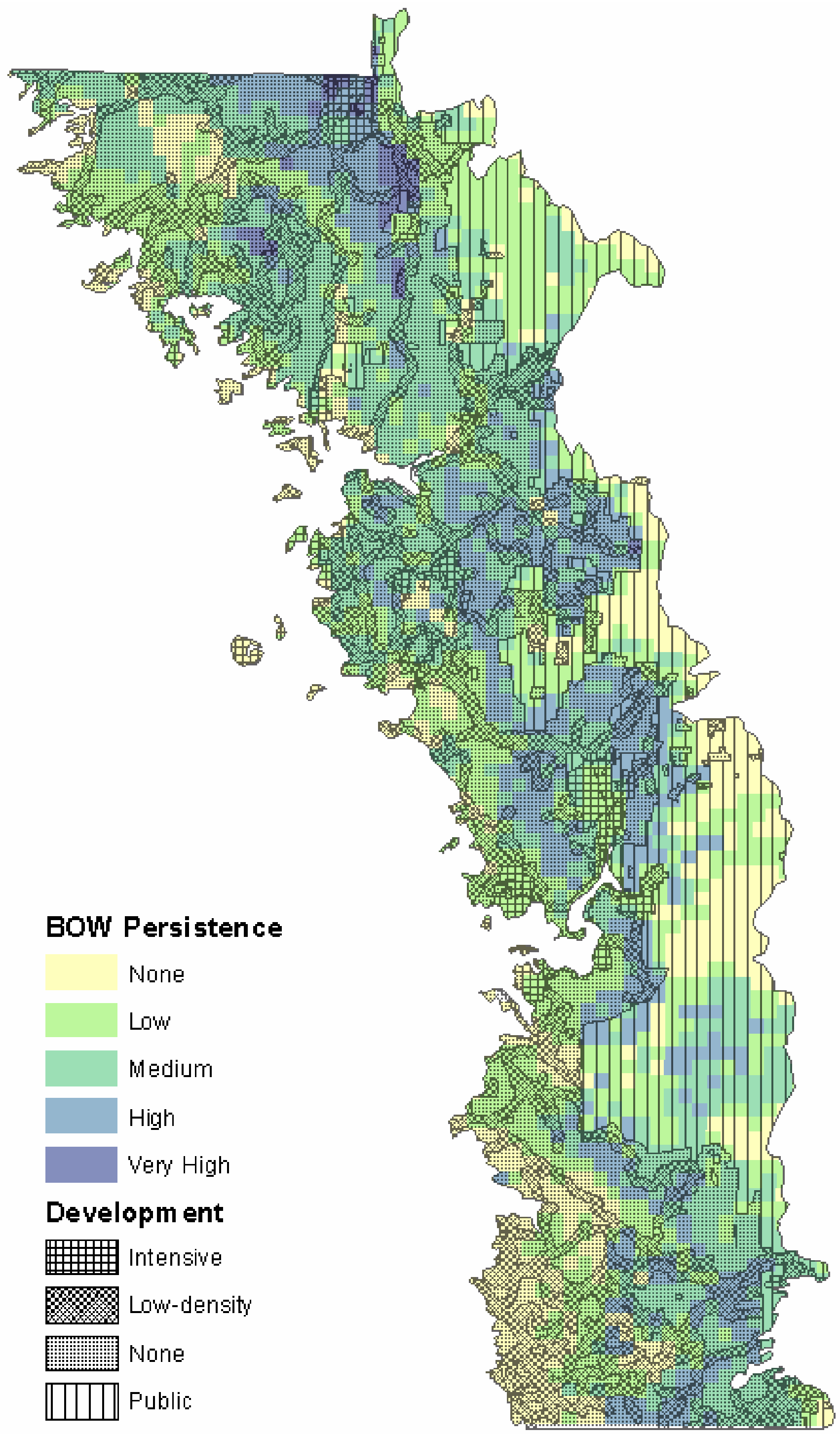


Figure 5.1: This map depicts the combination of development and climate change threats within blue oak woodland in our study area, as predicted by our analyses for 2080. Colors show the level of blue oak persistence while hatch marks show development classifications.

Comparison to a Previous Assessment

In Part 1, we identify conservation priority areas that define areas of high biological diversity and habitat heterogeneity in Tulare County. Here, we evaluate the combined threats of climate change and development within this set of priority conservation areas. Figure 5.2 combines the climate change and development results in a simplified way, classifying both intensive and low-density development as threatened and classifying all areas with medium-to-very high likelihood of persistence as suitable blue oak habitat in 2080. We use this framework to analyze the combined effects of development and climate change.

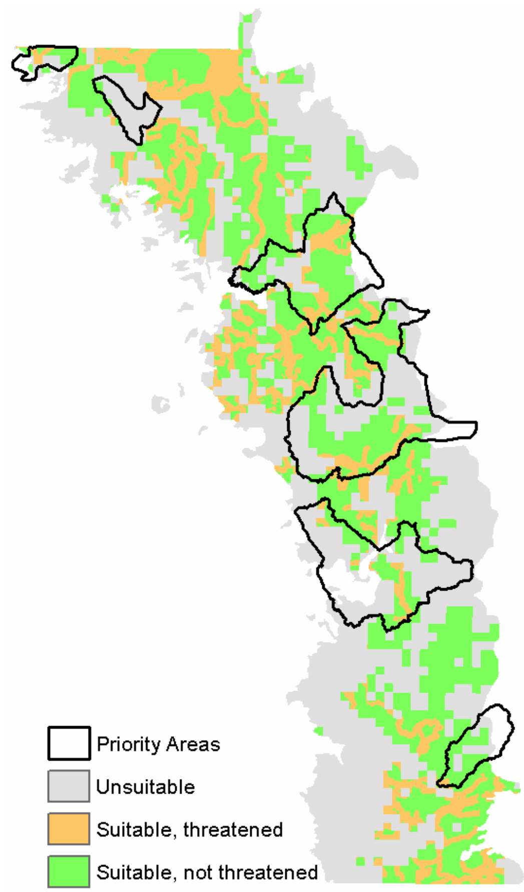


Figure 5.2: This map shows the distribution of development impact within areas of likely persistence for blue oak woodland in the year 2080, along with the priority areas from our multi-criteria analysis.

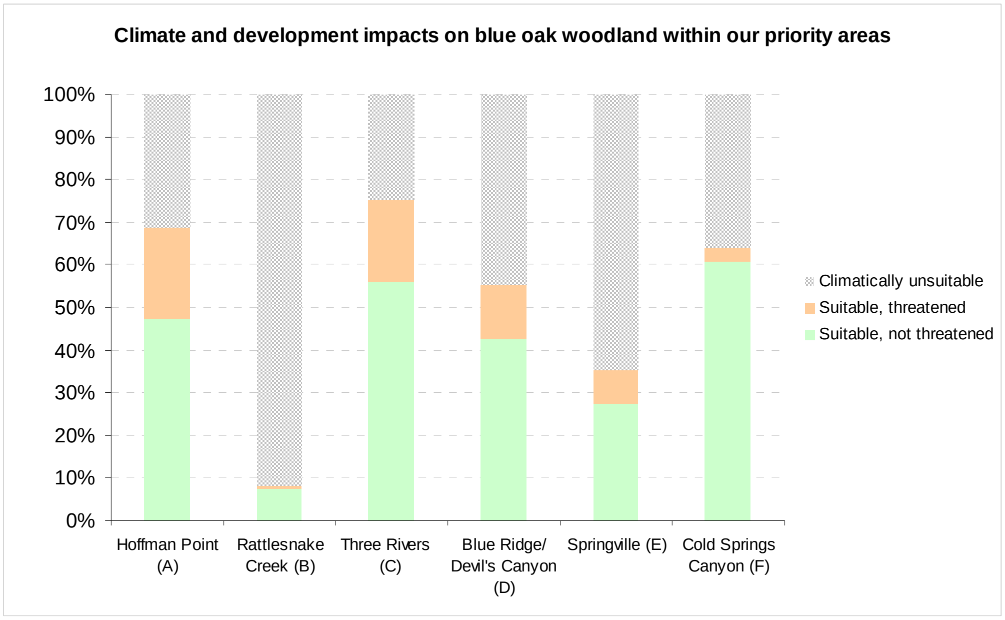


Figure 5.3: The graph shows the percent of current blue oak woodland that will be made climatically unsuitable by climate change (gray), suitable habitat that may be impacted by development (orange), and unthreatened habitat (green) within the priority areas from our multi-criteria analysis. In the bar graphs, the left-to-right order of sites corresponds to a north-to-south order on the map in Figure 5.2.

A spatial examination of the threat synergy both within and outside of the priority conservation areas is warranted. Consistent with our focus on blue oak woodland, all of our priority areas are constrained to the elevational range where blue oaks are present. There are a few notable areas with medium to high likelihood of blue oak persistence and relatively extensive development threats that are not included in any of the sites: one area falls between Three Rivers and Rattlesnake Creek: one area is southwest of Three Rivers, and the final area is south of Cold Springs Canyon. Three of our six priority areas are predicted to have over 50% coverage of persistent blue oak woodland in 2080. However, the proportion of threatened habitat within our priority areas is relatively small, most likely because our multi-criteria analysis preferentially selected watersheds with few roads.

The spatial distribution of threats may be the most informative measure for decisions regarding where to conserve within the selected areas. At a coarse scale the statistics shown in the graphs of Figure 5.3 provide a basis for selection of planning units. For instance, of all of our priority areas, the Three Rivers unit has both the highest overall blue oak habitat persistence and the highest percentage of unthreatened habitat, followed by Devil's Canyon and Blue Ridge. Thus, conservation is likely to be more effective over the long term in these areas.

Discussion

Our analysis shows that the selected conservation target and the conservation approach taken vary depending on goals and priorities. If the goal were simply to protect sites presently containing the highest habitat scores, then the results from the multi-criteria analysis could be used as-is. However, an analysis of those sites with respect to climate change finds that a few of the sites become unlikely candidates for preserving blue oak woodland in the long term. A different suite of sites would be recommended if the priority were to conserve the highest habitat quality for a future time period. Likewise, the selection of priority areas would be different if development threats were included. We did not incorporate threats directly into the multi-criteria analysis when initially selecting our priority areas. The multi-criteria analysis could be repeated incorporating threats, and a comparison of the resulting priority site selection would be interesting.

Our results show climate change to be the greatest threat to blue oak woodland in the southern Sierra in the long-term. Climate change poses a greater threat to the current range of blue oak woodland (47.3%) than does future development (31.1%). Additionally, the majority of the development threat (80.7%) is in the form of low-density development, and blue oak woodland habitat would continue to exist in these areas, albeit as lower quality habitat. Because climate change is predicted to have a large impact, incorporating climate change into blue oak woodland conservation planning is necessary. However, uncertainty in our climate change modeling exists at the scale of our analyses, in the various existing models of climate change on regional and global scales, and in the availability of data. As climate modeling becomes more sophisticated, climate change can be incorporated into conservation planning with more certainty. Overall, the combination of development and climate change threats will result in the loss of almost half of the current range of blue oak woodland in the study region by 2080. Our analysis provides strong support for taking action to conserve blue oak woodland in Tulare County.

Recommendations

As humans' imprint on the global landscape grows ever larger, we face the potential loss of millions of species. Conservation planners struggle to protect remaining biodiversity across multiple temporal and spatial scales and against a myriad of threats. Historically, conservation was often done in an *ad hoc* manner, resulting in a reserve system that exists primarily in the highest elevations of our state. Consequently, the preservation of lower-elevation, human-friendly landscapes is crucial. Research shows that a systematic, adaptive approach to conservation is more effective at preserving biodiversity than are opportunistic systems or static blueprints. Our research provides conservation planners with an example of a systematic, replicable, yet dynamic strategy for conserving blue oak woodland. We determined the relative ecological value of watersheds within Tulare County blue oak woodland and we analyzed the threats of development and climate change across multiple temporal scales. The information provided here may also be used to build upon existing reserves in Tulare County.

This is an optimal time to conserve blue oak woodland in Tulare County. Development on the western slope of the Sierra Nevada is skyrocketing and blue oak woodland in many counties is already being degraded and fragmented by increased urbanization and ranchette sprawl. Although development pressure in Tulare County is significant, the southern Sierra foothills have experienced lower growth rates than foothill sections in other parts of the Sierra. Tulare County therefore contains a large, contiguous band of relatively good quality blue oak woodland habitat. Evidence indicates that land in the southern Sierra is less costly than in other foothill regions, providing more opportunities for conservation on a limited budget. Furthermore, Tulare County is in the midst of updating their General Plan, providing an opportune time to consult with local planners and policy makers about implementing smart growth strategies and preserving foothill open space. Finally, over half of Tulare County is public land. As climate change warms the planet, blue oaks and associated species may be forced to shift ranges. A conservation plan that protects biodiversity today *and* tomorrow will likely need to contain, or protect connections to, reserves that allow for both an upslope migration and dispersal to new latitudes. The network of public lands within Tulare County provides a solid baseline of protected land from which to work.

We recommend using a multi-faceted, adaptive approach to ensure the persistence of blue oak woodland, an example of which is provided in this report. Following are specific recommendations for blue oak woodland conservation in Tulare County:

1. Work within conservation priority areas.
Conservation organizations all over the world are working to preserve the diversity of plants, animals and ecosystems on this planet. The conservation priority areas selected

by our multi-criteria model represent watersheds or watershed conglomerations that are likely to contain high levels of biodiversity within Tulare County's blue oak woodland. We therefore recommend that conservation planners focus their efforts on protecting sites within those watersheds, or similar systematically-chosen priority areas.

2. Use threat-synergy in making conservation decisions within and between priority areas.

Conservation planners have long struggled to protect landscapes from an ever-increasing human population and associated development and fragmentation. In addition to the perils of habitat loss and degradation, climate change presents a new and serious threat to our natural environment, with potentially devastating consequences. Conservation planners, land managers, and policy makers must now reconcile protecting habitat from the immediate threat of development with planning for an eventual range shift by target biota.

Our threat and threat synergy analyses provide one way to incorporate a dynamic environment into long-term conservation planning. We offer the means for planners to identify and compare the relative persistence of, and threat to, patches within the landscape. Conservation planners can use this information to rank conservation priorities.

3. Use bands of high persistence to connect reserves.

Our conservation strategy assumes that lands outside of Tulare County foothill reserves will be managed in a manner that will allow for inter-reserve migration. The majority of the Tulare County foothills is presently used to graze cattle. While this activity degrades woodland habitat, it also supports a relatively high level of biodiversity. Our designation of conservation priority areas do not therefore consider the spatial pattern or connectivity of selected watersheds.

Nevertheless, a growing Tulare County population and associated development is likely to eventually fill in the gaps between foothill reserves. We therefore suggest that conservation planners and public and private conservation organizations cooperate to establish an inter-reserve corridor of protected land. Although this report does not explicitly design a corridor system, our climate change data could be used to identify connecting patches of high persistence between reserves. Figure 6.1 illustrates a relatively continuous band of land that is likely to persist as good blue oak habitat.

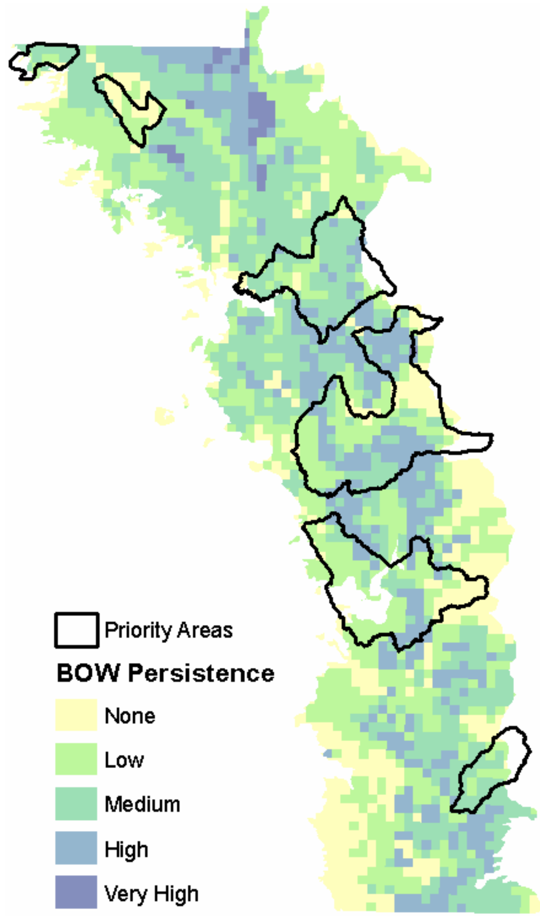


Figure 6.1: Bands of high persistence (shown in blue) may be used to guide the creation of a corridor system between conservation priority areas.

A 2002 study performed by the California Wilderness Coalition identified lands in the Sierra Nevada bioregion that should be conserved as part of a comprehensive statewide program to ensure the long term survival of California's biodiversity. The study used a site selection optimization program called SITES (Andelman *et al.* 1999) to identify "Wildland Conservation Areas," which they defined as large, contiguous, undisturbed expanses of habitat designed to maintain the viability of species over time (Shilling *et al.* 2002). The authors then used a least-cost-path analysis to delineate potential wildlife movement paths between the Wildland Conservation Areas, called "Wildland Linkages." We overlay the Wildland Linkage corridor for the foothill section of the Sierra Nevada Bioregion on our map depicting habitat persistence under climate change in Figure 6.2. The Wildland Linkage corridor corresponds closely to bands of high persistence habitat.

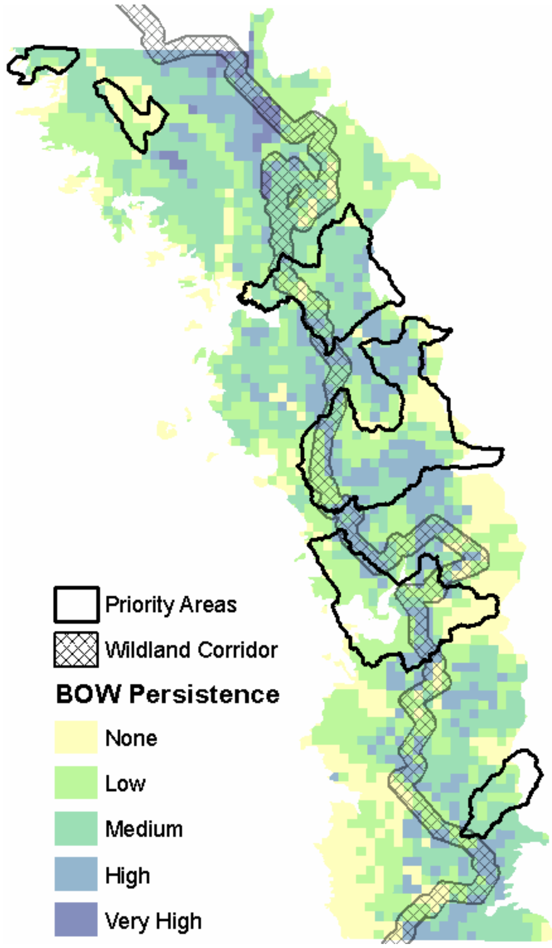


Figure 6.2: An overlay of the Wildland Linkage Corridor (Shilling *et al.* 2002) shows high correspondence to bands of high-persistence habitat between conservation priority areas.

4. Manage lands to optimize the chance of blue oak regeneration.
Our climate change models assume the successful recruitment of blue oaks under current climate conditions. There is evidence, however, that blue oaks in Tulare County are experiencing inadequate regeneration. Fortunately, there are strategies that may be utilized by land managers to facilitate blue oak seedling survival and increase regeneration. Studies have demonstrated that oaks can benefit from human intervention and protection in areas where acorns are germinating but seedling and sapling survivorship is low. Artificial regeneration may be necessary in areas where oaks are not regenerating on their own or to restore stands that have been lost or degraded.

The simplest, and possibly most effective, protective measure is the use of wire cage enclosures to protect emergent seedlings from grazing in areas where deer and cattle have access. Young trees should be protected until tree height exceeds the browse line (Swiecki *et al.* 1994). In areas where rodent damage is a problem, root-caging for rodent protection may be necessary as well (Howard 1992; Swiecki *et al.* 1994). Grazing should be kept to 10 – 20 acres per cow per year and pastures allowed to rest in the spring and summer.

Competition for water may also limit regeneration in some areas. Mulching and weed control can conserve soil moisture. Irrigation can also be used to increase soil moisture, although studies found that its effectiveness varied from site to site. The manual clearing of vegetation from around emergent seedlings will help reduce water and light competition as well.

5. Use species targets to determine site size, configuration, and connectivity.
Our conservation priority areas were designed at a scale of Calwater planning watersheds; most foothill reserves, however, begin with the purchase of a parcel of land from a single land owner. Our models do not address the size or configuration of potential reserves. With good stewardship, blue oaks will likely survive within a fragmented landscape; however, the blue oak woodland community will suffer with increased fragmentation and decreased patch size. The requirements of blue oak woodland species can be used by conservation planners to determine the spatial extent and configuration of reserves. Schonewald-Cox *et al* (1983) estimated a minimum reserve size of $10^3 - 10^4$ hectares (ha) would be required to maintain viable populations of small mammals, and $10^6 - 10^7$ ha for larger mammals. These guidelines will likely be influenced by the management of lands outside of the reserve system.

Blue oak species can also help conservation planners prioritize sites within selected conservation areas based on fine-scale landscape features. *Clemmys marmorata*, for example, requires sites with low-flow streams and ponds with adequate vegetation and exposed basking sites. If, on the other hand, a conservation group wants to ensure the persistence of *Felis concolor* in Tulare County blue oak woodland, only land parcels of 10,000 acres or more should be considered and a higher priority given to reserve connectivity.

6. Work with local institutions to maximize blue oak persistence outside of designated reserves.
Land use planning is one of the most effective means of conserving habitat. Smart growth principles can indirectly preserve blue oak woodland by encouraging high-density, clustered development, thereby preserving large patches of uninterrupted open space.

Tulare County is currently updating their General Plan. It is an opportune time for conservation planners to work with county officials to create smart-growth policies, set-aside land as designated open-space, and encourage measures that will preserve the county's foothill resources. Tulare County is also presently considering a General Plan Amendment that would allow for the development of Boston Ranch in the Yokohl Valley. Boston Ranch provides connectivity in a long stretch of relatively pristine blue oak woodland. The Yokohl Ranch Project would not only impact a large area of blue oak woodland, it would interrupt the north-south corridor, set a precedent for new-town development in the Tulare County foothills, and provide an urban nexus from which foothill development could spread. The denial of a General Plan Amendment by the county may make a major contribution to the conservation of Tulare County blue oak woodland.

The other largest single landowner of blue oak woodland in the Tulare County foothills is the Tule River Indian Reservation. Like Boston Ranch, the Tule River Indian Reservation is an important link in the contiguous north-south stretch of blue oak woodland. Conservation organizations may want to consider working with reservation leaders to promote land management strategies that complement the needs of a blue oak woodland community.

Finally, as blue oak range-shifts into higher elevations are likely, conservation organizations may want to coordinate with the public agencies managing lands in the eastern portion of Tulare County to facilitate this transition. This may include managing disturbance regimes and maintaining the integrity of the connection between public and private reserves.

Concluding remarks

Blue oaks are one of California's most conspicuous and charismatic species. In addition to providing habitat and food for countless woodland creatures, blue oaks are an integral part of our human history. Native Americans used blue oak acorns for food, shoots for baskets, and bark for dyes. Early settlers relied on blue oaks for firewood and grazed cattle under their canopies. Modern landowners pay more for views of oak woodland, counties pass ordinances to protect individual trees, and municipalities use "oak" in the name of cities, streets, and parks. Blue oaks symbolize longevity, strength and beauty—qualities that are admired in people and trees alike. These trees have long captivated the hearts, minds and imaginations of both California residents and visitors. Blue oaks are an iconic part of the California landscape; dynamic conservation planning can help ensure that they remain so.

References

Allen-Diaz, B. H., and J. W. Bartolome. 1992. Survival of Quercus douglasii (Fagaceae) seedlings under the influence of fire and grazing. Madrono **39**:47-53.

Andelman, S.A., I. Ball, F. Davis, and D. Stoms. 1999. Sites v1.0: an analytical toolbox for designing ecoregional conservation portfolios. Santa Barbara, CA: University of California. Manual prepared for The Nature Conservancy.

Baker, G.A., P.W. Rundel, and D.J. Parsons. 1981. Ecological relationships of *Quercus douglasii* (Fagaceae) in the foothill zone of Sequoia National Park, California. Madrono. **28**:1 (1-12).

Barrett, N.M. 1998. Bullock's Oriole/Baltimore Oriole. Pages 518-519 in H.E. Kingery, editor. Colorado breeding bird atlas. Colorado Bird Atlas Partnership and Colorado Division of Wildlife, Denver.

Bartolome, J. W., M. P. McClaran, B. H. Allen-Diaz, J. Dunne, L. D. Ford, R. B. Standiford, N. K. McDougland, and L. C. Forero. 2001. Effects of fire and browsing on regeneration of blue oak in R. B. Standiford, M. D., and K. L. Purcell, editors. Proceedings of the Fifth Symposium on Oak Woodland: Oaks in California's Changing Landscape. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, San Diego, CA.

Bolsinger, C. L. 1988. The hardwoods of California's timberlands, woodlands, and savannas. Resource Bulletin PNW-RB-GTR-160. Albany (CA): Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Pages 1-30 Callaway, R. M. 1992. Effect of shrubs on recruitment of *Quercus douglasii* and *Quercus lobata* in California. Ecology **73**:2118-2128.

California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program.

California Department of Fish and Game. California Interagency Wildlife Task Group. 2005. CWHR version 8.1 personal computer program. Sacramento, CA.

Coleman, J.S. and S. A. Temple. 1993. Rural residents' free-ranging domestic cats: a survey. Wildlife Society Bulletin **21**:381-390.

Crooks, K. R., and M. E. Soule. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature **400**:563-566.

Davis, F. W., R. W. Brown, B. Buyan, and J. Kealey. 1995. Vegetation change in blue oak and blue oak/foothill pine woodland. 32 p. A report to the California Department of Forestry and Fire Protection, Sacramento, CA.

Davis, F. W., D. M. Stoms, A. D. Hollander, K. A. Thomas, P. A. Stine, D. Odion, M. I. Borchert, J. H. Thorne, M. V. Gray, R. E. Walker, K. Warner, and J. Graae. 1998. The California gap analysis project. Final Report. University of California, Santa Barbara.

Davis, M. B. 1981. Quarternary history and the stability of forest communities. Pages 134-153 in D. C. West, H. H. Shugart, and D. B. Botkin, editors. Forest Succession: Concepts and Applications. Springer-Verlag, New York.

Debinski, D. M., and P. F. Brussard. 1994. Using biodiversity data to assess species-habitat relationships in Glacier National Park, Montana. Ecological Applications **4**:833-843.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Reviews of Ecology and Systematics **34**:487-515.

Fire and Resource Assessment Program. The Changing California Forest and Range 2003. Assessment. ON-line Technical Report. Chapter 1. Biodiversity Hardwoods. October 2003. Available from http://www.frap.cdf.ca.gov/assessment2003/Chapter1_Biodiversity/hardwoods pdf (accessed March 2007).

Fisher, C. S., and L. M. Levien. 2001. Monitoring California's hardwood rangelands using remotely sensed data in R. B. Standiford, D. McCreary, and K. L. Purcell, editors. The Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, San Diego.

Foreman, R. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Reviews of Ecology and Systematics **29**:207-231.

Fraterrigo, J. M. and J. A. Wiens. 2005. Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. Landscape and Urban Planning **71**:263-275.

Giusti, G. A., R. B. Standiford, D. McCreary, A. Merenlender, and T. Scott. 2004. Oak woodland conservation in California's changing landscape. 6 p. University of California Integrated Hardwood Range Management Program.

Glanzig, A. 1995. Native vegetation clearance, habitat loss and biodiversity decline. Environment Australia, Department of the Environment and Heritage.

Gordon, D. R., and K. J. Rice. 2000. Competitive suppression of *Quercus douglasii* (Fagaceae) seedling emergence and growth. American Journal of Botany **87**:986-994.

Hannah, L., G. F. Midgley, and D. Millar. 2002. Climate change-integrated conservation strategies. Global Ecology and Biogeography **11**:485-495.

Hansen, A. J., R. L. Knight, J. M. Marzluff, S. Powell, K. Brown, P. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. Ecological Applications **15**:1893-1905.

Hatch, D. A., J. W. Bartolome, H. F. Heady, and M. P. McClaran. 1992. Long-term changes in perennial grass populations in oak savanna. Bulletin of the Ecological Society of America **73** (2 supplements): p.202.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology. **25**:1965-1978.

Holmes, T. H., and K. J. Rice. 1996. Patterns of growth and soil-water utilization in some exotic annuals and native perennial bunchgrasses of California. Annals of Botany **78**:233-243.

Howard, J. L. 1992. Quercus douglasii. 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/ (accessed April 1 2007).

Huntsinger, L., L. Buttolph, and P. Hopkinson. 1997. Ownership and management changes on California hardwood rangelands: 1985 to 1992. Journal of Range Management **50**:423-430.

Knapp, E. E., M. A. Goedde, and K. J. Rice. 2001. Pollen-limited reproduction in blue oak: Implications for wind pollination in fragmented populations. Oecologia **128**:48-55.

Kueppers, L. M., M. A. Snyder, L. C. Sloan, E. S. Zavaleta, and B. Fulfrost. 2005. Modeled regional climate change and California endemic oak ranges. Proceedings of the National Academy of Sciences of the United States of America **102**:16281-16286.

Lenth, B. A., R.L. Knight, and W.C. Gilgert. 2006. Conservation Value of Clustered Housing Developments. Conservation Biology 20 (5):1445-1456.

Maestas, J. D., R. L. Knight, and W. C. Gilgert. 2003. Biodiveristy across a rural land-use gradient. . Conservation Biology **17**:1425-1434.

Masnick, G. 2001. America's shifting population: Understanding migration patterns in the west. Rocky Mountain West's Changing Landscape, 2(2). O'Connor Center for the Rocky Mountain West, University of Montana, Missoula, MT.

McClaran, M. P. 1983. *Quercus douglasii* stand age structure on grazed and ungrazed sites in Tulare County, California. 17 p. Report to the Sequoia Natural History Association; Three Rivers, California. Department of Forestry and Resource Management, University of California, Berkeley 94720.

McClaran, M. P., and J. W. Bartolome. 1990. Comparison of actual and predicted blue oak age structures. Journal of Range Management **43**:61-63.

McCreary, D. 2004a. Managing and restoring California's oak woodlands. Natural Areas Journal **24**:269-275.

McCreary, D. 2004b. Oak Woodland Conservation Act of 2001. 2004. Sierra Foothill Research and Extension Center. Paper 2004_oak_woodland_conservation_act_2001. Available from http://repositories.cdlib.org/anrrec/sfrec/2004_oak_woodland_conservation_act_2001/ (accessed June 2006)

McCreary, D. D., and M. R. George. 2005. Managed grazing and seedling shelters enhance oak regeneration on rangelands. California Agriculture **59**:217-222.

McCreary, D. D., and J. Tecklin. 2005. Restoring native California oaks on grazed rangelands. Pages 109-112 in L. Riley, editor. 2004 Western Forest and Conservation Nursery Association Meeting. USDA Rocky Mountain Research Station, Medford, OR.

McCreary, D. 2004c. Fire in California's oak woodlands. University of California Integrated Hardwood Range Management Program. Pages 1-8. Available from http://nature.berkeley.edu/forestry/sodsymposium/Fire_in_Cal_Oak_Woodlands_McCreary_623041.pdf (accessed March 2007).

McDonald, P. M. 1985. Blue Oak. United States Department of Agriculture, Forest Service. Available from http://www.na.fs.fed.us/spfo/pubs/silvics_manual/volume_2/quercus/douglasii.htm (accessed March 2007).

Mensing, S. A. 1992. The impact of European settlement on blue oak (*Quercus douglasii)* regeneration and recruitment in the Tehachapi Mountains, California. Madrono **39**:36-46.

Merenlender, A., K. L. Heise, and C. Brooks. 1998. Effects of subdividing private property on biodiversity on California's north coast oak woodlands. Pages 9-20. Transactions of the Western Section of the Wildlife Society.

Meyer, C., P. Weiant, L. Serpa, C. Tam, R. Cox, and J. Gaither. 1999. Sierra Nevada Ecoregional Plan. The Nature Conservancy, California. 172 pages.

Mintier & Associates, Matrix Design Group. 2006. Tulare County General Plan, Goals and Policies Report, Public Review Draft. Available from http://www.westplanning.com/docs/tulare/documents.htm (Accessed 2006-2007).

Naiman, R. J., H. DeCamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications **3**:209-212.

Neal, D. L. 1980. Blue oak-digger pine Pages 126-127 in F. H. Eyre, editor. Forest cover types of the United States and Canada. Soc. Amer. Foresters, Washington, D.C.

Odell, E. A., and R. L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. Conservation Biology **15**:1143-1150.

Owen, J. G. 1990. Patterns of mammalian species richness in relation to temperature, productivity, and variance in elevation. Journal of Mammology **71**:1-13.

Pavlik, B. M., P. C. Muick, S. Johnson, and M. Popper 1991. Oaks of California. Cachuma Press and the California Oak Foundation, Los Olivos, CA.

Reichard, S. 2000. Hedera helix. Pages 212-216 in J.M Randall, C. Bossard, and M.C. Hoshoveksy, editors. Invasive plants of California wildlands. University of California Press, Berkeley, California, USA.

Resource Management Agency. Agenda Item February 7, 2006. County Staff Report

Ritter, L. V. 1998. Blue oak woodland. Page 4. California Wildlife Habitat Relationships System. California Department of Fish and Game, California Interagency Wildlife Task Group.

Roy, G. D., and J. L. Vankat. 1999. Reversal of human-induced vegetation changes in Sequoia National Park. Can. J. For. Res. **29**:399-412.

Rudzitis, G. 1999. Amenities increasingly draw people to the rural west. Rural Development Perspectives **14**:23-28.

Saving, S. C., and G. B. Greenwood. 2002. The potential impacts of development on wildlands in El Dorado County, California in R. B. Standiford, D. McCreary, and K. L. Purcell, editors. The Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, San Diego, CA.

Schonewald-Cox, C.M., S.M. Chambers, B. MacBryde, and W.L. Thomas. 1983. Genetics and conservation: A reference for managing wild animal and plan populations. Menlo Park, CA: The Benjamin/Cummins Publishing Co., Inc.

Shilling, F., E. Girvetz, C. Erichsen, B. Johnson, and P.C. Nichols. 2002. A guide to wildlands conservation in the greater Sierra Nevada bioregion. California Wilderness Coalition. Davis, CA. 201pp.

Sork, V. L., J. Bramble, and O. Sexton. 1993. Ecology of mast-fruiting in three species of North American deciduous oaks. Ecology **74**:528-541.

Sork, V. L., F. W. Davis, P. E. Smouse, V. J. Apsit, R. J. Dyer, J. F. Fernandez-M, and B. Kuhn. 2002. Pollen movement in declining populations of California valley oak, *Quercus lobata*: where have all the fathers gone? Molecular Ecology **11**:1657-1668.

Standiford, R. B., J. Klein, and B. Garrison. 1996. Sustainability of Sierra Nevada hardwood rangelands. in: Status of the Sierra Nevada: Volume III Sierra Nevada Ecosystem Project Report. Pages 637-680. UC Division of Agriculture and Natural Resources. Wildland Resources Center Report No. 38.

Standiford, R. B., N. K. McDougland, W. Frost, and R. Phillips. 1997. Factors influencing the probability of oak regeneration of southern Sierra Nevada woodlands in California. Madrono **44**:170-183.

Standiford, R.B. and T.A. Scott. 2001. Value of oak woodlands and open space on private property values in Southern California. Special issue - Investigación Agraria: Sistemas Y Recursos Forestales - Towards The New Forestlands Commercial and Environmental Benefits Accounting. Theories and Applications (P. Campos Palacin, ed.). 1: 137 - 152.

Stralberg, D., and B. Williams. 2001. Effects of residential development and landscape composition on the breeding birds of Placer County's foothill oak woodlands in R. B. Standiford, D. McCreary, and K. L. Purcell, editors. The Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, San Diego, CA.

State of California, Department of Finance, Population Projections by Race/Ethnicity for California and Its Counties 2000–2050, Sacramento, California, May 2004.

Swiecki, T. J., and E. Bernhardt. 1998. Understanding blue oak regeneration. Fremontia **26**:19-26.

Swiecki, T. J., and E. Bernhardt. 2001. Effects of fire on naturally occurring blue oak (*Quercus douglasii*) saplings in R. B. Standiford, D. McCreary, and K. L. Purcell, editors. Fifth Syposium on Oak Woodlands: Oaks in California's Changing Landscape. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, San Diego, CA.

Swiecki, T. J., E. A. Bernhardt, and C. Drake. 1993. Factors affecting blue oak sapling recruitment and regeneration. Pages 1-142. Prepared for: Strategic Planning Program, California Department of Forestry and Fire Protection, Contract 8CA17358.

Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and urban planning **39**:25-36.

Thuiller, W. 2003. BIOMOD - optimizing predictions of species distributions and projecting potential future shifts under global change. Global Change Biology **9**:1353.

Tulare County Annual Crop and Livestock Report. 2005. Gary W. Kunkel, Agricultural Commissioner/Sealer of Weights of Measures. Available from http://agcomm.co.tulare.ca.us/pdf/2005CropReport.pdf. (accessed March 2007).

Tyler, C.M., B. Kuhn, and F.W. Davis. 2006. Demography and recruitment limitations of three oak species in California. The Quarterly Review of Biology. **81**:2 (127-152)

Tyler, C.M., B.E. Mahall, F.W. Davis, and M. Hall. 2002. Factors limiting recruitment in valley and coast live oak. In: Standiford, R.B., McCreary, D., Purcell, K.L., tech. coord. Proceedings of the fifth symposium on oak woodlands: Oaks in California's changing landscape. Gen. Tech. Rep. PSW-GTR-184. Albany, CA: Pacific Southwest Research Station, USDA Forest Service, pp 565-572.

U.S. Census Bureau. TIGER Census. Geography Division.

U.S. Census Bureau. 2007. State & County QuickFacts. U.S. Census Bureau. Available from http://quickfacts.census.gov/qfd/index.html. (accessed March 2007).

University of California; SNEP Science Team and Special Consultants. 1996. People and Resource Use in Status of the Sierra Nevada: Sierra Nevada Ecosystems Project Final Report to Congress. SNEP Vol 1 Chapter 2. Regents of the University of California.

Valley Voice. September 2005. Green Light For Boswell's Yokohl Study Expected. Available from http://www.valleyvoicenewspaper.com/vvarc/2005/september212005.htm (accessed March 2007).

Verner, J., and A. S. Boss. 1980. California wildlife and their habitats: western Sierra Nevada. Page 439. Gen. Tech. Rep. PSW-37. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

Viers, J. H., J. H. Thorne, and J. F. Quinn. 2006. CalJep: A spatial distribution database of CalFlora and Jepson plant species. San Francisco Estuary & Watershed Science **4**:1-18.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology **66**:1211-1214.

Zhao, S., and J. Fang. 2006. Patterns of species richness for vascular plants in China's nature reserves. Diversity and Distributions **12**:364-372.

Appendices

Appendix I: Conserving the Blue Oak Woodland Community

Rare, threatened, and endangered (RTE) species, landscape species, and whole communities can be important drivers for conservation, can act as targets for management objectives, or can simply be concerns in managing lands for multiple uses. In this conservation plan for blue oak woodland, we consider blue oak woodland species as a criteria in our multi-criteria analysis (Part I), and as targets for conservation planners making decisions on the local level. In this section, we provide information on species of importance in blue oak woodland and explore RTE species in the region. We then explore several wide-ranging species that can be used in determining appropriate reserve sizes for conserving blue oak woodland, given different management objectives. While the models used in Parts I and II of this report are at the scale of Calwater planning watersheds, conservation organizations often purchase or protect smaller parcels; thus, the wildlife information we provide here will assist managers in fine-scale conservation.

Background

Our group explored RTE species in blue oak woodland primarily through two commonly-used biological tools: the California Wildlife Habitat Relationship (WHR) System, which provides species ranges based on habitat association; and the California Natural Diversity Database (CNDDB), which provides data for actual occurrences of species. Each of these tools provides a different set of species data—one theoretical, and one actual.

California Wildlife Habitat Relationship System

The California WHR system is a matrix model developed by the California Interagency Wildlife Task Group (CIWTG) to predict wildlife habitat relationships for 675 terrestrial vertebrates in California. It is now a standard tool utilized by California's natural resource managers, and a required component of some harvest plans in the state (CDF&G 2005). We use the WHR system to predict what species would be present in Tulare County blue oak woodland and blue oak-foothill pine habitats, determine the state and federal status of these species, and create a list of priority species that could be found within conservation priority areas in the Tulare County foothills.

California Natural Diversity Database

The CNDDB is the only comprehensive database recording occurrences of RTE plant and animal species state-wide. Occurrences are submitted to the CNDDB by scientists, consultants, and hobbyists around the state and CNDDB staff review these submittals before adding them to current lists and GIS maps—there is no systematic survey of species for CNDDB.

CNDDB is commonly used by researchers, public agencies and conservation organizations to determine approximate locations of target species. The database lists and ranks species according to rarity; conservation efforts often focus on G1/T1, G2/T2, and G3/T3 species. These are defined as having "less than 6 known viable occurrences, 1,000 individuals, or 2,000 acres," "6 – 20 known occurrences, 1,000 – 3,000 individuals, or 2,000 – 10,000 acres," and "21 – 100 known occurrences, 3,000 – 10,000 individuals, or 10,000 – 50,000 acres," respectively (Meyer *et al.* 1999).

Pros and cons of WHR and CNDDB

There are pros and cons to using either the WHR System or CNDDB to determine target species in a specific area. For example, while CNDDB data may indicate where a species has been seen, it does not account for any movement of that species. Additionally, CNDDB is limited by the fact that it depends on personal sightings of species, instead of comprehensive surveys. On the contrary, the WHR System depends only on species-habitat relationship modeling, and does not account for actual sightings, meaning it only represents the potential for a species to occur in a given location. The WHR System also has the limitation that it provides information on vertebrate species only, whereas CNDDB provides occurrences for vertebrate, invertebrate, and plant species.

While both WHR and CNDDB have their limitations, the two provide complementary information, and can be used together to create a robust list of RTE species in blue oak woodland.

Description of blue oak woodland

According to the California WHR System, blue oak woodland is generally composed of 85 – 100% blue oak, ranging from 5 – 15 m (16 – 50 ft) in height, and an understory of annual grasses, such as brome grass, wild oats, foxtail, needlegrass, filaree, and fiddleneck. The trees often form a relatively closed canopy when found on good quality sites, and can also be found with some shrubs including poison-oak, California coffeeberry, buckbrush, redberry, California buckeye, and Manzanita spp. The habitat type is typically found in shallow, rocky, infertile, and well-drained soils (CDF&G 2005).

Blue oaks are well adapted to dry climates and the trees have an atypical tolerance of severe drought, even shedding their leaves during times of intense water stress. Because of this high tolerance, they compete most successfully with other tree species in drier areas (McDonald 1985). Tree species associated with blue oak woodland in the Sierra Nevada include interior live oak, and valley oak where deep soil has formed. At higher elevations blue oak woodland also intergrades with blue oak-foothill pine (CDF&G 2005).

Biodiversity within blue oak woodland can be very high, and includes approximately 10 mammals, 57 bird species, and 29 species of amphibians and reptiles (Verner and Boss 1980). The WHR System stresses the importance of some of these species for blue oak recruitment. Scrub jays, yellow-billed magpies, western gray squirrels, and California ground squirrels collect and bury acorns, assisting in the regeneration of blue oaks (CDF&G 2005).

Description of blue oak-foothill pine
According to the California WHR System, this habitat type is a mix of hardwoods and conifers, dominated by blue oak and foothill pine, respectively. Blue oak is often the most abundant tree species, though when foothill pine dominates, the blue oaks tend to die off due to an intolerance of shade. The habitat type is found at elevations between 150 and 915 m, in the foothills encircling California's Central Valley. Most stands of this habitat type are currently in mature stages, with canopies ranging 10 – 59% at heights around 15 m for the oaks, and 30 m for the pines. This habitat type also includes a variety of shrubs and an understory of annual grasses. In the foothills of Tulare County, other trees associated with blue oak-foothill pine include coast live oak, interior live oak, and California buckeye. Interior live oak can even sometimes dominate the overstory of blue oak-foothill pine in rocky areas or on north-facing slopes at higher elevations (Neal 1980). Associated shrub species include California coffeeberry, California redbud, California yerba-santa, Ceanothus spp., blue elder, mariposa Manzanita, Parry Manzanita redberry, whiteleaf Manzanita, poison-oak, silver lupine, and rock gooseberry (CDF&G 2005).

Methods

California Wildlife Habitat Relationship System
The California WHR system provides the likelihood of a species being found in a specific habitat based on the suitability of that habitat for three criteria: reproduction, cover, and feeding. In the WHR system, a user can input locations, habitat types, and species groups to determine species likely to be found within a specific habitat.

For our conservation plan for blue oak woodland, we limited our analysis to Tulare County and conducted general queries for both blue oak woodland and blue oak-foothill pine habitats. We identified only those species most highly dependent on blue oak woodland and/or blue oak-foothill pine, and thus searched for only those species for which blue oak woodland or blue oak-foothill pine is "highly suitable habitat" for all three criteria. Given that we do not have data for stand structure of blue oak woodland or blue oak-foothill pine in Tulare County, we looked at all stages of blue oak woodland and blue oak-foothill pine habitat. We did not exclude any elements from our query, selected all species included in the WHR System for consideration, and selected all Special Status categories except for Harvest species (meaning WHR would disregard any species with the sole status of Harvest, while it returned species that had other statuses including Harvest). We also selected all seasons and all locations for consideration. We then generated a table of species resulting from this general query (Table A1).

California Natural Diversity Database
Using CNDDB data in GIS, we investigated vertebrate, invertebrate, and plant species actually observed in blue oak woodland and blue oak-foothill pine in Tulare County. Using the same Calwater planning watersheds that we used for the multi-criteria analysis, we generated a table of all species that were recorded as one or more occurrence in CNDDB (Table A2). Additionally, we looked at CNDDB species found within only the six priority areas that we selected in our multi-criteria analysis, and highlighted these species within Table A2.

Lastly, we make some recommendations of priority species from our tables generated with CA WHR and CNDDB (A1 and A2, respectively), to be used in finer-scale conservation efforts.

Results

California Wildlife Habitat Relationship System
Using the general query approach described above, we were able to generate a list of sensitive vertebrate species (Table A1) that possibly occur within Tulare County blue oak woodland and blue oak-foothill pine. These include 4 reptiles, 4 amphibians, 11 mammals, and 25 birds. In general, the species are the same in the two habitat types, except for a few, for which only one habitat was suitable.

Table A1: RTE species in blue oak woodland and blue oak-foothill pine as determined by CA WHR.

Scientific name	Common name	Status	Habitat*
		Reptiles	
Emys marmorata	Western pond turtle	CA Species of Special Concern, BLM Sensitive, USFS Sensitive	BOW, and BO-FP
Eumeces skiltonianus	Western skink	Species of Special Concern, BLM Sensitive	BOW, and BO-FP
Pituophis catenifer	Gopher snake	Species of Special Concern	BOW, and BO-FP
Diadophis punctatus	Ring-necked snake	USFS Sensitive	BO-FP only
		Amphibians	
Taricha torosa	California newt	CA Species of Special Concern	BOW, and BO-FP
Ensatina eschscholtzii	Ensatina	CA Species of Special Concern, BLM Sensitive, USFS Sensitive	BOW, and BO-FP
Batrachoseps relictus	Relictual slender salamander	CA Species of Special Concern, USFS Species of Special Concern	BOW, and BO-FP
Ambystoma californiense	California tiger salamander	Federal Threatened, California Species of Special Concern	BO-FP only
		Mammals	
Myotis thysanodes	Fringed myotis	BLM Sensitive	BOW, and BO-FP
Lepus californicus	Black-tailed jackrabbit	CA Species of Special Concern, Harvest	BOW, and BO-FP
Glaucomys sabrinus	Northern flying squirrel	CA Species of Special Concern, USFS Sensitive	BOW, and BO-FP

Chaetodipus californicus	California pocket mouse	CA Species of Special Concern	BOW, and BO-FP
Bassariscus astutus	Ringtail	California Fully Protected	BOW, and BO-FP
Taxidea taxus	American badger	CA Species of Special Concern, Harvest	BOW, and BO-FP
Myotis yumanensis	Yuma myotis	BLM Sensitive	BOW only
Antrozous pallidus	Pallid bat	CA Species of Special Concern, BLM Sensitive, USFS Sensitive	BOW only
Perognathus inomatus	San Joaquin pocket mouse	CA Species of Special Concern, BLM Sensitive	BOW only
Puma concolor	Mountain lion	California Species of Special Concern	BOW only
Sylvilagus bachmani	Brush rabbit	Federal Endangered, California Endangered, Harvest	Bo-FP only
		Birds	
Ardea Herodias	Great blue heron	CDF Sensitive	BOW, and BO-FP
Ardea alba	Great egret	CDF Sensitive	BOW, and BO-FP
Gymnogyps californianus	California condor	Federal Endangered, California Endangered, California Fully Protected, CDF Sensitive	BOW, and BO-FP
Elanus leucurus	White-tailed kite	California Fully Protected	BOW, and BO-FP
Accipiter striatus	Sharp-shinned hawk	California Species of Special Concern	BOW, and BO-FP
Accipiter cooperii	Cooper's hawk	California Species of Special Concern	BOW, and BO-FP
Buteo swainsoni	Swainson's hawk	California Threatened	BOW, and BO-FP
Buteo regalis	Ferruginous hawk	California Species of Special Concern, BLM Sensitive	BOW, and BO-FP
Aquila chrysaetos	Golden eagle	California Fully Protected, California Species of Special Concern, BLM Sensitive, CDF Sensitive	BOW, and BO-FP
Falco columbarius	Merlin	California Species of Special Concern	BOW, and BO-FP
Falco peregrinus	Peregrine falcon	California Endangered, California Fully Protected, USFS Sensitive, CDF Sensitive	BOW, and BO-FP
Falco mexicanus	Prairie falcon	California Species of Special Concern	BOW, and BO-FP
Athene cunicularia	Burrowing owl	California Species of Special Concern, BLM Sensitive	BOW, and BO-FP
Asio otus	Long-eared owl	California Species of Special Concern	BOW, and BO-FP
Eremophila alpestris	Horned lark	California Species of Special Concern	BOW, and BO-FP
Progne subis	Purple martin	California Species of Special Concern	BOW, and BO-FP
Aphelocoma californica	Western scrub-jay	California Species of Special Concern	BOW, and BO-FP
Lanius ludovicianus	Loggerhead shrike	Federal Endangered, California Species of Special Concern	BOW, and BO-FP
Dendroica petechia	Yellow warbler	California Species of Special Concern	BOW, and BO-FP

Pipilo maculates	Spotted towhee	California Species of Special Concern	BOW, and BO-FP
Pipilo crissalis	California towhee	Federal Threatened, California Endangered	BOW, and BO-FP
Passerculus sandwichensis	Savannah sparrow	California Endangered, California Species of Special Concern	BOW, and BO-FP
Junco hyemalis	Dark-eyed junco	California Species of Special Concern	BOW, and BO-FP
Nycticorax nycticorax	Black-crowned night heron	BLM Sensitive	BOW only
Strix occidentalis	Spotted owl	Federal Threatened, California Species of Special Concern, BLM Sensitive, USFS Sensitive, CDF Sensitive	BO-FP only

*BOW = blue oak woodland. BO-FP = blue oak-foothill pine.

California Natural Diversity Database

In CNDDB, we found 54 vertebrate, invertebrate, and plant species in the Calwater planning watersheds of Tulare County blue oak woodland and blue oak-foothill pine. Table A2 is a list of all these species, which were identified as one or more occurrence in CNDDB. Highlighted within this table are those species that occurred within our six selected conservation priority areas.

Table A2: List of all CNDDB species found within the Calwater planning watersheds of Tulare County blue oak woodland and blue oak-foothill pine (sorted by global rarity—GRANK). (Grey highlights indicate species found within our six conservation priority areas.)

Scientific name	Common name	Federal list	California list	Global distribution*
Central Valley Drainage Hardhead/Squawfish Stream	Central Valley Drainage Hardhead/Squawfish Stream	None	None	G?
Gymnogyps californianus	California condor	Endangered	Endangered	G1
Sidalcea keckii	Keck's checkerbloom	Endangered	None	G1
Helminthoglypta callistoderma	Kern shoulderband	None	None	G1
Batrachoseps regius	Kings River slender salamander	None	None	G1
Navarretia setiloba	Piute Mountains navarretia	None	None	G1
Calochortus westonii	Shirley Meadows star-tulip	None	None	G1
Clarkia springvillensis	Springville clarkia	Threatened	Endangered	G1
Sycamore Alluvial Woodland	Sycamore Alluvial Woodland	None	None	G1
Calicina cloughensis	(No common name)	None	None	G1
Leptosiphon serrulatus	Madera leptosiphon	None	None	G1?
Lytta morrisoni	Morrison's blister beetle	None	None	G1G2
Talanites moodyae	(No common name)	None	None	G1G2
Mimulus pictus	Calico monkeyflower	None	None	G2
Githopsis tenella	Delicate bluecup	None	None	G2
Fritillaria brandegeei	Greenhorn fritillary	None	None	G2
Brodiaea insignis	Kaweah brodiaea	None	Endangered	G2

Mimulus norrisii	Kaweah monkeyflower	None	None	G2
Delphinium purpusii	Kern County larkspur	None	None	G2
Lytta molesta	Molestan blister beetle	None	None	G2
Iris munzii	Munz' iris	None	None	G2
Delphinium recurvatum	Recurved larkspur	None	None	G2
Pseudobahia peirsonii	San Joaquin adobe sunburst	Threatened	Endangered	G2
Orcuttia inaequalis	San Joaquin Valley orcutt grass	Threatened	Endangered	G2
Ribes tularense	Sequoia gooseberry	None	None	G2
Eryngium spinosepalum	Spiny-sepaled button-celery	None	None	G2
Fritillaria striata	Striped adobe-lily	None	Threatened	G2
Ambystoma californiense	California tiger salamander	Threatened	None	G2G3
Big Tree Forest	Big Tree Forest	None	None	G3
Bruchia bolanderi	Bolander's bruchia	None	None	G3
Rana boylii	Foothill yellow-legged frog	None	None	G3
Branchinecta lynchi	Vernal pool fairy shrimp	Threatened	None	G3
Spea (=Scaphiopus) hammondii	Western spadefoot	None	None	G3
Emys (=Clemmys) marmorata	Western pond turtle	None	None	G3G4
Desmocerus californicus dimorphus	Valley elderberry longhorn beetle	Threatened	None	G3T2
Cypseloides niger	Black swift	None	None	G4
Gulo gulo	California wolverine	None	Threatened	G4
Myotis thysanodes	Fringed myotis	None	None	G4G5
Ribes menziesii var. ixoderme	Aromatic canyon gooseberry	None	None	G4T2
Vulpes macrotis mutica	San Joaquin kit fox	Endangered	Threatened	G4T2T3
Taxidea taxus	American badger	None	None	G5
Accipiter cooperii	Cooper's hawk	None	None	G5
Juncus nodosus	Knotted rush	None	None	G5
Myotis evotis	Long-eared myotis	None	None	G5
Accipiter gentilis	Northern goshawk	None	None	G5
Martes pennanti (pacifica) DPS	Pacific fisher	Candidate	None	G5
Antrozous pallidus	Pallid bat	None	None	G5
Myotis ciliolabrum	Western small-footed myotis	None	None	G5
Empidonax traillii	Willow flycatcher	None	Endangered	G5
Erigeron inornatus var. keilii	Keil's daisy	None	None	G5T1
Eriogonum nudum var. murinum	Mouse buckwheat	None	None	G5T2
Galium angustifolium ssp. Onycense	Onyx Peak bedstraw	None	None	G5T2
Dudleya cymosa ssp. costafolia	Pierpoint Springs dudleya	None	None	G5T2
Eumops perotis californicus	Western mastiff bat	None	None	G5T4

*A lower G value indicates less abundance/fewer occurrences. T = subspecies distribution.

Discussion

The species lists generated with both the WHR System and CNDDB are provided primarily to guide decision-making on the fine scale of local conservation projects in the foothills of Tulare County. They can be used as-is when considering land purchases and management decisions, or can be further reduced to target a succinct number of species that may be under the most threat.

For an example, one succinct list of species can be generated by targeting species listed as endangered or threatened on the federal or state levels, as in Table A3.

Table A3: Threatened/endangered species in Tulare County blue oak woodland/blue oak-foothill pine.

Scientific name	Common name	Federal list	California list
Ambystoma californiense	California tiger salamander	Threatened	
Branchinecta lynchi	vernal pool fairy shrimp	Threatened	
Brodiaea insignis	Kaweah brodiaea		Endangered
Buteo swainsoni	Swainson’s hawk		Threatened
Clarkia springvillensis	Springville clarkia	Threatened	Endangered
Desmocerus californicus dimorphus	valley elderberry longhorn beetle	Threatened	
Empidonax traillii	willow flycatcher		Endangered
Falco peregrinus	Peregrine falcon		Endangered
Fritillaria striata	striped adobe-lily		Threatened
Gulo gulo	California wolverine		Threatened
Gymnogyps californianus	California condor	Endangered	Endangered
Lanius ludovicianus	Loggerhead shrike	Endangered	
Orcuttia inaequalis	San Joaquin Valley orcutt grass	Threatened	Endangered
Passerculus sandwichensis	Savannah sparrow		Endangered
Pipilo crissalis	California towhee	Threatened	Endangered
Pseudobahia peirsonii	San Joaquin adobe sunburst	Threatened	Endangered
Sidalcea keckii	Keck's checkerbloom	Endangered	
Strix occidentalis	Spotted owl	Threatened	
Sylvilagus bachmani	Brush rabbit	Endangered	Endangered
Vulpes macrotis mutica	San Joaquin kit fox	Endangered	Threatened

Appendix II: Selecting Appropriate Reserve Size

One of the original goals for our conservation planning project was to recommend a minimum reserve size for maintaining blue oak woodland and the communities that depend on this habitat. We approach this problem from a species perspective. In this section, we explore the home-range size of several species that we found to be residents or transients in blue oak woodland or blue oak-foothill pine.

Background

When conducting conservation projects, it is often difficult to determine the appropriate size of land to conserve. Reserve size depends on the species present, the home range of the species, and the disturbance regimes of the given habitat (D. Cameron, personal communication 2007). The role of disturbance in blue oak woodland is a difficult and controversial subject, however, while information on species is generally available, allowing for a broad exploration of reserve size.

We decided that large-ranging species would be the most appropriate for designing reserves in Tulare County blue oak woodland as it would allow for the conservation of large areas encompassing a diversity of other, smaller, more specialized species. Conserving lands based on the range of the larger predators in the region is also a viable approach as these predators are often keystone species—they have a large impact on the landscape, compared to their actual population size. Thus, conservation of these species may play an important role in the health of the habitat and ecosystem.

Three large-ranging species that utilize blue oak woodland or blue oak-foothill pine for the WHR criteria of reproduction, cover, and feeding include mountain lion, coyote, and black bear. Here we analyze the area requirements of these species, as well as look briefly at other keystones species, such as American badger and some birds and small mammals that play a large role in blue oak regeneration. We then explore a tiered approach for conserving lands, based on the different requirements of these species and given specific conservation goals.

Species area requirements

Mountain lion (*Felis concolor*)
According to the WHR System, various stages of blue oak woodland habitat are of low to medium suitability for this species, and various stages of blue oak-foothill pine are of low to high suitability. Mountain lion is a California Species of Special Concern (CDF&G 2005).

The WHR System indicates that the minimum home range of a male mountain lion is 40 km^2 (9,884 acres). The home range for females is a bit smaller at 8 – 32 km^2, and WHR indicates that these ranges, for both males and females, can be considerably larger.

Additionally, much of the range requirements of mountain lion will depend on food resources, primarily mule deer, which make up 60 – 80% of a mountain lion's diet year-round (CDF&G 2005); blue oak woodland has an abundance of such resources (D. Cameron, personal communication 2007). The home ranges of female mountain lions may overlap with the ranges of other females or males, but females with young will usually occupy distinct areas. Male mountain lions will usually occupy distinct areas, but are tolerant of both male and female transients (CDF&G 2005).

Black bear (*Ursus americanus*)
Black bear is not a blue oak woodland specialist, but its range does include the Sierra Nevada foothills. WHR does not have habitat suitability data for black bear in blue oak woodland, but it shows low, medium, and high habitat suitability for black bear for various stages of blue oak-foothill pine habitat (CDF&G 2005). In general, the species remains at higher elevations within public lands, including the national forests and Sequoia National Park. Blue oak woodland habitat does, however, provide important food in the form of acorns, which are an important mast food for the bears to fatten-up on for the winter (H. Werner, personal communication 2006). Black bear is not a species of special concern (CDF&G 2005).

The WHR System indicates that the average home range of a male black bear (studied in northwestern California) is 10.6 km^2 (2,619 acres). The home range for females is smaller, averaging around 3.6 km^2 in the same study area. Home range size varies considerably by region, from 10.6 km^2 in northwestern California to 51.5 km^2 in western Washington, for males, and from 3.6 km^2 in northwestern California to 5.3 km^2 in western Washington, for females (CDF&G 2005).

Coyote (*Canis latrans*)
Like mountain lion and black bear, coyote is not a blue oak woodland specialist, and coyote is even more wide-spread than either of the previous species. WHR shows low, medium, and high habitat suitability for coyote for various stages of blue oak woodland and blue oak-foothill pine habitat. Coyote is not a species of special concern (CDF&G 2005).

The WHR System indicates that the average home range of a male coyote in Sierra County varies from 10 km^2 (2,471 acres) to 100 km^2 (24,711 acres). The ranges of males tend to overlap, while those of the females do not (CDF&G 2005).

Other keystone species
In addition to large-ranging species, there are other species in blue oak woodland that act as keystone species. These include American badger, as well as western scrub jay, yellow-billed magpie, western gray squirrel, and California ground squirrel, which play an important role in "planting" blue oak acorns, and thus assisting with blue oak woodland regeneration (CDF&G 2005). All these species have much smaller ranges than the landscape species above, however—maximum 1,500 acres for American badger; around

100 acres for yellow-billed magpie, western gray squirrel, and California ground squirrel (CDF&G 2005).

Discussion

Analyzing the home range requirements for large-ranging and other keystone species can lead to a tiered approach to determining reserve size.

Using mountain lion may lead to the conclusion that an appropriate reserve size for blue oak woodland is greater than 10,000 acres. This would allow for on average only one mountain lion to reside in the reserve, however; thus, when considering mountain lion, conservation planners would have to seriously consider the connectivity between viable habitats. To maintain connectivity we thus recommend conservation organizations prioritize acquisition of land adjacent to public lands.

Looking at black bear, we could recommend a reserve size of approximately 2,600 acres, a much smaller area than estimated using mountain lion, but a more reasonable area for conservation through easements and land purchases. Moreover, this size area is likely to conserve most of the other species of the blue oak woodland community, besides mountain lion. If enough connectivity is preserved, especially with public lands, it might even be possibly to maintain some viable habitat for mountain lion as well. The results for coyote are similar to those of black bear, with a minimum reserve size of around 2,500 acres.

The lowest tier, targeting the smaller keystone species, would entail again smaller land purchases. Conservation of these species would at least preserve adequate habitat for smaller species, and could also preserve regenerative woodland and a food source for the larger predators. With this food source these predators may even manage to survive in the habitat given adequate connectivity with surrounding public lands. On this lowest level, land protection should be approached with the understanding that the just the persistence of smaller species and blue oaks themselves is likely, rather than the complete blue oak woodland community.

Appendix III: Managing Blue Oak Woodland

Our analyses in this report have assumed that blue oaks are regenerating successfully. Unfortunately, there is much evidence to indicate that natural recruitment of oaks is insufficient to offset natural mortality. This section contains an overview of the evidence indicating poor recruitment and discusses possible causes for the lack of regeneration.

Background

In a review of studies on the demography and recruitment of California oak trees, Tyler *et al.* (2006) found that the majority of demography-related research focused on blue oaks. Absence of blue oak saplings and seedlings has been noted throughout much of the species' range (Bartolome *et al. 2001*; Bolsinger 1988; McClaran 1983). This evidence, however, tends to be contradictory and site specific (Tyler *et al.* 2006). Mensing (1992) used stand age analysis to reconstruct former patterns of blue oak regeneration and recruitment in three blue oak woodlands on the Tejon Ranch, Kern County. Analysis of 279 cross-sections showed that over half of all stems sampled were recruited in 1856; prior to this date, recruitment was fairly continuous. Only 3% of the stems were recruited in the last 150 years. Swiecki and Bernhardt (1998) surveyed blue oak woodland at 15 locations; they found mortality at all 15 locations, but sapling recruitment at only 11. Tree core samples taken in Tulare County in the early 1980s indicate that blue oak establishment had been lacking in that county for at least 60 years (Baker *et al.* 1981; McClaran 1983). Other studies, however, suggest that there may be areas in which recruitment is occurring at a healthy rate. In their assessment of change in California's hardwood rangeland between 1991 and 1996, Fisher and Levin (2001) detected evidence of regeneration in 10 of the 14 counties they surveyed. Other studies have been less conclusive regarding regeneration problems over large areas. Davis *et al.* (1995) used aerial photographs to compare foothill woodland cover in 1940 and 1988; they found that changes in cover varied in sites and regions, but that decreases in tree cover in some places were offset by increases in others. Large changes were recorded at individual sites, but the mean cover over the entire study region remained virtually unchanged. This may be because even rare recruitment is sufficient to offset low rates of mortality of overstory individuals.

The causes of poor regeneration are varied and often site specific. Grazing, fragmentation, altered disturbance regimes, and invasive species are the most popular culprits. Below, we address each of these threats, and offer land management strategies that may encourage blue oak regeneration.

Factors affecting blue oak regeneration

Grazing

Opinion regarding the effects of grazing on oak survival and recruitment is mixed. Some studies argue that grazing is the principal factor in poor oak regeneration. The observed decline in regeneration roughly coincides with the widespread introduction of livestock into California in the late 18th and early 19th centuries (McCreary & George 2005). Cattle eat acorns, compact soil, and reduce organic material, thereby reducing the potential for initial seedling establishment. Surviving seedlings are often browsed and trampled, which shortens the life of individual seedlings and can eventually destroy the seed bank or seedling root system (Swiecki & Bernhardt 1998). Standiford *et al.* (1997) surveyed stands of blue oak in the southern Sierra Nevada; they found livestock grazing to be negatively correlated with blue oak seedling presence. In Tulare County, McClaran (1983) found more recent establishment of blue oaks on ungrazed sites than on those that contained livestock. Other studies suggest that grazing does not play a significant role in oak regeneration, citing instances in which the removal of livestock did not result in an increase in oak recruitment (Callaway 1992).

Some research suggests that the season of grazing has a much greater effect on seedling survival than grazing intensity. Studies have found that cattle can cause heavy damage to emerging oaks in the spring and summer, but damage is significantly less during the winter, when deciduous oaks do not have leaves (McCreary & George 2005; Tyler *et al.* 2006; J. Ver Steeg, personal communication, July 2006). Ironically, cattle grazing may positively affect seedling emergence indirectly by reducing growth and density of competing vegetation. McCreary and George (2005) found that seedlings protected from grazing did better at grazed sites than ungrazed sites due to reduced competition and lower damage by voles. Tyler *et al.* (2002) found no difference in seedling emergence in grazed and ungrazed plots in Santa Barbara's Sedgwick Reserve, but observed indications of higher mortality in ungrazed plots, likely due to increased predation by small mammals. Regeneration may be best achieved if pastures are rested in the summer, grazing is kept to 10 – 20 acres per cow per year, and seedlings are protected by cages from grazing until they are at least 6.5 feet tall (McCreary & George 2005; McCreary & Tecklin 2005).

Fire

California oaks evolved in a Mediterranean climate where natural fires burned regularly. Prior to European settlement, fires burned on average every 30 – 50 years in savanna woodland and chaparral plant communities (Pavlik *et al.* 1991). In the latter half of the 19th century, fires burned even more frequently. Both Native Americans and early range managers used fire as a management tool. Frequent, low-intensity woodland burning would have killed brush and small trees, resulting in the creation and maintenance of cohorts of large trees (Mensing 1992; McCreary 2004c).

Since the early part of the 20th century, fires have been suppressed in California. This has resulted in an accumulation of fuels, higher tree density, and a significant increase in downed material, creating ladder fuels and contributing to high-intensity crown fires. Oaks have evolved mechanisms to survive periodic burning and suffer little long-term damage from the burning of their foliage. Even oaks that have been girdled, losing the aboveground portion of the tree, will often sprout from their base the following year (McCreary 2004c).

Nevertheless, recent studies indicate that fire may do more harm than good. Some studies have linked past fire events with periods of high recruitment. These early associations between fire and blue oak regeneration may be due to the removal of older stems by fire and establishment of even-aged stems from the re-sprouting of pre-existing oaks (Tyler *et al.* 2006). It appears that fire can slow the advancement of small saplings to the understory. Although topkilled saplings show high rates of growth immediately after a fire, these fast growth rates are not sustained over time. It takes several years for topkilled saplings to regain their pre-burned aboveground biomass, during which time saplings are highly vulnerable to voles, vertebrates, and additional fires (Swiecki & Bernhardt 2001). Other studies comparing the effect of fire on regeneration have found no evidence that fire stimulates regeneration (Roy & Vankat 1999; Bartolome *et al.* 2001).

Invasive species

The pre-European oak woodland herbaceous community consisted primarily of native perennial bunchgrasses, including purple needlegrass (*Nasella pulchra*), blue wildrye (*Elymus glaucus*), California brome (*Bromus carinatus*), California melic (*Melica californica*), prairie junegrass (*Koeleria macrantha*), and California oatgrass (*Danthonia californica*), perennial forbs, and various legumes (Standiford *et al.* 1996). Early European settlers brought with them invasive annual grasses, displacing the native species. By the late 19^{th} century, woodland understories were dominated by invasive annual grasses (Holmes & Rice 1996; Standiford *et al.* 1996; Bartolome *et al.* 2001).

Annual grasses use water differently than native perennials. Exotic annuals grow rapidly in the winter, completing their life cycle by early summer. Annuals also grow dense, shallow roots, quickly depleting surface soil layers of water. Native grasses (mostly bunchgrass perennials) grow more slowly than annuals and allocate most of their energy to the production of a deep root system, which allows them to access water well into the dry season (Holmes & Rice 1996). It is thought that exotic annuals deplete surface soil water early in the growing season, which leaves emerging oak seedlings with less water; in contrast, oak seedlings growing with native perennials have access to soil moisture long into the summer (Tyler *et al.* 2006). Oak seedling growth, gas exchange rates, and survivorship are negatively correlated with the rate and extent of soil water depletion. A study done by Gordon and Rice (2000) found reduced recruitment of oak seedlings coincident with the replacement of native perennial herbaceous vegetation by exotic annuals.

There is some evidence that long-term protection from grazing may encourage the regrowth of native perennial bunchgrasses. A Hopland Field Station study looking at woodland and grassland plots excluded from grazing in 1957 found an increase in the density of perennials at both sites in 1991 (Hatch *et al.* 1992). There is a trade-off, however; a short-term release from grazing may also hamper regeneration due to increased competition from annual grasses.

Swiecki and Bernhardt's hypothesis
Swiecki and Bernhardt (1998) offer an alternative explanation for poor oak regeneration. In their 1998 paper, *Understanding Blue Oak Regeneration*, they explain that oak species produce seed crops that vary widely from year to year. Most acorns land under the parent tree, but some are planted at a distance by acorn-eating animals. No long-term oak seed banks exist because acorns do not survive from year to year. Instead of seed bank regeneration, most oaks sprout from a bank of persistent seedlings beneath the canopy of the parent tree, which is called "advance regeneration." Understory seedlings are suppressed by competition from the overstory; nevertheless, the seedlings may survive for a few years, producing a strong root system but little shoot growth. Shoots of persistent seedlings may periodically die back to the ground, but energy reserves in the taproot make it possible for seedlings to resprout from the root crown following shoot loss. Death or removal of overstory canopy releases these seedlings, which respond with rapid shoot growth and a pulse of regeneration. Swiecki and Bernhardt (1998) suggest that historic pulses of blue oak regeneration can be explained as the release of established advance regeneration.

Between 1850 and the mid-20th century, large areas of blue oak were cut and burned. Although many stands were obliterated during this period, blue oak rebounded throughout most of its range. Once released from overstory competition, established blue oak seedlings have strong resprouting ability and are not easily eradicated; this ability allows blue oaks to survive short-lived attempts at agriculture and routine wood harvesting.

Persistent seedlings do not, however, survive and resprout indefinitely. Seedlings that died back to the shoot base two years in a row had a mortality rate four times that of seedlings whose shoots persisted over the same two years. Seedling persistence can be affected by abiotic characteristics, like microclimate, or shoot-destroying disturbances like fire and grazing. According to Swiecki and Bernhardt (1998), a narrow window of opportunity exists for sapling recruitment after the death or removal of the overstory tree. Advance regeneration must be adequate before canopy loss, and then allowed to grow after canopy loss. If the production, survival, and release of advance regeneration is inhibited or destroyed by poor land management, overstory mortality will result in stable openings that causes the stand to thin, eventually to the point of extinction.

Management of rangelands changed in the 1940s. Ranchers began to use heavy equipment and herbicides to more efficiently eradicate all woody vegetation, likely destroying the sources of blue oak advance regeneration. These practices often resulted in a permanent conversion to grassland. Tree felling and understory clearing, fire, livestock grazing, and the introduction of non-native grasses have altered the composition of the oak woodland ecosystem. Consequently, the environment in which blue oak advance regeneration must establish and persist may be vastly different from presettlement conditions. Unfortunately, there is no way to return this landscape to its original condition; we must therefore determine how to manage for regeneration under these altered circumstances (Swiecki & Bernhardt 1998).

Assessing stand regeneration
Age structure analysis has been used to assess stand regeneration. It is very difficult, however, to determine the age structure of a stand of oaks. It is generally true that the oldest oaks are large, and the youngest are small, but this is often not the case (Tyler *et al.* 2006). McClaran and Bartolome (1990) took cross sections and measured the diameter at breast height (DBH) of over 350 oaks in the Sierra foothills. They discovered only a weak correlation between the size and age of the sampled trees. Tyler *et al.* (2006) suggest using size class rather than age class to predict the potential for reproduction for a given population. Larger individuals are less vulnerable to fire, drought, and grazing, and tend to have lower mortality rates. Larger trees also tend to produce larger acorn crops. Populations with many large individuals may therefore have the best chance at long-term viability (Tyler *et al.* 2006).

Discussion

Grazing, invasive species, fragmentation, and altered disturbance regimes may all play a role in low levels of blue oak regeneration. Nevertheless, blue oaks should not be seen as a lost cause. Oaks can live for hundreds of years. Although there is very little information available on oak mortality, most research indicates that the natural rate of mortality is relatively low. Most oak species tend to produce acorn crops that vary from year to year. Patterns of acorn production are a response to both weather conditions and prior reproductive events. Mast fruiting events appear to operate on a two-year cycle for black oaks, while white and red oaks have three and four year cycles, respectively (Sork *et al.* 1993). A fortuitous climatic cycle coinciding with a mast fruiting event could produce enough seedlings to ensure the survival of another generation of oaks. Nevertheless, if mortality in a given stand is exceeding recruitment, it may take a century to functionally replace the individuals lost. Conservation should therefore be pursued before populations decline to an irreplaceable level (Tyler *et al.* 2006).

Appendix IV: Tulare County General Plan Synopsis

Tulare County is currently updating its General Plan, a process that began in summer of 2003 and is scheduled to conclude summer 2007. An environmental impact report (EIR) is underway and will be completed prior to the adoption of the General Plan. All mitigation measures recommended to reduce the potential environmental impacts of the General Plan will be incorporated as policies and programs within the General Plan. Given the time constraints of our project, this section is an analysis of the most recent General Plan Draft, which was made available in December 2006. All data in this section are taken from this General Plan Draft, unless noted otherwise (Mintier & Associates 2006).

Tulare County demographics

For the past 100 years, Tulare County has been one of the most productive agricultural counties in the United States. Despite this, Tulare County's unemployment rate is much higher than the state average and the median household income remains significantly lower. Tulare County's primary goal, as stated in the General Plan, is to bring the county in-line with state employment and income growth averages. Tulare County is hoping to do this through the expansion and diversification of its agricultural economy. In the past 20 years, Tulare County has seen rapid growth in ethanol production, value-added food processing, and dairy production. Tulare County hopes to nurture these industries to serve as the economic base for the county.

Tulare County is experiencing rapid population growth. Between 2001 and 2005 the county's population grew from 368,021 to 410,874, a change of 11.6%. This growth rate is almost twice that of the rest of the state. Traditionally a rural, relatively obscure county, Tulare County is experiencing significant development pressure for the first time in its history. Tulare County's General Plan is therefore designed to accommodate the significant increase in population that is expected to occur over the next several decades.

Tulare County states in its General Plan that it intends to support the principles of smart growth by promoting mixed use development, encouraging infill, discouraging sprawl, and directing growth towards existing communities. The county also states that it will prevent incompatible uses, support compact development, and encourage the clustering of rural development.

City growth

Each of Tulare County's eight incorporated cities is surrounded by an urban development boundary (UDB), which delineates the area expected for urban growth over a 20-year period. Tulare County's 21 unincorporated communities and 13 hamlets also have designated development boundaries (DB), which divide the land to be developed from land to be protected for agricultural, natural, or rural uses, and serves as the official planning area for communities. Community and hamlet DBs also serve as 20-year growth boundaries to which services will likely be extended to accommodate new growth.

The General Plan policies state that development will only occur within the respective development boundaries and development corridors. There are, however, provisions within the General Plan that allow for the modification of both development boundaries and land use within those boundaries. UDBs will be reviewed by the county every five years, and requests for expansion can be applied for as part of a subdivision or specific plan proposal. These expansions will be considered if the city has demonstrated a need for additional land after documenting a good faith effort to implement an infill development program and minimize conversion of productive agricultural lands. Furthermore, if 80% of non-Williamson Act land within a UDB is developed, the county will look into expanding the UDB. The county will encourage the non-renewal of Williamson Act contracts for land within UDBs. Conversely, areas generally zoned for mixed-use or urban land uses may have portions that continue to be devoted to extensive agriculture where there are access constraints or where an inadequate amount of water or improper soils for wastewater disposal have been identified.

New towns
The General Plan states that the county will "discourage" the development of new towns. Nevertheless, the General Plan specifies criteria, most of which address economic concerns, which would need to be met for new town approval. The General Plan states that plans for new towns will be approved by the Board of Supervisors, should circumstances justify this development.

Agriculture
Tulare County agricultural production was valued at $4.3 billion in 2005, making it one of the most productive agricultural counties in the United States. The primary agricultural commodities in the county in 2005, based on gross value, were milk, oranges, cattle, grapes, and nut crops (Tulare County Annual Crop and Livestock Report 2005). In 2004, over 1.3 million acres of land in Tulare County were classified as "agricultural land" by the California Department of Conservation. Of this land, over 380,000 acres were classified as "Prime Farmland." However, due to conversion to development and other non-agricultural uses, both the amount of prime farmland and the amount of land under Williamson Act contract has been declining over the last 10 years.

Agriculture in Tulare County is guided primarily by the Rural Valley Lands Plan (RVLP). The RVLP contains policy to act as a guide to the Planning Commission and Board of Supervisors in determining appropriate minimum parcel sizes and areas where non-agricultural use exceptions may be allowed. This plan applies primarily to lands outside of UDBs and below and west of the 600-foot elevation contour line. Tulare County places high value on its agricultural resources and recognizes the effects of residential intrusion and checkerboard urbanization on the agricultural economy. The RVLP refers to a report prepared by the Ventura County Planning Department in 1970, which states that, from a property tax standpoint, agriculture is the only land use that pays for itself when industrial and commercial property is given a cost based on total urban expenditures by government.

Tulare County wants nonagricultural development to expand outward from existing communities in order to prevent fragmentation of agricultural lands and to keep service costs at a reasonable level. Where possible, Tulare County hopes to direct development to less desirable soils where conflicts with agriculture and impacts on future agricultural productivity will be minimized. The county uses a point system to determine the relative value of a parcel for agriculture. These points are based on soil classes, existing parcel size, suitability for cultivation, and surrounding land uses. This point system is used by planners to guide zoning in the San Joaquin Valley.

Foothill development

The foothill portion of the county covers about 675,641 acres between the Sierra Nevada and the valley floor. Land use and circulation patterns in the foothills are guided by the Foothill Growth Management Plan. There are two communities in the foothills, Three Rivers and Springville, each with their own community plan. There are two basic land use types identified in the Foothill section: agriculture and development.

The majority of the foothills are designated as "foothill agriculture." The minimum parcel size is 160 acres, although most properties are much larger, ranging into the tens of thousands of acres. The zoning for foothill agriculture allows for one dwelling unit every 80 acres and one additional unit every 40 acres, for employees or family members. Subdivision is generally discouraged by the county, but subdivision consideration is based on guidelines specified in the RVLP, which consider the viability of a given agricultural parcel if it is to be split.

Parts of the lower foothills, at the edges of the UDBs, are designated as "rural residential." This designation is designed to accommodate single-family dwellings and farm worker housing away from cities and communities. This area is zoned one dwelling every five acres if the slope is less than 30%, and one dwelling every ten acres if the slope is 30% or greater. A similar land designation, called "mountain residential," exists in the upper foothills. Density of one or two dwellings per acre is allowed on shallow slopes; one dwelling per 40 acres is allowed on slopes of 30% or greater.

Finally, the county has designated a 56,000-acre corridor as the "Foothill Development Corridor." The current draft of the General Plan has reassigned zoning in this corridor to be "foothill mixed use," which allows a maximum density of 15 units per acre. Uses typically allowed include residential dwellings, restaurants, retail establishments, and related service and industrial uses.

Water

Tulare County is located entirely within the Tulare Lake Basin, the closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed. The basin encompasses basins draining to Kern, Tulare, and Buena Vista Lakes. Demand for water within Tulare County is met from three major sources: groundwater, local streams and rivers, and imported surface water. The predominant water supply system providing service to the foothill and mountain regions of the county are individual systems.

The Department of Water Resources has estimated the groundwater overdraft by hydrologic region. For the Tulare Lake Basin, the total overdraft is estimated to be 820,000 acre-feet per year, the greatest overdraft projected in the state, and 56% of the statewide total overdraft. This overdraft is most pronounced along the western boundary of the county, as manifested by a lowering of pressure levels in the confined aquifers. There is also a progressive lowering of ground water levels along the easterly margins of the valley basin, particularly in the southern part of the Kern-Tulare Water District.

Tulare County's General Plan states that water supply systems must be adequate to serve the size and configuration of land developments. Furthermore, the county shall require separately-developed dwellings with individual water supplies to provide an acceptable guaranteed minimum supply of water for both fire safety and domestic needs. The county will also require a plan that describes safe and reliable methods of wastewater treatment and disposal before approving any project in the foothills. Minimum water requirements for projects will be determined by the Tulare County Health Department and the Fire Warden. A new implementation measure states that Tulare County will set up an ordinance to regulate the extraction and exportation of groundwater from the county.

Transportation

Tulare County is one of eight counties in the Central Valley that are part of the San Joaquin Valley Regional Blueprint Process, a program to enhance regional and local decision-making through local involvement. The goal is to assemble a blueprint that will suggest how to foster more efficient land use patterns. This program is supported by a $2 million grant from the State of California and a $500,000 matching grant from the San Joaquin Valley Pollution Control District. Each of the eight counties will receive about $325,000 to conduct their piece of the program.

The Tulare County Association of Governments (TCAG) is the agency responsible for overseeing and planning projects that transcend county boundaries, like roads and air quality. TCAG is currently updating the 2004 Regional Transportation Plan (RTP). The RTP is a 20-year planning document that is consistent with the Regional Transportation Improvement Program to qualify projects for the State Transportation Improvement Program. The most recent RTP was updated in 2001. The current RTP shows projects planned before 2025, including widening Highway 65 and parts of the Highway 99 corridor. The roads between Visalia and Tulare, and Dinuba and Goshen, will also be substantially expanded. Tulare County's General Plan identifies these areas as "regional growth corridors." Tulare County intends to develop a regional growth corridor plan, but pending the development and adoption of such a plan, the county may approve highway-oriented commercial industrial and mixed-use development within one-quarter mile of Highways 99 and 65.