Development of conceptual models and ecological baselines to support the creation of an adaptive management plan for Tejon Ranch, California

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

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March 2010

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The mission of the Bren School of Environmental Science and 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 principle 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 three-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:

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March 2010

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ABSTRACT

The Tejon Ranch Conservancy is developing a Ranch-Wide Management Plan (RWMP) with the goal of conserving and enhancing the natural heritage and biodiversity of Tejon Ranch in perpetuity. Our group project involved researching and collecting baseline information of the conditions on the Ranch and creating conceptual models for the major vegetation communities in order to assist the Tejon Ranch Conservancy in the development of their RWMP. The conceptual models we created identify key environmental drivers, stressors, and processes that affect each vegetation community, as well as uncertainties in these relationships. Research on baseline conditions involved collecting and analyzing data on landscape-level environmental stressors such as air pollution and climate, as well as data on ranch-level stressors such as hunting practices and fire management history. Baseline conditions were also collected for three vegetation communities, and a camera study was conducted documenting wildlife on the Ranch. After describing the major vegetation communities on the Ranch and collecting and analyzing baseline data, we developed management and monitoring recommendations for the Conservancy. The key management priority areas that we identified include grazing, fire, and climate. These recommendations can be used in an adaptive management framework toward the conservation and enhancement of biodiversity on Tejon Ranch.

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EXECUTIVE SUMMARY

Encompassing 270,000 acres, Tejon Ranch is situated at a critical location between large tracts of conserved public and private land at the confluence of four ecological regions. In a landmark conservation agreement signed in 2008, over 178,000 acres of Tejon Ranch (the Ranch) were dedicated to permanent conservation through the Tejon Ranch Conservation and Land Use Agreement (the Agreement), which was signed by the Tejon Ranch Company (TRC) and a consortium of natural resource groups. The Agreement fostered the creation of the Tejon Ranch Conservancy (the Conservancy), which must develop a Ranch-Wide Management Plan (RWMP) by 2013 to meet their mission of science-based conservation and enhancement of the natural heritage and biodiversity of the Ranch. This task has led to a partnership between the Bren School of Environmental Science and Management and the Tejon Ranch Conservancy. By applying conservation biology and landscape ecology principles, we have developed adaptive management recommendations and systematically explored the vast lands of Tejon Ranch to document and better understand its unique natural resources.

To inform the adaptive management process, our group classified and described the major vegetation communities on the Ranch by creating conceptual models, researching environmental stressors, and collecting and analyzing scientific baseline information. This baseline information included regional trends in climate, air quality, population growth, land use, and fire history as well as local trends for select vegetation communities on the Ranch. Through a landscape analysis and literature review, we identified and described eight major vegetation communities on the Ranch. These major vegetation communities include chaparral, Joshua tree woodlands, montane mixed hardwood and conifer forests, riparian, San Joaquin Valley grasslands, Antelope Valley grasslands, valley oak savanna, and foothill blue oak woodlands. Our conceptual models for each of these communities identify key environmental drivers, stressors, and processes, while highlighting uncertainties in these relationships and opportunities for future research.

ENVIRONMENTAL STRESSORS

CLIMATE

Climate is a primary driver of vegetation and wildlife habitat conditions on the Ranch. The effects of climate on ecosystems can be manifested through changes in fire intensity and frequency, precipitation, temperature, and snowpack duration. Analysis of historic temperature records indicates that there are statistically significant trends in historic average monthly temperature in the Tejon Ranch vicinity (WRCC 2009). Significant temperature trends include increasing temperatures at two high elevation climate stations and decreasing temperatures at one low elevation climate station. An analysis of historic precipitation records yielded statistically insignificant results; therefore, no solid conclusions can be drawn. Snow records are unavailable on the Ranch. In the future we recommend that temperature, precipitation, and snowpack records be kept for various sites on the Ranch.

AIR QUALITY

Air quality on the Ranch is a concern due to nitrogen deposition and potential ozone damage to vegetation. There are two distinct air basins that affect Tejon Ranch: the San Joaquin Air Basin (SJAB) to the north, and the Mojave Desert Air Basin (MDAB) on the south side of the Ranch. Currently there are no air quality monitoring stations on the ranch. Monitoring trends from stations on the valley floors outside ranch boundaries indicate that both the SJAB and the MDAB are in non-attainment for ozone and particulate matter (CARB 2009). To understand these trends across the Ranch, air quality monitoring needs to occur at varying elevations.

POPULATION

Population growth and associated land use change in the San Joaquin and Antelope Valleys indirectly affect ranch ecosystems through increased local traffic, night lights, habitat fragmentation, and potential visitor demand. Populations are increasing in many areas around the Ranch (U.S. Census Bureau 2009; Jantz 2010). This increase in human population should be considered in the development of the RWMP because it may increase the effects of environmental stressors such air pollution, fire, and hunting, and it may lead to an increase in the demand for hunting and recreational opportunities. When developing the public access portion of the RWMP, the Conservancy can use this data to help show the need for local recreational space.

GRAZING

Cattle grazing is a major revenue-generating activity practiced over 90% of Tejon Ranch. Grazing is also a system stressor that especially affects grassland and oak savanna communities on the Ranch in multiple ways, including effects on native species recruitment, soil erosion, altered streambank morphology, and increased invasion of exotic species. Available historical records on cattle grazing on the Ranch are sparse, and is an area for future research.

HUNTING

Hunting has historically been one of the most important commercial activities on Tejon Ranch. In order to analyze the hunting history on the Ranch, hunting records were acquired from the TRC and used to assess the numbers of each game species historically taken per year, as well as certain demographic traits of these species. Through analysis of these records, we found that there has been a decrease in the number of most species taken per year over the past several decades. For example, 474 deer were taken in 1987, while 118 deer were taken in 2008. Similarly, 150 bobcats were taken in 1978, while only nine were taken in 2008. It is uncertain whether this is due to decreased hunting effort, or a lower presence of hunted species.

Fire

The fire regime of Tejon Ranch is characterized by a historical range of variability in fire size, severity, and frequency. An ecosystem-level understanding of fire as a process that creates and maintains landscapes on the Ranch is necessary in order to effectively manage the conserved areas. We characterized the time since fire for different areas on the Ranch, generated a fire size distribution, and calculated the fire rotation interval from 1950 to 2008. Time since fire can be indicative of the ecological community present in a certain area and analyses of time since fire can provide information about fuel accumulation and future fire spread. Approximately 77% of the Ranch has not burned in the last 58 years and the largest areas have not burned in 10-30 years. Since 1980, Tejon Ranch has experienced not only more fires, but larger fires than in the past. An increase in the number of acres burned in the modern period (1980-2008) compared to the historic period (1950-1979) has led to a shorter fire rotation in the modern period. Fire suppression within and around the Ranch has been very reactive to fire, where fires are extinguished as soon as possible. Larger fires have most likely resulted under conditions unsuitable for fire suppression.

Different vegetation communities on the Ranch require fire at varying frequencies and intensities, especially montane and chaparral communities, and need to be managed based on those requirements. As the proposed developments on Tejon Ranch move forward, attention to wildfire will increase as the urban-wildland interface increases. Development of an ecologically-reasoned fire management plan (FMP) for the Ranch will help the Conservancy protect and enhance conserved lands.

Hydrology

Thorough understanding of water availability, including sources, supplies, and seasonality is a key component of resource management on the Ranch. Presently, historical records of water use, stream flow, and precipitation on the Ranch are sparse. Therefore, we recommend more comprehensive stream flow and precipitation monitoring data to improve water budgeting for future management of surface and ground water resources.

Vegetation Community Baseline Conditions

We performed baseline condition research on three vegetation communities on the Ranch: Joshua tree woodlands, valley oak savannas, and riparian communities. These baselines were collected to assess the health of vegetation communities across the Ranch, and to serve as a starting point from which future monitoring can be referenced.

Joshua Tree Woodlands

Field surveys and aerial imagery were used to analyze the cover and recruitment of Joshua trees on the Ranch. By comparing Joshua tree coverage from 1952 and 2009 aerial imagery, we found that the local Joshua tree population in the Tri-Centennial Acquisition Area is increasing, which may make this a valuable area for future conservation. We also performed belt transect surveys of Joshua tree heights on the south side of the Ranch, and found evidence of high levels of Joshua tree recruitment.

Valley Oak Savannas

The Old Headquarters Acquisition Area supports large expanses of valley oak savanna; however, tree diameter distribution data indicate an absence of recent recruitment of oaks. Comparisons of 1952 and 2009 aerial imagery for valley oaks within the Old Headquarters area shows a 1.1% decline in canopy cover. These findings suggest that valley oak regeneration should be a large concern for management. To address this concern, we recommend monitoring of sapling recruitment and processes affecting recruitment, such as browsing by deer and cattle.

Riparian

Tejon Ranch supports a diverse assemblage of riparian communities including montane riparian forests, valley and foothill riparian communities, desert washes and woodlands. We focused our research on valley and foothill riparian and sycamore alluvial woodlands. These communities are dominated to varying degrees by native riparian tree species such as willow (*Salix* spp.), Fremont cottonwood (*Populus fremontii*), western sycamore (*Platanus racemosa*), valley oak (*Quercus lobata*), and incense cedar (*Calocedrus decurrens*). Based on a multivariate analysis, riparian community species composition is associated with several environmental variables that co-vary along elevational gradients, the strongest of which is mean annual precipitation. Based on the modeled relationships between system stressors and riparian community ecosystem processes, we developed management and monitoring recommendations for riparian communities on the Ranch. These recommendations include the installation of experimental fenced cattle grazing exclosures, performing quantitative vegetation sampling, measuring stream flows, documentation of water diversions and groundwater pumping quantities, and adopting a hunting management plan and game species population monitoring on Conservancy-managed lands.

Management Priorities

Management concerns were developed for the eight vegetation communities described on the Ranch. These concerns are based on the relative magnitude of influence environmental stressors have within each of the eight communities. Due to the potentially negative effects they have throughout the Ranch, we identified three key system stressors as adaptive management priorities.: grazing, fire, and climate.

Ranch-level stressors can be altered or minimized through management decisions. The key ranch-level environmental stressors we identified are grazing and fire. For grazing, we recommend creating and implementing a rangeland productivity assessment protocol. Many key processes in rangeland ecology are affected, or may be assessed, by the height and architecture of grassland cover (Stewart et al. 2001). The Conservancy may also want to consider implementing an experimental seasonal grazing rotation program to study the effects of grazing seasonality on rangeland productivity, as well as grassland and oak savanna community health.

To address fire, we recommend that new CALFIRE fire perimeters be added to the existing ranch data in order to track the fire return interval in different vegetation communities. The Ranch may want to consider the development of a Fire Management Plan (FMP) that details specific fire management guidelines that will help the Conservancy protect and enhance the conserved lands. Fire plays an important role in maintaining community health and diversity, especially in montane and chaparral communities and the FMP may provide guidance for where wildfires are allowed to burn. The Conservancy may also consider the effects of prescribing fire under an adaptive management regime where outcomes of fires are monitored and used to inform future management decisions, which could help to restore structural and species diversity in these communities.

Regional stressors are at a larger scale, have less potential for management actions, and have varied sources. Climate is a landscape-level stressor that represents a major driver of change in vegetation communities on the Ranch. Although managers have little control over climate, management decisions will need to consider and adapt to changes in climate, especially in montane and Joshua tree woodland communities. Comprehensive climate monitoring at different elevations and areas on the Ranch should be considered a management priority.

Conclusion

Although our research informs the Conservancy of the conditions on the Ranch, current monitoring is limited and uncertainties about the current conditions on the Ranch remain. Our preliminary findings and baseline conditions will help inform the adaptive management process, as the Conservancy moves forward with the development of the RWMP. Adaptive management and monitoring of vegetation communities and key stressors such as grazing, fire, and climate will be necessary. As new information is gathered through experimental management actions and monitoring in the future, our conceptual models and recommendations can be changed and adapted to adjust to new information and resolved uncertainties. Throughout the development of our management recommendations, we were mindful of balancing traditional land-use practices in a working landscape with conservation and restoration objectives on the Ranch. These recommendations are intended to be used by the Conservancy in the development of their RWMP.

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ACKNOWLEDGEMENTS

Many people have helped us throughout this process and we are thankful to all of them. First, we would like to thank our group project advisor, Frank Davis, for his continued time and support. We would also like our client, the Tejon Ranch Conservancy, especially Science Director Mike White and Executive Director Tom Maloney.

We would also like to thank the following people for their guidance and support:

Bruce Kendall, PhD, University of California, Santa Barbara (UCSB)
David Stoms, Researcher, UCSB
Christina Tague, PhD, UCSB
Claudia Tyler, PhD, UCSB
Christopher Costello, PhD, UCSB
Sarah Anderson, PhD, UCSB
James Frew, PhD, UCSB
Patrick Jantz, UCSB
Theresa Nogeire, UCSB
Rusty Brown, UCSB
Alan Flint, USGS
Maki Ikegami, UCSB
Jennifer Browne, Tejon Ranch Conservancy
Rob Peterson, Tejon Ranch Company
Wayne Ferren Jr., UCSB, retired
Michael O'Connell, Irvine Ranch Conservancy

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ACRONYMS

the Agreement	Tejon Ranch Conservation and Land Use Agreement
AUM	Animal Unit Month
CARB	California Air Resource Board
CDFG	California Department of Fish and Game
CEC	California Energy Commission
CFC	chloroflorocarbon
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
the Conservancy	Tejon Ranch Conservancy
CRAM	California Rapid Assessment Method
DBH	diameter-at-breast-height
DCA	Detrended Correspondence Analysis
EIR	Environmental impact report
FMP	Fire Management Plan
GCM	global climate model
GHG	greenhouse gas
GIS	geographic information systems
GPS	global positioning system
HGM	hydrogeomorphology
LAI	leaf area index
LIDAR	light detection and ranging
MDAB	Mojave Desert Air Basin
MSHCP	Multiple Species Habitat Conservation Plan
NO_x	nitrogen oxides
N_2O	nitrous oxides
NHD	National Hydrography Dataset
NRDC	Natural Resource Defense Council
OHV	off-highway vehicle
PM	particulate matter
PFC	Proper Functioning Condition
QBR	qualitat del bosc de ribera or riparian forest quality
The Ranch	Tejon Ranch
The Resource Groups	Audubon California, the Endangered Habitats League, Natural Resources Defense Council, Planning and Conservation League, and the Sierra Club

RDM	Residual Dry Matter
RSC	Rosgen Stream Classification
RWMP	Ranch-Wide Management Plan
SJAB	San Joaquin Air Basin
SWAMP	Surface Water Ambient Monitoring Protocol
TRC	Tejon Ranch Company
UV	ultraviolet
VOC	volatile organic compounds
WRCC	Western Regional Climate Center
UCSB	University of California, Santa Barbara
USFS	U.S. Forest Service

1 INTRODUCTION

Encompassing 270,000 acres, Tejon Ranch is the largest contiguous privately-owned property in California (Figure 1-1). Tejon Ranch is an invaluable part of California's natural heritage, a hotspot of biological diversity lying at the confluence of four major ecological regions: the western Mojave Desert, the foothill oak woodlands and mixed coniferous forests of the Tehachapi Mountains, the San Joaquin Valley grasslands, and the southwestern California coastal ranges. These diverse vegetation communities include essential habitats for rare and endemic species, old growth oak woodlands, endangered California condors, intact watersheds and streams- all near California's largest metropolitan area, Los Angeles. Tejon Ranch also serves as a vital wildlife corridor between publicly-owned wilderness areas, parks, and national monuments.

In June 2008 the Tejon Ranch Company and a consortium of five natural resource organizations signed the historic "Tejon Ranch Conservation and Land Use Agreement" (the Agreement), dedicating 178,000 acres of the Ranch to permanent conservation (Appendix A). In return, the Tejon Ranch Company could develop on 30,000 acres of the Ranch without opposition from the five conservation organizations (the Resource Groups) that signed the agreement which include the Sierra Club, Natural Resource Defense Council (NRDC), Audubon, Planning and Conservation league, and the Endangered Habitats League. However, these developments are still subject to review and permitting requirements under local, state and federal policies such as the California Environmental Policy Act, California Endangered Species Act and the U.S. Endangered Species Act. The Agreement also gives the Resource Groups an option to acquire conservation easements over an additional 62,000 acres ("Acquisition Areas"), for which they are currently seeking funds. (Figure 1-2).

As per the Agreement, the Tejon Ranch Conservancy (the Conservancy) was created as an independent, non-profit organization to "preserve, enhance, and restore the native biodiversity and ecosystem values of the Tejon Ranch and the Tehachapi Range for the benefit of California's future generations" (TRC 2009a, p. 1). The Agreement represents one of the most significant and forward looking conservation achievements in California. Current land-use practices on Tejon Ranch include grazing, hunting, and filming operations. Under the ranch-wide agreement, the Tejon Ranch Company will work collaboratively with the Conservancy "to promote the long-term science-based stewardship of the ranch and provide for public enjoyment through educational programs and public access" (p. 20). The goal of our group project involved producing baseline ecological information and conceptual models of ecosystem processes to inform the Conservancy's development of a Ranch-Wide Management Plan (RWMP), according to an adaptive management standard.

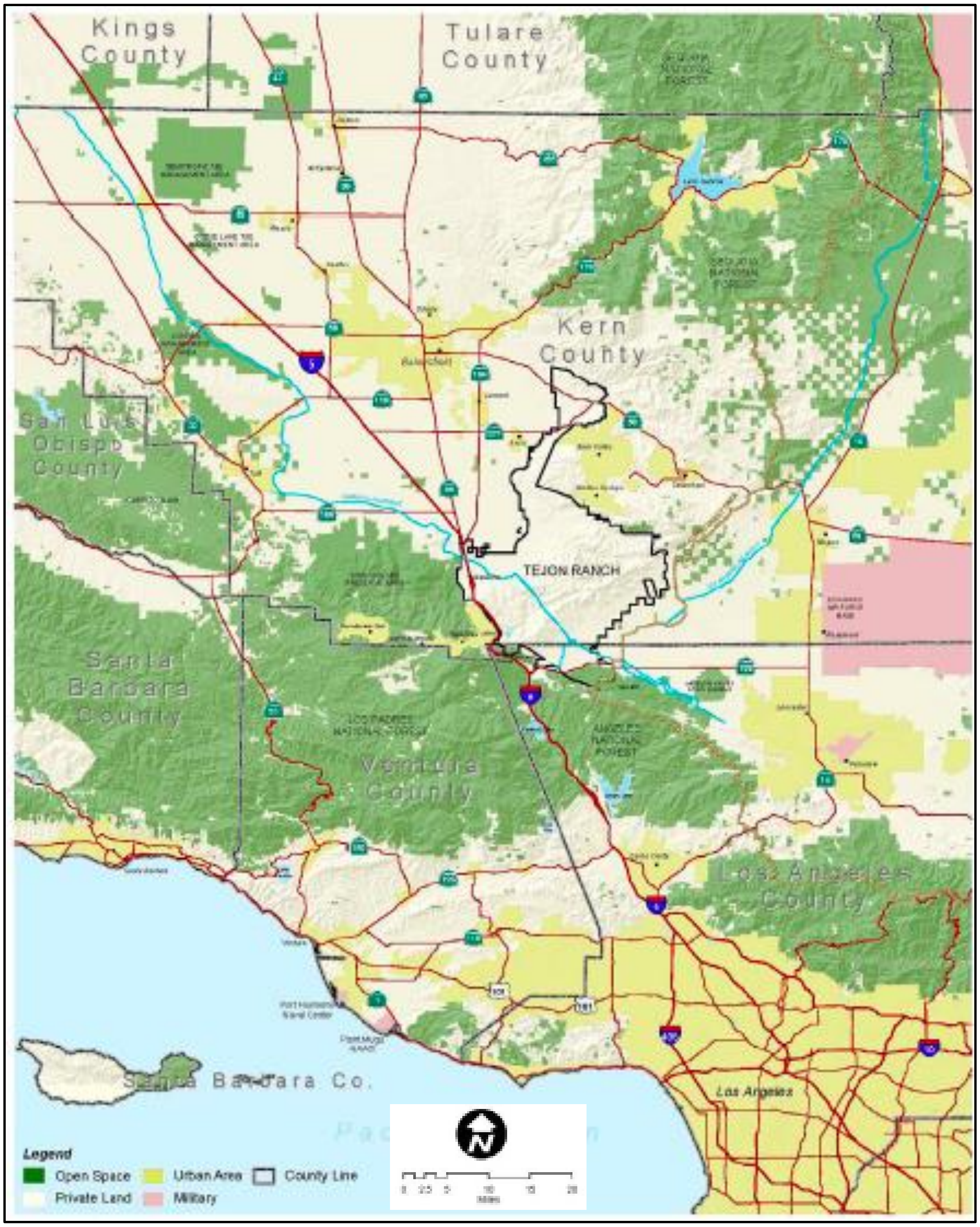

Figure 1-1. Location of Tejon Ranch. *Source: Tejon Ranch-Wide Interim Management Plan 2009.*

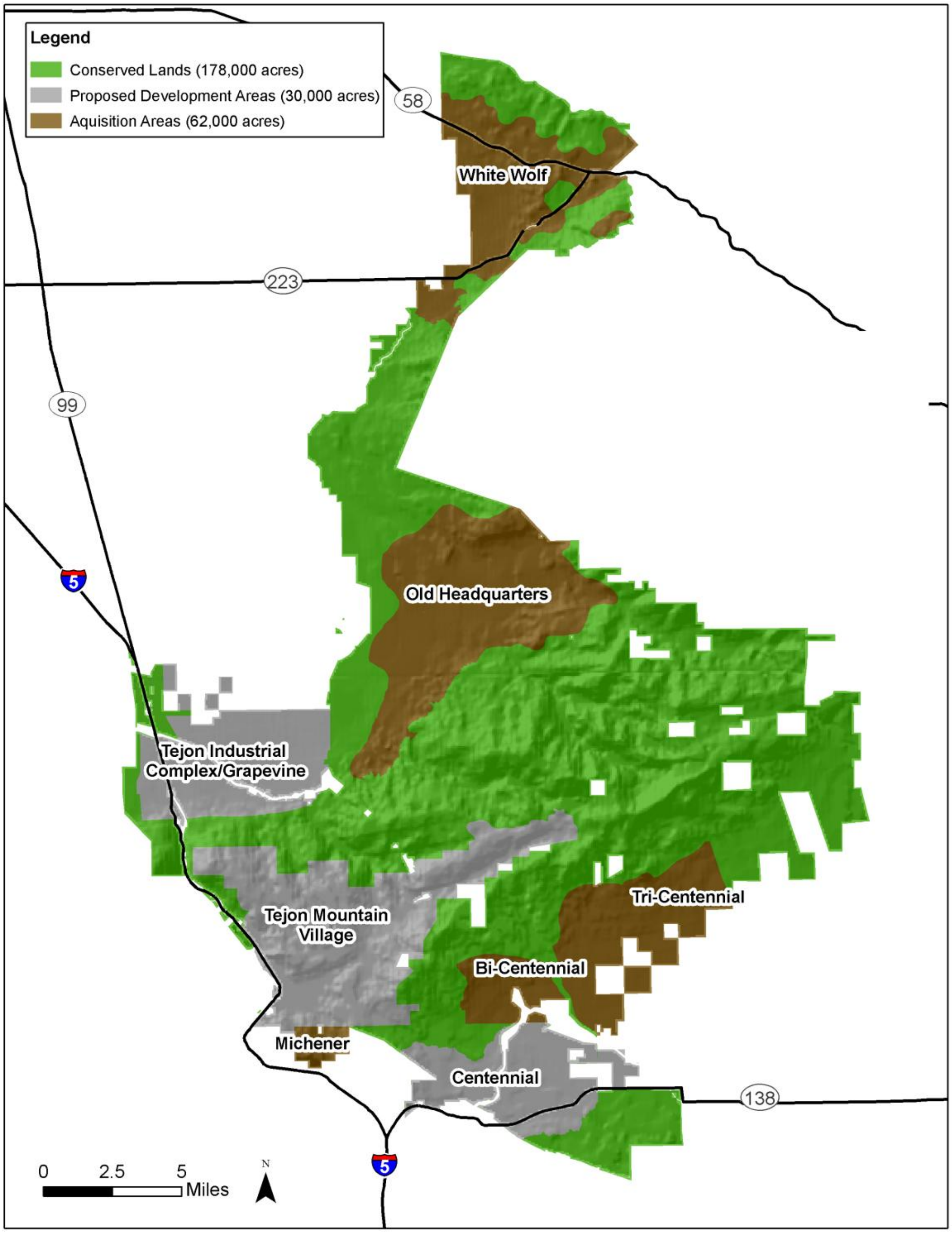

Figure 1-2. Proposed Development and Acquisition Areas. The proposed development areas are shown here in gray, and the acquisition areas are in brown. The largest proposed developments include the Tejon Industrial Complex/Grapevine; Centennial, and Tejon Mountain Village. *Source: Tejon Ranch Conservancy.*

1.1 PROJECT SIGNIFICANCE

According to the Agreement, one of the first obligations of the Conservancy is the creation and adoption of a RWMP for the conserved lands. A critical step in this process is formally conceptualizing conservation values, identifying restoration opportunities, and establishing baseline conditions. During an initial five-year period, the RWMP will focus on the preservation of existing conservation values by maintaining baseline conditions. After the initial period, the RWMP will implement a program for "restoring and enhancing the natural values of the conserved lands" (Adaptive Management Standard; TRC 2009b, p. 4). The main tasks of our group project included producing conceptual models to help refine and articulate conservation goals, and contributing to the establishment of baseline conditions for use in the RWMP.

As specified in the RWMP, an adaptive management and monitoring program is necessary to ensure the conservation and enhancement of the native biodiversity and natural heritage of Tejon Ranch in perpetuity. Adaptive management and monitoring promotes long-term, science-based stewardship by generating feedback to inform and refine future management decisions. These decisions are based on the rigorous experimental design of management actions and the systematic monitoring of ecosystem responses to different management treatments. An adaptive management plan will allow for flexibility in the face of changing climate conditions, shifting land use, improved ecological knowledge, and other unforeseen changes. An initial understanding of the environmental drivers and stressors that impact the natural resources on Tejon Ranch is necessary to develop an adaptive management plan. Conceptual models are diagrams that communicate the processes and relationships within a system. The purpose of developing conceptual models of the Ranch's main vegetation communities is to identify the drivers, stressors, processes, relationships, and measures of environmental change (endpoints) that will inform and assist management decisions. Additionally, the establishment of baseline conditions will allow future environmental changes to be assessed, such as changes in land use practices, grazing, or various climate change scenarios.

1.2 PROJECT OBJECTIVES

Our overall objective included gathering baseline data and historical information on Tejon Ranch's natural resources and land use, and developing conceptual models to support the development of the RWMP. Constraints to our project included the absence of complete historical information about Tejon Ranch and the short timeline of the project. Below are the main steps we took in order to achieve the stated objectives:

- Analyzed the landscape to identify major vegetation communities on the Ranch.
- Identified and described potential drivers of change on the Ranch, including major environmental stressors.
- Developed conceptual models and accompanying narratives of the nine major vegetation communities.
- Collected and analyzed baseline information on select vegetation communities.
- Established monitoring targets and frameworks for each of the eight vegetation communities.
- Created recommendations for future monitoring and management decisions.

1.3 REPORT STRUCTURE

This document is structured following the steps of our project approach. Our document starts with an introduction and background on Tejon Ranch, adaptive management, and conceptual models (Sections 1 and 2). In Section 3 we present the methods used for our landscape classification, the development of conceptual models, baseline data collection and analysis, development of management recommendations, and management prioritization steps. Then our results are presented, beginning with the landscape analysis in Section 4. In Section 5 we present our societal conceptual model, which illustrates the role of anthropogenic drivers on ecosystem processes and regional-level stressors, which provides the reader with a conceptualization of how each of the system stressors (Section 6) and vegetation communities (Section 7) fit into the larger context of human actions on both global and regional scales. In Section 8 we present a set of recommended management priorities and our rationale for their selection. The document concludes in Section 9 with a synthesis of main ideas and a compendium of references cited (Section 10). Specific technical analyses and detailed methodologies are provided as Appendices to this report.

An interested manager could begin by reviewing the descriptions of ranch-wide or landscape-level system stressors of interest, or could simply proceed to any of the vegetation communities of interest and follow these stand-alone sections, as they discuss the community's description, current baseline conditions, and the system-specific conceptual model for each of these communities. Alternatively, one could begin their review of the document with the societal conceptual model and follow anthropogenic drivers and stressors through the community level models. Finally, an interested manager could simply consider the recommended priorities for adaptive management identified in Section 8 as a snapshot of the entire effort, finding the supporting rationale for these recommendations included in Sections 6 and 7.

1.4 Introduction to Tejon Ranch

1.4.1. Location and Size

Tejon Ranch is situated in both Kern and Los Angeles Counties, approximately 60 miles north of the city of Los Angeles (Figure 1-1). As the largest contiguous, privately owned property in California, Tejon Ranch encompasses over 270,000 acres (Interim Ranch-Wide Management Plan 2009). Of the 270,000 acres, 247,000 are located in Kern County and 23,000 are located in Los Angeles County. The Ranch is approximately 40 miles long north to south, and 26 miles wide from east to west.

1.4.2 Cultural History

Historically, five Native American tribes lived on Tejon Ranch and the surrounding area before 1800. The Kitanemuk tribe occupied areas of the Tehachapi Mountains and the foothills east of Castaic Lake. The Yokut tribe inhabited areas of the San Joaquin Valley, while the Chumash tribe occupied the western edge of Tejon Ranch at the mouth of Grapevine Canyon. The Tatavium tribe inhabited the western edge of the Antelope Valley in the southern area of the Ranch, while the Kawaiisu tribe lived in the northern area of Tejon Ranch (Interim Ranch-Wide Management Plan 2009).

The Tejon region received its name in 1806, when at the mouth of a canyon Lieutenant Francisco Ruiz found a dead badger, naming the canyon “Tejon” after the Spanish word for badger. The Tejon Ranch property was purchased from the Rancho El Tejon Mexican land grant in the mid-1800s, when General Edward Fitzgerald Beale purchased the area that comprises Tejon Ranch (Interim Ranch-Wide Management Plan 2009). General Beale initially came to California as a naval officer, and in 1852 was appointed as the California Superintendant of Indian Affairs. In 1855 he began purchasing the land that now comprises Tejon Ranch. His first purchase consisted of 50,000 acres, and in just over a decade, he acquired 300,000 acres of Tejon Ranch (Interim Ranch-Wide Management Plan 2009).

1.4.3 History of the Tejon Ranch Company

General Beale was an instrumental figure in establishing the Tejon Ranch Company (TRC). In the early years of acquiring the property of Tejon Ranch, General Beale focused on sheep grazing and established the TRC. In 1880, he switched to cattle grazing, and added 55 acres of farming operations in the 1890s (Interim Ranch-Wide Management Plan 2009). General Beale passed away in 1893, bequeathing ownership of the Ranch to his son, Truxtun Beale, who managed the Ranch for a number of years. In 1912 Beale sold the Ranch to a group of Los Angeles businessmen, led by Harry Chandler and Moses Sherman. Chandler and Sherman expanded cattle grazing and farming operations on the Ranch, and used the area as a personal hunting retreat (Interim Ranch-Wide Management Plan 2009).

In 1936, Chandler incorporated TRC for public purchase. Company operations continued to focus on grazing and farming, but expanded to include development of Highway 99, which was later designated as the Interstate 5. In the early 1970's TRC contributed 30,000 acres to an agricultural partnership, reducing its landholding to the current 270,000 acres. In 1973, shares in TRC became traded on the American Stock Exchange (Interim Ranch-Wide Management Plan 2009).

The Chandler family sold their TRC shares in 1997, resulting in the transfer of livestock operations to two lessees, and an increased emphasis on real estate development on the Ranch. The Board of Directors instructed TRC to pursue development rights of several projects, starting with the Tejon Industrial Complex. TRC has continued to pursue development into the 2000's, with plans to develop the Tejon Industrial Complex, the Tejon Mountain Village, and Centennial California (Interim Ranch-Wide Management Plan 2009).

1.4.4 LANDSCAPE

TOPOGRAPHY

The landscape of Tejon Ranch is diverse and includes a variety of topographical and environmental features. The Ranch is divided into four ecoregions, the San Joaquin Valley, the Tehachapi Range, the Mojave Desert, and the southern California coastal ranges (Figure 1.4-1). Elevation varies on the Ranch from 400 to 6,800 feet above sea level (Interim Ranch-Wide Management Plan 2009).

GEOLOGY

Tejon Ranch is very geologically diverse (Figure 1.4-2; a list of geologic maps covering Tejon Ranch can be found in Appendix B.) The southern end of the San Joaquin Valley is mainly comprised of Quaternary alluvium deposits of gravel, sand, silt, and clay in active channels, terraces, and undissected alluvial fans. Younger deposits overlay older alluvium deposits that are most likely equivalent to the Modesto and Riverbank formations (Bartow 1986).

The Tehachapi Range is primarily Mesozoic quartz-diorite (Dibblee & Warne 1970). Where the Tehachapi Range converges with coastal ranges, there is an abundance of Jurassic and Cretaceous intrusive granite, granodiorite, and quartz monzonite

(Crowell 1957-1950). The Garlock fault is located at this convergence, and continues on a northeast trend along the southern edge of the Tehachapi Mountains. The southern edge of the Tehachapi Range converges with the Mojave Desert, with the boundary between the two regions roughly delineated by the southwest-northeast trending Garlock fault. The southern foothills of the Tehachapi Range are primarily Jurassic granite and diorite, as well as Precambrian schist and gneiss (Weise & Spencer 1964). The Mojave Desert portion of Tejon Ranch is comprised primarily of Quaternary alluvium and terrace deposits.

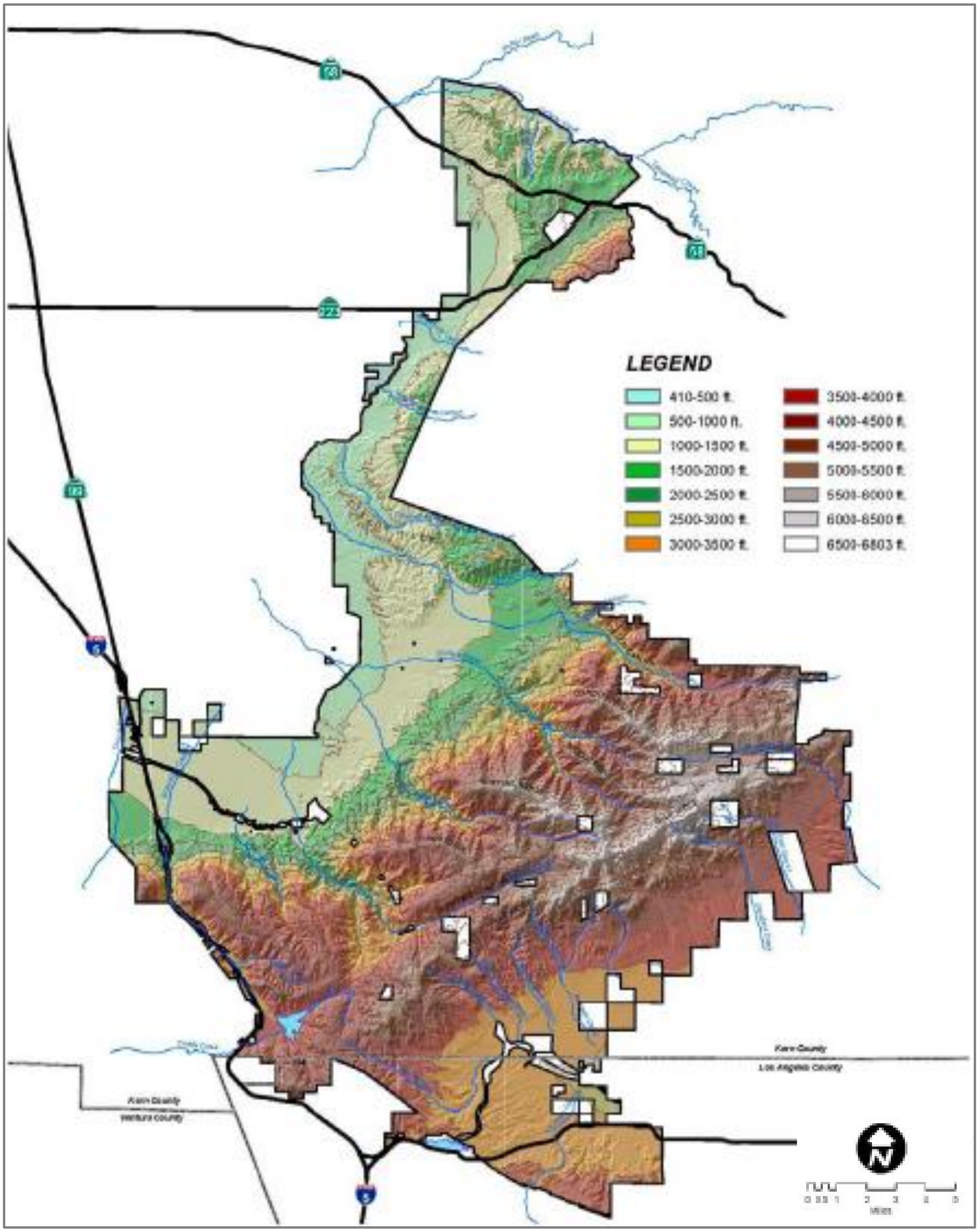

Figure 1.4-1. Elevation Map. *Source: Tejon Interim Ranch-Wide Management Plan 2009.*

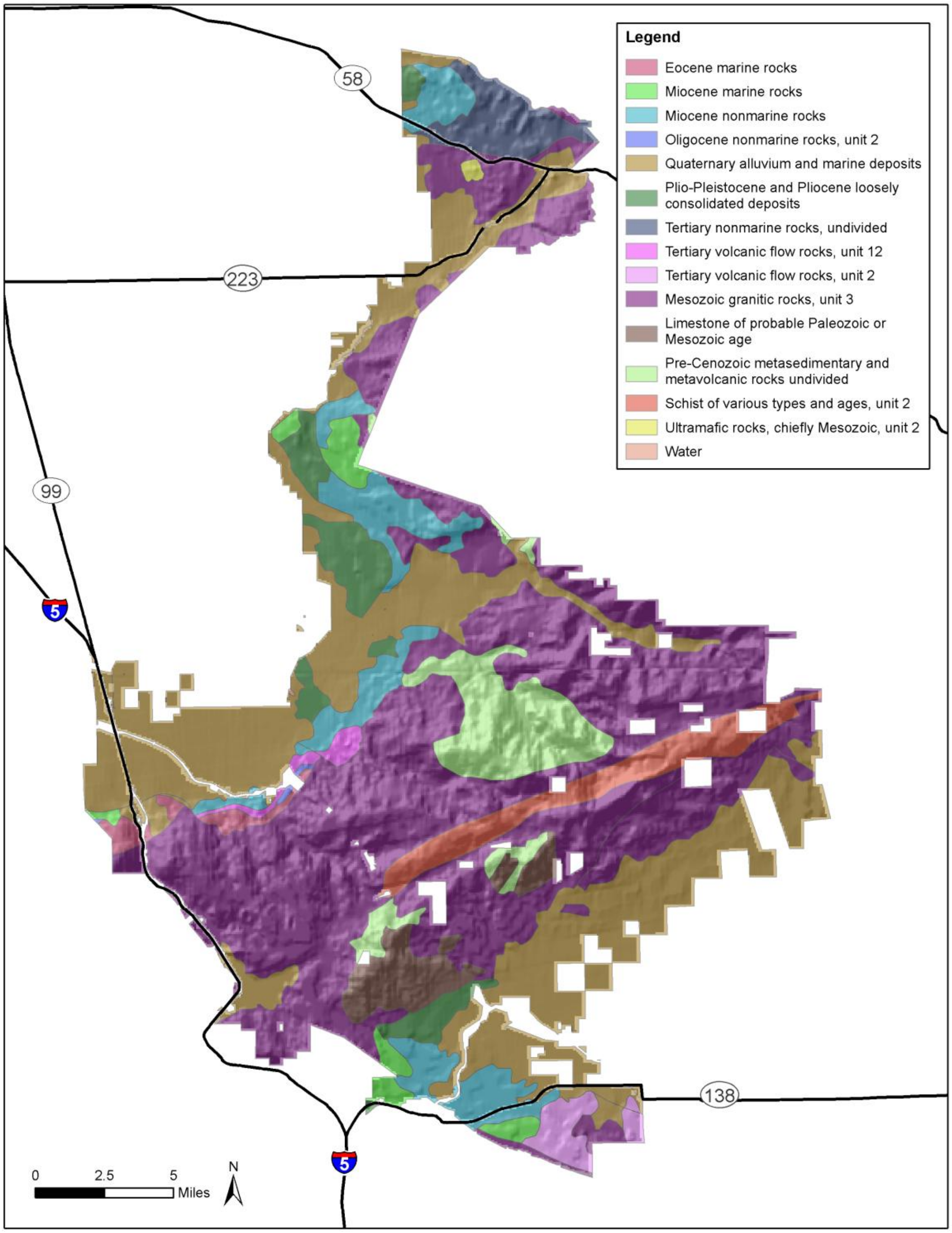

Figure 1.4-2. Geology Map. *Source: USGS 2005.*

1.4.5 NATURAL RESOURCES

VEGETATION COMMUNITIES

Tejon Ranch's complex landscape supports a wide range of vegetation communities in four distinct ecoregions (Figure 1.4-3). The vegetation communities support a variety of native wildlife, from western gray squirrels, California black bears, and mule deer, to red-tailed hawks and mountain lions (Interim Ranch-Wide Management Plan 2009). The vegetation communities found on the Ranch can be seen in Figure 1.4-4).

Tejon Ranch is a crucial piece of preserved land in an ever-growing urban landscape. The natural communities found on the Ranch represent habitat types found throughout southern and central California. The portion of the Tehachapi Mountains that runs through the Ranch provides a corridor for animal movement from the Sierra Nevada to the Coast ranges and mountains of southern California.

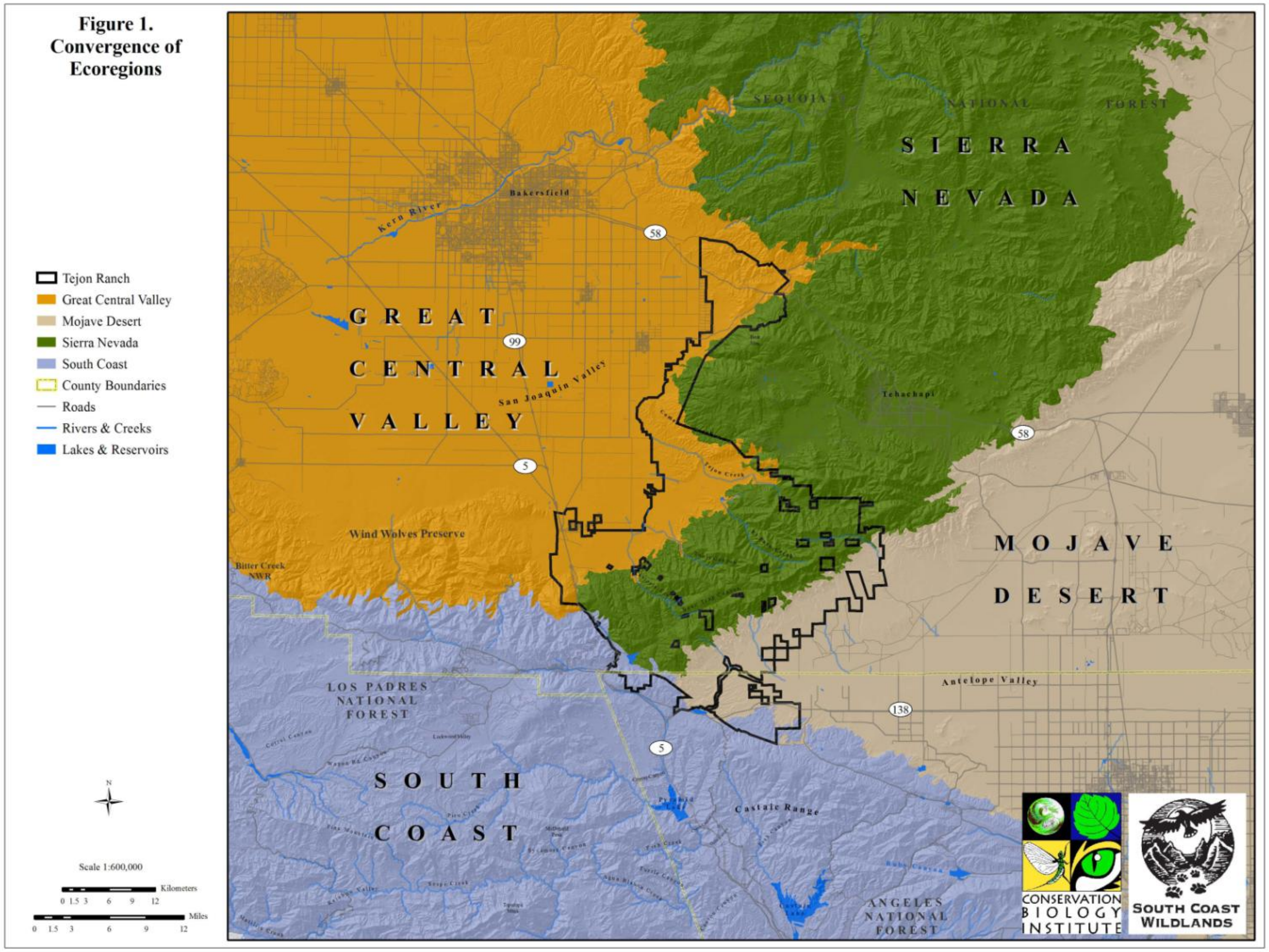

Figure 1.4-3. Eco-Region Map. *Source: Conservation Biology Institute and South Coast Wildlands 2006.*

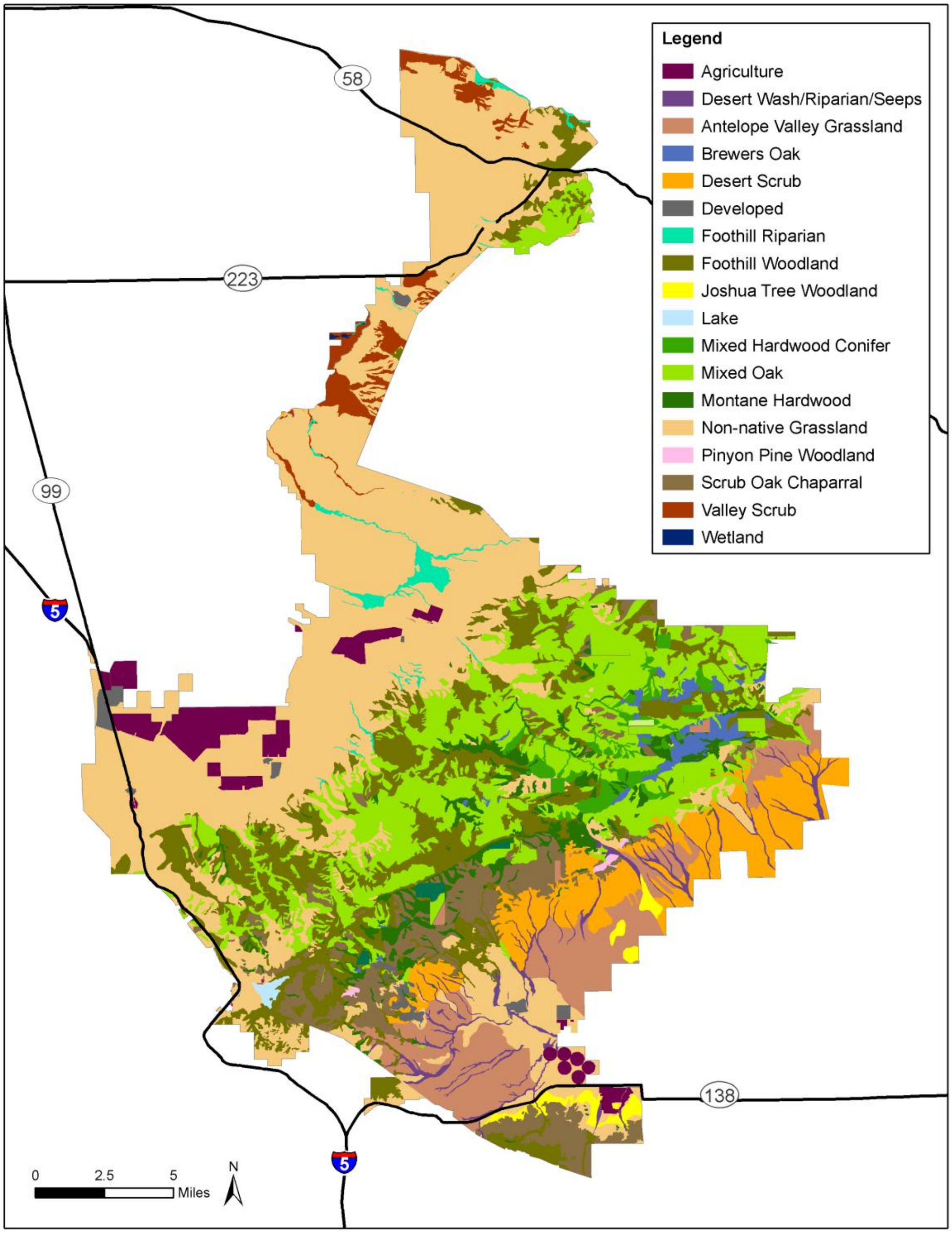

Figure 1.4-4. Vegetation Map. *Source: Tejon Ranch Conservancy.*

UNITED STATES FOREST SERVICE ECOLOGICAL SUB-SECTIONS

The U.S. Forest Service (USFS) has developed an ecosystem classification scheme based on biotic and environmental factors that shape the structure and function of each ecosystem. Using the USFS classification, Tejon Ranch falls within five sections and nine subsections (Figure 1.4-5). The following are descriptions of these sections and subsections in order to help characterize the varying ecosystems present on the Ranch (USFS 1997). Included in each description is a list of the vegetation types that have been mapped for the Ranch.

Great Valley Section: Contained within this section are the alluvial plains of the Sacramento and San Joaquin Valleys. Historically, fire disturbance within the Great Valley section has been characterized by frequent, fast-moving large fires. Due to land conversion for agriculture and urban development, the fire regime has been altered and is now dominated by small, infrequent fires.

Hardpan Terraces Subsection

On the Ranch, this subsection includes approximately 42,885 acres of terraces along the eastern edge of the San Joaquin Valley. There is a high proportion of alluvium from granitic rock sources. This subsection consists of gently sloping terraces, as well as small areas of floodplain and alluvial fans. The soils on Tejon Ranch that are located in the Hardpan Terraces Subsection are mostly Typic and Abruptic Durixeralfs and Typic, Mollic, and Ultic Palexeralfs. In relatively dry areas near the southern end of the San Joaquin Valley there are Xeric Torriorthents, Calcixerollic Xerochrepts, and Xeralfic Haplargids. The soils are well drained, and the terrace soils are characterized mainly by bicarbonate weathering and leaching and the accumulation of clay and silica. Calcium carbonates accumulation occurs in some of the drier soils. The soil temperature regimes are thermic, and soil moisture regimes are mostly xeric (USFS 1997).

The vegetation and land types present within this subsection on the Ranch include: agriculture, alkali meadow, desert scrub, foothill riparian, foothill woodland, mixed oak, non-native grassland, and valley scrub.

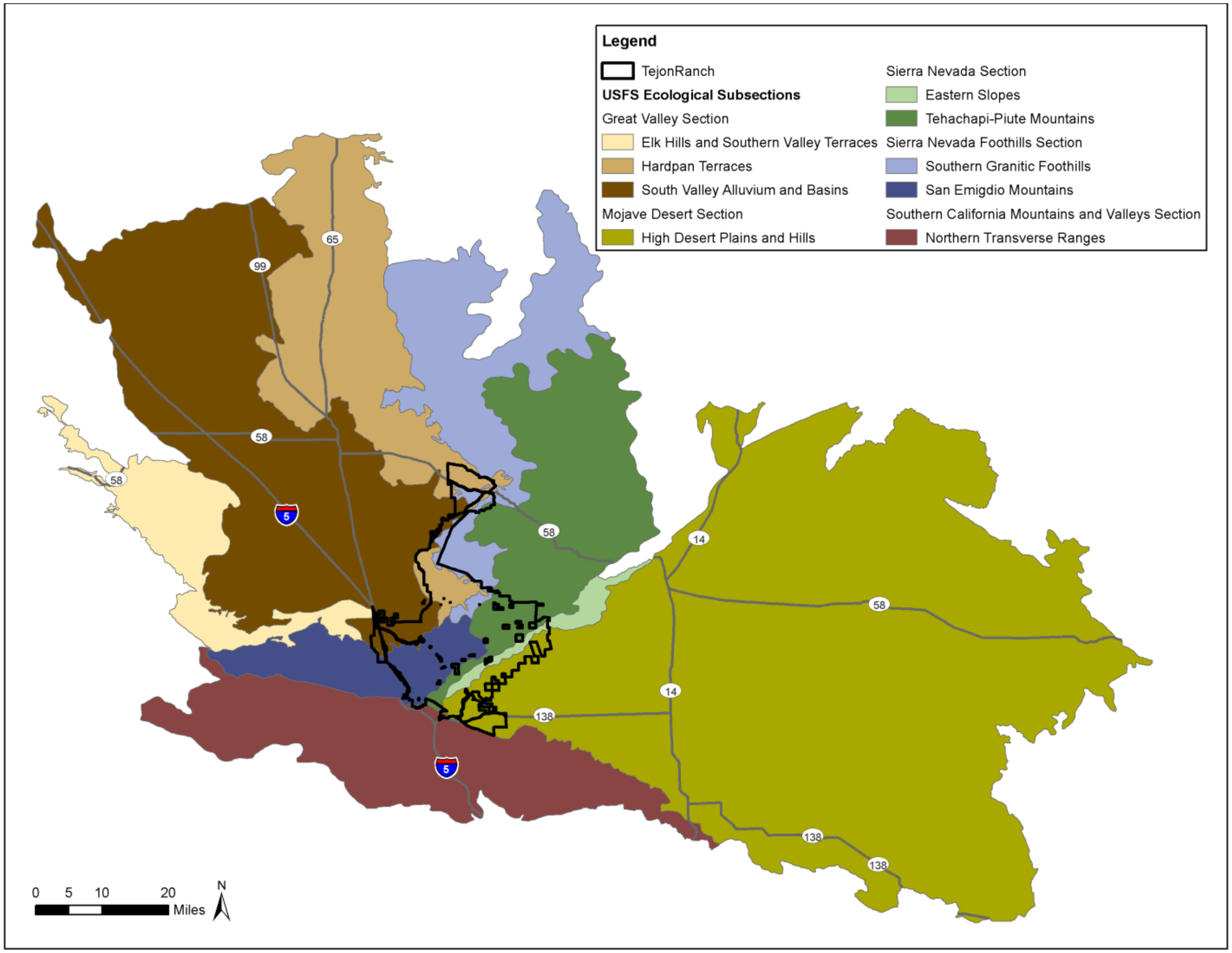

Figure 1.4-5. USFS Subsections. *Source: USFS 1997.*

South Valley Alluvium and Basins Subsection

This subsection includes the surrounding alluvial fans in the southern San Joaquin Valley and occupies approximately 32,885 acres of the Ranch. The subsection is nearly level, except for the gently sloping alluvial fans surrounding the basin. In the South Valley Alluvium and Basins Subsection of the Ranch, the soils are mostly well-drained Typic Torriorthents and Natrargids. The soil temperature regimes are thermic, and soil moisture regimes are aridic (USFS 1997).

The vegetation and land types present within this subsection include: agriculture, desert scrub, developed, foothill riparian, foothill woodland, non-native grassland, valley scrub, and wetland.

Elk Hills and Southern Valley Terraces

Approximately 110 acres of Tejon Ranch fall within this subsection and consist of the foothills of the mountains at the southern end of the Great Valley. The subsection is on moderately steep to steep hills that contain mostly marine Miocene sedimentary rocks. The soils in this part of the Ranch are derived mainly from Miocene sedimentary rocks. On the southern end of the Central Valley the soils are composed of well drained Calcixerollic Xerochrepts, Calcic Haploxerolls, and Typic Argixerolls. Here, the soil temperature regimes are thermic and the soil moisture regimes are aridic and xeric (USFS 1997).

The vegetation and land types present within this subsection include agriculture and non-native grassland.

Mojave Desert Section: This section includes the southern end of the Sierra Nevada and the north-northeastern side of the Transverse Ranges. Fires within the Mojave Desert section are rare since limited precipitation does not support vegetation for fuel. Areas that do receive some rainfall may experience fire due to growth of non-native grasses. This regime has created fires that are highly variable in frequency and intensity.

High Desert Plains and Hills Subsection

The High Desert Plains and Hills subsection consists on the Mojave Desert and occupies approximately 48,800 acres on Tejon Ranch. The soils in this part of Tejon Ranch are primarily Quaternary alluvium and lucustrine deposits in sloping pediments and alluvial fans. The soils are well-drained, with thermic temperature regimes and aridic soil moisture regimes. They are composed mostly of Typic Torriorthents, Typic Haplargids, Typic Torrifluvents, Typic Torripsamments, and Typic Argidurids. Fluvial erosion and deposition and eolian deflation and deposition are the main geomorphic processes (USFS 1997).

Vegetation and land-use types within this subsection include: agriculture, Antelope Valley grassland, desert scrub, desert wash/riparian/seeps, developed, foothill woodland, Joshua tree woodland, mixed oak, montane hardwood, non-native grassland, and scrub oak chaparral.

Sierra Nevada Section: This section includes the temperate to cold parts of the Sierra Nevada, which have a north-northwest alignment and are steeper on the eastern sides than the western sides. Tejon Ranch falls within the very southern, lower elevation portion of the Sierra Nevada section. The historic fire regime has been characterized by frequent, low-intensity ground fires; however, the present regime is characterized by infrequent, high-intensity stand replacing fires.

Eastern Slopes Subsection

The Eastern Slopes subsection occupies approximately 14,649 acres of Tejon Ranch and encompasses the Tehachapi Pass area. In this part of Tejon Ranch, the soils are mostly well drained Lithic Torriorthents; Typic and shallow Xeric Torripsamments; shallow Typic Xeropsamments; Aridic, Torriorthentic, and shallow Entic Haploxerolls; shallow Typic Cryopsamments; Andic and Lithic Cryumbrepts; Typic Argixerolls; and Ultic Haploxeralfs. The soil temperature regimes are thermic, mesic, frigid, and cryic, and soil moisture regimes are xeric in the north and aridic in the south of the subsection (USFS 1997).

The vegetation and land types present within this subsection on the Ranch include: Antelope Valley grassland, desert scrub, desert wash/riparian/seeps, developed, foothill riparian, mixed oak, montane hardwood, non-native grassland, pinyon pine woodland, and scrub oak chaparral.

Tehachapi-Piute Mountains Subsection

This subsection is found at the very southern end of the Sierra Nevada Section, and encompasses approximately 48,814 acres, including most of the Tehachapi and Piute Mountains. This subsection is characterized by Quaternary volcanic rocks and alluvial fans. The soils are mostly well drained Typic and Pachic Haploxerolls and Lithic and Typic Argixerolls. The soil temperature regimes are primarily thermic and mesic, and soil moisture regimes are mostly xeric (USFS 1997).

The vegetation and land types present within this subsection include: Antelope Valley grassland, Brewers oak, desert scrub, desert wash/riparian/seeps, developed, foothill woodland, mixed hardwood conifer, mixed oak, montane hardwood, non-native grassland, pinyon pine woodland, and scrub oak chaparral.

Sierra Nevada Foothills Section: This section encompasses the warmer foothills of the Sierra Nevada, with Tejon Ranch occupying the southern end of the section. Fires throughout this section are commonly low, moderate, and high-intensity surface or stand replacing fires.

Southern Granitic Foothills Subsection

Tejon Ranch covers approximately 22,057 acres of this subsection and includes the lower slopes of the Tehachapi Mountains. The subsection consists of predominately Mesozoic granitic rocks. In the Southern Granitic Foothills Subsection of Tejon Ranch, the soils are mostly well-drained Typic and Pachic Haploxerolls, shallow Typic Xerorthents, and Lithic and Typic Argixerolls. There is significant bicarbonate weathering, and clays accumulate in the subsoils. Some soils have calcium carbonate accumulation. The soil temperature regimes are mostly thermic, and the soil moisture regimes are mostly xeric (USFS 1997).

The vegetation and land types present within this subsection are: foothill riparian, foothill woodland, mixed oak, montane hardwood, non-native grassland, and valley scrub.

San Emigio Mountains Subsection

The Tejon Ranch portion of this subsection encompasses 65,526 acres in the southwest end of the Tehachapi Mountains. The subsection consists of predominately Mesozoic granitic rocks. In this area of Tejon Ranch, granitic substrates tend to yield soils that are mostly Typic and Dystric Xerochrepts; Typic and Pachic Haploxerolls; Ultic Haploxerolls; and Pachic Argixerolls. At lower elevations, Tertiary sedimentary rocks yield mostly Calcic Haploxerolls and Typic Argixerolls. The soils are well-drained, and bicarbonate weathering and leaching and accumulation of clay in subsoils are the main pedogenic processes. Soil temperature regimes are thermic and mesic, and soil moisture regimes are xeric (USFS 1997).

The vegetation and land types present within this subsection are: agriculture, Brewer's oak woodlands, developed, foothill riparian, foothill woodland, mixed hardwood conifer, mixed oak, montane hardwood, non-native grassland, pinyon pine woodland, and scrub oak chaparral.

Southern California Mountains and Valleys Section: This section includes the mountains, hills, and valleys of the Transverse Ranges and portions of the Peninsular Ranges. Only a small southwestern portion of Tejon Ranch is within this section. Fires within this section are typically stand replacing with variability in frequency, season, and intensity.

Northern Transverse Ranges Subsection

This subsection includes the north-northeast edge of the Transverse Ranges and encompasses approximately 865 acres of Tejon Ranch. This subsection contains large areas of Pre-Mesozoic gneisses, Mesozoic granitic rocks, Tertiary marine and non-marine sedimentary rocks, and Quaternary sediments. The Tertiary marine sedimentary rocks are mostly Eocene and Oligocene, and some are Miocene and Pliocene. The soils are mostly Lithic and shallow Typic Xerorthents, Entic and Pachic Haploxerolls, Typic and Pachic Argixerolls, Mollic Haploxeralfs, Typic Xerochrepts, Pachic Haploxerolls, and Mollic and Ultic Haploxeralfs. Most of the soils are leached free of carbonates. The soils are well drained, and most have been leached free of carbonates. The soil temperature regimes are mostly thermic and mesic, and the soil moisture regimes are xeric (USFS 1997).

The vegetation and land types present within this subsection of Tejon Ranch include: foothill woodland and non-native grassland.

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2 BACKGROUND

The Tejon Ranch Conservancy's mission is to conserve biodiversity on Tejon Ranch through long-term science-based stewardship. Pursuant to the Agreement, adaptive management and monitoring will be used by the Conservancy towards the goal of achieving biologically equivalent or superior conservation in the Conserved Lands and Acquisition Areas.

2.1 ADAPTIVE MANAGEMENT

Environmental management involves decision-making at varying levels of uncertainty, due to gaps in data or a lack of understanding of the ecosystems being managed. Adaptive management attempts to systematically reduce this uncertainty by evaluating management actions through experimentation (Murray & Marmorek 2004). Adaptive management is often referred to as "learning by doing," placing an emphasis on monitoring the outcomes of management in order to learn about their effectiveness (Holling 1978; McCarthy & Possingham 2007; Walters 1986). The integration of design, management, and monitoring through a combination of research and action allows environmental managers to test hypotheses and adapt management actions (Cottingham et al. 2001; Salafsky et al. 2001). Adaptive management should be used to improve environmental management while understanding the impact of incomplete knowledge (Schreiber et al. 2004).

The key starting point in adaptive management is the definition of conservation goals and the objectives of the overall project (Margoluis & Salafsky 1998). Adaptive management is dependent on the clear articulation of goals, such as conservation of biodiversity or maintenance of oak regeneration potential, to focus management objectives. Flexible goals, as well as a long-term commitment to detailed monitoring, are important in adaptive management in order to adjust and build knowledge (Murray & Marmorek 2004; Pastorok et al. 1997). Well-defined project objectives lay out a road map for the project (Pastorok et al. 1997). These desired outcomes, and the uncertainty about how to achieve these outcomes, drive the adaptive management process (Murray & Marmorek 2004).

Once management objectives have been defined and ecosystems identified, existing information for each ecosystem should be compiled through biological surveys, literature reviews, and an analysis of historical photographs and maps. The compiled information presents a baseline to monitor changes in the ecosystem, as well as to identify constraints and driving processes within the ecosystem (Haney & Power 1996). Existing knowledge should be described through conceptual models to promote a consensus, while identifying uncertainties in the system (Salafsky et al. 2002). The aim of conceptual models is to create a simplification of the relationships within an ecosystem in order to understand the environmental stressors and efficiently improve the ecosystem through an adaptive management approach (Haney & Power 1996; Sainsbury et al. 2000; Salafsky et al. 2002).

Following the implementation of management practices, an adaptive management process includes the monitoring and evaluation of an ecosystem (Murray & Marmorek 2004). Effective monitoring must include measurements in order to learn from failures and work efficiently towards conservation objectives (Redford & Taber 2000; Salafsky et al. 2002). For learning to occur, the information collected must be within the parameters identified in conceptual models of the system, in relation to the conservation goals (Schreiber et al. 2004). Monitoring data is used to validate or adjust components of the model (Haney & Power 1996). The evaluation and use of the results to modify future actions is the “closing of the loop” aspect of adaptive management (Murray & Marmorek 2004).

As a scientific process, adaptive management is vulnerable to poor planning and design, limited data, insufficient understanding of the system processes, and inadequate monitoring and evaluation (Schreiber et al. 2004). An understanding of these weaknesses can help evaluate whether adaptive management is possible for a given problem. Scientific evaluation of ecological processes in comparisons of management strategies is attractive to both scientists and managers (Carpenter 1990; Cottingham et al. 2001). Adaptive management is a process aimed at reducing the uncertainty in management decisions, as well as improving the chances of reaching specified conservation objectives (Murray & Marmorek 2004).

In order for adaptive management to be effective, conservation goals and objectives need to be formulated. Conservation goals are broad overarching statements that are brief, visionary, and inspire more specific objective setting (Tear et al. 2005). An example of a conservation goal could be the maintenance of biodiversity through time. Conservation objectives are more specific and are associated with a quantifiable metric, while conservation goals are more conceptual (Tear et al. 2005). Objectives target specific systems or outcomes and lead to the selection of a performance measure. An example of a management objective could be the maintenance of oak woodland regeneration. Performance measures are a quantifiable gauge of the condition of specified management objectives. An example of a performance measure would be surveys of oak seedling densities, where the objective is maintaining oak regeneration.

Emphasis should be placed on the conservation of representative ecosystems upon which sensitive species depend, rather than focusing solely on the recovery of endangered species themselves. This enables the conservation of non-target, but still valuable species and communities (Tear et al. 2005). Conservation planners must define performance measures that can be assessed over a specified space and time. Appropriate monitoring of the correct measures is critical to the success of adaptive management. Objective setting will employ the concepts of adaptive management in expectation of changes as scientific knowledge increases (Tear et al. 2005).

Science-based standards should also be applied to objective setting in order for conservation planning to be successful (Tear et al. 2005). Although goal selection and objective setting should be evidence-based and independent of feasibility considerations, objective setting should strive to identify multiple measureable alternatives for evaluation in order to enable an analysis of trade-offs (Tear et al. 2005). Objectives should be chosen for both short and long-term planning horizons. Additionally, objectives should be tailored to the specific biological system of concern; therefore, a variety of objectives may be needed depending on the diversity and complexity of the systems or species involved. The existence of error and uncertainty in scientific understanding of biologic processes and relationships should be acknowledged and described (Tear et al. 2005).

2.2 CONCEPTUAL MODELS

Conceptual models are an important tool to use within an adaptive management framework, and provide the foundation for decision making through the identification of drivers, stressors, processes, and endpoints. Conceptual models are visual interpretations of the current understanding of entities and relationships within a system, and are an important form of communication to an array of audiences. Conceptual models are the most important product of an environmental problem formulation exercise, and a critical component of risk assessment, management, and recovery processes (Gentile et al. 2001). When environmental managers are attempting to deal with a complex system, they must first describe it in a simple conceptual model so that they can both understand and efficiently change the system in order to solve the ecological problem (Parrish et al. 2003; Salafsky et al. 2002). Conceptual models are used to illustrate the connections between societal actions, environmental stressors, and ecological effects, while providing the basis for developing and testing causal hypotheses (Gentile et al. 2001).

The drivers and stressors controlling ecosystem structure and function, and the interactions among and between them, are identified through conceptual modeling. Drivers are large, over-arching factors that cause measurable changes in the properties of biological communities. Stressors are the physical, chemical, and biological changes that result from natural and anthropogenic drivers affecting other changes in ecosystem structure and function. Relevant drivers and stressors, and their interactions are modeled based on current knowledge and scientific understanding (Gentile et al. 2001). Drivers can be considered first-order influences, and stressors can be considered second-order influences in chains of cause and effect, where there are several links before the final effects on model endpoints (Henderson & O’Neil 2004). Stressors may affect a single resource component or may act on multiple ecosystem components simultaneously. As a result, stressor effects may be limited or widespread. Conceptual models can define relationships between drivers, stressors and ecosystem change.

To create an integrated assessment, conceptual models are used within an ecosystem management framework (Gentile et al. 2001). One role of conceptual models in the management process is to identify objectives and performance measures (Gentile et al. 2001). These models are developed by identifying drivers, stressors, processes, and performance measures, and can be used to formulate hypotheses to explain the current conditions of an ecosystem (Gentile et al. 2001). Information from site-specific surveys or case studies provides the basis for developing conceptual models of ecosystems (Pastorok et al. 1997; Schreiber et al. 2004). Through the development of conceptual models, a limited number of biological characteristics, ecological processes, and interactions with the physical environment are identified, along with linkages (Maddox et al. 2001). Performance measures (endpoints) are a quantifiable gauge selected to assess a system's response to management. These endpoints serve as a tool to measure the degree to which specified conservation goals and management objectives have been achieved. Conceptual models representing existing knowledge of a given system are crucial to identifying uncertainties, but collaboration is also essential to ensure realistic bounding of management problems, constraints on possible actions, and identification of realistic outcomes (Schreiber et al. 2004).

Conceptual models are not meant to be final or complete; rather they are to be used as a flexible framework that should evolve and change as understanding increases (Maddox et al. 2001). It is important to focus on drivers and stressors, which impact a specific environmental process of interest. Understanding of similar or related systems can be used to hypothesize relationships or stressors as additional knowledge or data is collected. Through the development of conceptual models, simplifications of reality are created that are useful to an adaptive management program (Sainsbury et al. 2000).

As a conservation management tool, conceptual models can be incorporated into all types of assessments and planning activities to describe the causal relationships among land uses, stressors, valued ecological resources, and their endpoints (Gentile et al. 2001). Conceptual models can also be used to structure management scenarios to predict the magnitude of system recovery, and are used in the initial development of performance criteria (Gentile et al. 2001). Conceptual models are developed to effectively illustrate a variety of activities and stressor-response relationships (Suter 1999a; Suter 1999b). If a conceptual model is properly developed, it captures the scientific understanding of an ecosystem and its response to natural and anthropogenic drivers and stressors (Gentile et al. 2001). A well-presented graphical representation of a conceptual model can express linkages and identify stressors clearly to an audience (Gentile et al. 2001). Conceptual models illustrate current linkages while providing a common language that people from different perspectives can understand (Salafsky et al. 2002). The appropriate levels of detail, resolution, and aggregation in conceptual models are necessary to fully communicate causal linkages for the setting, and are important for communicating with the public (Gentile et al. 2001).

Conceptual models are an extremely useful management tool for thinking through the potential efficacy of management options and for communicating to both the public and environmental managers who are not familiar with the environmental problem at hand (Gentile et al. 2001). Through the construction of a conceptual model, the scientific community can become engaged in an important dialog to clearly articulate the individual perspectives of scientists regarding how an ecosystem functions and responds to stress (Gentile et al. 2001).

Establishing baseline conditions is a key step in developing conceptual models for adaptive management. One way we compiled historical data on landscape structure was through analysis of aerial photography or satellite imagery to establish baseline conditions. Monitoring temporal landscape structure can be useful for identifying ecosystem responses to disturbance regimes such as grazing, climate change, deforestation, road density, agriculture, or other stressors (Noss 1989).

Baseline conditions help prioritize management objectives for the effective monitoring of future trends. Through the formulation of conservation objectives, conceptual models, and establishment of baseline conditions, an adaptive management approach can be taken to achieve conservation goals.

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3 METHODOLOGY

As part of the scope of this project, we collected and analyzed baseline data on the major vegetation communities that comprise the Ranch as well as their ecological stressors. This section describes the methodology used for each step in our project. These steps included performing a landscape analysis of Tejon Ranch, identifying the major environmental drivers and stressors on the Ranch, creating conceptual models for each community type, collecting baseline conditions on specific communities (Joshua tree woodlands, riparian communities, and valley oak savannas), and developing management and monitoring recommendations.

3.1 LANDSCAPE ANALYSIS METHODS

Using land cover information received from the Conservancy, we reclassified the information to represent the major vegetation communities on the Ranch (Figure 1.3-4; Davis 2009).

ECOLOGICAL LAND CLASSIFICATION

Mutual information analysis was applied in order to develop an Ecological Land Classification for Tejon Ranch. The objective was to divide the area into sub regions based on similarities with respect to one or more environmental variables (Davis & Dozier 1990). This analysis grouped vegetation types that share certain environmental attributes. By calculating the mutual information (MI) statistic between each vegetation and environmental variable, samples can be hierarchically stacked in accordance with the environmental variable that shows the highest MI statistic with vegetation.

We performed a mutual information analysis based on special correspondence between digital maps of vegetation types and other environmental variables, which included geology, soil available water holding capacity, soil pH, maximum and minimum temperatures, growing degree days above 5° Celsius, and mean annual precipitation. For our analysis, 1,000 random sample points were generated across Tejon Ranch at which we collected information on vegetation class and environmental variables. The vegetation types used in this analysis are those depicted in Figure 1.3-4. Geology data was taken from the National Geologic Map Database (USGS 2005) and soil information was downloaded from the Soil Survey Geographic Database (NRCS 2007; 2008a; 2008b; 2009). Climate data was derived from USGS data (unpublished Alan Flint).

3.2 Drivers and Stressors Methods

Literature Review

To create conceptual models and describe each of our identified nine vegetation communities, we first performed an extensive literature review on each community. Since scientific literature about Tejon Ranch's specific ecosystems either does not exist or is based on other areas in California, we primarily extracted information from articles, reports, and books written about vegetation communities in California that are also found on the Ranch. Because Tejon Ranch lies at the confluence of four major ecoregions, including regions found in both central and southern California, we looked at literature on ecosystems throughout the state. For most of the vegetation communities, we used descriptions of similar vegetation communities in southern areas such as the San Gabriel Mountains, San Bernardino Mountains, the Santa Monica Mountains, and Orange County. We also reviewed literature based on similar ecosystems in central and northern California, but found that the species composition on the Ranch better matched the systems in southern California.

While performing these literature reviews, we began to sketch out draft conceptual models of each vegetation community. As we collected more information, these models changed and grew. While sketching the conceptual models, we identified the major drivers and stressors that impact each vegetation community. However, not all drivers and stressors applicable to systems in other regions of the state apply to Tejon Ranch's ecosystems. For instance, one major driver of environmental change in montane forests in California is the logging industry. But according to Tejon Ranch Conservancy staff, there has not been extensive logging on the Ranch for over 100 years; thus, that driver was not included in our conceptual model. Other drivers, such as population growth and development, had to be adapted to the Ranch's vegetation communities. For instance, development around the Santa Monica Mountains in Los Angeles County is at a much larger scale than the area surrounding Tejon Ranch, so for a vegetation community such as chaparral, the impact of development on the Ranch was adjusted. Air pollution is another example of a stressor that we had to adapt existing literature to figure out potential effects on the Ranch. To account for air pollution's affects on Joshua Trees, we found most of the literature focused on Joshua Tree National Park and the air pollution sourced from the Inland Empire and the Los Angeles basin. However, in Tejon Ranch, the wind patterns and the degree of air pollution from the Los Angeles basin are different than what Joshua trees in the National Park experience. These adjustments to drivers and stressors on Tejon Ranch led to uncertainties in the degree to which these drivers and stressors exist on the Ranch.

STRESSOR BASELINE CONDITIONS

To address these uncertainties, we collected baseline information on various drivers and stressors present around the Tejon Ranch landscape. Since we wanted to describe the specific conditions on Tejon Ranch, we had to find data specific to the Ranch or surrounding areas. We searched old paper accounts from the Tejon Ranch Company for hunting records, pulled historical information from climate stations to describe temperature and precipitation trends, and analyzed fire perimeter records to describe the fire regime. We also collected data from air quality stations to describe trends in air pollution levels, collected census data to create population density and growth maps, and attempted to find records on hydrology and grazing on the Ranch. To see the results of our driver and stressor baseline data collection and synthesis, please see Section 6.

3.3 CONCEPTUAL MODEL METHODS

Once we had an idea of the magnitude of the drivers and stressors on the Ranch, we went back to the drafts of our conceptual models to make applicable edits. After multiple iterations of each conceptual model, we completed our eight conceptual models for vegetation communities on the Ranch (Section 7), and one model on societal drivers (Section 5). We chose not to include drivers in our vegetation community models, instead capturing their effect on stressors in the Societal Model.

To create each conceptual model, we read literature on model development and became familiar with the main function of a conceptual model in ecology and environmental management (Section 2.2). We also reviewed existing conceptual models for other areas, such as those created by the Biogeography Lab at the Bren School (www.biogeog.ucsb.edu), for use in the Santa Monica Mountains, and others created for Pinnacles National Monument. With those lessons and examples in mind, and following our vegetation community literature reviews described above, we created our conceptual models using Microsoft Visio software. Because conceptual models can vary drastically, our group came to an agreement on a standard format to display and construct our models.

3.3.1 CONCEPTUAL MODEL STRUCTURE

The top level in our models illustrates landscape-level stressors, such as air pollution and climate, which are indicated by blue boxes. The second level is ranch-level stressors, such as hunting and grazing, which are indicated by yellow diamonds. For each vegetation community, the stressors that impact the community may be different, and we chose to only include stressors that had large or ecologically important impacts. The third level in our models required the most analysis: key environmental processes (green hexagons). For each vegetation community we could have identified dozens of processes; however, the more detailed our models became, the harder they were to follow. Since our main reason for creating these conceptual models was to communicate important relationships, we only included processes that had the largest or most important effects in the system. These processes include such things as oak seedling establishment and nitrogen deposition. The final level in our conceptual models illustrates the main endpoints, which are monitoring targets to measure the community's health. Pink represents community level, orange represents species level, and purple represents landscape level endpoints. For example, a community level endpoint could be a survey of species composition. We selected our endpoints based on several criteria, including, but not limited to, whether the endpoint is feasible to measure, easily repeated, and responsive to management.

The next step in the creation of our conceptual models was to create linkages between stressors, processes, and endpoints. The blue lines show positive relationships. For example, more grazing can lead to more invasions by non-native species. The red lines show negative correlations; for example, more air pollution can lead to reduced foliage health. The black lines show uncertain relationships. Many of the uncertain relationships are good opportunities for future monitoring and field research as part of the adaptive management plan. The connections from drivers to stressors to processes to endpoints can be followed in either direction, in order to explain what may be occurring in the vegetation community.

While creating the conceptual models, we also wrote accompanying narratives (Section 7). The narratives were created based on information gathered from literature reviews, observations in the field, and personal communication with experts. The conceptual models and narratives can be used to help inform management decisions, address uncertainties, and communicate the complex processes within vegetation communities on Tejon Ranch.

3.4 BASELINE CONDITIONS METHODS

In order to gain a more comprehensive understanding of the vegetation communities on the Ranch, we conducted baseline conditions research on Joshua Tree Woodland, Riparian, and Valley Oak Woodland vegetation communities.

3.4.1 JOSHUA TREE WOODLANDS

Height Distribution Survey

We did an initial survey of Joshua tree heights on the south side of Tejon Ranch in the fall of 2009. Through this survey we documented the heights of Joshua trees for over 300 individuals. Our initial baseline surveys document the number of trees and Joshua tree heights within belt transects. To perform Joshua tree height surveys, surveyors laid out two 100-meter transect lines in the same direction, five meters apart to form a belt transect. Next, surveyors walked through the belt transect, starting at one end, documenting the heights of each tree on the data sheet. For trees below one meter in height, surveyors measured the height with measuring tape. For trees above one meter, surveyors estimated height. Height was measured from the ground to the highest branch. Please see Joshua tree monitoring recommendations in Appendix C for a more thorough and updated protocol for future surveys.

Changes in Joshua Tree Distribution Through Time

To document changes in Joshua tree distribution on the Ranch over time a Joshua tree mapping exercise was performed, comparing historic aerial imagery from 1952 to aerials taken in 2009. This analysis focused on Joshua tree woodlands within the Tri-Centennial Acquisition Area (Figure 1-2). The exercise involved overlaying a 50 meter point grid across the area, and assessing the presence or absence of Joshua trees at each grid point. The attribute table of the 50 meter grid layer was edited to identify the presence or absence of trees for both aerial photos. A comparison was then done between the number and location of presence points in 1952 and 2009.

3.4.2 Riparian

Riparian Assessment Survey

Assessment of the baseline biological conditions of the Ranch's riparian communities involved the collection and analysis of quantitative, descriptive data on riparian vegetation species composition and community structure. For the collection of descriptive riparian baseline data, we developed and implemented a standardized data collection methodology that involved qualitative reach delineation and stratified sampling of quantitative structural and compositional data along linear transects.

This assessment first involved the qualitative classification of riparian communities on the Ranch by conducting a reach delineation survey in 11 drainages. Surveyors delineated "like reaches" based on vegetation type. This was followed by standardized quantitative sampling within four of the major drainages on the Ranch, paired by watersheds. The drainages surveyed included Tejon Creek and El Paso Creek on the San Joaquin Valley side of the Ranch and Big Sycamore Canyon and Little Oak Canyon on the Antelope Valley side of the Ranch. Our methodology involved stratified random sampling of linear transects by reach.

The quantitative survey included surveyors randomly selecting two linear transects within each reach oriented perpendicular to the direction of flow within the stream. At each sample transect surveyors documented site conditions with digital photographs taken perpendicular to the channel as well as photos taken facing upstream and downstream. Surveyors then recorded GPS waypoints, latitude and longitude, and elevation using a handheld Geographic Positioning System (GPS) receiver. Along each transect, vegetation was sampled using a modified vertical quadrat sampling method (Curtis & Bignal 2004) to measure the relative contribution of different species or taxa to the overall vegetative cover of the riparian canopy within pre-defined strata or height classes. Along the sampling transects, surveyors measured species composition and community structure at one-meter intervals using a combination of line-intercept and vertical cube sampling. At each meter the surveyors visually estimated the percent cover by cover class of each species in four strata/height classes (defined as 0-1 m, 1-4 m, 4-8 m, & 8+ m). Along each transect the surveyors also measured the basal area and stem density of riparian trees and shrubs within a five-meter belt transect oriented perpendicular to the direction of flow. This allowed us to collect a representative size/age profile of the riparian tree component and to estimate tree and shrub coverage within the riparian zone of influence. Data collected through belt transects includes the diameter-at-breast-height (DBH) of adult trees (trunk diameter measured at 4.5 feet above ground surface), stem density (stems/ha) of shrubs and saplings (1-5 m tall), and stem density (stems/ha) of seedlings (woody vegetation <1 m tall) within each transect. In addition, each belt transect included a count of seedlings and saplings as a metric to quantify recruitment in the riparian zone. Characteristic hydrogeomorphic (HGM) data including channel width, depth, bank angle, approximate stream gradient, flow regime (perennial/non-perennial), and substrate size class were measured (channel widths and depths) or visually estimated (bank angles, gradients, substrate size) and recorded. A copy of the complete riparian assessment survey data sheet is included within Appendix D.

Data Entry and Analysis

After collecting quantitative and categorical transect data, the collected data was recorded into a Microsoft Excel Access database for data management. All species and environment data was then exported from Microsoft Access as comma delimited text (CSV) files which were subsequently imported into PC-ORD v. 4 (McCune & Mefford 1999) for analysis. We then added a field for flow accumulation and for the regional watershed to the newly created environmental matrix in PC-ORD.

GIS analysis

Using the ArcHydro toolkit in ESRI's ArcGIS ArcMap 9.3.1 (ESRI 2009) software package, a flow direction raster was generated using a 30-meter resolution Digital Elevation Model (DEM). Arc Hydro was then used to calculate the flow accumulation at each of the sampling transect locations.

Statistical Analysis: DCA ordination

Using the transect data collected during the riparian assessment surveys, a detrended correspondence analysis (DCA) was conducted (see Chapter 20 in McCune, Grace, & Urban 2002). DCA ordination enables ecologists to analyze samples by the presence of shared species that involves the ordering of samples (plots and transects) in ordination space, based on species similarity. The closer the samples are in ordination space, the more alike they are in species composition. DCA allows further analysis of statistical correlation of environmental variables from the environmental matrix with the ordination axes to determine their strength of prediction of sample species composition (McCune, Grace, & Urban 2002).

Statistical Analysis: Cluster Analysis & Species-Environment Biplot

A cluster analysis (see Chapter 11 in McCune, Grace, & Urban 2002) was performed to classify the sampling transects into groups based on species composition, enabling us to examine whether there appeared to be any generalizations that we could make about the co-occurrence of certain species within discrete groups. In order to group the samples by species, a cluster analysis using the Sorenson distance metric and a Flexible Beta linkage function of -0.25 was performed in PC-ORD (McCune & Mefford 1999). The cluster analysis was then pruned by the objective function measure of remaining information. All cluster analysis model parameters were selected based on the recommendations of McCune & Grace (2002).

Using the DCA ordination graph we then generated a species-environment biplot. A species-environment biplot graphically depicts important environmental variables as vectors relative to the ordination axes, with their relative lengths showing how strongly they correlate to the species that define the axes. Coupling the DCA ordination and cluster analysis with the species-environment biplot allows for the interpretation of species assemblages along gradients of environmental variables.

3.4.3 OAK WOODLANDS

Size Distribution Survey

Surveyors completed an initial survey of valley oak sizes on Tejon Ranch in the fall of 2009. The data was collected by groups of two in a portion of Old Headquarters Acquisition area (Figure 1-2). Each group of surveyors measured the DBH of every valley oak they encountered for a 30-minute period. The presence of saplings/seedlings or snags were also recorded. After a tree was surveyed it was marked with grass and twigs to notify other groups that it had already been surveyed. Through this survey DBH was measured for over 200 valley oaks. The goal of this survey was to collect data that could be used to determine an age distribution and recruitment success in the area.

Change in Distribution Through Time

In addition to collecting data on size distribution of oaks, change in canopy cover over time was calculated. Aerial interpretation and GS analysis were used to compare oak canopy cover between 1952 and 2009 within the Old Headquarters acquisition area (Figure 1-2). Multivariate Spatial Analyst tools, ISO Cluster and Maximum Likelihood Classification, were used to identify and classify the spectral bands within the aerial imagery. Only adult canopies larger than 150 square feet were used in this analysis. Species level distinctions were not able to be made at this scale, therefore only overall canopy cover was determined. Area of oak canopy cover for 1952 and 2009 were then calculated and compared.

3.5 MANAGEMENT AND MONITORING RECOMMENDATION METHODS

Using the conceptual models, an analysis of baseline data, and a thorough literature review, we developed adaptive management and monitoring recommendations for each of the vegetation communities on the Ranch. The development of management and monitoring recommendations entailed a thought exercise where we identified empirical data that would be useful feedback for management decision-making. These recommendations also were formulated with a research design that would allow for manipulative management and data collection. The adaptive management and monitoring recommendations fall generally into two classes: (1) the collection and analysis of additional baseline data to fill existing data gaps and establish environmental baselines; and (2) active experimental designs and actions (such as installing grazing exclosures) and subsequent quantitative or qualitative sampling. The vegetation community specific adaptive management and monitoring recommendations are included within the vegetation community sections (Section 7) of this document. The stressor-specific management and baseline data collection recommendations are presented with the stressor discussion in Section 6.

4 LANDSCAPE ANALYSIS

To classify the Ranch into distinct vegetation communities, we used land cover types in Figure 1.3-4 to select eight vegetation communities that represent the major systems present on the Ranch. The eight communities identified include:

- Chaparral
- Joshua Tree Woodlands
- Montane Mixed Hardwood & Conifer Forests
- San Joaquin Valley Grasslands
- Antelope Valley Grasslands
- Riparian
- Valley Oak Savanna
- Foothill Blue Oak Woodlands

These eight communities represent the dominant vegetation types as well as the unification of similar vegetation types into larger communities.

ECOLOGICAL LAND CLASSIFICATION

To develop an Ecological Land Classification for Tejon Ranch, we performed a mutual information analysis with the objective to divide the Ranch into sub-regions based on similarities with respect to one or more environmental variables (Davis & Dozier 1990). This analysis grouped vegetation types that share certain environmental attributes. The hierarchical tree output of our analysis can be seen in Figure 4-1. Based on our analysis, we found that the statistical association between vegetation and maximum temperature was the strongest (MI = 3,833.27), as can be seen from its placement at the top of the tree in Figure 4-1. Once the samples were stratified by maximum temperature, the next strongest association varied for each class, but showed that geology (MI = 1,625.82 and MI = 252.36), minimum temperature (MI = 400.54), and growing degree days above 5 degrees (MI = 167.25) had a high level of influence on vegetation type.

The next level in the hierarchy showed the different classes having varying influences. The strong association between vegetation pattern and maximum temperature is not surprising, as the influence of temperature on vegetation type is fairly intuitive. The climatic data used in this analysis are all influenced by elevational gradients. We did not include elevation in our analysis, but it is a strong determinant of vegetation type on the Ranch. The climatic variables analyzed here may directly relate to changes along elevation gradients.

The goal of this analysis was to characterize the distribution of vegetation types on Tejon Ranch. The gray boxes in Figure 4-1, to the right of the second level, show the percentages of the strongest vegetation class represented for each maximum temperature class. For areas where maximum temperature was below 30 degrees, mixed oak, foothill woodland, and scrub oak chaparral vegetation classes dominated, whereas in areas where maximum temperature was above 35 degrees non-native grassland, agriculture, and valley scrub vegetation classes were the dominant vegetation types. A histogram of the frequency distribution of the different maximum temperature classes across the Ranch is represented in Figure 4-2. The results suggest that broad climate zones, highly correlated with elevation, appear to have a large influence on vegetation, as does geology.

The land classification scheme can be useful in understanding the complex relationships between vegetation and environmental variables. The results obtained through this analysis may differ depending on layer resolution and accuracy, as well as the method chosen for classifying continuous variables. Sensitivity analysis of the variable classes will help show the importance of certain variables. Testing our results with other land classifications in the region is an appropriate measure of accuracy. Davis and Dozier (1990) performed a mutual information analysis of a region in southern California and while the environmental variables used in their analysis differ from the ones used in our analysis, both analyses demonstrated that vegetation is strongly associated with changes in topography. Davis and Dozier (1990) found radiation as the second level of the hierarchy, which is directly related to elevation. This elevation gradient was also found in our model as maximum temperature.

The results of this analysis indicate that climate has the strongest influence on vegetation type. The future distribution of the Ranch's vegetation communities could be impacted by climate change. In order for the Conservancy to adapt to and understand changes in climate, we recommend detailed climate monitoring across varying elevations on the Ranch. Future iterations of this analysis are recommended to better understand the relationships between vegetation and other environmental variables that were not analyzed.

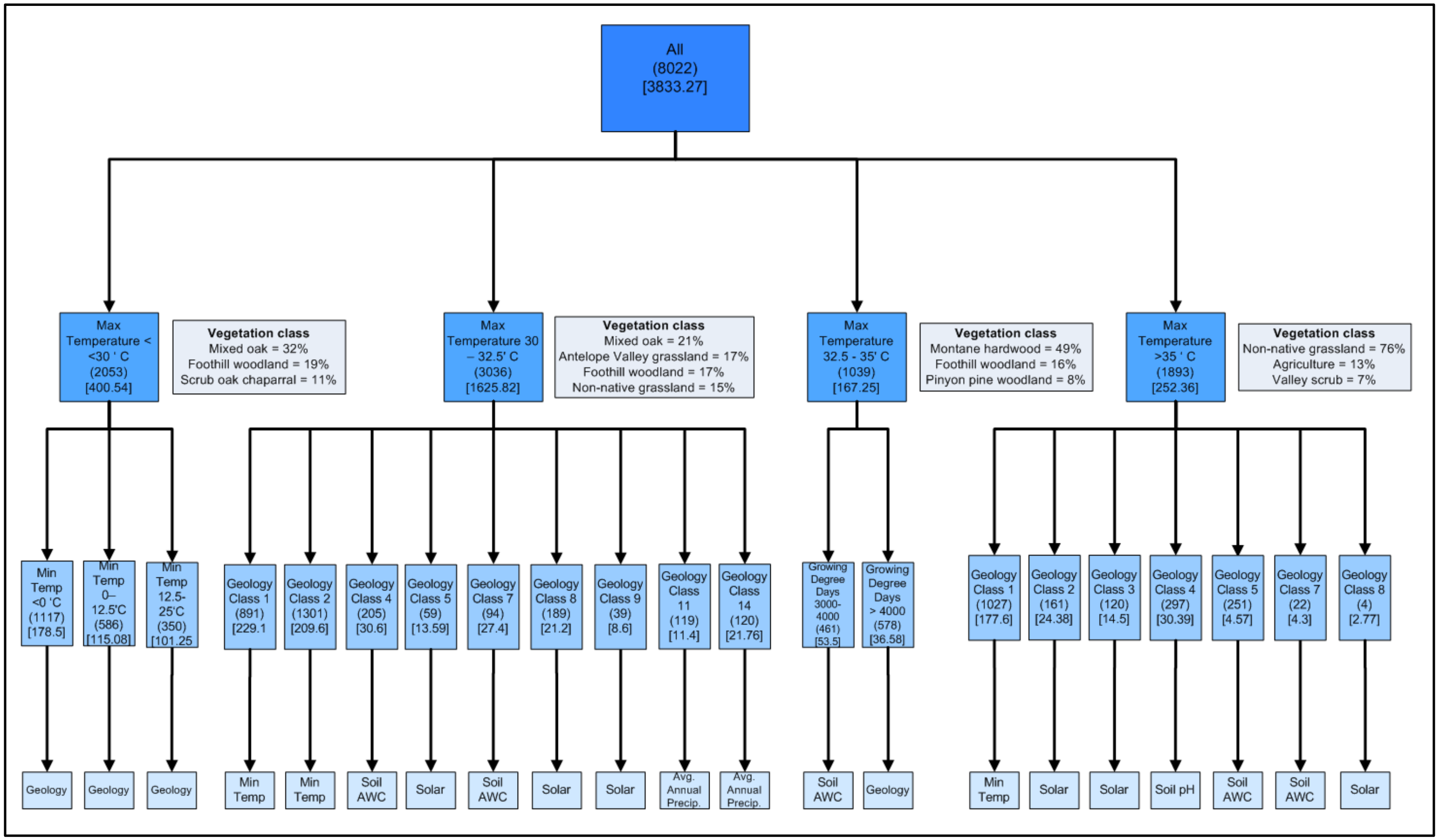

Figure 4-1. Ecological Land Classification. Based on mutual information (MI) analysis of 10,000 samples on Tejon Ranch. Numbers in parentheses are the sample size for each class and numbers in the brackets are the MI statistic. Geology classes: 1) Eocene marine rocks; 2) Miocene marine rocks; 3) Miocene nonmarine rocks; 4) Oligocene nonmarine rocks, unit 2; 5) Quaternary alluvium and marine deposits; 7) Tertiary nonmarine rocks, undivided; 8) Tertiary volcanic flow rocks, 9) Mesozoic granitic rocks, unit 3; 11) Pre-Cenozoic metasedimentary and metavolcanic rocks undivided; and 14) water.

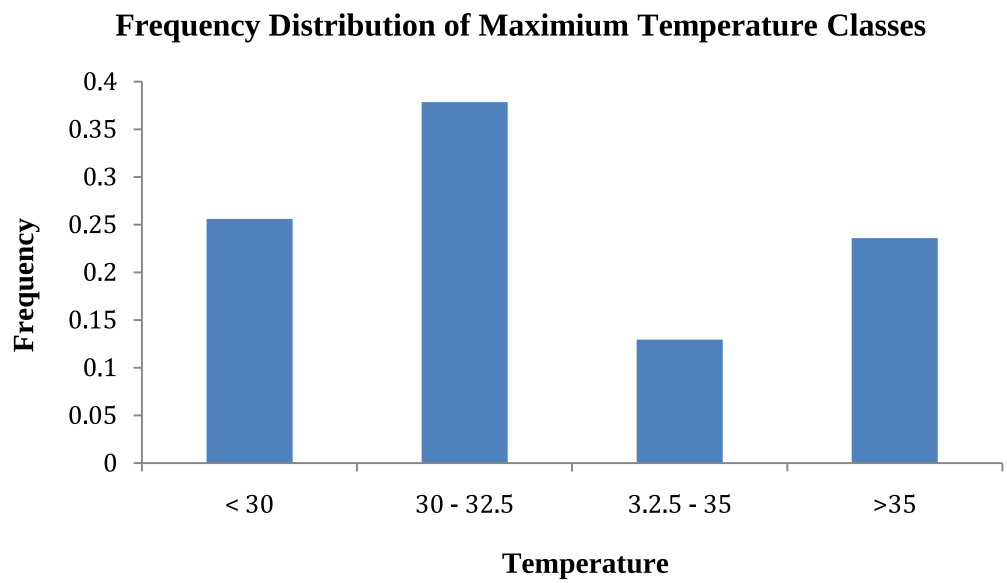

Figure 4-2. A histogram of the frequency distribution of maximum temperature classes across the Ranch. *Source: Alan Flint, Unpublished data USGS.*

5 SOCIETAL CONCEPTUAL MODEL – DRIVERS OF ENVIRONMENTAL CHANGE

A societal conceptual model provides a useful framework to contextualize the effects of higher-order ecological drivers on individual vegetation communities or ranch-level systems. Drivers are overarching processes and pressures above the level of the community-specific conceptual models that result in stress on natural resources and ecosystem functions. For our purposes, these drivers and stressors are assessed in the context of their influence on ranch-specific ecosystem processes and resulting biological conditions which can be found in our community-specific models. In general, changes in resource use and environmental degradation are driven by population growth and the increased demand for resources. The effects of population growth and improved quality of life are manifested in the following regional and ranch-wide drivers:

- *Climate change* through the increased emissions of greenhouse gases (GHG) has impacts at the global and regional scale.
- *Demand for recreational resources* will likely be increasing, as both active recreation such as hunting, and passive recreation such has hiking, have impacts as a regional level stressor.
- *Fire protection* as a regional or landscape level ecosystem driver will likely increase in demand, which may lead to fuel modification at local and regional levels.
- *Land use patterns* may change, such as through urban development, and is a regional ecosystem driver.

When combined, these drivers and their resulting stressors lead to changes in ecological processes and environmental impacts associated with land use and resource management practices. Examples include the impacts of aerial drift of agricultural pesticides and vegetation type conversion due to fire suppression.

SOCIETAL CONCEPTUAL MODEL STRUCTURE

Using the drivers identified above, we created a societal conceptual model for Tejon Ranch (Figure 5-1). The model displays drivers and stressors at multiple spatial scales. The regional-level represents drivers or stressors that occur outside of the Ranch boundaries, the ranch-level includes drivers and stressors that occur within the Ranch, even if the source is external. Drivers are represented by trapezoids, with seven primary anthropogenic drivers identified. For example, in one pathway, increased urbanization and altered land use contributes to increased extent of urban-wildland interface, leading to habitat degradation, fragmentation, traffic, and invasive species. Regional-level stressors are represented by blue rectangles, ranch-level stressors by yellow diamonds, and stressors that occur at both scales are indicated by green circles.

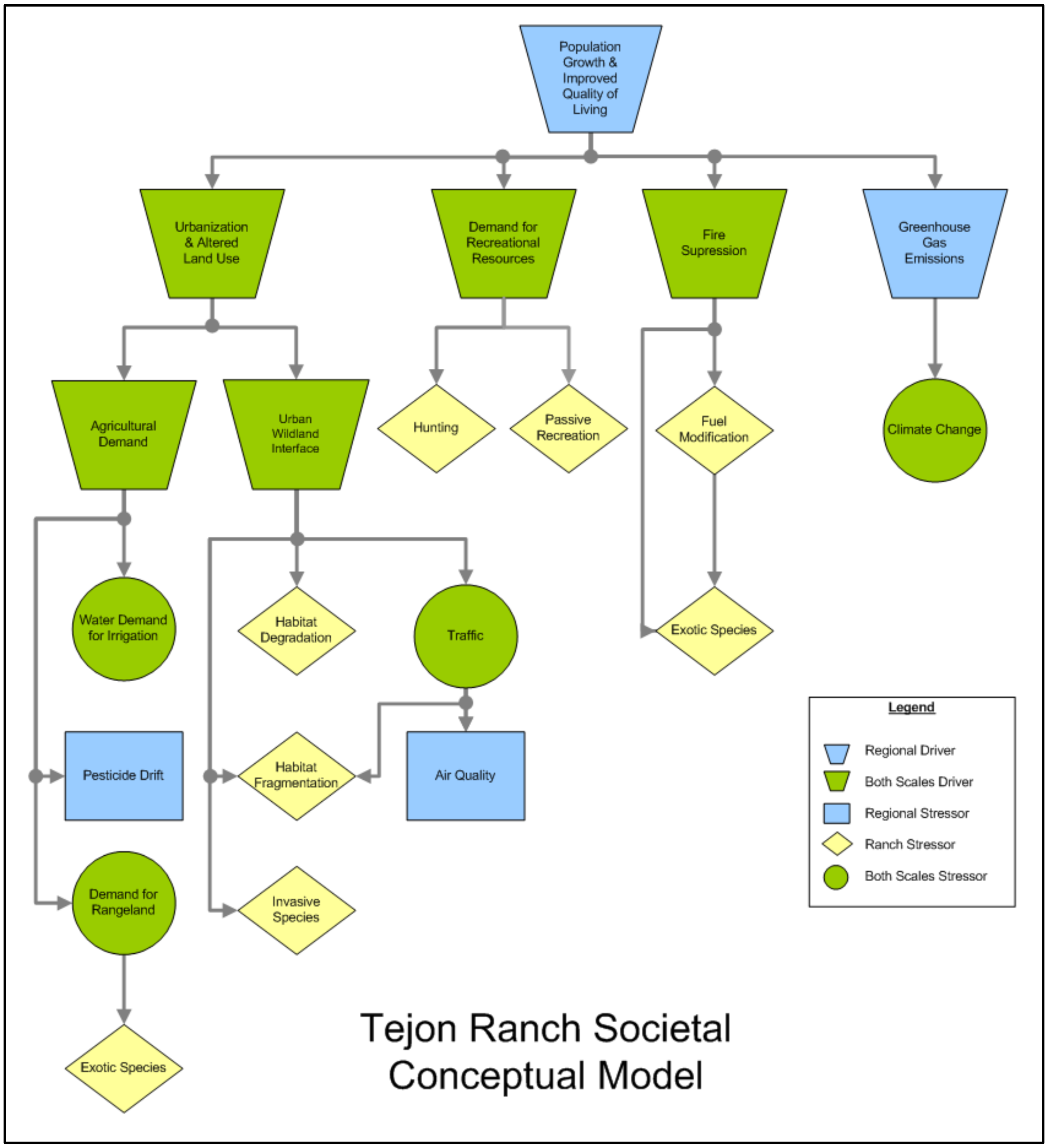

Figure 5-1. Societal Conceptual Model.

5.1 POPULATION GROWTH

In order to document human population growth in the areas surrounding Tejon Ranch, we collected population census data from 1990 and 2000 (U.S. Census Bureau 2009; Jantz 2010). Using ArcGIS (ESRI 2009), we displayed census data in maps of Tejon Ranch and the surrounding 15 miles of the Ranch border. Absolute population levels in the year 2000 are shown in Figure 5.1-1. We also created a map showing absolute change in population (Figures 5.1-2) and a map reflecting our calculations of percent change in population density (Figure 5.1-3). Our maps and data analysis indicate that population growth is increasing in most areas around the Ranch, particularly to the north and north-east. Population density is especially increasing in areas of Kern County around Bakersfield.

This increase in human population should be considered in the creation of the RWMP in two ways. First, many stressors and drivers are directly influenced by human activities, such as air pollution, fire, and hunting. Therefore, an increase in human population around the Ranch may lead to an increase in many or all of these stressors. Secondly, it can be inferred that an increase in population density in the Tejon Ranch vicinity may lead to an increase in demand for hunting and recreational opportunities. When developing the public access part of the RWMP, the Conservancy can use this data to help show the need for recreational space in the area.

5.2 CLIMATE CHANGE

Greenhouse Gases (GHGs) are a group of gaseous compounds including carbon dioxide, water vapor, nitrous oxide, methane, and chlorofluorocarbons that have been linked to atmospheric warming (IPCC 2007). Increased atmospheric GHG levels have resulted from many anthropogenic sources including fossil fuel combustion and deforestation. GHGs have been shown to cause increased entrapment of long-wave radiation emitted from Earth's surface, a phenomenon similar to the warming of a greenhouse. Long-term global changes in climate have been documented as a result of increased concentrations of greenhouse gases. As the Intergovernmental Panel on Climate Change (IPCC) stated in 2007, "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007). The global and regional effects of anthropogenic climate change that have been observed or hypothesized and may be of concern to the Conservancy include increased temperatures, altered precipitation patterns including changes in seasonality and abundance, increased storm intensities, desertification, as well as other possible changes (IPCC 2007).

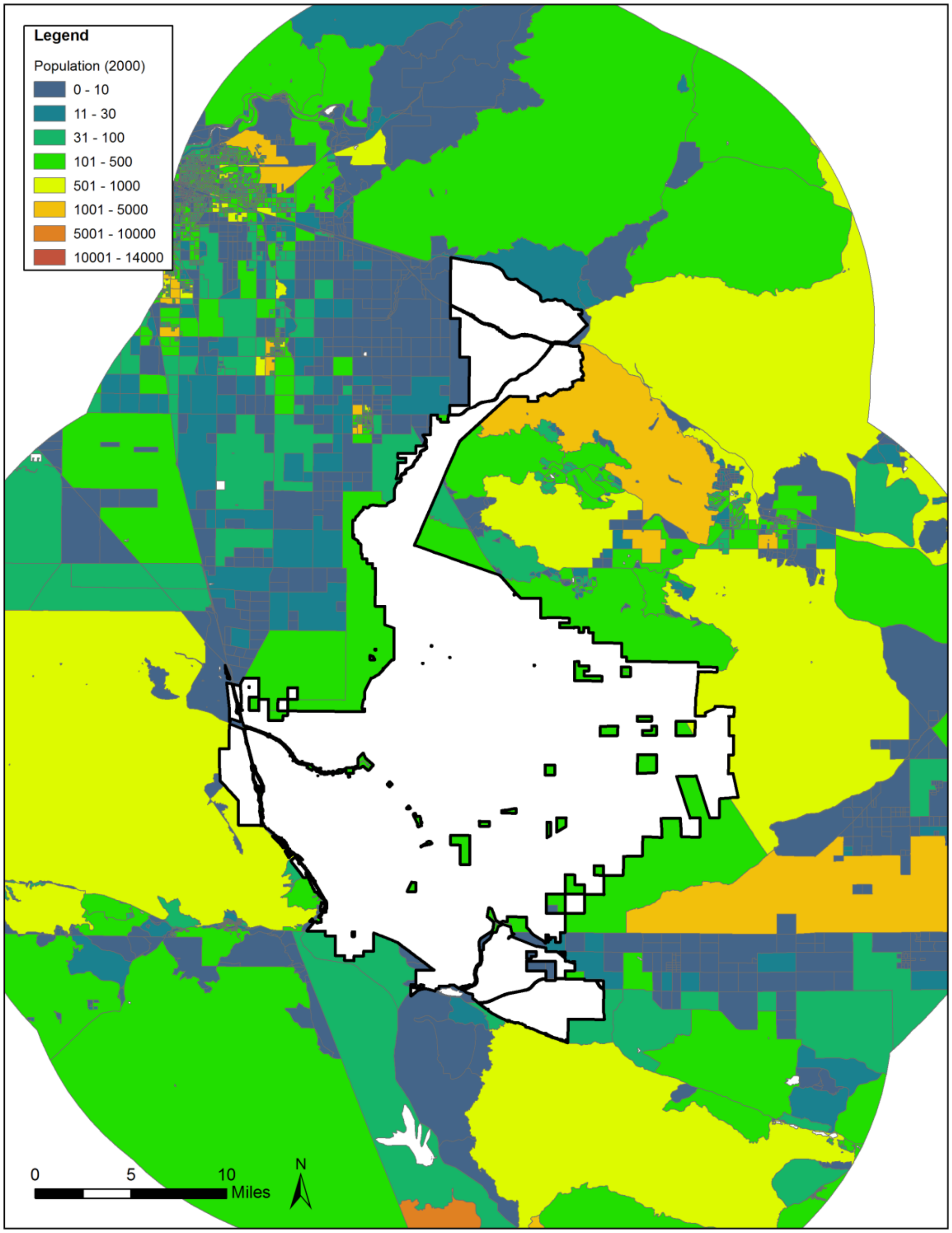

Figure 5.1-1. Human Population in the year 2000 within 15 miles of Tejon Ranch. *Source: U.S. Census Bureau 2009; Jantz 2010.*

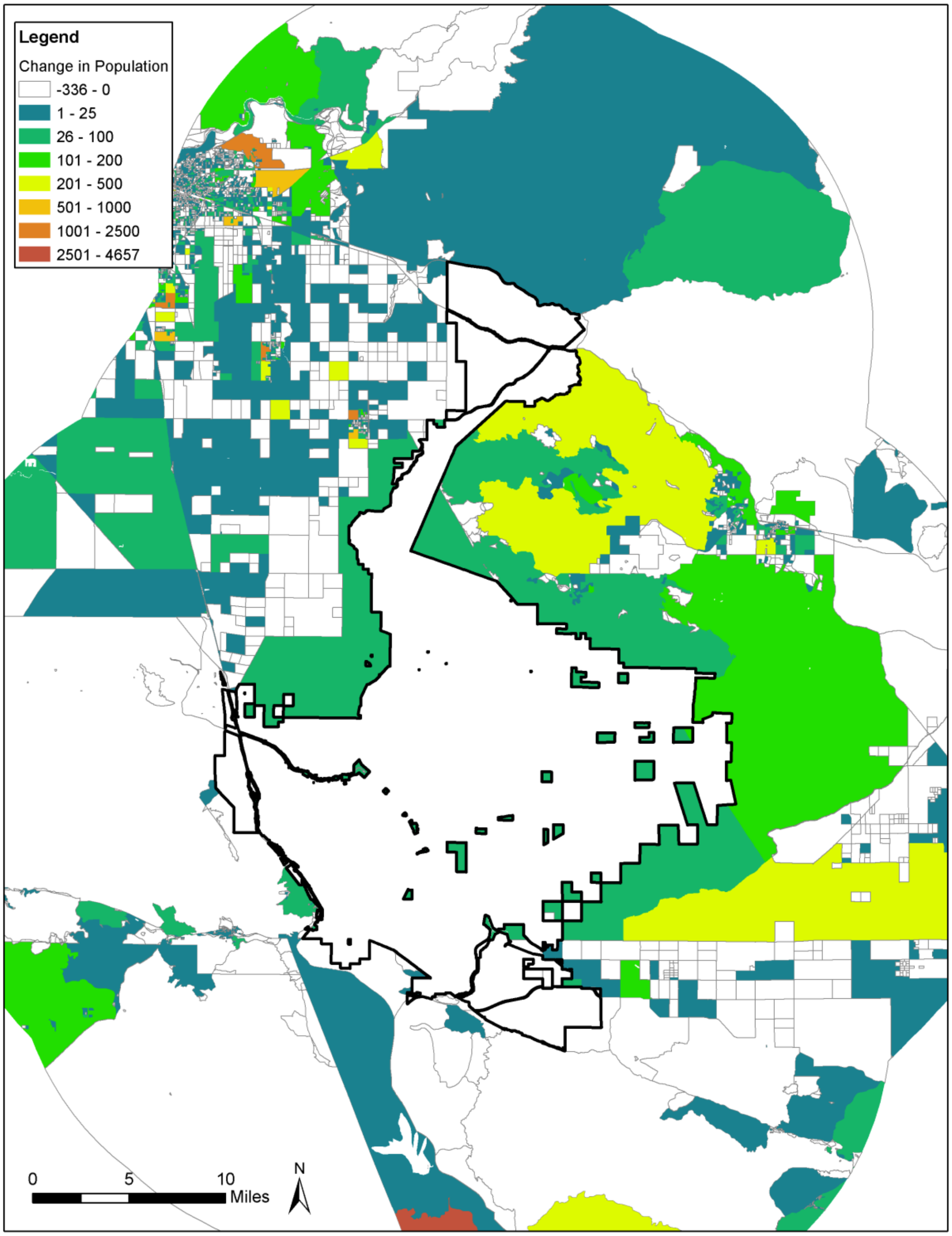

Figure 5.1-2. Absolute Change in Human Population between 1990 and 2000 within 15 miles of Tejon Ranch. *Source: U.S. Census Bureau 2009; Jantz 2010.*

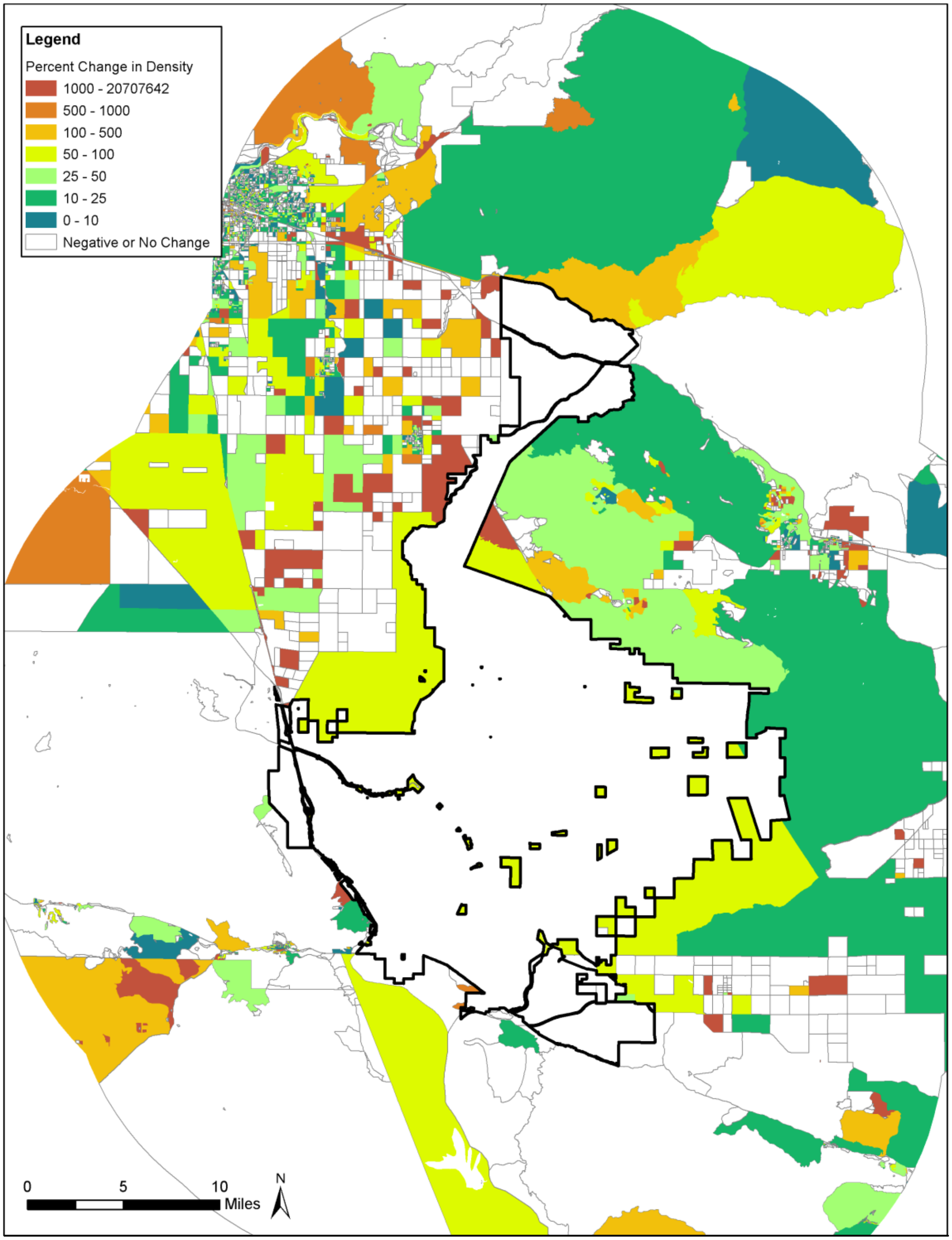

Figure 5.1-3. Percent Change in Density of Human Population Between 1990 and 2000 within 15 miles of Tejon Ranch. S*ource*: *U.S. Census Bureau 2009; Jantz 2010.*

5.3 FIRE SUPPRESSION

Increasing population at the urban-wildland interface greatly increases demand for fire protection, which involves vegetation removal for fuel modification. Human health and safety, as well as structure protection are the highest priorities for fire management in the western United States. Consideration of habitat conservation is usually secondary, although fire management decisions greatly affect terrestrial biology and environmental quality. Fire as a system stressor is discussed in more detail in Section 6.4.

5.4 LAND USE CHANGES

Development leads to urbanization of the landscape and corresponding changes in local and regional land uses. This most often involves the conversion of historically agricultural land to urban or suburban residential land uses. Urban encroachment may lead to habitat degradation and habitat fragmentation via roads and development. Within the Ranch boundaries, this may involve impacts from the conversion of open space or agricultural land to residential, industrial, or commercial development, as well as additional impacts associated with roads and infrastructure projects such as transmission lines and pipelines. Meanwhile, increased traffic density could further lead to increased habitat fragmentation, as well as noise, light, and air pollution.

On the regional scale, there has been a loss of agricultural lands through the conversion to urban and suburban landscapes in central and southern California; yet, the demand for quality rangeland and cropland to produce food persists, leading to increased land use planning conflicts. Management of surface and groundwater supplies and the demand for agricultural irrigation is a related issue. As a result of water shortages outside of the Ranch's boundaries, there is an increasing water demand for irrigation and drinking water, which must be reconciled or balanced with the naturally occurring water budget for the Ranch and its surroundings.

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6 STRESSORS

Through our literature review and development of conceptual models, we identified the major environmental stressors that impact each vegetation community. To better understand these stressors and the relative impact that they have on different regions of the ranch, we collected baseline information on the stressors present around the Tejon Ranch landscape. The results of our environmental stressor baseline data collection and synthesis are below.

6.1 AIR QUALITY

There are two distinct air basins that affect Tejon Ranch: the San Joaquin Air Basin (SJAB) to the north of the Ranch, and the Mojave Desert Air Basin (MDAB) on the south side of the Ranch. Pollution in the SJAB drifts south from as far north as Sacramento and the Bay Area, settling in the Central Valley. In the MDAB emissions are carried north from the greater Los Angeles area, and transported south from the San Joaquin Valley. The California Air Resource Board (CARB) sources major emissions within the SJAB, to agriculture, motor vehicles, forest products, oil production, and oil refining operations (CARB 2009). Major sources of emissions in the MDAB include military activities, motor vehicles, cement manufacturing, and mineral mining operations (CARB 2009). Major emissions from agricultural areas are typically in the form of ammonia and nitrous oxides from pesticides and fertilizers, as well as particulate matter in the form of dust blown from dirt roads and fallow fields. Motor vehicles and power plants are the major emitters of oxidants and nitrates.

Both the San Joaquin and the Mojave Desert Air Basins are in non-attainment (above the state standard) for both ozone and particulate matter (PM10). Ozone is formed in the lower atmosphere when nitrogen oxides, carbon monoxide, and volatile organic compounds (VOCs), react in the atmosphere in the presence of ultraviolet radiation. Ozone is a highly toxic gas both to human and ecosystem health (McKee 1994). Motor vehicle exhaust, industrial emissions, and chemical solvents are the major anthropogenic sources of ozone precursor emissions. Direct impacts to vegetation from tropospheric ozone include premature foliar senescence and abscission, chlorotic mottling, and increases susceptibility to pests. In general, ozone can damage leaves and needles of plants and is therefore linked to declines in vegetation health (Barbour 2007). Figure 6.1-1 shows that both the San Joaquin and the Mojave Air Basin's eight-hour maximum ozone level exceeded the state standard between the years of 1992-2008 (CARB 2009). Similar to tropospheric ozone, particulate matter is another major concern because it often exceeds state standards in both air basins.

Particulate matter emissions come from fossil fuel combustion, forest fires, and fugitive dust from fallow fields and dirt roads. The effects of inhaling particulate matter have been widely studied in humans and animals, such effects include asthma, lung cancer, and cardiovascular issues. Particulate matter can also be composed of chemically toxic compounds like heavily metals or VOCs. Figure 6.1-2 shows the 24-hour maximum average for particulate matter between 2.5 and 10 micrometers in both air basins (CARB 2009). The SJAB annually exceeded the 24-hour state standard during the monitoring period, while the MDAB was more closely in line with the standard.

Of particular interest for Tejon Ranch is the rate of PM deposition and its chemical composition. Deposition of nutrients, mainly nitrogen and phosphorous, increases the availability of nutrients in the environment. Ecosystem structure and diversity can be negatively affected by nitrogen concentrations as low as 3 to 8 kg/ha/year (California Energy Commission 2005). Nitrogen deposition can cause decreased plant function, promote exotic species, and leach into surface and ground waters, leading to accelerated algae growth and oxygen depletion in recipient water bodies (California Energy Commission 2005).

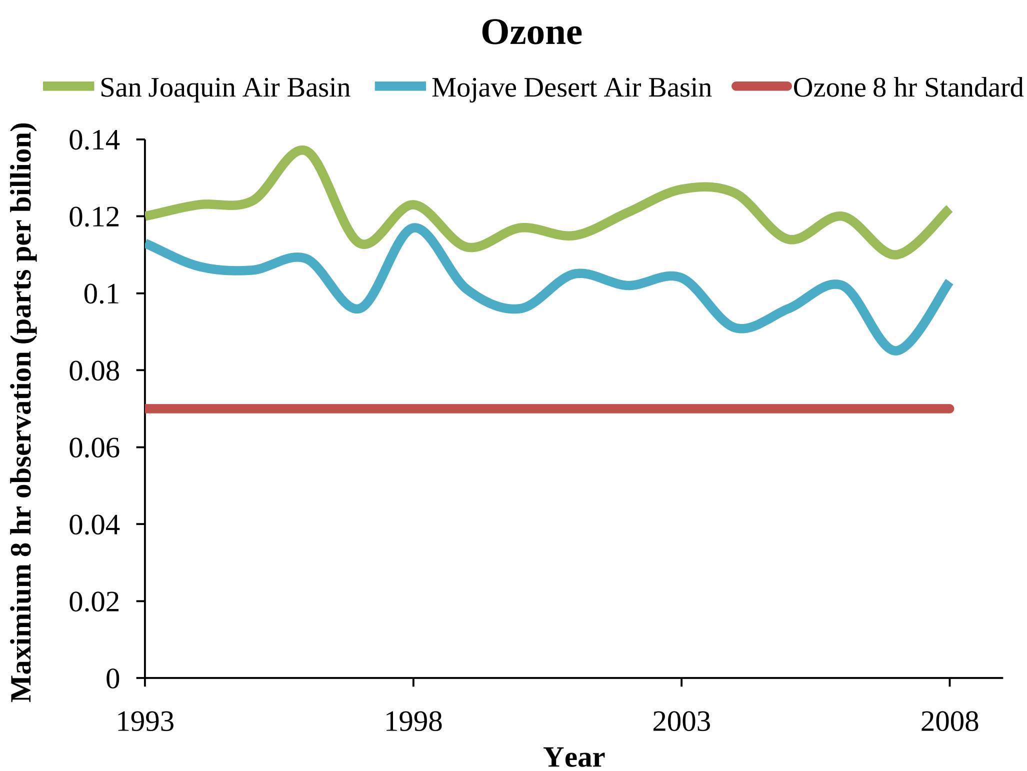


Figure 6.1-1. Ozone levels for the San Joaquin and Mojave Desert Air Basins. *Source: CARB 2009.*

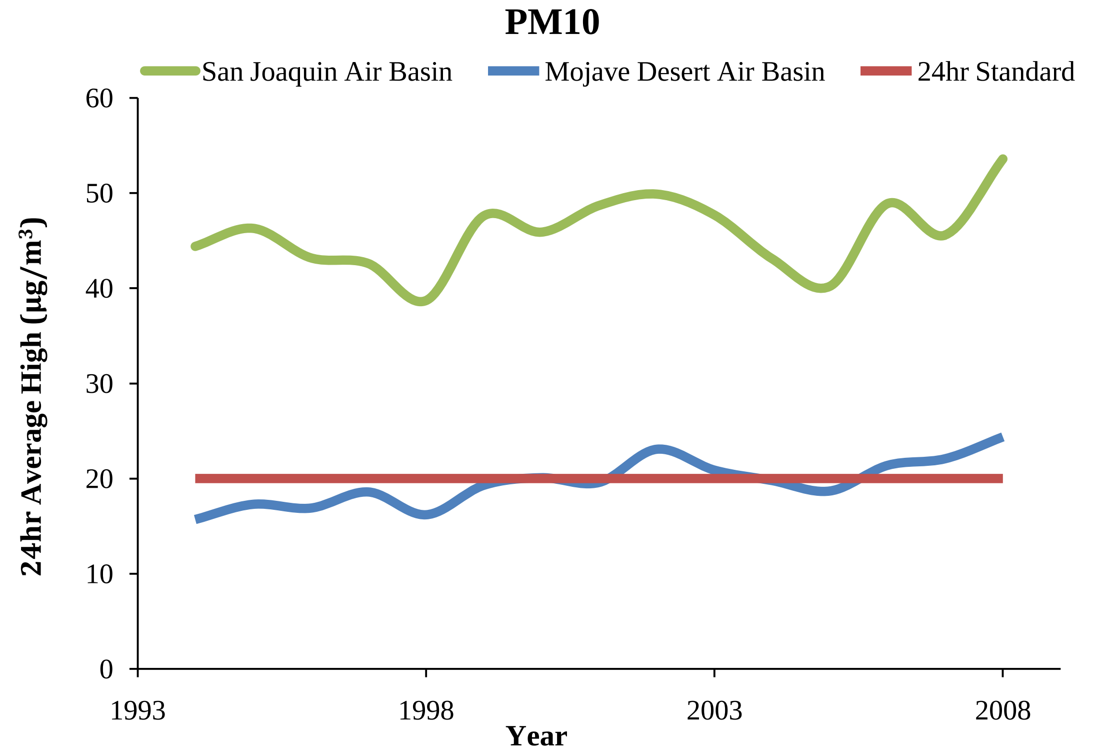


Figure 6.1-2. Particulate Matter (PM10) levels for the San Joaquin and Mojave Desert Air Basins. *Source: CARB 2009.*

6.1.1 Future Monitoring Recommendations

The air quality monitoring stations in the graphs depicted above, are located on the valley floors of each basin, and may not represent the air quality found at all elevations on the Ranch. We therefore recommend additional air quality monitoring of ozone and particulate matter, as well as the monitoring of nitrogen deposition rates at different locations and elevations across the Ranch.

6.2 Climate

Climate is a major stressor on Tejon Ranch. The effect of climate on ecosystems can be manifested through changes in stressors such as fire intensity and frequency, precipitation, temperature, and snowpack duration. With uncertainty as to how climate change could directly affect Tejon Ranch, our conceptual models address only the most important effects. Therefore, if changes to Tejon's vegetation communities are observed, the conceptual models in Section 7 may aid in determining whether those changes are due to a variety of climactic factors or from other stressors.

We collected temperature data from the Western Regional Climate Center (WRCC 2009) for climate stations around Tejon Ranch, and found that three stations had the most complete data set: Tehachapi, Sandberg, and Tejon Rancho. According to average monthly temperature records from three climate stations over the last 50-100 years, it appears that two areas of the Ranch are experiencing a trend of increasing temperatures, especially at higher elevations (Figures 6.2-1 and 6.2-2). Of the three weather station records analyzed, the two higher-elevation stations at Tehachapi and Sandberg show warming trends; whereas the lower-elevation station at Tejon Rancho shows cooling trends for both January and July average temperatures (Figures 6.2-1, 6.2-2, and 6.2-3). The results indicate that there are statistically significant trends in temperature. Significant trends include the Tehachapi January and July average temperatures, which are both increasing, the Sandberg January average temperature, which is also increasing, and the Tejon Rancho January and July average temperatures, which are decreasing.

Similarly, we analyzed historical data on precipitation from WRCC climate stations located on the Ranch or in its vicinity. For our analysis, we collected historic precipitation data from the Lebec, Tejon Rancho, Sandberg, Tehachapi, and Neenach climate stations (WRCC 2009). We conducted a linear regression of annual precipitation amounts, as well as seasonal precipitation quantities. The earliest period of record at most of the stations contained many incomplete records which were removed from the data set to normalize the data. In general, no apparent long-term trend or pattern emerged with respect to precipitation amounts or seasonality. All linear regressions yielded statistically insignificant results, as evidenced by the low R-squared values. Therefore, no solid conclusions can be drawn from the historic precipitation data. It is possible however that the lack of any discernable trend may be an artifact of the incomplete data sets.

6.2.1 Future Monitoring Recommendations

In the future we recommend that both temperature and precipitation records be kept for sites on the Ranch. Key areas of the Ranch, such as Joshua Tree Woodlands, may experience range shifts as a result of a changing climate (see Joshua Tree Woodlands in Section 7.2); thus monitoring these climate variables at different elevations on both sides of the ranch is important. Snow records are also unavailable on the Ranch. We recommend that snowpack duration and depth be monitored in the future, especially as it relates to environmental effects in montane forests.

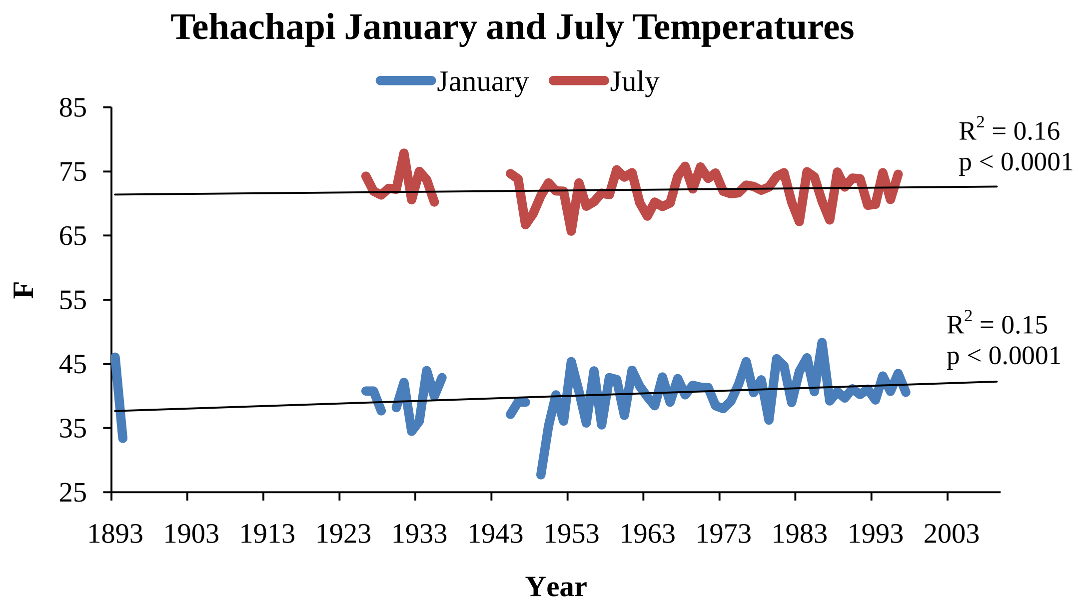


Figure 6.2-1. Tehachapi Temperatures in January & July; Elevation 4,017 ft. *Source: WRCC 2009.*

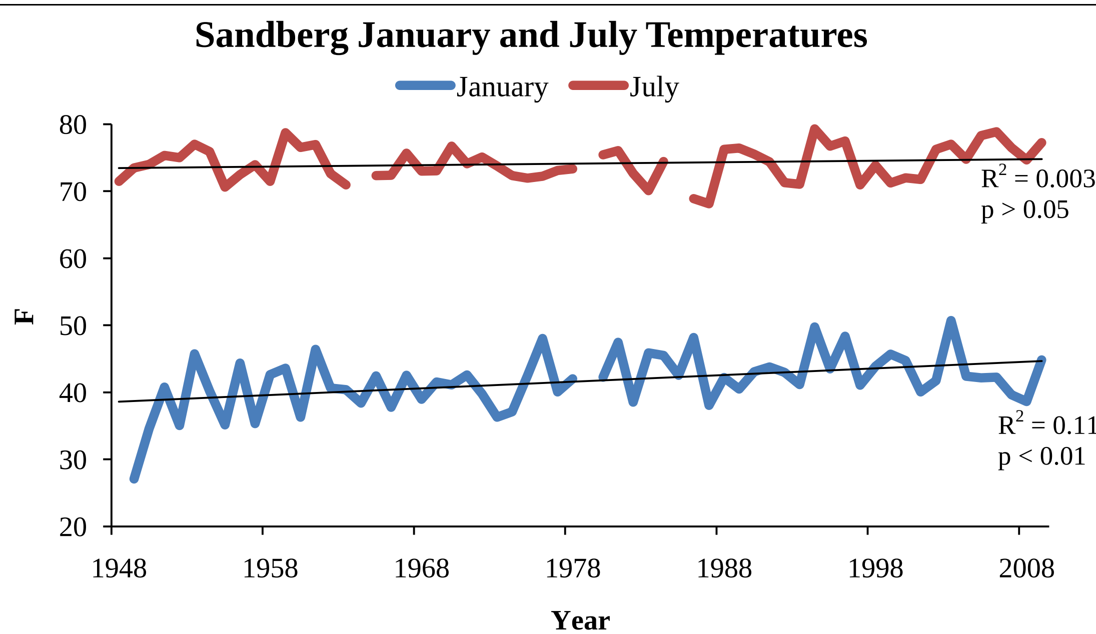


Figure 6.2-2. Sandberg Temperatures in January & July; Elevation 4,510 ft. *Source: WRCC 2009.*

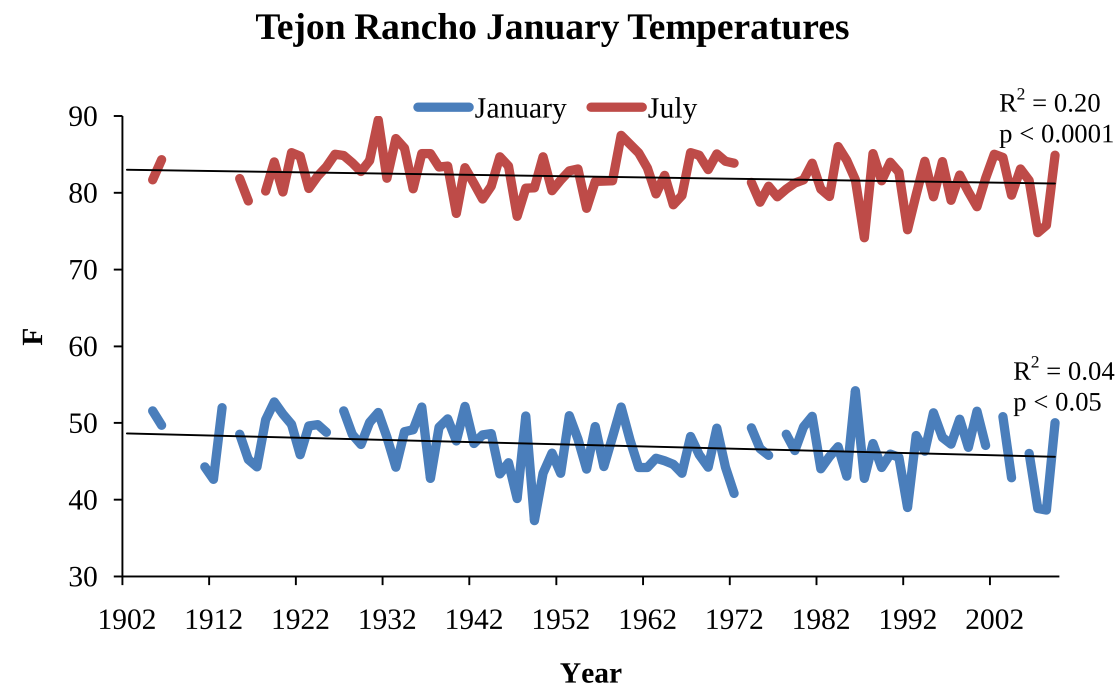


Figure 6.2-3. Tejon Rancho Temperatures in January & July; Elevation 1,425 ft. *Source: WRCC 2009.*

6.3 Development and Roads

The 2008 Agreement between the Tejon Ranch Company and five conservation organizations allows for development on 30,000 acres of the Ranch without opposition from the conservation organizations that signed the agreement. These proposed developments include the Tejon Industrial Complex/Grapevine, Centennial California, and Tejon Mountain Village (Figure 1-2; TRC 2009b).

One of the largest proposed developments is the Tejon Industrial Complex/Grapevine, a partially-completed development located on the western corner of the Ranch, at the junction of the Interstate 5 and Highway 99 west of the Grapevine Development. It is planned to ultimately encompass 1,450 acres, with some portions already built such as the Commercial Center and Grapevine Center, which include gas stations, lodging, and restaurants. Ultimately, the Tejon Industrial Complex is slated to include 1,030 acres of industrial buildings, 222 acres of freeway commercial buildings, 132 acres of infrastructure, and 66 acres of open space (TRC 2010).

Tejon Mountain Village is a residential housing development proposed for the highlands of Tejon Ranch surrounding Beartrap Canyon. This development will include 3,450 new homes and a publicly accessible Village Commercial Center. As part of the development, two golf courses are planned, approximately 75 miles of trails to accommodate equestrian use, hiking, and biking, equestrian amenities, and up to 750 hotel rooms and resort style amenities (TRC 2010). However, 80% of the development area of Tejon Mountain Village will be preserved as open space to accommodate many of the aforementioned activities.

Another large proposed development on the Ranch is Centennial California, which is planned to encompass 11,070 acres and will be located at the southern end of the Ranch in the Antelope Valley. Centennial will provide 23,000 homes total, built in eight communities over 20 years. Centennial will include a main east-west route known as the Centennial Parkway, as well as transit centers, bicycle and pedestrian pathways, and Neighborhood electric vehicles. The final plans for numbers of highways and numbers of lanes will be determined after the implementation of a traffic study, as part of the EIR (TRC 2010).

6.3.1 Future Monitoring Recommendations

Overall, these developments will increase human impact on the Ranch by increasing the development footprint, expanding the number of roads, augmenting the number of people with access to parts of the Ranch, and increasing the demand for recreation within Tejon Ranch. Road development and use, as well as added housing units, should be monitored in order to model impacts.

6.4 Fire

Tejon Ranch lies within California's Mediterranean climate and is subject to periodic wildfires, with long, dry summers characterized by low humidity and strong winds (Sugihara & Barbour 2006). The fire regime of an ecosystem is characterized by the historical range of variability in fire size, severity, and frequency. The regime can be evaluated to understand the character, effect, and disturbance patterns of ecosystems (Schoennagel et al. 2004).

Two primary anthropogenic mechanisms have altered the fire regimes within California ecosystems: (1) fire suppression; and (2) an increased number of ignitions. Fire suppression has excluded fires from many ecosystems, which has led to an unnatural amount of fuel accumulation, such that when fires do occur they lead to high-intensity crown fires. These high-intensity crown fires tend to be outside the historical range of variability. Increased anthropogenic ignitions typically occur near human development; thus, as urban areas continue to expand into wildlands, more fires will likely occur. The increase in ignition sources has led to a higher fire frequency than historical regimes, even with suppression practices (Syphard et al. 2007).

From looking at historical records, it can be determined that most terrestrial ecosystems were dependent on fire (Sugihara, Wagtendonk, & Fites-Kaufman 2006).

The composition of dominant plant species within an ecosystem is the result of interactions between many factors, including climate, species relationships, and disturbance regimes such as fire. In some ecosystems, fire is a major factor in determining the community structure, as different ecosystems produce and accumulate fuels at differing rates, ultimately affecting the frequency and intensity at which fire occurs. An ecosystem-level understanding of the processes that create and maintain the landscape is necessary in order to effectively manage wildland areas.

6.4.1 FIRE ON TEJON RANCH

Fire activity on Tejon Ranch is based on weather, fuel, and ignition, which are a result of the climate, weather, and topography of the landscape. Climate and weather determine plant growth and fuel accumulation, as well as soil moisture availability. Soil moisture plays an important role in the heat transfer of the landscape. Moist soils have a greater heat capacity and require more energy to rise in temperature affecting the spread of fire (Sugihara, Wagtendonk, & Fites-Kaufman 2006). Relative humidity, temperature, and wind speed affect fuel moisture and fire intensity (Minnich 2006b).

The magnitude of effect that a fire has on the environment is referred to as fire severity and is affected by fire line intensity (the rate of energy release per unit length of fire front), fire duration, and the amount of available fuels (Van Wagtendonk 2006). High-intensity crown fires result in the death of canopy trees and are also referred to as stand-replacing fires. They are infrequent and can result after years of fire suppression and the accumulation of ladder fuels. High wind speed and increased temperatures can also turn a ground fire into a crown fire. Frequent surface fires that are controlled by spatial and temporal variation in fine fuels characterize low-intensity fire regimes. Low-intensity fires burn at a lower temperature than the high-intensity fires.

In order to characterize the fire regime on Tejon Ranch, fire perimeter data was obtained from the Fire and Resource Assessment Program (CALFIRE 2008). Fire perimeter information on private lands in California reliably began in 1950. Fire perimeter data on Tejon Ranch from 1950 to 2008 was analyzed, as were prescribed burn records for the Ranch.

While it is important to understand what is happening within Ranch boundaries, it is also important to describe the area surrounding Tejon Ranch. Fire is able to spread across a landscape without consideration of property boundaries. Management of fire within the Ranch must also consider the fire regime of the surrounding area. The ecological subsections (USDA 1997) described in Section 1.3.5, were used to determine the surrounding area of the Ranch. The entire subsection was used when a portion intersected the Ranch (Figure 1.3-5). To characterize the fire regime for Tejon

Ranch we analyzed time since fire, seasonality, fire size, and rotation interval. Ignition sources are also considered by fire proximity to major highways.

6.4.2 Time Since Fire

Time since disturbance, such as fire, can be indicative of the ecological community present in a certain area. Species within certain vegetation communities have varying rates of recovery and re-colonization following a fire. Relationships between existing vegetation communities and their time since fire can allow for predictions about future vegetation distribution after a fire. Analyses of time since fire can provide information about fuel accumulation and future fire spread.

Time since fire for Tejon Ranch and the surrounding area are shown in Figure 6.4-1. The large proportion of white area in the map illustrates that a majority of the area within and outside the Ranch has not burned within the past 58-year data range. More specifically, 77% of the Ranch and 87% of the area outside the Ranch has not burned in the last 58 years. In Figure 6.4-1 the redder areas have burned more recently and the greener areas have not burned in over ten years. The percent of the area corresponding to each time since fire is shown in Figure 6.4-2. From this graph it can be seen that for both inside and outside the Ranch, the largest areas have not burned in 10-30 years. This information can be used in conjunction with vegetation maps to further analyze ecological community distribution and structure.

6.4.3 Seasonality

The long, dry summers of southern California are conducive to wildfire. Knowing the peak periods for fire risk on Tejon Ranch allow for management of fuel sources and ignitions, as well as help to better protect human infrastructure in surrounding areas. Figure 6.4-3 shows that June and July experience the majority of fires on the Ranch. This is similar to the trend observed outside of the Ranch’s boundaries, as can be seen in Figure 6.4-3, which also shows more fires during June and July.

6.4.4 Fire Size Distribution

Fire size history is also important to consider. In order to assess shifts in fire size distribution, the time period of data was divided into a historic time period of 1950-1979, and a recent period of 1980-2008. Rank order plots of fire size are shown in Figure 6.4-4 for inside and outside the Ranch. This graph ranks fires from largest to smallest for each time period, plotting them against each other. There have been significantly more fires in the recent period than during the historic period for both regions, as shown by the greater length of the line representing the present time period.

Within Tejon Ranch, the recent time period has not only had more fires, but larger fires. The largest ranking fire for the present period was bigger than the largest

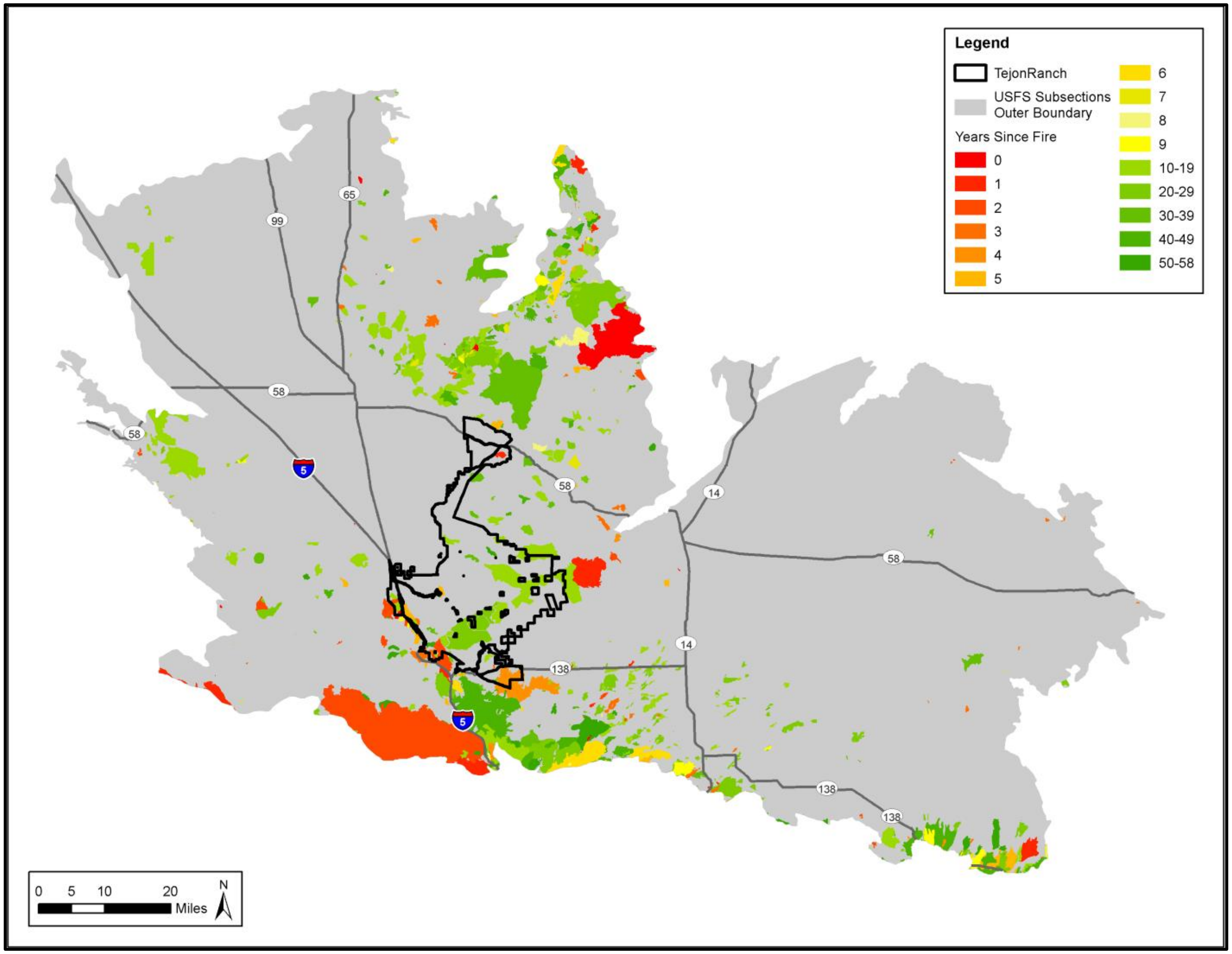


Figure 6.4-1. Time Since Fire Map for Inside and Outside Tejon Ranch. *Source: CALFIRE 2008; USFS 1997.*

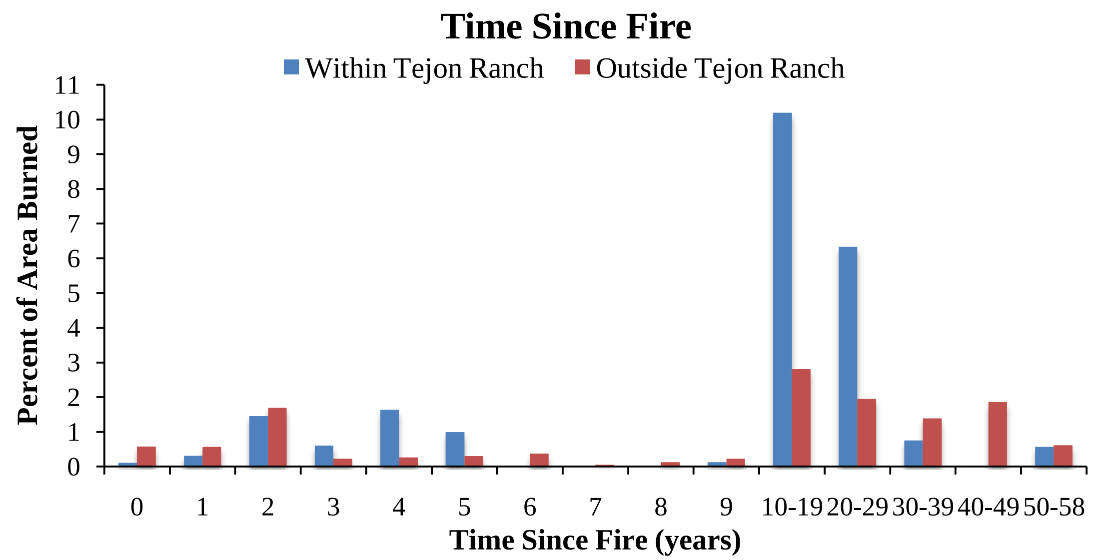


Figure 6.4-2. Time Since Fire Graph for Inside and Outside Tejon Ranch. *Source: CALFIRE 2008; USFS 1997.*

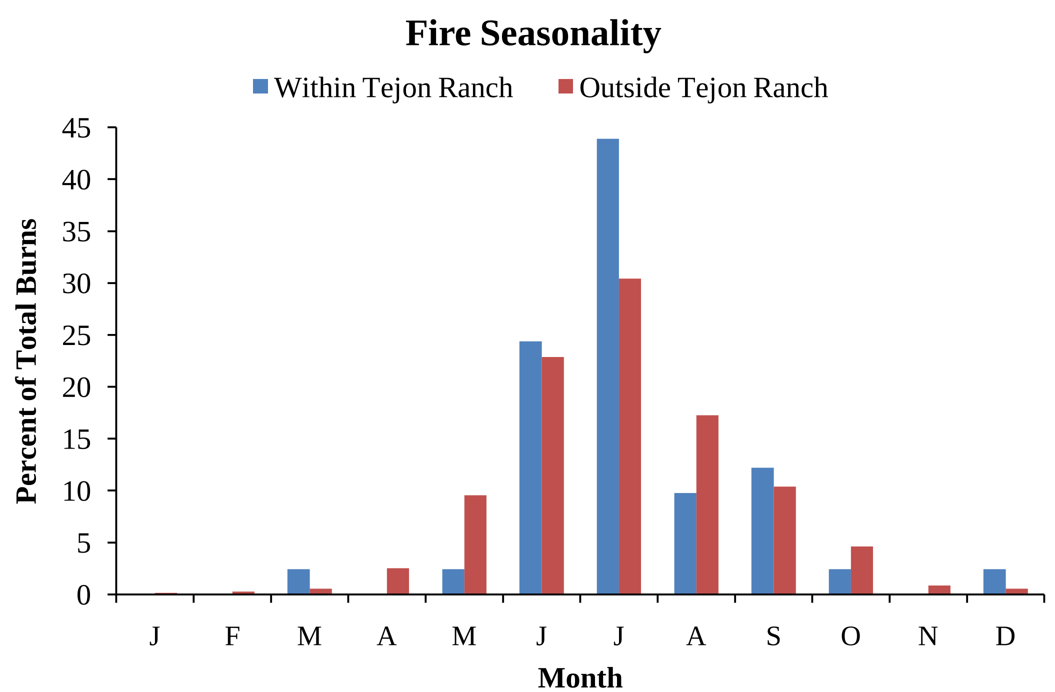
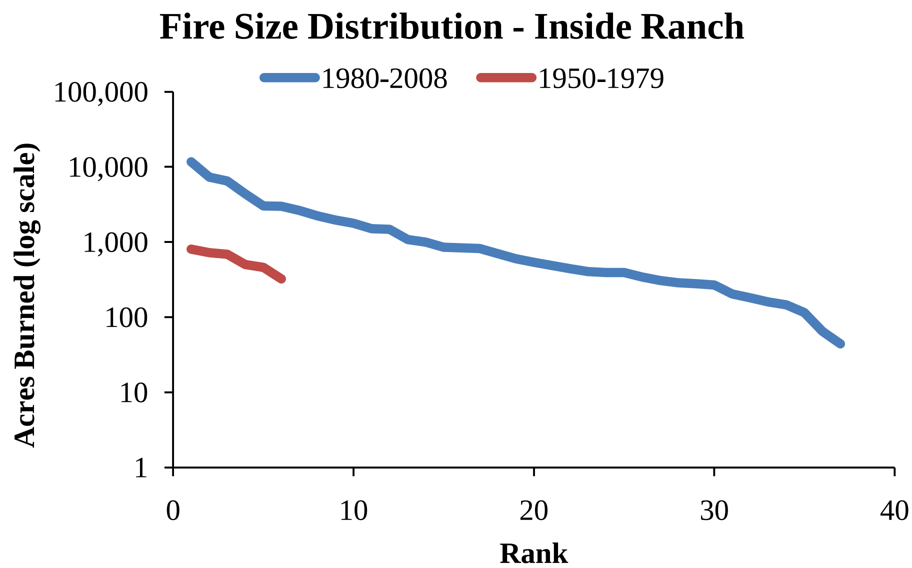


Figure 6.4-3. Fire Seasonalitly Distribution for Inside and Outside Tejon Ranch. *Source: CALFIRE 2008; USFS 1997.*



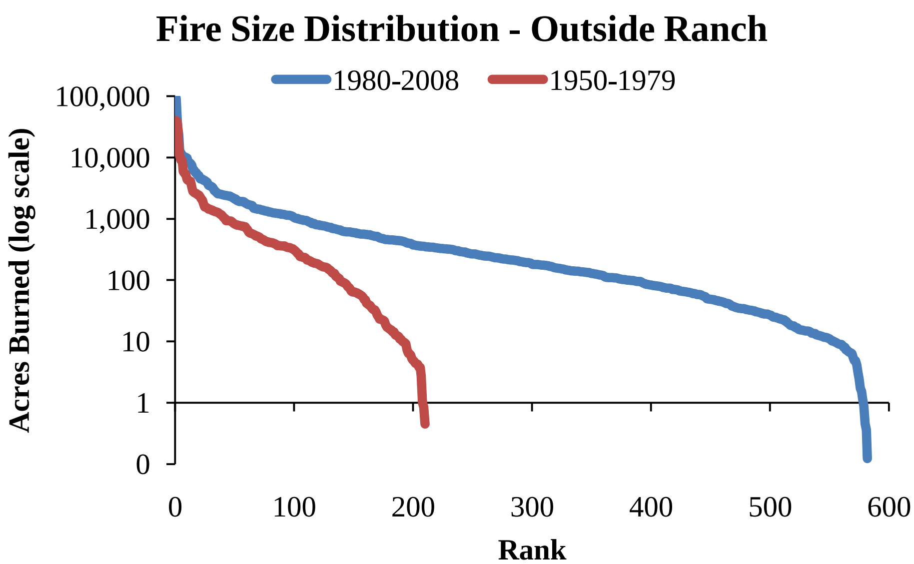


Figure 6.4-4. Fire Size Distribution for Inside and Outside Tejon Ranch. *Source: CALFIRE 2008; USFS 1997.*

historic fire. The region outside the Ranch shows less disparity between the largest fires for the historic and present period.

6.4.5 Fire Rotation Interval

A fire rotation interval is the length of time necessary to burn an area of a specified area, based on the area's fire history. Fire and Resource Assessment Program data (CALFIRE 2008) was used to calculate the fire rotation intervals for each of the ecological subsections (USDA 1997) within the Ranch, for the modern period (1980-

2008) and the historic period (1950-1979) period. This was then compared to the same subsections outside the Ranch (Table 6.4-1).

As shown in Table 6.4-1, an increase in acres burned in the modern period compared to the historic has led to a shorter fire rotation in the modern period. Table 6.4-1 also presents the fire rotation for the prehistoric period. This trend has been observed throughout southern California ecosystems as fire frequency increases due to ignitions at the growing wildland-urban interface (Syphard, Franklin, & Keeley 2006). The relative short period of fire history (58 years) used in this analysis is a limitation in the findings.

Table 6.4-1. Fire Rotation for Inside and Outside Tejon Ranch. Historic period is from 1950-1979 and the modern period is from 1980-2008. *Source: CALFIRE 2008; Sugihara et al. 2006; USFS 1997.*

Unit	Fire Rotation (years)				
	Inside		Outside		Prehistoric
	Historic	Modern	Historic	Modern	
Hardpan Terraces	2,227	879	2,284	489	1 - 3
South Valley Alluvium and Basins	3,058	404	21,992	3,484	
Elk Hills and Southern Valley Terraces	-	-	22,842	194	
High Desert Plains and Hills	-	191	2,615	1,020	Unknown
Eastern Slopes	-	59		65	7 - 15
Tehachapi-Piute Mountains	918,286	56	675	165	
Southern Granitic Foothills	546	517	166	112	
San Emigdio Mountains	1,288	116	1,782	221	
Northern Transverse Ranges	37,730	78	153	78	33 - 50

6.4.6 IGNITIONS

Anthropogenic ignitions have increased as human populations grow and move closer to natural areas, as has happened in the land surrounding Tejon Ranch (Section 5.1). The Fire and Resource Assessment Program database (CALFIRE 2008) contains information about identified ignition sources, however most are classified as “unknown” or “other”. Figure 6.4-1 shows that the more recent fires tend to occur near the southwest corner of the Ranch, adjacent to Interstate 5. The areas outside the Ranch show a similar trend, where more recent fires tend to occur near major highways.

This pattern may reveal information on ignition sources. In order to analyze this, a 5,000 meter buffer was made around the major highways seen in Figure 6.4-1. The buffer was divided into 1,000 meter increments and the number of fires occurring in each increment was recorded. Figure 6.4-5 shows the number of fires that occurred within 5,000 meters of a major highway, in 1,000 meter increments. This graph demonstrates that there are a greater number of fires that occur within 1,000 meters of these highways than beyond.

Vehicles on highways are the source of many ignitions. This often happens when cars pull off to the side of the road and stop, and the high heat generated by the vehicle ignites brush or weeds. In other cases involving vehicles, an out of tune catalytic convertor may spit hot metal shavings from the exhaust pipe, causing ignitions as they reach the side of the road (Chandler 2009). Tejon Ranch's location along the steep grapevine on Interstate 5 may play an important factor in increased vehicle ignitions. Older vehicles may overheat or have difficulties making the climb. These interfaces should be considered high priority areas for fire management, since fires that begin by the highway will most likely spread onto the Ranch. This is also important to consider for potential future development on the Ranch as increasing population and roads may lead to more ignitions.

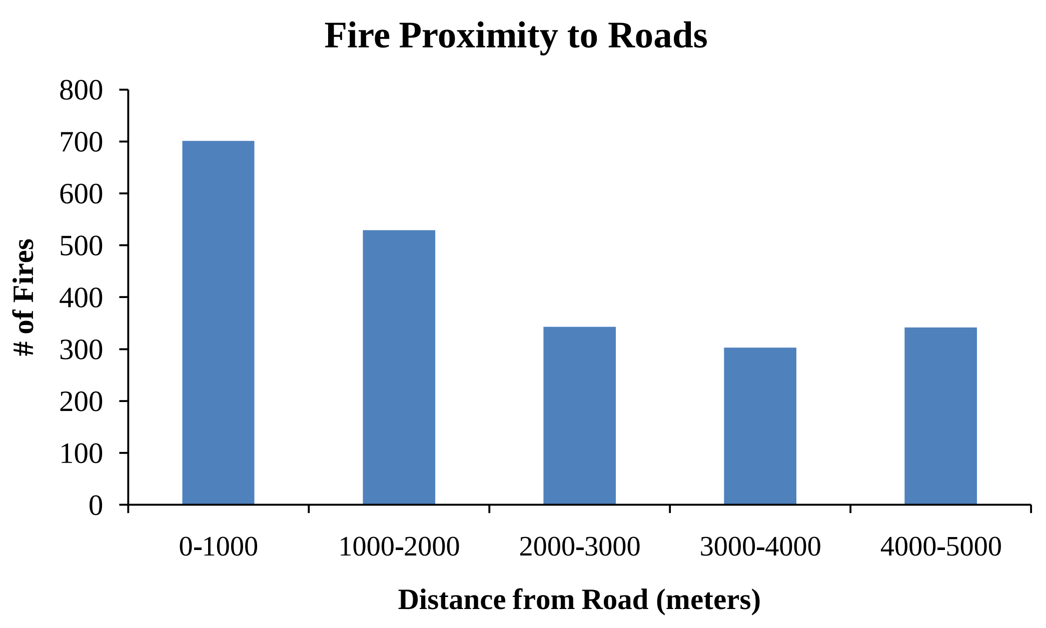


Figure 6.4-5. Fire Proximity to Roads. Source*: CALFIRE 2008; USFS 1997.*

6.4.7 Prescribed Burn History

Two methods were used to compile the prescribed burn history on Tejon Ranch: Tejon Ranch Company (TRC 2009c) paper records and fire perimeter records (CALFIRE 2008). From these records, we found that there have been four recorded prescribed burns on the Ranch since 1950 (Figure 6.4-6):

1. **Sycamore Canyon:** In April 1987, approximately 3,344 acres were burned. The management goals of the Sycamore Canyon burn included reducing fuel loads and enhancing grazing habitat.
2. **Bronco Canyon:** This burn occurred in April 1988 in Bronco Canyon, burning approximately 2,000 acres. The fire burned chaparral and woodland vegetation.
3. **Lecheria Canyon:** Approximately 3,000 acres was burned in Januray 1989 in chaparral and scrub habitat.
4. **Escondido Canyon:** In March 1990 approximately 5,000 acres of mixed chaparral on the east side of the Ranch was burned. The objective of the burn was to remove 20-30% of standing and dead brush in order to improve wildlife habitat and provide browse for cattle.

6.4.8 Future Monitoring Recommendations

The fire record we examined over the past 58 years is relatively short in trying to understand the fire regime of an area. In the future, CALFIRE fire perimeter data should continue to be added to this data set in order to expand these records. Different vegetation communities require fire at varying frequencies and intensities (Section 7), and need to be managed based on those requirements. As the proposed developments on Tejon Ranch move forward, attention to wildfire will increase as the need to protect human life and infrastructure becomes an issue. Development of an ecologically reasoned fire management plan (FMP) for the Ranch that details specific fire management guidelines will help the Conservancy protect and enhance the conserved lands. For example, the FMP may provide guidance for where wildfires are allowed to burn.

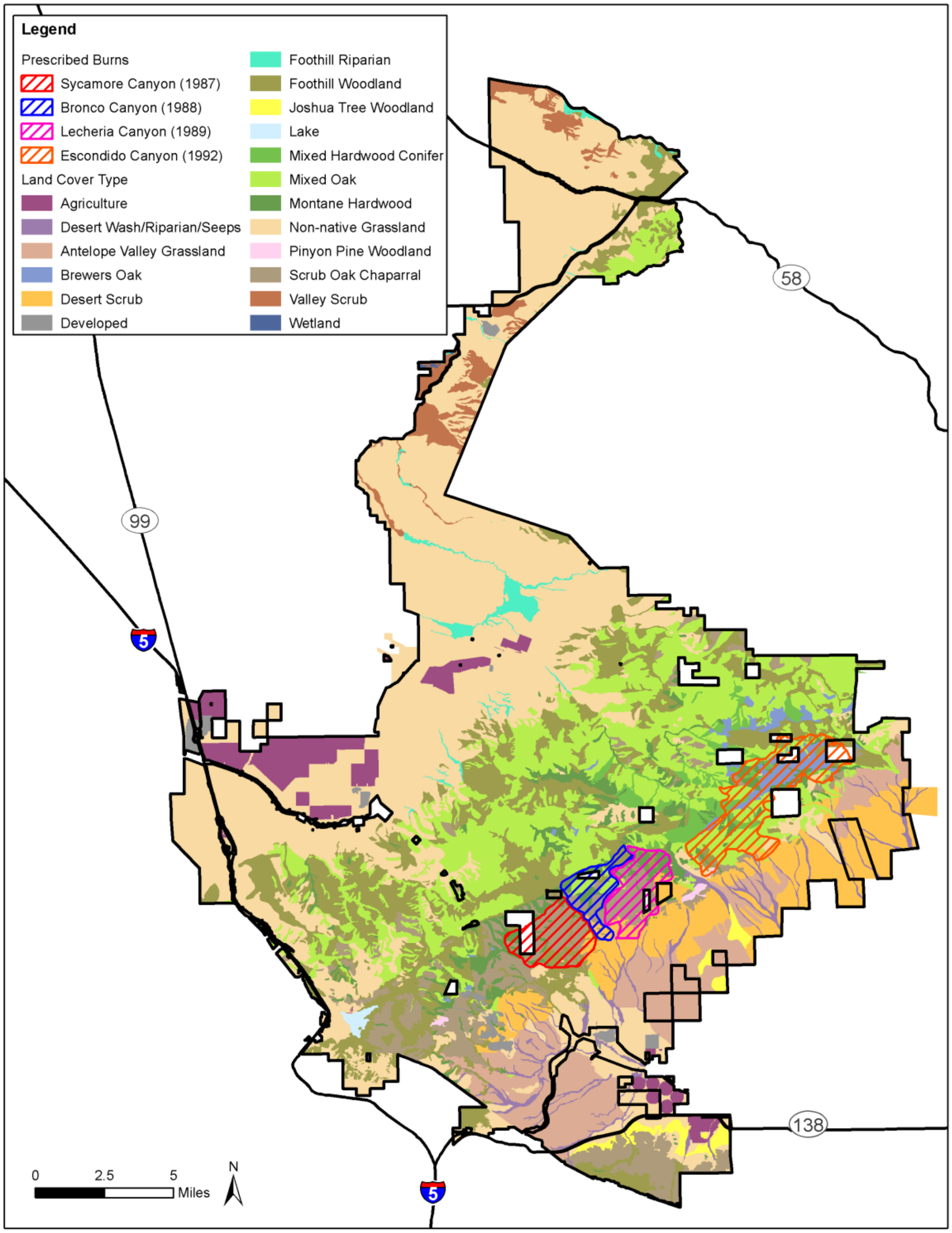


Figure 6.4-6. Prescribed Burn Locations on Tejon Ranch. *Source: CALFIRE 2008.*

6.5 GRAZING

Livestock grazing is a major revenue generating activity practiced over 90% of Tejon Ranch (Interim Ranch-Wide Management Plan 2009). According to Mahall et al. (2005), "Cattle grazing is arguably the most pervasive anthropogenic disturbance in oak woodlands, savannas, and grasslands in California." It is also believed to be a "probable cause contributing to the invasion of non-native grasses, a lack of recruitment of oaks, and a decline in biodiversity" (Mahall et al. 2005). Livestock are attracted to the shade and lower temperatures that our found near streams. Livestock eat and trample understory seedlings, decreasing or eliminating regeneration of oaks and potentially other riparian tree and shrub species (Yolo County 2007, Belsky et al. 1999). Meanwhile, plant species that commonly increase with livestock grazing are usually weedy exotics that benefit from disturbance, upland species that that prefer the drier conditions created by grazing, or sub-dominants released from competition with native riparian species (Belsky et al. 1999).

With respect to soils, a major effect of cattle grazing is soil compaction by hoof action, which reduces macropore space. Hoof action therefore results in increased bulk density and reduced soil porosity, infiltration, percolation, and root growth (Clary & Kinney 2002). Livestock grazing has also been demonstrated to result in elevated soil and streambank erosion in the form of channel incision and downcutting, accompanied by bank retreat (Belsky et al. 1999) and increased wetted channel width (Clary & Kinney 2002) occurring as a result of accelerated discharge of runoff from uplands in the watershed. With respect to riparian communities, livestock grazing reduces herbaceous plant cover on streambanks, reducing resistance to particle erosion as well as resistance to streambank compression and shear. Research demonstrates that protection of riparian zones via grazing enclosures increases litter biomass, particularly of grass species, as opposed to forbs (Sarr, 2002). Some researchers have hypothesized that livestock grazing may be beneficial to seedling and sapling oaks within a savannah landscape. The reduction of evapotranspiration from competing annual grasses and forbs may reduce water stress to non-grazed plant species like oaks.

Another resource management practice related to the historical cattle grazing on Tejon Ranch is predator control, which can affect wildlife populations and their associated communities. Large predators of livestock, namely mountain lion, have occasionally been legally "taken" by hunters and/or trappers under depredation permits issued by the state to protect livestock on the Ranch. This continued practice has far reaching consequences on the top-down control of native ungulates and pigs, as well as the communities in which they occur.

It is important to note that much of the literature reviewed regarding ecosystem responses to livestock grazing were specific to biogeographic regions other than that of Tejon Ranch and surrounding environs. Much of the literature reviewed discussed experimental grazing management conducted in the Northern San Joaquin and Sacramento Valleys, Great Basin, or other parts of the arid and semi-arid western United States with different climates, soil properties, or representative riparian and rangeland vegetation community assemblages.

6.5.1 Future Monitoring Recommendations

In order to adaptively manage grazing operations on the Ranch, we recommend that the Conservancy, in collaboration with TRC, rangeland management specialists at the University of California Division of Agriculture and Natural Resources, and grazing leaseholders, develop a grazing management plan which includes rangeland health assessment and rangeland productivity monitoring.

Rangeland Health Assessment

Many key processes in rangeland ecology are affected by the height and architecture of grassland cover (Stewart et al. 2001). The importance of managing grasslands to prescribed heights and structures has long been recognized in conservation and agriculture (Stewart et al. 2001). In the western U.S., several detailed, standardized approaches for forage measurement and monitoring for rangelands and annual grasslands have been developed. A few of these approaches are described below.

According to Guenther (2007), the first step in the process of rangeland monitoring and assessment is that the investigator must establish Residual Dry Matter (RDM) classes to be utilized in monitoring, with three classes of RDM as the standard recommendation. For RDM management purposes, California grasslands and associated oak woodlands and savannahs can be divided into three types. The first includes dry annual grasslands defined as annual plant dominated grasslands with average annual rainfall less than 12 inches. The second includes annual grassland/hardwood range defined as annual understories within variable oak or shrub canopy with average annual rainfall amounts between 12 and 40 inches. The third type includes coastal prairies within which perennial grasses are common in a variable woody overstory with variable rainfall amounts (Bartolome et al. 2006). The RDM classes utilized for monitoring forage on a typical California range site are defined on an lbs/acre scale based on range type.

The second step in the process includes the collection of supporting information at RDM reference monitoring sites. This data collection may involve precise, but labor intensive clipping of plots, or other less precise but more practical estimation techniques such as Guenther's photo estimation technique (Guenther 2007). Techniques such as this can be honed or calibrated to improve precision and expedite data collection. Several techniques have been devised to measure sward height and structure, with sward being the surface layer of ground containing a mat of grass and grass roots (Stewart et al. 2001). The direct measurement method is the most consistent with fairly accurate results compared with an independent parameter, soil temperature, and is the only method suitable for measuring variation in short turf (Stewart et al. 2001). The direct measurement method involves placing a card or hand lightly on the vegetation at the level below which about 80% of the vegetation is visually estimated.

RDM or biomass is only a single metric of total productivity, but can be coupled with other related structural or compositional attributes of grassland ecosystems such as percent cover, native cover, or species richness and evenness to assess community health. The key is to statistically define the relationship between RDM and these other more biologically significant attributes related to ecosystem health and biodiversity. These relationships can be established by conducting quantitative sampling of vegetation characteristics such as total cover, percent native cover, and species richness and evenness within permanent sampling plots stratified by grassland or other community types (e.g. valley oak savanna) with adequate replication. The structural and compositional data could then be analyzed and the vegetative metrics correlated to RDM levels using multivariate statistical analysis. Using calculated correlation scores between RDM levels and other vegetation metrics, as well as specified cover and diversity targets, the Conservancy can then set allowable RDM levels and calculate the allowable number of animal unit months (AUMs) for a range site or pasture.

6.6 HUNTING

Hunting has occurred on Tejon Ranch since 1827, when Jedidiah Strong Smith initiated the exploration of the Tehachapi Mountain area by beaver trappers (TRC 2010). Through the following decades, hunting and wildlife management has evolved on the Ranch and now the Tejon Ranch Company now manages the largest private hunting program in California.

Hunting is a major source of revenue for the Tejon Ranch Company, which offers guided and non-guided hunts for Rocky Mountain bull elk, black bears, pronghorn antelope, mule deer, wild pigs, turkeys, doves, quail, chukar partridges, band-tailed pigeons, cottontail rabbits, squirrels, and “varmints” such as bobcats, coyotes, and gray foxes (TRC 2010). Tejon Ranch serves as a hunting license agent for the California Department of Fish and Game, and sells all tags and licenses, except for bobcat licenses, which must be purchased from a regional office of the California Department of Fish and Game.

In order to develop a historical record of hunting practices on Tejon Ranch, hunting records were obtained from the Tejon Ranch Company (2009d). Records were not complete for all years of Ranch operation, and only some species were represented. Available records were compiled and analyzed, as shown below.

Hunting records between 2001 and 2008 are available for Rocky Mountain elk, black bears, pronghorn antelope, mule deer, wild pigs, wild turkeys, and bobcats (TRC 2009d). As Figure 6.6-1 shows, mule deer and wild pigs are the most widely hunted animals on Tejon Ranch.

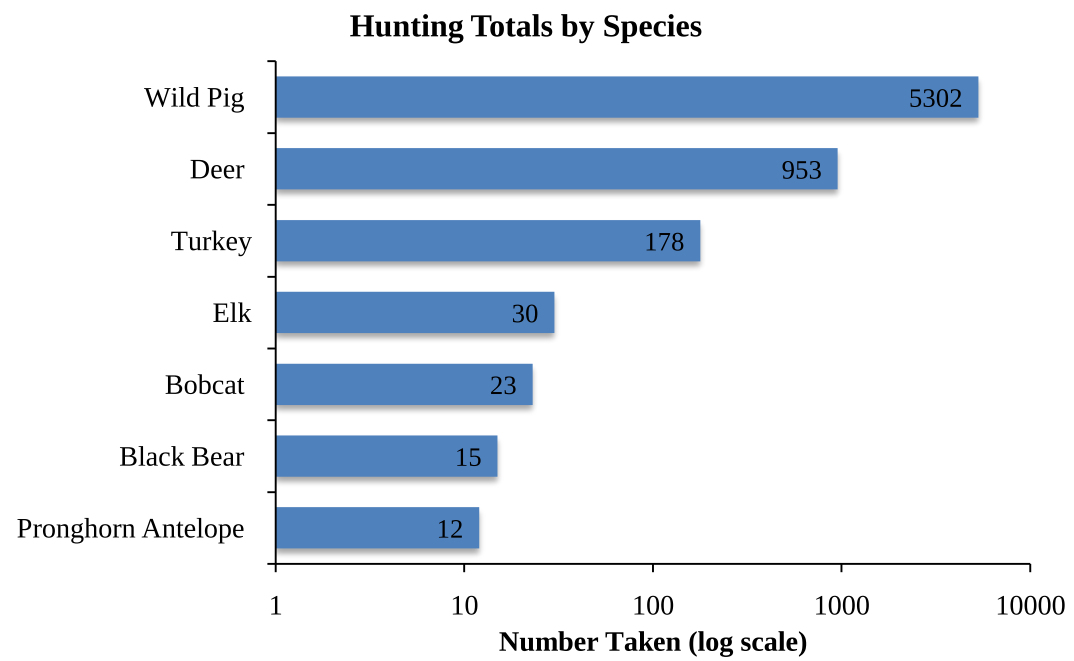


Figure 6.6-1. Hunting Record Totals for Tejon Ranch between 2001-2008. *Source: TRC 2009d.*

The number of hunted pronghorn antelope, black bears, and Rocky Mountain elk remained relatively steady between 2001 and 2008 (Figure 6.6-2). The number of black bears taken fell from three in the 2001-2002 season to zero taken in the 2004-2005 season; however, hunting records show that black bears taken increased again to three taken every year between 2005 and 2008 (Figure 6.6-2). The number of pronghorn antelope taken per year varied between zero and three, from 2001 through 2008. The number of Rocky Mountain elk taken per year decreased from six in 2004 and 2005, to three in 2007 and 2008 (Figure 6.6-2).

An average of 25.4 wild turkeys were hunted on Tejon Ranch each year between 2001 and 2008, with a minimum of eight turkeys in 2003 and 2004, and a maximum of 41 turkeys in 2006 and 2007 (Figure 6.6-2).

Wild pigs have been the most widely hunted animal on Tejon Ranch, with an average of 757.4 pigs taken every year since 2001 (Figure 6.6-2). The highest number of pigs taken was 967 in 2002 and 2003. The number of pigs hunted on Tejon Ranch makes up the vast majority of all wild pigs hunted in Kern County.

More historical hunting records are available for bobcat and mule deer (Figure 6.6-3 and 6.6-4). Bobcat records extend back to 1975, and show that a maximum number of 150 bobcats were taken in 1978. The number of bobcats taken has steadily decreased since 1975; although there are no hunting records available between 1989 and 2002. Since 2002, records show that fewer bobcats have been taken than in previous decades. For example, only nine bobcats were taken in 2008.

Similarly, the number of mule deer harvested on Tejon Ranch has also declined since previous decades (Figure 6.6-4). Deer records are available from 1980, when 221 deer were taken. The largest number of mule deer taken occurred in 1987, when 474 deer were taken. There is a lack of deer hunting records between 1994 and 2001, but since 2001 the annual number of deer taken has been, on average, lower than in the 1980's and has been steadily decreasing.

Records of the number of deer hunter days are available from 1980 to 1993 (Figure 6.6-5). During years of high harvests, such as the year 1987 when 474 deer were taken, there were fewer hunter days than in years of low harvest where there are more hunter days per deer taken. This data suggests that more effort was required to hunt each deer. However, there is no correlation observed between the average number of hunter days per deer taken and the harvest size in the following year.

An approximation of annual mule deer and pronghorn antelope fecundity levels can be obtained from fawn to doe ratios and kid to doe ratios. Between 1980 and 1995 there are estimates of the number of fawns per 100 does observed (Figure 6.6-6). Measurements taken in the fall include counts of fawns born in April; therefore, annual measurements may show changes in fecundity. However, fawn to doe ratios in the records are highly variable. Similarly, pronghorn antelope kid to doe ratios are available between 1986 and 1995, and are also highly variable (Figure 6.6-7).

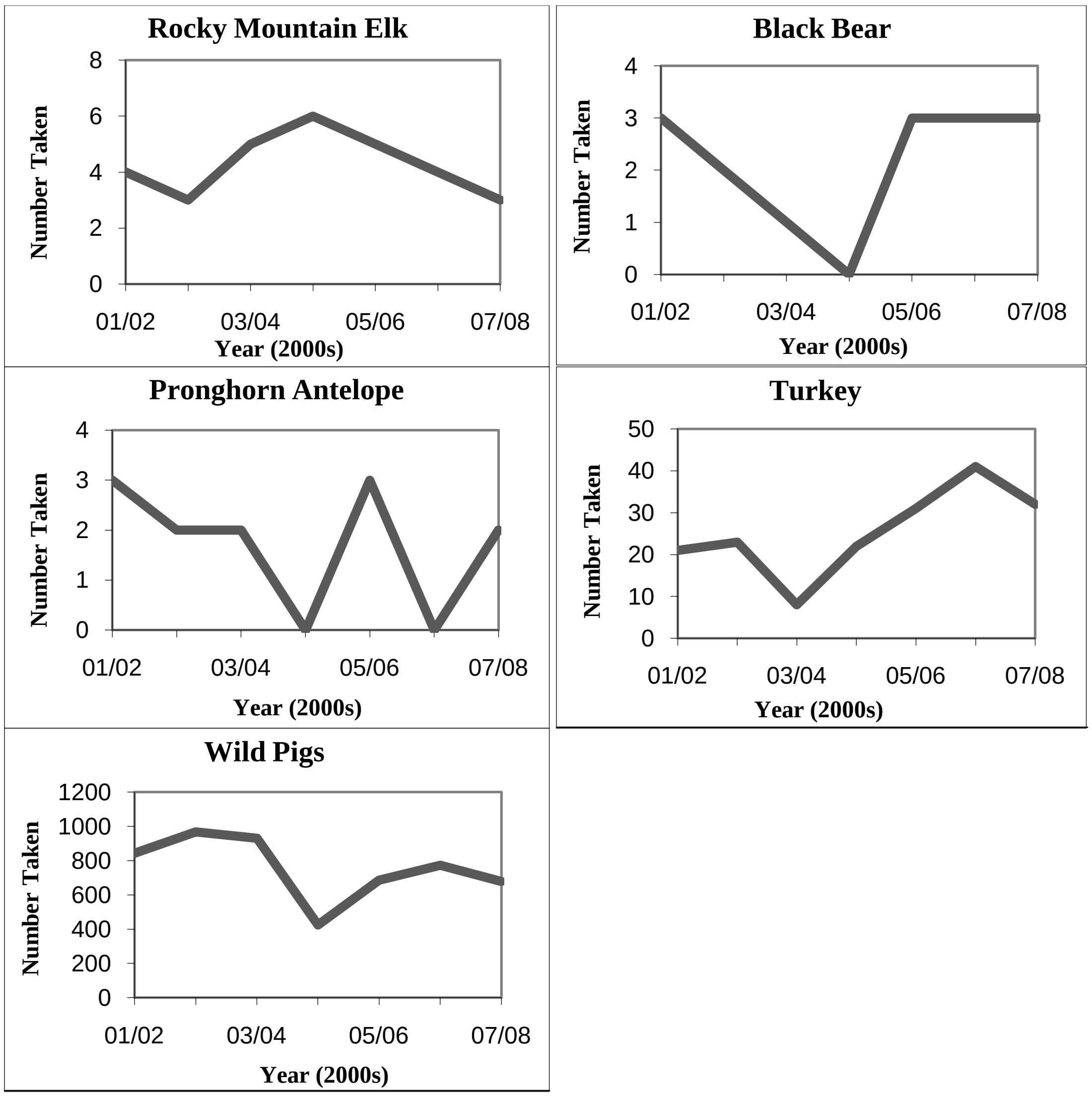


Figure 6.6-2. Number of Animals Taken Per Year. *Source: TRC 2009d.*

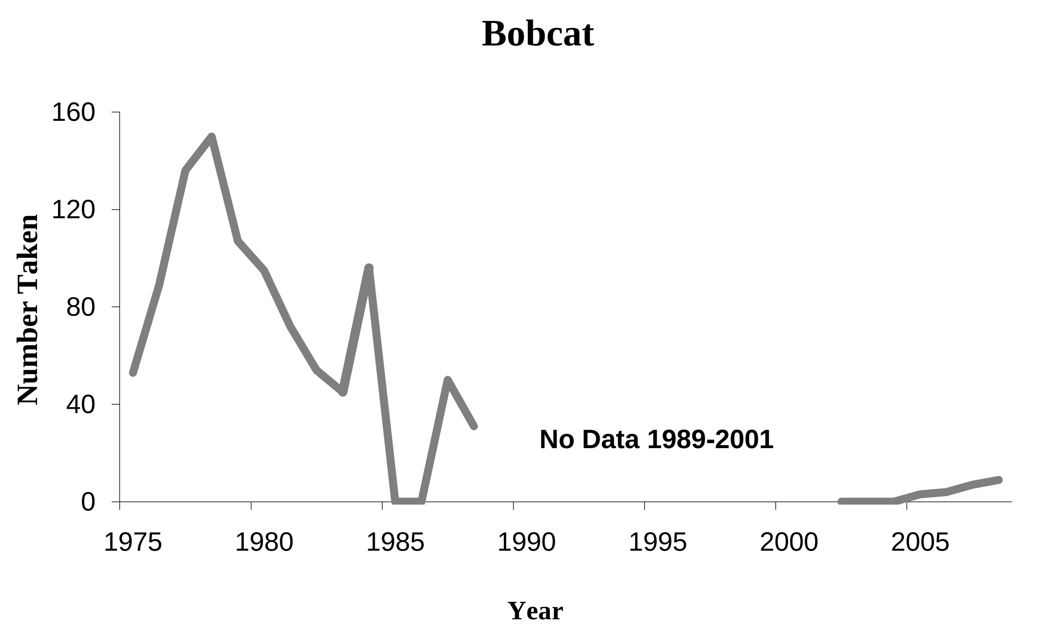


Figure 6.6-3. Number of Bobcat Taken from 1975-2008. *Source: TRC 2009d.*

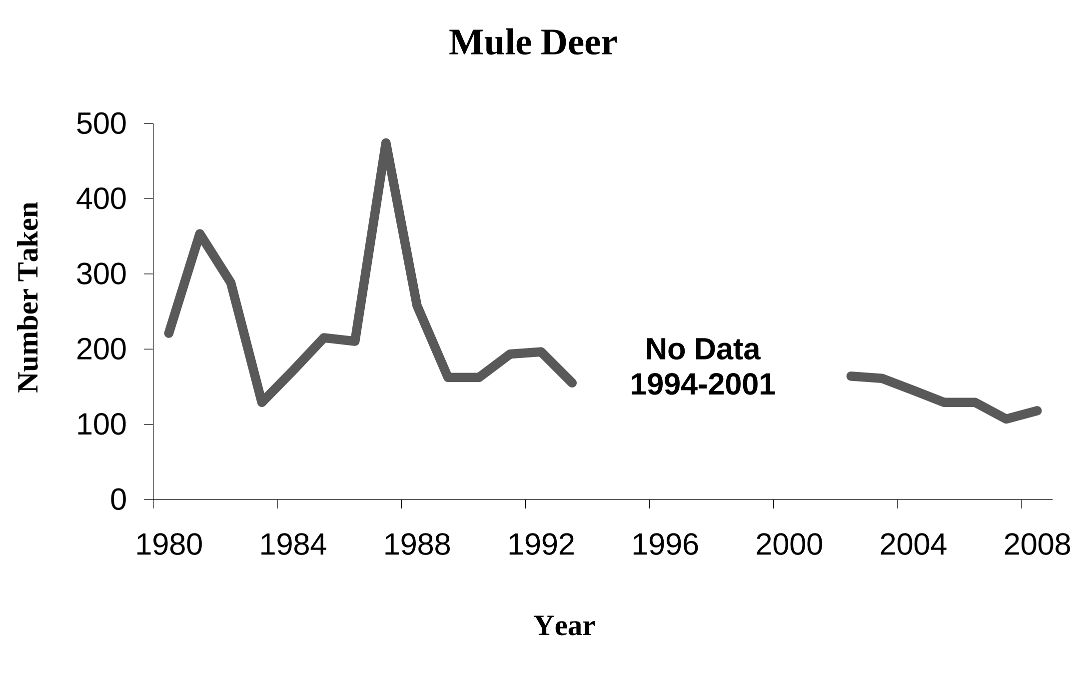


Figure 6.6-4. Number of Mule Deer Taken from 1980-2008. *Source: TRC 2009d.*

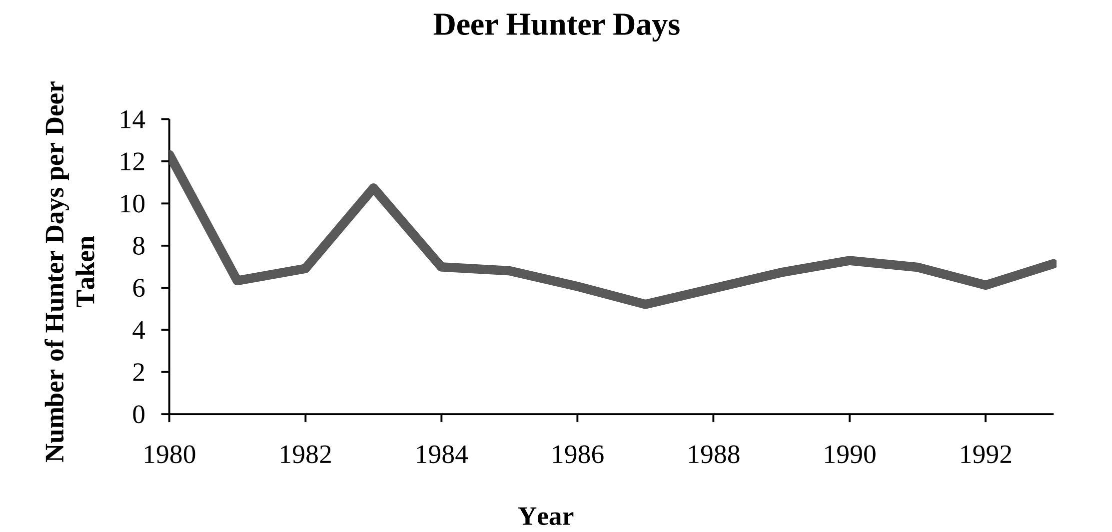


Figure 6.6-5. Hunter Days per Mule Deer Taken. *Source: TRC 2009d.*

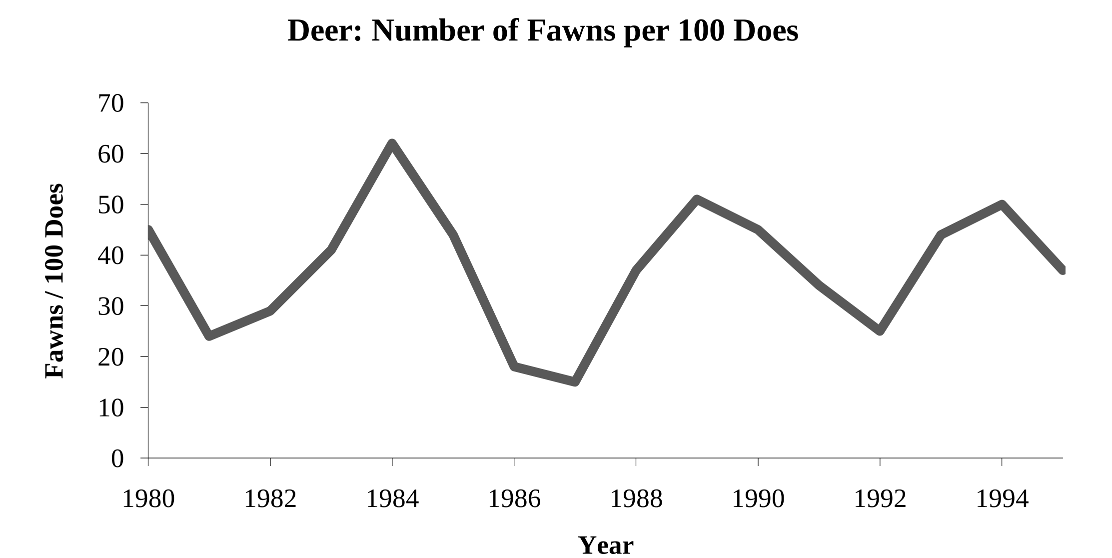


Figure 6.6-6. Number of Fawns Per 100 Does (Mule Deer). *Source: TRC 2009d.*

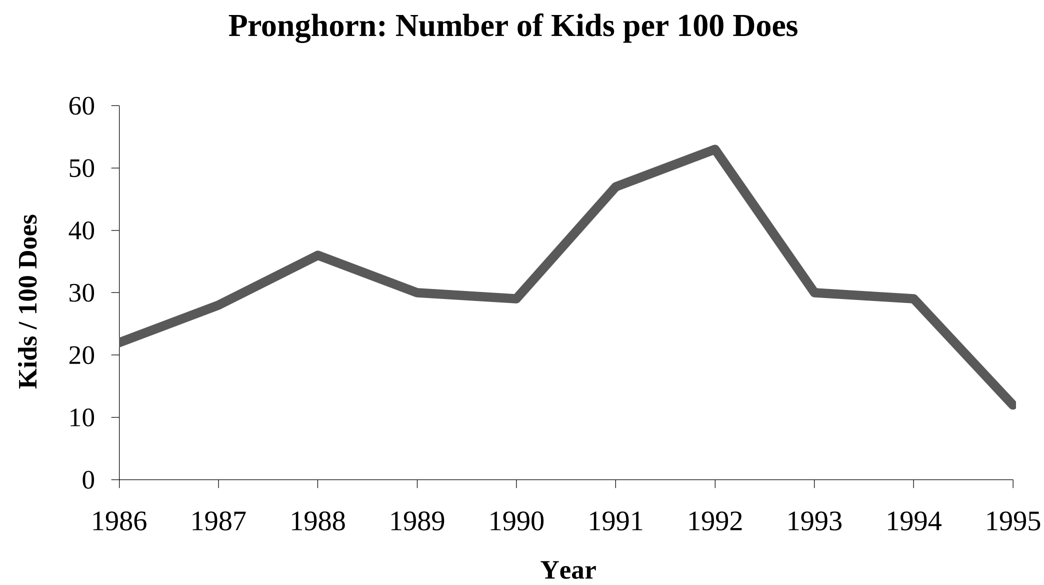


Figure 6.6-7. Number of Kids per 100 Does (Pronghorn). *Source: TRC 2009d.*

6.6.1 FUTURE MONITORING RECOMMENDATIONS

Based on the available hunting records, it is uncertain why there are fewer deer hunted now than there were in the past. This could be due to a reduced hunting effort, or due to lower mule deer populations. The lower numbers of bobcats being hunted is likely due to a reduction in fur trapping. However, without records of mule deer and bobcat populations or hunter effort, the trend in these takes cannot be explained. This applies to all species of game hunted on the Ranch. It is therefore recommended that detailed annual records of takes and hunter days (hunter effort) be kept for each species hunted on the Ranch. In addition, population censuses of deer and pigs, the two most hunted species, should be conducted as often as possible in order to assess how hunting activities impact these populations.

There are two common methods of estimating deer populations, which may be options for estimating the mule deer population on Tejon Ranch. The Conservancy should evaluate the costs and benefits of performing such surveys before deciding whether to implement them. One commonly used deer census technique is pellet-group counts, which involves surveys of deer feces as a measure of population size (Eberhardt & Etten 1956). Another common method of measuring deer populations is through aerial surveys (Floyd et al. 1979). In aerial surveys, line transects are flown about 25 meters above the ground, at approximately 45 mph, while observers identify clusters of deer and count them (White et al. 1989). We recommend using one of these methods for estimating the size of the mule deer population on Tejon Ranch.

Knowing the size of the mule deer population on the Ranch will help game managers analyze how the number of animals hunted affects the overall population.

Since wild pigs are the most hunted species on Tejon Ranch, we also recommend monitoring the population size of pigs on the Ranch. This can be done by annually through monitoring pig signs such as rooting, trails, scat, tracks, beds, wallows, and carcasses along transects, and relating them to pig density (Barrett et al. 1988). Another potential method for assessing wild pig population levels would be to calculate the hunting take per unit effort (hunter days) from the number of permitted hunter days and the number of pigs taken. Wild pig populations and density are important to monitor, as these animals may have major effects on the native vegetation of Tejon Ranch.

6.7 HYDROLOGY

There are four major classes of anthropogenic modifications or stressors which may affect water supplies: (1) diversions, which reduce total discharge volume; (2) impoundments, which change in discharge duration, seasonality, and volume; (3) irrigation, impervious surfaces, and/or removal of vegetation which frequently leads to perennialization of streams and acceleration of runoff rates; and (4) groundwater pumping. These anthropogenic modifications may lead to one or more of the following system responses to surface and/or groundwater hydrology which impact surface streams and their associated riparian communities. Modifications may include lowering of the water table depth, altered hydroperiod, changes in flood regimes, alteration of landforms or channel morphology, and changes in nutrient cycling rates. Responses to hydrologic alterations on the Ranch may include less diverse age structure, reduced structural diversity, lower recruitment, and less habitat heterogeneity or niche diversity.

In addition to changes in consumption patterns, water availability will likely be affected on the supply side through anthropogenic climate change. Models project that a potential consequence of climate change may be through changes in intensity and seasonality of precipitation. Recent climatological corroborating evidence includes a measured trend of 20% more frequent intense rainfall events, defined as >4in/day, in the western U.S. over last century (Groisman et al. 2004). This may result in complications for management including greater volumes of runoff collected over shorter periods.

6.7.1 FUTURE MONITORING RECOMMENDATIONS

In general, a key management concern for both resource managers and conservation practitioners is accurate water budgeting for both agricultural operations (e.g. livestock grazing) and ecosystem support. To this end, we analyzed historic precipitation data for several monitoring stations located both on and in the vicinity of

Tejon Ranch (WRCC 2009). Based on our review and analysis of historic precipitation records, this dataset appears to be largely incomplete prior to the 1950's and does not provide adequate data with which to draw well-informed conclusions. Based on regression analysis of the available precipitation data over time, no statistically significant trend related to the amount or seasonality of precipitation emerges. As a result, the existing historic data offers little predictive value for modeling or forecasting future precipitation and water availability. Due to the incompleteness of the historic precipitation dataset and its possible responsibility for the lack of a detectable long-term trend, the collection of more comprehensive precipitation data is recommended to improve the predictive power of future precipitation models. In addition, thorough monitoring and recording of precipitation amounts across the full elevational gradient of the Ranch would facilitate better understanding of the spatial variability in precipitation. Ultimately, more comprehensive precipitation monitoring data would likely improve water budgeting for future management of surface and ground water resources.

Surface stream gauge data for the Ranch and surrounding vicinity is also extremely limited and insufficient to establish a clear baseline for managerial purposes. Management relevant issues related to surface stream flows on the Ranch include the allocation of water for agricultural diversion while conserving adequate supplies to support native riparian vegetation communities or to maintain critical hydrologic and ecosystem processes. In order to better establish a baseline for surface water resources on the Ranch, stream gauges should be installed to record flow in select drainages on the Ranch. In addition, meters should be installed on diversion systems to quantify the amount of water diverted for agricultural use. Both of these should then be coupled with annual sampling of vegetation community structure and species composition along transects to evaluate the effects of surface hydrology on riparian community health and structure.

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7 VEGETATION COMMUNITIES

For each vegetation community analyzed, a brief introduction of the size, composition, and location of the community on the Ranch are described below. Baseline conditions for each community type are also presented, followed by a conceptual model and narrative describing the system. The conceptual models identify key environmental stressors and processes within each community type. A description of the conceptual model format can be found in Section 3.3.1. In addition, future monitoring and management recommendations were proposed for each vegetation community.

7.1 CHAPARRAL

Chaparral is a complex of shrubby vegetation types, characterized by evergreen sclerophyll shrubs in genera such as *Adenostoma*, *Ceanothus,* and *Arctostaphylos*, which dominate many sites at low to middle elevations throughout California (Conard and Weise 1998). On Tejon Ranch, chaparral is found primarily along the southeastern edge of the Tehachapi Mountain Range, as well as on the southern end of the Tejon Ranch property, adjacent to the Interstate 5 Freeway. Tejon Ranch chaparral communities consist primarily of scrub oak chaparral, mixed chaparral, and chamise chaparral (California Wildlife Habitat Relationship System CDFG; Holland 1986).

7.1.1 BASELINE CONDITIONS

The existing chaparral communities on Tejon Ranch are widely distributed across a variety of elevations. These shrub-dominated mesic communities are located on gentle to steeply sloping east, south, and west-facing ridges and slopes. Due to limited time, resources, and other vegetation communities as a higher priority, we did not collect baseline data on the chaparral communities on Tejon Ranch.

7.1.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION OBJECTIVE: Promote intermediate fire intervals (20-100 years) in chaparral communities.

Grazing does not significantly impact chaparral communities on Tejon Ranch, due to vegetation density which deters cattle (Figure 7.1-1). There is some browsing by deer, and grazing by cattle is minimal. Chaparral on Tejon Ranch is primarily affected by fire. High fire frequencies contribute to a dominance of crown-sprouting species, whereas low fire frequencies contribute to a dominance of seeding species. Monitoring the species composition and vegetation height can indicate time since fire, and inform decisions to administer controlled burns or practice fire suppression.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

Ranch Stressor: Fire Frequency

Fire is an integral component of chaparral ecosystems. Chaparral is an intermediate fire-return interval system, which typically burns with high-intensity crown fires approximately every 20–100 years (Conard & Weise 1998). There are many chaparral species that are fire-dependent during part of their life-cycle, and some require fire for germination (Barbour et al. 2007). Chaparral vegetation rapidly regenerates after fire, through both seeding and resprouting. These post-fire regeneration strategies can be combined in one species, but most often a chaparral species reproduces exclusively by one or the other (Keeley & Zedler 1978).

Key Process: Low Fire Frequency and Seedling Establishment

Longer intervals between fires (low fire frequency) can result in more obligate-seeding species regeneration, due to larger openings in the chaparral canopy following the mortality of obligate-sprouting species (Keeley & Zedler 1978).

Key Process: High Fire Frequency and Crown-Sprouting

Conversely, high fire frequencies generally result in a dominance of sprouting species. This phenomenon may be due to less intense fires, lower shrub mortality, less canopy openings for seedlings, or insufficient time between fires to replenish the existing seed-bank (Keeley & Zedler 1978).

Endpoint: Species Composition Surveys

Chaparral species composition can be affected by precipitation, slope aspect, topography, soil composition, and fire. A higher percentage of sprouting species suggests the community has burned recently, whereas a higher percentage of seeding species suggests that it has been longer since the community burned.

Landscape Stressor: Climate

Chaparral vegetation communities occur in Mediterranean climates, with dry summers and wet winters. Climate temperature can influence chaparral community type. For example, summer drought and winter freezing temperatures can limit the growth, survival, and distribution of chaparral species. Water stress during summer drought can result in gas embolism in woody stems, which blocks water transport and causes shoot dieback. Freezing temperatures can also cause embolism and shoot mortality (Langan et al 2007).

Ranch Stressor: Precipitation

Over 60% of the chaparral communities in California occur in areas that receive between 250 – 750 mm of precipitation per year. Precipitation in chaparral communities is a predictor of species diversity, with higher precipitation levels contributing to higher species diversity (Keeley, Fotheringham, & Baer-Keeley 2005).

Key Process: Slope Aspect and Topography

On a local scale, chaparral communities express turnover at varying elevations and on different slope aspects (Keeley 2000).

Key Process: Soil Composition

Inland chaparral soils tend to be shallow and rocky. Substrates include fractured sandstones and shales, coarse-grained granitic soils, and fine-grained weathered volcanic and mafic substrates such as serpentine and gabbros (Barbour et al 2007). Substrate type can influence species composition and diversity. For example, substrates with low soil fertility, such as serpentine soils, can harbor high levels of endemic species richness, due to less canopy cover and more open spaces (Safford & Harrison 2004).

<u>Endpoint: Faunal Indicator: California Thrasher</u>

The California thrasher (*Toxostoma redivivum)* occupies moderate to dense stands of chaparral in the foothills and lowlands of California. It feeds on insects, spiders, and other invertebrates, as well as fruit, acorns, and forb seeds (California Wildlife Habitat Relationships). Presence/absence surveys for the California thrasher can be used to assess the habitat suitability of dense chaparral for this umbrella species on Tejon Ranch.

7.1.3 Future Monitoring and Management Recommendations

1. *Management Target:* Maintain a diversity of sprouting and seeding chaparral species across the Ranch.
   Monitoring Recommendation: Line intercept species composition surveys.

2. *Management Target*: Maintain chaparral habitat suitability for the California Thrasher.
   Monitoring Recommendation: Conduct presence/absence surveys of the California Thrasher. In the future, more bird species may need to be monitored to assess the different habitat suitability of open chaparral stands on Tejon Ranch.

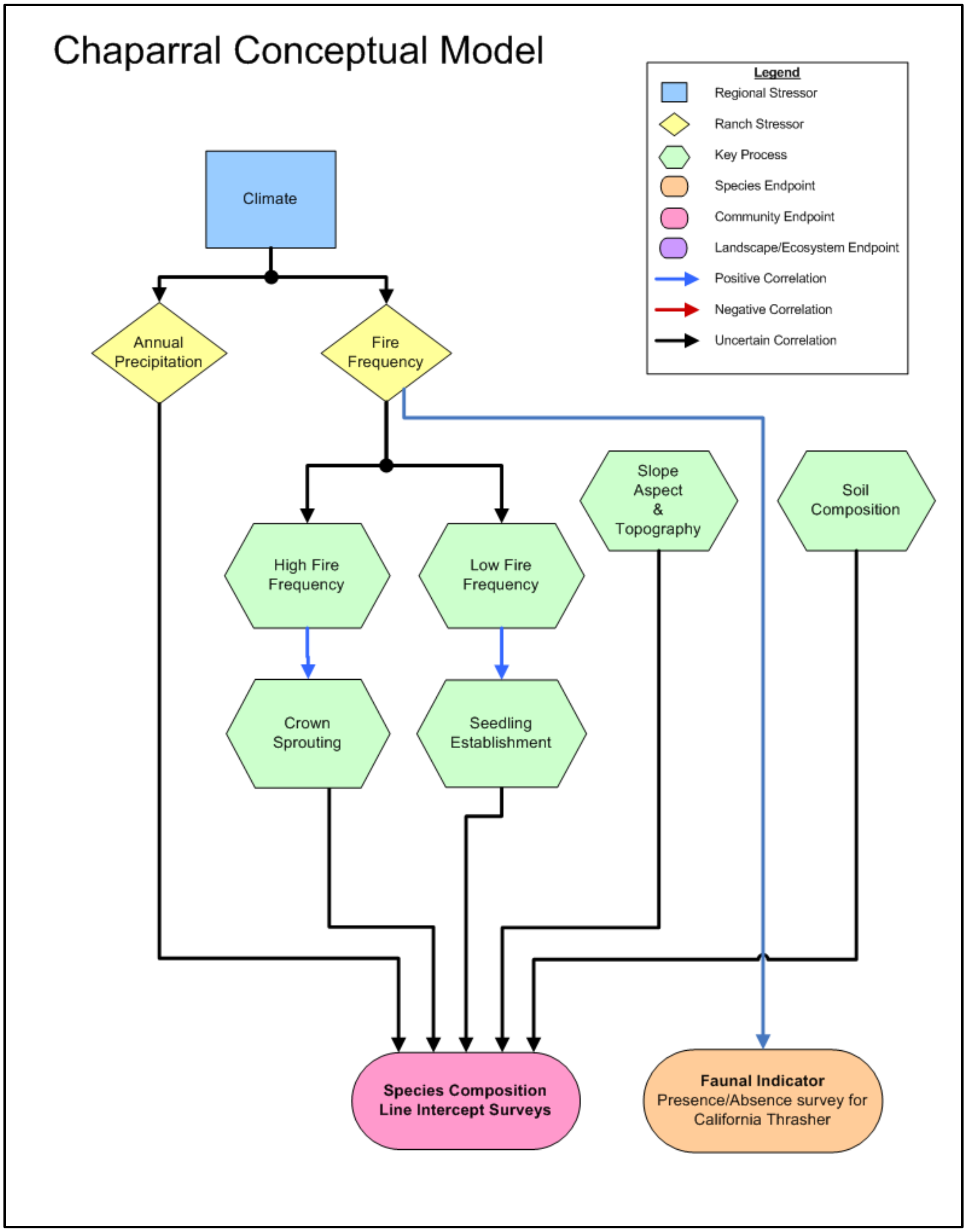

Figure 7.1-1. Conceptual model for chaparral communities on Tejon Ranch.

7.2 JOSHUA TREE WOODLANDS (UPPER SLOPE MOJAVE SCRUB)

Joshua trees (*Yucca brevifolia*) are endemic to the Mojave Desert and are found in southern Nevada, southwestern Utah, western Arizona, southeastern California, and northern Baja California Norte (Gucker 2006). There are approximately 2,000 acres of Joshua tree woodland mapped on Tejon Ranch (Figure 1.3-4), however this size may be an underestimation of what is actually on the ranch. They appear to be in good health, although more research is needed (see baseline conditions).

The subspecies of *Yucca brevifolia* that occurs on Tejon Ranch is the *herbertii* form which is characterized by rhizomatous clumps along the western margin of the Mojave Desert, the slopes of the Tehachapi Mountains, the southern Sierra Nevada, and the Antelope Valley (Webber 1953). *Yucca brevifolia herbertii* typically occurs on loose, rocky soils and gentle substrates, such as those characterized by many areas in the southeast side of Tejon Ranch in the Antelope Valley (Barbour et al. 2007). These soils are necessary for Joshua trees to re-sprout from their rhizomes or for the seedlings to become established. *Yucca brevifolia herbertii* is a short-stature sub-species of Joshua trees, and individuals are generally under three meters tall (Barbour et al. 2007). *Yucca brevifolia herbertii* typically occurs with several different desert plant communities with understory shrubs and grasses (Barbour et al. 2007). The Joshua tree provides a valuable habitat for many wildlife species. For birds such as the ladder-backed woodpecker (*Picoides scalaris)*, the cactus wren (*Campylorhynchus brunneicapillus)*, and Scott's oriole (*Icterus parisorum)*, Joshua trees provide perches and nest sites (Stebbins 1966). In addition, the Joshua tree's sharp leaves provide a protective habitat for birds and lizards. Specifically, the desert night lizard (*Xantusia vigilis)* needs fallen branches and dead clumps of Joshua trees or other yuccas for shelter (Stebbins 1966). In addition, small mammals depend on Joshua trees for seeds and fruit, and in turn, the plants depend on rodents for seed dispersal (Esque et al. 2003).

Throughout the western Mojave and on Tejon Ranch, Joshua tree woodlands are subject to many environmental stressors. The main environmental stressors to Tejon Ranch's Joshua tree woodlands are air pollution, climate, grazing, hunting, and fire. Air pollution can lead to nitrogen deposition as well as negatively affect Joshua tree foliage health, which then reduces the production of seeds, seed dispersal, and ultimately the recruitment of young Joshua trees (Allen et al. 2009). Changes in climate can affect the Joshua tree's main pollinator, the pronuba moth (*Tegeticula synthetica)*, through parasite invasion, which could ultimately affect seedling establishment and recruitment. Climate, as defined by precipitation, temperatures, and fire, can influence invasion by non-native species and natural processes such as rhizome sprouting or seedling establishment; however, the sub-species of Joshua tree that occurs on Tejon Ranch is known to be resilient and re-sprout well following wildfires. Hunting in and around Joshua tree woodlands could alter native mammal populations that browse Joshua tree seeds and seedlings, although to what extent is uncertain. In addition, the uncertain effect of grazing on the composition of Joshua tree woodland species is an opportunity for future monitoring and field research.

7.2.1 Baseline Conditions

By evaluating baseline data collected in 2009 on Joshua tree woodlands located within the Tri-Centennial Acquisition Area of Tejon Ranch, we see evidence of high levels of Joshua tree recruitment, as evidenced by the amount of Joshua trees in the 0-1 meter height range (Figure 7.2-1). Additionally, through an analysis of aerial imagery involving a grid sampling of Joshua trees in one part of the Tri-Centennial Acquisition Area, we found that between 1952 and 2009 Joshua trees had expanded in their distribution by more than 108 points (Figure 7.2-2 and 7.2-3). This could have important implications for future conservation and preservation of Joshua trees on Tejon Ranch, as the trees are in the western edge of their range, in an area where there is the possibility for Joshua trees to expand to higher elevations in the face of a changing climate. With these baseline conditions, we have only started to describe the current status of Joshua trees on the Ranch.

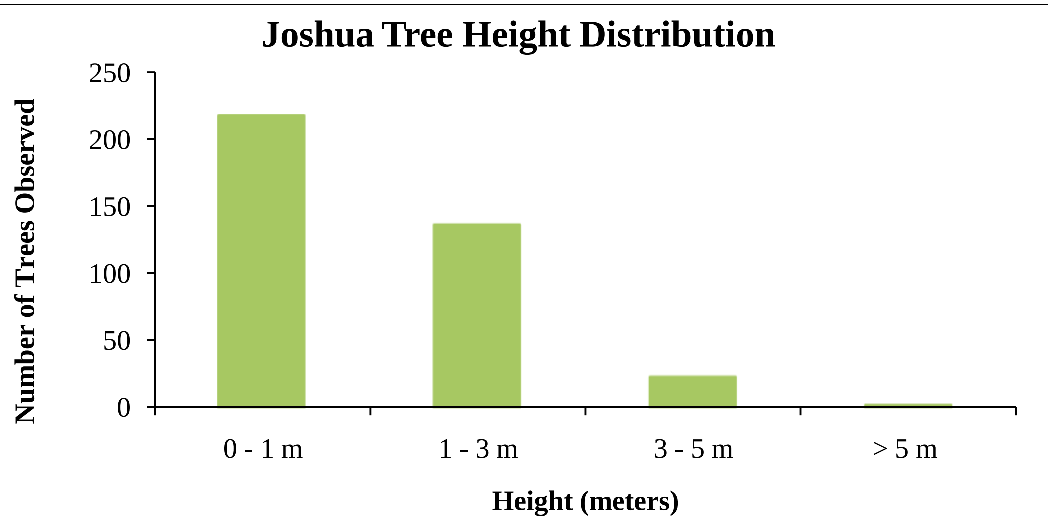

Figure 7.2-1. Joshua Tree Height Distribution.

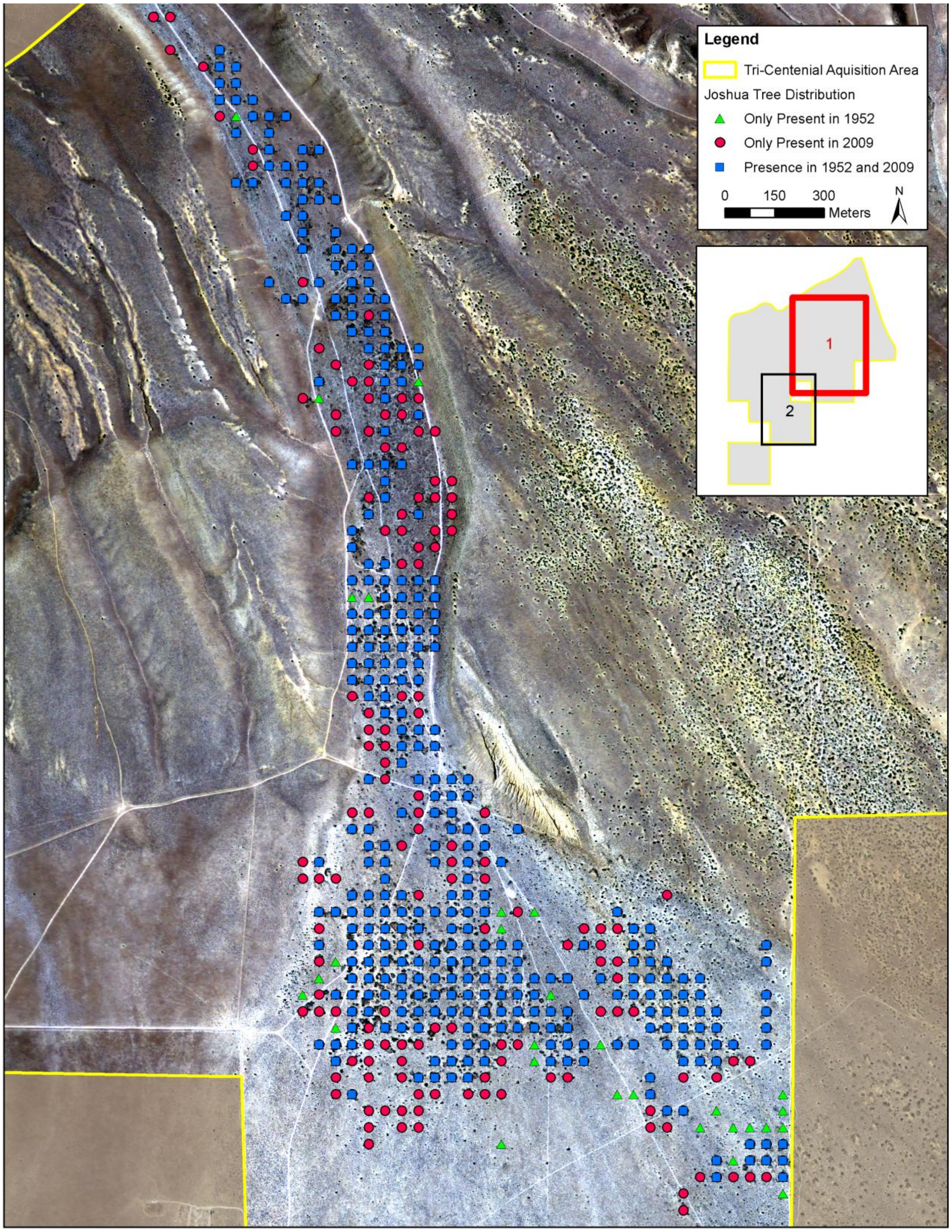

Figure 7.2-2. Joshua Tree Historic Distribution Map 1 of 2 for the Tri-Centennial Acquisition Area. Compares Joshua tree presence in 1952 with presence in 2009.

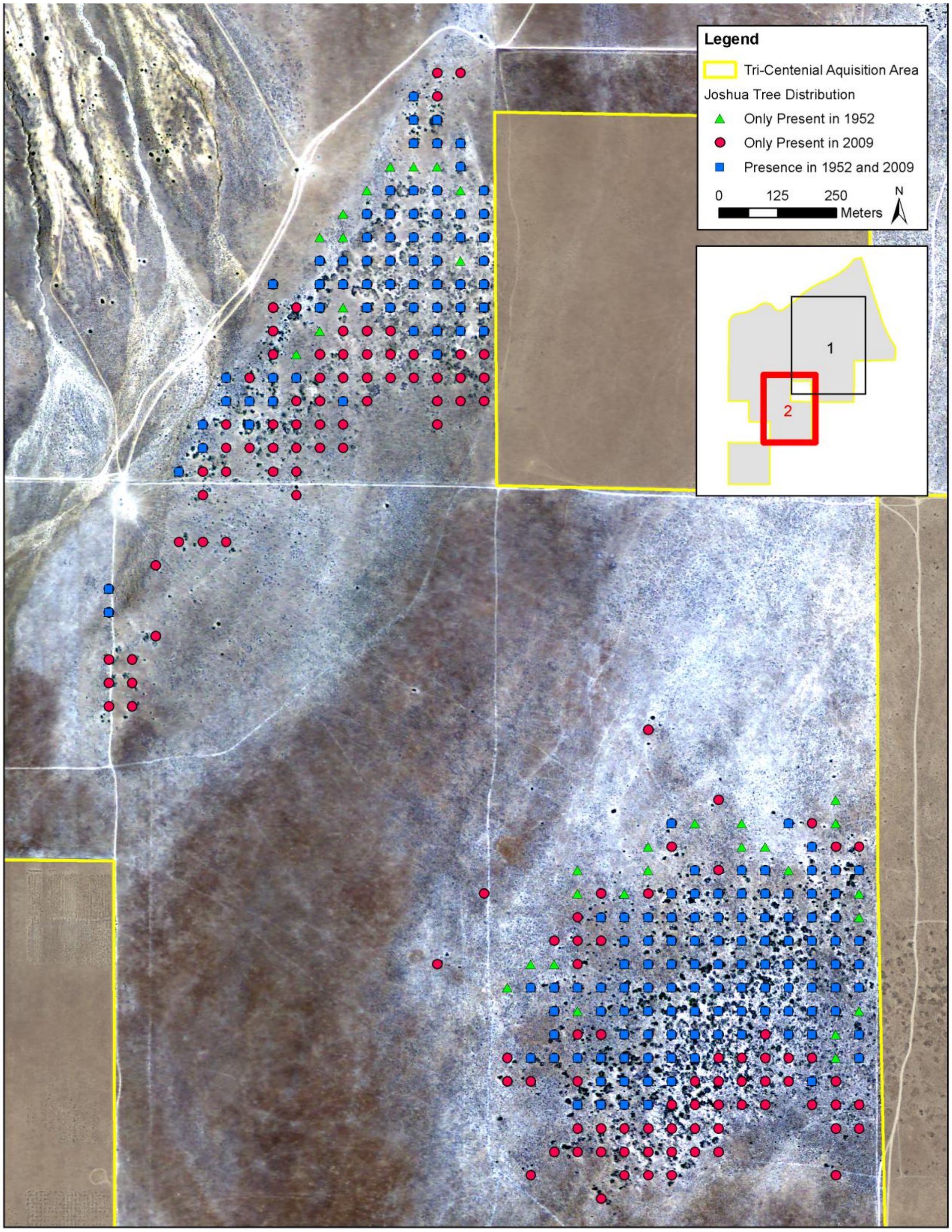

Figure7.2-3. Joshua Tree Historic Distribution Map 2 of 2 for the Tri-Centennial Acquisition Area. Compares Joshua tree presence in 1952 with presence in 2009.

7.2.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION GOAL: Sustained Joshua Tree Woodland Health & Recruitment

The Joshua Tree Woodland conceptual model (Figure 7.2-4) shows management goals that include sustaining the continued presence of healthy, reproductive Joshua trees on the Ranch at a variety of ages, as well as sustaining the composition of native woodland and shrub species. Although the Ranch's Joshua tree woodlands currently appear to be healthy, further research is needed to assess the woodlands through surveys of species composition, particularly of native grasses and shrub species, as well presence/absence surveys of desert night lizards, Joshua tree condition surveys, continued surveys of Joshua tree recruitment and structural diversity, and ground-truthing the distribution of Joshua trees.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

<u>Landscape Stressor: Air Pollution</u>

The Mojave Desert receives nitrogen emissions from urban sources In Los Angeles County, especially from vehicle emissions (Section 6.1; Allen et al. 2009). Air pollution in the Mojave Desert basin alters soil composition through nitrogen deposition, which can lead to invasion and replacement by non-native vegetation.

Key Process: Nitrogen Deposition

Nitrogen deposition can alter soil composition and may ultimately change the species composition of Joshua tree woodlands, and likely affects the persistence of desert night lizards as well due to loss of habitat (Allen et al. 2009). In addition, nitrogen deposition may favor non-native species, especially grasses.

Key Process: Joshua Tree Foliage Health

Another effect of air pollution is lowered health of foliage, which then affects *Yucca brevifolia herbertii*'s ability to produce seeds. Lowered production of seeds, and thus lowered rates of seed dispersal, negatively affect seedling establishment (Allen et al. 2009). In addition to the effects described above, the effects of atmospheric carbon dioxide (CO_2) concentrations on *Yucca brevifolia* recruitment (via seedling cold tolerance) are discussed under the climate landscape stressor below.

<u>Endpoint: Air Pollution Monitoring</u>

The effects of air pollution can be monitored through quantitative sampling of species composition within Joshua tree woodlands on Tejon Ranch and by measuring annual Joshua tree recruitment (through height surveys) and condition surveys.

Landscape Stressor: Climate

Changes in climate can affect biotic processes in Joshua tree woodlands such as competition, disease, pollination, predation, and species recruitment or shifts in distribution, but these effects can be difficult to model relevant to climate change (Dole et al. 2003). Additionally, changes in atmospheric CO_2 concentrations can have direct effects on the physiology of Joshua trees which could counter or amplify the direct effects of climate change on Joshua tree woodlands (Dole et al. 2003). Climate change also may affect the pollination and flower production of Joshua trees.

Joshua trees survive in areas with cold winters, hot summers, and little precipitation, with an essential dormant period during the cold winter (Gucker 2006). However, prolonged drought or low precipitation, combined with the effects of herbivorous rodents (refer to Section 6.6) can lead to Joshua tree mortality (Esque et al. 2003).

Key Process: Joshua Tree Seedling Recruitment

The current distribution of Joshua trees is strongly restricted by lethal low-temperatures, especially for seedlings since this is the stage most sensitive for recruitment (Dole et al. 2003). Short durations of hot temperatures may increase Joshua tree germination, whereas cold periods are required for optimal seedling growth (Gucker 2006). Therefore, changes in climate may affect Joshua trees, although future climate conditions are uncertain. Studies have shown that Joshua tree growth at day/night air temperatures of 20/5 ºC combined with 700 parts per million (ppm) CO_2 concentrations increases the low-temperature tolerance of Joshua tree seedlings by 1.6 ºC (Loik et al. 2000; Dole et al. 2003). The effects of increased CO_2 have the potential to increase recruitment and may allow the range of Joshua trees to expand into regions with cooler climates than current range limits, such as into the higher elevations of Tejon Ranch (Dole et al. 2003).

The potential for Joshua tree range expansion has implications for management, as higher elevation areas around the current Joshua tree distribution should be managed for compatible land use as well as current Joshua tree woodlands.

Key Process: Joshua Tree Insect Pollinators

Another effect of climate on Joshua trees is related to insect pollinators. The female yucca moth, *Tegeticula synthetica*, is the Joshua tree's primary pollinator. Yearly she emerges from her pupa near a Joshua tree, mates in a flower where she lays her eggs in the flowers' ovaries, and flies to a freshly opened flower. When the larvae hatch, they feed on the yucca seeds.

Key Process: Parasite Invasion

However, *Tegeticula synthetica* is susceptible to parasitism by endo- and ectoparasites, which can become more prevalent with warmer temperatures (Gucker

2006). Therefore, climate can affect parasite populations, which prey on pollinators, ultimately decreasing Joshua tree pollination, fruiting, and seedling establishment.

Ranch Stressor: Fire

Within the western Mojave Desert, Joshua trees are a fire adapted species. Apical meristems growing above the ground surface and fire-resistant bark on mature Joshua trees help Joshua trees to survive fire. If the top of the tree is killed or damaged by fire, trees can sprout from the root crown, rhizomes, and/or branches (Gucker 2006). The low, rhizomatous forms of *Yucca brevifolia herbertii* are known to resprout well following fires, whereas other forms of the *Yucca brevifolia* species tend to re-sprout weakly or are killed by fire (Barbour et al. 2007).

Key Process: Joshua Tree Mortality

Following high-intensity stand-replacing fires, Joshua trees may be unable to resprout, leading to tree mortality and impacts on dependent faunal species such as the desert night lizard (*Xantusia vigilis*). Joshua trees provide protection and feeding sites for the small desert night lizard which is often found in Joshua tree bark and clusters of dead leaves. Joshua tree bark provides protection and shelter for the desert night lizard, therefore monitoring the lizard could be a good indicator of Joshua tree woodland structural diversity (Gucker 2006).

Key Process: Invasion by Non-native Plant Species

Re-sprouting of *Yucca brevifolia herbertii* is generally successful following fires, but they must compete with post-fire species such as *Chrysothamnus nauseosus* and *Achnatherum speciosum* (Barbour et al. 2007). In addition, increases in herbaceous non-native vegetation such as cheatgrass (*Bromus tectorum*) and red brome (*Bromus madritensis*) facilitate increased fire incidence and fire size (Gucker 2006, Brooks et al 2004). Fires can be more intense and frequent with the presence of non-native species, as they have altered the fuel structure and fire behavior in a vegetation community that is relatively fire-resistant (Gucker 2006). When considering fire management alternatives, control of these non-native species may aid in sustaining Tejon Ranch's Joshua tree populations.

Ranch Stressor: Hunting

Hunting of small mammals occurs throughout Tejon Ranch, including around Joshua tree woodlands, although the effects (if any) are uncertain in Joshua tree woodlands. Ground squirrels, woodrats, jackrabbits, kangaroo rats, and mice utilize Joshua tree woodlands and feed on Joshua tree fruits, and in turn disperse seeds (Gucker 2006; Vander Wall et al. 2006). Although hunting may have some influence on rodent populations, the effect is uncertain and likely relatively small compared to other system stressors.

Key Process: Joshua Tree Seed Dispersal

According to some studies, it is thought that the Joshua tree – rodent seed dispersal interaction is an obligate mutualism for the plant and animal (Vander Wall et al. 2006). Therefore, disturbances to rodent populations may alter Joshua tree seed dispersal.

Key Processes: Joshua Tree Seedling Establishment and Annual Precipitation

Although small mammals are important to the dispersal of seeds, they can also affect seedling establishment by browsing on seedlings or damaging adult Joshua trees by consuming the bark-like tissue (periderm) on the trunks in times of drought (Esque et al. 2003). These small mammals normally forage on seed, shoots, fruits, and roots of plants, but in times of drought have been documented to remove and consume the periderm from Joshua trees (Esque et al. 2003). The combination of drought and rodent predation of Joshua trees has led to the death of numerous plants in Joshua tree National Park, and may merit monitoring on Tejon Ranch (Esque et al. 2003).

<u>Endpoint: Rodents and Hunting</u>

Through surveys of Joshua tree condition, if periderm damage from rodents is detected, management actions may be considered. In addition, California ground squirrels (*Spermophilus beecheyi*) are known to climb Joshua trees and consume the fleshy fruits and seeds, thus destroying some of the seed crop (Gucker 2006). Although no documentation on specific impacts to rodent populations or Joshua tree woodlands exists for Tejon Ranch, hunting may have a small effect on native browser populations, in turn altering seed dispersal and establishment. Therefore, we recommend surveys on Joshua tree heights and conditions be completed in order to document potential changes from rodent populations and drought.

<u>Ranch Stressor: Grazing</u>

Grazing occurs at Tejon Ranch, and although there is likely some effect on Joshua tree woodlands, these effects are not well understood. What is known is that grazing in Joshua tree woodlands could affect species composition, especially of grass and shrub species, which young Joshua trees need as shrubs and perennial grasses serve as nurse plants for Joshua tree seedlings (Brittingham & Walker 2000). Grazing within Joshua tree woodlands therefore merits additional study.

7.2.3 FUTURE MONITORING AND MANAGEMENT RECOMMENDATIONS

Continued presence of healthy, reproductive Joshua trees (*Yucca brevifolia*) on Tejon Ranch as well as a variety of ages and sizes of trees will indicate healthy Joshua tree woodlands. In addition, species composition surveys of both native and non-native grass and shrub species are important to track changes in Joshua tree woodland composition and determine management options. The presence of desert night lizards (*Xantusia vigilis*), also indicates a healthy ecosystem, as it is a native species dependent on Joshua trees. Recommended monitoring targets for Joshua tree woodlands on the Ranch include:

1. *Management Target:* Sustaining the continued presence of healthy, reproductive Joshua trees on the Ranch at a variety of ages
   Monitoring Recommendation: Continued and expanded surveys of Joshua tree heights and surveys of Joshua tree health/condition (Appendix C). We recommend the continued measurement of the heights of live Joshua trees within belt transects, also documenting the presence of dead trees. These belt transect should be laid out randomly in 100 m lengths, 5 m wide. For every Joshua tree encountered, document the height (could be estimated or measured). Using the data sheets created (Appendix C), document each Joshua tree measured into the appropriate height bin. Bins include height classes from 0-.5 meters, .5-1 meter, 1-2 meters, 2-5 meters, and 5+ meters. For each Joshua tree measured and recorded, also record the distance on transect the tree was encountered. This data can be used to evaluate whether the Joshua tree stands are clumped or spread out. By tracking the amount of land covered by these belt transect surveys, Joshua tree density may be calculated. These surveys should be completed regularly (ideally every 5 years). Results of these surveys could be used to quantify Joshua tree recruitment, which is an important attribute of healthy Joshua tree woodlands After completing Joshua tree height surveys, and assessing how long the woodlands have existed since the last major disruption (i.e. fire), calculate Joshua tree ages based on height (Gilliland et al. 2006). Survey for Joshua tree condition, or damage to trunks (could be done simultaneously with height surveys). This damage could indicate herbivory from rodents, especially in times of drought.

2. *Management Target:* Maintain a balance of species composition of woodland, grassland, and desert shrublands.
   Monitoring Recommendation: Surveys using Species Composition Area Plots, including identification of native and non-native species.

3. *Management Target:* Continued presence of desert night lizards on the Ranch.
   Monitoring Recommendation: Presence/Absence surveys of desert night lizards.

4. *Management Target:* Protect existing Joshua tree woodlands and potential expansion areas around existing woodlands.
   Monitoring Recommendation: Continued and expanded mapping of Joshua tree distribution over time to asses any major shifts or changes in distribution. We recommend that the method described in Section 3.4.1, be

continued every 25 years with the most recent aerial photos that are available.

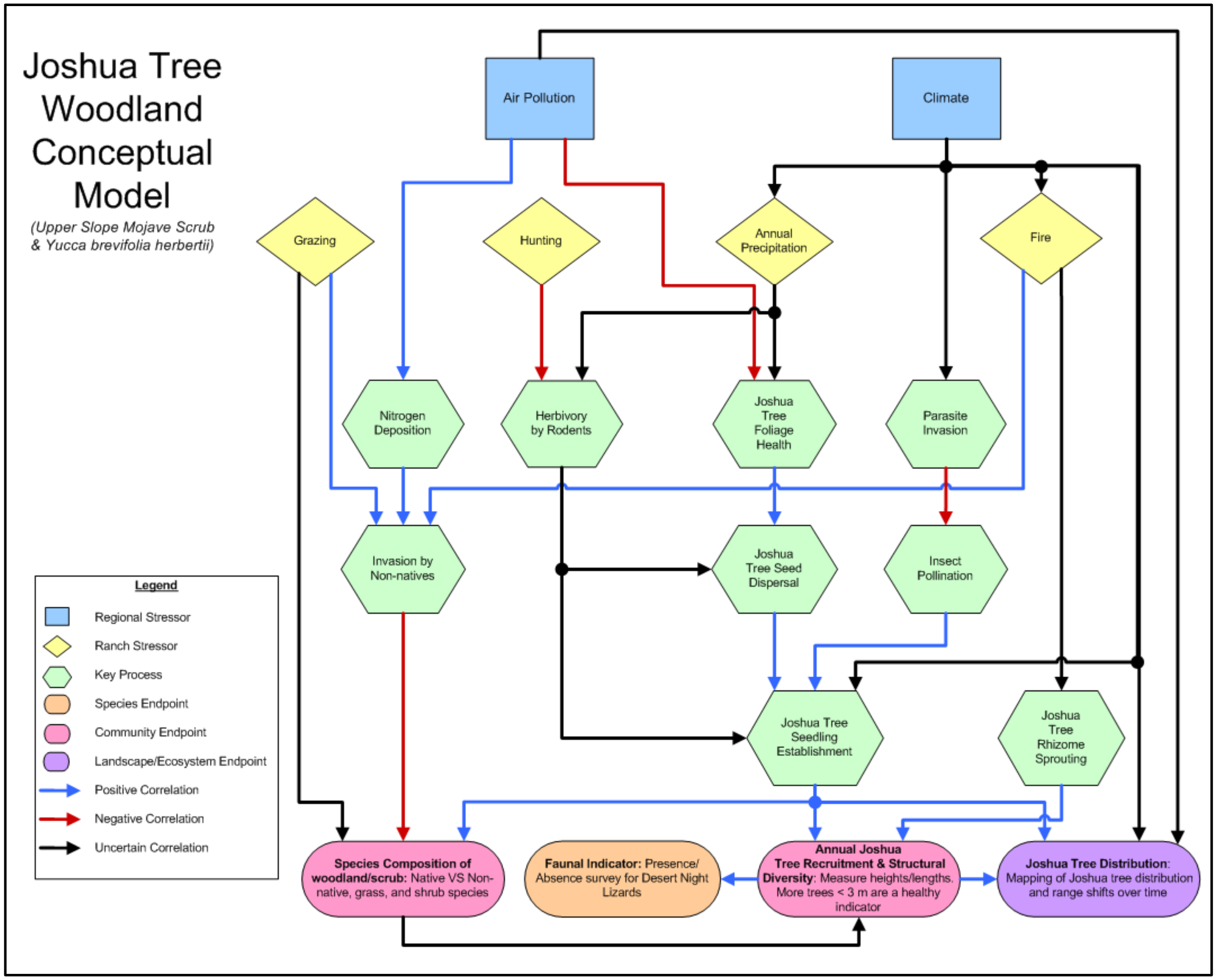

Figure 7.2-4. Conceptual model for Joshua Tree Woodlands on Tejon Ranch.

7.3 MONTANE MIXED HARDWOOD & CONIFER FORESTS

Montane mixed hardwood and conifer forests, which include vegetation classes of canyon live oak woodlands, black oak woodlands, mixed-oak woodlands, white fir/mixed oak, white fir stands, incense cedar stands, intermixed conifers, and conifer/mixed oak forests occur at the higher elevations of Tejon Ranch (Figure 1.3-4). These communities exhibit spatial patterns and gradients related to climate, productivity, topography, and chaparral understory (Barbour et al. 2007). Tree species prevalent in these high-elevation forests on the Ranch include canyon live oak, white fir, black oak, incense cedar, ponderosa pine, box elder, big leaf maple, sugar pine, dogwood, and Jeffrey pine. Mixed hardwood montane forests may also support understories of annual grasses, shrubs and herbs, as well as meadows dominated by grasses, sedges, and rushes in areas of near-surface groundwater (Barbour et al. 2007). For additional information regarding other vegetation communities included within and amongst montane forests, please refer to the conceptual models and narratives for chaparral and riparian systems (Sections 7.1 and 7.4). Patterns of tree dominance tend to follow a precipitation gradient where ponderosa pine, white fir, sugar pine, and incense cedar tend to dominate moist windward slopes ad mid-elevations, and Jeffrey pine and white fir tend to dominate leeward slopes (Barbour et al. 2007). Canyon live oaks tend to occur at mid-elevations of steep slopes, whereas black oaks tend to be restricted to granite substrates, sandstones, and alluvium at mid-elevations (Barbour et al. 2007). Wildlife including large ungulates such as Rocky Mountain elk, mule deer, and cattle live in montane forests, as do large mammals such as mountain lions, black bears, ringtails, bobcats, coyotes, and gray foxes.

7.3.1 BASELINE CONDITIONS

In general, the montane forests on Tejon Ranch appear to be limited in range, but otherwise in good health. Although the Ranch's montane forests appear to be healthy, further research and monitoring is needed to assess community health through sampling of foliage health indicators, vegetation diversity and structure, stand density, and tree mortality. Due to limited time, resources, and other vegetation communities as a higher priority, we did not collect baseline data on montane forest communities on Tejon Ranch.

7.3.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION GOAL: Sustained Montane Forest Health

The montane mixed hardwood and conifer forests on Tejon Ranch are subject to natural and anthropogenic disturbances which influence their long-term dynamics (Barbour et al. 2007). The main environmental stressors to Tejon Ranch's montane forests are air pollution, climate change (affecting fires, precipitation, and snowpack), and grazing by livestock (Figure 7.3-1). In addition to baseline condition surveys being needed, montane forests should be regularly monitored in order to track the possible effects of increased stressors on the ranch, especially since montane forests may be the first areas to show sensitivities to climate change and air pollution.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

Landscape Stressor: Air Pollution

On Tejon Ranch, air pollution is a major concern and annually exceeds both ozone and PM10 levels (see Section 6.1). The pollution likely comes from agricultural areas in the form of ammonia and nitrous oxides in pesticides and fertilizers, and from cars and power plants in the form of oxidants and nitrates from emissions. The pollutants are then dispersed to Tejon Ranch's montane forests via wind currents.

Key Process: Foliage Health & Tree Growth

Effects of these pollutants on montane forests include lower photosynthetic rates, lower production of carbohydrates, and changes in plant priorities which can limit tree growth and reduce plant health (Barbour et al. 2007). In addition to pollutants, montane forests are susceptible to damage from tropospheric ozone. Foliage is longer-lived in conifers, so ozone exposure and uptake is higher. Ponderosa and Jeffrey Pines are the most sensitive to ozone (McBride & Laven 1999; Barbour et al. 2007). Ozone induces premature foliar senescence and abscission (Barbour et al. 2007). Ozone also leads to other physiological impacts such as crown injury and chlorotic mottle on older needles.

Key Process: Pest Invasion

Ozone and air pollution can lead to increased susceptibility to pests. Air pollution, including tropospheric ozone, weakens trees physically and alters resource allocation priorities, which can leave the vegetation susceptible to invasions from pests such as bark beetles (Barbour et al. 2007).

Endpoint: Foliage Health Surveys

Several vegetation characteristics can be used as indicators of changes to montane mixed-hardwood forest health resulting from air pollution. Changes that would be attributable to air pollution would most easily be observed through an assessment of foliage health indicators such as crown condition surveys, tree damage surveys, and ozone injury surveys.

Endpoint: Vegetation Diversity & Structure

In addition to foliage health surveys, vegetation diversity and structure can be a good indicator of whether air pollution may be playing a role in altering the species composition of a forest.

Endpoint: Tree Mortality

Another indicator of air pollution (and other stressor) effects on montane forests is the level of tree mortality within a stand and resulting downed woody debris. An increase in the amount of dead trees may be attributed to pests, which may have killed trees as they were weakened by air pollution.

Landscape Stressor: Climate

Climate is a major landscape-level stressor on Tejon Ranch. The effect of climate on montane mixed-hardwood forests can be manifested through processes such as fire intensity and frequency, precipitation (or lack thereof), and reduced snowpack duration. With uncertainties surrounding future emissions scenarios, coupled global climate models (GCM's), and the specific responses of vegetation community distribution to changing climate envelopes on the Ranch, this conceptual model addresses only the most important ecosystem processes due to climate. In the future, if changes to mixed-hardwood montane forests are witnessed, the conceptual model may be used to determine whether those changes are due to identified climactic factors or from other causes.

Key Process: Snowpack Duration

Snowpack duration is an important factor for montane forests, as soils need to be replenished with water and an appropriately long winter season ensures snowpack and moisture for vegetation. Although soil moisture recharge at lower elevations is linked to storm precipitation, at higher elevations soil moisture replenishment occurs mainly during the snow melt season in the spring or summer. The soil water is then restored by percolation from snowmelt or through runoff and down-slope percolation (Minnich 1986; Barbour et al. 2007). One scenario of climate change includes a shorter winter snow season, with the first frost occurring later, and the first melt occurring earlier. A shortened snow season and warmer temperatures could lead to a shorter snowpack duration which decreases summer and fall soil moisture, thus affecting conifer germination and hardwood establishment (Barbour et al. 2007).

Ranch Stressor: Annual Precipitation

In addition to snowpack, a decrease in annual precipitation, such as a prolonged drought may lead to increased susceptibility to pests, directly affecting the health of the tree. The effects of climactic stress through altered precipitation, temperature, and snowpack can be monitored through any of the three endpoints identified above.

Key Process: Soil Moisture

Both snowpack duration and annual precipitation directly affect soil moisture. The amount of soil moisture during the growing season and summer drought severity are important limiting factors in montane forests. Decreased soil moisture can affect conifer germination and hardwood establishment, as well as affect a tree's susceptibility to pests (Barbour et al. 2007).

Ranch Stressor: Fire

Climate and fire management practices have the potential to alter the fire regime on Tejon Ranch. Fire is a natural and necessary part of mixed-hardwood and conifer forests in order to maintain vegetation diversity and enable conifers to germinate. If the natural fire regime has been suppressed in a forest for long periods of time (e.g. decades), such has been the case in many areas of Tejon Ranch, any fire that does burn the area may be in the form of a high-intensity crown fire due to the density of trees and massive buildup of fuels (Minnich 1988; Barbour et al. 2007). Two particular scenarios are addressed in the conceptual model: high-intensity crown fires and low-intensity ground fires.

Key Process: Decrease in Ponderosa & Jeffrey Pines

The absence of all fire from the montane forest ecosystem would have a negative effect on the forest's overall diversity and structure, as shade-tolerant and dense species such as incense cedars and white firs would begin to dominate the community as their growth had time to increase (Barbour et al. 2007).

Key Process: High-intensity Crown Fire

High intensity crown fires would have a negative effect on conifer germination and hardwood establishment, as entire stands would likely be destroyed, and conifers are non-sprouters if entirely defoliated by a fire (Barbour et al. 2007). Following a high-intensity, stand-replacing crown fire, mixed-hardwood and conifer forests would likely be replaced by shrublands and chaparral (Barbour et al. 2007). High intensity crown fires negatively affect hardwood establishment by killing seedlings and saplings, as well as eliminating adult oaks.

Key Process: Low-intensity Ground Fire

Low intensity ground fires burn at a lower temperature and occur at more frequent intervals. Low-intensity fires help in maintaining vegetation diversity and structure as they clear duff and prevent the accumulation of ladder fuels, allow chaparral to co-exist, and affect the two processes below (McBride and Laven 1999; Plumb 1979). These effects should be considered in the establishment of a fire management plan for Tejon Ranch.

Key Process: Hardwood Establishment

Black oaks and canyon live oaks respond to low-intensity ground fires with sprouting (McBride and Laven 1999; Plumb 1979).

Key Process: Conifer Germination

Low-intensity ground fires are important and natural for montane forest ecosystems, especially for conifers, as they need fire to germinate (Barbour et al. 2007).

<u>Ranch Stressor: Livestock Grazing</u>

It is unknown exactly how much of the Ranch's montane forests are used for livestock grazing. This is therefore a critical activity to characterize in order to establish a management baseline (see Section 6.5). Cattle can have a profound effect on hardwood species through direct browsing of seedlings and saplings and soil compaction. Cattle grazing can also contribute to increased soil erosion. In montane forests, livestock grazing typically increases woody species while reducing herbaceous layers and seedlings, impacting hardwood establishment while also impacting faunal species such as birds that have ground nests (CalPIF 2002).

Key Process: Soil Moisture

Livestock grazing negatively affects soil moisture, which in turn affects the endpoints of foliage health and vegetation diversity. Surface soils are compacted in areas used for livestock grazing and result in increased soil bulk density, which reduces the amount of water that is able to infiltrate the surface and therefore becomes surface runoff (Tyler et al. 2006).

<u>Endpoint: Grazing</u>

The effect of livestock grazing could be monitored by assessing vegetation diversity and structure or foliage health, although several other stressors and processes may have a greater impact on those endpoints.

<u>Ranch Stressor: Hunting and Game Management– Pigs and Deer</u>

Hunting of pigs and deer may have a positive effect on hardwood establishment, and thus vegetation diversity and structure, as seedlings have fewer animals consuming them. Browsing by deer has been shown to reduce the growth of oak saplings (White 1966). However, there are other stronger factors that may influence hardwood establishment. This is an area with high uncertainty and opportunity for future research.

7.3.3 Future Management and Monitoring Recommendations

Optimal vegetation community composition and structure is a robust mixture of species, age and size classes, and healthy canopy, shrub, herb, and duff layers. These diverse, mature forest habitats are defined as having the presence of old trees, a variety of ages and sizes of trees, a mix of native species including both conifers and hardwoods in the canopy, presence of herbaceous and shrub layers in patches/variability, presence of standing dead trees/snags, downed logs and woody debris, thick leaf litter/organic matter in duff, and occasional canopy gaps due to tree fall (Barbour et al. 2007). Recommended monitoring endpoints for the montane forest communities on the Ranch include:

1. *Management Target:* Maintain and improve foliage health
   Monitoring Recommendation: Crown condition surveys, tree damage surveys, and ozone injury surveys

2. *Management Target:* Maintain vegetation diversity and structure.
   Monitoring Recommendation: Species Composition Area Plots, surveys of tree height and DBH

3. *Management Target:* Maintain presence of tree snags and woody debris for wildlife habitat
   Monitoring Recommendation: Survey of abundance of dead trees/snags, downed logs, woody debris, and leaf litter/duff

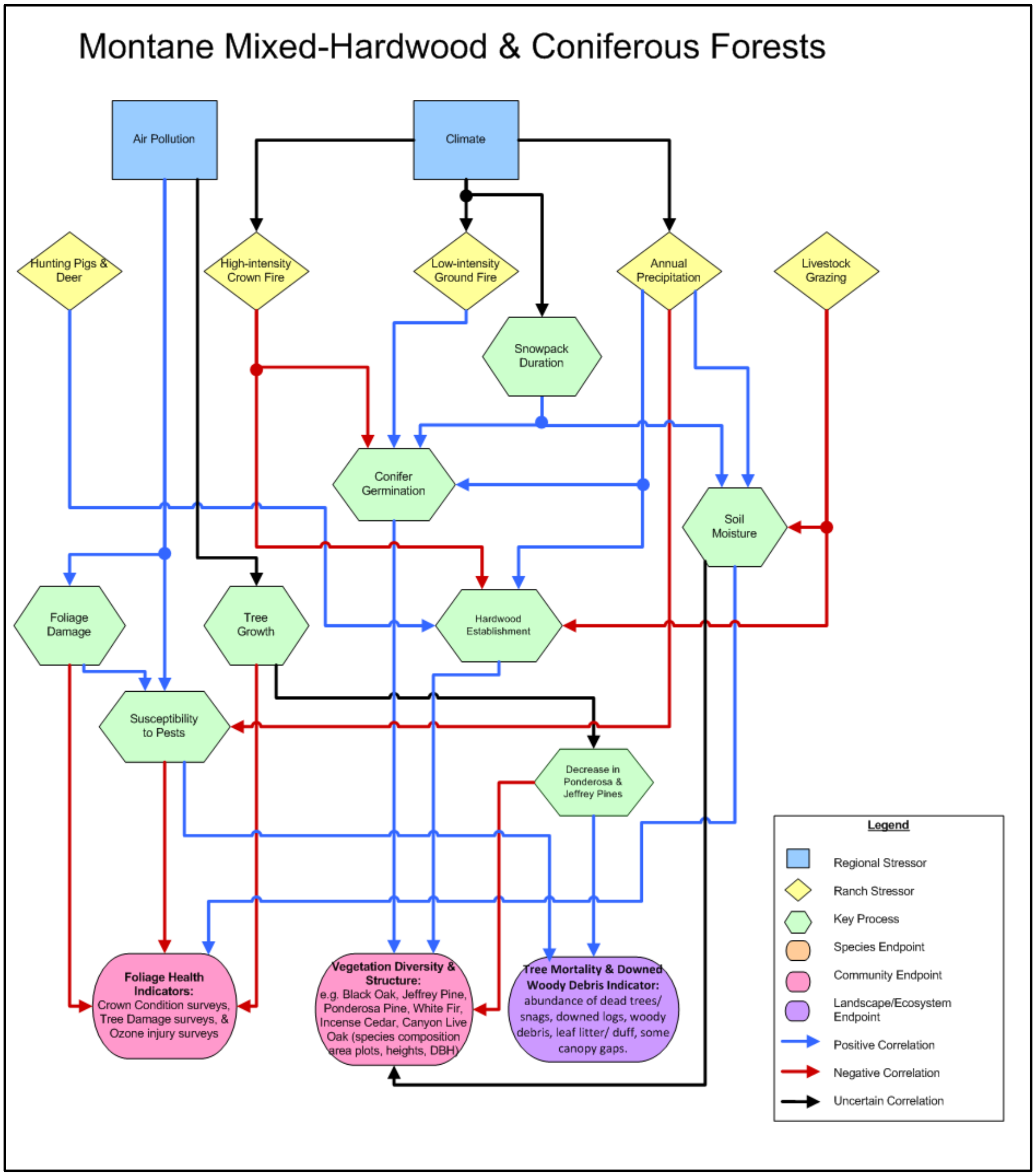

Figure 7.3-1. Montane Hardwood & Conifer Forest Conceptual Model for Tejon Ranch.

7.4 RIPARIAN

Riparian systems on Tejon Ranch are a highly diverse group of plant communities associated with perennial, intermittent, or ephemeral streams. Riparian communities on the Ranch are structured based on geology, topography, and precipitation, all of which determine the flow regimes (frequency and volume) of the streams. These in turn influence community compositions and structures. Riparian communities on the ranch include the following general community types: valley and foothill riparian, which includes woodlands and riparian forests such as southern willow scrub or cottonwood willow riparian forest (ephemeral, intermittent, or perennial); montane riparian forest (intermittent/perennial); sycamore alluvial/sycamore woodlands (ephemeral); and desert washes (ephemeral).

7.4.1 BASELINE CONDITIONS

Riparian communities on Tejon Ranch are heavily disturbed by human activities, particularly by agricultural land use. Streams and riparian communities on the Ranch display artificial flow regimes and reduced flow volumes due to diversion for livestock, streambanks denuded by grazing, increased soil compaction and soil bulk density due to cattle hoof action, and either incised or atypically low bank angles.

A riparian assessment survey was implemented in the summer of 2009, the methods of which are presented in Section 3.4.3. This survey found that riparian communities on the Ranch are more structurally and species diverse at lower elevations, and on the San Joaquin Valley side of the Ranch. This is likely due to the fact that the San Joaquin Valley has a longer growing season, greater flow accumulations, and more persistent stream flows throughout the year than the Antelope Valley side of the These generalizations are based on the findings of a three-part statistical analysis of the riparian assessment survey's quantitative vegetation data presented in Appendix E.

7.4.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION GOALS:

- To maintain a diversity of age and size classes of riparian tree species within riparian corridors.
- To maintain suitable riparian structure for riparian dependent passerine bird use.
- To maintain a natural or minimally-altered hydrological state of streams and drainages on the Ranch.
- To maintain upstream-downstream linear connectivity of the riparian corridor forest canopy or shrub community, in order to support wildlife migration and movement patterns.

One of the major pathways of disturbance to riparian communities on the Ranch (Figure 7.4-1) is through hydrologic modifications in the form of water diversion and potential groundwater pumping. These changes in hydrology can also affect community structure and composition. Community distributions, composition, and structure mostly follow water abundance and hydrogeomorphology as well as disturbance factors (e.g. grazing) via recruitment and survivorship.

In addition to hydrologic modifications, livestock grazing is also a major stressor on riparian communities. Cattle spend a disproportionate amount of time near water sources due to the cooler temperatures and greater availability of food and water. Cattle impact community health through selective browsing, compacting soils, and altering streambank morphology. As with cattle, riparian systems are also affected by the presence of feral pigs. Pigs are the focus of much of the hunting effort on the Ranch and have their own suite of associated environmental impacts. In addition to affecting the recruitment of riparian species, pigs and cattle can accelerate invasion of riparian communities by invasive species. Through pig population levels and other game species, the influence of hunting and game management on the Ranch is connected to the physical and biological conditions of the riparian communities.

Riparian vegetation community responses to climate change, grazing, and water use, including changes in structure and composition, are just a few of the key management uncertainties that we identified during the process of developing our conceptual model and analyzing baseline data on riparian communities. Fortunately for land managers, many vegetation metrics such as structural diversity can be sampled as useful indicators of the health of the riparian community and the surrounding watershed.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

Landscape Stressor: Climate

Regional and local climate and topography control the characteristic hydrology of the Tehachapi Mountains and the streams and watersheds which drain Tejon Ranch. In addition, human population growth, economic development, and resulting land use practices, such as land development and agricultural production, have given rise to exploitative uses of the natural resources on the Ranch (e.g. grazing, water use, etc.).

Landscape Stressor: Development

Potential future development and altered land use patterns on the Ranch are expected to have direct and indirect impacts on the Ranch and many of its constituent subsystems. In addition to indirect edge effects on many systems, urbanization and development are expected to have downstream impacts on riparian communities through alterations of watersheds and drainage.

Ranch Stressor: Mining

In several of Tejon Ranch's watersheds there is ongoing aggregate mining of sand and gravel for the raw materials used in construction and paving. The specific impacts of these mining operations on the Ranch are uncertain, and could be an area for future research.

Ranch Stressors: Hydrologic Modification & Water Use

Streams are physically characterized by their hydrology and geomorphology. For the purpose of this conceptual model, the "hydrology" of a system refers to the in-stream surface hydrology of a landscape, the depth and movement of groundwater, and the level of soil moisture or saturation within the riparian zone surrounding a stream. A stream's surface hydrology is characterized by its specific flow rates, volumes, and periodicity. Hydrology is influenced by water sources such as surface runoff, snowmelt, and groundwater; local and regional climate and precipitation patterns; topography and elevation; and geological characteristics such as origin and soils. In-stream hydrology and periodic overbank flows control many of a stream's biotic attributes, including vegetation community composition, structure, and architecture.

There are four major classes of hydrologic modifications which may affect water supplies on Tejon Ranch: diversions which reduce total stream flows; impoundments, including changes in discharge patterns; pavement or removal of vegetation which frequently leads to perennialization of streams and acceleration of runoff rates; and groundwater pumping. These anthropogenic modifications may lead to one or more system responses in the surface or groundwater hydrology of streams on the Ranch and their associated riparian communities. System responses include lowered water table depth, altered hydroperiod, changes in flood regimes, alteration of landforms or channel morphology, and changes in nutrient cycling rates. Changes in streamflow may in turn increase water stress on riparian plants along these streams, thereby affecting riparian community health (Medina 1990).

Key Process: Flood Frequency and Magnitude

A stream's flood regime affects recruitment in riparian systems, as many species are dependent on overbank flow or periodic scour of the ground surface to transport propagules or open the ground surface for colonization. Additionally, in order to colonize or regenerate along floodplain habitats, some riparian species such as Santa Ana woolly star (*Eriastrum densifolium sanctorum*) require deposition of new sediments from in-stream or overbank flow (USACOE 1993). Flood frequency can also influence the survival or mortality of mature shrubs or trees within the floodplain of a stream or river, as high energy flows have the potential to physically remove trees or shrubs from streambanks.

Key Process: Soil Moisture

The saturation state of the soil (soil moisture) and the depth to groundwater (water table) influence the availability of water for transpiring terrestrial plants. A water deficit, or conditions where water availability is below the immediate demand, lead to water stress and a variety of impacts to plant recruitment, establishment**,** and survival (Medina 1990)**.** Soil moisture within the root zone affects the recruitment of riparian species by controlling whether a germinant can survive long enough for its roots to reach groundwater before the onset of localized water deficit.

Key Process: Water Table Depth/Groundwater

Groundwater depth also influences the recruitment of riparian vegetation, as the roots of many species must reach the water table in order to become established and survive water deficits in shallow soil strata. Therefore, the shallower the depths to groundwater, the more likely riparian plants are to become established prior to desiccation and death.

Key Process: Adult Tree Mortality

Depth to groundwater can also affect the survival or mortality of mature trees and shrubs. Declining water tables may leave the roots of some individuals above the vadose zone, where water availability is too low to meet the demands of some hydrophytic species. In addition, flood frequency also influences the survival or mortality of mature shrubs or trees within the floodplain. High energy flows have the potential to physically remove trees or shrubs from the banks of a stream or river.

Key Process: Soil and Streambank Erosion

Important hydrogeomorphic processes, such as streambank erosion, have the potential to result in disturbances to the biotic community. These disturbance patterns affect channel morphology and the succession, recruitment, and age structure of riparian vegetation communities. Types of channel morphological changes that can occur as a result of altered flow regimes include downcutting, headcutting, and channel scour. Surface hydrology is sensitive to changes in land use, particularly to urbanization and development.

<u>Endpoint: Streambank Integrity</u>

Streambank integrity refers to the tendency of a streambank to maintain or return to a certain overall structure or condition during or after significant stress or disturbance.

Key Process: Riparian Tree and Shrub Recruitment

Soil moisture within the root zone affects the recruitment of riparian species by controlling whether a germinant can survive long enough for its roots to reach groundwater before the onset of localized water deficit. Similarly, groundwater depth also influences the recruitment of riparian vegetation, as the roots of many species must reach the water table in order to become established and survive water deficits in shallow soil strata. Therefore, the shallower the depths to groundwater, the more likely riparian plants are to become established prior to desiccation and death. The flood regime of a stream affects recruitment in riparian systems as many species are dependent on overbank flow or periodic scour of the ground surface to either transport propagules or to open up the ground surface for colonization. Meanwhile some riparian species require deposition of new sediments resulting from in-stream or overbank flow to colonize or regenerate along floodplain habitats.

Key Process: Fire

Fire is a riparian ecosystem process that plays a role in both the community and the landscape-level by shaping the riparian systems, uplands, and watersheds of the Ranch and surrounding landscape. According to Pettit and Neiman (2007), fire regimes in riparian areas generally occur with lower intensity and less frequency than in surrounding uplands. The occurrence of combustion is dependent on the state of the fuel, including moisture content, fuel size, and oxygen levels. Fine fuels are generally involved in flaming combustion, while larger fuels are consumed in residual combustion. As such, moisture levels impose controls on combustion and feedback to the overall fire regime. Water availability in the riparian zone during the growing season gives rise to fine fuels for ignition and flaming combustion, while seasonal water stress, particularly in arid environments such as the desert southwest, reduces the moisture content of plant tissues, making them more prone to ignition and flaming combustion (Pettit & Neiman 2007). In addition, fire frequency has the potential to affect soil and streambank erosion on the landscape and ecosystem level by increasing the volumes and rates of water running off from uplands in a watershed.

Key Process: Invasive Species

Invasive species can affect the vegetation community structure and composition of riparian communities. In Mediterranean climates such as southern and central California, invasions of exotic or alien species have resulted in declines in native species richness (Gaertner et al. 2009). In addition, invasive species can change larger disturbance regimes. For example, according to Bell (1997), if an invasive species such as giant reed (*Arundo donax*) becomes abundant it can effectively change riparian forests from a flood-defined to a fire-defined natural community, as has occurred on the Santa Ana River in Riverside County, California.

Hydrologic modification, including stream perennialization and flow regulation, may alter the suitability of riparian communities for riparian adapted invasive exotic species and increase possible vectors for invasion. According to Nilsson and Svedmark (2002) there is evidence that invasion by exotics is promoted by flow alterations. One example, discussed in Shafroth et al. (2002) is the widespread establishment of salt cedar (*Tamarix* spp.) in western North American riparian ecosystems. In these arid southwestern communities, the establishment of *Tamarix* has been attributed, in part, to flow regulation. Shafroth et al. (2002) indicate that the altered timing of flood events resulting from flow regulation may favor *Tamarix* recruitment because it has a longer period of seed dispersal and seed viability relative to native *Populus* and *Salix* spp.

Endpoint: Species Diversity and Evenness

Species diversity and evenness are intrinsically valuable attributes of a community, and may have effects on processes such as plant productivity (Wilsey & Potvin 2000) and on resistance to invasion (Gilbert et al. 2007).

Landscape Stressor: Grazing

Livestock grazing is a major revenue generating activity practiced over 95% of Tejon Ranch (Interim Ranch-Wide Management Plan 2009). Cattle tend to avoid hot, dry environments and congregate in wet areas along streams for water and forage (Belsky et al. 1999). Therefore, grazing likely has large impacts on the riparian areas of the Ranch.

Key Process: Riparian Tree & Shrub Recruitment

Livestock affect recruitment by eating and trampling understory seedlings, and depleting or eliminating understory regeneration of oaks and other riparian tree and shrub species (Yolo County 2007; Belsky et al. 1999).

Key Process: Soil Moisture

Studies in the Midwest and northern Great Plains have documented higher evapotranspiration rates in ungrazed grasslands as compared to grazed grasslands (Bremer et al. 2001; Frank 2003). Studies in wetlands and riparian habitats have shown significant negative effects of abundant vegetation such as annual grasses on hydrology (Moorhead 2003; Bliss & Comerford 2002; Marty 2005).

Key Process: Soil and Streambank Erosion

Livestock grazing also has been demonstrated to increase soil and streambank erosion in the form of channel incision and downcutting. This is often coupled with bank retreat and increased wetted channel width, occurring as a result of accelerated discharge of runoff from uplands in the watershed (Belsky et al. 1999; Clary & Kinney 2002). In riparian communities, livestock grazing reduces herbaceous plant cover on streambanks, reducing resistance to particle erosion as well as resistance to streambank compression and shearing (Clary & Kinney 2002). Removal of grazing livestock allows for the accumulation of an herbaceous layer of annual biomass and thatch. Research demonstrates that management actions such as protection of riparian zones by grazing exclosures increase litter biomass, particularly of grass species (Sarr 2002).

Key Process: Soil Compaction

A major effect of cattle grazing is soil compaction by hoof action, which reduces soil macropore space and increases bulk density. Hoof action results in reduced soil porosity, infiltration, percolation, and root growth (Clary & Kinney 2002).

Key Process: Invasive Species

Plant species that commonly increase with livestock grazing are invasive species of weedy exotics that benefit from disturbance, upland species that prefer the drier conditions created by grazing, or sub-dominants released from competition with native riparian species (Belsky et al. 1999).

<u>Endpoints: Structural Diversity/Community Architecture and Habitat Suitability for Nesting Birds</u>

In many situations, management of riparian ecosystems focuses on the three-dimensional riparian architecture due to its documented influence on wildlife use (particularly avian), and the degree to which it contributes to overall biological diversity (Deppe & Rotenberry 2008; Kus 1998). Some species of passerine birds have specialized niche requirements, such as cavity nesting, that are strongly controlled by tree mortality and limb fall in oak woodlands and riparian forests in Central California (Mummert et al. 2002).

<u>Landscape Stressor: Hunting and Game Management</u>

Hunting, inclusive of such things as game management, ranch access for hunting activities, and Off-highway Vehicle (OHV) use, can affect riparian systems in several ways.

Key Process: Browsing by Pigs

Feral pigs are the targets of much of the hunting efforts on the Ranch. Unchecked, the feral pig population on Tejon Ranch would likely continue to grow. If pig hunting effort were to increase, pig population levels would likely decrease, as would their associated ecological impacts.

Key Process: Riparian Tree and Shrub Recruitment

Pig foraging behavior can cause direct mortality of riparian shrub and tree species through selective browsing of seedlings or saplings and consumption of acorns, negatively affecting recruitment.

Key Process: Soil and Streambank Erosion

Pig foraging can cause physical damage to streambanks resulting in increased streambank erosion and subsequent in-stream sedimentation.

Key Process: Browsing by Ungulates

As with feral pigs, browsing by ungulates and rodents can limit the establishment and recruitment of new riparian shrub and tree species as well.

Endpoint: Total/Native Vegetation Cover:

Total percent cover, native cover, basal area, and foliar density are all attributes of terrestrial vegetation communities (including riparian communities) that reflect levels of disturbance and provide quantifiable metrics with which to evaluate community responses to various management actions.

Endpoint: Age Structure

Maintaining a mixed age structure within a riparian community provides propagules for site recolonization and for system resilience, as "transitioning between life history stages might be paramount for species that cannot rely on seed bank structure to perpetuate community structure" (Lovell et al. 2009).

Endpoint: Niche Diversity

Niche diversity is a community attribute adapted from the structural patch richness attribute of the California Rapid Assessment Method (CRAM) for wetlands (CRAM 2008). Under this methodology, structural patch types may include features such as standing snags and downed wood, biomass that accumulates as a result of biotic and abiotic processes. According to CRAM, "the richness of physical, structural surfaces and features in a wetland reflects the diversity of physical processes, such as energy dissipation, water storage, and groundwater exchange, which strongly affect the potential ecological complexity of the wetland. The basic assumption is that natural physical complexity promotes natural ecological complexity, which in turn generally increases ecological functions, beneficial uses, and the overall condition of a wetland" (CRAM 2008).

7.4.3 FUTURE MANAGEMENT AND MONITORING RECOMMENDATIONS

1. *Management Target:* We recommend installing rectangular, fenced cattle exclosures across stream corridors in a paired control-impact design stratified by species group or reach. Coupled with annual sampling of vegetation community structure and species composition along transects, this would highlight differences in vegetation community structure and species composition produced from grazing. Similarly, we recommend implementing an experimental seasonal grazing rotation system in each of the different riparian species groups or at different elevations in selected drainages followed by quantitative sampling of the vegetation community structure and species composition along linear transects.

2. *Management Target:* Stream gauges should be installed to record flow in the major drainages on the Ranch. In addition, meters should be installed on diversion systems to quantify the amount of water diverted for agricultural use. Both of these should then be coupled with annual sampling of vegetation community structure and species composition along transects to evaluate the effects of surface hydrology on riparian community health and structure.
   Monitoring Recommendation: While there are a large number of accepted riparian assessment and sampling methods described in the scientific literature, we recommend a sampling and monitoring protocol that is fundamentally geared towards the standardized measurement of quantifiable, descriptive characteristics of the riparian community. Other riparian and wetland survey protocols such as CRAM are relativistic or designed to evaluate the state of a wetland or riparian area relative to an ideal or undisturbed reference. We recommend stratified sampling of transects in a nested design to account for the nested spatial scales of control (including the effects of drainage area and flow accumulation) on community composition and structure within riparian corridors and along the vertical/elevation gradient in a stream or drainage. In order to be consistent with the baseline data collection, we strongly recommend replicating the quantitative transect sampling conducted in summer 2009, the methods of which are described earlier in Section 3.4.3.

Riparian Community Age and Size Structure

In order to monitor the health and integrity of riparian communities on Tejon Ranch, the Conservancy must implement a program of standardized vegetation and hydrogeomorphic sampling. Either randomly selected or stratified permanent sampling transects should be established with replication in multiple drainages across the Ranch. The species composition and age/size structure of the shrub and tree components of a riparian community can be sampled in a variety of ways. In particular, we recommend that the basal area and stem density of riparian trees and shrubs be sampled within a belt transect oriented perpendicular to the direction of flow within a stream or channel to collect a representative size / age profile of the riparian tree component and to estimate tree and shrub coverage within the riparian zone of influence. Data that could potentially be collected under this methodology includes the basal area (m^2/ha) of trees (>5 m tall), stem density (stems/ha) of shrubs and saplings (1-5 m tall), and stem density (stems/ha) of seedlings (woody vegetation <1 m tall) within each transect.

Alternatively plot-transect data collection may be implemented to collect quantitative data. Within the shrub and tree layers permanent 5 x 2 m plots would be selected within which the following attributes of the riparian community shall be sampled:

- Canopy coverage class (%)

- Total number of stems (class)
- Stem count per individual or species (class)1
- Tree diameter (diameter at breast height) – basal area
- Dominant species relative decadence (%)
- Dominant species coverage (%)
- Total plot decadence (%)
- All tree and shrub species present in each plot (species richness) and whether native or nonnative

Riparian Community Structural Diversity and Canopy Architecture

The structure and architecture of riparian forest and woodland community canopies can be quantitatively sampled using a customized cover and dominance visual estimation/assessment methodology. We recommend a modified version of a vertical cube sampling method to measure the relative contribution of different species or taxa to the overall vegetative cover of the riparian canopy within pre-defined strata or height classes. Alternatively, SWAMP prescribes a visual estimation method for riparian vegetation in which investigators estimate riparian vegetation within the riparian corridor along a sampling transect by dividing the vegetation into predefined strata with investigators estimating foliar cover or density within each category.

As an alternative to the exact replication of the quantitative riparian vegetation sampling conducted this past summer, the Conservancy may consider applying the "Stacked Cube" method (Kus 1998; Kus & Peterson 2001). This vertical cube sampling method, developed for use in structurally diverse riparian forest communities in southern California, quantitatively measures canopy architecture of riparian forests and woodlands. The measurements of structural diversity and canopy architecture can then be compared to documented measurements of structural diversity of occupied habitats for specific riparian bird species of conservation interest such as least Bell's vireo (*Vireo bellii pusillus*) or southern willow flycatcher (*Empidonax traillii extimus*) to evaluate or assess habitat suitability and to set targets for restoration.

Depending on the management objectives for the riparian communities on the Ranch, the Conservancy may also choose to monitor the growth and vigor of riparian vegetation based on the foliar structure of the riparian canopy. In order to quantitatively measure this community characteristic, foliar density can be measured by recording a series of densitometer readings from the midpoint of each sampling transect, or alternatively Leaf Area Index (LAI) may be sampled using a standardized "indirect" sampling method or remote sensing protocol such as LIDAR.

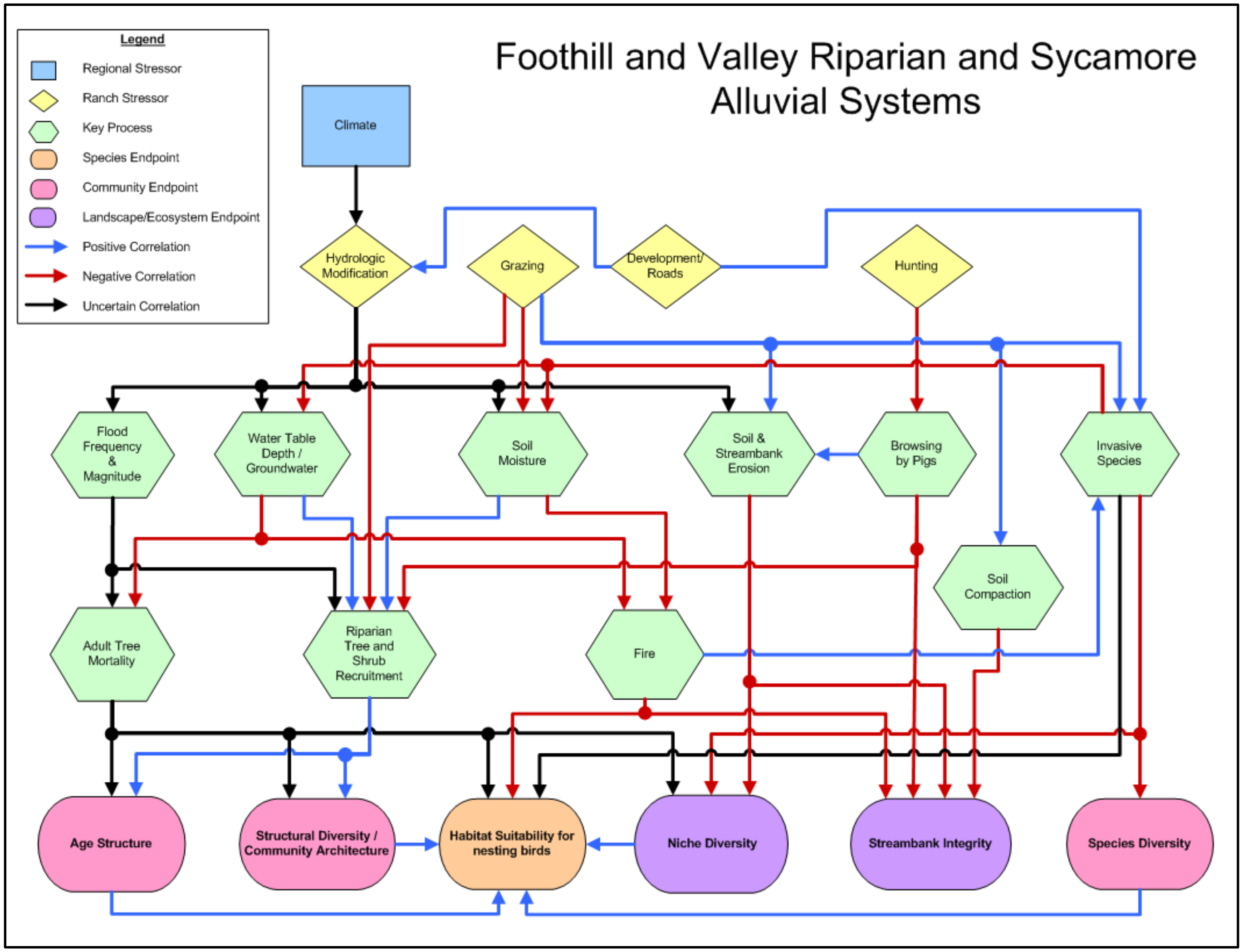

Figure 7.4-1. Riparian Conceptual Model for Tejon Ranch.

7.5 San Joaquin and Antelope Valley Grasslands

A large portion of Tejon Ranch is dominated by grassland vegetation, an ecosystem with high species diversity (Barbour et al. 2007). Grasslands are an important ecosystem for both wildlife and livestock on the Ranch. The low-elevation land on the western side of the Tehachapi Mountains supports San Joaquin Valley grassland, whereas the eastern side of the ranch comprises the Antelope Valley grassland. On both sides of the ranch these grassland environments extend into the understory of blue oak and valley oak communities as well as Joshua tree woodlands (Sections 7.7 and 7.2) where grasses and forbs dominate the understory.

Historic California grasslands are thought to have been dominated by perennial bunch grasses interspersed with a rich array of annual and perennial grasses and forbs (Barbour et al. 2007). Perennial grasses have adapted to allocate a high proportion of their biomass to the production of a deep root system, which allows them to access soil moisture well into the dry season (Holmes & Rice 1996).

San Joaquin Valley Grasslands

On Tejon Ranch, the San Joaquin grasslands are on the north-western side of the ranch. The San Joaquin Valley once supported a diverse array of perennial bunchgrasses. *Stipa pulchra* was abundant, as well as *Elymus* and *Melica* species (Barbour et al. 2007). Today the San Joaquin Valley grasslands on the Ranch are almost entirely non-native annual species. Although the composition of Tejon Ranch's grasslands has changed, mass flowerings of both annual and perennial forbs such as the California poppy (*Eschscholtzia californica*), lupines (*Lupinus* spp.), blue dicks (*Dichelostemma* spp.), and purple owl clover (*Orthocarpus purpurascens*) still occur on Tejon Ranch. Presence of forbs should be maintained due to their importance as a forage species for deer and cattle as well as for species diversity. Tejon Ranch's San Joaquin Valley grasslands support several large ungulates including Rocky Mountain elk, mule deer, cattle, and pigs. Several rodents are endemics or near-endemics to the southern San Joaquin Valley including the San Joaquin pocket mouse (*Perognathus inornatus*) and the giant kangaroo rat (*Dipodomys ingens*). Predators potentially utilizing Tejon Ranch grasslands for much of their prey include mountain lions, ringtails, bobcats, coyotes, gray foxes, badgers, and the San Joaquin Valley kit fox (*Vulpes velox*). Many species of raptors also use the Ranch's grasslands to forage for prey.

Antelope Valley Grasslands

The Antelope Valley grasslands differ from the San Joaquin Valley grasslands through several important environmental characteristics. The elevation of the Antelope Valley is higher than the San Joaquin Valley, and average precipitation tends to be lower in the Antelope Valley due to the rain shadow effect of the Tehachapi Mountains. Overall productivity tends to be lower in the Antelope Valley.

Similar to the San Joaquin Valley, non-native grasses and forbs have a large presence in the Antelope valley, including *Bromus hordeaceus*, *Avena barbata*, and redstem filaree (*Erodium cicutarium*). The impact of non-native species in the Antelope Valley grasslands is less than in the San Joaquin Valley, as perennial bunch grasses still persist on the Antelope Valley side of the ranch. Important native grasses in Antelope Valley grasslands include foxtail fescue *(Festuca megalura)*, desert needlegrass (*Stipa speciosa*), and the bunch grass *Melica imperfect*. Dominant native forbs include pygmy lupine (*Lupinus bicolor*), goldfields (*Lasthenia* spp.), owl clover (*Orthocarpus purpurascens*), California poppy (*Eschscholzia californica*), and blue dicks (*Dichelostemma capitatium*) (Pomona). Tejon Ranch's Antelope Valley grasslands support ungulate species including Pronghorn antelope, mule deer, cattle, and pigs. Mammalian predators that may potentially utilize the Antelope Valley Grasslands on the Ranch include coyotes, mountain lions, ringtails, bobcats, and grey foxes. Burrowing owls have a strong presence in the Antelope Valley and rodent species potentially include California ground squirrels, gophers, mice, hares, rabbits, and kangaroo rats.

7.5.1 Baseline Conditions

Non-native annual grasses introduced to Tejon Ranch have greatly altered the Ranch's grassland ecosystems. In most California grasslands native taxa comprise less than 1% of the standing grassland species (Ricketts et al. 1999). Alteration of hydrologic regimes, grazing by domestic livestock, fires, and introduced plants and animals have all contributed to the changes in native habitats (Ricketts et al. 1999). Annual grasses tend to be faster-growing than perennial bunch grasses while producing large quantities of seeds which can remain in the seed bank for many years. Annual species are better adapted to cool-season growth. Most growth for these species occurs after winter rains and before the onset of warmer, sunnier days (Barbour et al. 2007). This earlier season growth can inhibit perennial seedling establishment as surface soil moisture is quickly diminished by fast growing annuals (D'Antonio et al. 2000). Failure of new seedlings to establish in the presence of competing annuals could represent a major limitation for populations of native perennial grasses to recover in the Ranch's grasslands (Potthoff et al. 2006). Late in the season, perennial grasses provide green forage that may be subjected to greater browse stress when annual grasses have all senesced. Therefore the introduction of non-native grazers such as cattle and other livestock to grasslands can further increases the stress on native species while further contributing to the conversion of most perennial grasslands to an annual species dominated grassland (D'Antonio et al. 2000). Collection of baseline monitoring of Tejon grasslands was not done but is recommended through the creation of a range assessment protocol (Section 6.5.1).

7.5.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION GOAL: Maintain grassland functionality and species diversity

The San Joaquin and Antelope Valley grassland conceptual models (Figure 7.5-1 and 7.5-2) illustrate the importance of the timing and quantity of annual precipitation, livestock grazing, and hunting on the composition and overall production of the grassland community. The endpoints that can be used to characterize the health of this system include several vegetation community-level endpoints that focus on the diversity and productivity of grassland species, such as cover of annual grasses as well as annual and perennial forbs. Faunal indicator species include populations of burrowing owls, pronghorn antelope, and kangaroo rats. The model describes the impact of hunting, grazing, and grassland composition on these indicator species. Uncertainties within the model include how different fire regimes and the timing of grazing will impact grassland composition but more so, the overall annual range productivity (RDM). The challenge for management will be to consider these uncertainties in testing different management strategies, while attempting to maintain the endpoints in the model.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

Landscape Stressor: Climate

Annual fluctuations in rainfall seasonality and amount, as well as fluctuations in temperature can greatly influence inter-annual difference in species composition and overall production (Barbour et al. 2007). The effect of climate on grassland communities can be manifested through the alteration of both hydrologic and fire regimes. If climate change persists with current climate predictions of wetter winters and drier summers, native grassland species in Tejon Ranch could be faced with a reduced growing season that could further reduce their ability to compete with fast growing annual species (D'Antonio et al. 2000).

Key Process: Early Winter Rains

Early season droughts have a strong effect on the growth and survival of fast-growing annuals which usually sprout after the first winter rains (Potthoff et al. 2006).

Key Process: Growing Season Soil Moisture

Drought periods during the rainy season will lower the productivity of invasive annuals and benefit perennial species which are better adapted to low soil moisture levels (George et al. 2001). Changes to the timing and/or quantity of precipitation could greatly impact grassland vegetation.

Landscape Stressor: Fire

Climate and fire management practices have altered Tejon Ranch's fire regime. Frequent low-intensity fires tend to favor perennial species in California grasslands and prescribed burns are sometimes used as a management tool (D'Antonio et al. 2000). Native Americans used fire to increase the abundance or fecundity of geophytes, grasses, and particular forbs (Stromberg et al. 2007). Grassland fires can be hot enough to kill non-native seeds in the soil, in addition to killing seeds on adult plants, both of which can benefit native perennial species capable of re-sprouting after fires (Potthoff et al. 2006). Fires also release large amounts of nutrients to the soil which can stimulate growth of native perennials. Conversely, nutrients can stimulate exotic annual grass productivity which could interfere with efforts to establish native species if the seed bank is retained. In addition, reductions in non-native annual grass biomass that may be observed in the first season following fire are rarely sustained beyond the next few years (D'Antonio et al. 2000). Frequent fires have also been shown to negatively affect populations of kangaroo rats (Williams et al. 1997).

Key Process: Competition from non- native annuals

Fire can have variable effects on the abundance of non-native annuals depending on the timing and intensity of fire. Controlled burns could be used to manage grassland species composition; although, this would be a costly practice that would result in reduced grazing fodder the initial year after fire. Therefore, rotational grazing may be a more realistic method of adaptively managing grassland composition.

<u>Landscape Stressor: Livestock Grazing</u>

In grassland communities livestock grazing can produce very different outcomes depending on the timing and intensity of grazing. Managed grazing at specific times of the year may provide benefits to native grasses and forbs.

Key Process: Competition from non-native annuals

Grazing in winter and early spring can help control fast-growing annuals while benefiting perennial bunch grasses (D'Antonio et al. 2000). Continuous grazing on the other hand, has been shown to have little effect on controlling exotic grasses and forbs, particularly when grazing occurs in the dry season (Potthoff et al. 2006). Additionally, grazing affects the amount of plant litter at the soil surface, impacting nutrient cycling and patterns of germination and seedling establishment (Potthoff et al. 2006).

Key Process: Soil Compaction

A major effect of cattle grazing is soil compaction, which reduces soil porosity, infiltration, and root growth (Clary & Kinney 2002).

Key Process: Ground Squirrel Abundance

Ground squirrels are an opportunistic species in comparison to other native grassland rodents. It has been hypothesized that grazing by cattle may actually reduce seed supplies to other rodent species giving ground squirrels and advantage in heavily grazed environments. A study looking at exactly this relationship, monitoring populations of ground squirrels in a California oak savanna under different grazing intensities, found no significant relationship between grazing and ground squirrel densities (Fehmi et al. 2005).

Landscape Stressor: Air Pollution

Both the San Joaquin Valley and the Los Angeles basin are major sources of air pollution to Tejon Ranch (see Section 6.1).

Key Process: Nitrogen deposition

Nitrogen deposition results in increased nutrient levels in an environment. It can result in increased overall productivity which could be measured through residual dry matter, but it can also disrupt species composition as some species are more competitive in a low nutrient environment. Nitrogen deposition therefore may be having a larger impact on the Antelope valley side of the ranch, which is characterized by sandier lower nutrient soils.

Key Process: Competition from non-native annuals

Nitrogen deposition has been shown to alter grassland communities by generally favoring non-native annuals, particularly in nutrient-poor desert soils (Brooks 2003; Barbour et al. 2007). Therefore, although deposition rates are lower, the potential benefit to annual species may be higher in the Antelope Valley than in the San Joaquin Valley were productivity is already much higher.

Ranch Stressor: Hunting

Hunting is known to occur in the Ranch's grasslands and may result in different community outcomes depending on the species being hunted. For more information on hunting practices within Tejon Ranch, see Section 6.6.

Key Process: Soil Disturbance and Browsing by Pigs

The feeding activities of feral pigs can result in soil disturbances on the Ranch. Pigs can reduce the cover of established native perennials due to disruption of below-ground biomass. Feral pigs have been observed to avoid grubbing directly under established native perennial grasses and turn up enormous swaths of annual dominated grassland with unknown effects on native species diversity (Potthoff et al. 2006). Other studies have shown that disturbance from pigs increases overall species diversity, both native and non-native (Potthoff et al. 2006).

Key Process: Ground Squirrel Abundance

Hunting of ground squirrels and depredation of other "pest species" such as coyotes is not well documented on the Ranch, although both are known to occur. In grassland communities, ground squirrel dens provide important nesting habitats for burrowing owls. California ground squirrels (*Spermophilus beecheyi*) and other rodents are potentially important prey species for numerous raptors, owls, and mammalian predators that forage in Tejon Ranch's grasslands.

<u>Ranch Stressor: Development and Roads</u>
Conversion of grassland communities to agricultural and developed land has greatly impaired grassland dependent wildlife. Burrowing owls and kangaroo rats have both been shown to be negatively impacted by increased development and roads (Williams 1997).

7.5.3 FUTURE MANAGEMENT AND MONITORING RECOMMENDATIONS

A comprehensive rangeland assessment protocol should be developed in order to track grassland productivity as well as species composition and structural diversity on Tejon Ranch over time. Suggestions of a rangeland assessment method can be found in Section 6.5.1. In addition, species of particular interest that are representatives of a healthy grassland community include burrowing owls, kangaroo rats, and pronghorn antelope. Monitoring these species over time to assess the impacts of management decisions is also recommended.

1. *Management Target*: Maintenance of current populations of native bunch grasses and forbs as well as overall functional and species diversity.
   Monitoring Recommendation: Through the implementation of a rangeland assesment protocol, measures of Residual Dry Matter (RDM) can be coupled with other structural and compositional attributes of grassland ecosystems. Plot surveys of percent cover of different life forms (geophytes , annual forbs, and perenial and annual grasses), and species composition should be done in order to quantify species richness, evenness, and functional diversity inorder to assess grassland community health. In addition occurances of populations of rare native plant species can be monitored and assesed through these plot surveys.

2. *Management Target*: Sustained range productivity to support wildlife and ongoing grazing activities.
   Monitoring Recommendation: In order to sustain grazing practices on the Ranch, an adequate level of palatable fodder will need to be maintained. Over-grazing can lead to a reduction in rangeland productivity, and assessing trends in RDM through a rangeland assessment method should be done.

3. *Management Target*: Maintaining important faunal species such as burrowing owls, pronghorn antelope, and kangaroo rats.

Monitoring Recommendation: Surveys of these indicator species can be done every one to two years.

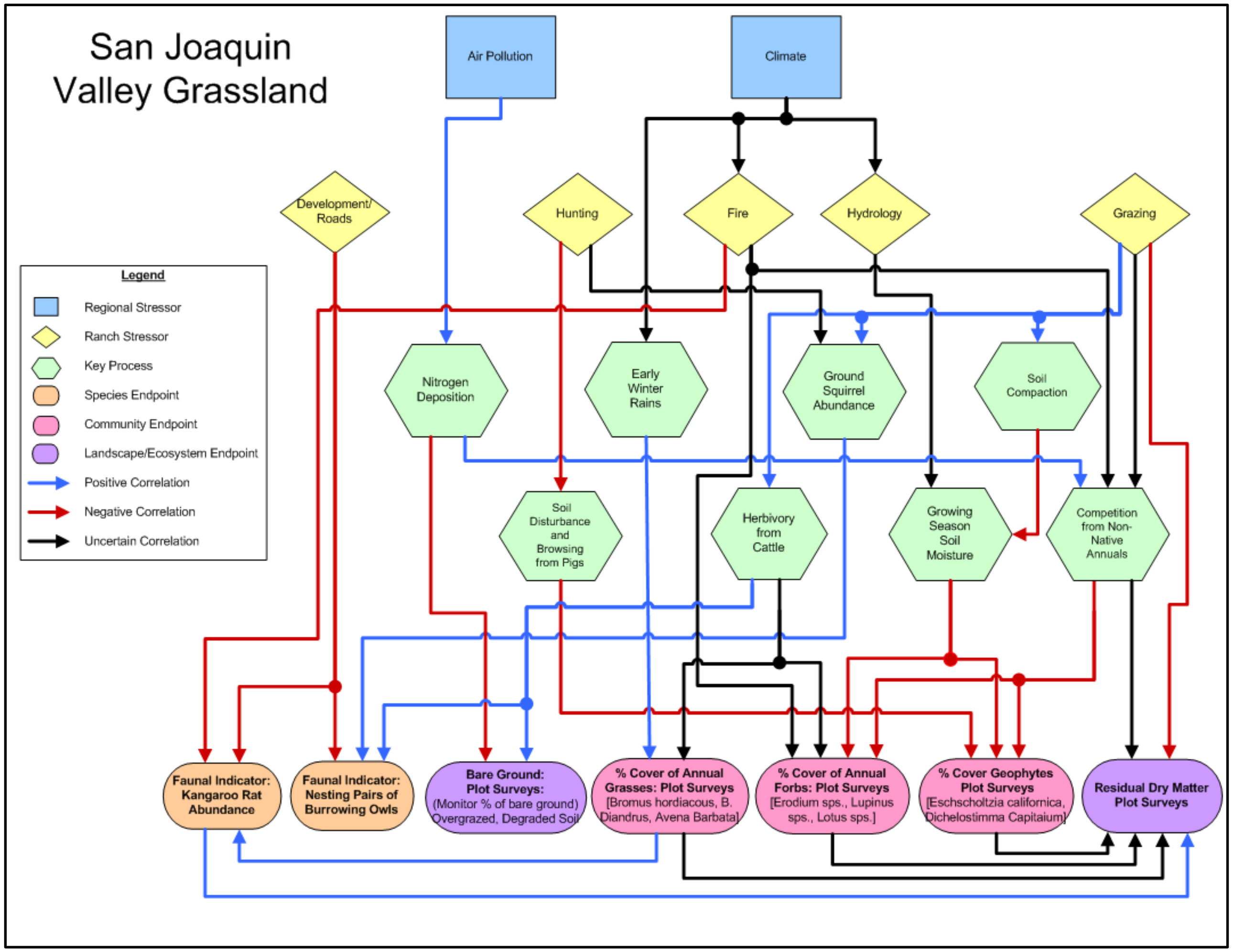

Figure 7.5-1. San Joaquin Grassland Conceptual Model for Tejon Ranch.

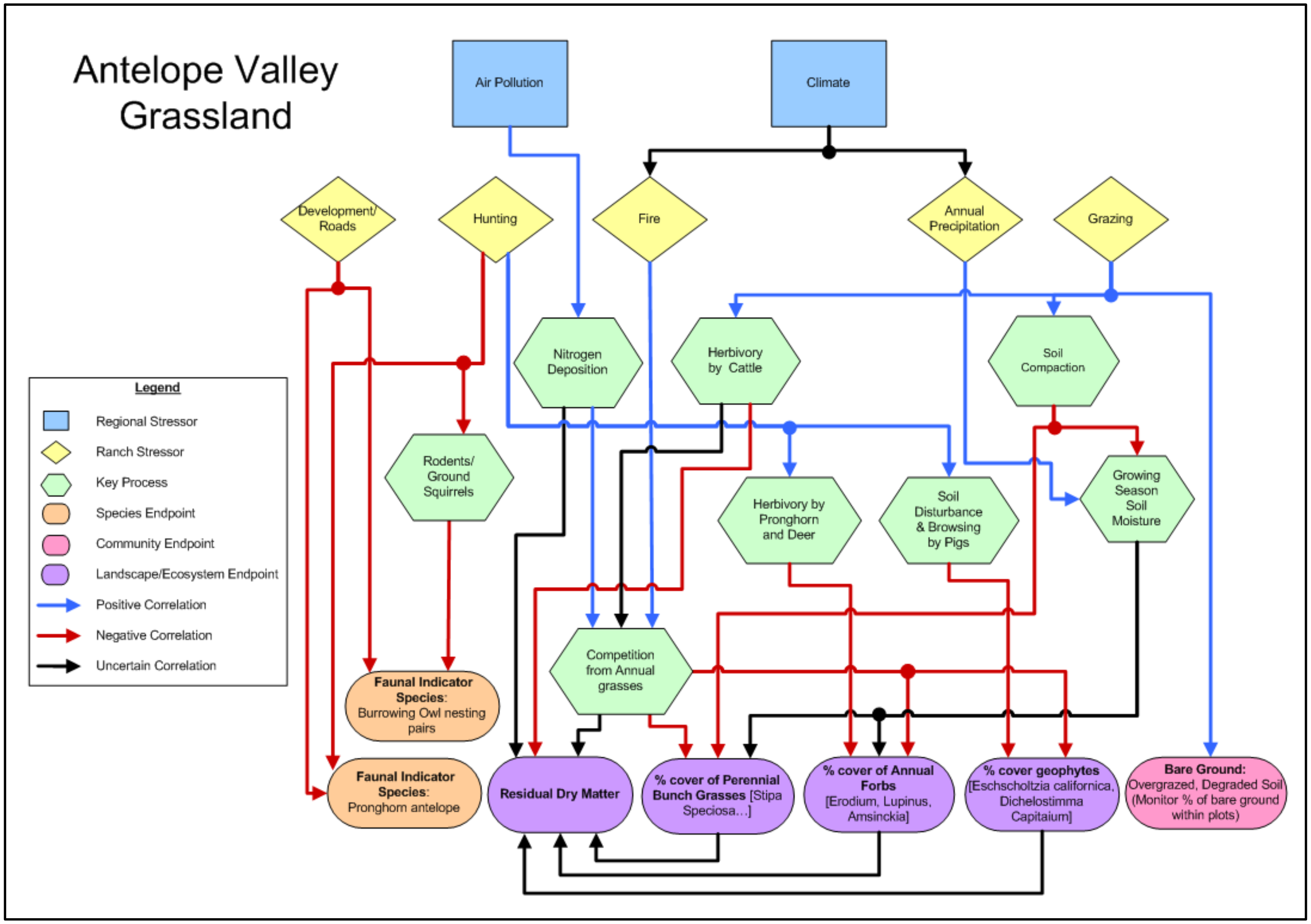

Figure 7.5-2. Antelope Valley Grassland Conceptual Model for Tejon Ranch.

7.6 VALLEY OAK SAVANNA AND FOOTHILL BLUE OAK WOODLANDS

Oak woodlands occupy approximately 82,130 acres of Tejon Ranch. These woodlands are dominated by either valley oaks (*Quercus lobata*) or blue oaks (*Quercus douglasii*).

VALLEY OAK SAVANNA

Valley oaks are large, long-lived deciduous trees that can reach over 100 feet in height. Adult trees have round, spreading canopies with drooping younger branches that may touch the ground. Valley oaks are endemic to California and typically found in fertile, well-drained, deep soils at elevations below 2,000 feet (Yolo County 2007). Although valley oaks were once widely distributed throughout California, they now have a very patchy distribution, occupying only 2.7% of the state. Patches of valley oaks are commonly found distributed within the matrix of modern day land-uses, such as agriculture and urban areas. Their decrease has been attributed to direct mortality and lack of recruitment.

FOOTHILL BLUE OAK WOODLAND

Blue oaks are deciduous trees endemic to California and can reach up to 60 feet in height (Yolo County 2007). They are commonly found on hot,dry slopes and on poorly developed soils. On steeper slopes, blue oak woodlands occur with other vegetation such as annual grasslands, chaparral, and riparian forests (Allen-Diaz, Standiford, & Jackson 2007). Foothill pine (*Pinus sabiniana*) and California buckeye (*Aesculus californica*) are common associates of blue oak stands. Foothill blue oak woodlands typically consist of dense stands of medium to large blue oak trees. Conversion to savannas and grasslands is a concern, and occurs as adult trees die and are not replaced (Allen-Diaz, Standiford, & Jackson 2007).

7.6.1 BASELINE CONDITIONS

Two techniques were used to collect baseline information about oak woodlands on Tejon Ranch: ground surveys and aerial photo interpretation (Section 3.4.3). These baselines were collected within the Old Headquarters Acquisition Area (Figure 1-2).

In October 2009, a sampling of diameter-at-breast-height (DBH) of valley oaks in the Old Headquarters area shows little evidence of recruitment, as displayed by the lack of trees in the 0-10 cm DBH category (Figure 7.6-1). This data suggests that valley oak regeneration should be a large concern for management.

Aerial imagery was used to map oak canopy cover (>150 ft^2) for the entire Old Headquarters Acquisition Area (see Section 3.4.3 for Methodology). We were unable to determine oak species and density through aerial interpretation; however, overall canopy cover for 1952 and 2009 were compared. We found that canopy cover in the

Old Headquarters Acquisition Area has decreased from 2.7% to 1.6% over the past 57 years. These results show that there has not been enough canopy development and growth to replace dying trees. Although we were unable to reveal any information on density or recruitment, this data is important to establish the current condition of oak woodlands in the Old Headquarters area of the Ranch.

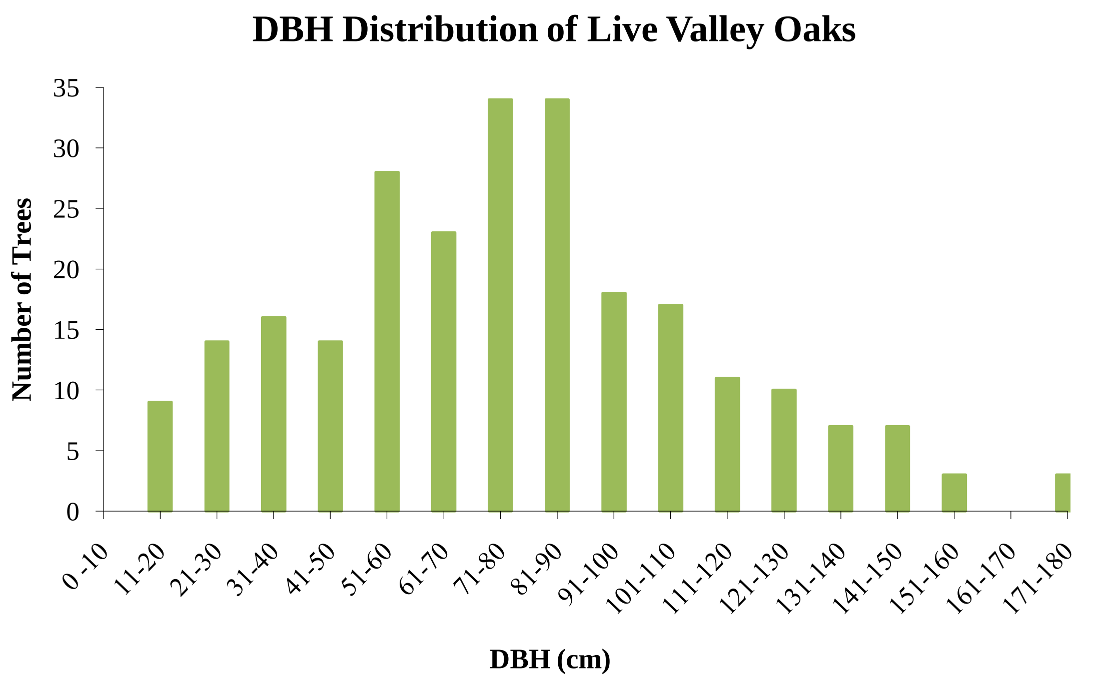

Figure 7.6-1. Distribution of DBH Mesurements of Live Valley Oaks within the Old Headquarters Aquisition Area.

7.6.2 CONCEPTUAL MODEL AND NARRATIVE

CONSERVATION GOAL: Maximize Valley and Blue Oak Regeneration

The Valley Oak Savanna and Foothill Blue Oak Woodland conceptual models (Figure 7.6-2. and 7.6-3) illustrate important relationships in the vegetation communities. Some important relationships include the effect of climate on fire and annual precipitation; the impact of hunting and livestock grazing on herbivory; competition and annual precipitation’s effects on the establishment of oak seedlings and the overall structure of the community. Endpoints that can be used to characterize the health of oak woodlands include several community-level targets that focus on the success of oak regeneration, such as cover of annual invasive species and ground disturbance. Species-level endpoints include populations of western scrub-jays, acorn woodpeckers, and California legless lizards. Analysis of the relationships among the stressors reveals management regimes such as hunting and livestock grazing that can influence herbivory and disturbance by rodents, ground squirrels, pigs, deer, and cattle. Herbivory and disturbance may commonly cause mortality of oak seedlings and saplings. Uncertainties within the model include the relationship between grazing, oak regeneration and rodent populations, as well as the impact of fire on the vegetation community.

STRESSORS, KEY PROCESSES, AND ENDPOINTS

Ranch Stressor: Hunting

Hunted species in oak woodlands include mule deer, wild pigs, ground squirrels, and other rodents, such as gophers and mice. The growth and survival of oak seedlings and saplings can be greatly impacted by predation and disturbance by these species, as they all have the potential to limit or eliminate oak regeneration. Rodents and ground squirrels chew at juvenile stems and acorns, while browsing by deer can suppress growth and kill juvenile oaks (Yolo County 2007). Older saplings may be able to recover from intense herbivory due to their large below-ground growth, but defoliation of new seedlings will likely cause death. Rodent herbivory may therefore lead to larger first and second year oak seedling mortality (Davis et al. 1991). As hunting increases, the presence of these animals is expected to decrease. Therefore hunting may have a beneficial effect on oak survival, although more research is needed.

Key Process: Predation by Rodents/Ground Squirrels

Predation on oak seedlings by rodents and ground squirrels has been found to have an effect on seedling survival. When blue oak seedlings were protected from gophers, seedling survival increased from 22% to 44% (Davis et al. 1991). Increased mortality due to gophers has also been documented for valley oak seedlings (Adams & Weitkamp 1992).

Key Process: Ground Disturbance/Browsing by Pigs

Wild pigs are a large source of ground disturbance and direct predation of acorns. Acorn mast is the main food source for wild pigs and their rooting activities are highly destructive to saplings and seedlings (Sweitzer & Van Vuren 2002). Reduction in acorn results in less recruitment. As described in the Hunting Stressor Description (Section 6.6), Tejon Ranch is where the majority of all pigs are hunted in Kern County. As hunting of wild pigs on the Ranch increases, the disturbance and predation on oaks is expected to decrease. This decrease in disturbance and predation of oaks may aid in oak recruitment success.

Key Process: Browsing by Deer

Browsing by deer has been shown to reduce the growth of oak saplings (White 1966). Clipping experiments have been used to simulate browsing, and findings show that the survival of blue oak seedlings was greatly reduced with simulated browsing and reduced soil water (Welker & Menke 1990).

Key Process: Acorn Predation

Valley oaks and blue oaks produce acorns within one year. Oaks typically drop acorns between September and November. Before they drop from the tree, acorns are susceptible to heat, fungus, insects (such as weevils and moth larvae), birds (including jays and acorn woodpeckers) and mammals (including rodents, squirrels, and pigs). Once acorns reach the soil surface, they have the potential to be killed by heat, desiccation, or predation. Acorn burial is crucial to survival and may be accomplished in multiple ways. Acorns may be buried indirectly, such as by wind-blown litter, or acorn-caching animals such as woodpeckers and jays may play a significant role in seedling burial and therefore, seedling establishment. In a single season, a western scrub jay may cache up to 5,000 acorns, while only relocating and consuming half of this number. Ground squirrels and other rodent species are additional common acorn caching animals (Tyler et al. 2006).

Acorn predation can lead to lack of oak regeneration. Tyler et al. (2002) studied factors limiting valley oak establishment by planting approximately 1,000 seedlings. When protected from mammals, the maximum rate of acorn survival and germination was 71%, whereas survival of unprotected acorns was 30%.

<u>Landscape Stressor: Climate</u>

Climate is a stressor of oak ecosystems on Tejon Ranch through perturbations of the hydrologic cycle and fire regimes. The amount of annual precipitation can greatly affect the success of oak seedlings.

<u>Ranch Stressor: Fire</u>

Fire intensity, frequency, size, pattern, and seasonal timing are important factors that influence the oak vegetation communities on Tejon Ranch. Infrequent fire has been shown to be negatively correlated with sapling recruitment (Swiecki et al. 1997). However, low-severity ground fire may improve conditions for oak seedling and sapling establishment. Fire removes herbaceous competitors and increases soil nutrients, which may aid in oak regeneration. Using fire scars to age oak stands, some correlation between fire events and oak recruitment has been found; however, it has also been suggested that this correlation may be due to the temporal concentration of re-sprouts, creating a uniform age stand (Tyler et al. 2006). Juxtaposed to Tyler et al.'s findings, Swiecki and Bernhardt (2002) found that moderate intensity fire has negative effects on blue oak saplings and does not enhance regeneration. Top-killed saplings may exhibit growth right after fire; however this growth may not be sustained over time. Saplings are highly susceptible to browsing during this re-growth stage and it may take years in order for oaks to regain the above-ground biomass they had before the fire.

There are two major types of important fire regimes addressed in the conceptual models: high-intensity crown fires and low-intensity ground fires.

> <u>High-Intensity Crown Fire</u>
>
> High-intensity crown fires negatively affect oak regeneration by killing seedlings and saplings, as well as eliminating adult oaks. These fires typically occur when there is a build-up of fuels, as is the case with years of fire suppression. Crown fires are rare in open oak woodland and savanna systems.
>
> <u>Low-Intensity Ground Fire</u>
>
> Low-intensity ground fires burn at a lower temperature and occur at more frequent intervals. The impacts of these fires are uncertain and are an area for future research.

<u>Ranch Stressor: Annual Precipitation</u>

Tejon Ranch experiences a Mediterranean climate typical of California, experiencing wet winters and dry summers. Summer drought in California's foothills may extend up to six months or more (Tyler et al. 2006). The amount of annual precipitation is directly linked to the amount of water that will be available to oaks during the growing season.

Key Process: Growing Season Soil Moisture

Summer drought severity and the amount of soil moisture available during the growing season are important limiting factors in oak seedling survival and growth. Adult oak canopies provide shade that reduces evapotranspiration; however, they also compete with the seedlings for soil moisture (Yolo County 2007). Seedlings are more susceptible to water stress than adults since their roots are unable to reach the water table (Tyler et al. 2006). In areas with higher soil moisture, valley oak seedling regeneration is present even with an overstory canopy (Yolo County 2007).

The amount of precipitation during the first year of an oak's establishment has been shown to be a decisive factor in recruitment success for valley oak seedlings (Tyler et al. 2002). Low emergence and establishment of oaks has been observed during years of below average rainfall (Griffin 1971; Adams et al. 1997b).

Key Process: Water Table Depth (Valley Oak Savanna Only)

Valley oaks send out deep roots that can reach groundwater as a year-round moisture supply. Therefore, water table depth is an important factor for tree growth, especially when groundwater tables sink deeper due to a lack of recharge and overdraft. Tree canopy growth is dependent on this constant source of water and a lowering of the water table can place the tree under severe stress. Root growth can keep up with small fluctuations in the water table, however rapid drops of several feet or more can severely debilitate or kill mature trees. Oaks in sandier soils often feel more severe effects of a lowered water table depth than those in loam or clay loam soils due to the amount of moisture stored in the soil profile (Yolo County 2007). Increased soil compaction also reduces water table depth, since less water is able to infiltrate the surface.

Key Process: Soil Erosion (Foothill Blue Oak Woodland Only)

The severity of erosion is partially determined by the type of soil present. Foothill Blue Oak Woodlands typically occur on slopes and are susceptible to erosion. Erosion causes loss of the upper soil layer which is rich in organic matters and nutrients (Dahlgren, Singer, & Huang 1997). Loss of these nutrients may make it difficult for seedlings to establish.

<u>Ranch Stressor: Livestock Grazing</u>

Most valley oak savanna and foothill blue oak woodlands are used for livestock grazing, specifically cattle grazing. Cattle have a profound effect on oak systems through soil compaction and direct browsing of seedlings and saplings. Cattle grazing can also contribute to increased soil erosion in foothill blue oak woodlands.

Key Process: Browsing by Cattle

Livestock grazing has been shown to have both positive and negative effects on oaks, and is controversial in its effects on oak regeneration. Tyler et al. (2002) found that oak seedling emergence may be higher in grazed plots than ungrazed plots. This could be due to the dense herbaceous layer of ungrazed plots that may compete for water. Cattle reduce the leaf surface area of grasses, further reducing the amount of evapotranspiration and loss of soil water (Hall et al. 1992; Jansen et al. 1997). The harmful effects of grazing on oaks are through direct browsing of seedlings and acorns. Cattle may show preferences to browse near and under adult oak trees, due to increased forage levels and cooler temperatures, resulting in more damage to oak seedlings (Hall et al. 1992). However, cattle may decrease rodent abundance by reducing their habitat, thereby reducing predation of acorns and saplings. Grazing also eliminates fuel ladders, reducing the risk of high-intensity crown fires (Allen-Diaz, Standiford, & Jackson 2007).

The timing and intensity of grazing has been shown to have an effect on browse utilization levels (Hall et al. 1992; Jansen et al. 1997). Hall et al. (1992) found that high intensity spring and summer grazing resulted in the lowest blue oak seedling survival, while winter grazing was less damaging.

Key Process: Soil Compaction

Surface soils on many parts of Tejon may be compacted from years of cattle use. Soil compaction results in increased soil bulk density, which reduces the amount of water that is able to infiltrate the surface, eventually becoming surface runoff (Tyler et al. 2006). Acorn survival and germination requires natural leaf litter mulch for protection from predation and desiccation. Soil compaction caused by livestock grazing creates areas that lack natural mulch, and few acorns may be able to survive and germinate (Yolo County 2007). Compacted soils also make it difficult for an oak seedling's roots to penetrate the surface and reach water (Tyler et al. 2006). With increases in livestock grazing on the Ranch, further soil compaction is expected.

Key Process: Soil Erosion (Foothill Blue Oak Woodland Only)

Foothill blue oak woodlands are typically found on slopes, where increased soil erosion may occur when there is grazing by cattle. Loose sediment is sent downhill when trampled by the cattle.

Endpoint: Percent Cover of Annual Invasive Species

The increased presence of annual invasive species has the ability to affect oak woodland systems. The reduction of native species can reduce the overall habitat value of the vegetation community. Invasive annual species grow quickly in the winter and early spring, which rapidly depletes soil moisture (Tyler et al. 2006; Yolo County 2007). Compared to annual species, native perennials have slower growth rates and consume less water, allowing for growth into the summer months. Invasive annual species have roots that are shallower and denser within the topsoil zone, depleting soil moisture near the surface early in the growing season, leaving less water available to oak seedlings.

Seedling growth and survival in both valley and blue oaks has been shown to decrease significantly when grown with annual grasses versus when grown with native species (Tyler 2006). Seedlings grown with native perennial grasses showed greater emergence and growth rates when compared to those grown with annual grasses (Tyler 2006).

Endpoint: Oak Regeneration

Throughout California there is concern for the lack of native oak regeneration. Successful regeneration is necessary to replace the loss of mature trees. If regeneration does not occur, oak stands will thin over time and eventually disappear.

Endpoint: Bare Ground/Herbaceous Layer

The presence of bare ground or disturbed soil may be an indicator of overgrazing or degraded soil. Soil compaction from grazing can lead to bare ground where seedlings are not able to establish. The presence and species within the herbaceous layer can be an indicator of soil quality.

Endpoint: Age/Size Class Structure (Foothill Blue Oak Woodland Only)

Foothill Blue Oak Woodland communities tend to occur in close association with other native species. In these communities, species composition as well as age and size class structure, are important to monitor in order to determine shifts in dominance. Understory composition is also important, as it may affect recruitment. A study by Callaway (1992) suggests that shrub canopies may act as protection for blue oak seedlings. Survival in blue oak seedlings was highest under shrub canopies during a dry year with only 50% of average rainfall and may act as caging and shading.

Endpoint: Niche Diversity

Fallen oak trees and snags provide cavities that are utilized by various species. The presence of dead trees and large downed woody debris improves the habitat value for native wildlife, especially birds. The amount of snags and woody debris in a woodland is related to the age distribution of the stand, since older trees are more likely to die or fall. Management should allow for downed woody debris to remain on the ground (Yolo County 2007).

Endpoint: Oak Dependent Bird Species

The presence of oak-dependent bird species, such as the western scrub-jay and acorn woodpecker are not only indicators for a healthy system, but may also aid in the dispersal of acorns and presence of future trees.

7.6.3 Future Management and Monitoring Recommendations

Oak recruitment and regeneration on Tejon Ranch are the primary concern within Valley Oak Savanna and Foothill Blue Oak Woodland vegetation communities. Diversified age and size structure are indicators of healthy oak systems. Monitoring bare ground and cover of annual grasses is important in order to understand the factors that may affect recruitment. Presence of species such as the western scrub-jay and acorn woodpecker also indicate a healthy ecosystem. Monitoring target recommendations for Valley Oak Savannas and Foothill Blue Oak Woodlands include:

1. *Management Target*: Promote age structure diversity through oak regeneration.
   Monitoring Recommendation: Sapling recruitment should be monitored in order to determine the status of oak regeneration on the Ranch. Success of saplings outside of the browsed layer will contribute to overall regeneration. Sample plots should be established in which to monitor recruitment. Surveys should be conducted every five to ten years to monitor new saplings and small trees out of the browsed layer. As evidenced by the data we collected in Valley Oak Savanna (Figure 7.6-1),

there is little to no regeneration occurring. In addition to sapling surveys, implementing a range productivity assessment would allow for the monitoring of grazing intensity and seasonality impacts on oak communities over time. Experiments involving active restoration can be used to determine some of the processes negatively affecting recruitment. For example, Tyler et al. (2002), conducted a large-scale planting experiment to determine the effects of cattle and other ecological factors on oak seedling establishment. Large plots were established, grazed and ungrazed, and within plots various protection from browsing and predation were established.

2. *Management Target*: Reduce oak sapling and seedling competition by assessing the cover of annual invasive species.
   Monitoring Recommendation: Perform annual grass biomass surveys in the spring to assess the depletion of upper soil moisture.
3. *Management Target*: Improve conditions for regeneration by minimizing bare ground and degraded soil due to livestock grazing.
   Monitoring Recommendation: Carry out surveys recording percent of bare ground and degraded soils within oak woodlands. Measures of RDM can be used to assess the effects of the seasons forage production and disappearance due to grazing. These surveys may be done in conjunction with the above recruitment surveys, using the same plots.

4. *Management Target*: Monitor oak-dependent bird species such as the western scrub jay (*Aphelocoma californica)* and acorn woodpecker *(Melanerpes formicivorus).*
   Monitoring Recommendation: Monitor the number of western scrub-jay and acorn woodpecker territories. Surveys may be conducted every one to two years.

5. *Management Target*: Maintain niche diversity through abundance of dead trees and snags, downed logs, and woody debris.
   Monitoring Recommendation: Survey the abundance of dead trees, snags, downed logs, and woody debris.

6. *Management Target*: Maintain species diversity through a variety of age and size class distributions (foothill blue oak woodlands only).
   Monitoring Recommendation: Complete surveys to identify species composition and age structure every 5-10 years in order to monitor sapling success, overstory morality, and species diversity. Establish permanent sampling plots that can be monitored over time.

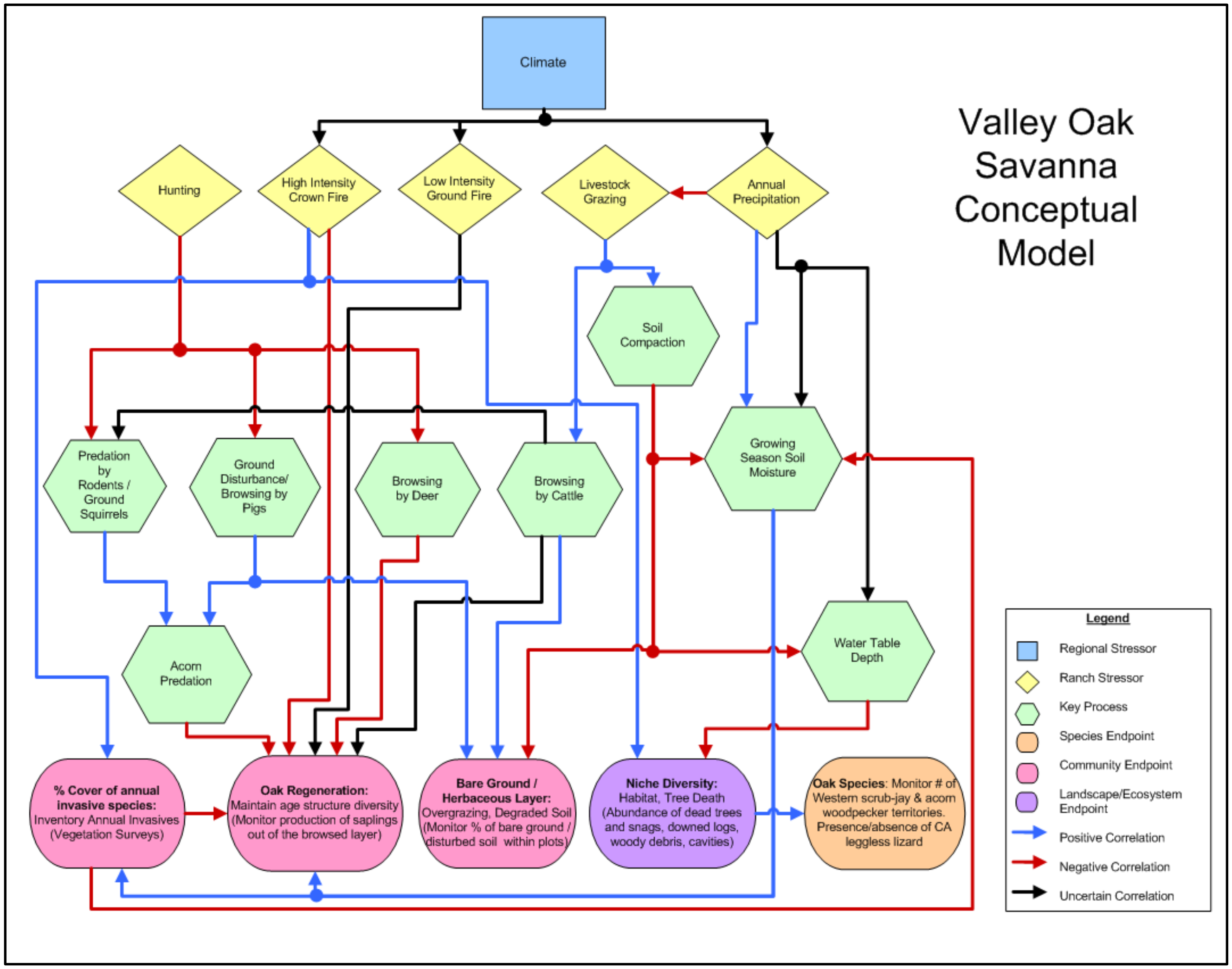

Figure 7.6-2. Valley Oak Savanna Conceptual Model for Tejon Ranch.

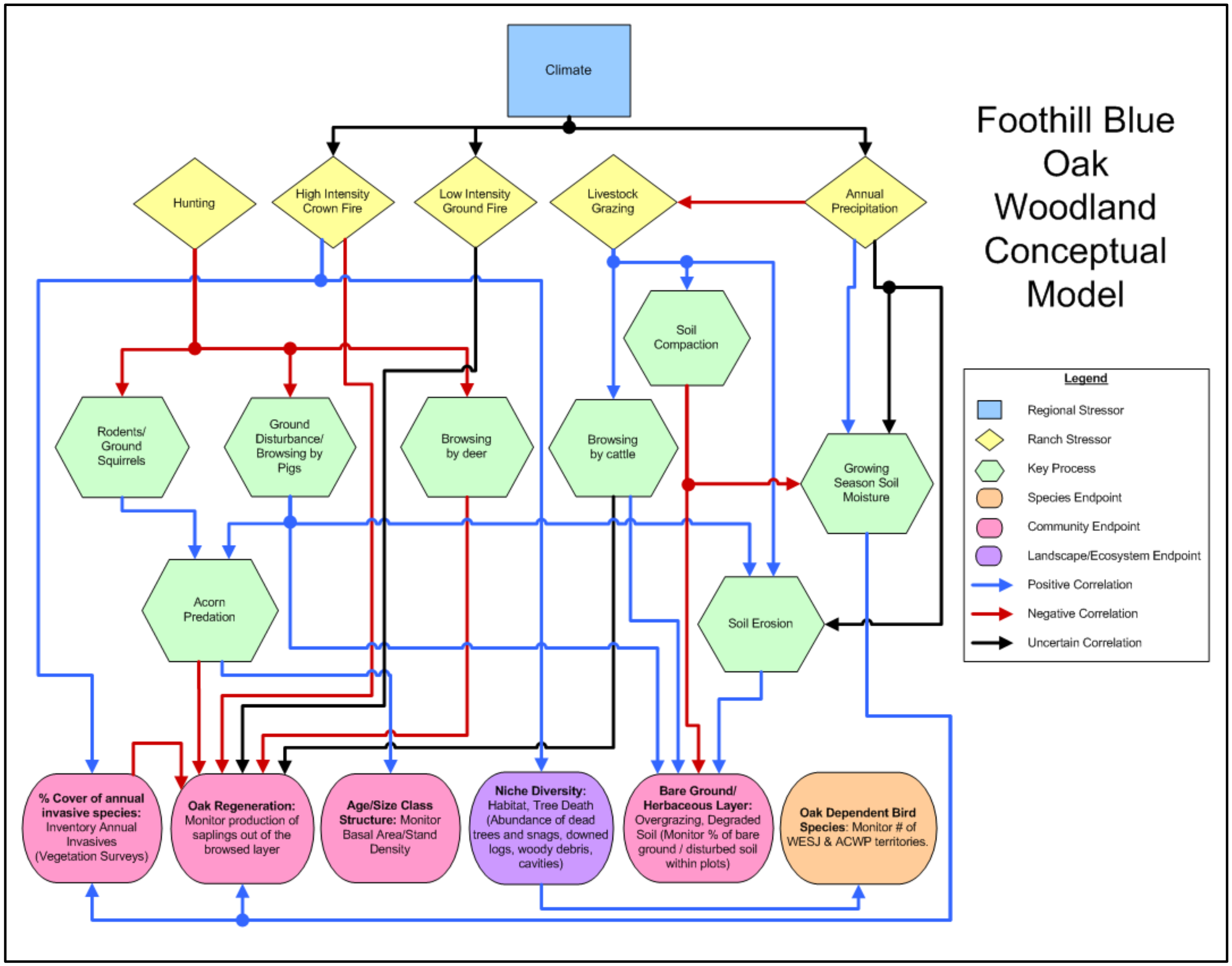

Figure 7.6-3. Foothill Blue Oak Woodland Conceptual Model for Tejon Ranch.

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8 MANAGEMENT CONCERNS AND UNCERTAINTIES

Based on existing scientific literature and baseline information, we identified areas that can be adaptively managed to help achieve the goals of the Conservancy to conserve and enhance biodiversity on the Ranch. We analyzed the pathways and ecosystem processes (e.g. invasion of exotic species) through which system stressors propagate effects to the natural communities of the Ranch. Based on our analysis, we identified four key environmental stressors: grazing, fire, hunting, and hydrologic management (Table 8-1). We also identified climate change, air quality, and land use change as key ecological drivers that operate regionally but also influence management outcomes. Management goals and priorities differ among the eight vegetation communities that we assessed. We have used the dashboard symbols in Table 8-1 to convey our best judgment regarding the relative level of management concern for stressors in each vegetation community. The red circles represent areas of high management concern, orange represents moderate concern, and green represents areas of low concern. The highest-level management concerns are where the Conservancy may want to first focus management and monitoring efforts, due to the influence these stressors have in affecting change in certain vegetation communities. Additionally, the uncertainty surrounding these concerns is represented in Table 8-2. Uncertainty is based on a lack of scientific support of relationships between stressors and vegetation communities and/or knowledge of community conditions on the Ranch. Relationships with uncertainty may also represent key areas for future monitoring in order to better describe the effects. Management and monitoring of vegetation communities and associated stressors within the adaptive management framework will be necessary to resolve such areas of uncertainty. Finally, in addition to identifying the stressors of management concern, we assessed the manageability of these stressors and characterized their relative level of priority for adaptive management.

Table 8-1. Management Concerns. The colored circles represent the magnitude of influence the stressor has on the community; red depicts an area of high management concern, orange represents moderate concern, and green represents low concern.

Management Concerns	Ranch-Level Stressors				Regional-Level Stressors		
	Grazing	Fire	Hunting	Hydrology	Climate	Air Quality	Development & Roads
Chaparral	🟢	🔴	🟢	🟢	🟠	🟠	🟠
Joshua Tree Woodlands	🟠	🟠	🟢	🟢	🔴	🔴	🟠
Montane Mixed Hardwood & Conifer Forest	🟠	🔴	🟠	🟢	🔴	🔴	🟠
Riparian	🔴	🟠	🟠	🔴	🟠	🟢	🟠
San Joaquin Valley Grasslands	🟠	🟠	🟢	🟠	🟠	🟠	🟠
Antelope Valley Grasslands	🔴	🟠	🟢	🟠	🔴	🟠	🟠
Valley Oak Savanna	🔴	🟠	🟠	🟠	🟠	🟢	🟠
Foothill Blue Oak Woodlands	🟠	🟠	🟠	🟢	🟠	🟢	🟠

Table 8-2. Management Uncertainties. This table builds upon Table 8-1, where the open circles represent uncertainty surrounding the concern.

Management Uncertainties	Ranch-Level Stressors				Regional-Level Stressors		
	Grazing	Fire	Hunting	Hydrology	Climate	Air Quality	Development & Roads
Chaparral	● green	● red	● green	● green	○ orange	○ orange	● orange
Joshua Tree Woodlands	○ orange	○ orange	○ green	● green	● red	● red	● orange
Montane Mixed Hardwood & Conifer Forest	○ orange	● red	○ orange	● green	● red	● red	● orange
Riparian	● red	○ orange	● orange	● red	○ orange	● green	○ orange
San Joaquin Valley Grasslands	○ orange	○ orange	● green	● orange	○ orange	○ orange	● orange
Antelope Valley Grasslands	○ red	○ orange	● green	● orange	○ red	○ orange	● orange
Valley Oak Savanna	○ red	○ orange	○ orange	● orange	○ orange	● green	● orange
Foothill Blue Oak Woodlands	● orange	○ orange	○ orange	● green	○ orange	● green	● orange

CHAPARRAL

For chaparral, fire is the main management concern. Some chaparral areas have burned within the last 50 years on Tejon Ranch, but other chaparral areas have unknown fire histories. Since fire is such an important component of chaparral, fire records should continue to be kept on the Ranch, and species composition should be monitored in these communities to assess the time since fire. As more fire history data is collected the Conservancy may desire to more actively manage fire regimes in chaparral in the future. However, right now there is not enough fire history data to recommend active management of fire in chaparral.

Uncertain stressors in chaparral systems are climate and air quality. The effects of precipitation and temperature are well-known in chaparral systems, but climate data from Tejon Ranch is very sparse. Therefore, the impact of climate on Tejon Ranch chaparral is categorized as uncertain.

Finally, there is limited information on the effects of air quality on chaparral, so this stressor is categorized as uncertain.

JOSHUA TREE WOODLANDS

In Joshua tree woodland communities on the Ranch, air quality and climate are the major management concerns. Air pollution can have direct effects on Joshua trees which could counter or amplify the direct effects of climate change on Joshua tree woodlands, and is therefore a management concern (Dole et al. 2003). The effects of increased CO_2 have the potential to increase recruitment and may allow the range of Joshua trees to expand into regions with cooler climates than current range limits, such as into the higher elevations of Tejon Ranch (Dole et al. 2003). Changes in climate can also affect Joshua tree woodland health, recruitment, and Joshua tree distribution on the Ranch; thus, this is a key community in which to study the potential effects of both air pollution and climate change.

Uncertainty in Joshua tree woodland communities lies in the impacts of grazing, fire, and hunting. Grazing in Joshua tree woodlands could affect species composition, especially of grass and shrub species, which serve as nurse plants for Joshua tree seedlings (Brittingham & Walker 2000). Fire can influence invasion by non-native species however, the sub-species of Joshua tree that occurs on Tejon Ranch is thought to be resilient and re-sprout following wildfires. Hunting in and around Joshua tree woodlands is another management uncertainty that could potentially alter native populations of ground squirrels that browse Joshua tree seeds and seedlings, although this relationship is highly uncertain.

MONTANE MIXED HARDWOOD & CONIFER FOREST

The main management concerns in Tejon Ranch's montane forests are air pollution, climate, and fire, with grazing and hunting as areas of management uncertainty. The effect of climate on montane mixed-hardwood forests can be manifested through drought and reduced snowpack duration. Baseline data on historic climate is incomplete, yet climate may explain potential changes in montane forest health. Monitoring of climate trends is necessary, and management decisions need to be able to adapt to a changing climate. Air pollution and ozone in montane forests can limit tree growth, reduce plant health, and can lead to increased susceptibility to pests. Since montane forests are in the higher elevations of Tejon Ranch, they are more susceptible to ozone, and are therefore a management concern that should be monitored regularly through surveys to document potential impacts. In addition to more comprehensive baseline surveys being needed, montane forests should be regularly monitored in order to track the possible effects of increased stressors on the ranch, especially since montane forests may be the first areas to show sensitivities to climate change and air pollution.

Fire is a natural and necessary part of mixed-hardwood and conifer forests in order to maintain vegetation diversity and enable conifers to germinate. If the natural fire regime has been suppressed in a forest for long periods of time (e.g. decades), such has been the case in many areas of Tejon Ranch, any fire that does burn the area may be in the form of a high-intensity crown fire due to the density of trees and massive buildup of fuels (Minnich 1988; Barbour et al. 2007). In a regime of fire suppression, there could be a negative effect on the forest's overall diversity and structure, as shade-tolerant and dense species such as incense cedars and white firs would begin to dominate the community as their growth had time to increase (Barbour et al. 2007). Therefore, the Conservancy may want to consider evaluating fire regimes in their management decisions.

Uncertainty in montane forest communities lies in the impacts of grazing and hunting. It is unknown exactly how much of the Ranch's montane forests are used for livestock grazing, although it is likely that the understory layers are heavily grazed. Therefore, surveys are needed in order to establish a management baseline. In montane forests, livestock grazing typically increases woody species while reducing herbaceous layers and seedlings, impacting hardwood establishment while also impacting faunal species such as birds that have ground nests (CalPIF 2002). Hunting is also an area with high uncertainty and an opportunity for future research. Further research and monitoring is needed to assess community health through sampling of foliage health indicators, vegetation diversity and structure, stand density, patterns of tree species recruitment, and tree mortality.

Riparian

The health and condition of riparian vegetation communities on the Ranch are influenced by several system stressors including, in order of relative influence, livestock grazing, hydrologic processes, hunting and game management, climate, development and roads. Riparian community health on the Ranch is affected by cattle grazing activities, as cattle cause direct damage to native riparian vegetation through browsing, increasing susceptibility to invasion by non-native species, altering streambank morphology, and causing soil compaction and erosion. We recommend that the Conservancy install and monitor experimental fenced grazing exclosures around riparian corridors to evaluate the effects of grazing on riparian community species composition and structure. Because riparian communities also appear to be strongly affected by feral pigs, these exclosures should include nested hogwire exclosures to separate the effects of cattle exclusion from pig exclusion.

Riparian communities on the Ranch are strongly influenced by water use and hydrologic modifications. Many of the riparian systems on the Ranch are either directly or indirectly affected by management of water supplies such as groundwater pumping and stream diversion. We recommend that the Conservancy measure and record stream flows, agricultural diversion quantities, and groundwater withdrawals to establish a baseline for future water resource management and planning.

Riparian communities are also likely to be affected by changing climate patterns. Possible climate change affects may be seen in the amount and seasonality of precipitation and the resulting changes in water availability which could strongly affect riparian community species composition and structure. We recommend that temperature and precipitation be measured and recorded for select locations and elevations across the Ranch. For example, measurements could be taken at high, medium, and low elevations in the Tejon Creek, El Paso Creek, and Big Sycamore Canyon watersheds.

Riparian community health on the Ranch could be impacted by planned urbanization and development within certain watersheds. Direct and indirect effects of altered runoff patterns and stormwater discharge as well as other hydrologic modifications associated with development and urbanization in a watershed may affect the structure and species composition of downstream riparian communities.

Available baseline data on historic climate, stream flows, agricultural diversions, and cattle grazing intensity is sparse, leading to high levels of uncertainty surrounding the effects of these stressors on riparian community health. Fire is also an uncertain management concern in riparian communities, although wildfire effects on riparian community health have been documented in arid environments in the Mojave Desert and are well studied in montane forests of the Sierra Nevada.

SAN JOAQUIN GRASSLANDS AND ANTELOPE VALLEY GRASSLANDS

The main management concerns in Tejon Ranch's grassland communities are air pollution, climate, and grazing. In grassland communities on the Ranch, grazing is the greatest management concern, particularly in the Antelope Valley where a greater composition of native forbs and bunch grasses is still maintained. Antelope Valley grasslands may also be more susceptible to over-grazing, as overall productivity is lower. Grazing intensity and timing can greatly alter species structure and composition. Implementing a rangeland productivity assessment protocol would allow for the monitoring of species composition as well as overall grassland production in order to assess the impacts of grazing on grassland communities over time.

Climate also has a major influence on grassland productivity and species composition. Annual fluctuations in rainfall seasonality and amount, as well as fluctuations in temperature can greatly influence inter-annual differences in species composition and overall production (Barbour et al. 2007). The effect of climate on grassland communities can be manifested through the alteration of both hydrology and fire regimes. Therefore, monitoring of climate trends is necessary, and management decisions about the duration and intensity of grazing need to be able to adapt to a changing climate.

Nitrogen deposition can alter grassland species composition. Nitrogen deposition can also lead to increased nutrient levels in terrestrial ecosystems as well as increased overall productivity which can be measured through residual dry matter surveys. However, nitrogen deposition can also disrupt species composition, as some species are more competitive in a low-nutrient environment. Nitrogen deposition may have a larger impact on the Antelope Valley side of the Ranch, which is characterized by sandier, low-nutrient soils.

Currently it is unknown whether nitrogen deposition rates are occurring at levels which may be altering vegetation communities on the Ranch. The effects of climate on grassland communities are well understood but the current trends in precipitation in this system are not well understood. Air quality monitoring across the Ranch would allow the Conservancy to ascertain whether or not nitrogen deposition is occurring at levels that are harmful to vegetation communities. The community-specific effects of grazing on the Ranch are largely uncertain as there is no grazing monitoring program currently in place. As a result, the degree to which grazing affects the health of grassland communities on the Ranch is uncertain. Since grazing is such a major activity on the Ranch, as well as a major grassland system stressor, it should be considered a monitoring priority.

Valley Oak Savanna and Foothill Blue Oak Woodlands

Many animal species can limit oak recruitment; notably, species under direct management control such as cattle, pigs, and deer. Sorting out the relative importance of these animals could be done through long-term nested experimental exclosures for different combinations of species. Grazing intensity and timing could be monitored through a rangeland productivity assessment protocol in order to assess the impacts of grazing on oak sapling survival and understory composition.

Temperature and precipitation regimes also have an influence on oak regeneration. Therefore, climate is an important stressor within oak communities. Changes in temperature and timing of precipitation can influence understory species composition as well as oak regeneration.

Fire return intervals within oak communities influence species structure and composition, as well as seedling sprouting and sapling survival. It is uncertain what the potential impacts of varying fire intervals will be in oak communities on the Ranch. The prehistoric fire intervals for these communities are estimated to be between seven and 15 years, whereas the historic and modern intervals are around 100 years. Continued monitoring of fire on the Ranch, combined with historic records, will help characterize this stressor and future management.

8.1 Management Priorities

Following the identification of environmental stressors of management concern, our analysis involved a characterization of stressor manageability and the capacity for managers to adapt to changes. The following section presents the rationale behind the selection of three key system stressors (grazing, fire, and climate) as adaptive management priorities.

8.1.2 Ranch-level Environmental Stressors

Ranch-level stressors are key environmental stressors that can be changed or minimized through management decisions. The key ranch-level environmental stressors we have identified are grazing and fire.

Grazing

To address grazing, we recommend creating and implementing a rangeland productivity assessment protocol. Many key processes in rangeland ecology are affected, or may be assessed, by the height and architecture of grassland cover (Stewart et al. 2001). The importance of managing grassland cover to prescribed heights and structures has long been recognized in conservation and agriculture (Stewart et al. 2001). Implementation of rangeland productivity monitoring as described in Section 6.5.1 would establish a baseline with which to adaptively manage future grazing activities in the different vegetation communities on the Ranch.

The Conservancy may also want to consider designing and implementing an experimental seasonal grazing rotation program to study the effects of grazing seasonality on grassland and oak savanna community health, as well as rangeland productivity. Certain communities may benefit from seasons of grazing exclusion; for instance, grassland communities may see increases in native cover and annual productivity when grazing pressure is excluded in late summer (Potthoff et al. 2006). Through the implementation of an adaptive or experimental design, ecosystem responses to seasonal grazing rotation in grasslands and oak savannas can be monitored through the rangeland productivity assessment.

FIRE

We recommend that new CALFIRE fire perimeters be added to existing ranch data in order to track the fire return interval in different vegetation communities. The Ranch may want to consider the development of a Fire Management Plan (FMP) that details specific fire management guidelines that will help the Conservancy protect and enhance conserved lands. Fire plays an important role in maintaining community health and diversity, especially in montane and chaparral communities, and the FMP may provide guidance for wildfires that are allowed to burn. The Conservancy may also want to consider the effects of prescribing fire under an adaptive management regime where outcomes of fires are monitored and used to inform future management decisions, which could help to restore structural and species diversity in these communities.

8.1.3 REGIONAL-LEVEL ENVIRONMENTAL STRESSORS

Regional-level stressors represent influences on the Ranch that occur outside ranch boundaries. Due to their larger scale and sources, the Conservancy has less management control over these stressors. We identified climate as a major stressor on the Ranch.

CLIMATE

Climate is a regional-level stressor that represents a major driver of change in vegetation communities on the Ranch. Although managers have little control over climate, management decisions will need to consider and adapt to changes in climate, especially in montane and Joshua tree woodland communities. Comprehensive climate monitoring at different elevations and areas of the Ranch should be considered a management priority.

9 CONCLUSION

The Tejon Ranch Conservancy came to the Bren School seeking assistance to better understand the vegetation communities and conditions on the Ranch. Our Group Project fulfilled the Conservancy's need through the creation of conceptual models, the collection of baseline data, and the development of management and monitoring recommendations that address management uncertainties, system stressors, and ecosystem processes. Conceptual models are meant to express the connections and relationships between ecosystem components and outcomes. The information depicted in these models can be used to forecast outcomes of management decisions or environmental variation within an adaptive management framework. The baseline conditions we collected can serve as a foundation for adaptive management, providing a standard upon which future monitoring designs can be based and a data set with which future monitoring results can be compared in order to assess trends and changes over time.

During the process of collecting and analyzing baseline data and constructing conceptual models for each system, our team identified key management uncertainties and data gaps. Using the knowledge gained through this process, we developed a set of preliminary management and monitoring recommendations where the Conservancy can focus management and monitoring efforts. Adaptive management and monitoring of each of the Ranch's vegetation communities, as well as key environmental stressors such as grazing, fire, and climate, will be necessary in order to achieve the Conservancy's goals and objectives. Throughout the development of these management recommendations, we were mindful of balancing agreement-authorized activities with the Conservancy's conservation goals and objectives. Our management and monitoring recommendations were selected due to their perceived responsiveness to management and their influence in vegetation communities on the Ranch.

Our preliminary findings and baseline conditions will help inform the adaptive management process as the Conservancy moves forward with the development of the RWMP. Although our research informs the Conservancy of the existing conditions on the Ranch, current monitoring is limited and uncertainties about the conditions on the Ranch remain. In the future, as new information is gathered about the native biodiversity and vegetation communities on the Ranch, our conceptual models and recommendations can be changed and adapted to incorporate new information and resolved uncertainties. Our adaptive management and monitoring recommendations are intended as suggestions for the Conservancy to consider in the development of the RWMP.

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APPENDICES

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A TEJON RANCH CONSERVATION AND LAND USE AGREEMENT: SUMMARY OF KEY PROVISIONS

The Tejon Ranch Company (TRC) and Audubon California, the Endangered Habitats League, Natural Resources Defense Council, Planning and Conservation League and Sierra Club (the Resource Groups) have reached a Conservation and Land Use Agreement that will provide for permanent conservation of more than 240,000 acres of the 270,000-acre Tejon Ranch — approximately 90% of the entire property. The guiding principles of the agreement are as follows:

- The Resource Groups are assured phased dedication, at no cost, of approximately 178,000 acres of the Ranch in the form of dedicated conservation easements and designated project open spaces.
- The Resource Groups are granted an option expiring December 31, 2010, with defined extensions, to acquire conservation easements over an additional 62,000 acres, at a price established pursuant to an appraisal process conducted by the State, bringing total conserved lands to 240,000 acres. These 62,000 acres are considered by TRC to be future development areas.
- TRC is assured that it will have the ability to proceed with the entitlement processes for Centennial, TMV and Grapevine development projects with no opposition from the Resource Groups. Development entitlements are still subject to all necessary local, state, and federal regulatory processes.
- A governance structure for conserved lands is provided in the form of the Tejon Ranch Conservancy, a non-profit, 501(c)(3) tax-exempt corporation.

A more detailed description of the key provisions of the agreement is as follows:

<u>Conserved Lands</u>

- **Management Plan.** Upon execution of this agreement, all lands identified for conservation will be managed pursuant to a Ranch-Wide Management Plan developed by TRC and the Conservancy. Management of these lands will begin immediately, i.e., prior to recordation of conservation easements.

- **Dedicated Conservation Areas.** TRC will permanently protect approximately 178,000 acres through a combination of dedicated conservation easements and designated project open spaces.

  - A conservation easement of up to 10,000 acres will be dedicated to allow for realignment of approximately 37 miles of the Pacific Crest Trail through the Ranch.
  - An additional 33,000 acres of open space areas within the permitted project areas will be designated as part of the project development process.

    - Conservation easements over the remaining 135,000 acres will be dedicated in six (6) phases as TRC receives development approvals, with an outside date of 30 years from final approval of the first project.
    - Prior to these dedications, no unauthorized development will be permitted. Grazing, game management and other existing ranch activities will continue to occur subject to the Ranch-Wide Management Plan.

- **Acquired Conservation Areas.** TRC will provide separate options for the Resource Groups to purchase development rights through acquisition of conservation easements, or potentially a fee interest, for five (5) separate Acquisition Areas, totaling an additional 62,000 acres.

    - The option period expires December 31, 2010, with possible defined extensions if certain criteria are met.
    - Each Acquisition Area may be acquired separately and in any order except that Bi-Centennial can be acquired only after Old Headquarters, Tri-Centennial and White Wolf are acquired.
    - An appraisal process to establish the acquisition price for each Acquisition Area will be conducted by the State of California pursuant to all applicable laws and regulations. Should the State elect not to appraise one or more of the Acquisition Areas, an independent appraisal process would take place for those areas.
    - During the option period, no unauthorized development will be permitted. Grazing, game management and other Ranch activities will continue to occur subject to the Ranch-Wide Management Plan.
    - In the event there are unacquired Acquisition Areas at the end of the option period, the Resource Groups and TRC agree to meet and confer with no pre-determined parameters.

- **Federal and State Uses.** The parties will commit to work with the appropriate stakeholders to provide the opportunity for significant public access and community education programs on the conserved lands.

    - **State Park.** The Resource Groups and TRC commit to work with the Conservancy and the California State Parks Department toward creation of a State Park within the conserved lands.
    - **Pacific Crest Trail.** TRC commits to work with the Conservancy and the US Forestry Service to provide an easement on conserved lands to realign a 37-mile segment of the Pacific Crest Trail through the Ranch.
    - **University of California Natural Reserve.** The Conservancy commits to work with the University of California Natural Reserve System to determine whether certain conserved lands may be viable for a future UC Natural Reserve.

Tejon Ranch Conservancy

- **Independent Conservancy.** The Conservancy will be created as a non-profit corporation that will qualify as a 501(c)(3) tax-exempt organization.

    - A 12-member board will be established consisting of four members appointed by the Resource Groups, four members appointed by TRC and four independent members jointly appointed by the Resource Groups and TRC during the first three years and by the Conservancy Board thereafter.
    - It is expected that the Conservancy will hire permanent employees with expertise in land trust administration, conservation biology, ecology and population biology, habitat restoration, and open space land management.
    - It is expected that the Conservancy will establish a Scientific Advisory Panel and other stakeholder working groups.

- **Ranch-Wide Stewardship.** The Conservancy will bring together the expertise of leading experts in conservation, natural resource management and business interests to further develop the framework for stewardship of conserved lands.

    - Conservancy mission: To preserve, enhance and restore the native biodiversity and ecosystem values of the Tejon Ranch and Tehachapi Range for the benefit of California's future generations. The Conservancy will work collaboratively with TRC to promote long-term, science-based stewardship of this historic 270,000-acre property to provide for public enjoyment through educational programs and public access.
      The Conservancy will develop, monitor and enforce implementation of the Ranch-Wide Management Plan, which will be applicable to all conserved lands.
    - The Conservancy will monitor and maintain natural resource mitigation on conserved lands and will hold all conservation easements, subject to regulatory agency approval, if required.
    - The Conservancy will receive and allocate conservation fees and other sources of funding.
    - The Conservancy will oversee managed public access to conserved lands and will provide interpretive and environmental education programs for the local communities, focusing in particular on underserved populations.

- **Conservancy Funding**. Funding of the Conservancy will be assured through a combination of advances from TRC and payment of conservation fees collected at the time of title transfers of residential units within current development areas.

- TRC shall cause a conservation fee covenant to be recorded encumbering the development projects of Centennial, Tejon Mountain Village and Grapevine. The covenant shall provide for a fee, payable in perpetuity, equal to one quarter of one percent (0.25%) of the retail sales price of each covered transaction, which generally includes initial sales and resales of custom lots and single-family attached and detached homes and excludes units designated as affordable.
- Prior to the receipt of conservation fees by the Conservancy, TRC will advance amounts necessary to adequately fund the Conservancy, as described below. In future years, conservation fees in excess of amounts required to meet the Conservancy's core obligations will be used to repay TRC advances, without interest.
- In Year 1, which will be 2008, TRC advances will be $250,000 plus the actual costs of Conservancy formation and start-up.
- In Years 2-7, which may be extended to Years 8-14 if at least four Acquisition Areas are purchased by the Resource Groups, TRC annual advances will be $800,000.
- Two years prior to the date at which the Conservancy will first take responsibility to monitor and maintain natural resource mitigation on the conserved lands, the TRC annual advance will be adjusted to $1,500,000
- In the year the Conservancy first takes responsibility to monitor and maintain natural resource mitigation, the TRC annual advance will be adjusted to $1,500,000 plus the actual mitigation costs for that year.
- TRC advances will be repaid by the Conservancy in years for which the conservation fees received exceed the obligations described above.

Management of Conserved Lands

- **Public Access.** Public enjoyment of the conserved lands is a high priority to TRC and the Resource Groups. TRC commits to work with the Conservancy to establish and implement a public access plan to conserved lands that will include encouraging and facilitating public access, including among underserved populations. The Conservancy shall also manage public access to Bear Trap Canyon through the use of docent-led tours consistent with the public access plan.

- **Ranch-Wide Management Plan (RWMP).** The RWMP will be developed by the Conservancy and TRC to identify and assess natural resource and conservation attributes of the conserved lands in order to develop sustainable stewardship management strategies that provide for protection and enhancement of natural resource values and appropriately managed existing ranch uses.

    - **Development and Implementation.** TRC and the Resource Groups have jointly developed policy-level guiding principles that will be used by TRC and the Conservancy to develop a detailed and comprehensive RWMP. TRC will work with the Conservancy to draft and implement an interim RWMP within one year. The Conservancy will prepare the initial RWMP within five years.

- **Identification of Conservation Values and Existing Ranch Uses.** The RWMP will identify natural resources and conservation values of the conserved lands as well as opportunities to protect, enhance and restore identified resources and values. In addition, the RWMP will establish best management practices for continued use of the conserved lands for existing ranch uses to meet RWMP conservation objectives.
- **Current Stewardship.** During an initial five-year period, the RWMP will focus on preservation of existing conservation values by maintaining baseline conditions (Stewardship Standard).
- **Restoration and Enhancement.** After the initial period, the RWMP will include programs, funded by the Conservancy, for restoring and enhancing the natural values of the conserved lands (Adaptive Management Standard).

- **Core Activities.** TRC will be permitted to continue certain core activities on conserved lands without interference (e.g., comply with obligations pursuant to existing leases and easements, perform natural resource mitigation, comply with applicable laws, etc.).

- **Existing Ranch Uses.** TRC will be permitted to continue certain existing uses on conserved lands, subject to the stewardship and adaptive management standards in the Ranch-Wide Management Plan.

  - Grazing, game management and filming activities will generally be permitted ranch-wide.
  - Farming, sand and gravel mining, and oil and gas extraction activities will be permitted within existing areas and defined expansion areas.

Permitted Development

- **Permitted Developments.** TRC will proceed through the entitlement processes for the planned communities of Centennial and Tejon Mountain Village and its development project at Grapevine on a total of approximately 30,000 acres, exclusive of designated project open spaces, on the southwestern portion of the property, within designated development envelopes and subject to local, state and federal approvals.

- **Project Design Measures.** Centennial, Tejon Mountain Village and Grapevine will be required to incorporate specific design measures in their entitlement applications to minimize impacts on the environment (e.g., energy reduction requirements in excess of Title 24 standards, construction waste recycling, onsite shuttle bus systems connecting to regional routes, environmental education outreach programs, etc.).

- **Non-Opposition.** The Resource Groups will refrain from opposing the entitlement and permit applications and approvals for the three development projects.

B GEOLOGIC MAPS OF TEJON RANCH

The following is a list of geologic maps that cover Tejon Ranch:

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C JOSHUA TREE HEIGHT DISTRIBUTION SURVEY RECOMMENDATIONS

We did an initial survey of Joshua tree heights on Tejon Ranch in the fall of 2009. Through this survey we documented the heights of Joshua trees for over 300 individuals. For our initial survey, we did not have a GPS device to document the precise locations of the survey transects, and not all survey groups remembered to write down the lengths of their sampling transects. Finally, surveyors did not look for or document damage to Joshua tree periderm. Therefore, our initial baseline surveys documented the number of trees and Joshua tree heights. In the following methodology the actual baseline sampling methodology is coupled with proposed methodological improvements to create a comprehensive monitoring procedure.

Materials:

- 100 meter transect lines (two)
- Tape measure to measure Joshua tree heights below 1 meter (1-2) and distance between transect lines.
- GPS to document start and end of transect location
- Data sheets (see below)
- Pencil
- Camera to document suspected damage to Joshua tree periderm (bark-like tissue)

Procedure:

1. Lay out the two 100-meter transect lines in the same direction, 5 meters apart (best to have two people lay out each line simultaneously.)
2. Document GPS start location and ending location on data sheet.
3. Walk through the belt transect, starting at one end, documenting the heights and approximate location of each tree on the data sheet.
4. For trees below 1 meter in height, measure the height. For trees above 1 meter, estimate height. Height is measured from the ground to the highest branch.
5. If damaged trees are seen, document their location by using the GPS, and take a photograph of the damage.
6. If dead trees are seen, document their height and location on transect (if fire is suspected, put in notes).

Researcher(s):

Date: _______ Transect #: _______ ________________________

GPS Transect End:

GPS Transect Start: ____________ _____________

Meter Mark (1-100)	0 - .5 meters	.5 - 1 meters	1 -2 meters	2 - 5 meters	5+ meters	# of Damaged Trees	# of Dead Trees	Comments /GPS (if needed)

Joshua Tree Height Survey – Created for the Tejon Ranch Conservancy 2/2010

D RIPARIAN ASSESSMENT DATA SHEET

I. Site /Transect Location and Environmental Description:

Drainage Name: ______________________ Reach #:____________ Transect #:__________________
Transect Location:____
Date:____
Surveyors names:____

GPS waypoint #: _________ **GPS name:** _______________ **GPS datum: (NAD 27)** _______ **Is GPS within stand?** Yes / No
If No, cite from GPS point to stand, the distance ______**(in meters) and bearing** ______**(in degrees)** **GPS Error:** ±_____ **ft / m**
UTM field reading: **UTME** ___ ___ ___ ___ ___ ___ **UTMN** ___ ___ ___ ___ ___ ___ ___ **UTM zone:** _____________

Elevation: ____. Photos: upstream: ____, downstream: ____, bank to bank ____@____&____@____

Slope exposure (circle one and/or enter actual °): **NE**______ **NW**______ **SE**______ **SW**______ **Flat**__ **Variable**__
Slope steepness (circle one and enter actual °): **0°**__ **1-5°** _____ **5-25°**_____ **> 25°**_____ **Upland** or **Wetland/Riparian** (circle one)

Site history, stand age, and comments: ____
____
____
Type/ Level of disturbance (*use codes*): ____/___ ____/___ ____/___ ____/___ ____/___ ____/___ ____/___ ____/___

II. Drainage Description:

Widths: Riparian Zone:_________ flood prone:__________ bank full__________ thalwag:_________
Bank Angle (Averaged 5M of each side of transect): L:________R:________. Gradient:_____________

SUBSTRATE (%) – pg. 22 (add to 100%)		INSTREAM COVER – pg. 23 (check all that apply)	
Boulder – 10 in. diam.		Undercut Banks	
Cobble/Gravel –10 to .08 in. diam.		Overhanging Vegetation	
Sand – coarse grain		Deep Pools	
Silt/Detritus/Muck - fine grain/organic matter		Boulders	
Hardpan/Bedrock – solid clay/rock surface		Aquatic Plants	
Artificial – manmade		Logs or Woody Debris	
Unknown			

RIVER MORPHOLOGY – pg. 23			
Riffle	Present		Abundant
Pool	Present		Abundant
Channel	Natural	Recovering	Maintained
Designated Drain	?	Y	N

STREAM CORRIDOR – pg. 26				
Riparian Veg. Width ft.(L)	<10	10-30	30-100	>100
Riparian Veg. Width ft.(R)	<10	10-30	30-100	>100
Bank Erosion	0	L	M	H
Streamside Land Cover	Bare	Grass	Shrub	Trees
Stream Canopy %	<25	25-50		>50

Additional Comments: disturbance indicators, abiotic features, other general observations:________
____
____
____
____
____
____

III: Biotic Characteristics: DBH, Seedlings & Saplings within 5 m belt, 2.5 m each side of transect.

No. of trees: _________________________ No. of seedlings/Saplings: _________________________

Strata	Species	DBH		Strata	Species	DBH

CALIFORNIA PLANT COMMUNITIES RELEVÉ FIELD FORM (PART 2)

SPECIES SHEET (Revised 5/17/01)

Page_______ of Relevé # ____________

Cover Class Intervals: 1 (<1%), 2 (1-5%), 3a (>5-15%), 3b (>15-25%), 4 (>25-50%), 5 (>50-75%), 6 (>75%)

L=Low herbs and subshrubs (<0.5 m.), M=Medium height (0.5 m.-4.0 m.), T=Tall height (>4.0 m.)

L	M	T	Vascular plant name or moss/lichen cryptogamic crust cover	Final species determination or Tree dbh	Cover Class	%

Total Vegetation Cover (Class): ________ Total Tall________ Total Medium ________ Total Low ________ Total Non-Native ___________

percent cover of above: ________ ________ ________ ________ ___________

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E RIPARIAN ASSESSMENT RESULTS

Riparian Assessment Survey

The baseline riparian assessment survey developed for riparian communities on the Ranch involved the collection and analysis of quantitative, descriptive data on riparian vegetation species composition and community structure. For the collection of descriptive riparian baseline data, we developed and implemented a standardized data collection methodology that involved qualitative reach delineation and stratified sampling of quantitative structural and compositional data along linear transects.

Materials:

1. Geographic Positioning System (GPS)
2. Digital camera
3. Rolo-tapes/Transect tapes – metric units (2)
4. DBH tape measure
5. Field maps (scaled aerial photographs)
6. Digital clinometer
7. Data sheets (Appendix D)
8. Pin flags (100)
9. Flagging tape
10. Compass
11. Telegraphing pole (graduated at 1 m, 4 m, and 8 m)
12. Stadia rod - English units
13. Pencil
14. Field Notebook

Procedure:

1. Qualitatively classified riparian communities on the Ranch by conducting a reach delineation survey in 11 drainages. Surveyors delineated “Like Reaches” based on vegetation type.
2. Standardized quantitative sampling within four of the major drainages on the Ranch, paired by watershed. Drainages surveyed included Tejon Creek and El Paso Creek on the San Joaquin Valley side of the Ranch and Big Sycamore Canyon and Little Oak Canyon on the Antelope Valley side of the Ranch.
3. Stratified random sampling of linear transects by reach.
4. Randomly selected two linear transects oriented perpendicular to the flow of the stream.
5. At each sample transect, documented site conditions with digital photographs taken perpendicular to the channel as well as photos taken facing upstream and downstream.

6. Recorded GPS waypoints, latitude and longitude, and elevation using handheld Trimble Geographic Positioning System (GPS) receivers.
7. Implemented a modified version of a vertical quadrat sampling method (Curtis and Bignal 2004) to measure the relative contribution of different species or taxa to the overall vegetative cover of the riparian canopy within pre-defined strata or height classes.
8. Along the sampling transects we measured species composition and community structure and architecture through 1-meter interval line-intercept/cube sampling.
9. At each meter we visually estimated the percent cover (by cover class) of each species in four strata/height classes (defined as 0-1 m, 1-4 m, 4-8 m, & 8+ m).
10. Measured the basal area and stem density of riparian trees and shrubs within a 5-meter belt transect oriented perpendicular to the direction of flow. This allowed us to collect a representative size/age profile of the riparian tree component and to estimate tree and shrub coverage within the riparian zone of influence.
11. Data collected includes the diameter-at-breast-height (DBH) of adult trees (trunk diameter measured ad 4.5 feet above ground surface), stem density (stems/ha) of shrubs and saplings (1-5 m tall), and stem density (stems/ha) of seedlings (woody vegetation <1 m tall) within each transect.
12. Each belt transect included a count of seedlings and saplings as a metric to quantify recruitment in the riparian zone.
13. Hydrogeomorphic (HGM) data including bank angle, approximate stream gradient, flow regime (perennial/non-perennial), and substrate size class.

Data Entry and Analysis

After collecting and recording quantitative vegetation and environmental data for riparian communities on the Ranch, the collected data was statistically analyzed using multivariate analysis techniques. All species and environmental data was exported from a Microsoft Access database as comma delimited text (CSV) files which were subsequently imported into PC-ORD v. 4 (McCune & Mefford 1999) for analysis. Statistical analyses included cluster analysis, statistical ordination via detrended correspondence analysis (DCA), and species-environment relationship characterization through the calculation of the degree of correlation between the measured environmental variables and the DCA ordination scores.

CLUSTER ANALYSIS

Our cluster analysis identified four distinct groupings within the sampling transects based on species composition (Figure E-1). These groupings included transects that were dominated either with canyon live oak, incense cedar, western sycamore, or "other" species (e.g. samples comprised of various willow [*Salix*] species, Fremont cottonwood [*Populus fremontii*], valley oak [*Quercus lobata*], etc.) hereafter referred to as intermediate plots.

<u>Dominant Species for Each Group:</u>

1. Canyon live oak and thicket-forming willow
2. Incense cedars
3. Alluvial sycamore woodlands
4. Species diverse

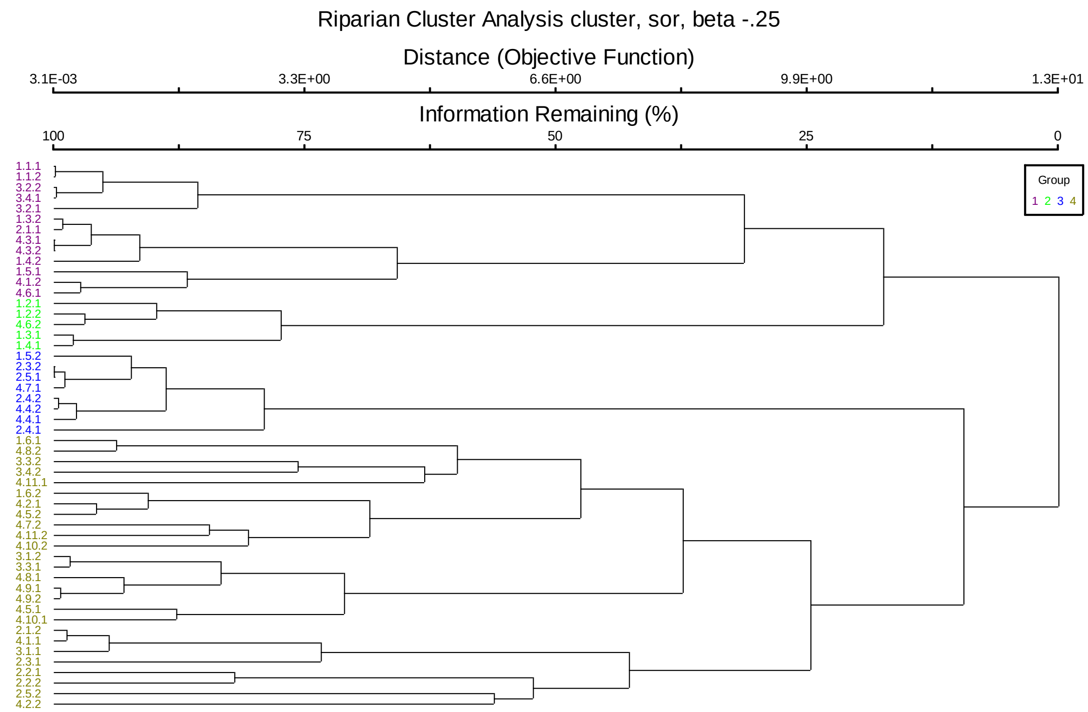

Figure E-1. Cluster Analysis Dendrogram. This dendrogram represents a graphical output of the cluster analysis displaying the clusters and their dissimilarity based on an "objective function" distance.

DETRENDED CORRESPONDENCE ANALYSIS (DCA)

The samples included in the first two groups (those dominated by canyon live oak or incense cedar are generally, high stature communities which are densely shaded and have little understory vegetation. The third vegetation class (Group 3) corresponds strongly to open alluvial sycamore woodlands with an understory of annual grasses. Finally, the intermediate plots (Group 4) are generally more species diverse and are tolerant of a wider range of environmental conditions as evidenced by their broader scatter on the ordination graph (Figure E-2). The closer samples are in ordination space, the more alike they are in species composition. Sample transects are represented in ordination space (Figure E-2). Species-environment biplot vectors in Figure E-2 represent significant (r>0.2) environmental variables relative to the ordination axes, with their relative lengths showing how strongly they correlate to the species that define the axes.

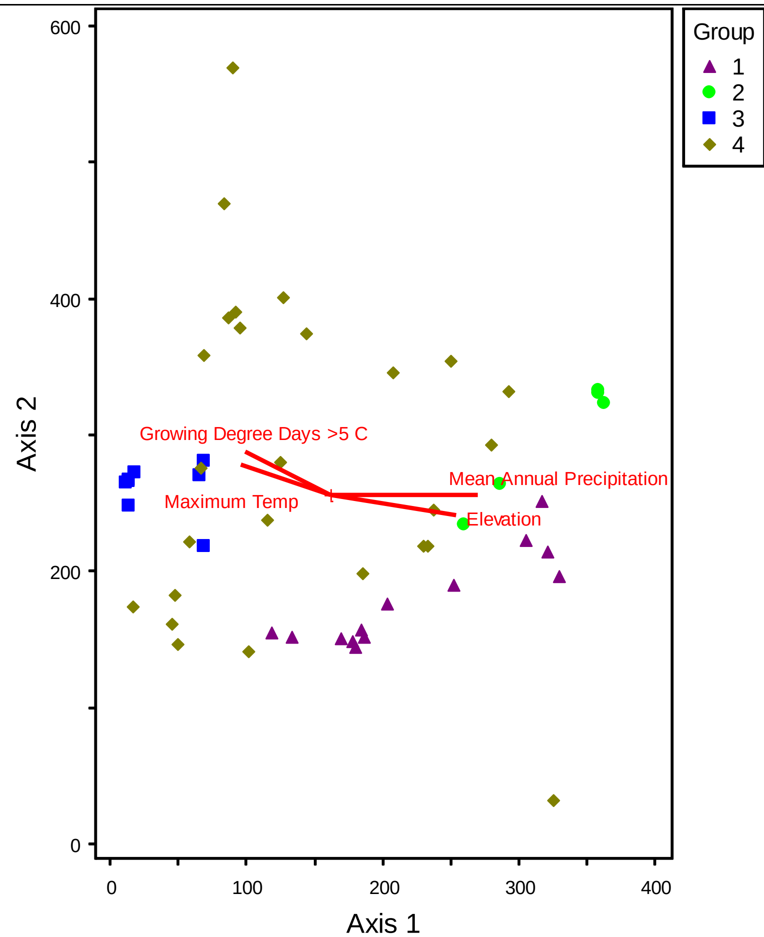

Figure E-2. DCA Ordination. The vectors and axis tick marks represent the correlation between the environmental variables and the axes. The clusters are organized by the four community groups that were identified by the cluster analysis.

Based on its r^2-value correlation value (explanation of the axis) of 0.34 (Table E-1), current mean annual precipitation was the most important predicting environmental variable defining the DCA ordination and is oriented along axis 1 (Pearson and Kendall Correlations with Ordination Axes). Properties including elevation, maximum current temperature, and growing degree days above 5 degrees also appear on the ordination. The climatological properties (maximum current temperature, growing degree days, and mean annual precipitation) covary in space as a function of elevation. For this reason, these other variables predictably aligned along the same ordination axis as elevation, revealing their high degree of correlation.

Table E-1. Correlations between quantitative environmental variables and ordination axes. Axis 1 shows the strongest correlation with mean annual precipitation.

Environmental Variable	Axis 1		Axis 2	
	R^2	tau	R^2	tau
Minimum Temperature	0.2	-0.05	0.17	0.32
Maximum Temperature	0.16	-0.27	0.14	0.29
Growing Degree Days >5°C	0.15	-0.23	0.19	0.31
Mean Annual Precipitation	0.34	0.40	0.02	-0.08
Elevation	0.25	0.36	0.13	-0.20
Weighted Flow Accumulation	0.13	-0.36	0.14	0.12

DATA GAPS

Development of the environmental matrix identified certain useful environmental attributes that were incomplete or unavailable. These attributes included stream gauge data on stream flow volume and velocity and stream order data. Stream gauge data has not historically been recorded (or is not publically available) for any of the main study drainages on the Ranch. Stream order is not captured in the National Hydrography Dataset (NHD; USGS 1999) used for our geospatial analyses and could not be created because of the insufficient resolution of DEM to identify stream order using available ArcHydro tools (ESRI 2009). In order to comprehensively analyze species – environment correlations, these missing parameters should be measured and recorded and included in the analysis of correlation when sufficient data is available.