National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Santa Monica Mountains National Recreation Area

Natural Resource Report NPS/SAMO/NRR—2013/715




ON THE COVER
Clockwise from top left: Carlisle Canyon, photograph by Mike Malone; arboreal salamander (*Aneides lugubris*), photograph by NPS; *Dudleya cymosa* ssp. *cymosa* at Carlisle Canyon, photograph by Tarja Sagar; and post-fire regrowth, photograph by Tony Valois. Photographs courtesy of Santa Monica Mountains National Recreation Area.

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Natural Resource Report NPS/SAMO/NRR—2013/715

David M. Stoms
Patrick A. Jantz
Frank W. Davis

Donald Bren School of Environmental Science & Management
University of California Santa Barbara
Santa Barbara, CA 93106-5131

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available from the Mediterranean Coast Network Inventory and Monitoring Program (http://science.nature.nps.gov/im/units/medn/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). The GIS data layers produced for the report are available from the Mediterranean Coast Network Research Learning Center (http://www.mednscience.org) or by contacting the Santa Monica Mountains National Recreation Area. To receive this report in a format optimized for screen readers, please email irma@nps.gov.

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Commonly Used Abbreviations

Acronym	Definition
ARD	Air Resources Division (NPS)
BLM	Bureau of Land Management
CARB	California Air Resources Board
CEHC	California Essential Habitat Connectivity Project
CGS	California Geological Survey (CGS)
DPR	Department of Pesticide Regulation (California)
DTR	Distance to roads
ECA	Essential Connectivity Area
ECI	Ecological condition index
EPA	Environmental Protection Agency (US)
GCM	Global climate model
GFDL	Geophysical Fluid Dynamics Laboratory
GDD	Growing degree days
GHG	Greenhouse gas
GIS	Geographic Information System
GRD	Geologic Resources Division (NPS)
ICLUS	Integrated Climate and Land Use Scenarios (EPA)
IPCC	Intergovernmental Panel on Climate Change
IRMA	Integrated Resource Management Applications (NPS)
I&M	Inventory & Monitoring (NPS)
MCB	Modified census block
NLB	Natural Landscape Block
NLCD	National Land Cover Dataset
NPS	National Park Service
PAD	Protected Areas Database
PBG	Partial block group
PCB	Polychlorinated biphenyls
PCM	Parallel Climate Model
PLSS	Public Land Survey System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SAMO	Santa Monica Mountains National Recreation Area
SMMZ	Santa Monica Mountain Zone
TMDL	Total Maximum Daily Load
VTM	Vegetation Type Mapping (US Forest Service)
UCSB	University of California Santa Barbara
USGS	United States Geological Survey

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xxii) for more information.

Executive Summary

This report is an assessment of condition of the natural resources of Santa Monica Mountains National Recreation Area (SAMO) and an evaluation of the threats and stressors that act on these resources. The analysis was conducted primarily in 2009 through 2010. An improved understanding of the state of knowledge regarding the condition of SAMO's natural resources and the threats acting on these resources is needed to guide data collection and broader natural resource management efforts. This condition assessment was undertaken to provide NPS managers, interpreters, and planners with a synthesis of the most current information on the natural resources in and around SAMO. The assessment is divided into five chapters: (1) **NRCA Background Information** describes the purpose and use of the assessment; (2) **Park Resource Setting/Resource Stewardship Context** provides an overview of the natural resources of the recreation area and the planning and science perspectives about their management; (3) **Study Approach** outlines the key management questions, the process used to identify priority indicators, the assessment framework, and the analytical methods in the assessment; (4) **Natural Resource Conditions** contains the heart of the report with the assessment of status and trends of the stressors and resources of concern; and (5) **Discussion and Conclusions** answers management questions, synthesizes major themes of the assessment, highlights the emerging threats and data gaps identified, and makes recommendations for future study.

The Santa Monica Mountains National Recreation Area, established by Congress in November 1978, protects the largest expanse of mainland Mediterranean ecosystem in the national park system. The recreation area provides for a range of scientific, educational, and recreational activities for the surrounding communities and visitors to the area. No other national park features such a diverse assemblage of natural, cultural, scenic and recreational resources within easy reach of more than 12 million Americans, nearly 5% of the nation's total population. While SAMO is a unit of the National Park System and is administered by the National Park Service, there are many different public and private agencies managing land within the Santa Monica Mountains because the 1978 legislation recognized that the recreation area would be a partnership among federal and state parks agencies, local governments and private landowners.

Neither the SAMO Resource Management Plan (1999), nor the General Management Plan (2002), contain specific management directives or planning guidance. Further, the park has yet to develop foundation statements describing park fundamental resources and values or a resource stewardship plan. The 1999 Resource Management Plan identified two broad goals for the resource management program: (1) Obtain knowledge and understanding of natural and cultural resources; and (2) Implement conservation and restoration actions to protect natural and cultural resources. Much of the efforts of the park and network staff over the past few decades have been focused toward the first goal of obtaining a better understanding of park resources and resource threats.

The assessment followed an iterative process between NPS staff and the authors to identify the ultimate set of indicators of stressors and resources of greatest concern. Indicators are grouped

hierarchically according to the NPS Ecological Monitoring Framework used by the NPS Inventory and Monitoring (I&M) Program. Prior to compiling spatial data and conducting the assessment, conceptual models were developed that characterize the natural and anthropogenic drivers of environmental stressors that affect resource endpoints through ecological pathways. These conceptual models are valuable tools for communication of the cause and effect relationships and about what information is actually available about these ecological processes. The assessments of each stressor or resource were conducted by either spatial or statistical analysis. Where endpoint data were not available, the assessment was done on a midpoint indicator such as on stressors or ecological pathways. I&M or Vital Signs data were used as much as possible. Ecological processes operate at different spatial scales. Often a process such as a stressor beyond the park unit boundary has distinct consequences for the resources in the park. Therefore three reference scales were designated and the individual resources and stressors were characterized at one or more scales as appropriate. The "local" scale or reference region is the SAMO boundary itself. For the "landscape" scale processes such as wildfire, a reference region was generated that extends 5 kilometers beyond the boundary of the current vegetation map of SAMO and surrounding undeveloped areas. For "regional" drivers and stressors such as housing development, a grouping of "hydroecoregions" was used that encompasses much of Ventura and Los Angeles Counties and a tiny part of eastern Santa Barbara County.

Summary of status, trends, and data confidence for indicators used in the condition assessment report. Confidence in data sources used in the assessment was rated High for primary (direct observation) data and Medium for modeled results.

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	CON-FIDENCE
STRESSORS				
Housing development	Most land within SAMO was undeveloped or developed at rural densities in 2000. However, population, housing, and land conversion rates between 1990 and 2000 were higher than the surrounding region. The amount of urban land per housing unit was also considerably higher.	NA		High confidence
Road distance and accessibility	83% of SAMO is within 1 km of a paved road. Accessibility or travel time from the park entrances averages just under a half-hour. The average fragment size between roads is 34.21 km^2, or 1/18th the size of SAMO. Some sections of major highways carry more than 300,000 vehicles per day.	NA		Medium confidence
Pesticides affecting amphibians	Application rates in the Oxnard Plain of pesticides known to have adverse effects on amphibians are similar in magnitude to those of California's Central Valley where studies have attributed amphibian population declines in Yosemite and Sequoia/Kings Canyon National Parks to regional pesticide use. The chytrid fungus, a major factor in declines of California anuran populations, is potentially exacerbated by immunosuppressant effects of pesticides. These pesticides also cause declines in phytoplankton and zooplankton at low concentrations. Use for agricultural purposes within SAMO is very low.	NA		High confidence in data on agricultural pesticide application rates; Low confidence in potential impacts on amphibians.

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	CON-FIDENCE
	Residential use is unknown. Ground applications made up the majority of pesticide applications for all scales. Therefore it is unknown what level of impact if any these pesticides are having on amphibians in SAMO.			
Rodenticides	Because of the interspersion of private and public lands in and around SAMO, wildlife species of management concern (e.g., bobcats) are at risk of exposure to anticoagulant rodenticides. Rodenticides were applied primarily in the Oxnard Plain and the Santa Clara River Valley. Few agricultural applications were reported within the administrative boundary of SAMO. Thousands of individual rodenticide applications are possibly being applied in the region every year. The more lethal second generation rodenticides were applied infrequently and only at the regional scale. Home and garden uses are generally exempt from reporting requirements, and thus their contribution to the exposure for wildlife is unknown but is suspected to pose a serious risk to wildlife.	NA		Low confidence because only agricultural applications are reported by location.
Human footprint	One-third of the area of SAMO is mapped in the highest intensity footprint classes, with the remainder in the medium intensity. When including the surrounding landscape in the analysis, the intensity increases with 2/3 in high intensity. Housing density and other factors associated with the footprint have been and are most likely to continue increasing. We can presume then that the human footprint is increasing at all ecological scales.	NA		Medium confidence
AIR AND CLIMATE				
Air quality	SAMO has exceeded the 75 ppb threshold for “significant concern” status for ozone since the late 1990’s (NPS 2011). The majority of SAMO and its surroundings were subject to average annual nitrogen deposition rates in 2002 of 12 kg/ha/ yr, above the upper critical load threshold for coastal sage scrub communities and for lichen communities in chaparral.	Ozone: 75 ppb annual fourth highest 8 hour average ozone concentration (EPA); ≤ 60 ppb is "good condition" (NPS) Nitrogen deposition: 0.25 kg N/ha/yr is natural background; <1.0 kg N/ha/yr is "good condition" (NPS standards); the		Medium confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	CON-FIDENCE
		critical load for lichen communities in California chaparral = 5.5 kg N/ha/yr; critical load for coastal sage scrub = 7.8 – 10 kg N/ha/yr.		
	Annual sulfur wet deposition from SO4 averaged 0.72 kg ha-1 yr-1 from 1994 – 2009 and decreased over time.	Sulfur deposition: 0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS standards)		
	Five year average visibility index values exceeded the threshold for “significant concern” since 2001 – 2005.	Visibility: < 8 deciviews (5 year average deciview values minus estimated deciview values in the absence of human caused degradation)		
Climate	Minimum temperature declined 0.25°C per decade during the early part of the 20th century followed by a stronger positive trend of 0.6°C per decade over the last 60 years. Maximum temperature increased by 0.01 °C per decade. Downscaled climate models consistently project a 25 – 34% increase in growing degree days (GDD) by 2100 for SAMO, resulting in future conditions that are currently found in the western Mojave. Minimum winter temperatures are projected to increase by 2.1 - 2.8ºC while maximum summer temperatures are projected to increase by 4.0 – 5.3ºC. Precipitation projections are variable, either increasing or decreasing depending on the global climate model (GCM). Projected distributions indicate that under future climates, Valley Oak, *Quercus lobata*, which is at the southernmost part of its distribution at SAMO, will become further restricted to the coolest and wettest sites.	4.5 ºC (Mean annual temperature of the coldest period over past 50 years) 32.3 ºC (Mean annual temperature of the warmest period over past 50 years) 16.9 ºC (mean annual temperature of past 50 years) 427 mm (Mean annual precipitation over the past 50 years)		Medium confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	CON-FIDENCE
WATER				
Water quality	Water quality ranks among the most important indicators of ecosystem health. The Los Angeles Regional Water Quality Control Board has identified 38 water quality limited segments (primarily streams and beaches) within or near SAMO that do not meet standards for at least one of 37 pollutants. These pollutants span a range of nutrients, pesticides, pathogens, toxicity, metals, and others. A plan, called a Total Maximum Daily Load or TMDL, is required for each of the 134 segment-pollutant combinations that violate standards. USEPA has currently approved 54 TMDLs, leaving 80 that must still be developed and approved. The most frequent pollutants to be addressed are DDT, PCBs, indicator bacteria, and coliform bacteria. Segments in Calleguas Creek have as many as 14 pollutants identified. Addressing this large spectrum of water quality issues, which typically involves a contentious, drawn-out planning process, could become extremely burdensome to NPS resource staff. At the same time, these water quality violations represent a large number of stressors and pathways that can impact the aquatic resources at SAMO in complex, synergistic ways.			High confidence
BIOLOGICAL INTEGRITY				
Invasive plants	Over 300 non-native plants in more than 10,000 populations have been detected at SAMO. The most vulnerable locations in SAMO tend to be in the lower reaches of the coastal canyons where the invasive populations occur in or near disturbed or highly invasible landscapes.	No invasive plants		Medium confidence
LANDSCAPES				
Fire regime	The mean fire rotation interval for the Santa Monica Mountains subsection for the period 1946-2008 was 34 years, which is shorter than many chaparral-dominated landscapes in California but still within the historical range of variation typical of many chaparral landscapes. The annual area that re-burned within a decade of the last fire peaked in 1993, but the annual area subjected to such short-interval burning did not increase between 1960 and 2008. However, some localities in the Santa Monica Mountains and the Simi Valley–Santa Susana Mountains are burning at very high frequency, notably the western Santa Susana Mountains (South Mountain, Oak Ridge, and Oat Mountain),	The historical range of variation in fire return frequency in chaparral - dominated landscapes in California is 20-60 years.		High confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	CON-FIDENCE
	the Simi Hills, and the ocean-facing canyons of the Santa Monica Mountains above Malibu. Trends in fire history data from 1946-2008 do not support the proposition that fire suppression has led to fewer and larger chaparral fires; the time since fire distribution has not changed appreciably over the interval.			
Predicted future fire regime	Wildfire is sensitive to climate change and urban growth. Change in fire frequency in SAMO by the end of the century ranges from a 62% increase under a low emissions and growth scenario to 88% under a high emissions and growth scenario. Countering the potentially significant impact of increased fire on ecosystems may require substantial increases in fire management resources.	NA		Medium confidence
Habitat connectivity	SAMO contains a set of Natural Landscape Blocks, identified by the California Essential Habitat Connectivity Project. Collectively they are linked by an Essential Connectivity Area with the Santa Susana Mountains into the Sespe Condor Sanctuary and the Los Padres National Forest to the north. Maintaining the park unit's habitat value will depend in part on the functioning of the connectivity area, which primarily crosses private, unprotected land. SAMO staff has already participated in detailed design of habitat linkages for focal species, which tend to corroborate the more generalized connectivity area. Park planners should remain vigilant about activities proposed by adjoining land owners that may degrade habitat quality within SAMO by increasing its isolation.	NA		Medium confidence
Dark night sky	A model based on population in 1990 identified SAMO as one of the most affected park units in the nation, relative to conditions before human settlement.The Mean Schaaf class was 2.27. As the number of housing units within SAMO's surrounding region has increased, we might expect that the skyglow has increased as well. However, new local lighting ordinances may have reversed this trend and darkened skies of the region. Countering that trend is the increasing development within inholdings of SAMO, probably causing greater direct lighting effects in local areas.	Schaaf class 7 (no artificial light)		Medium confidence

= baseline only = no significant trend = increasing trend

The staff at SAMO identified a set of management and research questions. This NRCA has made progress in answering some of them and identified the limits of our current knowledge. Here we provide brief summaries of what was found.

1. *Can we model or predict future development and land use changes in the region? What work has been done and is there anything we can learn from the results?* Two recent studies have modeled future urban growth for the SAMO region. Both studies indicate a densification of residential use within and surrounding SAMO with all the attendant stressors that entails.

2. *How will increasing development affect habitat connectivity and habitat quality?* Most of the native vegetation in SAMO currently constitutes one large, interconnected habitat patch. In the growth scenarios on flatter slopes, that large patch would become more perforated but remain mostly intact. However, with a higher slope limit, that patch would become fragmented into smaller patches. All three scenarios showed future build-out in the neck connecting Cheseboro Canyon to the main portion of SAMO. This site is an important connectivity area that would be a critical loss if fully developed.

3. *What were the historic land uses and vegetation patterns and what role has land use had in creating vegetation patterns we see today. Can observed land use changes be mechanistically linked to changes in vegetation and other resources?* Comparing land cover maps from 1945 and 2009, chaparral and coastal sagebrush have each lost nearly one-quarter of their area to human-dominated uses. Grass and woodland types were rare in 1945, but a significant fraction of their area has been converted since then. This comparison is only indicative of the types and magnitude of changes because of the difference in spatial scales of the two maps.

4. *Are there species that are particularly likely to be affected by changes in habitat quality and/or configuration? How is the herbaceous flora, particularly the post-fire flora, affected by interaction between fire and competition from non-native invasive species?* SAMO is prone to short-interval fires, especially near major roads and at wildland-urban interfaces. Non-native invasive plants are promoted by short intervals between fires whereas native chaparral and coastal sage scrub plant and animal species tend to be strongly negatively impacted. As a result, very short intervals of six years or less result in significant reduction in the abundance of native shrubs and post-fire herbs and can lead to the replacement of chaparral and coastal sage scrub by alien-dominated grasslands.

5. *Has the vegetation community structure, distribution, composition, and function changed with changing fire regime and establishment of invasive plant species? Are there other factors affecting vegetation community change? How do these factors interact? How can we monitor this? Are there specific species or species characteristics we should be concerned with—either specific invasive species/characteristics or native species?* In principle, most of the main stressors at SAMO act synergistically to promote changes in structure, distribution, composition, and function. Increasing fire frequency tends to suppress native shrubs and grasses and promote exotic plants. Housing and infrastructure development within the park boundaries disturbs the soil surface (e.g., cut slopes) and changes hydrology (e.g., increased runoff and lawn watering), offering further

opportunities for plant invasions. Nitrogen is often a primary limiting nutrient on overall productivity of ecosystems. Continued growth in the Los Angeles region as forecast is likely to continue increasing nitrogen deposition at SAMO, which causes an increase in non-native annual plants and loss of native plant diversity. This in turn can alter the fire regime, favoring more frequent fires that further retard growth of native plants. Climate change is also expected to increase the frequency of burning, further amplifying the impacts of nitrogen. One can either monitor changes in stressors (e.g., fire frequency, climate, nitrogen deposition, invasive plant populations, and land use) or endpoint indicators (e.g., lichen community composition).

6. *Are there any manageable dimensions to the changes we're seeing due to increased fire frequency and establishment of invasive plant species? Is there any way to offset/mitigate changes/impacts – especially considering elements we have no control over? What are the mechanisms of change and what actions have or have not been successful in managing change?* This question is predicated on the premise that fire frequency is increasing. Trends in fire history data from 1946-2008 examined in this condition assessment do not support the proposition that fire frequency has increased over that period. The time since fire has not changed appreciably over that interval. Fire regime is probably being affected by several countervailing influences including increased ignition frequency due to increased vehicle traffic and human population, increased fuel fragmentation due to development and associated fuel breaks, vegetation changes in areas of high fire frequency, and changing weather and climate associated with regional and global climate change.

7. *How do we expect fire regime to change with continued development and climate change?* Change in fire frequency in SAMO by the end of the century could range from a 62% increase under the low emissions and growth scenario to 88% under the high emissions and growth scenario. High urban growth rates and sprawl would tend to dampen the rate of increase in fire frequency. Modeling did not include changes in Santa Ana wind frequency, timing, or intensity. These winds are known to be a major factor in the fire regime.

8. *What are the potential effects of changing climate in this region (e.g. rain, temperature, and drought) and what are the implications for the park (changes to fire regime, vegetation distribution, interactions between fire and invasive species, etc.)?* Minimum temperatures increased on average by $0.6^{o}C$ decade^{-1} over the last 60 years, while maximum temperatures and precipitation barely increased. Climate modeling consistently projects a large increase in minimum winter temperatures of 2.1 - 2.8ºC while maximum summer temperatures are projected to increase nearly double that by 2100. Precipitation projections are much more variable between GCMs, so it is unclear if SAMO will become warmer and wetter or warmer and drier. Fire frequency could increase dramatically in SAMO by the end of the century (62-88%) as a result. The combination of large projected increases in temperature and relatively modest changes in precipitation can be expected to reduce the growth and recruitment of many plant species at SAMO. Our projection indicates that under future climates, Valley Oak will become further restricted to the coolest and wettest sites in increasingly isolated patches. Greater fire frequency will also make SAMO more sensitive to invasions of non-native plants.

9. *Are there other important resource threats we are not considering?* Argentine ants have invaded widely throughout Mediterranean climate regions such as SAMO. They can seriously deplete the abundance and diversity of native ant species, such as the common harvester ant by raiding their nest colonies. Loss of native ants has at least two secondary impacts—reduction of dispersal of large seeds (Carney et al. 2003) and loss of primary diet for the coast horned lizard, a California Species of Special Concern.

10. *What ecosystem elements, species or species groups might be particularly important to monitor in light of current knowledge of resource threats and stressors.* Two invasive species, the New Zealand mudsnail and the Argentine ant, may be important to monitor because of their potential to displace native species and disrupt food web dynamics. The mudsnail became quickly established after it first appeared in Malibu Creek and also spread rapidly to other watersheds (Abrams 2009). Because it is a recent invader to SAMO, the ecological impacts are not yet known. Recent studies in southern California have shown that Argentine ants are most successful at invading native ant communities near urban areas, which are spreading at SAMO. The evidence from studies suggests that the extent of its invasion and the consequences could become significant in SAMO.

11. *How has the hydrology in the mountains changed over the past century? Can increases in water availability and decreases in water quality be quantified or described with existing data and information? What implications do these changes have for native communities? What information and research is needed to best address these questions?* This assessment did not address water quantity or trends in quality. The focus here was on specific water quality limited segments that currently exceed water quality standards in one or more pollutants. Many of the TMDLs that have been completed are for indicator bacteria thought to be associated with pathogens known to affect human health. Although the exposure level of pollutants is known, the effects on native communities and species are not well known.

The condition assessment identified a number of emerging issues that may become of greater management concern in the future. The most obvious of these is climate change from anthropogenic emissions of greenhouse gases. Modeling predicts that SAMO will become similar to current conditions in the western Mojave Desert in terms of growing degree days. Minimum winter temperatures and maximum summer temperatures are both forecasted to increase. Models are less consistent in forecasting precipitation changes. Most ecological resources in SAMO would be affected by these changes in climate, including the frequency of wildfire and the area burned; plant-pollinator phenology; range shifts of plant and animal species; and added stress on amphibians.

Trends of many other drivers are also expected to continue increasing along with the corresponding and interacting stressors. Housing density is predicted to increase, which in turn would increase rodenticide application, irrigation runoff, nitrogen deposition, skyglow, noise, road kill, and wildfire risk. These stressors threaten mesopredators, aquatic habitats, gene flow, native vegetation, lichen communities, and favors invasions by non-native plants and Argentine ants. Future development may also imperil SAMOs tenuous connectivity with other blocks of natural landscapes to the north. Human occupancy and activity in the region has degraded water quality to unacceptable levels in many of the water segments and for many different pollutants.

This leads to temporary closures of popular beaches because of bacteria. Addressing this large spectrum of water quality issues, which typically involves a contentious, drawn-out planning process to determine Total Maximum Daily Loads (TMDLs), could become extremely burdensome on NPS resource staff and may impose restrictions on park management actions.

The report identifies data gaps that, if filled, would improve the usefulness of the stressor or resource condition indicators assessed in future reports. These data would either improve the accuracy of the indicator value or in many cases provide trend information where only baseline values are currently known. Key data gaps include:

- Pesticides affecting amphibians—the volumes applied on agricultural lands are known but the amounts transported into SAMO such as by aerial drift, and the amounts used within SAMO, have not been inventoried or monitored, and the levels in aquatic habitats have not been comprehensively assessed.

- Rodenticides—the volume applied on agricultural lands outside the park is reported. The main use is around structures, some of which are adjacent to or within the park boundary, but this use is generally not reported to the California Department of Pesticide Regulation.

- Air quality—there is a dearth of air quality data sampled within SAMO boundaries. Much of the information for this assessment was obtained from air quality data from nearby monitoring stations.

- Invasive plants—trend data are still too short and too geographically limited to determine whether non-native plants are expanding or whether recent control activities have had the desired impact on invasions. Increased summer flows in intermittent streams are blamed for invasions in riparian habitat, but the exact pathway by which flows are increasing is not fully known.

- Invasive ants—information about Argentine ant invasion and its ecological impacts in southern California come primarily from studies south of the Los Angeles Basin. The evidence from such studies suggests that the extent of invasion and its consequences could be significant in SAMO as well. Monitoring this invasion, or the condition of plant and animal community indicators at risk, is needed.

- The cause of most wildfires is not known or recorded, although SAMO is working to fill this gap to the extent practical. Trends in vegetation structure and composition would also be helpful in interpreting modern fire history data.

- Dark night sky—trends are not well known. Cloud cover is known to strongly affect skyglow but this has not been accounted for. The subdiscipline of light ecology is just emerging, so which species are most sensitive to light pollution and how they are affected is poorly known.

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Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xxiii) for more information.

Chapter 1 NRCA Background Information

> ***NRCAs Strive to Provide…***
>
> *Credible condition reporting for a subset of important park natural resources and indicators*
>
> *Useful condition summaries by broader resource categories or topics, and by park areas*

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the topics identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, NRCAs:

- are multi-disciplinary in scope[1]
- employ hierarchical indicator frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]

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[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition reporting by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")

- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products

NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, landscape, or regional scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options are outside the project scope.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subject matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate

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[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products

[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].

NRCA Reporting Products…

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations ***(near-term operational planning and management)***

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values ***(longer-term strategic planning)***

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

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[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

Chapter 2. Park Resource Setting / Resource Stewardship Context

Introduction

The Santa Monica Mountains National Recreation Area (SAMO) protects the largest expanse of mainland Mediterranean ecosystem in the national park system. This extraordinarily diverse ecosystem is home to 26 distinct natural communities, from freshwater aquatic habitats and coastal lagoons to oak woodlands, valley oak savanna and chaparral. Situated in densely populated southern California, the recreation area is a critical haven for close to 500 animal species, including mountain lions, bobcats and golden eagles. It is also home to more than ten threatened or endangered plants and animals. The park is rich in cultural resources, with over 1,000 archeological sites located within the park boundary—one of the highest densities of archeological resources found in any mountain range in the world. Finally, the recreation area provides for a range of scientific, educational, and recreational activities for the surrounding communities and visitors to the area. No other national park features such a diverse assemblage of natural, cultural, scenic and recreational resources within easy reach of more than 13.5 million Americans, nearly 5% of the nation's total population (U.S. Census Bureau 2010).

Enabling Legislation

The park was established by Congress in November 1978. Section 507(a) of the enabling legislation (National Parks and Recreation Act 1978) states*:*

"The Congress finds that –

1) *there are significant scenic, recreational, educational, scientific, natural, archeological, and public health benefits provided by the Santa Monica Mountains and the adjacent coastline area;*

2) *there is a national interest in protecting and preserving these benefits for the residents of and visitors to the area; and*

3) *the State of California and its local units of government have authority to prevent or minimize adverse uses of the Santa Monica Mountains and adjacent coastline area and can, to a great extent, protect the health, safety, and general welfare by the use of such authority.*

The enabling legislation goes on to state that the park shall be managed "in a manner which will preserve and enhance its scenic, natural, and historical setting and its public health value as an airshed for the Southern California metropolitan area while providing for the recreational and educational needs of the visiting public."

While the recreation area is a unit of the National Park System and is administered by the National Park Service, there are many different public and private agencies managing land within the Santa Monica Mountains and the 1978 legislation recognized that the recreation area would be a partnership among federal and state parks agencies, local governments and private landowners. However, the National Park Service and the Santa Monica Mountains Conservancy are the only agencies specifically charged with protecting resources within the entire recreation area; all other state and local agencies are focused on their specific sites.

Geographic Setting

The cooperative framework of agencies also means that SAMO has rather complex boundaries compared to other national park units. The legislated boundary of this park unit generally covers the Santa Monica Mountain region in southern California (Figure 1). The total area within the boundary is 62,018 hectares, of which 27,963 hectares is protected park land. The remainder of the land within the park boundary is privately owned. Three large state parks (Point Mugu, Malibu Creek, and Topanga State Parks), already in existence when SAMO was established, formed the initial core park lands for the recreation area. The National Park Service currently owns approximately 9,383 hectares of park land and is still actively purchasing park land, as are the Santa Monica Mountains Conservancy, a state agency, and the Mountains Recreation and Conservation Authority, a joint-powers authority between state and local agencies. The distribution of park land ownership is shown in Figure 2.

Figure 1. Location map of SAMO.

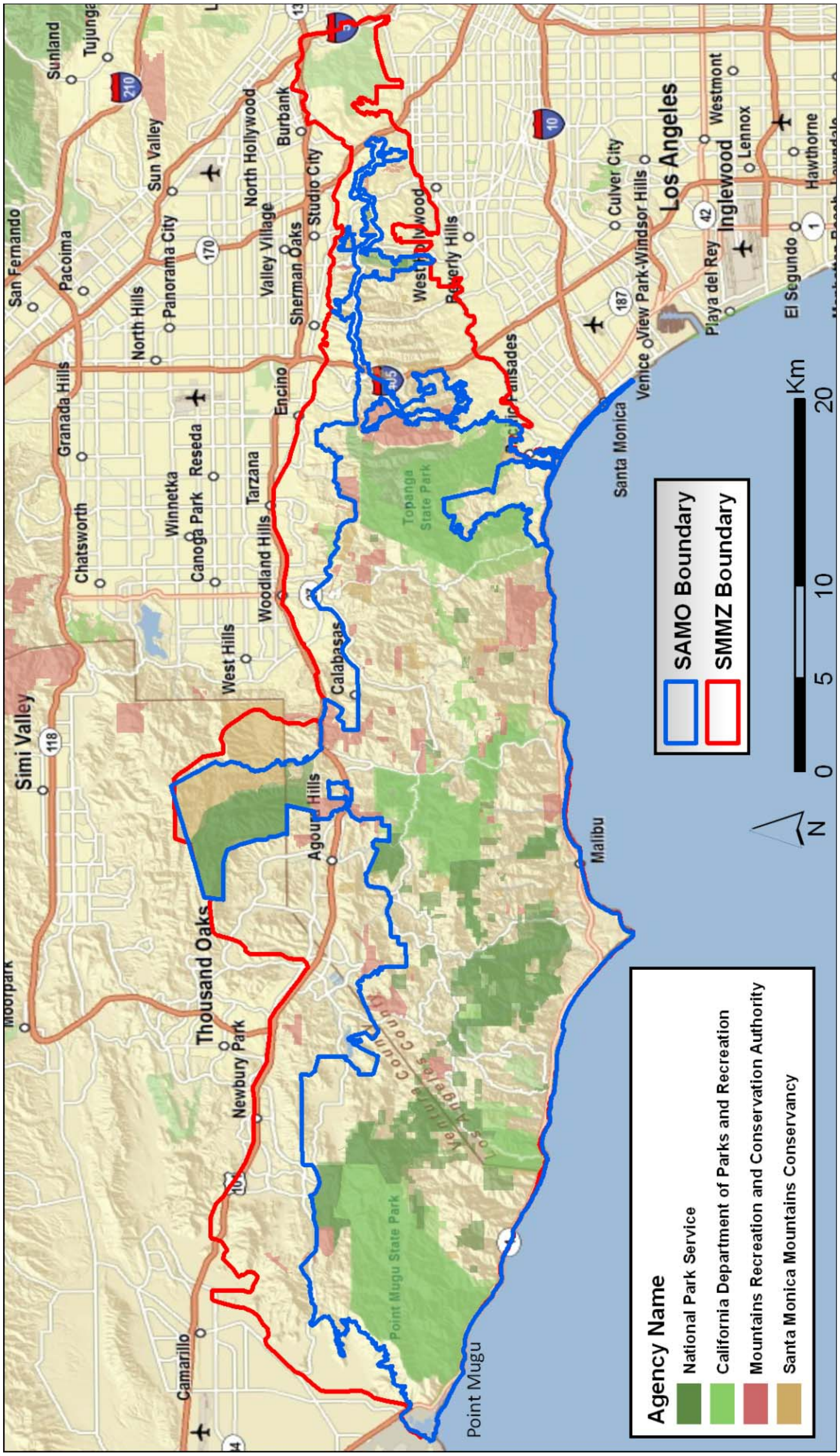


Figure 2. Ownership by major park agencies at SAMO.

The recreation area extends from the Hollywood Hills on the east, 74 kilometers west to Point Mugu, and averages about 11 km in width. To the north, the recreation area is bordered by the city of Simi Valley, the San Fernando Valley, and communities that have developed along Highway 101. These include Calabasas, Thousand Oaks, Woodland Hills, and Agoura Hills. The recreation area encompasses the cities of Malibu and Topanga as well as smaller pocket communities and more rural residential areas. In the east the recreation area begins just north of Hollywood with small, undeveloped canyons interspersed with older residential communities. A little farther west, in Topanga State Park, the mountains reach a width of eight miles across, most of which is within the city limits of Los Angeles. The further west one travels, the wilder and less developed the mountains become; ending at Point Mugu State Park, which contains the recreation area's only designated wilderness area (Boney Mountain State Wilderness).

The Santa Monica Mountain Zone (SMMZ), comprising an additional 30,351 hectares, was also established by the 1978 legislation. It extends beyond the boundaries of the national recreation area and includes the entire Santa Monica Mountain range as well as a portion of the Simi Hills to the north to include the entire Malibu Creek Watershed. Local and state agencies are responsible for land use regulations within this zone (including within the park boundary), but the National Park Service retains, by law, reviewing authority on projects involving federal funds, permits, or licenses that may affect the recreation area. This authority was provided by Congress to reduce downstream impacts on recreation area resources when possible. The SMMZ incorporates watersheds and canyon slopes associated with, but not formally included in SAMO, as well as the easternmost portion of the Santa Monica Mountains encompassing Griffith Park.

In spite of this patchwork of park land and private land, natural habitat and developed areas, and multiple agency ownerships, more than 90% of the land within SAMO boundary is currently still undeveloped. The east-west trending mountain range is geologically complex and characterized by steep, rugged mountain slopes and canyons. Elevations range from sea level to 918 meters. The park is bordered by 74 kilometers of scenic California coastline with sandy beaches and rocky tide pools and lagoons. Long, wide, white beaches stretch along much of the coast, occasionally giving way to high bluffs and rocky outcrops jutting seaward. At 567 hectares, Mugu Lagoon is the largest coastal wetland outside the San Francisco Bay area. Malibu Lagoon and Mugu Lagoon are important stopovers for neotropical and other birds migrating along the Pacific flyway. The mountain slopes exhibit a typical Mediterranean type shrub cover of coastal sage scrub at the lower elevations and in drier habitats and dense chaparral at the higher elevations. Riparian woodlands border streams in the canyon bottoms, while oak woodland, oak savannah, or open grassland cover the flatter valley floors.

Natural Resources

Resource Descriptions

Geology

The Santa Monica Mountains are the southernmost mountain range in the transverse ranges of southern California. The overall appearance of the Santa Monica Mountains is steep and rugged, with low valleys spaced intermittently along the north and south slopes with numerous deeply incised north-south trending canyons draining from the mountains into the Pacific Ocean. The highest point is Sandstone Peak (actually a volcanic formation) with an elevation of 918 meters. The spiny backbone of the range skirts the northern edges of the Los Angeles Basin and Santa Monica Bay before descending into the sea at Point Mugu (Tennesen 2007); the southwestern extension is the Channel Islands. Folded and faulted structures characterize these east-west–trending mountains, with five geologic stages having profoundly marked the more than 150-million-year history: (1) subduction; (2) rifting, rotation, and extension; (3) volcanic eruption; (4) compression and uplift; and (5) erosion (Kyriazis 2008).

Santa Monica Slate is the oldest rock unit exposed in the national recreation area; this rock was deposited as mud and other sediment on the ocean floor during the Late Jurassic Period (161–145 million years ago). The slate is overlain by an extensive sequence of Tertiary sedimentary and volcanic rocks, many of which have their type section in the Santa Monica Mountains. The Eocene–Early Miocene Sespe and Vaqueros formations represent coastal alluvial deposits (Sespe) with equivalent nearshore marine deposits (Vaqueros). The Miocene (20–10 million years ago) Topanga Formation is the most extensive geologic unit in Santa Monica Mountains National Recreation Area. This sequence of rocks consists of nonmarine and marine deltaic sandstone and conglomerate in the eastern Santa Monica Mountains and marine shelf and submarine deposits in the western Santa Monica Mountains (Eugene Fritsche, California State University Northridge, communication during field trip, May 8, 2008). Another widespread formation is the Conejo Volcanics. Stretching of Earth's crust during the rotation process allowed hot, melted rock to escape to the surface and produced a period of volcanism in the Santa Monica Mountains area (Eugene Fritsche, California State University Northridge, presentation, May 7, 2008). The upper Miocene Modelo Formation, representing a deep submarine fan complex, crops out in a belt along the northern Santa Monica Mountains stratigraphically above the Topanga Formation and Conejo Volcanics.

Frequent landslides and occasional earthquakes remind visitors that the rocks and landforms at Santa Monica Mountains National Recreation Area have not stopped moving or forming. The Santa Monica Mountains are naturally prone to landslides due to an unstable combination of steep slopes and often poorly cemented sedimentary rock. More than 1,700 quaternary landslide deposits are still apparent in the Santa Monica Mountains and Simi Hills (California Geological Survey 1997-2002). The ancient quaternary slides represent major events. However, frequent smaller slides and slumps continue to occur. The 1994 Northridge earthquake alone triggered more than 1400 individual landslides within the mountains (U.S. Geological Survey 1996). Landslides of any size have the potential to destroy or damage homes, roads, and utility lines. Residential irrigation and septic tanks have exacerbated the problem – particularly along the coast – by adding water to expansive clay soils.

Debris flows are a type of stream flow that occur with some regularity in the Santa Monica Mountains, where sufficient sediment mixes with the water flow to form a thick slurry of water, soil, and rock with great destructive power. The necessary environment for debris flows is a relatively steep stream channel, a generous supply of sediment from the streambed or adjacent slopes, and sufficient rainfall to mobilize them. Though naturally occurring in the Santa Monica Mountains, debris flows are aggravated by any disturbance of slopes, soils or vegetation, including roads, housing pads, fire control lines, and fires. The intense development surrounding the Santa Monica Mountains has also altered the natural regime. As streams are channeled and formerly permeable soil is covered with impervious concrete and blacktop, both the amount and velocity of storm runoff is increased, thus increasing the likelihood of debris flows.

Currently the NPS Geologic Resources Division and the California Geological Survey are working together to develop a GIS database of the geology of the park. The data will include bedrock geology (based on USGS sources) and a detailed landslide map developed from existing maps augmented with field mapping.

Paleontological Resources

According to Koch et al. (2004), the park contains one of the most extensive and diverse assemblages of fossil material known in the National Park Service. Invertebrate, vertebrate, paleobotanical, protista, and trace fossils occur in over 2,300 known localities, representing more than a dozen fossiliferous geologic formations. The diversity of the fauna, both marine and terrestrial, is extraordinary with many type species named from the Santa Monica Mountains. The quality of preservation is remarkable in many specimens, especially the fully articulated skeletons of fossil fish in the upper diatomaceous part of the Monterey Formation that are comparable to the world-famous Eocene Green River Formation fossil fish from Wyoming, Utah, and Colorado. Also, fossils in volcanic rocks are rare, yet within a small area of Malibu Canyon in Santa Monica Mountains National Recreation Area, more than 200 fossil localities occur in the lenses of calcareous sandstone interbedded within volcanic rocks.

Fossils at the recreation area range in age from Jurassic to Pleistocene. More than 134 species of gastropods and bivalves occur in the lower Topanga Canyon Formation (Miocene) in a localized area near the type locality; many more fossil localities exist at this stratigraphic horizon, and some localities contain species not present near the type locality (John Alderson, Los Angeles County Museum, e-mail, September 21, 2008). Vertebrates include a pygmy baleen whale. Participants also mentioned rodents and frogs from the Lower Miocene Sespe Formation near Saddle Peak.

In addition to fauna, recent discoveries highlight the national recreation area as a notable fossil flora site. Since 2003, investigators have found exceptional samples of petrified wood from the Fernwood Member of the Topanga Canyon Formation; one specimen is a 15-m- (50-ft-) long log, though not intact (John Alderson, Los Angeles County Museum, personal communication during scoping, May 7, 2008). Also, algal limestone (stromatolites) occurs in the Santa Susana Formation (Paleocene) in the national recreation area.

Two NPS publications document the paleontological resources of Santa Monica Mountains National Recreation Area: Koch and Santucci (2003) and Koch et al. (2004). Both publications contain an extensive reference list, and Koch et al. (2004) provides a list of paleontological species. Hoots (1930) recorded many fossil localities, which may be useful for the national recreation area's GIS. Areas of particular sensitivity are along Old Topanga Canyon Road and Mulholland Drive.

Soils

The Natural Resources Conservation Service recently mapped soils within the Santa Monica Mountains (Natural Resources Conservation Service 2006). Portions of the Santa Monica Mountains Zone and areas surrounding the park are included in recently updated surveys (Natural Resources Conservation Service 2005 and 2008).

The soils in the mountains can be grouped by the general geomorphic areas in which they occur. These groupings include:

- The outwash plain of Calleguas Creek, which occurs in the extreme western area of the recreation area either in the tidal floodplain of Mugu Lagoon or within the Point Mugu Pacific Missile Test Center (U.S. Navy). These are level, somewhat poorly drained soils that formed in alluvium from mixed rock sources and include the Camarillo Consociation, Corralitos-Coastal Beach Association, Pacheco consociation, and the Sulfic Fluvaquents, frequently flooded, Consociation.

- Mountain valley fan remnants and axial stream floodplains within the mountains themselves, such as La Jolla Valley and Serrano Valley. These are moderately sloping to gently sloping, moderately well to well-drained soils that formed in alluvium, residuum and colluvium from sedimentary rock sources and/or basic igneous rock sources. Soils include the Elder Consociation, Kayiwish Association, La Jolla Consociation, and Cumulic Haploxerolls-Riverwash Association.

- Igneous hills and mountains such as Sandstone Peak. These are moderately sloping to very steeply sloping, well-drained soils that formed in residuum and colluvium from basic igneous rock sources. The Cotharin-Talepop Association is included in this group.

- Non-marine sedimentary shale and sandstone hills and mountains such as Castro Peak and Laguna Peak. These are moderately sloping to very steeply sloping, well-drained soils that formed in residuum and colluvium from shale and sandstone, including soils such as Chumash-Boades-Malibu Association, Mipolomol-Topanga-Rock Outcrop Complex, Topanga-Mipolomol-Sapwi Association, Zumaridge-Greenbark, moderately deep-Rock Outcrop Complex.

- Marine sedimentary shale and sandstone hills, such as the Simi Hills. These are moderately sloping to steeply sloping, well-drained soils that formed in residuum and colluvium from marine sediments. Castaic-Linne-Los Osos Association is included in this grouping.

- The Malibu Plain and other ocean terraces and alluvial fans adjacent to the ocean. These are the gently to moderately sloping, well-drained soils, such as Gazos-Lockwood-Rincon Association, that formed in alluvium from mixed rock sources.

An important concern is the shrink-swell behavior and erodibility of soils throughout the mountains. Ungraded, native soils in lowlands exhibit the highest potential for shrinkage and swelling, and would have to be removed or extensively modified before development could occur. A majority of these features may be attributable to the erosion characteristics of the underlying bedrock. Rocks and soils prone to instability include alluvium, terrace deposits, shale, metamorphic schist and siltstone.

Soil erosion typically results from concentrated runoff on unprotected slopes or along unlined stream channels. This could be an issue particularly after wildfire or when vegetation cover is destroyed by grading operations.

Climate and Weather
The Santa Monica Mountains National Recreation Area, like most of coastal southern California, has a Mediterranean-type climate. Mediterranean climates, which are characterized by mild, wet winters and hot, dry summers, occur in only five locations throughout the world including the west coast of the U.S. and Mexico, along the Mediterranean Sea, in central Chile, southern/southwestern Australia, and in South Africa.

In southern California, January and February are typically the coolest and wettest months and August and September are the hottest. The rainy season generally extends from November through May, with dry summers. Overall rainfall varies greatly within and around the Santa Monica Mountains. While mean annual precipitation in Los Angeles is 15.01 inches per year (measured at Los Angeles Civic Center 1877–1987), it can be as much as 30 inches near the crest of the Santa Monica Mountains. Precipitation is also highly variable from year to year. Extended droughts lasting several years punctuated by moderate to extremely wet years are not uncommon.

Wind speeds vary in intensity and duration throughout the year within and adjacent to the Santa Monica Mountains. During summer days, airflow is generally directed inland from the west, southwest, south and southeast. At night, airflow patterns reverse and travel toward the ocean. Santa Ana winds, strong, very dry winds from the northeast caused by buildup of high pressure conditions over the Great Basin, can occur during the late fall and winter and into the spring. Some of the most disastrous fires occur during Santa Ana wind conditions in the fall and early winter, when the air is dry and the fuel moisture extremely low.

During the summer, coastal fog is common and in the morning inland valleys may be fog-shrouded as well, but as temperatures increase, the fog dissipates until it crests the mountains and is vaporized or pushed out to sea.

Air Quality
Congress recognized the significance of the Santa Monica Mountains, situated between the highly developed Los Angeles Basin, the San Fernando Valley, and the Oxnard Plain, in the recreation area's enabling legislation, Public Law 95-625, which specified that "...the Secretary shall manage the Recreation Area in a manner which will preserve and enhance …its public value as an air shed for the southern California metropolitan area."

Since the 1940s when local and state agencies began to tackle the air pollution problem in southern California, air quality has improved in the Los Angeles area. Nitrogen dioxide, sulfur dioxide, and lead standards have been met and other pollutant concentrations are significantly reduced (South Coast Air Quality Management District 2003). However, air quality measurements taken adjacent to the Santa Monica Mountains in urban Los Angeles still are among the worst in the United States and, in particular, the South Coast Air Basin is designated as an "extreme" nonattainment area for ozone (South Coast Air Quality Management District 2003). Air quality in the Santa Monica Mountains varies widely as a result of physiography, climatological conditions, the location or presence of an inversion layer, distance from the coast and the amount of pollutants emitted into the atmosphere. Overall, coastal areas experience better air quality than inland interior valleys and the Santa Monica Mountains exhibit better air quality than the surrounding urban landscape. However, localized air quality in the mountains will likely continue to degrade as long as expanding development results in increased traffic volumes in and around the mountains.

Currently Los Angeles County does not meet federal or state standards for ozone, carbon monoxide and particulate matter (National Park Service 2002). Ventura County is in attainment or is unclassified for all federal ambient air quality standards except ozone and particulate matter, and does not meet California air quality standards for ozone, carbon monoxide and particulate matter (National Park Service 2002). High ozone levels place the park flora, particularly ozone-sensitive species, at high risk for foliar ozone injury (National Park Service 2004).

Water Resources

Dozens of north-south stream canyons parallel each other throughout the mountains with associated riparian vegetation. In addition, there are a large number of east-west trending drainages coming down the slopes of these canyons. Most streams within the mountains flow seasonally.

The largest watershed located completely within the SMMZ is the Malibu Creek watershed, extending from its headwaters in the Simi Hills through the Santa Monica Mountains to the ocean at Malibu Lagoon. It contains a total of 272 square kilometers and incorporates several major drainage basins (Medea Creek, Triunfo Creek, Cold Creek, Malibu Creek, Las Virgenes, and Potrero Valleys).

Runoff generated from developed areas has placed increasing pressure on the existing fresh water resources. Runoff from urbanized areas (e.g., roads, parking lots, residential areas) may occur more quickly and with higher concentrations of pollutants than pre-development areas. The runoff from the developed areas could contain elevated levels of nutrients (such as phosphorous and nitrogen), pathogens, toxicants (e.g., heavy metals), and litter and trash loads. Malibu Creek and many of its tributaries, Topanga Creek, Solstice Creek and beaches east from the Los Angeles/Ventura County line have been identified as water quality limited for various pollutants and listed as impaired as required by Section 303(d) of the Federal Clean Water Act.

Vegetation

The Santa Monica Mountains are the westernmost and lowest of the Transverse Ranges of southern California, and are notable for the large expanse of natural ecosystems and native vegetation they support immediately adjacent to Los Angeles. They lie in the central portion of the Southwestern region of the California Floristic Province (Hickman 1993) in what is generally defined as the South Coast Ecoregion: the Transverse and Peninsula Ranges and the foothills, valleys, and coastal terraces lying to the south and west of these ranges (Stein et al. 2000, Conservation Biology Institute 2001).

California’s South Coast Ecoregion is highly biologically diverse, supporting more than 33 percent of California’s native plant species in eight percent of the land area (Sawyer et al. 2009). More endemic plant and animal species occur in this ecoregion than any other ecoregion in the country (Stein et al. 2000). This species richness and high endemism is contained within a comparable diversity of vegetation assemblages generally characterized by evergreen shrublands typical of Mediterranean-climate regions (Rundel and Tiszler 2007). Vegetation consists primarily of sclerophyllous chaparral and drought-deciduous sage scrub occurring in association with woodlands, grasslands, and riparian habitats. These general types are acted upon by complex geology and topography, soils, differences in moisture and temperature regimes, and varying fire histories to create a panoply of vegetation alliances and associations unique to the region (Conservation Biology Institute 2001, Barbour et al. 2007, Keeler-Wolf et al. 2007).

The park recently completed a vegetation classification (Keeler-Wolf and Evens 2006) and a digital vegetation map (Aerial Information Systems, et al. 2007) as part of the USGS-NPS Vegetation Characterization Program (http://biology.usgs.gov/npsveg/index.html), employing the National Vegetation Classification Standard (NVCS) developed by NatureServe. The map was based on photo-interpretation of 712 color aerial photographs (1:12000 scale) taken in 2001. The minimum mapping area is one acre. Accuracy assessment was performed on all vegetation alliances and mapping types that were represented by 20 or more mapped occurrences. In total, 50 alliances and 6 mapping types were assessed based on 2,200 field visits. The overall spatially-weighted accuracy of the map is 86%. The final accuracy assessment report will be available online along with all final classification and map products at the program website (http://biology.usgs.gov/npsveg/index.html).

The map covers the vegetation of the Santa Monica Mountains, Simi Hills, and nearby natural areas. This 320,000-acre region forms an ecological island defined by urban development to the north and east, agriculture to the west, and the Pacific Ocean to the south. Over 50,000 stands of natural and modified vegetation were mapped. The native vegetation is dominated by chaparral and sage scrub formed into a complex pattern of 84 vegetation alliances, 204 associations and 73 phases of associations (Keeler-Wolf and Evans 2006). Many of these alliances are unique to or have their greatest occurrence in the Santa Monica Mountains. These include alliances defined by locally common but regionally restricted species, and also by alliances represented by species widely distributed in coastal southern California but having a concentrated distribution and broader variation of vegetation associations in the Santa Monica Mountains than elsewhere (Keeler-Wolf et al. 2007). The most widespread vegetation alliance occurring in the Santa Monica Mountains, *Ceanothus megacarpus* shrubland, is endemic to the western Transverse Ranges and has its center of distribution in the Santa Monica Mountains (Sawyer et al. 2009).

Fire history, differences in soil, moisture, and temperature regimes, and topography all combine to create complex patterns of woodland, chaparral, coastal scrub, and grassland vegetation. The mountains are home to several locally common but regionally restricted species (such as *Ceanothus spinosus, C. megacarpus, Eriogonum cinereum,* and *Coreopsis gigantea*); each because of its high sociability and abundance defines its own suite of vegetation types. Other alliances defined by *Encelia californica, Salvia leucophylla, Juglans californica,* and *Rhus integrifolia* are regionally distributed in southern, coastal California and display a more concentrated distribution and a broader variation of vegetation associations here than anywhere else.

While the Santa Monica Mountains are the lowest of the Transverse Range—the highest point is Sandstone Peak at 918 m—there are small stands of higher-elevation chaparral alliances such as *Quercus wislizeni* var. *frutescens* and *Arctostaphylos glandulosa,* remnants of a cooler and perhaps moister climate. In the higher elevation areas of the mountains, more extensive stands of chaparral alliances such as *Ceanothus oliganthus* and *Adenostoma sparsifolium* can be found.

In addition, the Santa Monica Mountains contain the southernmost stands of *Quercus lobata* woodlands in California and among the largest remaining woodlands of *Juglans californica*. The seaward bases of the mountains have succulent coastal scrub like that of Baja California, including stands of *Opuntia littoralis, O. oricola,* and *O. prolifera* along with drought deciduous scrubs such as *Salvia leucophylla, Artemisia californica,* and the largely insular *Coreopsis gigantea.* The core of the mountains covers thousands of acres and includes varied examples of *Ceanothus spinosus* and *C. megacarpus* alliances, both representing the center of their world distribution. Riparian vegetation includes extensive woodlands of *Platanus racemosa, Salix lasiolepis,* and *S. laevigata,* which often interface with lower slope woodlands of *Quercus agrifolia, Juglans californica,* and *Umbellularia californica*. Further south, the latter two alliances diminish significantly, thus signifying the biogeographic role of the Santa Monica Mountains as crossroads between northern and southern California coast range vegetation.

Plant species lists are available at http://www.mednscience.org/biological or through the Integrated Resource Management Applications (IRMA) at http://irma.nps.gov.

Wildlife

The Santa Monica Mountains support an abundant wildlife community, which is reflective of the diversity of the vegetation within the park boundary. While the park is just beginning to learn more about invertebrate populations, the vertebrate species have been well-inventoried and more than 490 native species are known to occur in the park, including 447 mammals, 391 birds, 19 species of fish, and 34 reptiles and amphibians. The relatively intact wildlife populations of the mountains are especially impressive considering their proximity to one of the largest urban areas in the United States. However, the continued maintenance of wildlife populations in the Santa Monica Mountains is dependent on the ability of public and private land managers to ensure adequate habitat for the most sensitive species. Urban development within the mountains continues to remove and fragment habitat available to wildlife, as it climbs up canyons, expands in pockets of low lying land, tops ridges, and encroaches on habitat adjacent to protected public land.

Mammals Mule deer (*Odocoileus hemionus*) are the largest herbivores in the Santa Monica Mountains. Mule deer are found throughout the mountains in a variety of habitats. Their distribution is limited by the fluctuating availability of water, cover and vegetation.

Lagomorphs, or rabbits, are represented by three species, including the brush rabbit (*Sylvilagus bachmani*), Audubon's cottontail (*Sylvilagus audubonii*) and the black-tailed jackrabbit (*Lepus californicus*). Collectively these species inhabit brushy areas and especially meadows and grasslands. Nine species of bats have been confirmed within SAMO, with another seven species probably present within the park. Another species, California Leaf-nosed Bat (Macrotus californicus), has likely been extirpated from the region.
Rodents comprise the final segment of the herbivorous mammals of the Santa Monica Mountains. Common species include the California ground squirrel (*Spermophilus beecheyi beechyi*), fox squirrel (*Sciurus niger*), deer mouse (*Peromyscus maniculatus*), dusky-footed woodrat (*Neotoma fuscipes*), Pacific kangaroo rat (*Dipodomys agilis*), and the pocket mouse (*Perognathus californicus*).

The Santa Monica Mountains still contain mountain lions (*Felis concolor*), although their continued ability to survive in the face of large-scale habitat fragmentation and destruction is uncertain. It is likely that their persistence in the mountains would depend upon their capability of dispersing to and from other habitat areas beyond the Santa Monica Mountains.

Other predators include bobcats *(Lynx rufus*), coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), badgers (*Taxidea taxus*), ringtails (*Bassariscus astutus*), raccoons (*Procyon lotor*), spotted and striped skunks (*Mephitis mephitis and Spilogale putorius*), and long-tailed weasels (*Mustela frenata*). In general, the survival of carnivores will depend on their ability to survive amid increased developments and the extent to which these species can disperse between open space areas and park lands.

Marine mammals that occur within the boundary of the park are limited to harbor seals (*Phoca vitulina*), and California sea lions (*Zalophus californianus*) which breed in Mugu Lagoon. Other marine mammals that can be readily observed from within the boundary include migrating California gray whales (*Eschrichtius robustus*) and bottlenosed dolphins (*Tursiops truncatus*).

Birds Located along the Pacific flyway, currently 391 species of native birds (including vagrants) are known to occur in the mountains. Of these, 113 species breed within the park. Thirteen of these breeders are raptors, which is an unusually high concentration. Sheer high cliffs of sedimentary and volcanic origin provide excellent raptor nesting areas. Historically, California condors, bald eagles and peregrine falcons nested here. Currently, golden eagles (*Aquila chrysaetos*), red-tailed hawks (*Buteo jamaicensis*), red-shouldered hawks (*Buteo lineatus*), Cooper's hawks (*Accipiter cooperii*), and northern harriers (*Circus cyaneus*) nest here. American kestrels (*Falco sparverius)*, white-tailed kites (*Elanus leucurus*), barn owls (*Tyto alba*), great horned owls (*Bubo virginianus*), western screech-owls (*Otus kennicottii*), burrowing owls (*Athene cunicularia*), long-eared owls (*Asio otus*) and turkey vultures (*Cathartes aura*) also nest within the recreation area.

Reptiles Twenty-four species of reptiles inhabit the Santa Monica Mountains, including two turtles (one introduced), seven lizard and 15 snake species. The western pond turtle (*Clemmys marmorata pallida*) is considered extremely rare. Common lizards include western fence lizards (*Sceloporus occidentalis longipes*), side-blotched lizards (*Uta stansburiana elegans*), and alligator lizards (*Elgaria multicarinata webbii*). The California horned lizard (*Phrynosoma coronatum*), a California species of special concern, is also regularly observed in the recreation area. Common snakes include southern Pacific rattlesnakes (*Crotalus viridis helleri*), gopher snakes (*Pituophis catenifer annectens*), and California striped racers (*Masticophis lateralis lateralis*). Little information is available about the distribution and status of many reptile species in SAMO. For example, two-striped garter snakes (*Thamnophis hammondi*), coastal western whiptail lizards (*Cnemidophorus tigris multiscutatus*), San Diego mountain kingsnakes (*Lampropeltus zonata pulchra*), and silvery legless lizards (*Anniella pulchra*) are believed to be in decline or very rare.

Amphibians The Santa Monica Mountains contain habitat for nine species of native amphibians, including four salamanders, four frogs or toads, and one newt. Two other species often listed for the Santa Monica Mountains, the arroyo toad (*Bufo californicus*) and the western spadefoot toad (*Spea hammondii*), occur nearby but no historical records exist for their occurrence and no populations have been found in SAMO. The California toad (*Bufo boreas halophilus*) and Pacific treefrog (*Hyla regilla*) are relatively common. Other amphibian species are suffering declines, including California newts (*Taricha torosa torosa*) and California treefrogs (*Hyla cadaverina*), likely as a result of predation by exotic species, habitat loss, and likely other factors (e.g. U.V. radiation). Until recently thought extirpated in the Santa Monica Mountains, a population of the federally threatened California red-legged frog *(Rana aurora draytonii*) has been found in one stream within SAMO and frogs may be dispersing to nearby streams. The NPS is investigating sites for potential re-introduction to other areas within the park. In general, the decline of amphibian populations in the Santa Monica Mountains has become a priority concern.

Fish A variety of native and introduced fish occur in the waters of the Santa Monica Mountains. Of significance are at least three spawning populations of the endangered steelhead trout (*Onchorynchus mykiss*) and one spawning population of Pacific lamprey (*Lampetra tridentata*), as well as several locations where California grunion (*Leuesthes tenuis*) spawn. Arroyo chub occur in the slow moving waters of Malibu Creek and a variety of introduced fish, such as largemouth bass, bluegill and goldfish, occur in freshwater streams up and downstream from recreational lakes and golf courses such as Malibu Lake and the Malibu Country Club.

The lagoons provide habitat to a number of migratory water birds, and supports one of the southernmost steelhead trout runs in the U.S. Besides the reintroduced tidewater goby, and resident steelhead, native fish in Malibu Lagoon include killifish (*Fundulus parvipinnis*), arrow goby (*Clevelandia ios*), staghorn sculpin (*Leptocottus armatus*), long-jawed mudsucker (*Gillichthys mirabilis*), opaleye (*Girella nigricans*), topsmelt (*Atherinops affinis*), diamond turbot (*Hypsopsetta guttulata*), northern anchovy (*Engraulis mordax*), California halibut (*Paralichthys californicus*), Pacific lamprey (*Lampetra tridentata*), queenfish (*Seriphus politus*), bay pipefish (*Syngnathus leptohynchus*), starry flounder (*Platichthys stellatus*), kelpfish (*Gibbonsia montereyensis*), and serranid (*Paralabrax* spp.) (Manion 1993; Manion and Dillingham 1989).

Insects Information on insects and their relationships to other organisms in the Santa Monica Mountains is very limited. The diversity and abundance of these organisms is certainly quite large. Aside from references by Emmel and Emmel (1973) and Hogue (1974, 1993), very little comprehensive information on insects exists for the mountains. Partial surveys and species lists exist from various sources (e.g. Resource Conservation District of the Santa Monica Mountains, docents from Charmlee County Park, etc.) and recent data mining accompanied by limited field-based inventories in cooperation with the Los Angeles Natural History Museum and others. The recent work includes a family level invertebrate inventory (Fiesler 2009), an inventory of beetles and moths (Caterino and Hopp 2009) and a survey of tardigrades (Johansson 2009).

Species lists are available at http://www.mednscience.org/biological or through the Integrated Resource Management Applications (IRMA) at http://irma.nps.gov.

Sensitive Species

More than twenty plant and animal species with potential to occur within the Santa Monica Mountains National Recreation Area are federally listed as threatened or endangered. Four additional state-listed species occur within the Santa Monica Mountains. Another 46 animal and 11 plant species are federal or state species of concern. In addition, a number of other plant and animal species are considered rare or locally threatened. Lists of these species can be found at http://www.mednscience.org/biological or through the Integrated Resource Management Applications (IRMA) at http://irma.nps.gov.

Wetlands

Due to the Mediterranean climate, wetlands and riparian habitats play a significant role in maintaining the natural ecological processes of the Santa Monica Mountains. Intermittent and perennial freshwater streams are the most important and common wetlands in the mountains, and there are a few ponds and other small depressional wetlands. Along the coast there are two large brackish and saltwater estuaries Mugu and Malibu Lagoons, as well as some smaller lagoons and tidal areas.

The larger of the two lagoons within SAMO, Mugu Lagoon, is owned by the U.S. Navy and is the largest relatively undisturbed salt marsh in southern California. The lagoon is a vital stop on the Pacific Flyway, a nursery ground for many marine fish and mammals, and is also a vital habitat for several threatened and endangered species. Some of these include the California least tern, light-footed clapper rail, Belding's savanna sparrow, and the tidewater goby. Although Mugu Lagoon has not been affected as much as other lagoons and estuaries in southern California, it has not been left unaltered. The effects of agriculture and urbanization within the Calleguas watershed and past base construction and other activities in the lagoon area by the U.S. Navy have resulted in significant changes and loss of habitat.

The large (272 square kilometer) Malibu Creek Watershed feeds the estuarine wetlands and salt marsh of Malibu Lagoon. The lagoon provides habitat to a number of migratory water birds, supports a dense riparian forest, supports habitat for the endangered tidewater goby and supports the southernmost reliable run of the remaining steelhead trout runs in the United States. There have been many alterations to the lagoon, from stream channelization to bringing in fill to construct baseball fields. Disturbance by humans, off-road vehicles, horses, and domestic pets are ongoing problems. The large watershed to the lagoon contributes a number of pollutants. In the highly urbanized parts of the watershed, non-point-source pollution comes from runoff of roads and other impervious surfaces such as roofs, parking lots, driveways and sidewalks. Wastewater, treated at the Tapia Water Reclamation Facility, is either discharged to Malibu Creek or sold for local landscape irrigation. Additionally, the residences and businesses of Malibu use septic systems for wastewater disposal, potentially affecting quality of local groundwater and coastal and lagoon waters.

Smaller lagoons are located at the mouths of Topanga, Zuma, and Trancas Creeks.

The US Fish and Wildlife Service National Wetlands Inventory, in cooperation with the Center for Geographic Studies at California State University Northridge, and the Southern California Coastal Water Research Project, is mapping wetlands throughout southern California based on 2005 one meter resolution color infrared air photos. The mapping program incorporates 10 meter digital elevation models (DEM) in a flow accumulation model to map stream networks, and a validation and quality assessment program that included some field visits. This data covers 90% of the National Recreation Area. For the 10% of the park where wetlands data have not been updated, the 1970s National Wetlands Inventory data combined with current USGS National Hydrography Data provides a medium resolution data set.

Resource Issues Overview

Fire

Fire has shaped the ecosystem of the Santa Monica Mountains and is a major factor controlling nutrient cycles and energy pathways. The park's vegetation and wildlife evolved in partial response to periodic lightning-caused fires. These lightning fires, in combination with aboriginal burning during the last 12,000 years, shaped the landscape. Fire was an integral part of the lives of the Chumash and Gabrielino as well as the early Spanish and European settlers, and continues to affect the inhabitants of the mountains today, particularly the large wind-driven fires that present the greatest public danger and account for most of the land burned in southern California.

Research indicates that in many areas fire return intervals have shortened in association with increasing settlement and human activity during the 20th century (Radtke et al. 1982, Barro and Conard 1991, NPS 1994, Conard and Weise 1998, Keeley et al. 1999), and in some areas fire occurrences are increasing to a frequency beyond which native vegetation can successfully recover.

For individual species, sensitivity to high fire frequencies varies with regeneration strategy. Non-sprouters show the greatest sensitivity to short fire return intervals and may be eliminated by a single burn before plants reach maturity and replenish seedbanks (Biswell 1989, Zedler 1995). Once lost from an area, recolonization of these species from other established populations can be extremely slow (Zedler and Zammit 1989). Obligate re-sprouters show greater resilience under short fire return intervals (Zedler et al. 1993, Fabritius and Davis 2000), but nevertheless may be severely impacted by sustained high-frequency fire regimes as successful germination and recruitment of new individuals is correlated with the cooler, moister, low light conditions and increased litter depth associated with the mature closed-canopy chaparral that develops over fire-free intervals of forty years or more (Lloret and Zedler 1991, Keeley 1992a & b, DeSimone 1995). Although facultative seeders re-sprout after fire, mortality of lignotubers, particularly in chamise, can be very high if fire returns prematurely (Kay et al. 1958, Zedler et al. 1983, Haidinger and Keeley 1993). Since a premature fire also kills seedlings that germinated in response to the previous fire, facultative seeders show only limited ability to persist under repeated disturbance.

Sensitivity of a vegetation community to short fire return intervals varies with species composition. A single premature fire can dramatically transform vegetation dominated by non-sprouters while vegetation dominated by re-sprouters may require years of sustained high frequency fires before a significant loss of shrubs occurs. Chaparral is generally believed to be adapted to fire return intervals ranging between 20 and 150 years, with average natural return intervals of 50 to 70 years (Minnich 1983, Davis and Michaelson 1995, Conard and Weise 1989, Mensing et al. 1999). The return interval which eliminates shrublands is not clearly defined and is dependent on the interaction of fire with other environmental conditions and disturbances (Keeler-Wolf 1995, Minnich and Dezzani 1998). O'Leary (1995) estimated that fire return intervals of five to 10 years can result in chaparral replacement by coastal sage scrub while others have found that this same interval will cause the replacement of coastal sage scrub with exotic grasslands (Timbrook et al. 1982, Minnich and Dezzani 1998). However, even fire intervals of 20 years or longer may result in significant changes in stand structure (Parker 1989).

Invasive Species

Invasive plants Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), altering fire regimes (Keeley et al. 2001; Keeley et al., 2011) and changes in water availability (D'Antonio and Mahall 1991). We have evidence that populations of rare plant species such as *Pentachaeta lyonii* are declining due to invasive species spread (Moroney 2011). Unnaturally frequent fires at SAMO have promoted landscape type conversions to non-native forbs and annual grasses following pressure from rodent herbivory post fire (Orrock and Witter 2010). Certain invasive species (*Phalaris aquatica*) are capable of invading multiple native plant communities across a variety of environmental conditions (Meiler 2007).

Globalization of commerce, increased transportation and human migration, land use change, and increased outdoor recreation have introduced invasive species to new areas at an unprecedented rate. The close proximity of SAMO to major ports of entry such as international airports and harbors, and a large human population make it difficult to prevent the introduction and expansion of invasive species. Additionally, many protected areas within the park are small and surrounded by private property with numerous recreation trails, roadways, and fire clearance zones bordering and crossing each property. These features result in a high edge-to-interior ratio with many pathways for invasives to travel into and across NPS property. Several of the worst invaders are currently used for landscaping (e.g., *Vinca major*, *Penniseteum setaceum*) and there is great potential for new invasive species to be introduced to the area through horticulture.

The park's current flora includes over 1200 species, of which approximately 300 are non-native. A panel of experts convened in 2000 identified 19 of the 300 non-native species as both ecologically harmful and currently of sufficiently limited distribution to have potential for either limiting spread or eventual eradication from the park (Table 1). The remaining 280 species were determined to be of limited ecological consequence, or to be already too widespread to effectively control.

In 2006, SAMO completed a 2-year survey and mapping project of all public roads and trails throughout the NRA for the target 19 invasive species. At that time over 4000 infestations were detected and the majority was less than 500 m^2. For established non-native plant populations within the park that show signs of impacting native biodiversity (e.g., diversity is reduced in the areas they occupy), SAMO utilizes a variety of methods to reduce and/or eliminate populations of established target invasive species. These methods involve mapping infestations, and then developing plans for strategic removal efforts.

SAMO actively participates in local weed management areas and works with neighboring land management agencies to tackle regional weed problems, although funding and priorities can differ between management agencies. Ongoing efforts include opportunistic, real-time reporting and mapping of six of the most aggressive invasive species on the target 19 list through the *What's Invasive* smart phone application. This application is freely available for both Android and iPhone and can be accessed at http://www.whatsinvasive.com. More formal surveys and mapping to assess spread and treatment efficacy are ongoing. In addition, the park is currently developing a protocol (in review) to 1. Determine the status and trend in the presence and spread (abundance and distribution) of invasive non-native plants on a park-wide basis; and 2. Develop and maintain an early detection reporting and tracking system that disseminates information to park management on new infestations in a timely and efficient manner to allow for effective response.

Table 1. List of target invasive plant species for Santa Monica Mountains National Recreation Area.

Species (scientific name)	Species (common name)
Ailanthus altisissima	tree of heaven
Acroptilon repens	Russian knapweed
Arundo donax	giant reed
Asphodelus fistulosus	onionweed
Centaurea solstitialis	yellow starthistle
Cortaderia jubata	Pampas grass, jubata grass
Conium maculatum	poison hemlock
Delairea odorata	Cape ivy
Euphorbia terracina	Geraldton carnation spurge
Foeniculum vulgare	sweet fennel
Lepidium latifolium	perennial pepperweed
Myoporum laetum	myoporum
Nicotiana glauca	tree tobacco
Pennisetum setaceum	fountain grass
Phalaris aquatica	Harding grass
Ricinis communis	castor bean
Salsola australis	Russian thistle
Spartium junceum	Spanish broom
Vinca major	periwinkle

Invasive Wildlife In creeks throughout the park and particularly those that feed from the developed recreational/water supply lakes in the mountains, a variety of non-native fauna have been introduced. This is a significant concern throughout southern California. At least 28 species of non-native fish have become established in southern California streams (Faber et al. 1989). For example, in Trancas Creek in the Santa Monica Mountains, goldfish, largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) have all been observed. In the Malibu Creek drainage, including Malibu Lagoon, largemouth bass, black bullhead (*Ictalurus melas*), green sunfish (*Lepomis cyanellus*), mosquito fish (*Gambusia affinis*), Oriental shrimp (*Palaemon macrodactylus*) and crayfish (*Procambarus clarki*) are known to occur. Recent research has demonstrated the serious consequences of the presence of several of these introduced species for native aquatic species populations (Gamradt and Kats 1996; Goodsell and Kats 1999).

The New Zealand mudsnail (*Potamopyrgus antipodarum)*, only recently discovered in the Santa Monica Mountains, is causing great concern. Found in Malibu Creek in 2005, by 2007 mudsnails were established within the watershed and by 2008 spread to at least two other watersheds in the mountains (Abramson 2009). Although the ecological impact of mudsnails is not yet known in our area, extremely high densities of snails have been documented (Dorgelo 1987) and could significantly alter food web dynamics by displacing native species.

<u>Habitat Loss and Habitat Fragmentation</u>

Perhaps the greatest threat to natural resource preservation in the Santa Monica Mountains National Recreation Area is the loss of habitat and habitat connectivity from increased development and urban encroachment. Natural areas that do remain in the recreation area are increasingly fragmented by development of single homes and small ranches, larger housing tracts, vineyards, firebreaks and fuel clearance, roads and trails, and other disturbances. This fragmentation and connectivity loss could potentially isolate plant and animal populations, reducing their numbers, increasing their susceptibility to environmental change, and exposing them to potential genetic deterioration. For some species, particularly larger animals with low population densities and large ranges, these consequences could be severe and result in their extinction from formerly occupied habitats. For example, in the Santa Monica Mountains, habitat loss, fragmentation, and loss of connectivity could impact the local survival of bobcats, gray foxes, and badgers. In addition, the Ventura Freeway (US 101) has been shown to be a barrier to movement for coyotes and bobcats resulting in genetic differences between populations north and south of this major freeway (Riley et al. 2006). The situation is especially critical for mountain lions, wide-ranging animals whose persistence in the recreation area likely depends on their ability to disperse to and from the Santa Monica Mountains from surrounding open space areas and mountain ranges. For other smaller sized and sedentary animals, habitat loss and fragmentation can also create barriers to dispersal. Urban development between habitat fragments can be difficult to cross for many species, even birds. Recent work has shown significant genetic divergence across very small geographic distances, but with intervening urban habitat, in three common lizards (*Sceloporus occidentalis*, *Uta stansburiana*, and *Plestiodon skiltonianus*) and a southern California bird, the wrentit (*Chamaea fasciata*). In addition, genetic diversity was negatively associated with the isolation of habitat patches (Delaney et al. 2010).

<u>Other Urban Impacts</u>

Anticoagulents Long-term research on mammalian carnivores at SAMO has determined that anticoagulant rodenticide poisons can have a significant impact on carnivore populations. Anticoagulant poisoning has been a major source of mortality for coyotes and mountain lions, and an interaction between anticoagulants and notoedric mange, an ectoparasitic disease, has resulted in widespread mortality and even local extirpation in bobcats. The park is investigating the sources of these anticoagulants and the path they take to causing mortality in carnivores.

Pollutants Runoff generated from developed areas has placed increasing pressure on the existing fresh water resources. Runoff from urbanized areas (e.g., roads, parking lots, residential areas) may occur more quickly and with higher concentrations of pollutants than undeveloped areas. The runoff from the developed areas could contain elevated levels of nutrients (such as phosphorous and nitrogen), pathogens, toxicants (e.g., heavy metals), and litter and trash loads. The impacts of these pollutant inputs on the health of the fresh water systems could be minimized through effective management of runoff from developed areas.

Resource Stewardship

Drawing upon the purpose and significance delineated in the original 1978 legislation, the staff of the National Park Service, California State Parks and the Santa Monica Mountains Conservancy created a joint mission statement in 1997:

> The mission of the Santa Monica Mountains National Recreation Area is to protect and enhance, on a sustainable basis, one of the world's last remaining examples of a Mediterranean ecosystem and to maintain the area's unique natural, cultural and scenic resources, unimpaired for future generations. The park is to provide an inter-linking

system of park lands and open spaces that offer compatible recreation and education opportunities that are accessible to a diverse public. This is accomplished by an innovative federal, state, local, and private partnership that enhances the region's quality of life and provides a model for other parks challenged by urbanization.

Management Directives and Planning Guidance

Neither the SAMO Resource Management Plan (1999), nor the General Management Plan (2002), contain specific management directives or planning guidance. Further, the park has yet to develop foundation statements describing park fundamental resources and values or a resource stewardship plan. The 1999 Resource Management Plan identified two broad goals for the resource management program: (1) Obtain knowledge and understanding of natural and cultural resources; and (2) Implement conservation and restoration actions to protect natural and cultural resources. Much of the efforts of the park and network staff over the past few decades have been focused toward the first goal of obtaining a better understanding of park resources and resource threats.

Status of Supporting Science

In 2002, the Mediterranean Coast Network (including Cabrillo National Monument and Channel Islands National Park as well as SAMO) began development and implementation of a monitoring program to determine status and trends in selected indicators of park ecosystem health. Information obtained from published literature, park resource managers, and academic subject matter experts was incorporated into a series of conceptual models that highlighted ecosystem functional relationships. The models provided a framework for understanding potential indicators of ecosystem condition by illustrating the ecosystem drivers, stressors, and ecological effects of the drivers and stressors within the southern California Mediterranean-type Ecosystem (Cameron et al. 2005).

The conceptual models were used to identify a long list of candidate vital signs. Again, the network pulled in outside expertise, as subject matter experts from outside the National Park Service worked together with park and network staff, through an internet-based exercise, to evaluate and rank the candidate vital signs according to ecological relevance, feasibility for monitoring, and utility and relevance to management of network parks. This process resulted in a priority list of vital signs for which monitoring protocols will be written and new monitoring implemented. Currently, at Santa Monica Mountains, the NPS is monitoring or in the process of developing monitoring protocols for aquatic amphibians, freshwater quality/riparian condition, invasive plants, landscape dynamics, native vegetation, and terrestrial amphibians and reptiles (Table 2). Current condition is updated annually and as enough data is collected and analyzed, trends will be identified. For resources with no vital signs monitoring program proposed (e.g. due to funding limitations), the park will attempt to track and assess indicators through other means such as soft-funded short-term inventory and monitoring projects, facilitation of academic research, projects with partners, cooperators and building onto existing programs.

Table 2. Draft Vital Signs Summary Table for SAMO.

Resource	Indicator	Associated Vital Sign Protocol	Current Condition	Reference Condition	Status and Trend	Comments
Native habitat, including shrub communities	Percent cover of major vegetation types, Percent development within SAMO	Landscape Dynamics and/or native vegetation	TBD	TBD Status at time of park establishment TBD	1) 2) Declining native habitat TBD	1) Is current cover greater or less than value 50 years ago? Some shrub recovery, some type conversion. 2) Address using simple GIS analysis of aerial photos/google earth TBD
Native shrub and animal communities	Fire frequency	Area of land in different fire return intervals	See FMP for status as of 2008	TBD	Increasing land area in fire frequency categories of short fire return interval	
Native Floristic Diversity	Post-fire recovery, 2) Native annual plant species richness	Estimates of resprouting, reseeding and annual plant response post-fire Native vegetationTBD	TBD	TBD	Decreasing positive response. Species loss post-fire due to drought, invasive species and change in fire frequency	Potentially addressed through What's Blooming project with CENS and citizen science initiative. Partner with RLC and schools TBD
Native Habitat	# of acres occupied by non-native invasive plants Richness of non-native invasive plants	Invasive species	Check recent mapping data and 2005 maps for reference	TBD	Total acreage could be increasing or decreasing. Richness is likely increasing.	
Native Habitat/Animal Population Health	Detection of new invasive plant and animal species	Invasive plant species and aquatic amphibians	Check current data	TBD	TBD	

Resource	Indicator	Associated Vital Sign Protocol	Current Condition	Reference Condition	Status and Trend	Comments
Carnivore Population Health	Abundance and survival rates for bobcats, coyotes, mountain lions.	None	TBD	TBD	Increasing mortality in bobcats due to mange epidemics.	
Herbivore Population Health	Abundance and survival rates and habitat measures for deer and rabbits.	None except landscape dynamics for habitat measures.	TBD	TBD	TBD	
Landbird Diversity	Bird species richness.	None	TBD	TBD	TBD	
Raptor Diversity	Distribution, abundance, nesting status of raptor species	None	TBD	TBD	TBD	reflects habitat quality, small mammal and bird populations, and presence of poisons
Insect Diversity	Insect diversity in per guilds, overall richness	None	TBD	TBD	TBD	
Air Quality	Levels of air pollutants in SAMO	None	TBD	TBD	TBD	
Water Quality	Levels of pollutants in SAMO waterways.	Fresh water quality	TBD	TBD	TBD	
Stream Community Health	Amphibian population distribution and abundance Number of invasive species in streams	Aquatic amphibians	Invasives in many streams	TBD	Trend appears to be towards lower quality – more invasive species, more urbanization, impacts of vineyards	
Animal Diversity – reptiles	Species richness and abundance of reptiles	Terrestrial reptiles and amphibians	TBD	TBD	TBD	

Resource	Indicator	Associated Vital Sign Protocol	Current Condition	Reference Condition	Status and Trend	Comments
Species of Low Abundance or Restricted Habitat	Abundance and distribution of threatened, endangered, rare or sensitive plants and animals	None	TBD	TBD	TBD	We monitor one federally endangered plant yearly. Developing a monitoring protocol for a second species. All other sensitive species are currently not monitored.

Chapter 3. Study Approach

Preliminary Scoping

As described in Chapter 2 above, the regional network had previously developed an Inventory and Monitoring Plan that selected Vital Signs indicators and prioritized those for which protocols were to be developed (Cameron et al. 2005). At the outset of this condition assessment, NPS staff provided a ranking of potential themes to be addressed (Table 3). They refined these general themes into the following set of preliminary management or research questions:

1. Can we model or predict future development and land use changes in the region? What work has been done and is there anything we can learn from the results?
2. How will increasing development affect habitat connectivity and habitat quality?
3. What were the historic land uses and vegetation patterns and what role has land use had in creating vegetation patterns we see today. Can observed land use changes be mechanistically linked to changes in vegetation and other resources?
4. Are there species that are particularly likely to be affected by changes in habitat quality and/or configuration? How is the herbaceous flora, particularly the post-fire flora affected by interaction between fire and competition from non-native invasive species?
5. Has the vegetation community structure, distribution, composition, and function changed with changing fire regime and establishment of invasive plant species? Are there other factors affecting vegetation community change? How do these factors interact? How can we monitor this? Are there specific species or species characteristics we should be concerned with—either specific invasive species/characteristics or native species.
6. Are there any manageable dimensions to the changes we're seeing due to increased fire frequency and establishment of invasive plant species? Is there any way to offset/mitigate changes/impacts – especially considering elements we have no control over? What are the mechanisms of change and what actions have or have not been successful in managing change?
7. How do we expect fire regime to change with continued development and climate change?
8. What are the potential effects of changing climate in this region (e.g. rain, temperature, and drought) and what are the implications for the park (changes to fire regime, vegetation distribution, interactions between fire and invasive species, etc.).
9. Are there other important resource threats we are not considering?
10. What ecosystem elements, species or species groups might be particularly important to monitor in light of current knowledge of resource threats and stressors.
11. How has the hydrology in the mountains changed over the past century? Can increases in water availability and decreases in water quality be quantified or described with existing data and information? What implications do these changes have for native communities? What information and research is needed to best address these questions?

Table 3. Priority rank potential focal themes for the natural resource condition assessment (updated version, 12/9/08). 3 = High, 0 = Low.

Potential Themes and Analyses	**Priority in SAMO***
Stressors	
Urban encroachment/rural development	3
Recreation	3
Logging or habitat conversion	2
Road and trail development	2
Grazing	1
Abandoned mine lands	0
Mines (active)	0
Acid mine drainage	0
Mine restoration	0
Air and climate	
Airborne dust	2
Point sources of air pollution	2
Moisture and climatic cycles	3
Global warming	1
Water	
Lakes and streams	3
Clean water	3
Groundwater flow	3
Flooding regimes	3
Flood control	3
Bank erosion	3
Soil erosion	3
Water diversion	0
Biological integrity	
Invasive species	3
Areas of pristine or old-growth vegetation	3
Phenological cycles	3
Areas with evidence of invasive plant or animal species	2
Areas of focal species	2
Habitat for focal species	2
Wetlands & Riparian Areas	2
Landscapes	
Fire regimes (including historic fire regimes)	3
Fire suppression and fuels management	3
Solitude and silence	2
Soil compaction	2
Roadless areas	1
Caves or karst features	0
Past logging and restoration of those lands	0
Karst processes	0
Carbon sequestration	0

* Priority (Importance): 0 – None; 1 – Low; 2 – Moderate; 3 – High.

These general themes and questions were transformed into a set of stressors and resources to be assessed through ongoing discussion with the NPS coordinators. It was agreed with NPS staff that detailed analysis of some key issues and indicators would be more helpful than a superficial treatment of everything and that new analysis would be a more efficient use of time than compilation of existing material. In general, the choice of stressors and resources was guided by the availability of geographically-referenced data for topics normally outside the usual scope of analysis by NPS staff.

Study Resources and Indicators

Assessment Framework Used in the Study

The NPS Ecological Monitoring Framework (Table 4) is a systems-based, hierarchical, organizational tool for the NPS Inventory and Monitoring Program for promoting communication, collaboration, and coordination among parks, networks, programs, and agencies involved in ecological monitoring (Fancy et al. 2009). This framework uses a 6-category classification to organize and report NPS I&M Program vital signs. The top reporting categories (Level 1) include: 1) Air and Climate, 2) Geology and Soils, 3) Water, 4) Biological Integrity, 5) Human Use, 6) Landscapes (ecosystem pattern and processes). Vital signs selected by parks and networks for monitoring are assigned to the Level 3 category that most closely pertains to that vital sign. The Ecological Monitoring Framework was selected as the hierarchical framework for this condition assessment because it is familiar to park resource staff, and it is a good fit for the indicators being assessed. The section of the report on Resource Conditions is organized around the categories of the framework.

Table 4. NPS Ecological Monitoring Framework (Fancy et al. 2009).

Level 1 Category	Level 2 Category	Level 3 Category	Comments
Air and Climate	Air Quality	Ozone	
		Wet and Dry Deposition	
		Visibility and Particulate Matter	
		Air Contaminants	
	Weather and Climate	Weather and Climate	
Geology and Soils	Geomorphology	Windblown Features and Processes	
		Glacial Features and Processes	
		Hillslope Features and Processes	
		Coastal/Oceanographic Features and Processes	
		Marine Features and Processes	
		Stream/River Channel Characteristics	
		Lake Features and Processes	
	Subsurface Geologic Processes	Geothermal Features and Processes	
		Cave/Karst Features and Processes	

Level 1 Category	Level 2 Category	Level 3 Category	Comments
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	
		Surface Water Dynamics	
		Marine Hydrology	
	Water Quality	Water Chemistry	
		Nutrient Dynamics	
		Toxics	
		Microorganisms	
		Aquatic Macroinvertebrates and Algae	
Biological Integrity	Invasive Species	Invasive/Exotic Plants	
		Invasive/Exotic Animals	
	Infestations and Disease	Insect Pests	
		Plant Diseases	
		Animal Diseases	
	Focal Species or Communities	Marine Communities	Includes coral communities
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	Marshes, swamps, bogs
		Riparian Communities	
		Freshwater Communities	Standing water (inland ponds and lakes) and flowing water (rivers and streams); emphasis on aquatic biota
		Sparsely Vegetated Communities	
		Cave Communities	Cave flora and fauna. Physical and chemical features and processes should go under Caves/Karst Features and Processes
		Desert Communities	
		Grassland/Herbaceous Communities	Includes tundra and alpine meadows, lichens, fungi
		Shrubland Communities	
		Forest/Woodland Communities	
		Marine Invertebrates	
		Freshwater Invertebrates	
		Terrestrial Invertebrates	
		Fishes	

Level 1 Category	Level 2 Category	Level 3 Category	Comments
		Amphibians and Reptiles	
		Birds	
		Mammals	
		Vegetation Complex (use sparingly)	Catch-all category to be used in rare cases where no other community type can be used.
		Terrestrial Complex (use sparingly)	Catch-all category to be used in rare cases where no other category can be used.
	At-risk Biota	T&E Species and Communities	
Human Use	Point Source Human Effects	Point Source Human Effects	
	Non-point Source Human Effects	Non-point Source Human Effects	
	Consumptive Use	Consumptive Use	
	Visitor and Recreation Use	Visitor Use	
	Cultural Landscapes	Cultural Landscapes	
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	
	Landscape Dynamics	Land Cover and Use	Includes landscape pattern, fragmentation
	Extreme Disturbance Events	Extreme Disturbance Events	Records of floods, windthrow, ice storms, hurricanes, etc., which might also be placed in Climate category.
	Soundscape	Soundscape	
	Viewscape	Viewscape/Dark Night Sky	
	Nutrient Dynamics	Nutrient Dynamics	
	Energy Flow	Primary Production	

Conceptual Models

Conceptual models describe the causal relationships among human activities--including park management decisions--environmental stressors, and endpoints of resources of concern in park management (Gentile et al. 2001, Fancy et al. 2009). The exercise of developing these models provides several benefits in framing a resource condition assessment. The model graphically represents current belief of how the system functions and shows the relationships in a way that is understandable by non-scientists. Therefore the process adds transparency to the selection of condition indicators and potentially enhances communication. It can also help identify key uncertainties about the causal relationships and offer hypotheses to be tested (Gentile et al. 2001). The models also help identify the appropriate spatial scales for data collection and analysis. Conceptual modeling is used as the framework for this resource condition assessment.

There are four fundamental concepts contained in conceptual models: drivers, stressors, pathways, and endpoints (Gentile et al. 2001). *Drivers* are natural and anthropogenic processes that cause changes in environmental conditions. *Stressors* are the physical, chemical, and biological changes that result from natural and human-caused drivers and in turn affect ecosystem structure and function through *ecological pathways*. Drivers can be considered first-order influences and stressors second-order influences in chains of cause and effect. The ecosystem resources that are considered ecologically significant and important to the public (Harwell et al. 1999) are known as *endpoints*. Either endpoints or stressors or drivers can be used as condition indicators, depending upon feasibility of measurement. For instance, if it is impractical to census the entire population of a species of special interest (an endpoint), it may be necessary to assess the status and trends of key stressors that are more amenable to mapping or monitoring and then infer effects on the endpoint. Based on the hierarchical framework, it is sometimes ambiguous which indicators are stressors or endpoints. Fire regime is a condition, but if it changes in response to land use or climate change, it can also be a stressor on other conditions.

Describing a holistic conceptual model that contains every resource of concern in a park unit would quickly lose its capacity to communicate with non-scientists. Gentile et al. (2001) therefore recommend dividing the modeling into a higher level societal model that illustrates the role of social actions and choices (anthropogenic drivers) in increasing environmental stressors and a second level that relates stressors to resource endpoints through ecological pathways. The societal level conceptual model can be holistic with all the important drivers and stressors for the ecosystem being assessed, but it need not be comprehensive because some candidate stressors may only be of minor impact on park resources. The conceptual models presented in this report reflect primarily the anthropogenic drivers. The second level of models can be applied at any ecological level, e.g., landscapes, ecosystems, species, or other resources. What links the two levels of conceptual modeling are stressors. The relevant stressors, but not necessarily all, from the societal model become "inputs" into the resource level models. Examining which stressors apply in which resource conceptual models gives an indication of their relative importance and perhaps the priority to monitor them.

Based on the assessment questions and priorities of SAMO staff, a societal conceptual model was developed (Figure 3). Six primary anthropogenic drivers, symbolized with rectangles, were identified. Clearly some drivers are related. For example, increased urbanization contributes to demands for recreation and fire protection as well as increased emissions of greenhouse gases. Nevertheless, this delineation provides a useful distinction of stressors (shown as ellipses). The model also identifies the spatial scale of the drivers and stressors. The gold color identifies processes that occur outside the park boundary, such as urbanization. Green symbolizes processes whose sources occur within the park unit. In some cases, the process and its impacts occur both internally and externally to the park unit, which is shown in yellow (e.g., light pollution occurs as skyglow from nearby urban areas but also from fixed and transient lighting within the park unit). Note that many of the stressors generated by the demand for outdoor recreation and by adjacent land management practices are similar to those from urban encroachment, but are not shown in the diagram for simplicity.

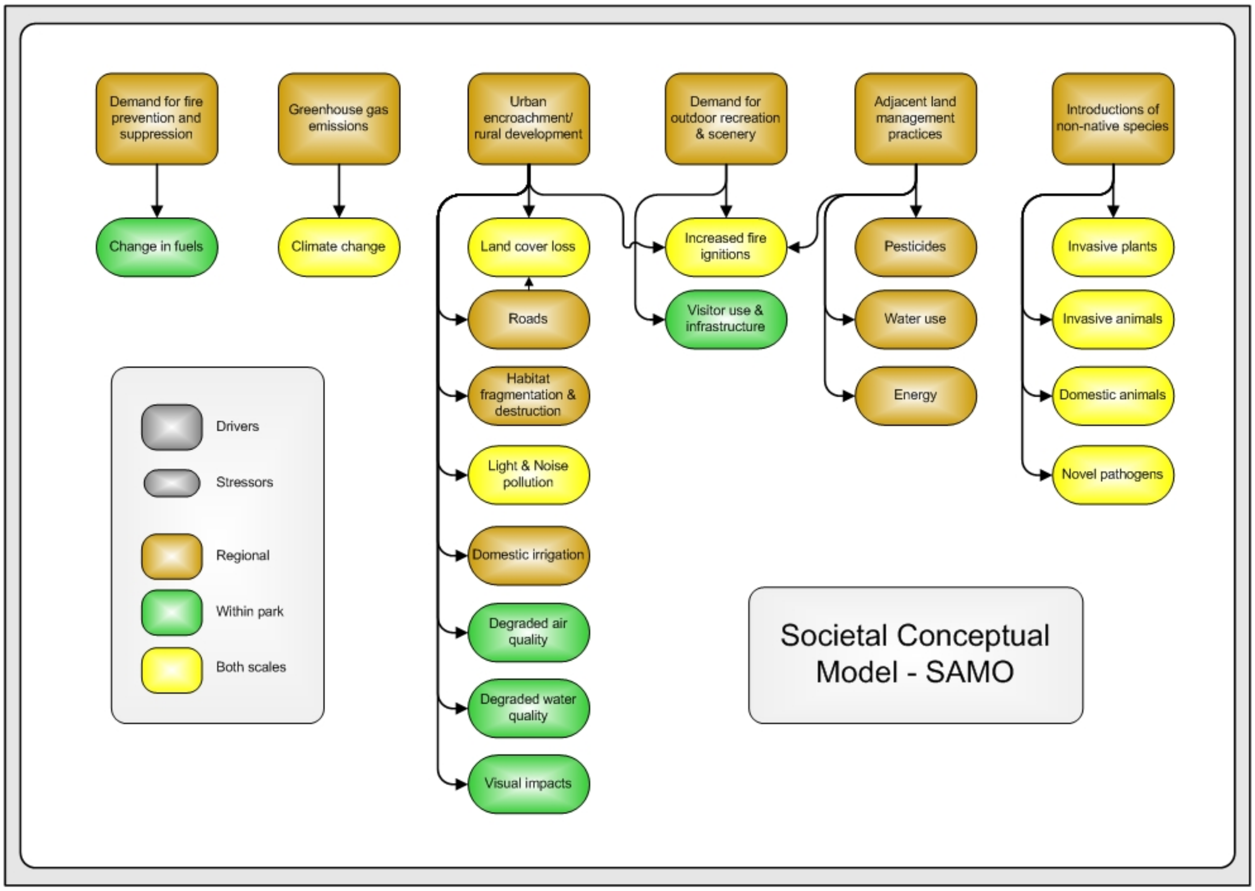


Figure 3. Societal conceptual model of drivers and stressors for SAMO.

Based on the set of management questions and resource indicators described above, second level resource conceptual models were developed (see Figure 4for an example for fire frequency). These models select the relevant environmental stressors from the societal conceptual model and link them through ecological pathways (diamond shapes) to one or more endpoint indicators (hexagons). The pathways qualitatively describe how the stressors may actually affect the indicators. For example, both climate change and urban growth may affect fuel loads. Climate change also alters the flammability of fuels through seasonal drying. Both pathways combine to affect fire frequency.

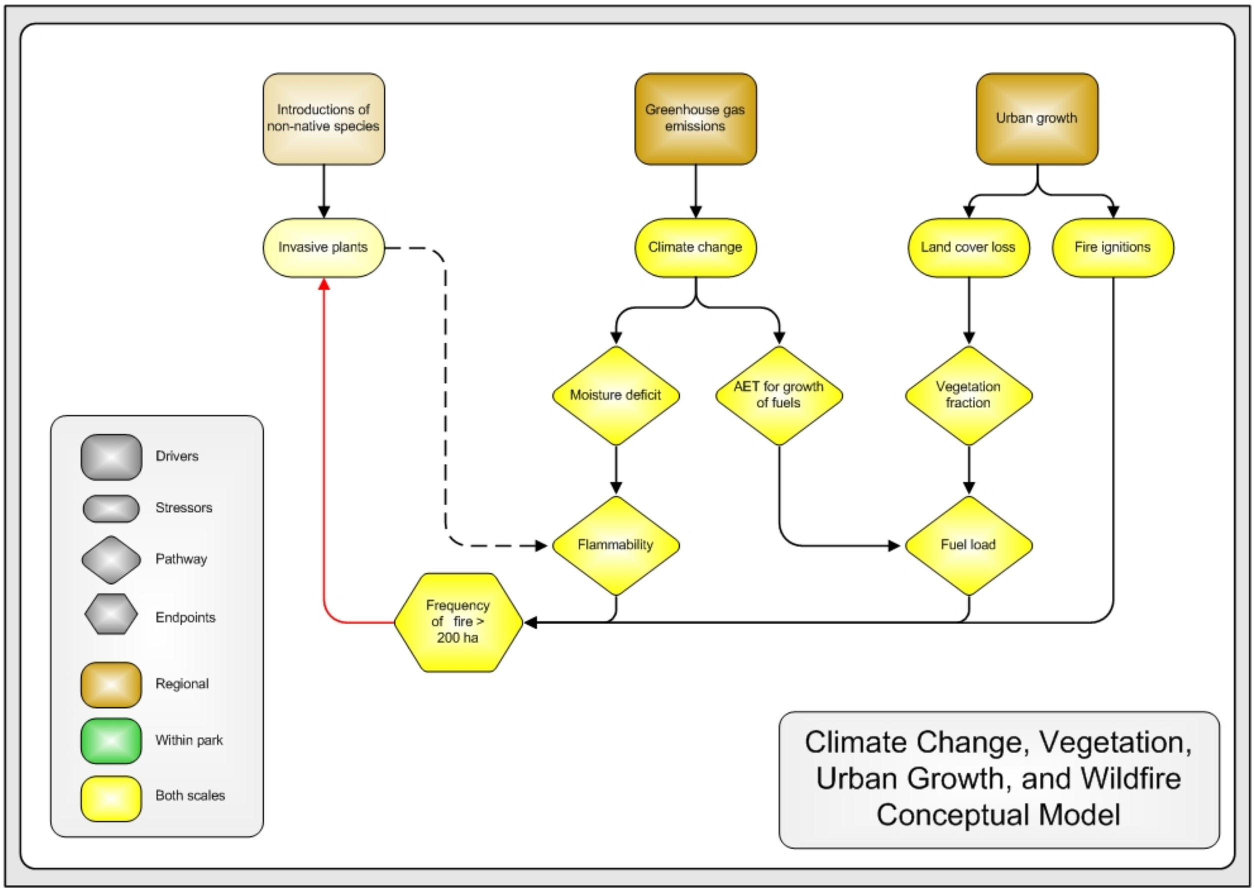


Figure 4. Fire frequency conceptual model of stressors, pathways, and endpoint indicators.

As part of the process of developing Vital Signs indicators, as discussed in Chapter 2, teams of subject matter experts developed a set of conceptual models of ecosystem functional relationships for many resources in the four park units within the Mediterranean Coast Network (Cameron et al. 2005). Those conceptual models tended to be very comprehensive, including all likely relationships between drivers, stressors, and resource conditions. In developing the conceptual models for this condition assessment report, we generally followed the logic of the models in Cameron et al. (2005), but tended to simplify the relationships to focus on mappable processes or patterns. We also adopted the syntax of Harwell et al. (1999) and Gentile et al. (2001), and identified the characteristic geographic scale of each feature in the model.

In some sections of the condition assessment, we also present "GIS conceptual models." These diagrams are similar to the ecological conceptual models except that they depict how spatial data layers are integrated to develop map products such as relative vulnerability or suitability. They omit the actual GIS operations in the diagrams and hence are conceptual rather than operational. The intent is to give the reader a visual representation of the analytical approach to complement the text.

Study Resources and Indicators

The societal conceptual models in the previous section identified key drivers and stressors associated with park resources. In some cases, a stressor is caused by multiple drivers, e.g., increased fire ignitions. The resource conceptual models defined the relationships between the resource endpoints and subsets of stressors. Stressors often appear in more than one conceptual model of the priority resource indicators selected for assessment in this report (Table 5).

Table 5. Relationships between environmental stressors and condition indicators in SAMO.

	STRESSORS				
Condition Indicators	Housing develop-ment	Road distance and accessibility	Pesticides affecting amphib-ians	Rodenticides	Human footprint
AIR AND CLIMATE					
Air quality	●	●			●
Climate	●				●
WATER					
Water quality	●	●	●		●
BIOLOGICAL INTEGRITY			(amphib-ians)	(carnivores, raptors)	
Invasive plants	●	●			●
LANDSCAPES					
Fire regime	●	●			●
Future fire regime	●				●
Habitat connectivity	●	●			●
Dark night sky	●	●			●

Study Methods

The approach used in this assessment generally follows a similar set of steps for most indicators.

1. Develop a conceptual model, where appropriate, to gain insight and communicate the relationships between stressors and endpoints.

2. Select the relevant scale(s) of ecological patterns and processes for the assessment (see below for description of the standardized scales used).

3. GIS data compilation, manipulation, and modeling as needed.

4. Summarization by reference scales and interpretation of status and/or trends.

Ecological assessment scales

As the color scheme in the conceptual models suggests, many drivers and stressors originate in a larger region beyond the park boundary. For instance, urban development within SAMO is relatively small compared to the surrounding metropolitan areas, with its accompanying air pollution, noise, and skyglow. Other stressors may predominantly operate within the park unit, such as road and trail access and associated fragmentation. Stressors such as non-native plants can potentially invade from adjacent lands into the park unit. Resource endpoints, by definition, are features within the park unit, although they may be part of a larger population or ecosystem that encompasses the park. This inherent nesting of spatial scales of ecological processes is reflected in this condition assessment. Although every ecological process has its own characteristic reference region, we have chosen to simplify this diversity by employing just three scales or geographic domains in the assessment. First is the park unit itself, defined by the designated NRA boundary. Lands within the NRA boundary, however, are managed by a variety of federal, state, and local agencies, conservancies, and private owners. To assess stressors and endpoints at the landscape scale across adjacent lands, an area encompassing SAMO and neighborhood was delineated. Vegetation had been mapped by AIS from 2001 color aerial photography to include undeveloped land up to State Highway 118 that the NPS believed influenced their management. A buffer out to 5 kilometers surrounding the SAMO vegetation map was delineated, which is referred to in this report as park-and-buffer scale. Regional scale assessment required finding a regional boundary that contains lands that were ecologically similar to the park unit or that affect resources in the park (e.g., sources of air pollution). No single geographic division (e.g., ecoregions, counties, watersheds) was adequate to delineate such an assessment region. We had previously integrated GIS layers of river basins with EcoMap subsections from the U. S. Forest Service (Goudey and Smith 1994, Miles and Goudey 1997) as a useful compromise between optimal units for aquatic and terrestrial species and ecosystems (http://knb.ecoinformatics.org/knb/metacat?action=read&qformat=nceas&sessionid=&docid=bowdish.58). For the SAMO condition assessment, a set of these "hydroecoregions" were aggregated to delineate an appropriate region. This region contains most of Ventura County and Los Angeles County excluding the Mojave Desert. A small piece of Santa Barbara County are also included. The three assessment scales are depicted in Figure 5. The assessments of specific stressors and indicators were performed at the scale(s) deemed most appropriate. One exception to these nested reference regions was for the assessment of fire regime trends, which was done by the EcoMap subsections. Note that because SAMO is a relatively small park, summaries are not reported by subareas.

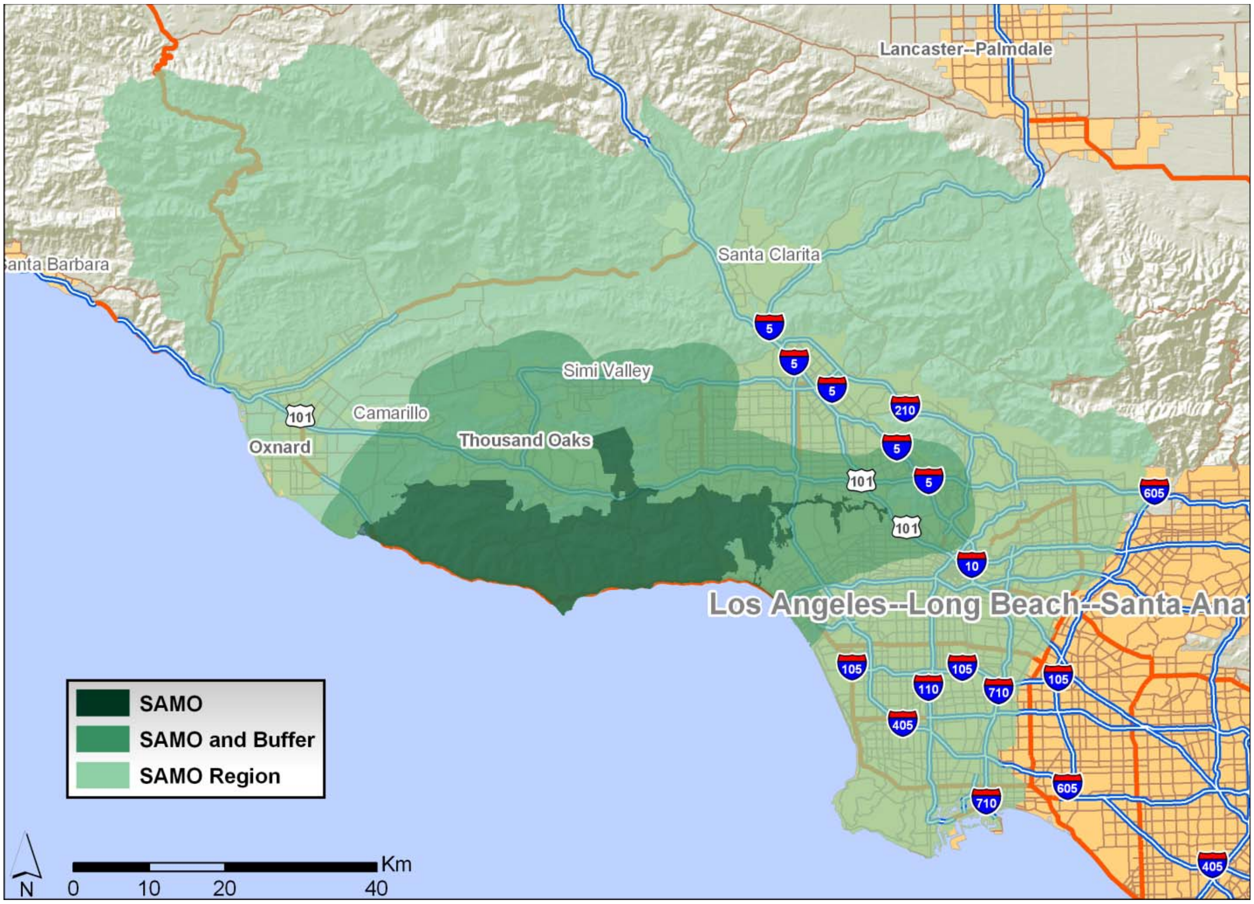


Figure 5. Geographic units for the three scales of condition assessment.

Climate change models

Several of the indicator assessments look not only retrospectively at current or recent conditions but also project responses into the future from changes in climate factors. This section provides background on the international efforts at projecting climate through the remainder of this century in response to continued emissions of greenhouse gases (GHG) into the atmosphere.

Climate is a complex system of interactions between the atmosphere, oceans, land, and the biota. All global climate models (GCMs) that model that complexity are based on principles of fluid dynamics and thermodynamics. Different research organizations, however, have developed GCMs to simulate the large-scale dynamics of the climate, but each uses a different set of parameterizations of variables to optimize for the climate feature they are most interested in. Therefore the models generate similar but somewhat different results for a given set of assumptions about GHG emissions. The Intergovernmental Panel on Climate Change (IPCC) states that:

> "There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g.,

temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases" (Solomon et al. 2007).

Three prominent GCMs that generated data for this assessment are the Centre National de Recherches Météorologiques CM3, Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 and National Center for Atmospheric Research PCM1.

The IPCC created a standardized set of scenarios about future GHG emissions over the coming century to integrate knowledge of demographic, economic, and technological systems to structure the policy discussion about climate change and its impacts (Nakićenović and Swart 2000). Of these scenarios, this condition assessment uses two of these scenarios that bracket the GHG emissions trajectories. The A2 scenario assumes business-as-usual, with a medium-high emissions trajectory leading to a CO_2 concentration in the atmosphere by end of century of more than triple the pre-industrial level. The B1 scenario assumes wider adoption of clean technologies and therefore a transition to low greenhouse gas emissions, which is nevertheless double the pre-industrial level.

GCMs of necessity are coarse-scale models. California is generally covered by just a few grid cells. For regional analyses, these coarse-scaled projections are "downscaled" using local topography. For assessment of future distributions of tree species, the climate variables were downscaled to 90 meters. For interaction of climate and wildfire, the data were downscaled to 1/8 degree cells (see Cayan et al. 2009). The outputs are either daily or monthly values for temperature and precipitation. These were then aggregated into seasonal or annual values or into other ecologically-relevant variables for modeling ecological responses. Our assessments used the combination of downscaled outputs for GCMs and scenarios that were available for specific indicators. In other words we have not attempted an exhaustive assessment of the range of possible outcomes for resource indicators but rather have attempted to indicate the potential direction and magnitude of changes that may occur.

Chapter 4. Natural Resource Conditions

This chapter contains assessments of two types of indicators: regional/landscape stressors and park-scale resources.

Regional/Landscape Context

Overview of Stressors

This section contains assessments of the key stressor indicators. Each assessment follows a similar outline. Each begins with a brief summary of that stressor. The color of the title box indicates the level of concern about the stressor (green = low, yellow = moderate, and red = high). The arrow indicates the trend in the stressor and thus the level of concern with respect to the key resources in SAMO. Then the methods are described followed by a description of the data used in the assessment. Results are presented next by status if only current conditions are known or trends if data were analyzed through time. The data and results sections discuss the relevant scales of assessment—regional, park-and-buffer, and park, as described above. Depending on the data, some stressors are reported by their spatial distribution in maps and some as trends in time-series plots. Each assessment then concludes with the identification of emerging issues and data gaps.

Stressor: Housing Development
Summary: Increasing

Housing growth near protected area boundaries decreases effective habitat area, decreases habitat connectivity, increases non-native species introductions, and disrupts ecological processes that maintain biodiversity (Shafer 1999, Hansen and DeFries 2007). This can decrease the probability of native species persistence within protected areas boundaries and constrain management options (Hansen and Rotella 2002, Wiersma et al. 2004, DeFries et al. 2007). Housing growth is influenced not only by population growth but also by demographic factors such as household size and socio-economic factors such as income, preference for residential setting, and seasonal home ownership (Liu et al. 2003). The direct impact of housing depends on the amount of land developed per unit which depends in turn on site level factors like the size of housing units and parcel configuration as well as larger scale factors like the road network, topography, and building regulations. Of the region beyond SAMO's boundary, 34% (2751 km^2) is protected and therefore not developable for residential uses. The majority of these areas are federally owned and managed by the U. S. Forest Service. For the rest of the region that is vulnerable to development, we used multiple U.S. Census Bureau databases to assess year 2000 distribution of housing as well as trends in housing, population, and household size over time. We used a U.S. Geological Survey land cover change database to estimate land development associated with residential housing growth. Future housing density was assessed with EPA high- and low-growth scenarios.

At the regional scale from 1940 - 2000, housing increased by 2 million units, from 839,000 units to 2.8 million. Overall housing density for the region increased from 103 units/km^2 to 351 units/km^2, or from suburban to urban density. Housing units increased by 4% from 1990-2000, population by 7%, and developed land by 1%. Household size increased 2%, from 2.93 people/unit to 2.98 people/unit. While the number of housing units has increased overall, each housing unit accommodated more people and required less developed land in 2000 than in 1990. If household size at the regional scale had stayed fixed at 1990 levels, an extra 47,066 occupied housing units would have been needed to accommodate the increase in population, leading to development of another 18 km^2 of land compared to the actual area developed.

At the park-and-buffer scale, overall housing density was 478 units/ km^2 in 2000, and had grown 4.1%, in the preceding decade. This has likely contributed to air quality issues at SAMO because of atmospheric transport from developed valleys surrounding it. The increase in traffic volume has also fragmented habitat, likely leading to decreased large scale terrestrial connectivity with surrounding protected areas such as Los Padres and Angeles National Forests. EPA growth scenarios project more land in urban and suburban densities by 2050. The high growth-high sprawl scenario would reduce the rural density land in the park-and-buffer region from 9 to 2%.

Most land at the park scale was undeveloped or developed at rural densities in 2000. However, population, housing, and land conversion rates between 1990 and 2000 were higher at the park scale than for the other scales. The amount of urban land per housing unit was also considerably higher. EPA growth scenarios show a strong shift from rural/exurban densities within SAMO toward suburban and urban classes in the coastal canyons by 2050.

Approach
For current status at the region, park-and-buffer, and park scales, we used a year 2000 U.S. Census bureau census block database as the 2010 Census results were not yet available. Census blocks are the highest resolution of census division, but GIS boundary files are not available for censuses prior to 1990. To assess longer term change, we used a database provided by Hammer et al. (2004), which was derived from the U.S. Census Bureau decadal census at partial block group (PBG) scale. Partial block groups are subdivisions of census tracts and are the finest census division for which long term housing data is available. We used PBG housing count data to tabulate the number of houses added to the region from 1940 – 2000. PBGs with >= 50% overlap with the regional extent were extracted from the PBG database and used to generate housing statistics and maps. For the 1990 – 2000 time period, we used census block relationship files to reconcile census block boundaries for the 1990 and 2000 decadal censuses. Reconciling decadal census blocks resulted in a spatial database of modified census blocks (MCB) with counts for population, housing, and occupied housing for 1990 and 2000. MCBs with >= 50% overlap with the regional extent were extracted from the database. Where MCBs intersected with the park-and-buffer analysis boundary, simple area weighting was used to allocate population, housing, and occupied housing units to the park-and-buffer extent. Household size was calculated by dividing population by occupied housing units. To assess change in developed land, we used the USGS 1992 – 2001 National Land Cover Database Retrofit Change Product, a 30m resolution database of land cover change at Anderson Level I thematic resolution. The area of urban land, which ranges in development intensity from industrial/commercial areas to golf courses and other green spaces, was tabulated in each MCB unit in each time period. The amount of urban land per housing unit for 1990 and 2000 was then calculated. Area of public lands and otherwise undevelopable area was calculated using a database of protected areas, PAD-US, maintained by the United States Geological Survey. (See the Appendix for GIS layers generated for the assessment).

Because housing density is such a powerful indicator of a variety of stressors on SAMO's resources, we also explored how housing density might change in the future. The two most relevant existing studies were done through urban growth modeling specifically at SAMO (Syphard et al. 2005) and a national model by EPA (U.S. EPA 2009, Bierwagen et al. 2010). Syphard et al. (2005) modeled growth based on historical growth patterns for scenarios with different maximum slope restriction criteria (25%, 30%, and 60%). Protected areas at the time of the study made up approximately half of the study area. The model did not consider further acquisition of conservation lands, but all unprotected lands were considered available for urban development subject to the maximum slope constraint. This model only classified land as urban or non-urban and did not attempt to predict housing density.

EPA's Integrated Climate and Land Use Scenarios (ICLUS) (U.S. EPA 2009, Bierwagen et al. 2010) modeled change in housing density to the end of the 21st century along storylines that were consistent with IPCC greenhouse gas emission scenarios (Nakićenović and Swart 2000). Housing density was driven by projected population growth. For the high growth, high sprawl A2 scenario, EPA assumed that urban growth would convert vegetated lands, whereas in the low growth, low sprawl B1 scenario, they assumed bare and agricultural areas would be converted first and vegetated lands would only be converted if more land was required. Thus the A2 scenario would eliminate more native vegetation than B1, both because of greater land requirements for the larger population and because of the assumed pattern of land use change.

ICLUS scenarios model 100m grid cells into housing density classes: urban greater than 1000 units/km^2, suburban 147 -1000, exurban 6-147, and rural <6, which is primarily housing in agricultural areas. Projections were modeled by decade from 2010 to 2100. A commercial/industrial class was included but was held constant (3% in the park-and-buffer area, 1% in SAMO) in all time periods. Similarly, public lands were excluded from development in the model, and these lands were held constant over all time periods. The latter figure is much larger than the roughly 50% assumed in the Syphard et al. (2005) model, presumably because of differences in area of protected land at the time of the two models. We limited the assessment to the results for 2010 and 2050 and only for the A2 and B1 scenarios. For the park-and-buffer and the park scales, we calculated the percent area in each housing density class for the two time periods and two scenarios. The 2010 model results were similar enough that only the A2 results are shown for that period. The developers of the ICLUS scenarios caution that they are intended for state or regional to national scale modeling (Bierwagen et al. 2010). Therefore we limit the use of the scenarios here to simple summaries of area by density classes rather than site-specific results.

The NPS landscape monitoring project (NPScape, National Park Service 2011) has developed a suite of measures for all park units using a standard 30-km buffer. NPScape used the same housing density projection data underlying the ICLUS scenarios for developing landcape measures (Svancara et al. 2009). The assessment was redone here with the buffer boundary customized for SAMO.

Data

U.S. Census Bureau, Census 2000 Tiger/Line Files

U.S. Census Bureau partial block group database - Hammer, R. B. S. I. Stewart, R. Winkler, V. C. Radeloff, and P. R. Voss. 2004. Characterizing spatial and temporal residential density patterns across the U.S. Midwest, 1940-1990. Landscape and Urban Planning 69: 183-199. http://silvis.forest.wisc.edu/Library/HousingDataDownload.asp?state=United States&abrev=US

Jantz, P.A. and Davis, F.W. In preparation. Stable Geographic Units for Assessing Housing and Population Change in the United States from 1990 - 2000.

1992 – 2001 National Land Cover Database Retrofit Change Product - Fry, J.A., Coan, M.J., Homer, C.G., Meyer, D.K., and Wickham, J.D., 2009, Completion of the National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit product: U.S. Geological Survey Open-File Report 2008–1379, 18 p.

Protected Areas Database of the United States - http://gapanalysis.nbii.gov/portal/community/GAP_Analysis_Program/Communities/GAP_Projects/Protected_Areas_Database_of_the_United_States

Future housing-density scenarios (ICLUS) - U.S. EPA. 2010 and 2050. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=205305.

Status

Regional scale:

In 2000, overall housing density was 351 units/km^2, which can be considered urban. However, housing is heterogeneously distributed in the region with the densest and most extensive settlements in the southeastern portion comprised of cities in the greater Los Angeles area (Figure 7). Twenty-two percent of the region was urban, 11% was suburban, 8% was exurban, and 12% was rural. The rest of the area was settled at densities lower than 1 unit/km^2 (Figure 6).

Park-and-buffer scale:

In 2000, overall housing density at this scale was even greater at 478 units/km^2, with 11% of the area settled at rural densities and 13% of the area settled at exurban densities. Urban and suburban areas covered the greatest proportion of the area at 29% and 27% respectively.

Park scale:

Most areas within SAMO's administrative boundary are rural or undeveloped, reflected in an overall housing density of 29 units/km^2. Suburban and exurban area covered 27% and 17% of the area respectively.

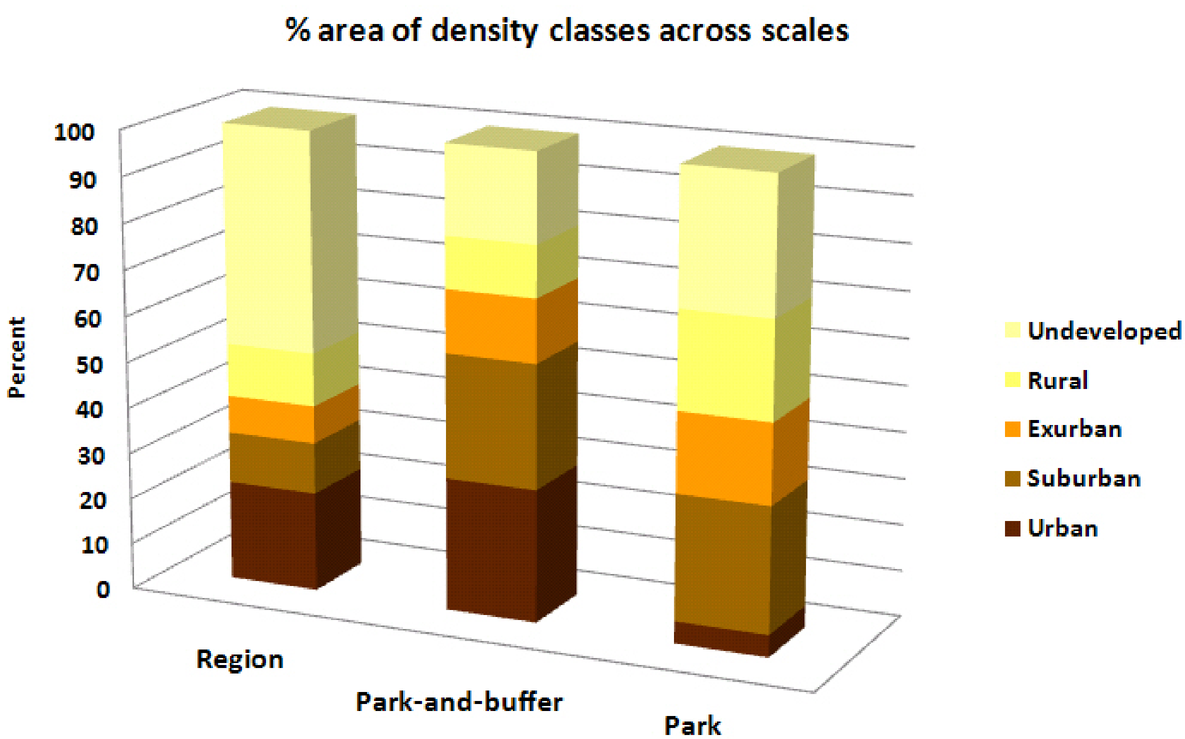


Figure 6. Proportion in each housing density class in 2000 by reference scale. Colors correspond to Figure 8 and Figure 9. Following the U. S. Census classification, Undeveloped < 1 unit/km, Rural = 1- 6 units/km^2, Exurban = 6 - 25 units/km^2, Suburban = 25 - 250 units/km^2, and Urban ≥ 250 units/km^2.

Trends and Projections

Regional scale:

About 2 million housing units were added to the area from 1940 - 2000 but were distributed unevenly throughout the region. The rate of growth of housing units decreased over time (Figure 7). Over half a million housing units were added between 1950 and 1960 whereas a little over 100,000 were added from 1990 to 2000. Areas classified as urban covered 13% of the region in 1940 (Figure 8) but received two-thirds of new housing units by 2000. Suburban areas also received a disproportionate share of housing units, covering 12% of the study area but receiving 24% of new housing units. While undeveloped and rural lands received small proportions of new housing units, 1% and 2% respectively, the 67,000 housing units added to these sparsely settled areas was enough to transition many of them to exurban and suburban densities. The most intense growth in areas that were rural and undeveloped in 1940 occurred just north of SAMO's administrative boundary, around Simi Valley, Oak Park, and Thousand Oaks (Figure 9).

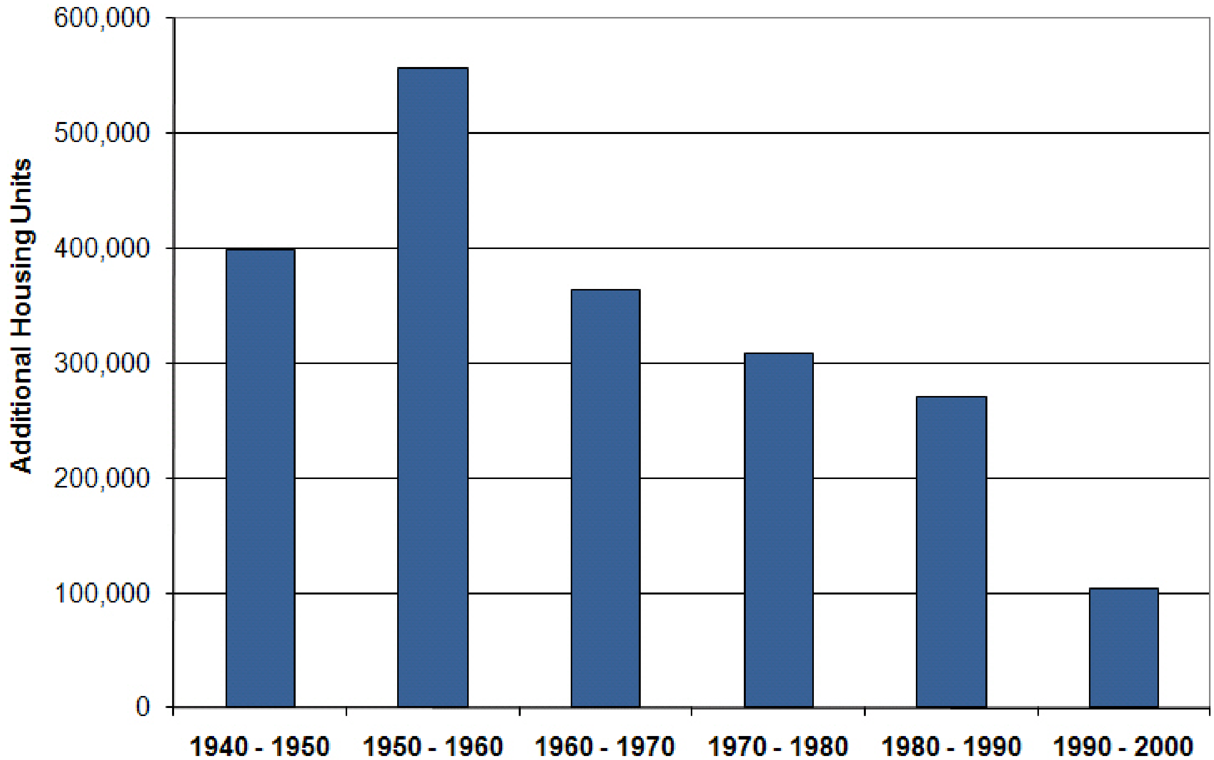


Figure 7. Housing units added per decade at the regional scale.

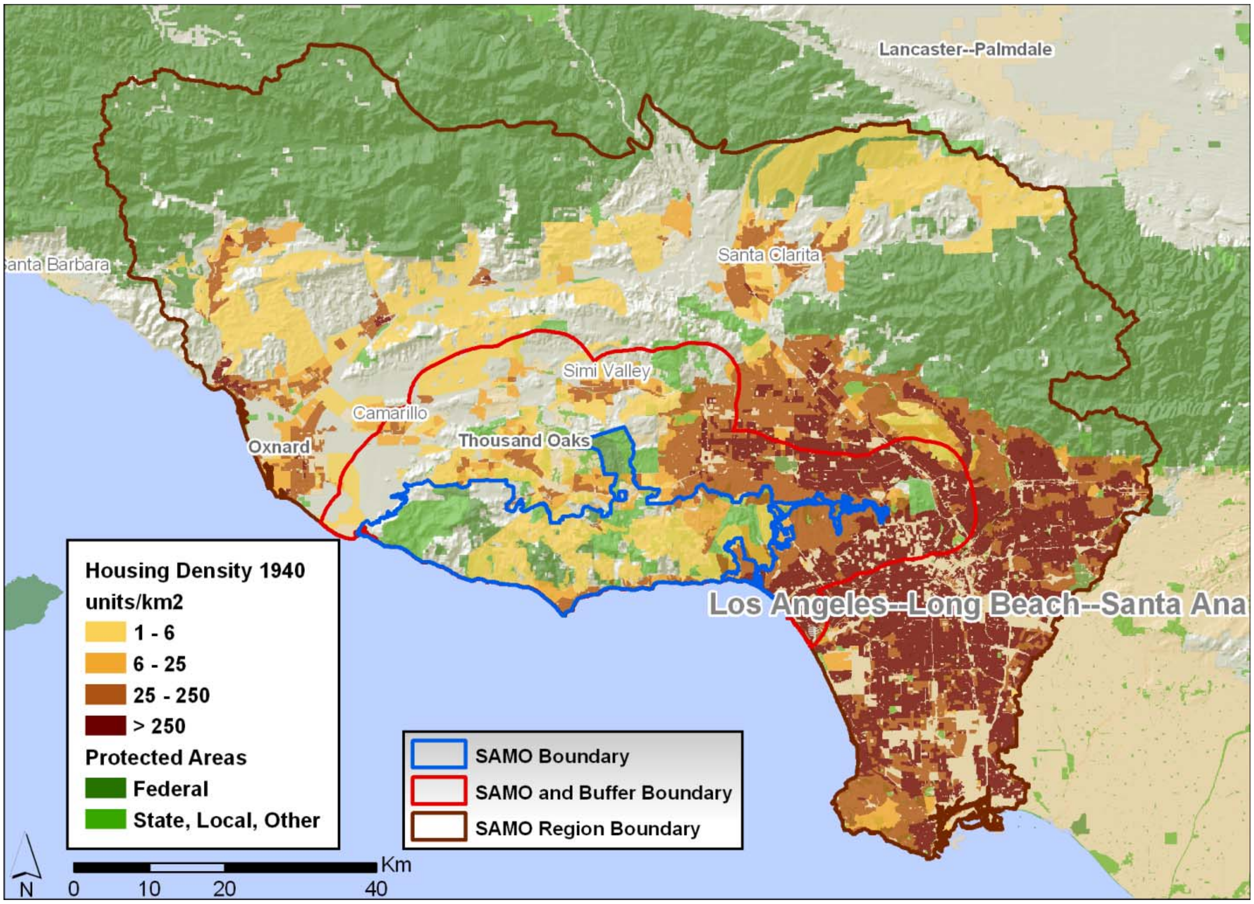


Figure 8. Housing density in 1940 derived from partial block group data.

From 1990 – 2000 at the regional scale, housing increased by 3.65%, while population increased by 7.02% (Table 6). Household size increased 1.73% from 2.93 people/unit to 2.98 people/unit, and the amount of developed land increased 1.32% from 2906 km^2 to 2944 km^2. Developed land per housing unit decreased 3.53% from 0.11 ha/unit to 0.10.

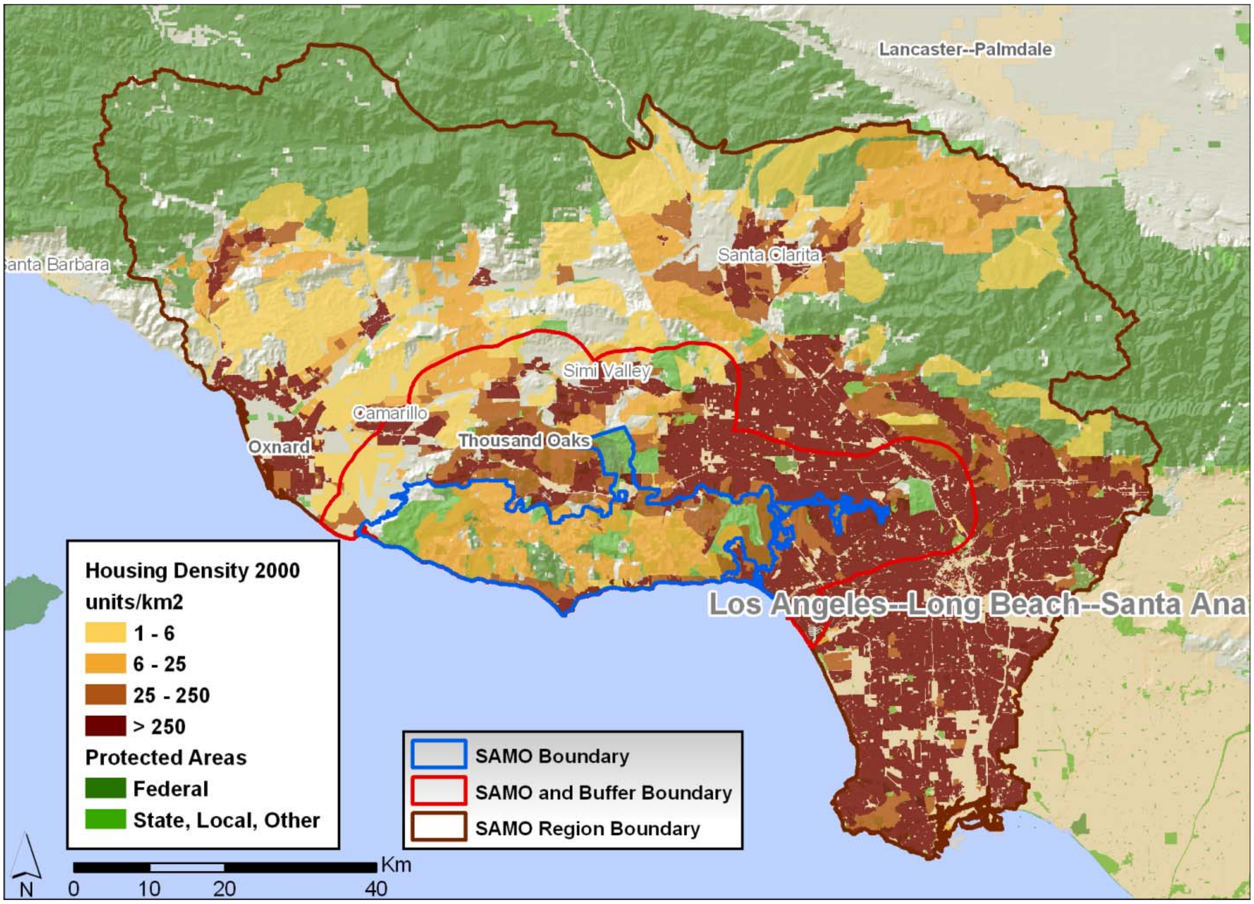


Figure 9. Housing density in 2000 derived from census block data.

Table 6. Percent change in census and land use variables between 1990 and 2000 at region, park-and-buffer, and park scales.

Scale	Population	Housing Units	Occupied Housing Units	Household Size	Developed Land	Developed Land Per Unit
Region	7.0	3.7	5.2	1.7	1.3	-3.5
Park-and-buffer	6.9	4.1	6.7	0.2	1.9	-2.1
Park	17.7	10.5	14.6	2.7	2.0	-7.7

<u>Park-and-buffer scale:</u>

From 1990 – 2000, population and housing increased at the park-and-buffer scale by 6.94% and 4.10%, respectively, a rate comparable to that of the regional scale. Household size increased 0.24% from 2.46 to 2.47 people/unit. The amount of developed land increased 1.87% from 936 km^2 to 954 km^2. Developed land per housing unit decreased from 0.10 ha/unit to 0.098.

The ICLUS scenarios for 2050 both show a trend toward greater housing density, but they differ somewhat in the spatial patterns because of their underlying assumptions (Figure 10). Both the A2 (high growth) and B1 (low growth) scenarios show a large increase in area of urban housing density by 2050. Much of that comes from intensification in areas currently in the suburban class. Suburban area also increases, especially for B1 that encourages infill. Rural area decreases, especially in A2 that fosters exurban development. Note that in ICLUS, the commercial/industrial class (3%) and undevelopable public lands (38%) are held constant over time and are not displayed in the bar chart. Also note that the density classes are different than those shown in Figure 8 and Figure 9.

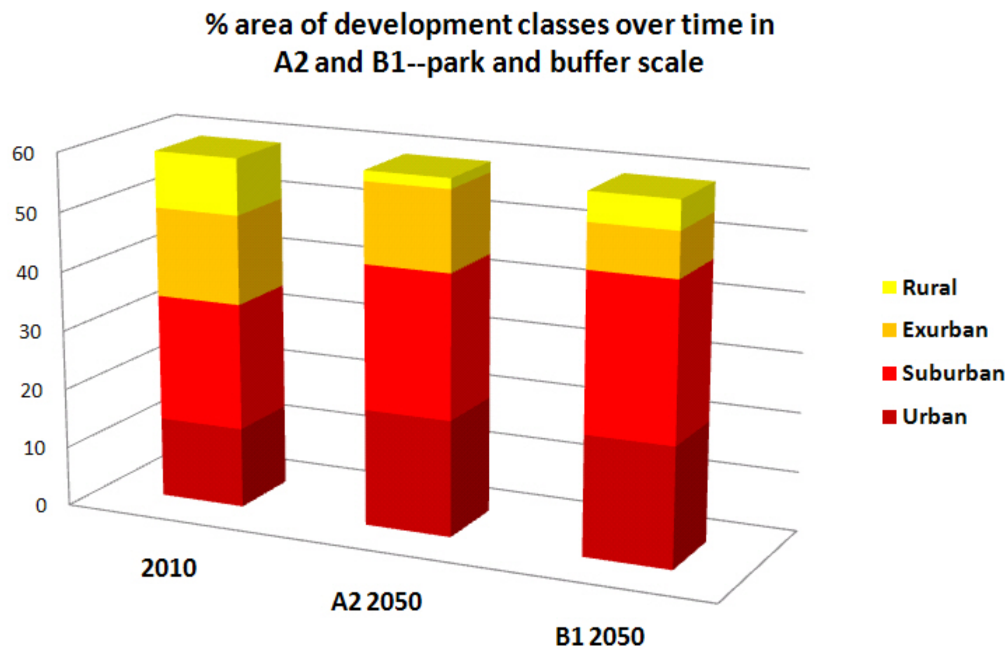


Figure 10. Housing density changes in ICLUS future growth scenarios at the park-and-buffer scale. An additional 3% of commercial/industrial land and 38% of undevelopable public land in all time periods and scenarios is not shown. Following the ICLUS classification, Rural < 6 units/km^2, Exurban = 6 - 147 units/km^2, Suburban = 147 - 1000 units/km^2, and Urban ≥ 1000 units/km^2. Note the difference from the Census classes.

<u>Park scale:</u>

At the park scale from 1990 – 2000, population and housing increased by 18% and 11% respectively, a higher rate of growth than at the other two scales. Developed land increased by 2% from 100 km^2 to 102 km^2. Developed land per unit declined by 7.7% from 0.43 ha/unit to 0.39 ha/unit, which is still four times as large as the regional and park-and-buffer scales.

The 2050 urban footprint modeled by Syphard et al. (2005) increased from 11% of SAMO in 2000 to 26%, 35%, and 47% respectively for maximum slope restriction criteria of 25%, 30%, and 60%. Nearly all unprotected land was projected for development with the 60% slope limit. In all scenarios, flatter lands tended to be developed before steeper lands. Growth rates declined to near zero by 2040 as most available land with slopes below the limits became developed.

The vast majority (85%) of SAMO was considered undevelopable in the ICLUS scenarios, whereas only 1% is commercial/industrial. The remaining 14% shows a dramatic shift toward higher housing densities in both scenarios (Figure 11). In both scenarios, the urban class doubles in area, although it only expands to 1% of SAMO. Suburban area triples in A2 in the coastal canyons at the expense of rural and exurban classes and doubles in B1 mostly between Malibu Canyon Road and Topanga Canyon Boulevard.

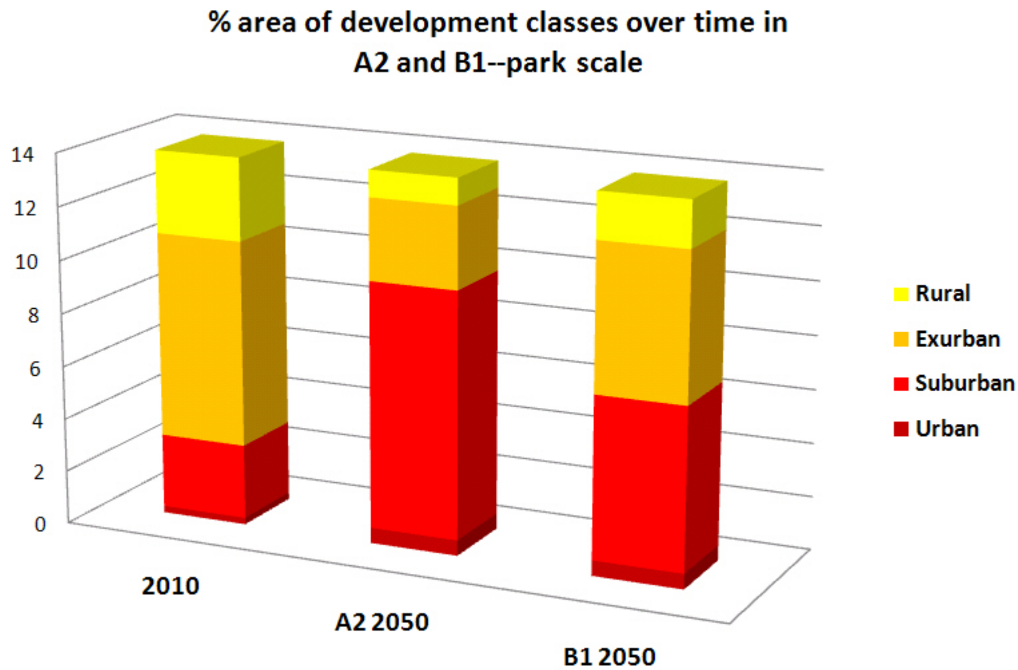


Figure 11. Housing density changes in ICLUS future growth scenarios at the park scale. An additional 1% of commercial/industrial land and 85% of undevelopable public land in all time periods and scenarios is not shown. Following the ICLUS classification, Rural < 6 units/km^2, Exurban = 6 - 147 units/km^2, Suburban = 147 - 1000 units/km^2, and Urban ≥ 1000 units/km^2. Note the difference from the Census classes.

Emerging Issues

Secondary exposure of non-target wildlife populations to anticoagulant rodenticides in and around developed areas has been documented in and around SAMO (Riley et al. 2007). In the absence of regulatory actions restricting the use of rodenticides and other toxicants, wildlife exposure to these toxicants will remain an issue at SAMO although more research is needed to determine population level effects on susceptible species. Development also subjects wildlife to predation from domestic animals (Lepczyk et al. 2003), fragments habitat for wide ranging carnivores (Riley et al. 2006), and exposes wild animal populations to infectious diseases, such as canine distemper, harbored by domestic animals (Daszak et al. 2000). Irrigation in landscaped areas within SAMO's boundaries combined with increases in built surfaces has increased runoff in summer months. Further residential development within SAMO's administrative boundary will continue to alter aquatic habitats and may promote the growth and spread of invasive aquatic species. Other issues include increasing light pollution, noise pollution, and an increase in the number of houses and people in areas of high wildfire risk.

Data Gaps

We are limited in our knowledge of housing distribution below the scale of census units. This is especially a problem in less densely settled areas where partial block groups and modified census blocks can span 1000's of hectares. Finer resolution data would improve our estimates of the areas occupied by different housing density classes. County assessor records for Los Angeles and Ventura Counties or high resolution aerial photos could be used to locate lower density development where the resolution of census data is coarse. The NLCD retrofit change product, by design, does not depict areas of change smaller than a few pixels, limiting the contribution of low density residential development to developed area calculations.

Key references

DeFries R., Hansen A., Turner B. L., Reid R. and Liu J. G. 2007. Land use change around protected areas: Management to balance human needs and ecological function. Ecological Applications 17: 1031-1038.

Hammer, R. B. S. I. Stewart, R. Winkler, V. C. Radeloff, and P. R. Voss. 2004. Characterizing spatial and temporal residential density patterns across the U.S. Midwest, 1940-1990. Landscape and Urban Planning 69: 183-199.

Hansen, A. J. and Rotella J. 2002. Biophysical factors, land use, and species viability in and around nature reserves. Conservation Biology. 16: 1112 – 1122.

Liu J. G., Daily G. C., Ehrlich P. R. and Luck G. W. 2003. Effects of household dynamics on resource consumption and biodiversity. Nature 421: 530-533.

Shafer, C. L. 1999. National park and reserve planning to protect biological diversity: some basic elements. Landscape and Urban Planning 44: 123 – 153.

Stressor: Road distance and accessibility
Summary: Baseline

Roads and, to a lesser degree, trails facilitate a variety of environmental impacts on the landscape in addition to their intended benefits (Forman et al. 2003). Their presence alters hydrologic processes and provides disturbed sites for invasions of non-native plant species. Their use can impact wildlife through habitat fragmentation, direct mortality, and behavioral modification. Increased access also increases the risk of wildfire ignitions and release of chemical contaminants and air pollutants. Four indicators related to overall influence of the existing road and trail infrastructure were assessed: mean distance from roads, accessibility or travel time, effective mesh size, and traffic volume. Mean distance to nearest road in SAMO is 517 m (median = 250 m); mean travel time from where main roads cross the park boundary (i.e., “entrances”) is just less than 0.5 hours (median = 0.3). The effective mesh size of SAMO is 34.21 km^2, or the equivalent of SAMO being divided into approximately 18 equal-sized blocks of contiguous land. Some sections of major highways carry more than 300,000 vehicles per day.

Approach

Because SAMO is adjacent to a major metropolitan area and is perforated with pockets of development, it is dissected with highways, residential streets, and recreational trails. Four indicators related to overall influence of the existing road and trail infrastructure were assessed: mean distance from roads, accessibility or travel time, effective mesh size, and traffic volume. The exposure to risk of ecological impacts associated with roads is often a function of (or within a specific) distance to the nearest road (Riitters and Wickham 2003). This assessment extracted the main roads in and near SAMO, excluding fire roads or roads not open to the public such as in Point Mugu State Park and the unpaved portion of Mulholland Drive. We applied standard GIS operations to calculate Euclidean or as-the-crow-flies distance to the nearest road (DTR) of 25 meter grid cells. Results were summarized as the mean and median distance for all of SAMO, and for subareas associated with type of ownership (NPS, state parks, conservancies, local and regional parks, and private) or general land cover types. The cumulative proportion within different distance zones was summarized for SAMO and compared to results from a national assessment by Riitters and Wickham (2003).

The degree to which areas of SAMO are accessible is related to their exposure to human impacts, such as wildlife road mortality or wildfire ignitions. Accessibility, defined as the one-way travel time for an average visitor to any location within a park, is increasingly used to represent intensity of human use and therefore exposure to stressors (Theobald et al. 2010). For this assessment, we applied the approach of Theobald et al. (2010) to model accessibility in terms of three phases—travel on roads from the park boundaries (i.e., “entrances”) to trailheads, travel on trails accounting for along-trail slope, and cross-country travel from nearest trail, also accounting for slope and the permeability of land cover. Minor modifications to the original methods were required. The original case study was in Rocky Mountain National Park (ROMO), which had a small number of controlled entrances on roads where the destination of most motorists was the park (Theobald et al. 2010). SAMO, in contrast, is embedded in an urban matrix and traversed by major highways with as many as 300,000 vehicles per day, many of which are not visiting the NRA for recreational purposes. For accessibility analysis at ROMO, the access time was calculated as the travel time from each entrance weighted by their estimated number of visitors.

Because of the different circumstances at SAMO (lots of entry points and many non-visitors on the road system), we decided not to do a visitor-weighted averaging of travel time. Travel was modeled from the boundary of SAMO at nine entry points on State Highways 1, 23, and 27, US Highway 101 and Interstate 405, and several local roads. We chose to omit access points inside SAMO such as at major crossroads along Pacific Coast Highway (State Highway 1) at Kanan, Malibu Canyon, and Topanga. Travel speeds in the streets geodatabase were used. It was assumed that visitors could only access off-trail areas from specific trailheads and not along the entry roads. Where a route was mapped as both a road and trail, precedence was given to the road label. The main exception was that the unpaved portion of Mulholland Drive, which is closed to vehicles, was classified as a trail. Walking speed is typically 5 km/hr on flat ground. The effect of slope on walking speed was based on the equation of Tobler (1993). Walking speed can also be impeded by the density of vegetative cover. Therefore a permeability factor (Table 7) was applied. Low density vegetation such as grassland that would not seriously impede cross-country walking has high permeability. Dense chaparral is very difficult to walk through and therefore has low permeability. We assumed that urban and agricultural land were privately owned and therefore not available to public access. NPS staff adapted factors developed for ROMO (Theobald et al. 2010) to fit the vegetation of SAMO. As with DTR, accessibility results were summarized as the mean and median travel time for SAMO and for categories of ownership and general land cover types. The cumulative proportion within different travel times was summarized for SAMO. Another difference from the ROMO assessment was that the SAMO assessment was based on the full existing road and trail infrastructure. In ROMO, accessibility was also assessed without trails and without roads or trails beyond the park entrances to determine the relative impacts. At SAMO, the roads are essential for private access to residences as well as for NRA visitors. That is, the roads would exist even in the absence of a park unit.

Table 7. Permeability of cover types for cross-country travel (adapted from Watts et al. 2003, Theobald et al. 2010).

Generalized cover type	Permeability value
Grassland	0.9
Coastal scrub	0.7
Chaparral/other shrubland	0.1
Woodland	0.8
Riparian/wetland	0.5
Agriculture	0.0
Urban/developed	0.0
Sparse/Non-Vegetated	0.8

Many landscape metrics have been developed to quantify the degree of fragmentation. One particularly useful metric is the effective mesh size (Jaeger 2000), which determines the probability that two points in a landscape are connected, i.e., not separated by roads or development. A small mesh size indicates a highly fragmented landscape, whereas the index can be as large as or larger than the study area if it is completely unfragmented. The cross-boundary connections method (CBC, Moser et al. 2007)) is an improvement over the original method, which artificially cut patches at the administrative boundaries. The calculations are based entirely on the area of “patches.” All entrance roads from the accessibility analysis were buffered by 10 meters from their centerlines and overlaid with the vegetation layer. Road buffers and urban and agricultural polygons were assigned a value of 0, while all other land cover types were assigned a 1. This layer was dissolved to aggregate land cover polygons into patches. The area of patches within the NRA and the full patch size were calculated with GIS operations.

Data on traffic volume over time was compiled from the California Department of Transportation (CalTrans) for 1992, 1995, 2000, 2005, and the most recent year available, 2009. Data are only available for state and federal highways for segments between major intersections. These data were supplemented with data for county highways and Mulholland Highway for 1998 (National Park Service 2002). (See the Appendix for GIS layers generated for the assessment).

Data

Park scale:

Roads: streets_ac geodatabase, containing the 2003 Tele Atlas Dynamap Transportation version 5.2 product, extracted for SAMO for the NPScape program. For this assessment, the main public roads in and near SAMO were extracted. The database contained a field for speed.

Traffic volume data: California Department of Transportation, online at http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/ as Excel files by year for state and federal highway segments. Supplemented with data from the SAMO General Management Plan & EIS (National Park Service 2002) for major local roads for 1998.

Trails: Public Trails.shp and Public Trailheads.shp from SAMO. These were modified to exclude trails that were also counted as roads in the entrance roads layer. Some editing was also performed to ensure that trails connected to entrance roads.

Slope: The 1/3 arc-second digital elevation model from the National Elevation Dataset was projected and resampled to 25 m cells and then converted to slope in degrees.

Land cover: Vegetation.shp shapefile from SAMO, mapped to the alliance/association classification level by Aerial Information Services in 2007 using color air photos from 2001. Cover classes were aggregated to major types for the accessibility assessment and to patches for the fragmentation assessment.

Land ownership: Tracts_Jun2005 from SAMO.

Status

Park scale:

The average distance to a road within SAMO is only 517 m (median = 250 m), with a maximum distance of 4.1 km in Point Mugu State Park and Topanga State Park (Table 8). Generally the state parks are the most remote (Figure 12). NPS land is very close to the NRA average. Private land, much of which is residential, averages half of the mean distance of the overall NRA, while the large state parks with limited road access to their interiors average twice the distance. Thirty percent of the NRA is within 100 m of a road, 83% is within 1 km, and 95% is within 2 km (Figure 13). This is similar to the national average, where 82% was within 1 km of a road (including unpaved roads) (Riitters and Wickham 2003). Grassland cover lies much farther from roads than the average; woodland is the only cover type less than average distance. Urban and agricultural land use types are much less than the average (not shown).

Table 8. Distance to nearest road (meters) and travel time (hours) to locations within SAMO from NRA "entrances."

	Averaging Unit	Mean (median) distance to nearest road (m)	STD distance (m)	Mean (median) travel time from entrance (hr)	STD travel time (hr)
SAMO		528 (254)	686	0.49 (0.30)	0.49
Ownership	NPS	548 (430)	463	0.53 (0.42)	0.39
	State Parks	1123 (838)	969	0.86 (0.72)	0.58
	Conservancies	479 (316)	488	0.43 (0.30)	0.39
	Local agencies	196 (145)	179	0.24 (0.20)	0.19
	Private/other	270 (125)	396	0.34 (0.22)	0.41
Ecological systems	Grassland	677 (353)	763	0.58 (0.33)	0.59
	Coastal scrub	605 (301)	785	0.59 (0.37)	0.56
	Chaparral/other shrubland	617 (353)	696	0.55 (0.35)	0.50
	Woodland	430 (180)	621	0.39 (0.23)	0.41
	Riparian/wetland	553 (226)	772	0.50 (0.33)	0.48

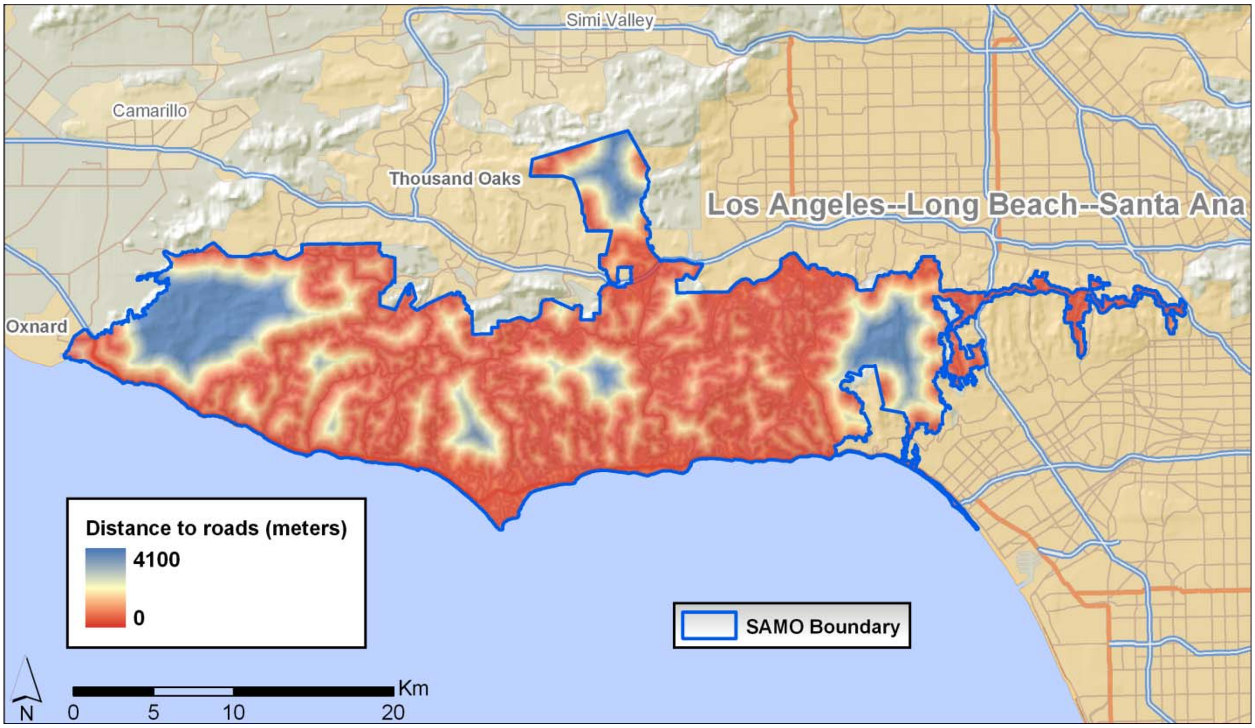


Figure 12. Map of distance to roads (DTR) for SAMO.

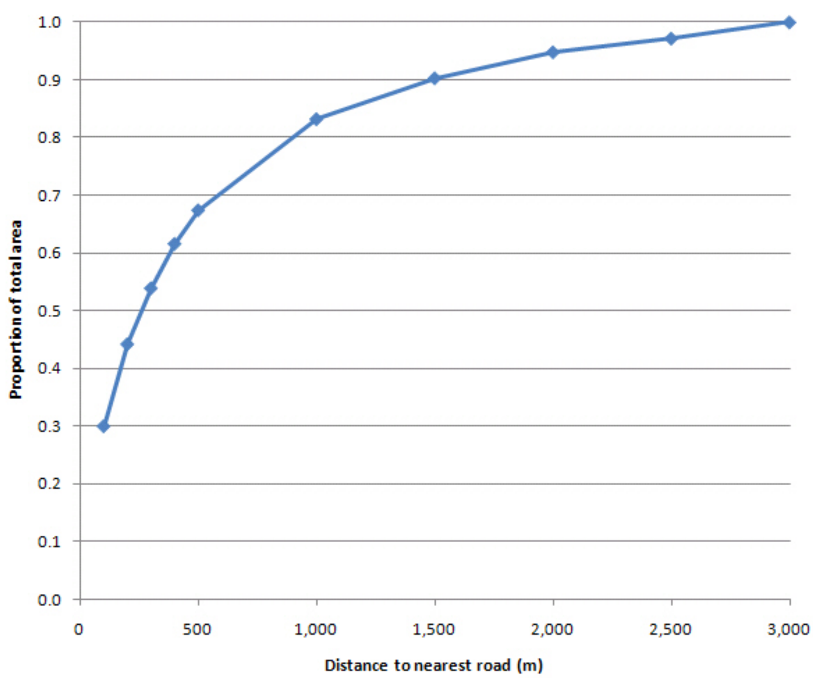


Figure 13. Cumulative proportion of the total area of SAMO located within specified distances from the nearest road.

Accessibility, measured as travel time from one of the park entrances, averaged just under ½ hour (Table 8), although the remotest portion of Point Mugu State Park is estimated at more than 2.5 hours (Figure 14). For comparison, accessibility in Rocky Mountain National Park averages 3.5 hours (Theobald et al. 2010) and the smaller Pinnacles National Monument averages 0.9 hours (Davis et al. 2011). As with distance to roads, private land and local agency lands have lower than average access times. State parks have longer than average because of the greater reliance on trail access to the backcountry there. Only 14% of SAMO is greater than 1.0 hour from an entry point as defined here (Figure 15). Woodland is the only cover type that is dramatically more accessible than park average, with an average travel time of just 0.39 hours or 23 minutes (Table 8). This seems to be caused by the pattern of woodland in the canyons, where much of the road and trail infrastructure is also located.

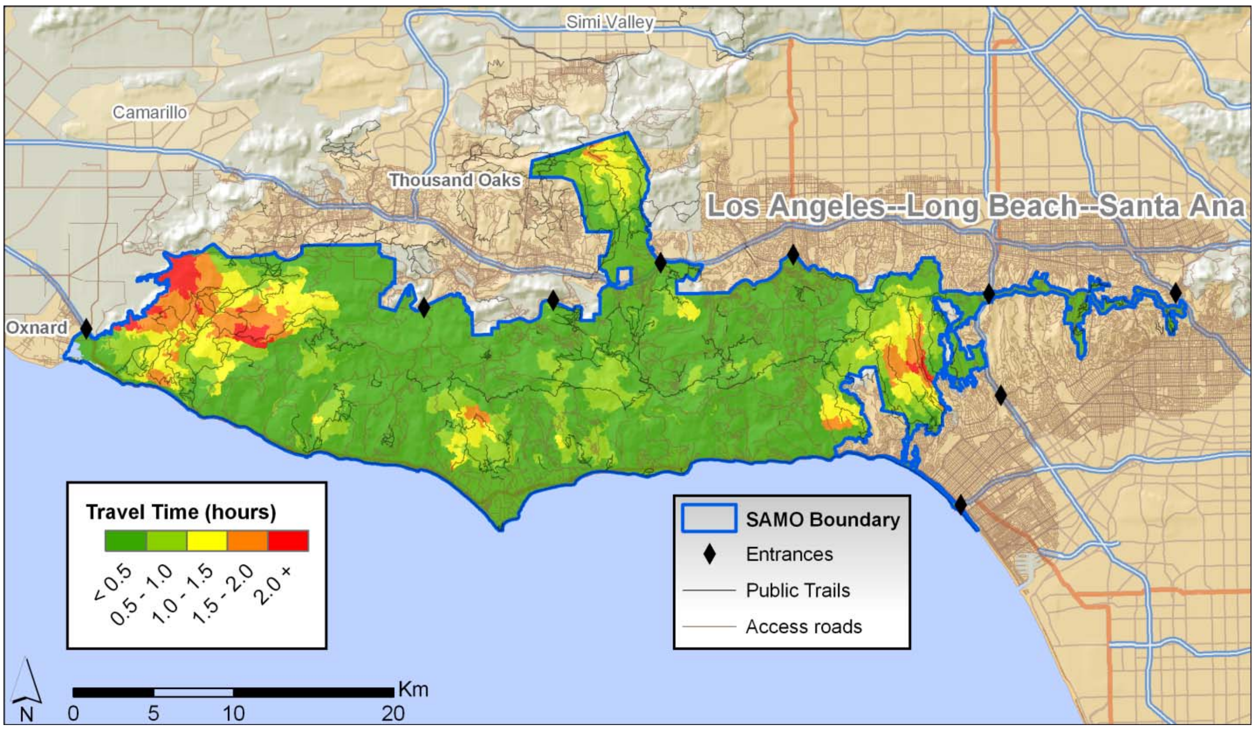


Figure 14. Map of travel times to locations in SAMO over roads, trails, and off-trail.

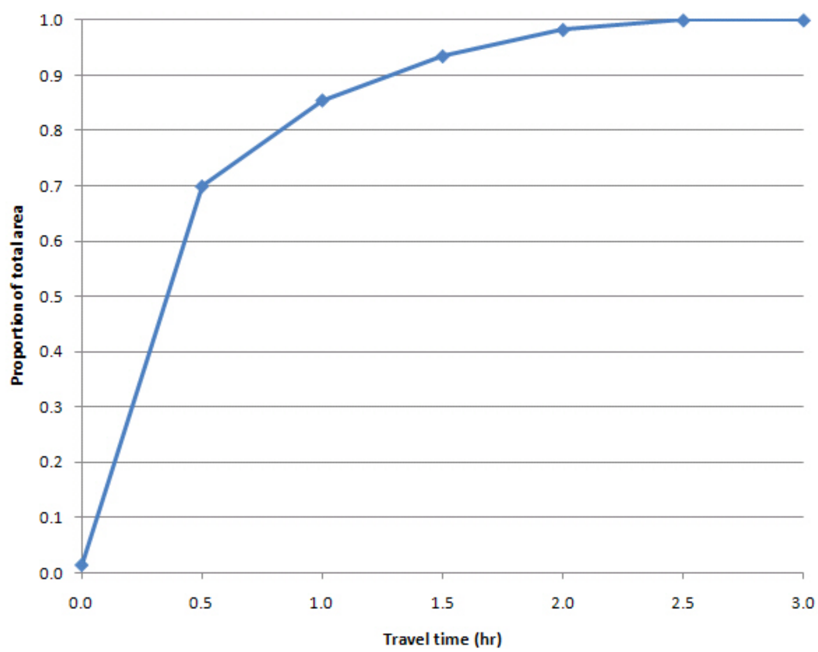


Figure 15. Cumulative proportion of the total area of SAMO located within specified travel times.

The effective mesh size of SAMO using the CBC method is 3421.02 hectares or 34.21 km^2. Alternatively, this can be thought of as SAMO being divided into a mesh of approximately 18 equal-sized blocks of contiguous land on average, or that there is a 5.5% chance that any point in SAMO is connected with any random point in a patch that lies all or partially within the park unit. There has not been much experience with this indicator to provide context for interpretation. However, for reference, Point Mugu State Park is 5648 hectares and Malibu Creek State Park is 2558 hectares. So the average sized mesh or block lies between the sizes of these two parks.

Traffic volume in SAMO ranges from quiet rural roads to some of the busiest freeways in the country (Figure 16). Sections of Highway 101 and Interstate 405 average more than 300,000 vehicles per day. The western end of Mulholland Highway averages around 150 vehicles per day (National Park Service 2002). Of the roads that bisect SAMO between Highway 1 (Pacific Coast Highway) and Highway 101, Malibu Canyon handles 22,800 vehicles daily, SR 27 (Topanga Canyon) averages 14,200, Kanan Dume Road averages 10,700, and SR 23 Westlake Boulevard and Decker Road) carries the least at around 1000 vehicles a day. The time series of AADT data from CalTrans indicates large variation over time on the roadways. Some roads have increased dramatically, such as sections of Highway 118, while others, such as Highway 101, have grown little or even declined in recent years. We are unsure if the decline is due to greater use of public transportation or telecommuting or reflects increasing gridlock and decrease of the Level of Service that allows fewer vehicles to pass.

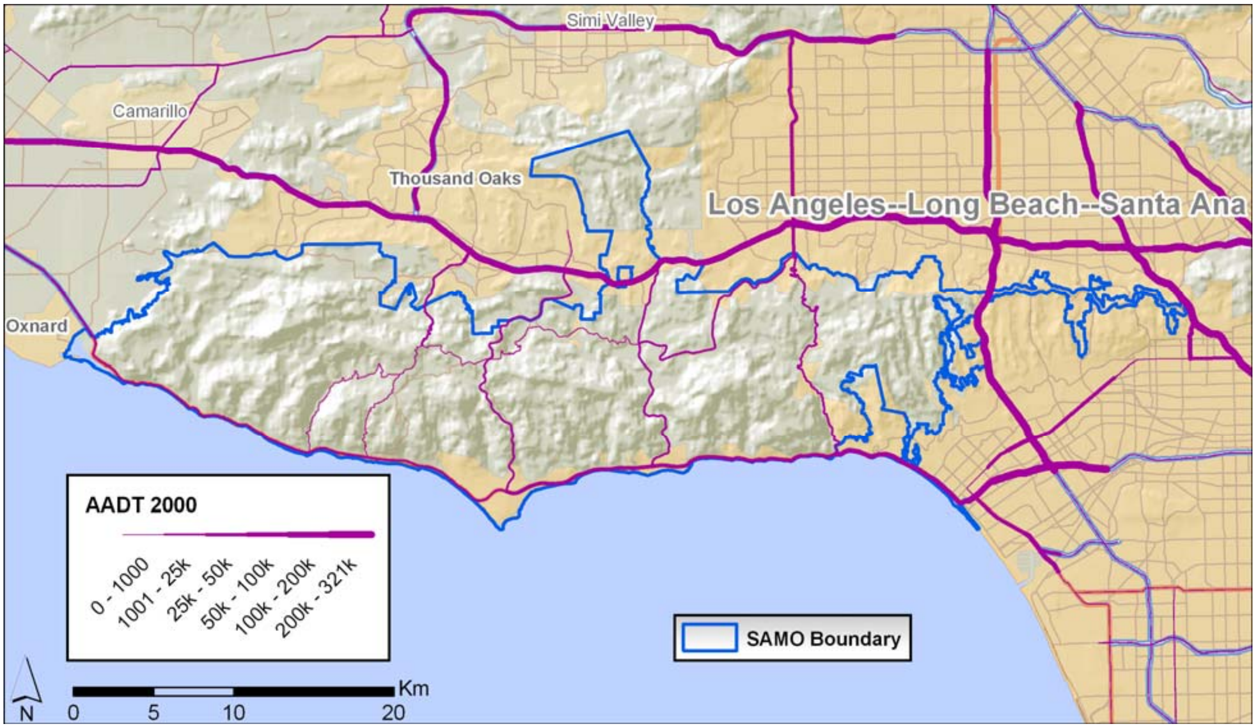


Figure 16. Map of traffic volume (Annual Average Daily Traffic) circa 2000 on major roads and highways.

Several recent studies have investigated whether wildlife species cross roads and highways in SAMO or if their movement behavior is influenced. Tigas et al. (2002) found that bobcats and coyotes preferentially crossed roads rather than using culverts, although they did use culverts where traffic volume was high. Many species do use culverts and undercrossings on major highways, but some species chose crossings with a larger proportion of natural habitat around the entrances (Ng et al. 2004). Riley et al. (2006) found bobcats and coyotes do cross busy freeways such as Highway 101, but apparently do not reproduce often as the populations on opposite sides are genetically differentiated from low gene flow. Vehicle collision caused 50% of the mortality of a set of radio-collared bobcats and coyotes (Tigas et al. 2002).

Emerging Issues

The road and trail infrastructure within SAMO is already in place, with no plans for dramatic changes in access (National Park Service 2002). Some further incursion for access to privately-developed inholdings may still occur. NPS has no control over the traffic volume on major roads and highways within SAMO. Such use may continue to increase with the attendant impacts on natural resources. Vehicle collisions are already a major source of mortality for mesocarnivores and other wildlife. Freeways isolating SAMO from other areas are apparently limiting gene flow even for mobile wildlife species with large home ranges, and signs are being detected of genetic differentiation between populations north and south of Highway 101. Even individuals who manage to cross this barrier are not contributing significantly to gene flow. Therefore future traffic increases are likely to increase stresses on wildlife.

Data Gaps

GIS data on the location of roads and trails are good. The permeability factor to adjust off-trail walking speed related to land cover were not available for SAMO, so data from other western states were adapted with local knowledge of the vegetation. We assume the results would not change substantially if more accurate permeability data were developed specifically for SAMO.

Key references

Moser, B., J. Jaeger, U. Tappeiner, E. Tasser and B. Eiselt. 2007. Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. *Landscape Ecology* 22: 447-459.

Riitters, K. H. and J. D. Wickham. 2003. How far to the nearest road? *Frontiers in Ecology and the Environment* 1: 125–129.

Theobald, D. M., J. B. Norman and P. Newman. 2010. Estimating visitor use of protected areas by modeling accessibility: A case study in Rocky Mountain National Park, Colorado. *Journal of Conservation Planning* 6: 1-20.

Stressor: Pesticides affecting amphibians

Summary: No significant trend of airborne pesticides

SAMO lies east and south of the Oxnard Plain, an important center of agriculture in California. Hundreds of thousands of kilograms of pesticides are applied annually to crops, placing downwind aquatic ecosystems of SAMO at risk of pesticide exposure. Upwind pesticide use is a significant factor in declines of several amphibian species in California including the California red-legged frog (*Rana aurora draytonii*), foothill yellow-legged frog (*R. boylii*), Cascades frog (*R. cascadae*), and the mountain yellow-legged frog (*R. sierrae*) (Davidson 2004, Davidson and Knapp 2007). Pesticides also cause declines in phytoplankton and zooplankton at low concentrations, disrupting aquatic ecosystems and increasing amphibian mortality (Relyea 2009). We georeferenced pesticide use reports to Public Land Survey System sections to calculate the weight of pesticide active ingredient applied from 1990 – 2007 for those known to affect amphibians at regional, park-and-buffer, and park scales. We differentiated by three general pesticide application methods: aerial spray, ground, and other. At the regional scale, pesticide use increased by 126%, from 409,000 kg of active ingredient in 1990 to 924,000 kg in 2007. At this scale pesticide application levels steadily increased beginning in1998 and leveled off in 2005. At the park-and-buffer scale, the amount applied increased by 122%, from 149,000 kg to 332,000 kg. At this scale, pesticide application levels increased steadily beginning in 1995, experienced a sharp increase in 2003 and leveled off in 2005. At the park scale, in contrast, pesticide applications decreased by 88%, from 16,173 kg in 1990 to 1866 kg in 2007.Ground applications made up the majority of pesticide applications for all scales and increases in ground applications were responsible for most of the observed trend. Airborne applications, which are of greater concern, were relatively steady. In the absence of direct empirical evidence of pesticides in aquatic habitats or amphibian tissue in SAMO or a mechanistic model of possible pesticide transport into the park, it is unknown what level of impact if any that pesticides are having on amphibians.

Approach

Current NPS air and water quality monitoring efforts at SAMO do not test for pesticides. The Western Airborne Contaminants Assessment Project monitored legacy and contemporary pesticides from 2002 – 2007 in several western U.S. park units but SAMO was not included. In the absence of park level pesticide contamination data, it was necessary to use outside data sources to assess this stressor. The California Department of Pesticide Regulation requires users to record the type and quantity of pesticide applied in agricultural settings (including parks, golf courses, cemeteries, rangeland, pastures, and along roadside and railroad rights-of-way), and the one mile square Public Land Survey System (PLSS) section where the application occurred. After associating each pesticide application record in the Pesticide Use Reports with a coverage of PLSS sections in a GIS, we calculated application rates for each PLSS section in 2007 (the last year for which data were available at the time of the analysis) for spatial analysis and the total amount of active ingredient applied at regional and park-and-buffer scales from 1990 – 2007 for temporal analysis. Pesticide Use Reports are available from 1974 but the 17 year period reported here was judged sufficient to show the trend in this stressor. Although pesticides affect a broad range of taxa and ecosystems, to focus the assessment we used a subset of 48 pesticides determined by the U.S. Environmental Protection Agency (EPA) to have adverse effects on a federally threatened species, the California Red-legged frog (*Rana aurora draytonii*), or its terrestrial and aquatic habitat. Many of these pesticides have also been shown to negatively affect other native amphibians and components of aquatic ecosystems. Because there is strong evidence of long-range transport (tens of kilometers) of currently used pesticides from agricultural valleys to adjacent mountain ranges in California, we assessed applications of the 48 EPA identified pesticides at the regional, park-and-buffer, and park scales (LeNoir et al. 1999).

Data

Regional, park-and-buffer, and park scales:

Compressed text files of statewide Pesticide Use Reports for individual years were downloaded from the California Department of Pesticide Regulation ftp site, ftp://pestreg.cdpr.ca.gov/pub/outgoing/pur_archives/.

Pesticides determined to have adverse effects on the California red-legged frog were identified from effects determinations published by the EPA. http://www.epa.gov/oppfead1/endanger/litstatus/effects/redleg-frog/

Public Land Survey System (PLSS) section GIS coverages for California are maintained by the Bureau of Land Management (BLM) and can be downloaded from http://www.blm.gov/ca/gis/.

Status

Regional scale: Most pesticide applications were restricted to low elevation agricultural lands in the Oxnard Plain and the Santa Clara Valley to the northwest of SAMO (Figure 17). In 2007, mean pesticide application rate on sections where it was applied in the region was 882 kg/km^2 (5034 lbs/mi^2) and a maximum 22,051 kg/km^2 (125,907 lbs/mi^2). The highest application rates were in the Oxnard Plain, roughly 10 km away from the administrative boundary. Pesticide application rates in the Oxnard Plain are similar in magnitude to those of California's Central Valley where studies have attributed amphibian population declines in Yosemite and Sequoia/Kings Canyon National Parks to regional pesticide use (Davidson 2004).

Park-and-buffer scale: The mean pesticide application rate was 966 kg/km^2 (5514 lbs/mi^2) and a maximum of 22,051 kg/km^2 (125,907 lbs/mi^2). Applications weres concentrated in the northwestern portion of the park-and-buffer boundary, with lower intensity and more scattered applications occurring in the remaining portion (Figure 17). Application rates of > 10,000 kg/km^2 can be found within 10km of the administrative boundary.

Park scale: Pesticide applications at this scale occur in a few locations within SAMO's administrative boundary and along the western edge of the boundary abutting the Oxnard Plain. Application rates are lower than for the other two scales with a mean of 35 kg/km^2 and a maximum of 438 kg/km^2.

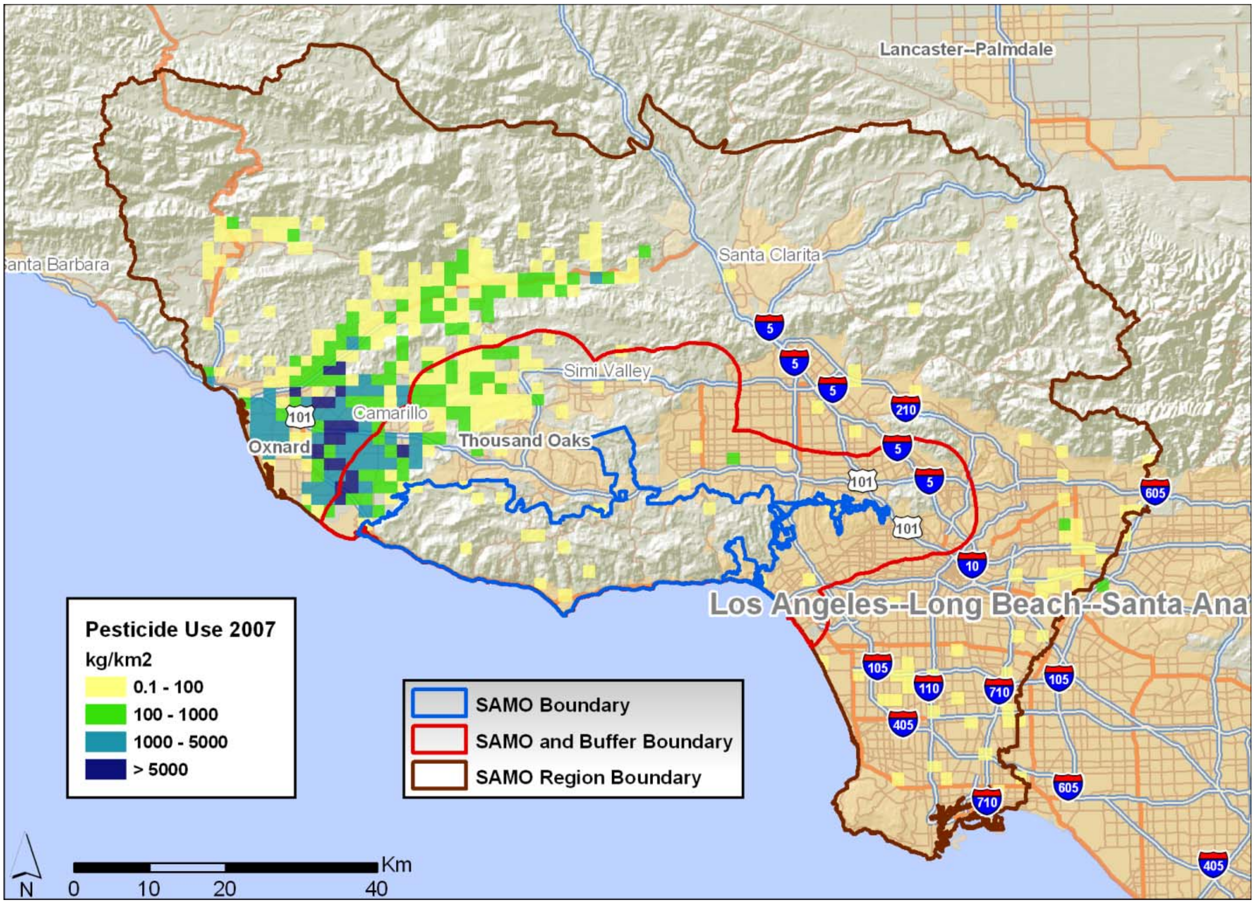


Figure 17. Pesticide use rate (active ingredients) in 2007 by Public Land Survey System sections.

Trends

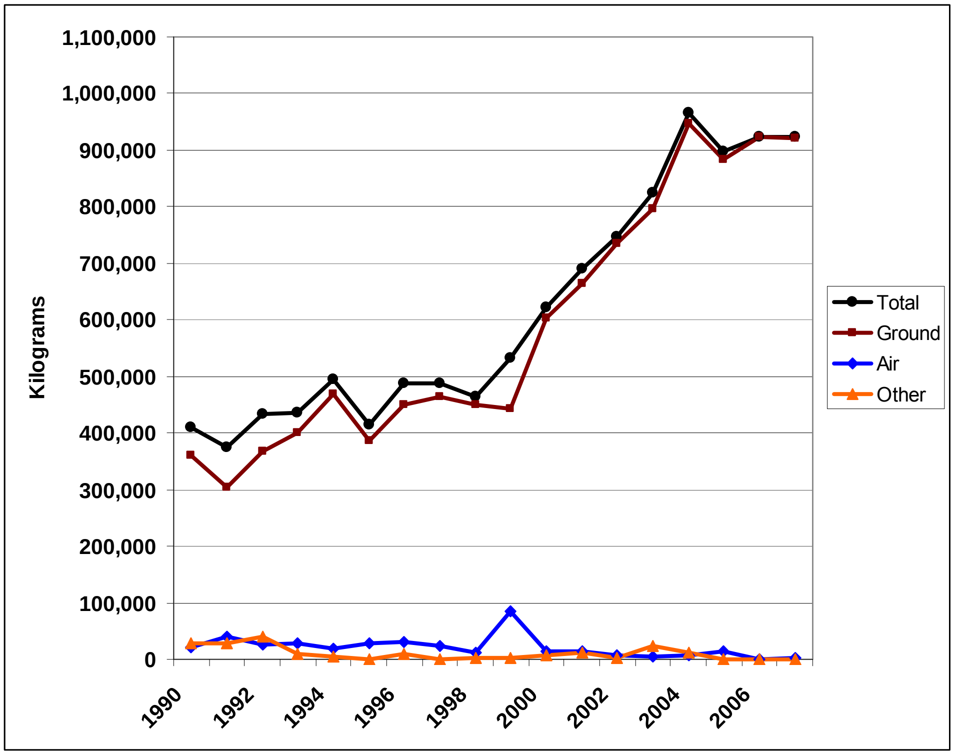
Regional scale: There has been a large increase in pesticide use at the regional scale, more than doubling from 1990 – 2007. Pesticide applications increased slowly from 1990 – 1997, then increased rapidly from 1998 – 2004 (Figure 18a). The large relative increase in overall pesticide use on top of an already large baseline at the regional scale likely reflects an expansion of agriculture, intensified management, a change in crop mix, a switch from other pesticides to the subset assessed here, or some combination of the above factors. However, most of the increase in pesticide use was in the form of ground applications. While aerial applications have greater probability of longer range atmospheric transport, volatilization of pesticides from soil and leaf surfaces has been observed and correlated with air concentrations of pesticides and their by-products within several miles of application sites (Bedos et al. 2002, Harnly et al. 2005).

Park-and-buffer scale: Pesticide use at the park-and-buffer scale also more than doubled from 1990 – 2007 (Figure 18b). The increase was steady from 1990 – 2003 but increased 34% from 2003 – 2004. While 48 pesticides were considered, only a few pesticides were responsible for most of the active ingredient weight in each year (Table 9). In all but one year, Chloropicrin and Metam-sodium, used primarily as pre-planting soil fumigants for row crops, were responsible for at least 40% of total active ingredient applied and averaged 62% of the total. Moreover, their share of total active ingredient applied increased over time, comprising 99% of active ingredient applied by 2007.

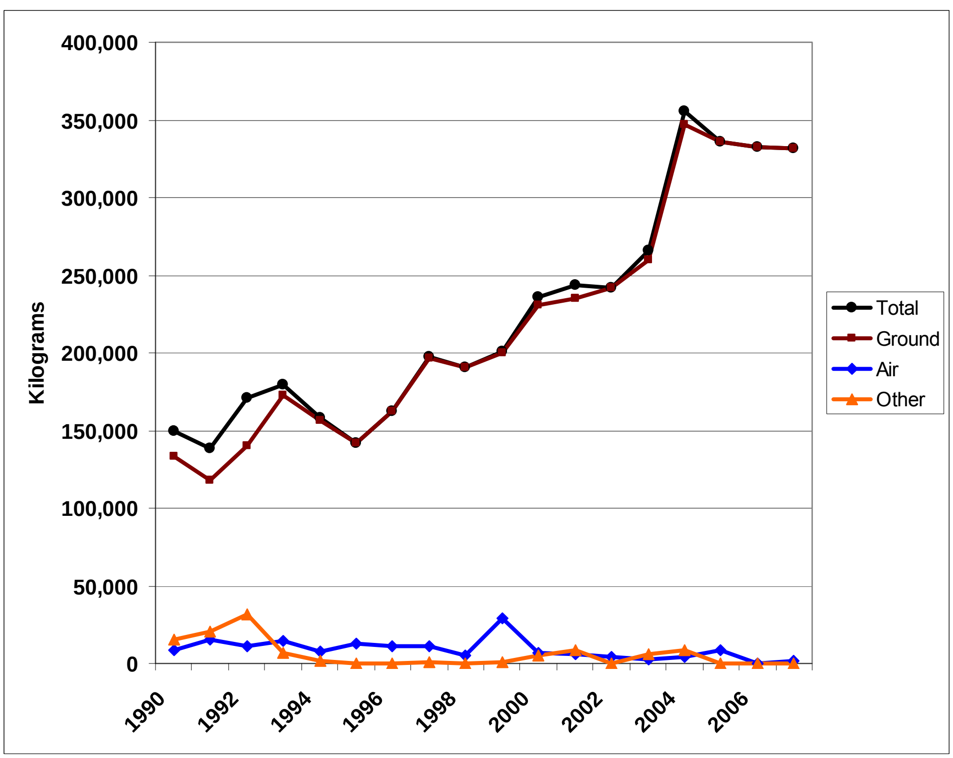
Table 9. Frequency that each of the 48 pesticides likely to adversely affect amphibians or their habitat occurred in the top ten by weight of active ingredient at the park-and-buffer scale. Maximum possible frequency between 1990-2007 is 18 years.

DPR Chemical Code	Name	Years Occurring in Top 10
136	Chloropicrin	18
616	Metam-sodium	18
677	Chlorothalonil	18
1855	Glyphosate, Isopropylamine Salt	18
369	Maneb	14
104	Captan	13
211	Mancozeb	13
1685	Acephate	13
367	Malathion	8
383	Methomyl	8
531	Simazine	8
1910	Oxamyl	8
105	Carbaryl	7
216	Dimethoate	3
2008	Permethrin	3
230	Methamidophos	2
231	Diuron	2
5820	Glyphosate, Potassium Salt	2
70	Eptc	1
83	Bromacil	1
198	Diazinon	1
361	Linuron	1
694	Propyzamide	1
802	Butoxyethanol ester	1
805	Diethanolamine salt	1
806	Dimethylamine salt	1
809	Isooctyl ester	1
810	Isopropyl ester	1
90045	Atrazine, Other Related	1
90104	Captan, Other Related	1
90394	Methyl parathion, Other Related	1
90518	Rotenone, Other Related	1

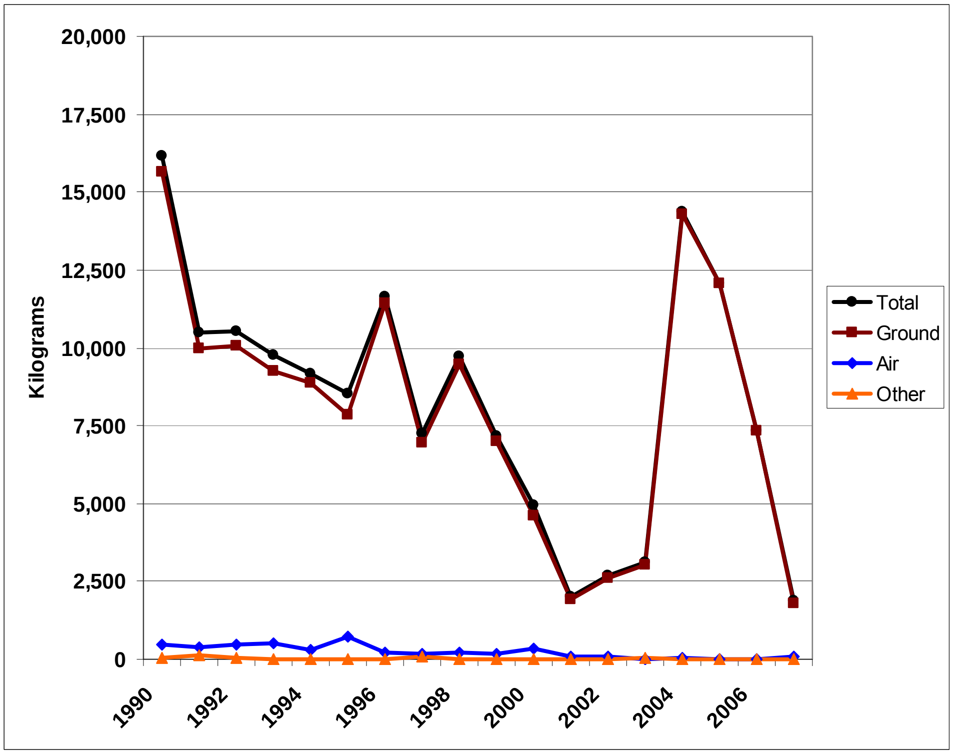
Park scale: Unlike trends at the other scales, pesticide applications declined overall within the SAMO administrative boundary. Active ingredient applied declined from 16,173 kg in 1990 to under 1866 kg by 2007 (Figure 18c). Applications were also highly variable over time, with a 363% increase from 2003 – 2004 followed by a rapid decline to the lowest level of the study period in 2007.



(a)



(b)



(c)

Figure 18. Trends in pesticide use at the regional (a), park-and-buffer (b), and park scale (c). Total use is the sum of active ingredients of the 48 chemicals likely to adversely affect amphibians or their habitat and the sum of the amount applied on the ground, in the air, or by other methods.

Emerging Issues

While direct mortality from exposure to pesticide concentrations in the environment is possible, a more likely scenario is the interaction of sublethal exposure with existing stressors to increase mortality of aquatic organisms. For example, human appropriation could decrease surface water availability during amphibian breeding periods that could increase the concentration of pesticides in remaining water bodies, increasing amphibian exposure during critical development phases. Mixtures of multiple pesticides may also be more toxic to non-target organisms than single pesticides (Releya 2009). Furthermore, expansion of testing to additional taxa may reveal that commonly used pesticides such as Endosulfan are more toxic than previously believed (Releya 2009).

Data Gaps

The measurements reported here account for the loadings of active ingredients to the environment surrounding SAMO. It is unknown what fraction of that loading is actually transported to SAMO by aerial drift or atmospheric transport, and how much becomes biologically available to amphibians. Transport risk depends on pesticide application method (e.g. direct soil injection, drip irrigation), containment actions such as tarping, local weather conditions, and how long each pesticide takes to become inert. Direct measurements of pesticide levels in the environment and in organisms are generally lacking but are key to determine the potential of this stressor to affect aquatic ecosystems and organisms. LA Department of Water and Power has done monitoring in Malibu Creek Watershed between 2001 and 2006 for chlorinated and organophosphate pesticides, which should be evaluated in the future. Because

DPR does not require all residential pesticide applications to be registered, it is unknown how much active ingredient is being applied on private lands within SAMO.

Key references

Bedos C., Cellier P., Calvet R., Barriuso E. and Gabrielle B. 2002. Mass transfer of pesticides into the atmosphere by volatilization from soils and plants: overview. *Agronomie* 22: 21-33.

Davidson, C. 2004. Declining downwind: amphibian population declines in California and historic pesticide use. *Ecological Applications* 14: 1892–1902.

Davidson, C. and Knapp, R.A. 2007. Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs. *Ecological Applications* 17: 587 – 597.

Harnly M., McLaughlin R., Bradman A., Anderson M. and Gunier R. 2005. Correlating agricultural use of organophosphates with outdoor air concentrations: A particular concern for children. *Environmental Health Perspectives* 113: 1184-1189.

LeNoir, J.S., L.L. McConnell, G.M. Fellers, T.M. Cahill, J.N. Seiber. 1999. Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada Mountain Range. *Environmental Toxicology and Chemistry* 18: 2715–2722.

Relyea R.A. 2009. A cocktail of contaminants: how mixtures of pesticides at low concentrations affect aquatic communities. *Oecologia* 159: 363-376.

Stressor: Rodenticides
Summary: No significant trend on agricultural lands

Anticoagulant rodenticides cause disease and mortality in raptors, meso-carnivores, and other non-target organisms (Stone et al. 1999, Brakes and Smith 2005, Riley et al. 2007). Because of the interspersion of private and public lands in and around SAMO, wildlife species of management concern are at risk of exposure to anticoagulant rodenticides. This class of pesticides has been documented as contributing to mortality of bobcats, coyotes, and mountain lions in SAMO that consume poisoned rodents (Riley et al. 2007), but the spatio-temporal distribution of the loading of rodenticides in the vicinity of SAMO has not been previously documented. We georeferenced rodenticide use reports to Public Land Survey System (PLSS) sections to quantify agricultural rodenticide applications from 1990 – 2007 in the vicinity of SAMO.

Rodenticides were applied for agricultural purposes primarily in the Oxnard Plain and the Santa Clara River Valley. Few applications were reported within the administrative boundary of SAMO. There were no clear trends in agricultural rodenticide applications at any of the scales analyzed. Total application varied between 0.1 and 0.5 kg at the regional scale until 2006, when applications increased to 0.9 kg before decreasing to 0.2. Rodenticide applications at the park-and-buffer scale followed a similar pattern. Agricultural application rates in 2007 were 0.000875 kg/km^2 at the region scale and 0.00109 kg/km^2 at the park-and-buffer scale. Diphacinone and Chlorophacinone made up the bulk of rodenticide used in most years. The more lethal second generation rodenticides, Brodifacoum and Bromadiolone, were applied infrequently and only at the regional scale. Residential applications adjacent to or within SAMO are likely a more serious threat to wildlife in the park. However, the locations and trends of these applications are not available.

Approach

Presence of anticoagulants in animals can only be measured through analysis of liver tissue after death (Riley et al. 2007). Therefore an indirect approach based on loadings of anticoagulant rodenticides was used for this condition assessment. The California Department of Pesticide Regulation requires users to record the type and quantity of pesticide applied in agricultural settings as well as the one mile square PLSS section where the application occurred. All records of six anticoagulant rodenticides used in California were extracted from the database (Table 10). After associating each rodenticide application record from the Pesticide Use Reports with a coverage of PLSS sections in a GIS, we calculated application rates for each PLSS section with reported applications in 2007 for spatial analysis and the total amount of active ingredient applied at regional and park-and-buffer scales from 1990 – 2007 for temporal analysis. Pesticide Use Reports are available from 1974 but the 18 year period reported here was judged sufficient to show any relevant trends in this stressor. (See the Appendix for GIS layers generated for the assessment).

Table 10. Anticoagulant rodenticides used in California. Second generation rodenticides are in **bold**.

DPR Chemical Code	Name
2049	**Brodifacoum**
2135	**Bromadiolone**
1625	Chlorophacinone
4014	**Difethialone**
225	Diphacinone
1636	Diphacinone, Sodium Salt
621	Warfarin

Data

Regional and park-and-buffer:

Compressed text files of statewide Pesticide Use Reports for individual years were downloaded from the California Department of Pesticide Regulation ftp site, ftp://pestreg.cdpr.ca.gov/pub/outgoing/pur_archives/.

Public Land Survey System section GIS coverages for California are maintained by the Bureau of Land Management and can be downloaded from http://www.blm.gov/ca/gis/.

Status

Regional scale: Rodenticides are applied for agricultural purposes primarily in the Oxnard Plain and generally at rates less than 0.01 kg-km^{-2} (Figure 19). The average application rate was 0.000875 kg/km^2, lower than the average rate of 0.0028 kg-km^{-2} for the state as a whole. Total application in the region was 0.2 kg in 2007. Diphacinone made up 95% of applications in 2007. Diphacinone is commonly used for California ground squirrel (*Spermophilus beecheyi*) control and is usually delivered using bait stations (Clark 1994). Recommended practice is to load bait stations with up to 2.3 kg of 0.005% bait. Assuming 2.3 kg of 0.005% bait, a bait station would receive about 0.000115 kg of active ingredient each day until control is achieved which can take several days to weeks (Whisson and Salmon 2009). One kilogram of active ingredient would be enough for thousands of bait station applications.

Although all the rodenticides used in California are lethal at low doses, second generation rodenticides are more potent than first generation. Recommended use for second generation rodenticides in bait stations is between 0.1 and 0.5 kg of bait per day at a concentration of 0.0025% which converts to 0.00001135 - 0.000002825 kg of active ingredient per baiting. Around 0.004 kg of second generation rodenticide was applied in 2007, enough for several hundred applications. One kilogram of active ingredient of second generation rodenticide would be enough for tens of thousands of bait station applications.

Rodenticide applications over time were concentrated in the Oxnard Plain, (Figure 20), but were applied infrequently to most sections in the region.

Park-and-buffer scale: Only a few PLSS sections to the north of SAMO had reported rodenticide applications in 2007. Application rates for these sections were less than 0.01 kg-km^{-2}. No second generation rodenticide applications were reported at the park-and-buffer scale in 2007. No applications were reported in 2007 within the administrative boundary of SAMO, with only rare applications since 1990.

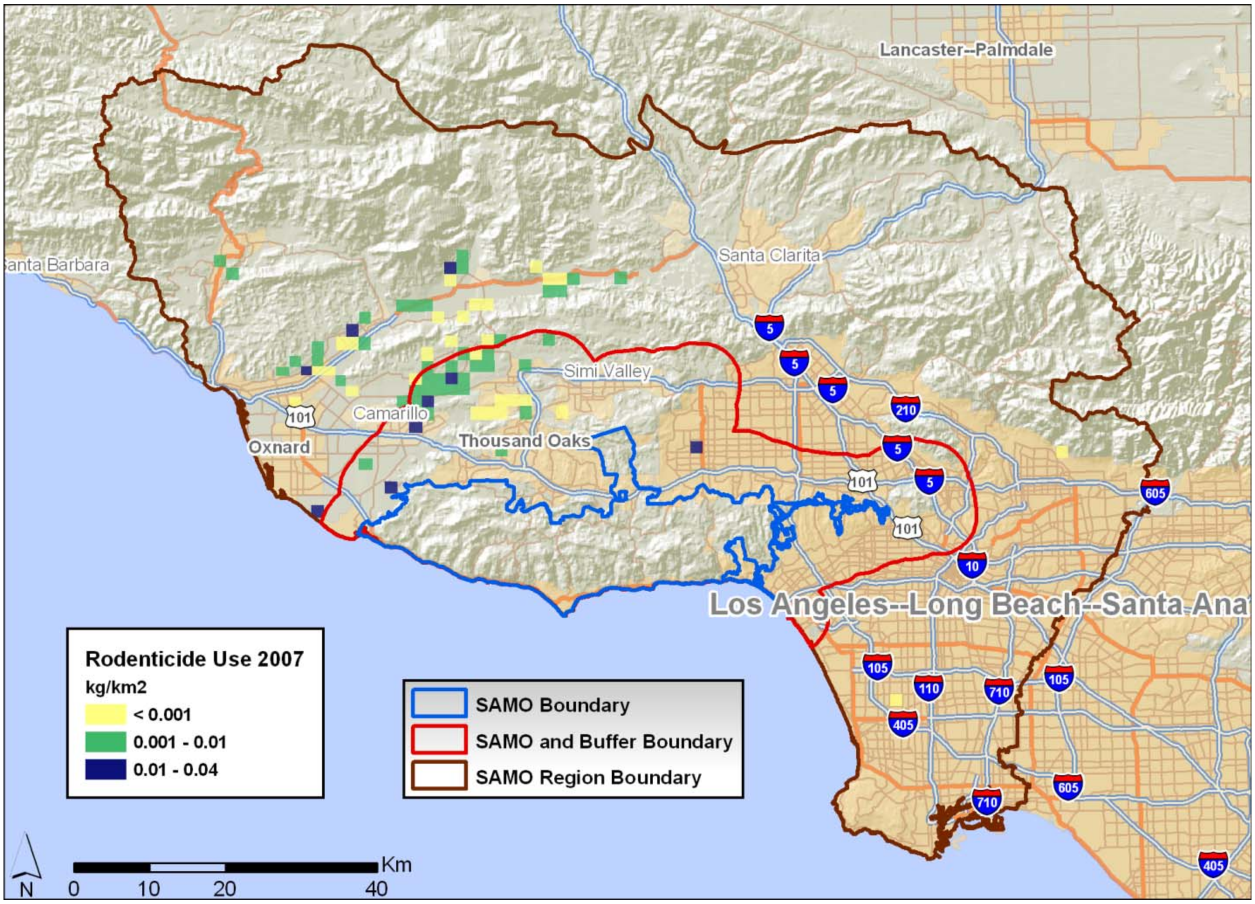


Figure 19. Rodenticide use in 2007 by Public Land Survey System sections.

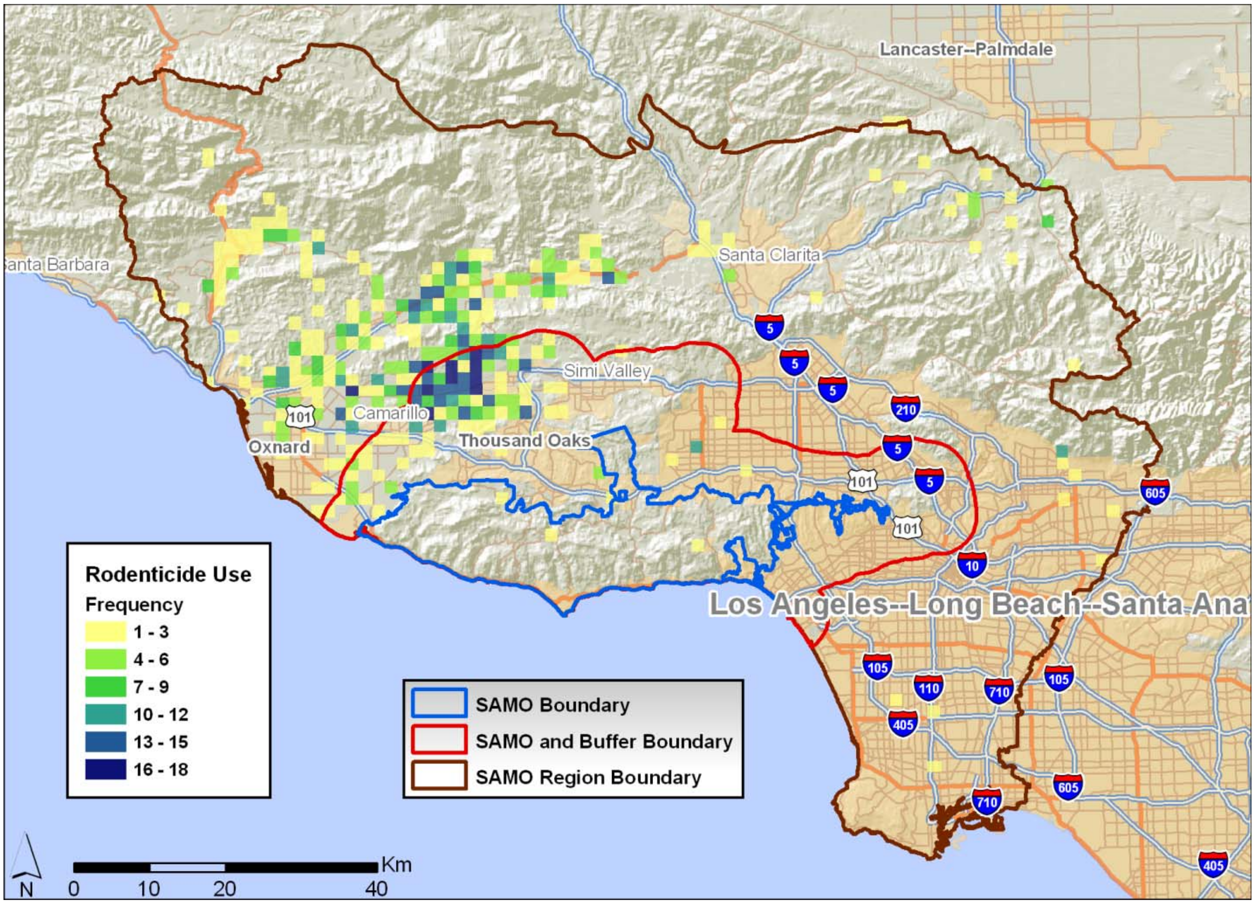
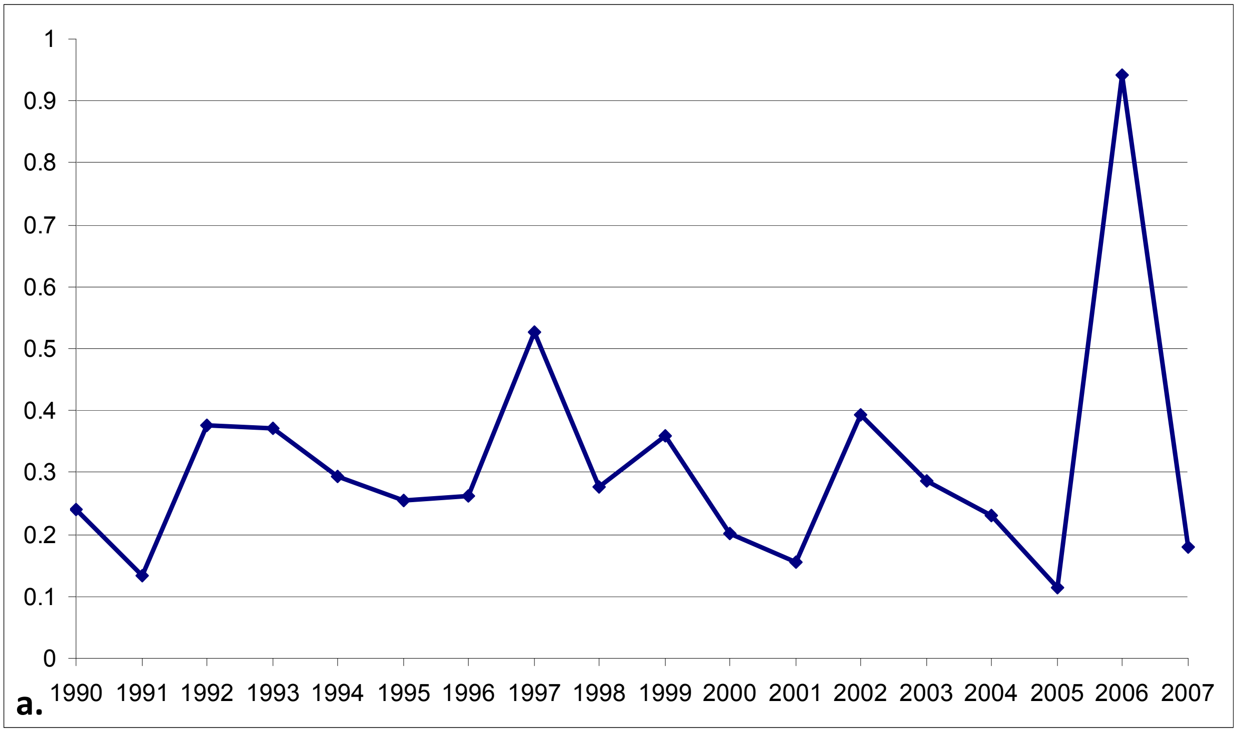


Figure 20. Number of years in which rodenticides were applied from 1990 – 2007 by Public Land Survey System sections.

Trends

Regional scale: There was no discernable trend in rodenticide applications at the regional scale (Figure 21a). Applications generally remained below 0.5 kg although they increased to 0.94 kg in 2006. Diphacinone was the most commonly reported rodenticide at all scales (Figure 22) and was responsible for the large increase in 2006. Difethialone use was not reported at any scale. Applications of second generation rodenticides were generally below 0.003 kg per year, enough for hundreds of bait station applications.

Park-and-buffer scale: There was no discernable trend in rodenticide applications at the park-and-buffer scale (Figure 21b). Diphacinone and Chlorophacinone were the only rodenticides reported at this scale.



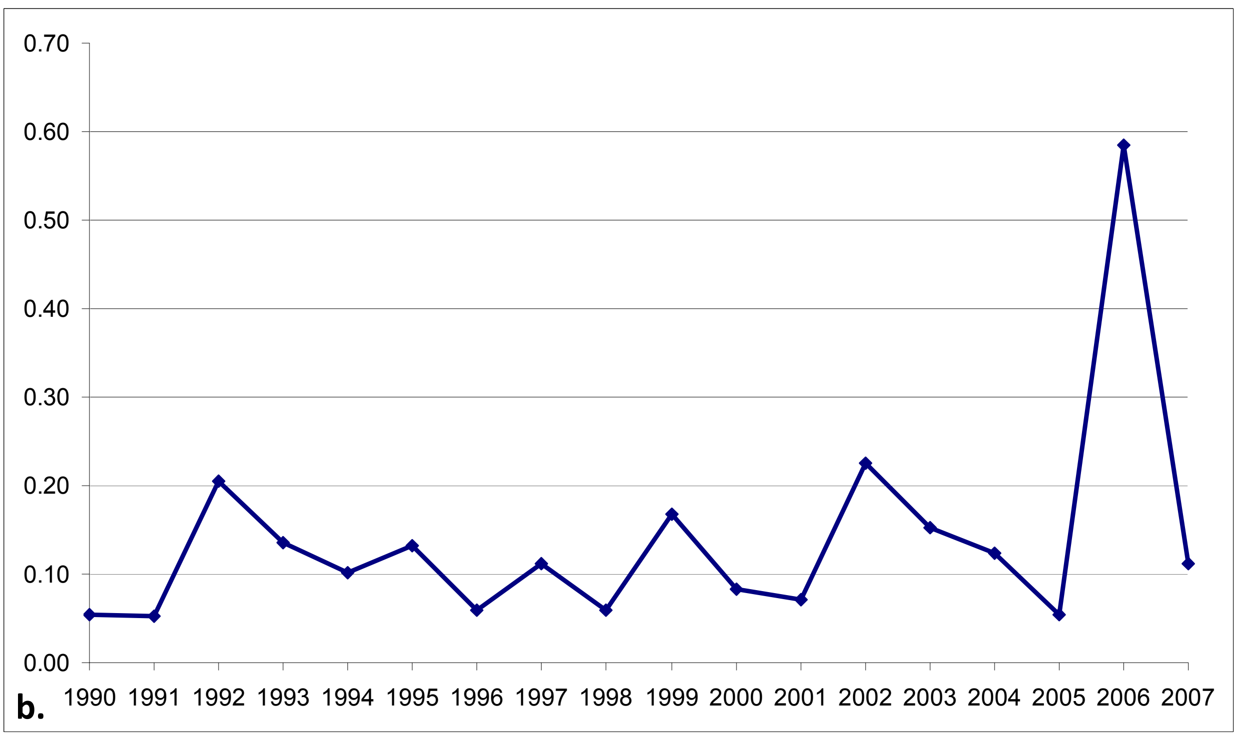


Figure 21. Trends in rodenticide use at the regional scale (a) and park-and-buffer scale (b). The y-axis is total kg of active ingredient of all anticoagulant rodenticides applied for agricultural purposes.

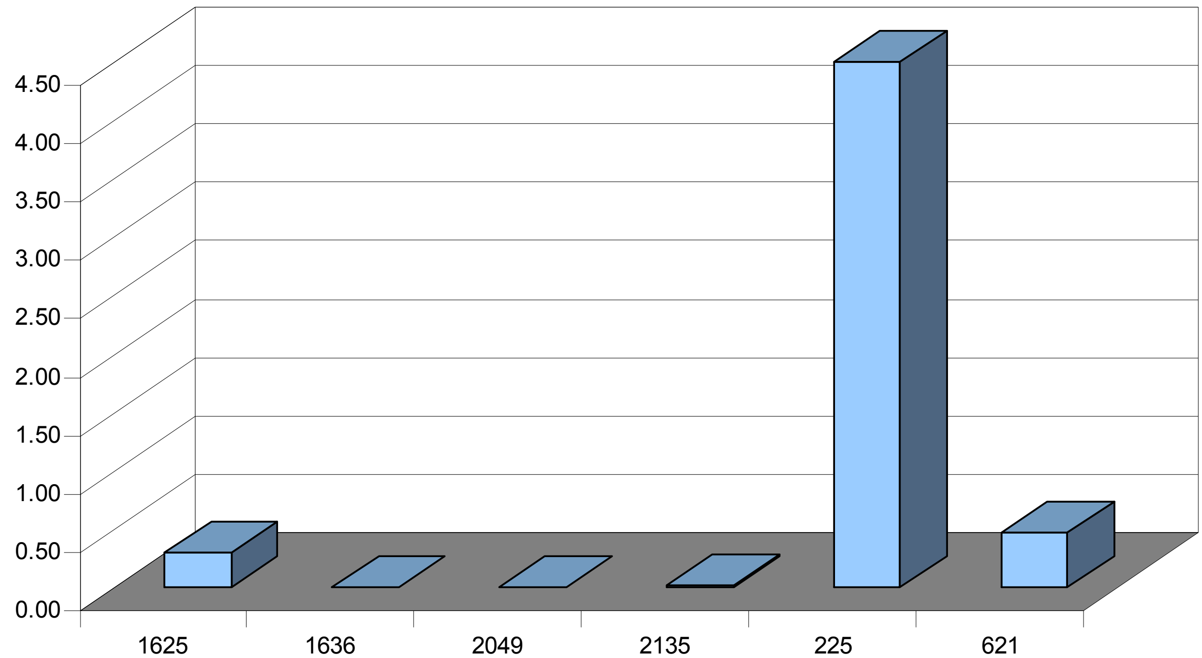


Figure 22. Cumulative applications of rodenticide (kg) from 1990 – 2007 by individual chemical at the regional scale. Chemical names associated with the codes on the horizontal axis are listed in Table 10.

Emerging Issues

In 2008 the Environmental Protection Agency introduced regulations to restrict residential use of four rodenticides that carry the most risk for wildlife - Brodifacoum, Bromadiolone, Difethialone, and Difenacoum. Only the first three rodenticides have been reported in the CA-DPR database for the study period. The extent to which these restrictions will reduce wildlife exposure is unknown. The rodenticides that made up the bulk of use near SAMO are not covered by these regulations. Moreover, residential use of rodenticides is not recorded in the CA-DPR database.

Data Gaps

The CA-DPR pesticide database only tracks reported applications of rodenticides. Home and garden uses are generally exempt from reporting requirements, and thus their contribution to the exposure for wildlife is unknown. Because residential land use is more common than agriculture within and adjacent to SAMO, it would be valuable to identify the rates of residential rodenticide application at a finer scale than for the whole county. The CA-DPR data alone do not suggest obvious pathways by which bobcats and other predators in SAMO might be exposed to anticoagulents. Rodenticide application methods are also unreported. The amount of active ingredient to which non-target species may actually be exposed is unknown but depends on availability of contaminated prey, which depends on a variety of factors including the timing and duration of rodenticide application, application method, bait formulation, and chemical concentration. Multiple stressors such as fragmentation, disease, and rodenticide exposure may interact to cause population declines in non-target species (Riley et al. 2007). More long term studies of wildlife populations will be necessary to reveal stressor interactions.

Key references

Brakes C.R. and R. H. Smith. 2005. Exposure of non-target small mammals to rodenticides: short-term effects, recovery and implications for secondary poisoning. *Journal of Applied Ecology* 42: 118-128.

Riley S. P. D., C. Bromley, R. H. Poppenga, F. A. Uzal, L. Whited, and R. M. Sauvajot. 2007. Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. *Journal of Wildlife Management* 71: 1874-1884.

Stone W. B., J. C. Okoniewski, and J. R. Stedelin. 1999. Poisoning of wildlife with anticoagulant rodenticides in New York. *Journal of Wildlife Diseases* 35: 187-193.

Stressor: Human Footprint
Summary: Baseline only

The Human Footprint model synthesizes information about many stressors into a cumulative indicator of human-caused disturbance. The GIS database for the western states developed by Matthias Leu and colleagues at USGS categorizes levels of footprint intensity or disturbance. SAMO is both surrounded by and punctuated with urban development and other disturbance factors. Consequently SAMO is rather heavily impacted for a unit of the national park system. One-third of the area of SAMO is mapped in the highest intensity footprint classes, with the remainder in the medium intensity. When including the surrounding landscape in the analysis, the proportions are reversed with 2/3 in high intensity. The human footprint has not been modeled for past times, so trend results are not available. However, we know that housing density and other factors associated with the footprint have increased and are most likely to continue increasing. We can presume then that the human footprint is increasing at all ecological scales.

Approach
Stressors do not operate independently from each other to affect natural resources. Some attempts have been made to develop synthetic indicators of stressors. The human footprint (Sanderson et al. 2002, Leu et al. 2008) is such an indicator. It can be used to plan land management actions, prioritize areas for restoration, and identify areas of high conservation value. It can also compare overall ecological condition between sites or over time to assess measures of success for conservation or other management actions (Haines et al. 2008). For this condition assessment, we used the GIS layer of the Human Footprint in the West as a standardized product that could be applied to all western park units. Details of the methods for compiling this synthetic indicator are provided in Leu et al. (2008), but are summarized here.

The human footprint was derived from seven input models of human-caused disturbance (Figure 23). Each model accounted for both the physical area occupied by the feature (e.g., road surfaces) and the "ecological effect area" defined by the ecological neighborhood of that feature. Three models were considered "top-down" and modeled threat from populations of predators such as corvids (crows, ravens, and magpies), domestic cats, and domestic dogs that deplete native species. Threat was based on proximity to human land uses. Four "bottom-up" models accounted for threat to habitat, again on the basis of land use plus wildfires. National or regional spatial data sets were acquired and manipulated to produce the seven models at a spatial resolution of 180 meters. The standardized scores of the seven input models were summed, and then the continuous values were binned into ten footprint intensity classes from lowest (class 1) to high (class 10). The footprint model was tested with data from the Breeding Bird Survey (Leu et al. 2008). The tests found that the footprint was positively correlated with the abundance of birds that are adapted to human-dominated environments and negatively for those that are sensitive to disturbance.

Note that the model of exotic plant invasion risk used for the human footprint is similar to the sensitivity component of the invasive plant model described above for this condition assessment. Because the scale of the human footprint modeling was for the entire western United States, it did not include some of the factors defining sensitivity (e.g., time since last fire) and totally omitted the exposure component due to lack of data.

The GIS data provides a visual overview of the pattern of the intensity of the human footprint, but it helps to have some summary analysis. Because the intensity values are recorded as classes rather than numerical values, it is not possible to compute averages or similar summary statistics. Therefore for this condition assessment, the area of the intensity classes were tabulated and converted to percentages at all three ecological scales (park, park-and-buffer and region). Comparing across scales provides context about the degree of isolation of the park.

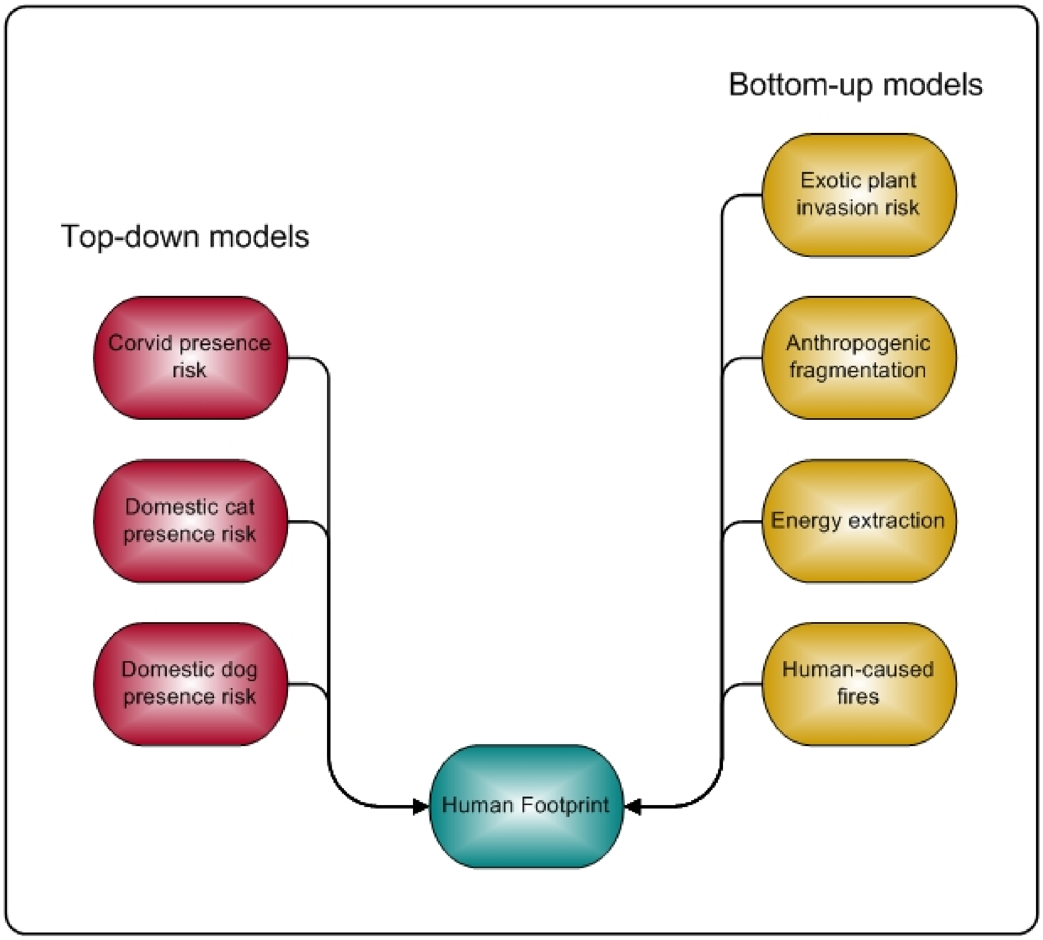


Figure 23. GIS conceptual model of the human footprint (redrawn from Leu et al. 2008). Each input model is based on multiple input factors.

Data

- Human Footprint in the West http://sagemap.wr.usgs.gov/HumanFootprint.aspx (Leu et al. 2008)

Status

The general pattern of urban development and agriculture can be clearly identified in the map of the human footprint with finer grain details produced primarily by the road infrastructure (Figure 24). The footprint is generally less intense within the SAMO boundary than the adjoining park-and-buffer area. In fact the SAMO boundary closely matches where the footprint intensity changes from medium (classes 4-7) to high (classes 8-10). Even within SAMO there are pockets of high intensity disturbance. The larger region is more complex, ranging from high intensity in the urban Los Angeles area to low intensity higher in the watersheds on National Forest lands. Although SAMO is far from pristine according to the human footprint analysis, it does appear to be severely isolated from other lands of comparable disturbance to the north and west by the ring of high intensity footprint around the park unit.

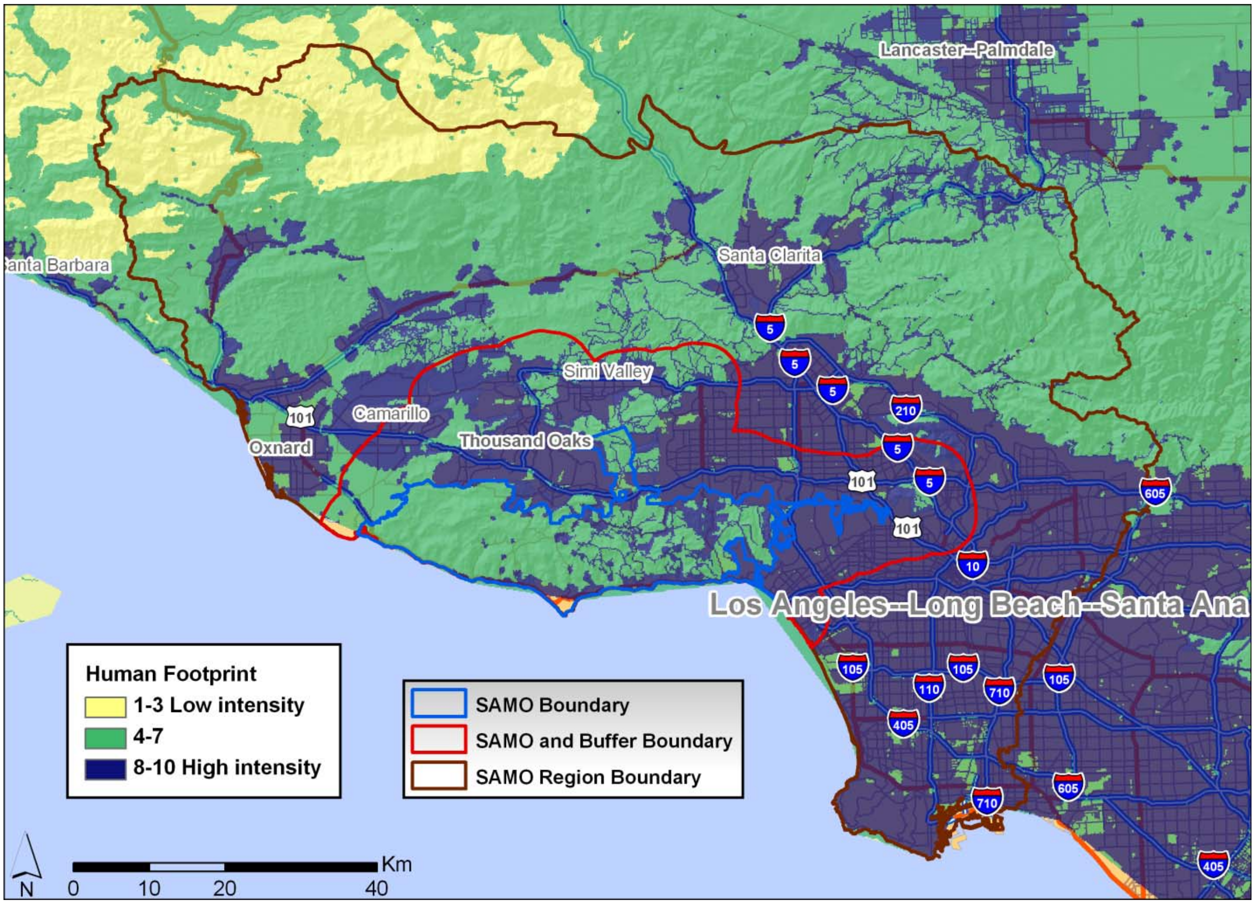


Figure 24. Map of the human footprint intensity (Leu et al. 2008) for SAMO and surrounding regions.

Tabulating percentages of area in each class quantifies the visual impressions from looking at the map in Figure 24. At all three scales, the footprint intensity peaks at class 6 (medium), with an additional high percentage in class 10, most intense (Figure 25). Within SAMO, the percentage in high intensity is much less than the other two scales, whereas the percentage in medium classes is greater. However, SAMO has no area with the lowest intensity footprint, unlike its broader region that does have a small percentage of relatively pristine land.

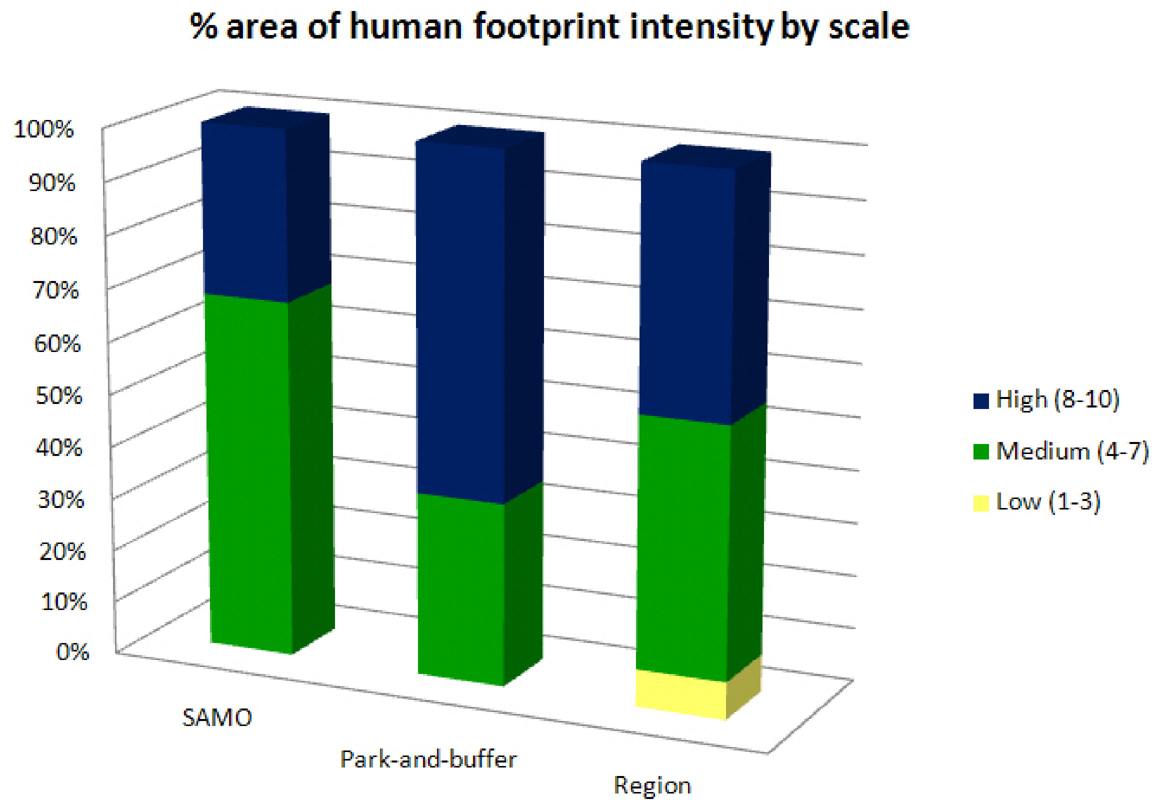


Figure 25. Bar graphs of the relative percentage of human footprint intensity for SAMO, the park-and-buffer landscape, and the region as the percentage of intensity grouped into low, medium, and high categories.

Emerging Issues

The Human Footprint synthesizes several of the stressors addressed individually elsewhere in this assessment. Consequently the areas of most intense footprint are also evident in the results for fire, housing density, fragmentation, and invasive plants. The footprint method extends the physical area of disturbance to incorporate the ecologically affected area as well. Thus a human footprint analysis in the future may detect broader impacts than the other stressor indicators from increasing low density development on private inholdings within SAMO.

Data Gaps

The Human Footprint data are a snapshot for a single point in time (circa 2000). Therefore trend data are not currently available to determine where (and how much) the human footprint has changed. Urban development has the greatest influence in the footprint model, so the change should closely follow the pattern found in the Housing Density stressor section. In addition, we would only expect the footprint to increase over time, because most of the inputs represent permanent change. The human footprint classes may be a conservative estimate of disturbance because of the equally-weighted summation method used to combine the seven input models. No matter how severe the impact of any one input model, it can only contribute 1/7th of the total score. An alternative approach would be to use the maximum score of any input model (Davis et al. 2006). Many of the input models use the same factors (e.g., agricultural lands, human populated areas). Hence there is a risk of cross-correlation of inputs and therefore of double-counting them. Finally, the footprint process standardized scores of input models by division of the highest value (Leu et al. 2008). If the highest values increase in the future, indicating an even more intense human footprint, the scale of scores would shift and make comparison with baseline scores harder to interpret.

The Human Footprint of the West was compiled based on the ecosystem and stressors relevant for the entire western region of the country using data that were available for the whole area. NPS may gain different insights about ecological condition if the analysis was redone for the SAMO region using factors and higher resolution data layers that are more locally relevant.

Key references

Davis, F. W., C. J. Costello and D. M. Stoms. 2006. Efficient conservation in a utility-maximization framework. *Ecology and Society* 11: 33. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art33/.

Haines, A. M., M. Leu, L. K. Svancara, J. M. Scott and K. P. Reese. 2008. A theoretical approach to using human footprint data to assess landscape level conservation efforts. *Conservation Letters* 1: 165-172.

Leu, M., S. E. Hanser and S. T. Knick. 2008. The human footprint in the west: A large-scale analysis of anthropogenic impacts. *Ecological Applications* 18: 1119-1139.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo and G. Woolmer. 2002. The human footprint and the last of the wild. *BioScience* 52: 891-904.

Summary of stressors

Table 11 summarizes the assessment of status and trends of stressors. Trend indicator icons reflect the direction of stressor measures rather than the condition of resources affected by the stressors.

Table 11. Summary of status and trends of stressors in the SAMO condition assessment report.

STRESSOR	MEASURES	RECENT DATA	STATUS	TREND
Housing development	Regional housing density (Census 2000) Park-and-buffer housing density Park housing density	351 units/km^2 478 units/km^2 29 units/km^2	Most land within SAMO was undeveloped or developed at rural densities in 2000. However, population, housing, and land conversion rates between 1990 and 2000 were higher than the surrounding region. The amount of urban land per housing unit was also considerably higher.	
Road distance and accessibility	Mean distance from roads Mean travel time	0.5 km (within park) 0.49 hr (within park)	83% of SAMO is within 1 km of a paved road. Accessibility or travel time from the park entrances averages just under a half-hour. The average fragment size between roads is 34.21 km2, or 1/18th the size of SAMO. Some sections of major highways carry more than 300,000 vehicles per day.	
Pesticides affecting amphibians	Regional pesticide application in 2007 Park-and-buffer pesticide application in 2007 Park pesticide application in 2007	924,000 kg active ingredient 332,000 kg active ingredient 1866 kg active ingredient	Application rates in the Oxnard Plain of pesticides known to have adverse effects on amphibians are similar in magnitude to those of California's Central Valley where studies have attributed amphibian population declines in Yosemite and Sequoia/Kings Canyon National Parks to regional pesticide use. The chytrid fungus, a major factor in declines of California anuran populations, is potentially exacerbated by immunosuppressant effects of pesticides. These pesticides also cause declines in phytoplankton and zooplankton at low concentrations. Use for agricultural purposes within SAMO is very low. Residential use is unknown. Ground applications made up the majority of pesticide applications for all scales. Therefore it is unknown what level of impact if any these pesticides are having on amphibians in SAMO.	
Rodenticides	Regional pesticide application rate in 2007 Park-and-buffer pesticide application rate in 2007	0.0009 kg-km^{-2} active ingredient 0.0011 kg-km^{-2} active ingredient	Because of the interspersion of private and public lands in and around SAMO, wildlife species of management concern (e.g., bobcats) are at risk of exposure to anticoagulant rodenticides. Rodenticides were applied primarily in the Oxnard Plain and the Santa Clara River Valley. Few agricultural applications were reported within the administrative boundary of SAMO. Thousands of individual rodenticide applications are possibly being	

STRESSOR	MEASURES	RECENT DATA	STATUS	TREND
			applied in the region every year. The more lethal second generation rodenticides were applied infrequently and only at the regional scale. Home and garden uses are generally exempt from reporting requirements, and thus their contribution to the exposure for wildlife is unknown but is suspected to pose a serious risk to wildlife.	
Human footprint	Regional area of high intensity Park-and-buffer area of high intensity SAMO area of high intensity	46% 65% 32%	One-third of the area of SAMO is mapped in the highest intensity footprint classes, with the remainder in the medium intensity. When including the surrounding landscape in the analysis, the intensity increases with 2/3 in high intensity. Housing density and other factors associated with the footprint have been and are most likely to continue increasing. We can presume then that the human footprint is increasing at all ecological scales.	

= baseline only = no significant trend = increasing trend

Resource Briefs

Overview of Resource Indicators

This section contains assessments of the key resource indicators. Each assessment follows a similar outline. Each begins with a brief summary of that resource. The banner of each section is colored according to a qualitative judgment of the current condition of that resource, along with an icon indicating the trend. Then the methods are described followed by a description of the data used in the assessment. Results are presented next by status if only current conditions are known and/or trends if data were analyzed through time. The data and results sections discuss the relevant scales of assessment—regional, park-and-buffer, and park, as described above. Depending on the data, some resources are reported by their spatial distribution in maps and some as trends in time-series plots. Each assessment then concludes with the identification of emerging issues and data gaps.

Air and Climate—Air quality
Summary: No significant change

SAMO lies in the South Coast Air Basin (Orange County and parts of Los Angeles, Riverside, and San Bernardino counties) and the South Central Coast Air Basin (Ventura, Santa Barbara, and San Luis Obispo counties). Although located in this heavily developed coastal area, the EPA has designated SAMO a Class II area under the Clean Air Act, recognizing it as a clean air area. However, because of extensive development, the region has historically had problems with high levels of ozone and other pollutants. In addition to the human health impacts of elevated ozone levels and the diminished visitor experience due to pollution-induced haze, air pollution has been identified as a threat to SAMO's lichen and coastal sage scrub communities (Fenn et al. 2003).

The 5 year average (from 2005 – 2009) annual 4th-highest 8-Hour average ozone concentration was 77 ppb, resulting in a classification of Significant Concern for ozone pollution. SAMO has exceeded the 75 ppb threshold for Significant Concern status since the late 1990's (NPS 2011). No significant trend in ozone concentrations from 1999-2008 was detected although recent concentrations appear to have been declining (National Park Service, Air Resources Division 2009).

Condition estimates for nitrogen deposition were not available for SAMO through the NPS Air Resources Division. However, modeled nitrogen deposition data from UC Riverside indicate that the majority of SAMO and its surroundings were subject to average annual deposition rates in 2002 of 12 kg ha^{-1} yr^{-1}, above the upper critical load threshold for coastal sage scrub communities (10 kg N ha^{-1} yr^{-1}), at which they become at risk from invasion by exotic annual grasses (Fenn et al. 2010). Dry deposition rates were not available. Wet deposition of nitrogen from NO3 and NH4 decreased over time. Because wet deposition data were interpolated at coarse scales this trend was assessed only qualitatively. In most years, wet deposition was in the Moderate Condition level, but in 1998 spiked to Significant Concern and in 2009 dropped to Good Condition.

Dry deposition rates for sulfur were not available. Condition estimates for sulfur deposition were not available for SAMO through the NPS Air Resources Division. Annual sulfur wet deposition from SO4 averaged 0.72 kg ha^{-1} yr^{-1} from 1994 – 2009, consistently in the Good Condition level. As with nitrogen wet deposition, this trend was only assessed qualitatively.

Visibility at SAMO is of Significant Concern. Five year average visibility index values exceeded the 8 deciview threshold for concern in each period measured starting with 2001 – 2005. The visibility index increased 4% (visibility declined compared to baseline conditions) from the period 2001 – 2005 to 2005 – 2009. However, visibility on the haziest 20% of days improved 12% and on the clearest 20% of days it improved 28% from the period 1999 – 2003 to 2005 – 2009.

Approach
SAMO does not have a dedicated air quality monitoring station. Data for all air quality conditions and trends at the park scale were acquired directly from publicly available gridded, interpolated estimates derived using nearby monitoring stations or from reports that cite

interpolated estimates. For status assessment, wet deposition rates for nitrogen and sulfur were acquired from gridded surfaces made available by the National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/NTN/grids.aspx). The gridded surfaces were sampled from a point located at the center of SAMO. Five year average nitrogen and sulfur concentrations as well as visibility estimates were acquired from NPS Air Quality Estimates tables (http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm). Total nitrogen deposition estimates for 2002 were acquired from gridded, modeled estimates generated by UC Riverside Center for Conservation Biology and summarized at the park, park-and-buffer, and regional scales.

The Air Resources Division (ARD) of the NPS publishes annual reports on trends in ozone, sulfur, and nitrogen. The ARD report uses an Environmental Protection Agency (EPA) ozone standard, which is the annual fourth highest 8-hour average ozone concentration, referred to hereafter as ozone concentration. Concentrations above 75 ppb are considered of "significant concern" for vegetation by the NPS, and a three year average of greater than 75 ppb exceeds the National Ambient Air Quality standard for ozone. Data and conditions for ozone were compiled from the 2008 report.

We acquired visibility data and wet nitrogen and sulfur deposition data from NPS Air Quality Estimates tables. The critical load estimate for nitrogen in coastal sage scrub is 7.8 – 10 kg N ha^{-1} yr^{-1}. Above this threshold, coastal sage scrub becomes at risk from invasion by exotic annual grasses, decrease in native plant richness, and decrease in arbuscular mycorrhizal spore density (Fenn et al. 2010). The critical load for epiphytic lichen communities in chaparral and oak woodlands is only 5.5 kg N ha^{-1} yr^{-1} (Fenn et al. 2010). Above this loading, these lichen communities shift in dominance from epiphytic to eutrophic lichen species. In chaparral communities, the critical load for exceedance of peak streamwater NO_3 concentration is estimated at 10-14 kg N ha^{-1} yr^{-1} (Fenn et al. 2010).

Visibility data were also obtained from NPS Air Quality Estimates tables. Visibility is expressed in terms of a haze index measured in deciviews. As the haze index increases, the visibility worsens. Because visibility under natural conditions varies by location, the haze index is calculated as the five-year average visibility minus the estimated visibility under natural conditions.

Data

Park:

National Atmospheric Deposition Program - http://nadp.sws.uiuc.edu/NTN/grids.aspx

National Park Service, Air Resources Division. 2009. Air quality in national parks: 2008 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2009/151. National Park Service, Denver, Colorado.

National Park Service, Air Resources Division. 2011. NPS Air Quality Estimates. National Park Service. Denver, CO. Available at - http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm

All Scales:

University of California Riverside, College of Engineering, Center for Environmental Research & Technology, University of California Riverside, Center for Conservation Biology, Biocomplexity Project. 2006. Total Deposition of Reduced and Oxidized Nitrogen During 2002. Available at - http://ccb.ucr.edu/biocommaps.html

Status

Park scale: Recent ozone concentrations exceed the EPA non-attainment standard of 75 ppb, resulting in a classification of "significant concern" (Figure 26). Total nitrogen deposition is relatively high at SAMO, 12 kg ha^{-1} yr^{-1} (Figure 27), compared to the estimated background rate of 0.25 kg ha^{-1} yr^{-1} in the western U.S (NPS 2009). Much of the park exceeded 10 kg N ha^{-1} yr^{-1} in 2001 (Figure 28). Average wet sulfur deposition was 0.29 kg ha^{-1} yr^{-1} in 2009. The average annual sulfur deposition rate of 0.72 from 1994 - 2009 is close to three times higher than the natural background deposition rate of 0.25 kg ha^{-1} yr^{-1}. Visibility condition at SAMO is just above the threshold of 8 deciviews for significant concern (Figure 29). Visibility conditions at SAMO, relative to reference conditions, are similar to those of Sequoia/Kings Canyon NP and Pinnacles National Monument.

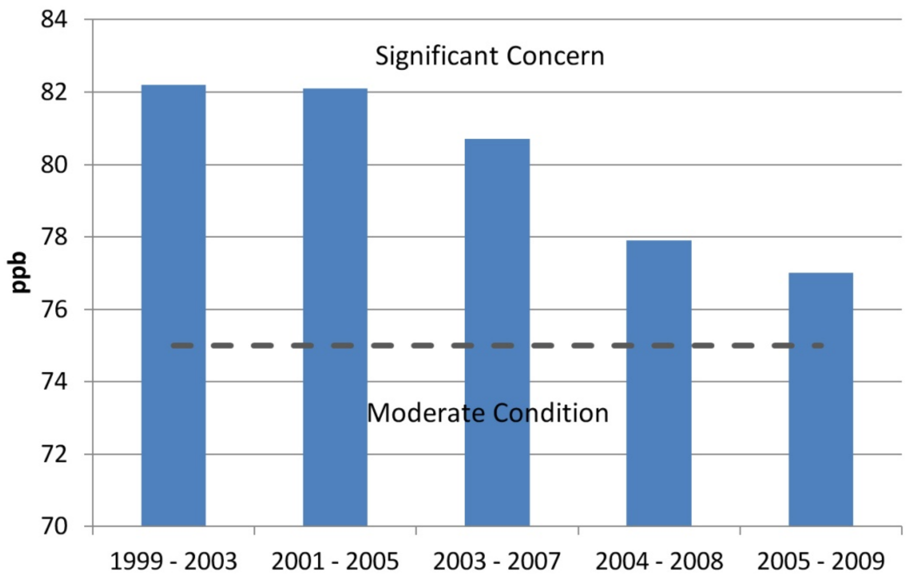


Figure 26. Annual 4th-highest 8-Hour average ozone concentrations, in parts per billion (ppb), averaged over five year intervals at the park scale. The EPAs 75 ppb threshold is indicated by the dashed line. Source: National Park Service, Air Resources Division. 2009.

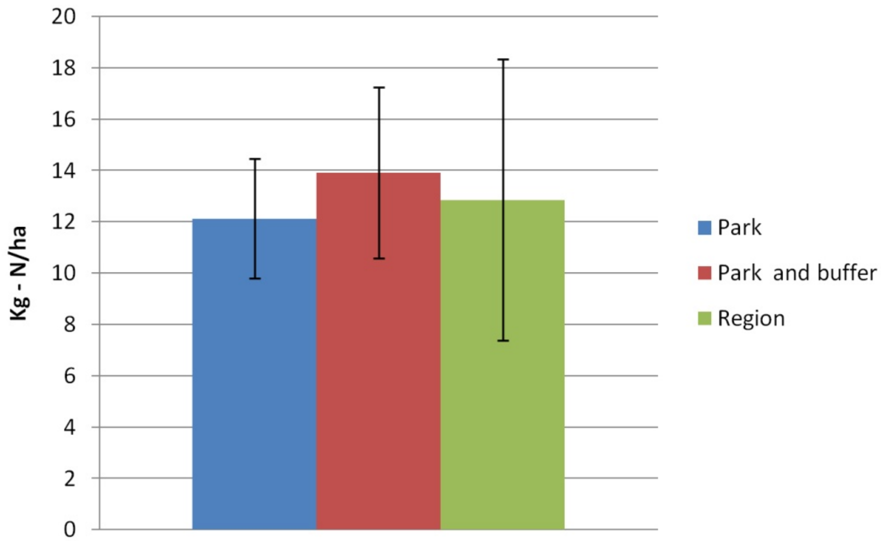


Figure 27. Total nitrogen deposition in kilograms per hectare for the year 2002 at different park scales. Derived from modeled data from U.C. Riverside Center for Conservation Biology. Error bars indicate one standard deviation.

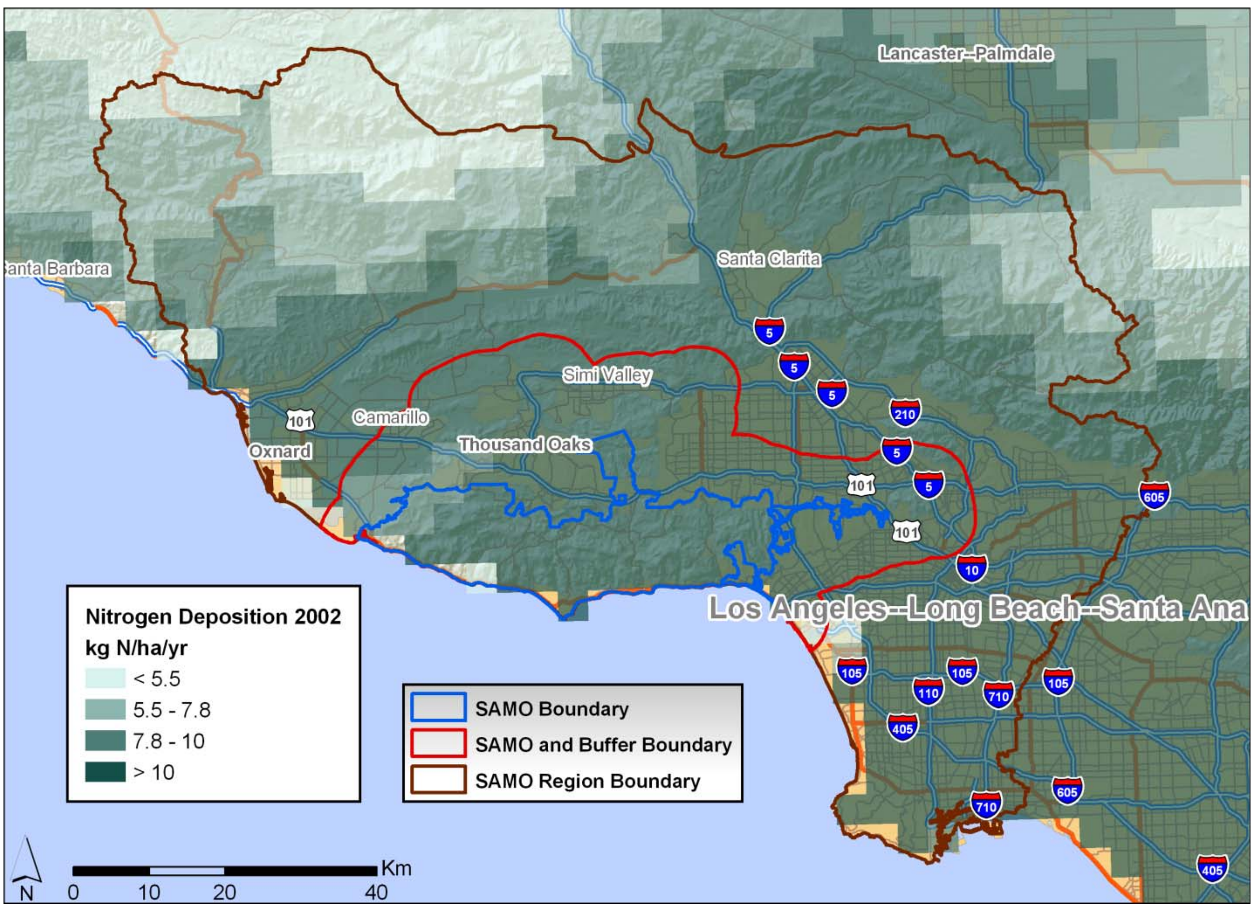


Figure 28. Modeled total nitrogen deposition rates in kilograms N per hectare per year in 2002. Source: U.C. Riverside Center for Conservation Biology.

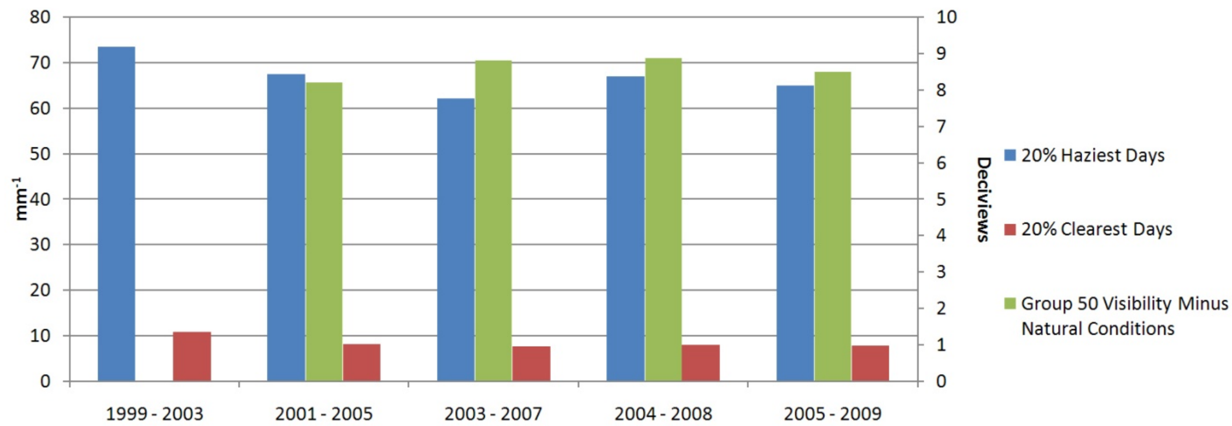


Figure 29. Primary axis: Visibility measured as light extinction for haziest 20% of days and the clearest 20% of days in units of inverse megameters, a measure of the fraction of light attenuation with distance. Higher values indicate more light attenuation and lower visibility. Secondary axis: Visibility index relative to natural conditions (group 50 visibility). This is calculated as five-year average visibility minus estimated visibility in the absence of human caused degradation expressed in deciviews. Values greater than 8 deciviews above reference conditions indicate significant concern. Source: National Park Service, Air Resources Division. 2009.

Park-and-buffer scale: Nitrogen deposition, at 14 kg ha-1 yr-1, is higher than at the park scale, mainly due to the inclusion of developed portions of the Los Angeles metropolitan area (Figure 27, Figure 28).

Regional scale: Nitrogen deposition, at 13 kg ha-1 yr-1, is in between rates found at the park and park and buffer scales. High rates of nitrogen deposition in the eastern part of the reference region are offset by lower rates on National Forest land in the northern part (Figure 27, Figure 28).

Trends

Park scale: No statistically significant trends in ozone concentration have been observed for SAMO although recent concentrations appear to be declining. Lack of appropriate data prohibits establishing robust trend estimates for nitrogen, sulfur, or visibility. However, interpolations of wet deposition rates indicate a decrease in nitrogen (Figure 30) and sulfur deposition (Figure 31) over the past decade.

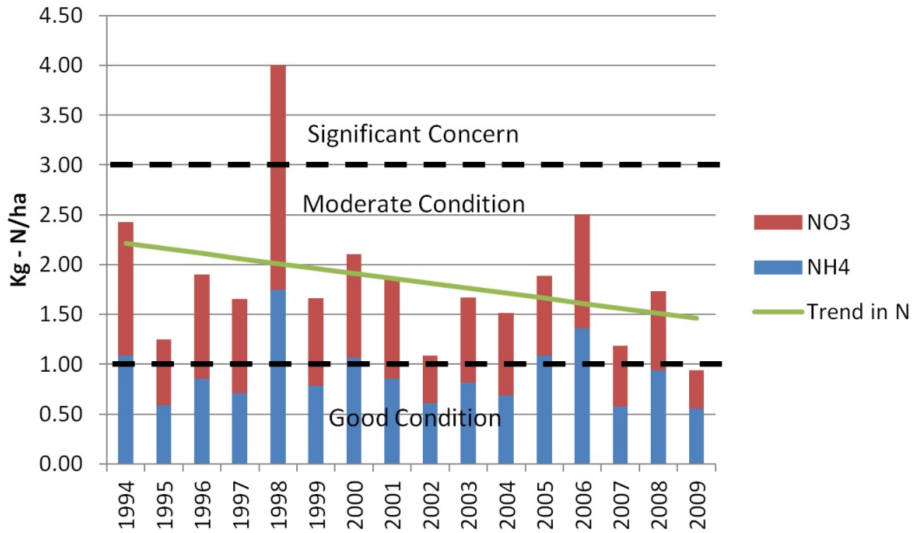


Figure 30. Interpolated wet nitrogen deposition in kilograms per hectare by analyte. The linear trend for total nitrogen deposition is shown in green. Derived from modeled data from National Atmospheric Deposition Program.

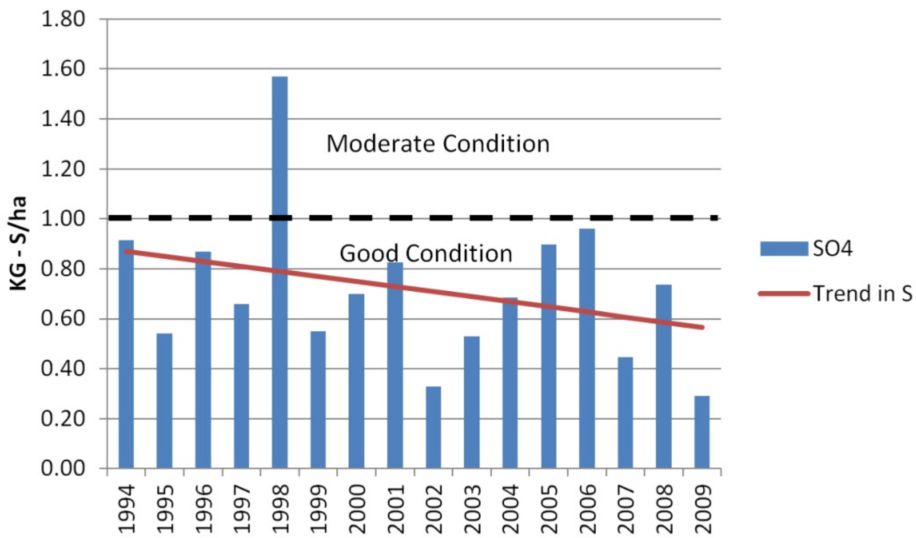


Figure 31. Interpolated wet sulfur deposition in kilograms per hectare. The linear trend for sulfur deposition is shown in red. Derived from modeled data from National Atmospheric Deposition Program.

Emerging Issues

Nitrogenous air pollutants have many sources, including transportation, agriculture, industry, electricity generation, wildfire, and are a growing threat to the biodiversity of California (Weiss 2006). Continued growth in the Los Angeles region as forecast could increase nitrogen loading at SAMO. The effects of increased nitrogen interact with other stressors and ecological processes. Nitrogen is often a primary limiting nutrient on overall productivity of ecosystems. Atmospheric nitrogen deposition alters terrestrial and aquatic ecosystem function, structure, and composition. Nitrogen deposition causes an increase in non-native annual plants and loss of native plant diversity. This in turn can alter the fire regime, favoring more frequent fires that further retard growth of native plants. Climate change is also expected to increase the frequency of burning, further amplifying the impacts of nitrogen. The challenge for SAMO is that management options to mitigate nitrogen deposition are limited (Fenn et al. 2010). Reducing emissions is the only effective strategy for protecting lichen communities in chaparral, but SAMO has little control over emissions. There are several mitigation methods in coastal sage scrub habitat, primarily controlling the seedbank and thatch cover of exotic annual grasses. These methods include prescribed fire, herbicides, mowing, and grazing, all of which would be of limited opportunity at SAMO.

Wildfires emit particulates that degrade visibility and pose a risk for human health (McKenzie et al. 2006). As discussed in the Future Fire Regime section below, models predict an increase in fire frequency and burned area in the future in response to any climate change scenario. As SAMO is already at levels of significant concern for visibility, such an increase will only compound this issue.

Data Gaps
There is an absence of air quality data sampled within SAMO boundaries. Much of the information for this section was obtained from air quality data interpolated for SAMO using nearby monitoring stations. The South Coast Air Quality Management District collects data on ozone, nitrogen dioxide, and sulfur dioxide at stations in Los Angeles County near the eastern half of SAMO. Ventura County has a similar station in Thousand Oaks. Data from these stations was not analyzed for this assessment.

Key References

Fenn M. E., Baron J. S., Allen E. B., Rueth H. M., Nydick K. R., Geiser L., Bowman W. D., Sickman J. O., Meixner T., Johnson D. W. and Neitlich P. 2003. Ecological effects of nitrogen deposition in the western United States. *BioScience* 53: 404-420.

Fenn, M. E., E. B. Allen, S. B. Weiss, S. Jovan, L. H. Geiser, G. S. Tonnesen, R. F. Johnson, L. E. Rao, B. S. Gimeno, and F. Yuan. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *Journal of Environmental Management* 91: 2404-2423.

National Park Service, Air Resources Division. 2009. Air quality in national parks: 2008 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2009/151. National Park Service, Denver, Colorado.

Air and Climate—Climate

Summary: Significant historical warming trend, increasing trend predicted

Climate at SAMO is characterized by hot, dry summers and mild, wet winters. Temperatures average 17 ºC (63 ºF) and total annual precipitation averages 43 cm (17 in). Minimum temperature exhibited a negative trend of 0.25 ºC decade-1 during the early part of the 20th century followed by a stronger positive trend of 0.6 ºC decade-1 over the last 60 years. Maximum temperature increased by 0.01 ºC decade-1. Precipitation showed a small but non-significant increase.

Downscaled climate models consistently project a 25 – 34% increase in growing degree days (GDD) by 2100 for the park scale, resulting in future conditions at SAMO that are currently found in the western Mojave Desert. Minimum winter temperatures are projected to increase by 2.1 - 2.8ºC while maximum summer temperatures are projected to increase by 4.0 – 5.3ºC. Seasonality, measured as the standard deviation of monthly mean temperatures, is projected to increase by 16 – 60%. Precipitation projections are variable, either increasing or decreasing depending on the global climate model (GCM). Climate can affect species distributions and ecological processes directly through changes in temperature and precipitation and indirectly through changes in species interactions. The combination of large projected increases in temperature and relatively modest changes in precipitation can be expected to reduce the growth and recruitment of many plant species at SAMO. Modeled associations with climate and soil indicate that suitability is low across much of the landscape for Valley Oak, *Quercus lobata*, which is at the southernmost part of its distribution at SAMO. Projected distributions indicate that under future climates, probability of occurrence will rarely exceed 0.1 for Valley Oak, further restricting it to the coolest and wettest sites. Areas surrounding SAMO are also expected to decrease in suitability, increasing the isolation of remaining trees. These changes could result in decreased cover and forage for the many bird and mammal species that use Valley Oak.

Approach

We obtained long term (1895 – 2011) historic spatial climate data from the PRISM (Parameter-elevation Regressions on Independent Slopes Model) mapping system. PRISM data was sampled at a point located at the center of SAMO. Trends for three climate variables, minimum temperature of the coldest period, maximum temperature of the warmest period, and annual precipitation, were assessed for SAMO.

We obtained spatial climate data at 90m resolution for historic (1971 – 2000) and future (2000 – 2100) periods that were downscaled by USGS from the Geophysical Fluid Dynamics Laboratory (GFDL) model and the Parallel Climate Model (PCM) global climate models (GCMs) for the A2 emissions scenario (medium-high emissions trajectory) (see Chapter 3 for details on GCMs and scenarios). We transformed the monthly temperature and precipitation data into five ecologically-relevant climate variables: GDD, minimum temperature of the coldest period, maximum temperature of the warmest period, mean annual precipitation, and temperature seasonality (the standard deviation of monthly mean temperatures). For the spatial data, GDD was derived from monthly average minimum and maximum temperatures and adjusted for the number of days in the month that would be above the 5ºC threshold. We summarized these variables as the spatial average at the three reference scales for the current time period and for future period forecasts generated by the two climate models. Comparing between models brackets the range of potential values and characterizes the degree of consensus about an uncertain future. Comparing across scales indicates how isolated SAMO is climatically from its surrounding region.

To illustrate possible biotic responses to climate change, we compared modeled historic distributions of Valley Oak, *Quercus lobata*, with their potential future distributions under climate change.

Data

Park scale:

Monthly time series of minimum temperature of the coldest period, maximum temperature of the warmest period, and precipitation from 1895 – 2011 were derived for the centroid of SAMO's boundary using the PRISM online map application: http://prismmap.nacse.org/nn/. All temperature measurements were converted from Fahrenheit to Celsius for analysis and precipitation was converted from inches to centimeters.

All scales:

Ninety meter resolution raster surfaces of climate variables were acquired from the USGS. Projections of each variable were generated for the A2 global emissions scenario by the GFDL and PCM models.

Ninety meter resolution raster surfaces depicting probability of occurrence of *Quercus lobata* under historic and projected climates. These data were developed by Maki Ikegami of the Biogeography Lab at the University of California Santa Barbara using the MaxEnt model using climate and soils as covariates.

Trends and Projections

Mean annual temperature at SAMO for the past 50 years, as modeled in PRISM, was 16.9 ºC. Minimum temperature of the coldest quarter was 4.5 ºC; maximum temperature of the warmest quarter was 32.3 ºC. Plots of the autocorrelation functions of minimum and maximum temperature time series revealed serial autocorrelation (Figure 32). Generalized least squares linear regressions, which adjust significance levels to account for autocorrelation, revealed significant positive trends in minimum (TMIN) and maximum temperature (TMAX) from 1895 – 2011 (TMIN: slope = 0.022, p = 0.0001, std = 0.32, AIC = 402.47; TMAX: slope = 0.01, p = 0.01, std = 0.24, AIC = 351.29). However, inspection of residuals for the TMIN regression showed a tendency to overestimate in the early and late parts of the time series. A "broken stick" regression, in which we assume more than one linear model for the data, was used to generate a model with a slope estimate for the first part of the time series and a different slope estimate for the second part of the time series. One way to set the knot point (or break point) for the slopes is to introduce the knot point as a parameter in the regression. However, this will result in a non-linear model. Instead, an iterative process was used in which each year from 1924 – 1974 was used as a knot point in a generalized least squares regression. This approach identified 1949 as the year that maximized the Akaike Information Criterion (AIC), a measure of model performance, and minimized the standard error (Figure 33). The final model for TMIN showed a significant negative trend of 0.25^{o}C decade^{-1} from 1895 – 1949 and a significant positive trend of

0.6^{o}C decade^{-1} from 1949 – 2011 (First trend: slope = - 0.025, p = 0.0039; Second trend: slope = 0.06, p = 0; Model: std = 0.07, AIC = 379.25; Figure 34). The final model for TMAX showed a trend of 0.01 ^{o}C decade^{-1} (Figure 35).

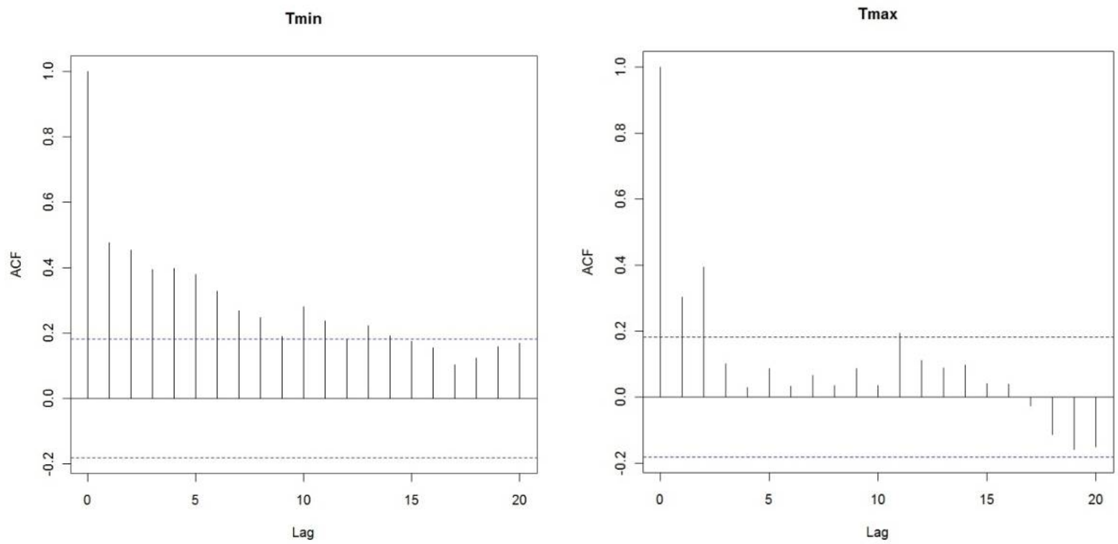


Figure 32. Plot of the autocorrelation function (ACF) of minimum temperature (Tmin) and maximum temperature (Tmax). Dashed lines show 95% confidence intervals.

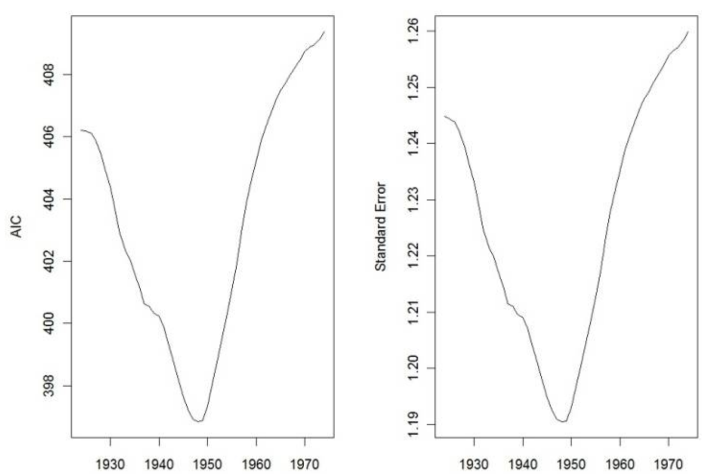


Figure 33. Plot of broken stick regression knot point against Akaike information criterion (AIC), first panel, and regression standard error, second panel.

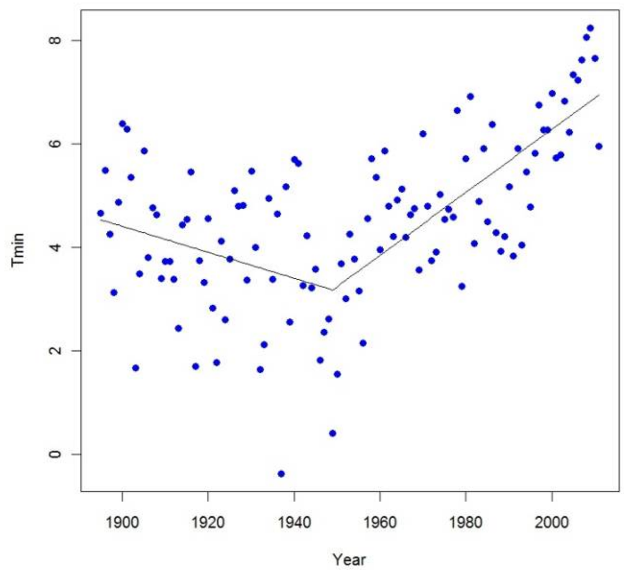


Figure 34. Broken stick regression of minimum temperature (Tmin in ºC).

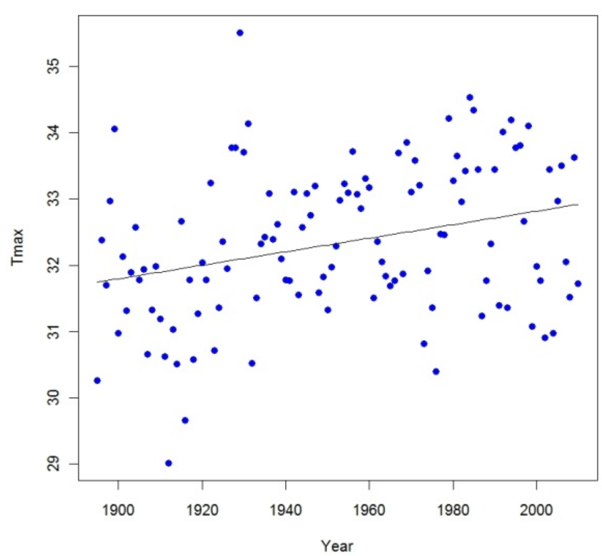


Figure 35. Maximum temperature (Tmax in ºC) with a linear fit indicated by the black line.

Mean annual precipitation at SAMO over the past 50 years has been 42.7 cm. A small but significant positive trend in annual precipitation was revealed by a least squares linear regression (adj. $r^2 = 0.03$, std = 20.46, slope = 0.11, $p = 0.04$, Figure 36). No autocorrelation was found in regression residuals (Durbin-watson, $p = 0.8269$). The residuals showed evidence of heteroscedasticity however (studentized Breusch-Pagan test: $p = 0.002$). Correcting the variance/covariance matrix for this reduced the significance of the slope estimate ($p = 0.07$).

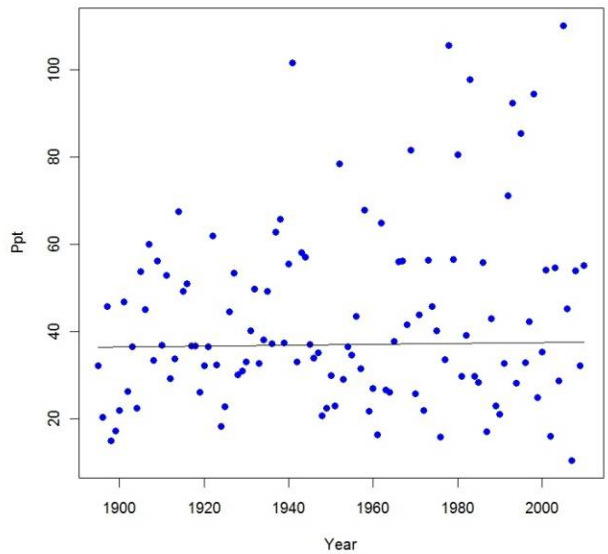


Figure 36. Precipitation (Ppt in centimeters) with a linear fit indicated by the black line.

GDD, minimum and maximum temperatures, and temperature variability are expected to increase from the current period (1971 – 2000) to 2100 (Figure 37). For example, current minimum temperatures within SAMO are expected to be found only at the region scale in the future in surrounding higher elevation areas. Future annual GDDs and maximum temperatures are projected to be similar to those currently found in the eastern Mojave (Figure 38). Annual precipitation increases in the PCM model but decreases in the GFDL model. Trends at the other scales are projected to be similar to those at the park scale. In general, the GFDL model projects a warmer and drier future than the PCM.

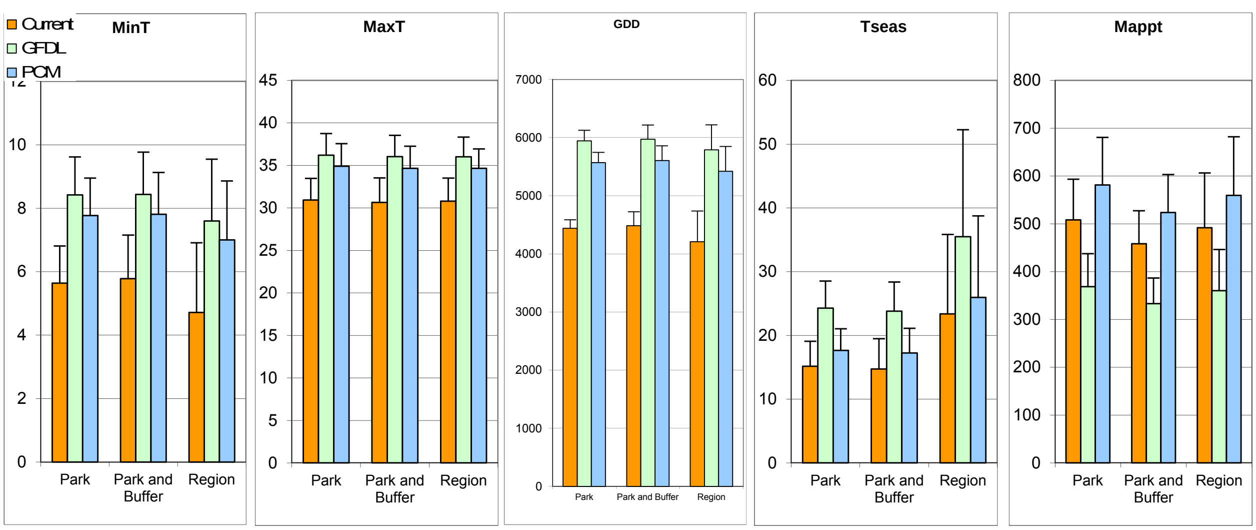


Figure 37. Current (1971 – 2000) and projected (2000 – 2100) values for climate variables summarized by three reference scales. Projected data from the Parallel Climate Model (PCM) and the Geophysical Fluid Dynamics model (GFDL). Error bars show the standard deviation of the spatial data at each scale. Climate variables are coded as follows: MinT = minimum temperature of the coldest period in ^{o}C, MaxT = maximum temperature of the warmest period in ^{o}C, GDD5 = growing degree days above 5^{o}C, Tseas = temperature seasonality (the standard deviation of monthly mean temperatures), MAppt = average annual precipitation in mm.

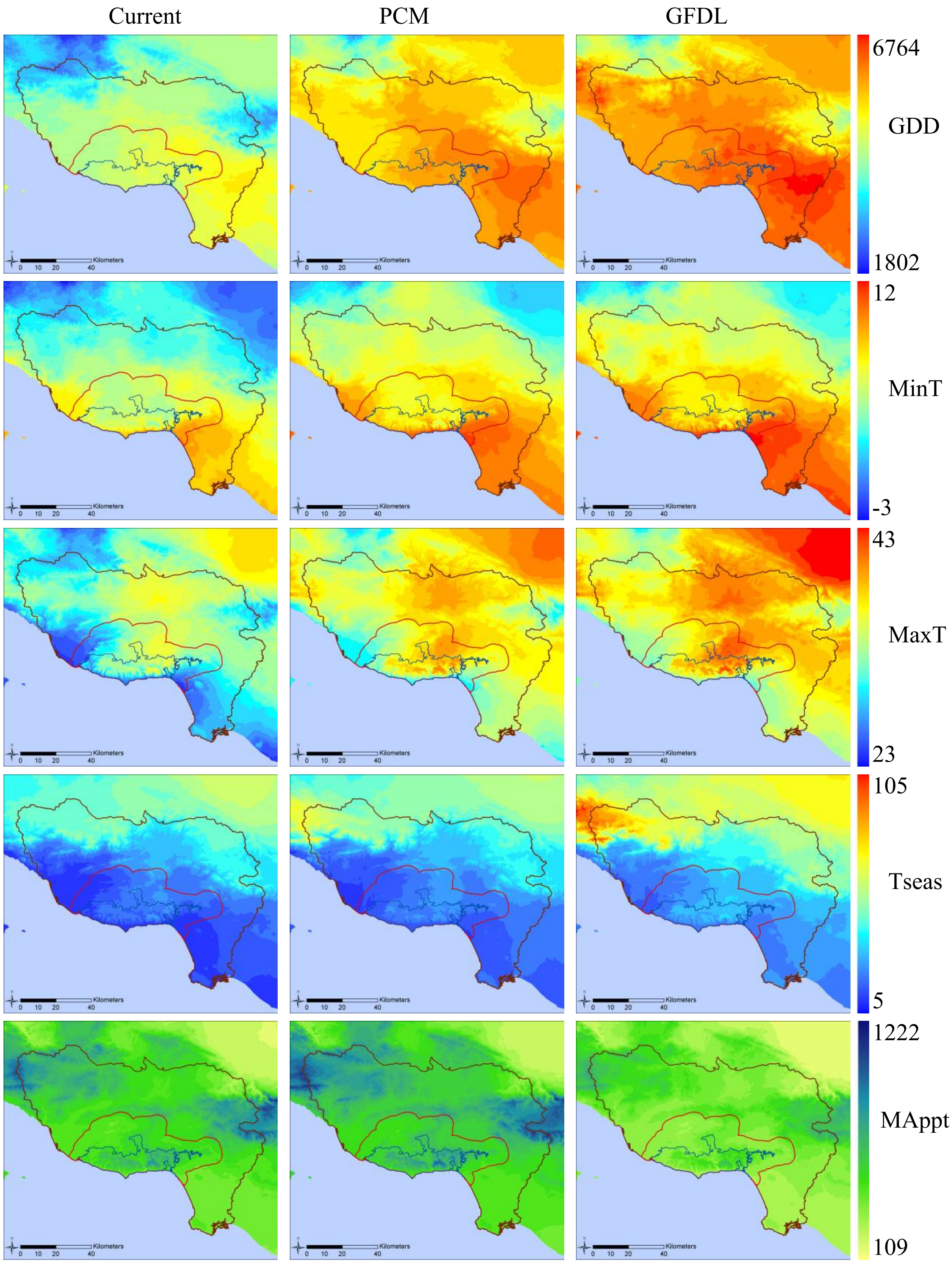


Figure 38. Maps show minimum temperature in °C of the coldest period (MinT), maximum temperature in °C of the warmest period (MaxT), temperature seasonality (Tseas), average annual growing degree days above 5 °C (GDD), and average annual precipitation (MAppt) for the current time period (1971 – 2000), for 2000 – 2100 projected by the parallel climate model (PCM), and for 2000 – 2100 projected by the Geophysical Fluid Dynamics model (GFDL).

Occurrence probabilities for *Quercus lobata* are expected to decrease to below 0.1 for most of SAMO under both climate models (Figure 39). Moderate occurrence probabilities in the future are expected to shift ~50 km north to the northern edge of the regional boundary (Figure 40).

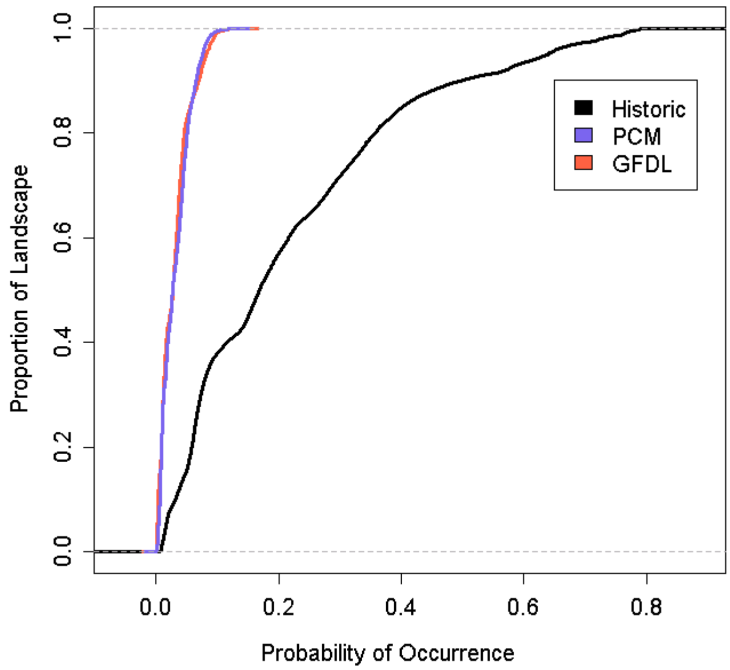


Figure 39. Empirical distribution functions of probability of occurrence for Valley Oak (*Quercus lobata*) under historic and projected climate conditions at the park scale.

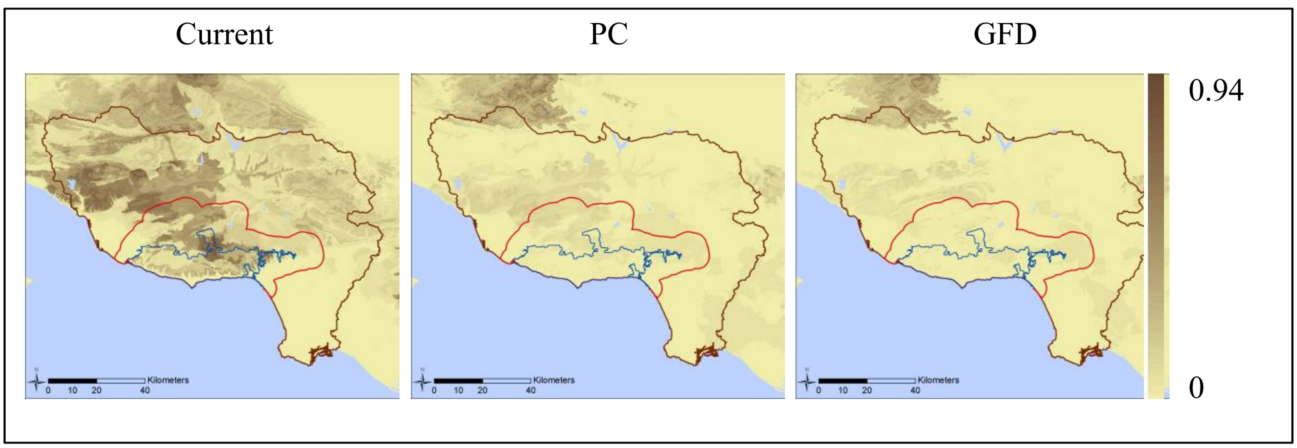


Figure 40. Mapped probability of occurrence for Valley Oak (*Quercus lobata*) under historic and projected climate conditions

Emerging Issues

Climate is so fundamental to many ecological processes that climate change will amplify effects of other stressors (Baron et al. 2009). For instance, biotic responses to climate change, such as shifts in range boundaries and community composition, have been well documented globally (Parmesan and Yohe 2003). However, species specific modeling approaches will likely be necessary to predict potential responses for SAMO and surrounding areas (Hannah 2008). Results for Valley Oak distributions showing a loss of suitable land area in SAMO under future climates reflect the findings of Kueppers et al. (2005) that the majority of land suitable for Valley Oak in the future will be outside the boundaries of current protected areas. Given SAMO's location in a human dominated landscape, societal adaptation in response to climate change, e.g., changes in water or fire management, will likely exert strong influences on ecological processes.

Data Gaps

The climate projections used here were generated globally and statistically downscaled using topographic and other data. This approach potentially misses fine scale dynamics such as "reverse reactions" in which coastally influenced areas are cooled as warm inland air results in increased onshore flow (Lebassi et al. 2009). Further refinement of global models and addition of local modeling results will improve the reliability of forecasts. Although another modeling study finds similar decreases in suitability for Valley Oak in the south Coast Ranges (Kueppers et al. 2005), a longer record of climate reconstructed from tree rings or sediments could help refine our understanding of potential biotic responses to climate change at SAMO. Monitoring data on biological responses to climate change, such as phenological changes, is important to assess hypothesized ecological changes. Hydrologic measurements could prove useful in assessing the relationship between altered precipitation patterns and water availability in streams at SAMO.

Key references

Kueppers, L. M., M. A. Snyder, L. C. Sloan, E. S. Zavaleta, and B. Fulfrost. 2005. Modeled regional climate change and California endemic oak ranges. *Proceedings of the National Academy of Sciences of the United States of America* 102 (45): 16281-16286.

Lebassi B., Gonzalez J., Fabris D., Maurer E., Miller N., Milesi C., Switzer P. and Bornstein R. 2009. Observed 1970-2005 cooling of summer daytime temperatures in coastal California. *Journal of Climate* 22: 3558-3573.

Water—Water quality
Summary: Baseline

The California Regional Water Quality Control Board, Los Angeles Region has identified 38 water quality limited segments (primarily streams and beaches) within SAMO that do not meet standards for at least one of 37 pollutants. These pollutants span a range of nutrients, pesticides, pathogens, toxicity, metals, and others. A Total Maximum Daily Load or TMDL is allocated for each of the 134 segment-pollutant combinations that violate standards and a plan is developed that prescribes the management actions to be taken to reach the standards. USEPA has currently approved 54 TMDL plans, leaving 80 that must still be developed and approved. The most frequent pollutants to be addressed are DDT, PCBs, indicator bacteria, and coliform bacteria. Pathogen pollutants have the highest percentage of approved TMDL plans, probably because they are associated with the public beaches and hence have a high profile. Segments in Calleguas Creek have as many as 14 pollutants identified. Malibu Creek has eight pollutants (only one TMDL plan approved so far by USEPA), and Las Virgenes Creek has seven (one approved TMDL plan). Addressing this large spectrum of water quality issues could become extremely burdensome to NPS resource staff to participate in contentious, drawn-out planning processes. At the same time, these water quality violations represent a large number of stressors and pathways that can impact the aquatic resources at SAMO in complex, synergistic ways. Therefore perseverance through the TMDL processes is necessary to protect these resources and to ensure that the prescribed remedies are acceptable to SAMO managers.

Approach

The Federal Clean Water Act (CWA) gives States the primary responsibility for protecting and restoring surface water quality. Under CWA section 303(d), State and Regional Water Boards assess water quality monitoring data for California's surface waters every two years to determine if they contain pollutants at levels that exceed protective water quality standards. Water body and pollutants that exceed protective water quality standards are placed on the State's 303(d) List of Water Quality Limited Segments. USEPA must approve the 303(d) List before it is considered final. Placement of a water body and pollutant that exceeds protective water quality standards on the 303(d) List, initiates the development of a TMDL plan. In some cases other regulatory programs will address the impairment instead of a TMDL (http://www.swrcb.ca.gov/water_issues/programs/#wqassessment).

In 2007 the SWRCB compiled GIS layers of the Water Quality Limited Segments from the 2006 303(d) list (the most recent approved by EPA). The database includes records of pollutants for which each segment exceeds standards and the status of the TMDL. The status can be either 1) addressed by USEPA approved TMDL plans, 2) still require TMDLs to be prepared and/or approved, or 3) being addressed by actions other than TMDLs. Mapping the 303(d) listed waters by SWRCB is a work in progress and will be updated during each listing cycle to better define the impacted areas.

For this condition assessment, the water quality limited segments fully or partly within the SAMO boundary were extracted from the SWRCB database (Figure 41). Other water bodies not on the list are also shown for completeness. The database was processed to display the pollutants by segments and segments by pollutants with the status of TMDLs.

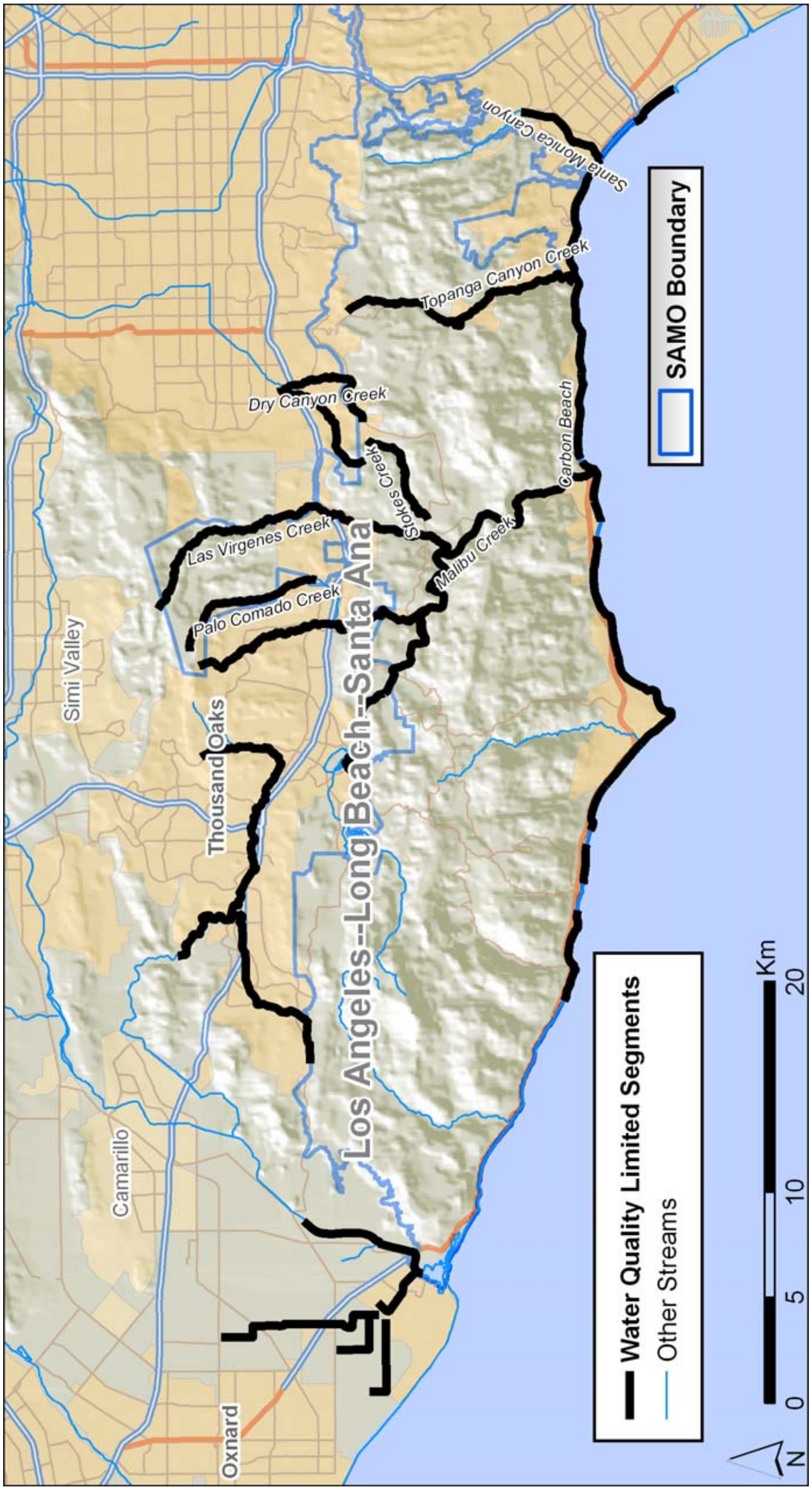


Figure 41. Map of water quality limited segments at SAMO where TMDLs either are required or have been approved by EPA or are not required.

Data

Park scale: GIS shapefiles of TMDL status obtained from
http://www.swrcb.ca.gov/water_issues/programs/tmdl/303d_lists2006_gis.shtml.

Status

Park scale:

As of the 2006 303(d) list, 38 segments that are at least partially within SAMO violated standards for one or more of 37 different pollutants (Table 12). Calleguas Creek, which is mostly outside of SAMO, has as many as 14 pollutants in some stream reaches. Of segments primarily inside SAMO with the most pollutants needing remediation, Malibu Creek has eight pollutants (only one TMDL approved so far by EPA), and Las Virgenes Creek has seven (one approved TMDL). Topanga Canyon Creek, on the other hand, has only one pollutant (lead). The beach segments typically have bacteria, DDT, and PCB pollutants. Thirty-seven different pollutants require TMDLs in one or more segments, including seven nutrients (Table 13), two other organics (Table 14), ten pesticides (Table 15 and Table 16), four pathogens and two toxicity pollutants (Table 17), five metals or metalloids (Table 18), and seven miscellaneous factors such as salinity, fish barriers, and trash (Table 19). Altogether, there are 134 segment-pollutant combinations, or 10% of the possible combinations (38 segments by 37 pollutants). Fifty-four of the 134 combinations have approved TMDLs in place, leaving 80 TMDL plans still to be developed and approved. As a group, the pathogen pollutants have the highest percentage of approved TMDLs. The most frequent pollutants are DDT (20 of the 38 segments), PCBs (19), Indicator Bacteria (14), and Coliform Bacteria (12).

Table 12. Pollutants by water quality limited segments.

Segment ID	Segment Name	Pollutant	Status
CAR40311000020000228145414	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2	ChemA (tissue)	EPA
		Chlordane (tissue)	EPA
		DDT (tissue & sediment)	EPA
		Nitrogen	EPA
		Sediment Toxicity	EPA
		Toxaphene (tissue)	EPA
		Toxicity	EPA
CAR40312000020000228111202	Calleguas Creek Reach 2 (estuary to Potrero Rd)	Ammonia	EPA
		ChemA (tissue)	Req
		Chlordane (tissue)	EPA
		Copper (Dissolved)	EPA
		DDT	EPA
		DDT (tissue & sediment)	EPA
		Dieldrin	EPA
		Endosulfan (tissue)	Req
		Fecal Coliform	Req
		Nitrogen	EPA
		PCBs (Polychlorinated biphenyls) (tissue)	EPA
		Sediment Toxicity	EPA
		Sedimentation/Siltation	Req
		Toxaphene (tissue & sediment)	EPA
CAR40364000020000229100105	Calleguas Creek Reach 13 (Conejo Creek South Fork)	Ammonia	EPA
		ChemA (tissue)	Req
		Chlordane	EPA
		Chloride	Req
		DDT (tissue)	EPA
		Dieldrin	EPA
		Endosulfan (tissue)	Req
		PCBs (Polychlorinated biphenyls)	EPA
		Sulfates	Req
		Total Dissolved Solids	Req
		Toxaphene (tissue & sediment)	EPA

Segment ID	Segment Name	Pollutant	Status
		Toxicity	EPA
CAR4041100019980918145717	Topanga Canyon Creek	Lead	Req
CAR4042100019990201132825	Malibu Creek	Coliform Bacteria	EPA
		Fish Barriers (Fish Passage)	Req
		Nutrients (Algae)	Req
		Scum/Foam-unnatural	Req
		Sedimentation/Siltation	Req
		Selenium	Req
		Sulfates	Req
		Trash	Req
CAR4042201019990201141611	Las Virgenes Creek	Coliform Bacteria	EPA
		Nutrients (Algae)	Req
		Organic Enrichment/Low Dissolved Oxygen	Req
		Scum/Foam-unnatural	Req
		Sedimentation/Siltation	Req
		Selenium	Req
		Trash	Req
CAR4042202019990201161555	Stokes Creek	Coliform Bacteria	EPA
CAR4042300019990201140017	Medea Creek Reach 2 (Abv Confl. with Lindero)	Algae	Req
		Coliform Bacteria	EPA
		Sedimentation/Siltation	Req
		Selenium	Req
		Trash	Req
CAR4042300019990201151533	Palo Comado Creek	Coliform Bacteria	EPA
CAR4042400019990201134442	Medea Creek Reach 1 (Lake to Confl. with Lindero)	Algae	Req
		Coliform Bacteria	EPA
		Sedimentation/Siltation	Req
		Selenium	Req
		Trash	Req
CAR4042400019990202081341	Triunfo Canyon Creek Reach 1	Lead	Req
		Mercury	Req
		Sedimentation/Siltation	Req
CAR4042400019990202082235	Triunfo Canyon Creek Reach 2	Lead	Req
		Mercury	Req
		Sedimentation/Siltation	Req
CAR4051300019980918150955	Santa Monica Canyon	Indicator bacteria	EPA
		Lead	Req
CAR4052100020020130141858	McCoy Canyon Creek	Fecal Coliform	Req
		Nitrate	Req
		Nitrogen (Nitrate)	Req
		Selenium (Total)	EPA
CAR4052100020020130145656	Dry Canyon Creek	Fecal Coliform	Req
		Selenium (Total)	EPA
CAX4041200019990922170849	Las Tunas Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4041300019990924081553	Topanga Beach	Coliform Bacteria	EPA
		DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4041500019990922165924	Las Flores Beach	Coliform Bacteria	EPA
		DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4041600019990922144015	Carbon Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4041600019990922162849	La Costa Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4042100019990923084019	Malibu Lagoon Beach (Surfrider)	Coliform Bacteria	EPA
		DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4042100020000321091234	Malibu Beach	DDT	Req
		Indicator bacteria	EPA
CAX4043100019990922101223	Big Rock Beach	Coliform Bacteria	EPA
		DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4043100019990922145850	Dan Blocker Memorial (Coral) Beach	Coliform Bacteria	EPA
CAX4043100019990923130035	Puerco Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4043100020000312160831	Amarillo Beach	DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4043400019990922153218	Escondido Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4043500019990923104303	Paradise Cove Beach	DDT	Req

Segment ID	Segment Name	Pollutant	Status
		Fecal Coliform	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4043500019990923104958	Point Dume Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4043600019990924091850	Zuma Beach (Westward Beach)	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4043700019990924083852	Trancas Beach (Broad Beach)	DDT	Req
		Fecal Coliform	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4044100019990923134843	Robert H. Meyer Memorial Beach	Beach Closures	Req
		DDT	Req
		PCBs (Polychlorinated biphenyls)	Req
CAX4044100020000301091908	Sea Level Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4044400019990922180357	Leo Carillo Beach (South of County Line)	Coliform Bacteria	EPA
CAX4044400019990923074411	Nicholas Canyon Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req
CAX4051300019990924080458	Santa Monica Beach	Indicator bacteria	EPA
CAX4051300019990924091258	Will Rogers Beach	Indicator bacteria	EPA
CAX4051300020000407104603	Castlerock Beach	DDT	Req
		Indicator bacteria	EPA
		PCBs (Polychlorinated biphenyls)	Req

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 13. TMDL status for the Nutrients category at SAMO.

Segment ID	Segment Name	Algae	Ammonia	Nitrate	Nitrogen	Nitrogen (Nitrate)	Nutrients (Algae)	Organic Enrichment/ Low Dissolved Oxygen
CAR4031100020000228145414	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2				EPA			
CAR4031200020000228111202	Calleguas Creek Reach 2 (estuary to Potrero Rd)		EPA		EPA			
CAR4036400020000229100105	Calleguas Creek Reach 13 (Conejo Creek South Fork)		EPA					
CAR4042100019990201132825	Malibu Creek						Req	
CAR4042201019990201141611	Las Virgenes Creek						Req	Req
CAR4042300019990201140017	Medea Creek Reach 2 (Abv Confl. with Lindero)	Req						
CAR4042400019990201134442	Medea Creek Reach 1 (Lake to Confl. with Lindero)	Req						
CAR4052100020020130141858	McCoy Canyon Creek			Req		Req		
Total # of segments not meeting standards		2	2	1	2	1	2	1

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 14. TMDL status for the Other Organics category at SAMO.

Segment ID	Segment Name	PCBs (Polychlorinated biphenyls)	PCBs (Polychlorinated biphenyls) (tissue)
CAR4031200020000228111202	Calleguas Creek Reach 2 (estuary to Potrero Rd)		EPA
CAR4036400020000229100105	Calleguas Creek Reach 13 (Conejo Creek South Fork)	EPA	
CAX4041200019990922170849	Las Tunas Beach	Req	
CAX4041300019990924081553	Topanga Beach	Req	
CAX4041500019990922165924	Las Flores Beach	Req	
CAX4041600019990922144015	Carbon Beach	Req	
CAX4041600019990922162849	La Costa Beach	Req	
CAX4042100019990923084019	Malibu Lagoon Beach (Surfrider)	Req	
CAX4043100019990922101223	Big Rock Beach	Req	
CAX4043100019990923130035	Puerco Beach	Req	
CAX4043100020000312160831	Amarillo Beach	Req	
CAX4043400019990922153218	Escondido Beach	Req	
CAX4043500019990923104303	Paradise Cove Beach	Req	
CAX4043500019990923104958	Point Dume Beach	Req	
CAX4043600019990924091850	Zuma Beach (Westward Beach)	Req	
CAX4043700019990924083852	Trancas Beach (Broad Beach)	Req	
CAX4044100019990923134843	Robert H. Meyer Memorial Beach	Req	
CAX4044100020000301091908	Sea Level Beach	Req	
CAX4044400019990923074411	Nicholas Canyon Beach	Req	
CAX4051300020000407104603	Castlerock Beach	Req	
Total # of segments not meeting standards		19	1

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 15. TMDL status for the Pesticides category at SAMO.

Segment Name	Chlordane	Chlordane (tissue)	DDT	DDT (tissue & sediment)	DDT (tissue)
Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2		EPA		EPA	
Calleguas Creek Reach 2 (estuary to Potrero Rd)		EPA	EPA	EPA	
Calleguas Creek Reach 13 (Conejo Creek South Fork)	EPA				EPA
Las Tunas Beach			Req		
Topanga Beach			Req		
Las Flores Beach			Req		
Carbon Beach			Req		
La Costa Beach			Req		
Malibu Lagoon Beach (Surfrider)			Req		
Malibu Beach			Req		
Big Rock Beach			Req		
Puerco Beach			Req		
Amarillo Beach			Req		
Escondido Beach			Req		
Paradise Cove Beach			Req		
Point Dume Beach			Req		
Zuma Beach (Westward Beach)			Req		
Trancas Beach (Broad Beach)			Req		
Robert H. Meyer Memorial Beach			Req		
Sea Level Beach			Req		
Nicholas Canyon Beach			Req		
Castlerock Beach			Req		
Total # of segments not meeting standards	1	2	20	2	1

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 16. TMDL status for Pesticides category at SAMO (continued).

Segment Name	Dieldrin	Endosulfan (tissue)	Toxaphene (tissue & sediment)	Toxaphene (tissue)	ChemA (tissue)
Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2				EPA	EPA
Calleguas Creek Reach 2 (estuary to Potrero Rd)	EPA	Req	EPA		Req
Calleguas Creek Reach 13 (Conejo Creek South Fork)	EPA	Req	EPA		Req
Total # of segments not meeting standards	2	2	2	1	3

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 17. TMDL status for the Pathogens and the Toxicity categories at SAMO.

Segment ID	Segment Name	Beach Closures (Pathogens)	Coliform Bacteria (Pathogens)	Fecal Coliform (Pathogens)	Indicator Bacteria (Pathogens)	Sediment Toxicity (Toxicity)	Toxicity (Toxicity)
CAR4031100020000228145414	Duck Pond Agricultural Drains/Mugu Drain/Oxnard Drain No 2					EPA	EPA
CAR4031200020000228111202	Calleguas Creek Reach 2 (estuary to Potrero Rd)			Req		EPA	
CAR4036400020000229100105	Calleguas Creek Reach 13 (Conejo Creek South Fork)						EPA
CAR4042100019990201132825	Malibu Creek		EPA				
CAR4042201019990201141611	Las Virgenes Creek		EPA				
CAR4042202019990201161555	Stokes Creek		EPA				
CAR4042300019990201140017	Medea Creek Reach 2 (Abv Confl. with Lindero)		EPA				
CAR4042300019990201151533	Palo Comado Creek		EPA				
CAR4042400019990201134442	Medea Creek Reach 1 (Lake to Confl. with Lindero)		EPA				
CAR4051300019980918150955	Santa Monica Canyon				EPA		
CAR4052100020020130141858	McCoy Canyon Creek			Req			
CAR4052100020020130145656	Dry Canyon Creek			Req			
CAX4041200019990922170849	Las Tunas Beach				EPA		
CAX4041300019990924081553	Topanga Beach		EPA				
CAX4041500019990922165924	Las Flores Beach		EPA				
CAX4041600019990922144015	Carbon Beach				EPA		
CAX4041600019990922162849	La Costa Beach				EPA		
CAX4042100019990923084019	Malibu Lagoon Beach (Surfrider)		EPA				
CAX4042100020000321091234	Malibu Beach				EPA		
CAX4043100019990922101223	Big Rock Beach		EPA				

Segment ID	Segment Name	**Beach Closures** (Pathogens)	**Coliform Bacteria** (Pathogens)	**Fecal Coliform** (Pathogens)	**Indicator Bacteria** (Pathogens)	**Sediment Toxicity** (Toxicity)	**Toxicity** (Toxicity)
CAX404310001999092214585O	Dan Blocker Memorial (Coral) Beach		EPA				
CAX4043100019990923130035	Puerco Beach				EPA		
CAX4043400019990922153218	Escondido Beach				EPA		
CAX4043500019990923104303	Paradise Cove Beach			EPA			
CAX4043500019990923104958	Point Dume Beach				EPA		
CAX4043600019990924091850	Zuma Beach (Westward Beach)				EPA		
CAX4043700019990924083852	Trancas Beach (Broad Beach)			EPA			
CAX4044100019990923134843	Robert H. Meyer Memorial Beach	Req					
CAX4044100020000301091908	Sea Level Beach				EPA		
CAX4044400019990922180357	Leo Carillo Beach (South of County Line)		EPA				
CAX4044400019990923074411	Nicholas Canyon Beach				EPA		
CAX4051300019990924080458	Santa Monica Beach				EPA		
CAX4051300019990924091258	Will Rogers Beach				EPA		
CAX4051300020000407104603	Castlerock Beach				EPA		
Total # of segments not meeting standards		1	12	5	14	2	2

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 18. TMDL status for the Metals/Metalloid category at SAMO.

Segment ID	Segment Name	Copper (Dissolved)	Lead	Mercury	Selenium	Selenium (Total)
CAR4031200020000228111202	Calleguas Creek Reach 2 (estuary to Potrero Rd)	EPA				
CAR4041100019980918145717	Topanga Canyon Creek		Req			
CAR4042100019990201132825	Malibu Creek				Req	
CAR4042201019990201141611	Las Virgenes Creek				Req	
CAR4042300019990201140017	Medea Creek Reach 2 (Abv Confl. with Lindero)				Req	
CAR4042400019990201134442	Medea Creek Reach 1 (Lake to Confl. with Lindero)				Req	
CAR4042400019990202081341	Triunfo Canyon Creek Reach 1		Req	Req		
CAR4042400019990202082235	Triunfo Canyon Creek Reach 2		Req	Req		
CAR4051300019980918150955	Santa Monica Canyon		Req			
CAR4052100020020130141858	McCoy Canyon Creek					EPA
CAR4052100020020130145656	Dry Canyon Creek					EPA
Total # of segments not meeting standards		1	4	2	4	2

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Table 19. TMDL status for miscellaneous categories at SAMO.

Segment Name	**Chloride** (Salinity)	**Fish Barriers (Fish Passage)** (Hydromodification)	**Scum/ Foam-unnatural** (Nuisance)	**Sedimentation/ Siltation** (Sediment)	**Sulfates** (Other Inorganics)	**Total Dissolved Solids** (Salinity)	**Trash** (Trash)

Segment Name	**Chloride** (Salinity)	**Fish Barriers (Fish Passage)** (Hydromodification)	**Scum/ Foam-unnatural** (Nuisance)	**Sedimentation/ Siltation** (Sediment)	**Sulfates** (Other Inorganics)	**Total Dissolved Solids** (Salinity)	**Trash** (Trash)
Calleguas Creek Reach 2 (estuary to Potrero Rd)				Req			
Calleguas Creek Reach 13 (Conejo Creek South Fork)	Req				Req	Req	
Malibu Creek		Req	Req	Req	Req		Req
Las Virgenes Creek			Req	Req			Req
Medea Creek Reach 2 (Abv Confl. with Lindero)				Req			Req
Medea Creek Reach 1 (Lake to Confl. with Lindero)				Req			Req
Triunfo Canyon Creek Reach 1				Req			
Triunfo Canyon Creek Reach 2				Req			
Total # of segments not meeting standards	1	1	2	7	2	1	4

EPA = Being Addressed by USEPA-approved TMDLs; Req = TMDL Required

Emerging Issues

SAMO's location within an urban matrix has left a legacy of many pollutants, including some such as DDT that are no longer used. Even if NPS activities are not the source of pollutants or TMDLs would not dictate NPS management, the natural resources and recreational value of SAMO are potentially impacted by these pollutants. Beach closures associated with pathogens are especially impactful. As a stakeholder in the TMDL planning process, SAMO staff may be asked to support development of TMDLs for the remaining 80 required plans identified above. In some cases, SAMO is assigned Load Allocations of pollutants by the TMDL that must be reduced to the Final Load Allocation. For example, in the case of trash in the Santa Monica Bay watersheds, for example, SAMO is assigned a Load Allocation based on the sum of the products of each land use subarea multiplied by the Load Allocation for the land use subarea (California Regional Water Quality Control Board, Los Angeles Region 2010). The TMDL requires a zero trash level within five years, along with rigorous monitoring and reporting of trash collected. This empirical data may be used to refine the Baseline Load Allocation when the TMDL is reconsidered. Given the number of water quality limited segments and pollutants at SAMO, this could lead to a substantial increase in the monitoring workload, not to mention mitigation actions to bring emissions into compliance.

Data Gaps

The origin of pollutants in water quality limited segments is not always obvious, particularly for nonpoint sources. As noted above in the case of the debris or trash TMDL, the Load Allocations are sometimes based on simple formulas of land use area and empirical data on generation or emission rates. The debris generation for open space lands was based on a single study by the City of Calabasas. The TMDL-mandated monitoring of actual generation rates on NPS lands will help refine these general estimates, but monitoring has not begun.

Also, there is much more to the 303(d) listing process then just the final list of impaired waterways and TMDL requirements. There may be some streams without enough monitoring data to determine if they are impaired. Such streams may have declining water quality due to upstream development, but it may not yet exceed the standards for the designated beneficial uses. There may also be issues regarding the beneficial uses designated for a given stream segment (they may be too inclusive or not inclusive enough).

There has been limited water quality monitoring in an effort to develop a monitoring protocol. A future research need is identifying all existing water quality data from the various agencies and projects over the years and analyzing those, with particular attention to data from streams which are not on the 303(d) list currently.

Key references

California Regional Water Quality Control Board, Los Angeles Region. 2010. Santa Monica Bay: Nearshore and Offshore Debris TMDL (Draft: July 30, 2010).

Biological integrity—Invasive species—Non-native invasive plants
Summary: Baseline only

SAMO is highly vulnerable to invasion by non-native plants, including over 300 species in more than 10,000 populations. A recent exotic threat assessment identified nine of these species as the most threatening to park resources and ranked their 3,729 populations for removal. A new GIS-based assessment was performed to estimate the relative vulnerability of SAMO to invasion from these high threat populations. This assessment used data from the original ranking assessment to measure relative exposure to invasion and combined that with environmental data on the invasibility of plant communities and disturbance factors to measure sensitivity to invasion. The product of exposure and sensitivity identified relative vulnerability. The most vulnerable locations in SAMO tend to be in the lower reaches of the coastal canyons where the invasive populations occur in or near disturbed or highly invasible landscapes. Eradication of the highest ranked populations would dramatically reduce vulnerability in these same general locations. The data cannot yet identify trends in the exposure component, although some populations have been recently controlled.

Approach

Invasibility has been defined “as the susceptibility of an environment to the colonization and establishment of individuals from species not currently part of the resident community” (Davis et al. 2005, p. 696). An Exotic Threat Assessment was recently completed for SAMO to determine which non-native plant species should be a priority for park management (Althoen et al. 2007). Thirty plant species were first assessed by their general biological attributes, history of invasiveness, and environmental impact. Species that ranked high by these criteria were further assessed by their distribution and impact within SAMO and their potential to be controlled through management. Of the 30 species, nine emerged as the greatest threat in SAMO (Table 20).

Table 20. Plant species considered high threat for invasion in SAMO (Althoen et al. 2007).

Common name	Scientific name
Yellow starthistle	*Centaurea solstitalis*
Pampas grass	*Cortaderia jabata*
German ivy	*Delairea odorata*
False caper	*Euphorbia terracina*
Fennel	*Foeniculum vulgare*
Tobacco tree	*Nicotiana glauca*
Harding grass	*Phalaris aquatica*
Russian thistle	*Acroptilon repens*
Perennial pepperweed	*Lepidium latifolium*

Althoen et al. (2007) then developed an approach for prioritizing populations within SAMO of the nine most threatening plants for removal. Criteria for prioritization were organized hierarchically. At the top level, the approach defined four criteria: Potential to be a source population, habitat quality, public relations, and ease of control. Each of these criteria was decomposed into more specific subcriteria. For example, the subcriterion for potential to be a source population was based on population size, watershed position (elevation), and distance from roads, trails, or streams by which the species could disperse. Through a literature review, Althoen et al. (2007) categorized land cover/use types into high invasibility (grassland, riparian, oak woodland, coastal salt marsh, agriculture, residential, cliff and drainage), medium (coastal sage scrub and coastal strand), and low (chaparral) classes. In all, 3,729 populations of the nine species were assessed by the multicriteria analysis and ranked for treatment to remove exotic plants.

We extended the assessment by Althoen et al. by modeling the relative vulnerability to invasion of all locations within SAMO. That is, if the populations of these exotic plants are potential sources of stress, where are they likely to disperse? Relative vulnerability was determined by the product of scores of the exposure to source populations (proximity and density) of invaders and the sensitivity of sites to invasion (Figure 42). Using the database of Althoen et al. (2007) of populations and their potential to become sources, we used GIS analysis to determine the cumulative exposure as a distance-weighted sum of scores of source potential. Further GIS analysis measured sensitivity as the maximum of the relative invasibility of land cover/use types (factors and references in Althoen et al. 2007) and the degree of disturbance from roads and recent fires that enhance establishment of invasive plants (Cameron et al. 2005). If the highest-ranked populations of threatening plants were eliminated by active management, the exposure component would be reduced, especially if these populations were clustered near each other. A second vulnerability assessment was conducted after excluding those populations from the database. (See the Appendix for GIS layers generated for the assessment).

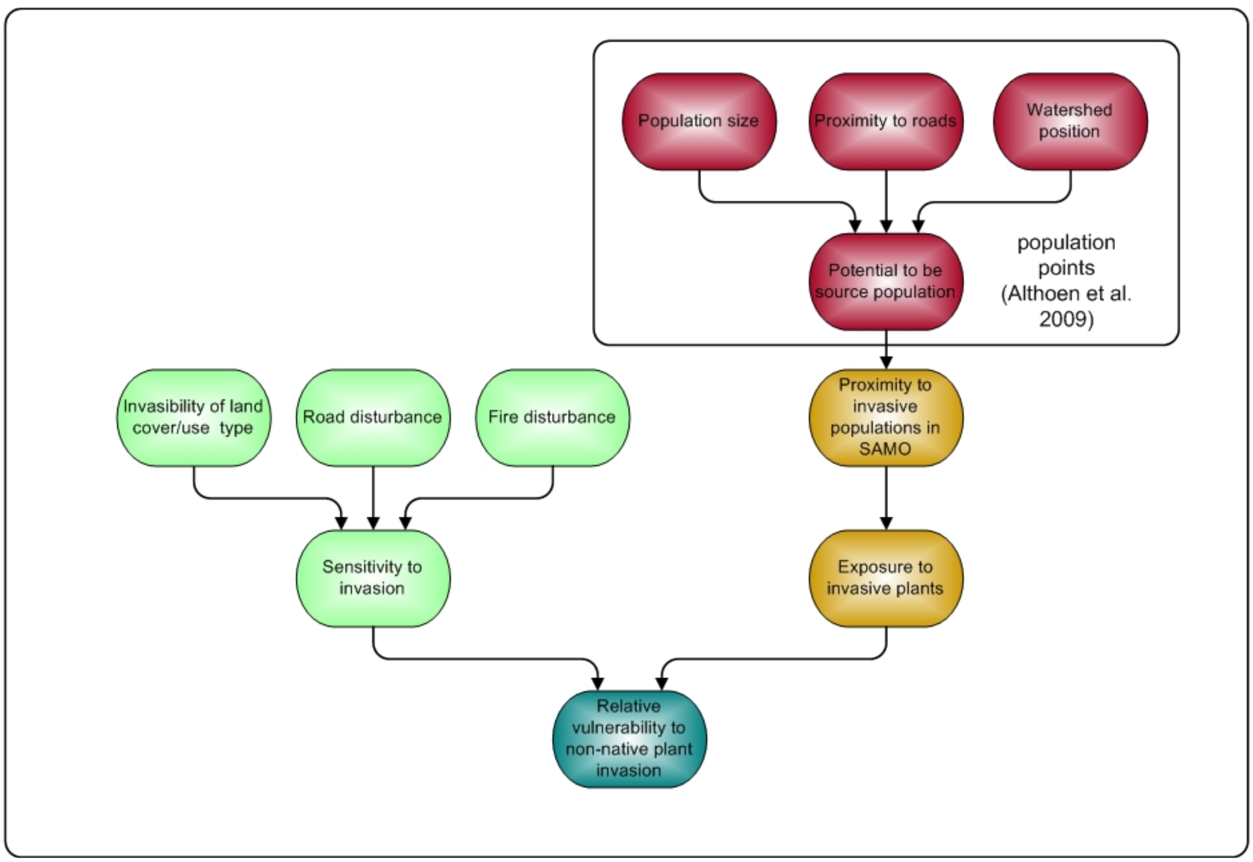


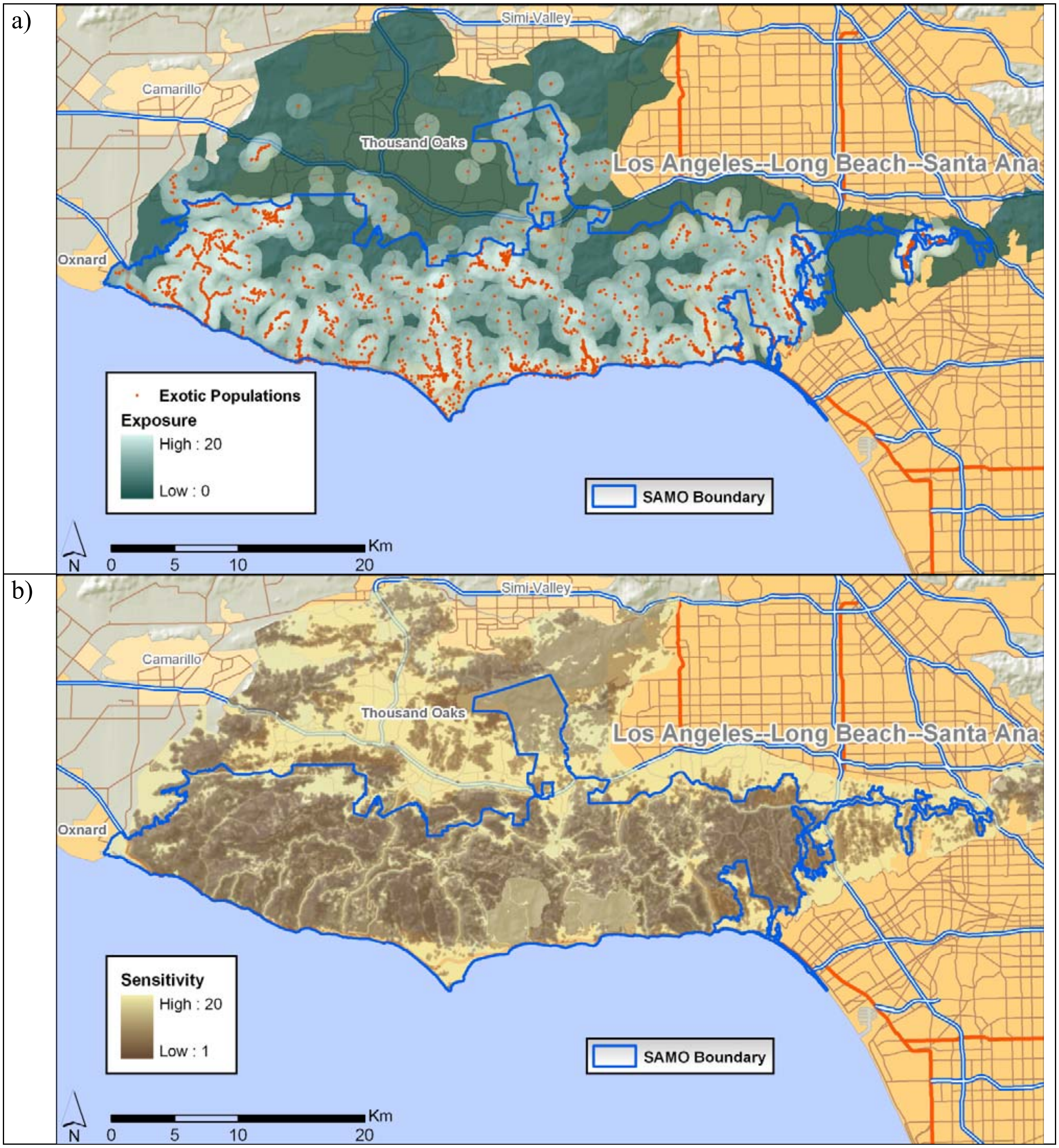
Figure 42. Conceptual GIS model of relative vulnerability to non-native plant invasions.

Data

Data on the potential for populations to become sources of invasion was had been compiled and assessed by Althoen et al. (2007). This database contained the point locations of 3,729 populations of the nine most threatening plant species, plus scores on their potential to spread. SAMO staff provided GIS layers for land cover/use, roads, and streams to extrapolate point data to the entire park unit. However, the previous assessment used these classes to evaluate habitat quality, whereas the current assessment is concerned with relative sensitivity to invasion. Therefore points were assigned to classes differently here. The land cover/use map was developed by Aerial Information Systems in 2007 from 2001 aerial photography.

Status

Relative exposure tends to be greatest up the canyons from the coastline, both from greater disturbance allowing opportunities for invasive plants to colonize and greater opportunity for observation from roads and trails compared to remote locations (Figure 43a). Much of SAMO is covered in chaparral, which is relatively insensitive to invasions. The most sensitive areas are developed areas, along roadways, riparian areas, and in recent burn areas (Figure 43b). As relative vulnerability was calculated as the product of exposure and sensitivity, it is not surprising that the most vulnerable sites follow roads and trails and creeks up the coastal canyons (Figure 43c).


a)
Simi Valley
Camarillo
Thousand Oaks
Los Angeles--Long Beach--Santa Ana
Oxnard
Exotic Populations
Exposure
High : 20
Low : 0
SAMO Boundary
N
Km
0
5
10
20
b)
Simi Valley
Camarillo
Thousand Oaks
Los Angeles--Long Beach--Santa Ana
Oxnard
Sensitivity
High : 20
Low : 1
SAMO Boundary
N
Km
0
5
10
20

c)

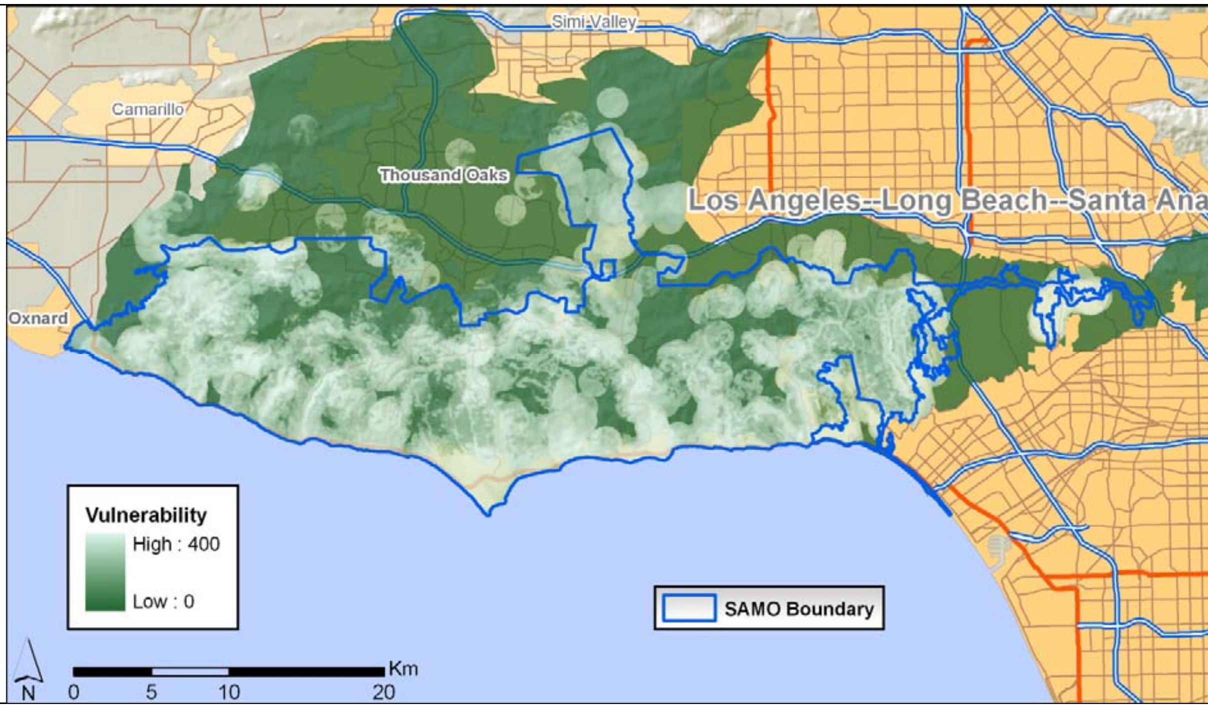


Figure 43. Maps of a) exposure to all known populations of the nine most threatening plants, b) sensitivity to invasion, and c) relative vulnerability to non-native plant invasion.

The top 10 percentile of these populations in terms of their potential to become source populations (Althoen et al. 2007) have a substantial effect on the map of relative exposure. Simulating what would happen if these highest-ranked populations were eradicated, relative vulnerability could be drastically reduced in many pockets along the Kanan-Dume Road, in Point Mugu State Park, in the Franklin and Fryman Canyon area on the east end of the park, and other scattered locations (Figure 44). Eliminating the top 10 percentile of populations could reduce the mean vulnerability of SAMO by nearly 20%. This information could provide the missing spatial analysis to improve the original prioritization of individual populations (Althoen et al. 2007).

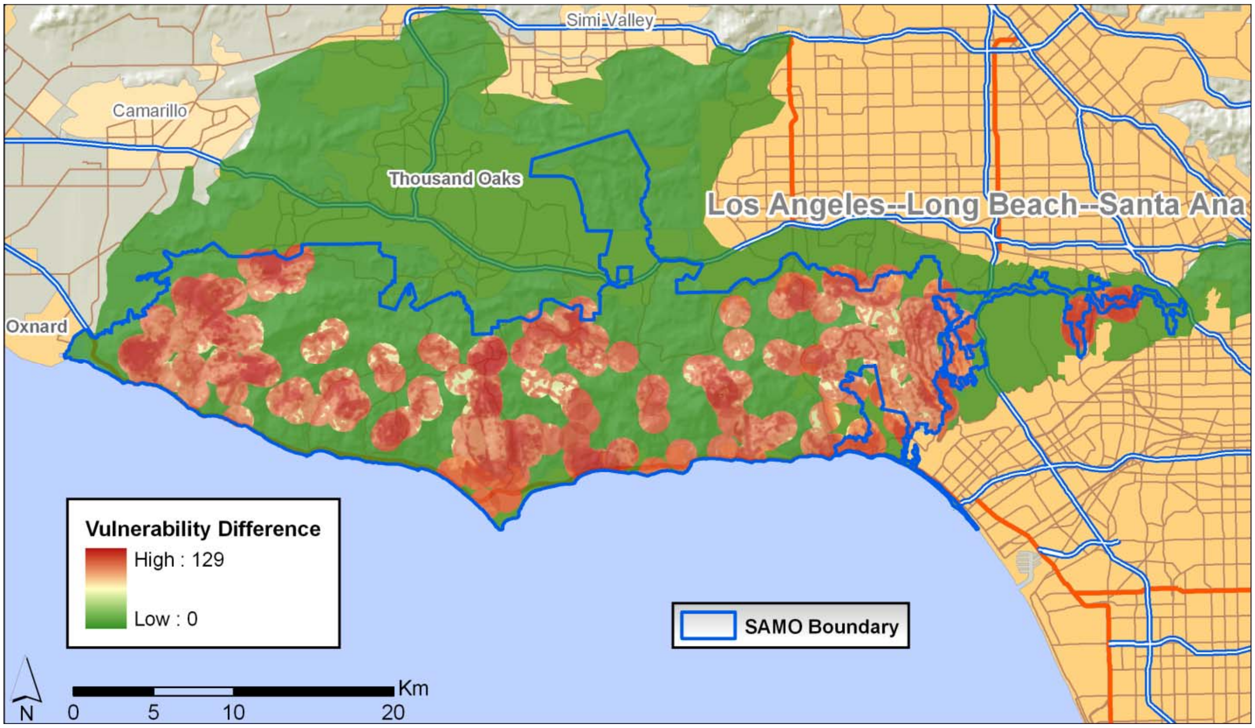


Figure 44. Map of the change in relative vulnerability to non-native plant invasion from populations of the nine most threatening plants if the highest-ranked 10 percentile of populations were removed.

Emerging Issues

Climate change can potentially influence the pattern and success of plant invasions in multiple ways. Shifting temperature and precipitation patterns can stress native plant communities and open opportunities for invaders. Climate-induced changes in fire regime can increase the frequency or severity of fire that would also provide disturbed niches for invaders.

Data Gaps

Trend data were not available to determine whether non-native plants are expanding or whether recent control activities have had much impact on invasions. Consequently the trends in the exposure component are unknown. The MEDN is in the process of developing an invasive plant I&M protocol with 2 main goals: 1) detect the presence and spread of invasive plants on a parkwide basis, and 2) early detection to allow for rapid response to incipient populations. The sensitivity component of vulnerability should be easier to track at least periodically. Land use changes can be mapped and updated. Fire perimeters are compiled by the state and can be readily used to update the time since last burn factor.

Summer flows seem to be increasing in urban streams that were historically intermittent. There are several stressors and pathways that may be contributing to increased summer stream flows and associated vulnerability to plant invasion. Runoff from irrigation of urban lawns and parks may be the cause (Cameron et al. 2005). Alternatively, deepening of stream channels may promote greater groundwater accumulation, or channelization may have reduced evapotranspiration losses. Whatever the cause, these increased flows potentially encourage invasion by non-native riparian plants such as *Arundo donax*. It will be important to determine which stressors are creating this effect to be able to mitigate the impacts.

Native species that could be vulnerable to non-native plant invasions (as mentioned in Chapter 2) could become indicators in future assessments if appropriate data are collected or spatial models can be developed.

Key references

Althoen, E. J., E. Chasin, S. Kent, E. Kiyan and S. Schliemann. 2007. *Biology and Management of Non-Native Plant Species in the Santa Monica Mountains National Recreation Area*. Masters thesis in Environmental Science and Management, Donald Bren School of Environmental Science & Management, University of California Santa Barbara. Santa Barbara.

Cameron, J. L., R. Sauvajot, D. Kamradt and L. Lee. 2005. *Mediterranean Coast Network Vital Signs Monitoring Plan*, National Park Service.

Davis M. A., Thompson K., Grime J. P. 2005. Invasibility: the local mechanism driving community assembly and species diversity. *Ecography* 28: 696–704.

Landscapes—Fire and fuel dynamics—Fire regime

Summary: No significant change

The mean fire rotation interval for the Santa Monica Mountains subsection for the period 1946-2008 was 34 years, which is shorter than many chaparral-dominated landscapes in California but still within the historical range of variation typical of many chaparral landscapes (~20-60 years). Since 1946, fire return intervals of ≤7 years - short enough to significantly reduce the density of non-resprouting chaparral shrubs - have occurred at least once across 13.8% of the Santa Monica Mountains subsection and 15.6% of SAMO. Fire return intervals of ≤12 years, which are considered a threat to non-sprouting chaparral species, have occurred across 25.0% of the Santa Monica Mountains and 28.9% of SAMO. Thus a significant fraction of the region is experiencing short return interval fires. The western Santa Susana, the Simi Hills, and the ocean-facing canyons of the Santa Monica Mountains above Malibu are especially prone to such fires and are currently dominated by annual grassland and coastal sage scrub communities.

Between 1946 and 2008 the annual total area burned in the Santa Monica Mountains subsection showed no significant trend. The annual area that re-burned within a decade of the last fire peaked in 1993, but the annual area subjected to such short-interval burning did not increase between 1960 and 2008. However, some localities in the Santa Monica Mountains and the Simi Valley – Santa Susana Mountains are burning at very high frequency, notably the western Santa Susana Mountains (South Mountain, Oak Ridge, and Oat Mountain), the Simi Hills, and the ocean-facing canyons of the Santa Monica Mountains above Malibu.

The fire regime of the Santa Monica Mountains has been strongly influenced by human cultures for thousands of years and has probably changed considerably over the past several centuries (Keeley 2002). Unfortunately there is scant documentation of pre-historic fire regimes (Radtke et al. 1982). Radtke et al. (1982) argued that the coastal slopes of the Santa Monica Mountains, being dominated by coastal sage scrub vegetation, had a higher fire frequency than chaparral dominated slopes further inland both in the pre-fire suppression period 1900-1918 as well as in the fire suppression period 1919-1980.

Approach

We analyzed the recent historical fire regime using ecological sub-sections, which are slightly different analysis regions than used for the other analyses in this report but provided us relatively consistent geographical and ecological fire regions in terms of climate, topography, soils and vegetation (Figure 45).

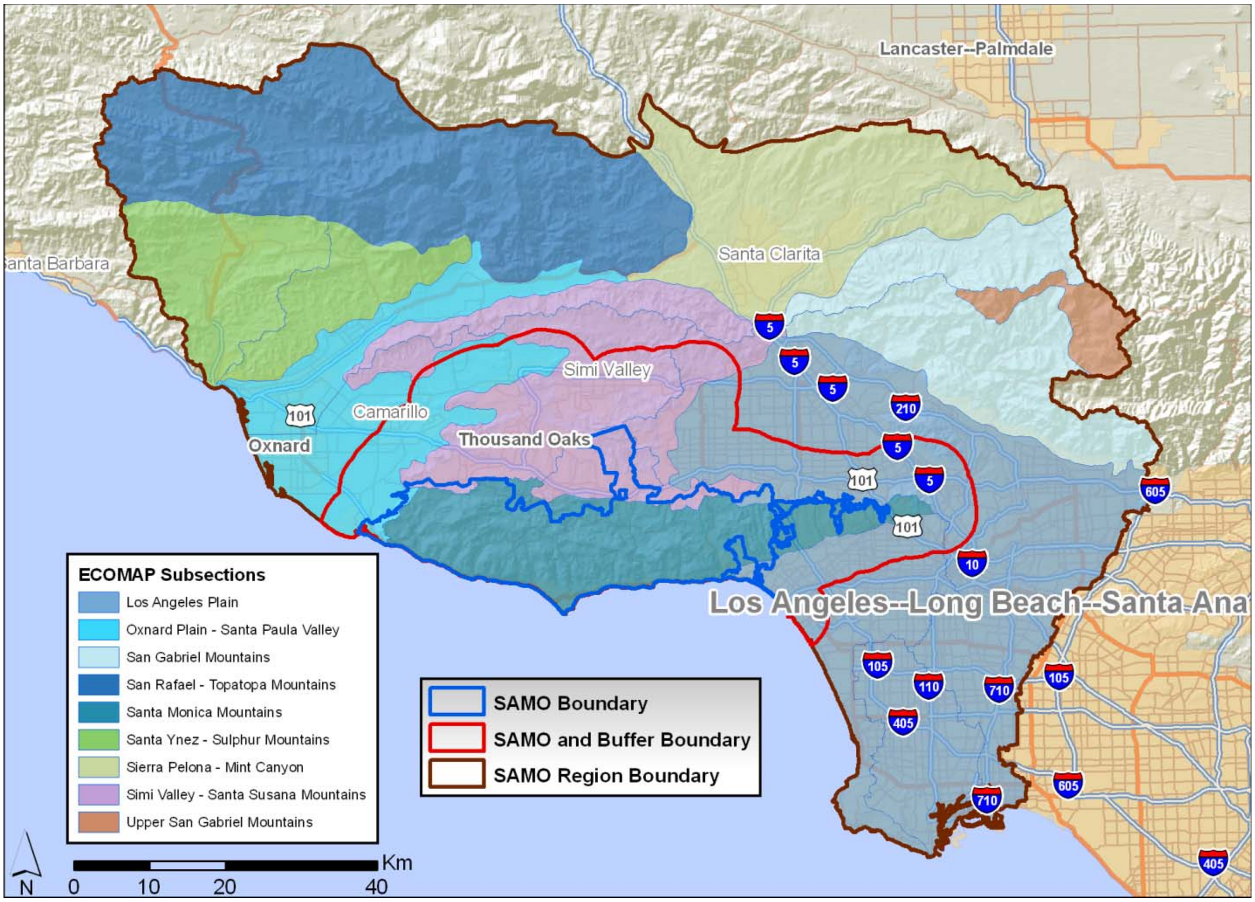


Figure 45. Ecological subsections used for fire regime analysis (Goudey and Smith 1994). Blue lines that subdivide the subsections are major watershed boundaries.

We confined our quantitative trend analyses to the 62-year period, 1946-2008, for which spatial fire perimeter data were deemed to be relatively consistent and complete. We excluded current urban and agricultural areas in all trend analyses. We examined all fire history data for the region but focused on four ecological subsections: the Santa Monica Mountains, the Simi Valley-Santa Susana Mountains, the Sierra Pelona-Mint Canyon area, and the San Rafael-Topatopa Mountains (Figure 45).

Data

Fire history data were obtained from the California Department of Forestry and Fire Protection (California Department of Forestry and Fire Protection 2008). The fire perimeters include both public and private lands and are consistently recorded for fires larger than 300 ac. The database is considered much less complete prior to 1950, especially for private lands. In screening these data we noticed that the Steckel fire was included twice in the perimeter data, with one polygon attributed to 1993 and the other to 1994. Based on newspaper articles we retained the 1993 polygons and deleted polygons from 1994.

Fire data were regionalized using ecological subsections as delineated in the USDA ECOMAP program (Goudey and Smith 1994).

Before calculating fire regime statistics we applied a regional mask of urban and agricultural areas as mapped in the California Department of Forestry and Fire Protections Multi-source land cover databases version 2002 (http://frap.cdf.ca.gov/data/frapgisdata/output/fveg02_1.txt).

Status

Fire frequency between 1946 and 2008 varied from areas that have not burned to a few localities that have burned 10 times during the interval (Figure 46). The highest concentration of fires occurred in the western Santa Susana Mountains (South Mountain, Oak Ridge, and Oat Mountain), the Simi Hills, and the Santa Monica Mountains above Malibu, areas currently dominated by coastal sage scrub and annual grasslands (Figure 46).

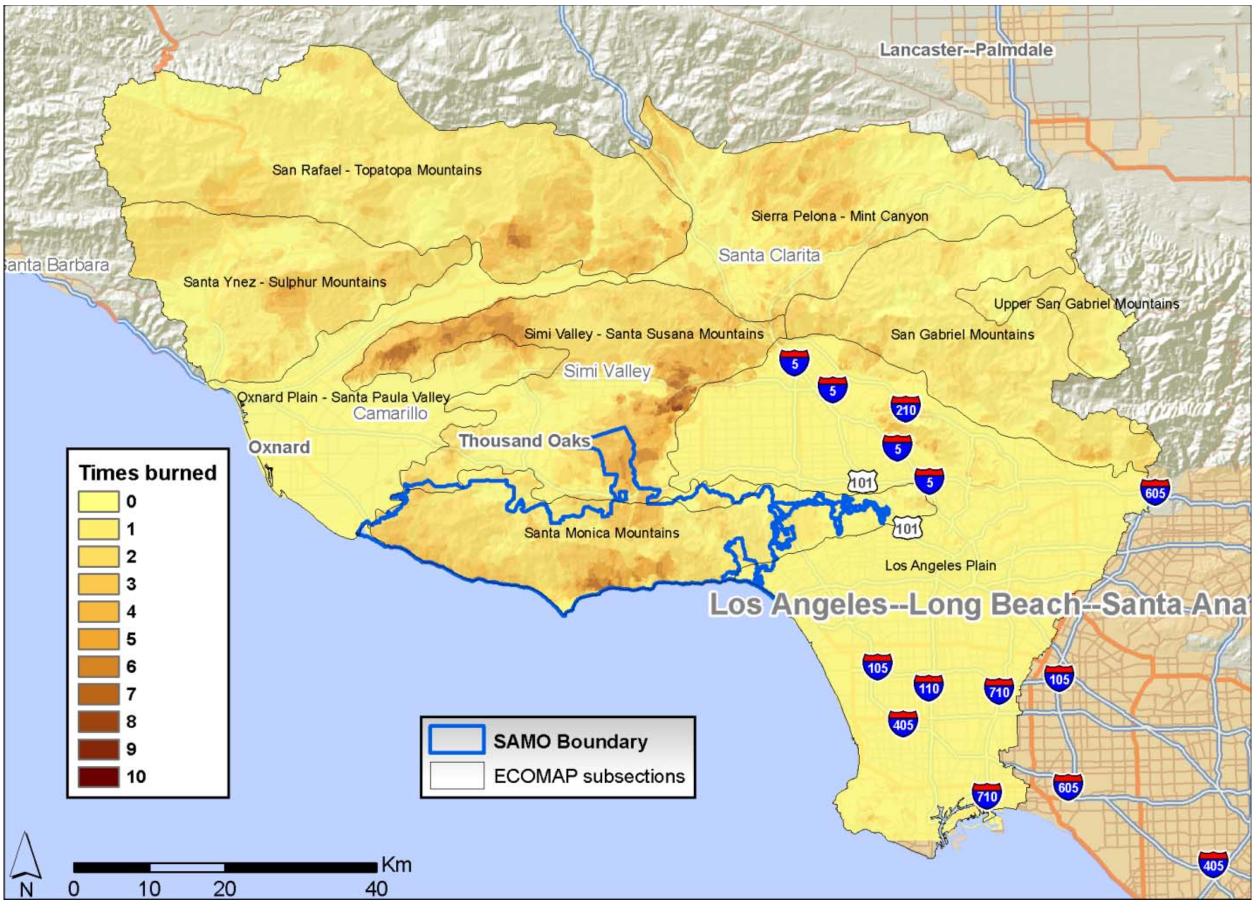


Figure 46. Map of fire frequency for the study region based on historical fire perimeter data.

A total of approximately 2.7 million mapped acres (1.1 million hectares) burned in the 62 year period. The cause of fire was not known for 63% of area burned. For the remainder, only 0.2% of area burned was lightning-caused; 40% was caused by equipment, 16% was caused by debris fires, and 6% was due to arson.

Regions vary considerably in the proportion of the landscape that has burned multiple times. In the Santa Monica Mountains, the mean and modal frequency for number of times a location has burned between 1946 and 2008 is 1.83 and 2, respectively. Twenty-four percent of the Santa Monica Mountains burned at least 3 times (Figure 47). In contrast, 37% of the Simi Valley –

Santa Susana Mountains region burned at least three times. Less than 15% of the Sierra Pelona – Mint Canyon region or San Rafael – Topatopa Mountains burned more than twice.

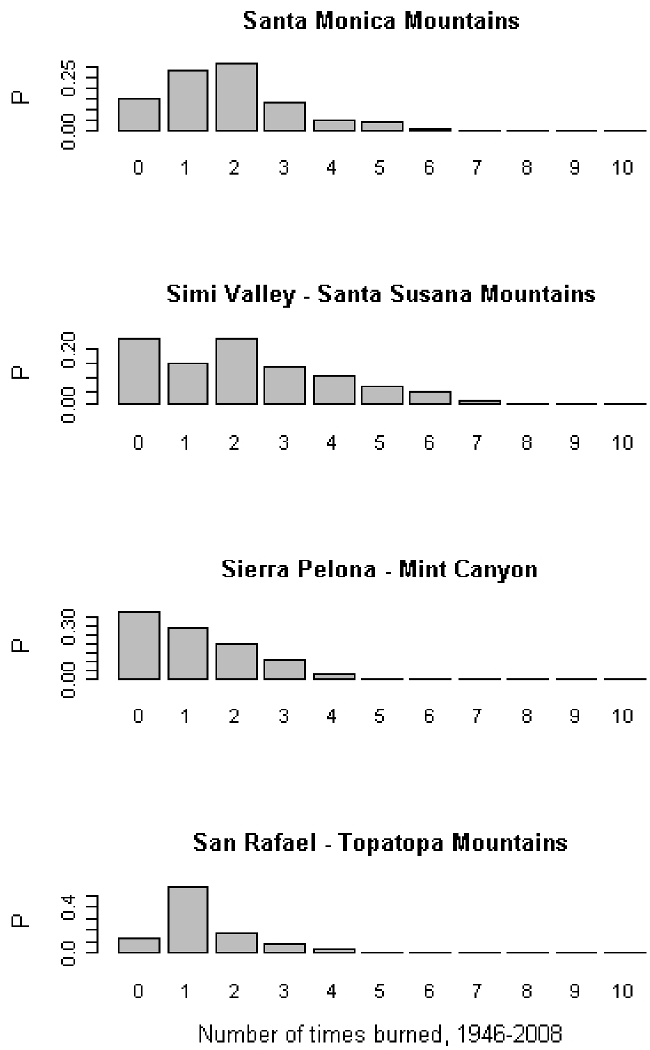


Figure 47. Frequency histograms showing the fraction of area burned from 0 to 10 times for four different ecological subsections during the period 1946-2008. Note the difference in scaling of the y axes.

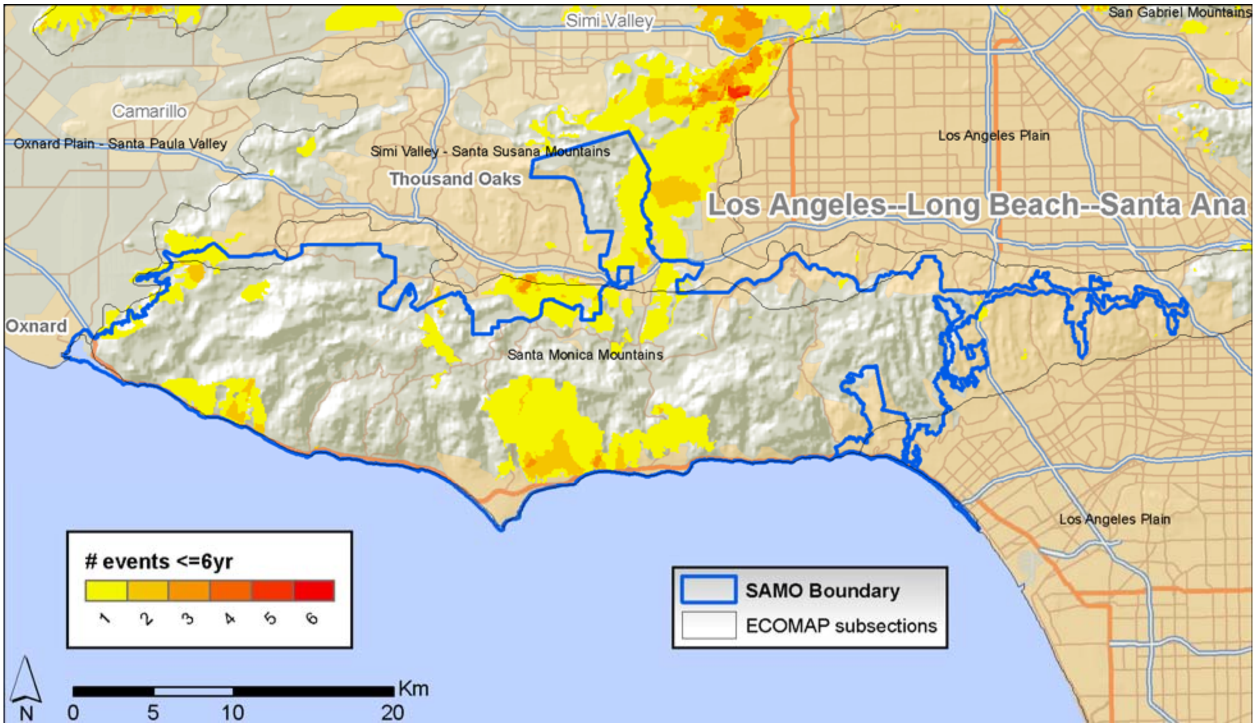
Since 1946 a significant fraction of the Santa Monica Mountains subsection and SAMO have experienced at least one short interval fire (Table 21). Short-interval fires pose a particular risk to non-sprouting chaparral shrubs that do not have adequate time to replenish seed banks. Intervals ≤12 yrs are considered threatening and intervals ≤6 yrs have been observed to reduce shrub density and promote cover by herbaceous species, particularly non-native species. Jacobsen et al. (2009) observed that chaparral at a coastal site in the Santa Monica Mountains that was previously dominated by *Malosma laurina*, *Ceanothus megacarpus*, and *C. spinosus* is today dominated by *M. laurina*, *Rhus ovata*, and exotic annuals. At that site, species of shrubs that rely exclusively upon recovery after fire by seed germination and establishment have been eliminated.

Table 21. Total area and percent of area that experienced from 0 to 7 short interval fires between 1946 and 2008. Statistics are summarized for both the Santa Monica Mountains National Recreational Area (SAMO) and the Santa Monica Mountains subsection.

	Fire return interval ≤ 6 years				Fire return interval ≤ 12 years			
# Events	SAMO (ha)	SAMO (%)	Santa Monica mountains (ha)	Santa Monica mountains (%)	SAMO (ha)	SAMO (%)	Santa Monica mountains (ha)	Santa Monica mountains (%)
0	52214	84.4%	55484	86%	43946	71.0%	48218	75.0%
1	8560	13.8%	7643	12%	9343	15.1%	9231	14.4%
2	1054	1.7%	1043	2%	4540	7.3%	3043	4.7%
3	50	0.1%	84	0%	2943	4.8%	2663	4.1%
4	0	0.0%	0	0%	718	1.2%	711	1.1%
5	0	0.0%	0	0%	343	0.6%	343	0.5%
6	0	0.0%	0	0%	23	0.0%	23	0.0%
7	0	0	0	0	22	0.0%	22	0.0%

Between 1946 and 2008, short-interval fires in the Santa Monica Mountains tended to recur on south facing slopes above Highway 1, especially above Malibu, and in canyons above Westlake Village and Agoura Hills (Figure 48).

a.



b.

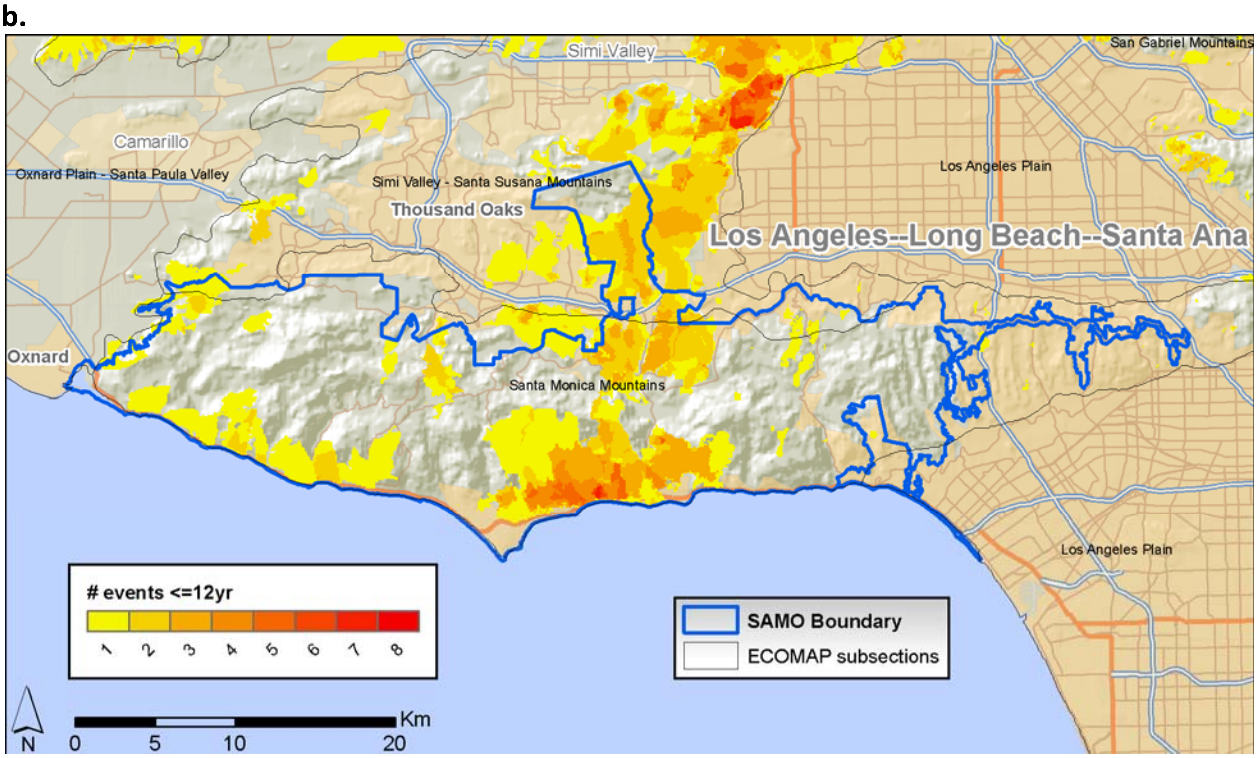


Figure 48. Frequency of short interval fires recorded between 1946 and 2008. a) Fire return interval ≤ 6 yrs. b) Fire return interval ≤ 12 yrs.

Trends

For the period 1946-2007, there is not a significant time trend in annual area burned in the Santa Monica Mountains (p=0.61,Figure 49).

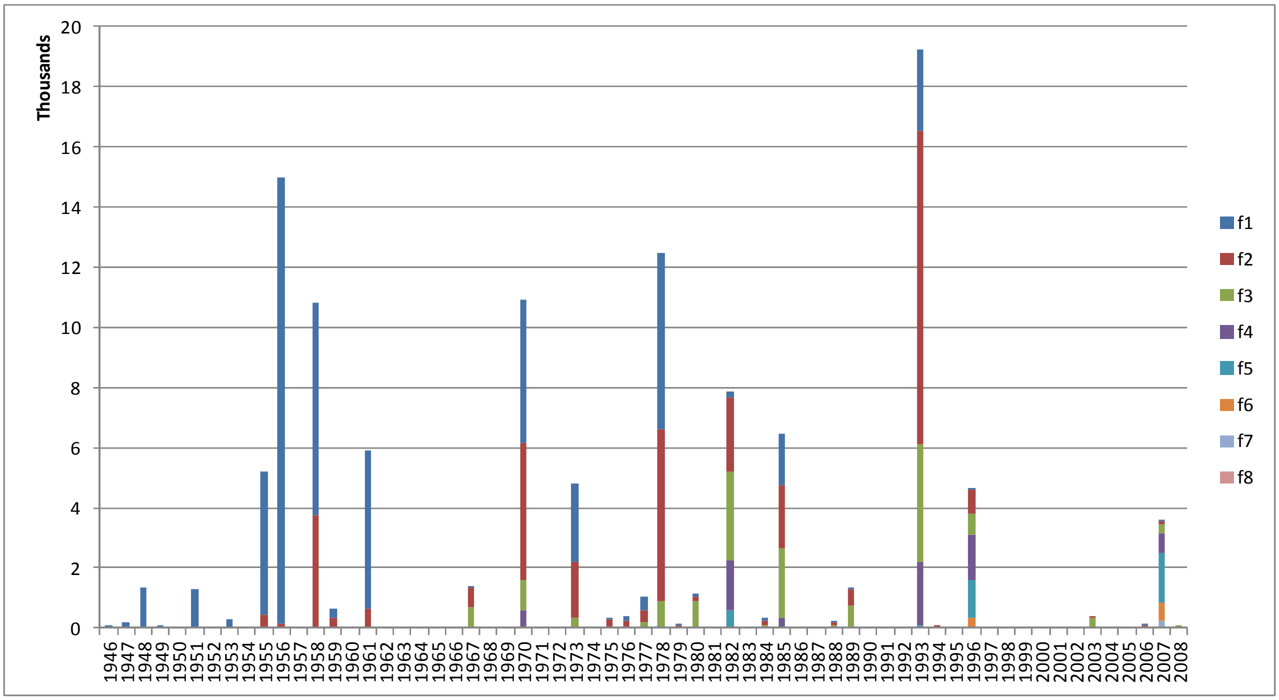


Figure 49. Total annual area burned (thousands of hectares) in the Santa Monica Mountains subsection for the period 1946-2008. Each year's area burned is partitioned to indicate areas that were burning for the first time since 1946 (f1), the second time (f2), up to the eighth time (f8). Areas mapped as urban and agriculture in 2006 were masked before calculating area burned.

Several authors have raised concerns that the time between fires is shortening in southern California (Keeley et al. 1999, Jacobsen et al. 2004, Syphard et al. 2009), increasing the risk of invasion by invasive weeds and threatening the persistence of obligate seeding chaparral shrubs. There is no evidence that the time between fires is shortening overall in the Santa Monica Mountains, at least not over the past 60 years (Figure 50). It appears, however, that the frequency of such fires has been higher than desirable- and higher than for most chaparral landscapes in southern California -for many decades.

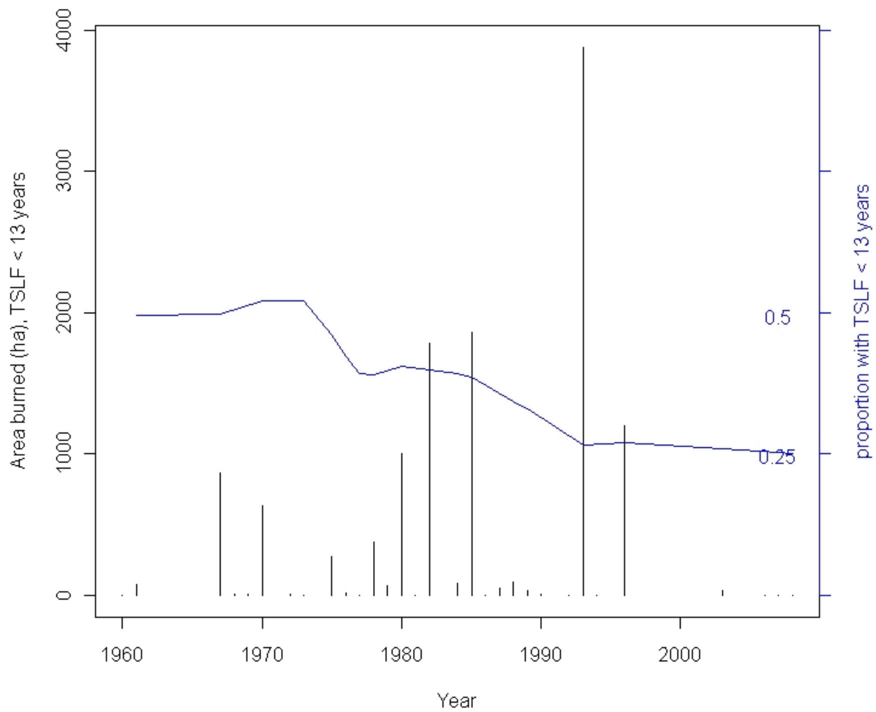


Figure 50. Annual area burned (vertical bars) in the Santa Monica Mountains, 1960-2008, where the time since the previously recorded fire (TSLF) was 12 years or less (left y-axis). Also shown is the proportion of total burned area that was in areas where the TSLF was 12 years or less (blue line, right y-axis). The line is a locally weighted regression line based on all years in which total burned area was at least 202 ha (500 ac).

Emerging Issues

Fire regime is probably being affected by several countervailing influences including increased ignition frequency due to increased vehicle traffic and human population, increased fuel fragmentation due to development and associated fuel breaks, vegetation changes in areas of high fire frequency, and changing weather and climate associated with regional and global climate change.

Data Gaps

The cause of most wildfires is not known or recorded. Trends in vegetation structure and composition would also be helpful in interpreting modern fire history data. Given the high year-to-year variation in area burned in wildfires, the fire history data are not yet of sufficient duration to detect trends in area-burned, time-since-fire distribution, or fire size.

Key references

California Department of Forestry and Fire Protection. 2008. Mapped fire history database for California; public version and detailed methodology.

Goudey, C. B. and D. W. Smith. 1994. Ecological units of California: subsections. USDA Forest Service, Pacific Southwest Region and Natural Resources Conservation Service, Washington, D.C.

Jacobsen, A. L., S. D. Davis, and S. l. Fabritius. 2004. Fire frequency impacts non-sprouting chaparral shrubs in the Santa Monica Mountains of southern California. Pages 1-5 in 10th Medecos Conference. Millpress, Rotterdam, Rhodes, Greece.

Keeley, J. E. 2002. Native American impacts on fire regimes of the California coastal ranges. *Journal of Biogeography* 29:303-320.

Keeley, J. E., C. J. Fotheringham, and M. Morais. 1999. Reexamining fire suppression impacts on brushland fire regimes. *Science* 284:1829-1832.

Radtke, K., A. M. Arndt, and R. H. Wakimoto. 1982. Fire history of the Santa Monica Mountains. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Syphard, A. D., V. C. Radeloff, T. J. Hawbaker, and S. I. Stewart. 2009. Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. *Conservation Biology* 23:758-769.

Landscapes—Fire and fuel dynamics —Future fire regime

Summary: Mixed trends predicted

SAMO has highly flammable vegetation (grasslands and shrublands), seasonal live fuel moisture deficit toward the end of the summer dry season, and hot, dry Santa Ana winds associated with regional atmospheric pressure gradients in the fall. Climate change is expected to expand grassland and shrubland cover as conditions get warmer, moisture deficit would become more pronounced and for longer during the year, and Santa Ana winds may shift later in the season when fuels are even drier. Thus the probability of fire occurrence and area burned are likely to increase (Miller et al. 2006). Westerling et al. (2009, 2010) modeled the response of wildfire to climate change scenarios in California over a representative range of greenhouse gas emissions scenarios, global climate models, and shifts in vegetation caused by both climate and urban development. Their results were summarized for SAMO out to the end of the 21st century relative to a 30 year reference or baseline period (1961-1990). For the model combinations we assessed, change in frequency of fires greater than 200 hectares in SAMO by the end of the century increased by 62% under the low emissions and urban growth scenario and 88% under the high emissions and growth scenario. High urban growth rates and sprawl would tend to dampen the rate of increase in fire frequency because it would reduce the proportion of vegetative fuel in the landscape. Lower growth rates with development constrained to agricultural or bare land predicts even higher fire frequency than the sprawl scenario by late-century.

Approach

Using historical data on fire perimeters, Westerling et al. (2009, 2010) modeled the occurrence of large wildfires (i.e., greater than 200 ha) in response to climatic, topographic, vegetation, management, and human population predictor variables. The conceptual model underlying the statistical logit model developed by Westerling et al. (2010) is depicted in Figure 51. The basic drivers of the model are increasing emissions that change key climate variables (temperature and precipitation) and urban growth that removes wild vegetation (i.e., reduces the vegetation fraction) but increases fire ignitions. The long-term climate affects the growth of vegetation and hence the fuel load. Shorter-term climate trends control the moisture deficit that determines the flammability of wildland fuels. Greater fire frequency can stimulate the invasion of non-native plants that may increase the flammability of the ecosystem. The Westerling et al. model did not account for such feedbacks, nor did it consider Santa Ana winds directly.

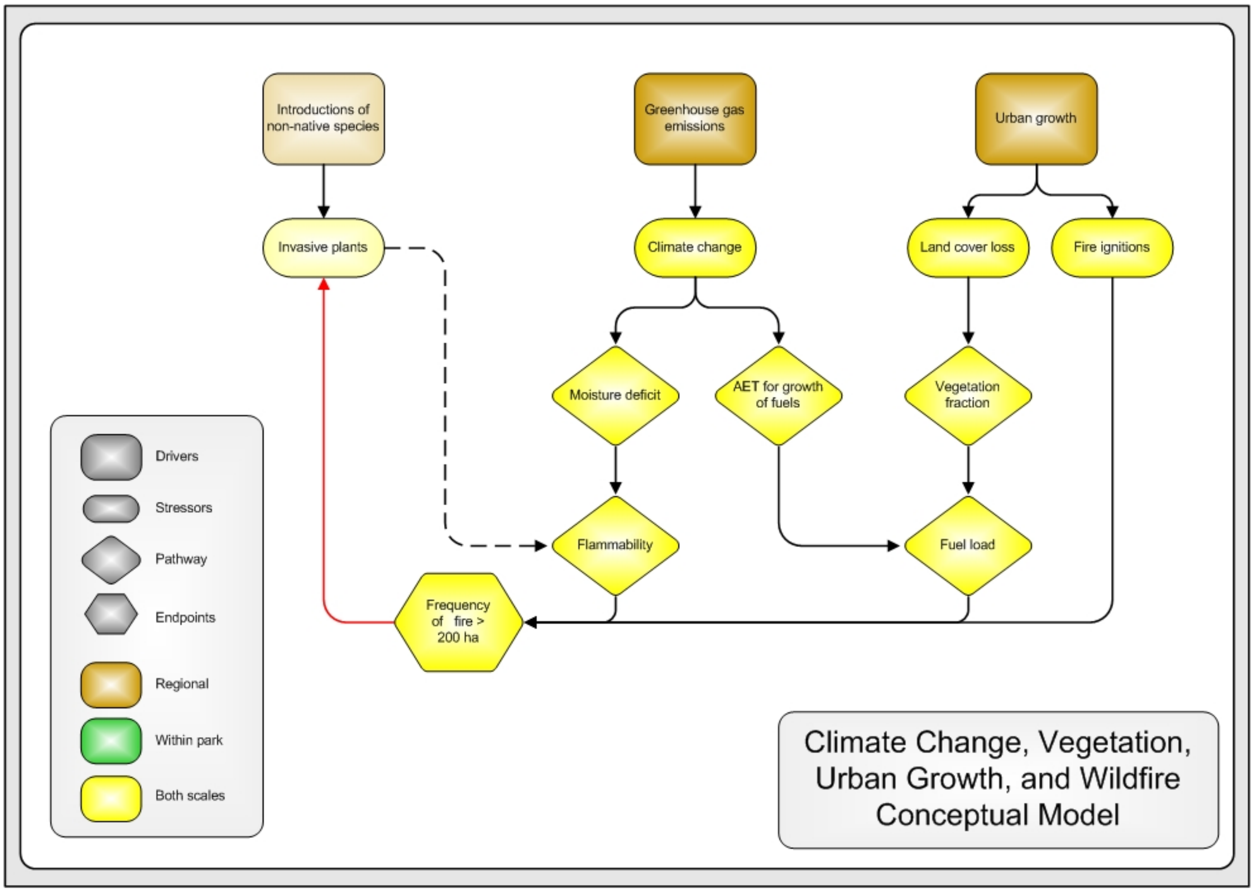


Figure 51. Conceptual model of the response of wildfire frequency to climate change and urban growth underlying the model of Westerling et al. (2010). Lighter colored icons and dashed arrows represent potential drivers and stressors that are not included in the current version of the Westerling model. The red arrow to invasive plants indicates potential feedback of wildfire on fuels, although this was not included in the Westerling model.

They then applied that model under a variety of climate change scenarios to analyze future wildfire regimes in California. They used both the A2 (medium-high emissions trajectory) and B1 (low emissions) scenarios from the IPCC (Nakićenović and Swart 2000) as adapted to California and three global climate models (GCM)— CNRM CM3, GFDL CM2.1 and NCAR PCM1 (see Cayan et al. 2009 and Chapter 3 for details on GCMs and scenarios). As reported in the Climate section above, temperatures are projected to increase at SAMO in all GCMs and scenarios, whereas precipitation increases in some models and decreases in others. GCM results were downscaled to 1/8 degree cells (~11.5 km wide by ~14 km high at the latitude of SAMO) and transformed into variables known to affect fire ecology including actual evapotranspiration (30 year average), moisture deficit (30 year, 2 year, 1 year, and current water-year to date), relative humidity (monthly average), precipitation (2 month cumulative to current month), and air temperature (monthly average). This range of time scales incorporated both longer-term conditions that control the amount of fuel and shorter-term variations affecting their flammability. Westerling et al. showed that the interaction between long-term actual evapotranspiration and moisture deficit is associated with vegetation distribution and patterns of fire regime response to climate variability. Therefore they included an interaction term in their logit model as a proxy for vegetation migration without having to model migration explicitly.

Using values of evapotranspiration and moisture deficit for future time periods derived from the downscaled GCMs allowed the researchers to simulate the effects of vegetation migration in response to climate change.

In the Westerling logit model, urban development affects fire frequency by reducing the burnable area for wildfire and increasing human-caused ignitions. The Westerling logit model included variables for vegetation fraction (proportion of the 1/8 degree cell that was not urban or agriculture) and a population term. Because California's population is expected to grow rapidly in the 21st Century, it was necessary to account for this in the modeled scenarios. Westerling et al. incorporated development patterns from EPA's Integrated Climate and Land Use Scenarios consistent with the A2 (high growth and high sprawl) and B1 (low growth and low sprawl) storylines (U.S. EPA 2009). For the high growth scenarios, the ICLUS modelers assumed that urban growth converted vegetated lands, whereas the low growth scenarios were assumed to convert bare and agricultural areas and only convert vegetated lands if more land was required. Thus the high growth scenarios would decrease the vegetation fraction more than the low growth, both because of greater land requirements for the larger population and because of the assumed pattern of land use change.

Westerling et al. applied the logit model of the probability of a wildfire > 200 ha occurring with all the emissions scenarios to bracket the range of plausible futures at three 30 year time periods centered on 2020, 2050, and 2085. The Westerling et al. study analyzed 264 combinations of two emissions scenarios, three GCMs, several urban growth scenarios, with and without vegetation migration in adaptation to climate change, and the three time periods.

For the SAMO condition assessment, the predicted change in frequency of fires > 200 ha from Westerling et al. (2010) was summarized over a subset of the scenarios at the regional, park-and-buffer, and park scales. At the park scale, we report the predicted percent change in frequency from the 1961-1990 baseline for the three GCMs and their mean for the A2-high growth and the B1-low growth emissions/urbanization scenarios. This identifies the variation between GCMs for an emissions scenario and between scenarios. Because it is difficult to interpret the relative contributions of climate change and population and urban growth on future fire regime, we also summarize the two emissions scenarios with no growth and low growth options. For comparing across scales, we limited the summarization to the basic A2-high growth and B1-low growth scenarios. The assumption that vegetation adapts or migrates with climate change is constant among the combinations reported here. In short, the results from Westerling et al. were averaged spatially across all 1/8 degree cells within each reference region for a scenario, and then averaged over the three climate models. Cells considered "unburnable" in the model because the vegetated fraction became zero were omitted from the averaging in that time period.

Data

- Shapefiles of 1/8 degree cells in California with predictions of burned area and fire frequency for 264 combinations of emissions scenarios, global climate models, urban growth scenarios, and assumptions about the rate at which vegetation adapts to climate change (Westerling et al. 2009, 2010) available at http://ulmo.ucmerced.edu/data/scen08/. Accessed July 2, 2010.

Predicted Trends

All three GCMs lead to forecasts of increasing fire occurrence for both emissions scenarios within SAMO (Table 22). The A2 scenario with high population growth leads to nearly doubling the frequency relative to the baseline period. The lower emissions B1 scenario with lower population growth also increases fire frequency but at a slower rate than A2. B1 also shows a slight drop in frequency after mid-century, but still substantially higher than SAMO currently experiences. The GFDL GCM tends to lead to the highest fire frequency predictions, while the NCAR model tends to be the lowest in both emission scenarios, particularly by late century.

Table 22. Predicted frequency of fires > 200 ha in SAMO (park scale) by GCM for the A2 and B1 emissions scenarios as a percentage of the 1961-1990 reference period (derived from data from Westerling et al. 2010).

	1961-1990	2005-2034	2035-2064	2070-2099
A2 emissions scenario—high growth				
CNRM CM3	100	142	155	191
GFDL CM21	100	156	217	244
NCAR PCM1	100	108	173	131
Mean	100	135	182	188
B1 emissions scenario—low growth				
CNRM CM3	100	142	163	153
GFDL CM21	100	171	195	198
NCAR PCM1	100	124	153	135
Mean	100	146	170	162

The results in Table 22 reflect the combined effects of both future emissions and future population growth and its corresponding urban footprint. By comparing results for each emissions scenario at different growth levels and between emissions scenarios at the same growth level, we can begin to tease apart the effects of these two drivers. For the no-growth options, Westerling et al. froze population and vegetation fraction at the 2000 level. Therefore all changes in fire frequency would be solely in response to climatic factors. The increases in frequency are much more modest at mid-century under both emissions scenarios (Figure 52) than for their associated growth scenarios shown in Table 22. For the low-growth options, frequencies are similar between A2 and B1 to mid-century, after which the A2 soars to 240% of baseline while B1 slightly drops off. We can presume that with identical growth factors, the increase in frequency is entirely a response to higher emissions in A2. Within the A2 emissions scenario, we find a complex response to growth options. No growth has the lowest frequency at mid- and late-century. High and low growth have similar values at mid-century after which low growth would increase dramatically more than high growth. In fact, the high growth curve tends to flatten out and nearly converges with the no growth option. As defined in Westerling et al. (2010), the high growth assumptions would reduce the vegetation fraction (burnable area) more than low growth. Thus high growth in SAMO apparently dampens much of the effect of climate change on fire frequency, so that by late century, frequency with high growth and no growth are almost identical.

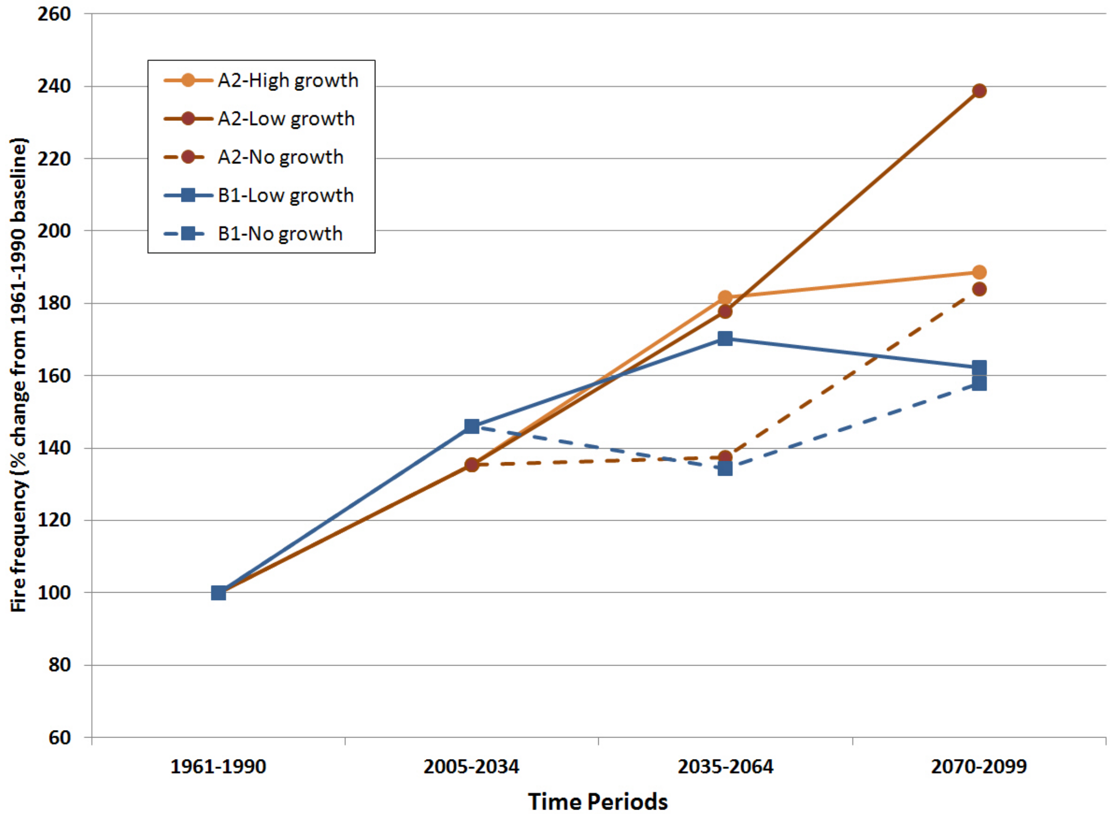


Figure 52. Graph of predicted frequency of fires > 200 ha in SAMO for the A2 and B1 emissions scenarios with different urban growth scenarios as a percentage of the 1961-1990 reference period (derived from data from Westerling et al. 2010). Each point represents the average of the three GCMs.

Average fire frequency at the park, park-and-buffer region, and the overall region are quite similar in the baseline period. The rate of increase is quite similar across scales within each emission scenario at least until mid-century (Table 23). Under the B1 emissions scenario with low growth, frequency stabilizes or slightly drops from mid- to late-century at all three scales, but about 60% higher than current. While SAMO's frequency levels off toward the end of the century under A2-high growth, the park-and-buffer and regional scales continue to increase rapidly to 2.5 times the current rate.

Table 23. Predicted frequency of fires > 200 ha in SAMO and reference regions for the A2 and B1 emissions scenarios as a percentage of the 1961-1990 reference period averaged over the three GCMs (derived from data from Westerling et al. 2010).

	1961-1990	2005-2034	2035-2064	2070-2099
A2 emissions scenario—high growth				
SAMO	100	135	182	188
Park-and-buffer	100	134	173	247
Region	100	128	158	245
B1 emissions				

	1961-1990	2005-2034	2035-2064	2070-2099
scenario—low growth				
SAMO	100	146	170	162
Park-and-buffer	100	146	164	163
Region	100	134	154	159

Emerging Issues

Wildfire is an important process in the ecosystems at SAMO as well as a management concern on the wildland-urban interface. Climate change forecasts lead to predictions of dramatically increasing fire frequency throughout the 21st century under many varying assumptions. These changes in fire regime would likely have important effects on ecosystem resources and processes that are of concern to SAMO managers. For instance, the combination of climate and wildfire frequency may convert shrubland and woodland to grassland and promote invasions by non-native plants. Attempting to mitigate those changes could require substantial increases in fire management resources or advances in fire-fighting technology. Therefore it is disturbing that recent observed emissions growth exceeded even the most fossil fuel-intensive scenario modeled by IPCC (Moser et al. 2009).

Data Gaps

The Westerling et al. database contains many additional scenarios that were not assessed here. We believe, however, that the scenarios in our assessment are illustrative of the range of expected and plausible responses of wildfire to climate change and urban growth. Santa Ana winds cause fires to spread rapidly so that more fires reach the 200 ha threshold size modeled by Westerling et al. These winds were not explicitly modeled, however, so the model tended to underpredict current fire frequency. Possible shifts in the timing and frequency of Santa Ana winds under climate change is still poorly understood. Westerling et al.'s modeling was based on historical wildfires and management strategies. Therefore potential effects of changes in management strategies, technology, or resources on fire frequency are not known. SAMO fire ecologists hypothesize that severe drought conditions causes dieback in twigs, stems or whole plants that may increase the fraction of dead fuels and lead to increased fire intensity/ size as a result of more extreme fire behavior. This relationship and its implications with climate change need further research.

Key references

Westerling, A. L., B. P. Bryant, H. K. Preisler, H. G. Hidalgo, T. Das and S. R. Shrestha. 2009. *Climate Change, Growth, and California Wildfire.* CEC-500-2009-046-D. Sacramento, California Energy Commission.

Westerling, A. L., B. P. Bryant, H. K. Preisler, T. P. Holmes, H. G. Hidalgo, T. Das, and S. R. Shrestha. 2010. Climate change and growth scenarios for California wildfire. Online at http://ulmo.ucmerced.edu/pdffiles/10CC_Westerlingetal.pdf.

Landscapes—Landscape dynamics—Habitat connectivity
Summary: Baseline

A functional network of connected wildlands is essential to the continued support of California's diverse natural communities in the face of human development and climate change. The California Department of Transportation and California Department of Fish and Game commissioned the California Essential Habitat Connectivity (CEHC) Project to delineate Essential Connectivity Areas that link Natural Landscape Blocks throughout the state. SAMO contains a set of these blocks, which collectively are linked by an Essential Connectivity Area with the Santa Susana Mountains into the Sespe Condor Sanctuary and the Los Padres National Forest to the north. NPS management is already geared toward maintaining the ecological integrity of natural landscape blocks. However, maintaining the park unit's habitat value will depend in part on the functioning of the connectivity area, which primarily crosses private, unprotected land. SAMO staff has already participated in more detailed design of habitat linkages for focal species. Continued review and comment on land use proposals with potential impacts to corridors is a highly valuable endeavor and should continue to be prioritized.

Approach
Habitat connectivity is a critical landscape property at all spatial and temporal scales, whether between stopovers on migratory flyways, corridors between summer and winter range, foraging throughout the home range of a large predator, gene flow between populations, access to different life history requirements, or wetlands and uplands (Crooks and Sanjayan 2006). At a regional scale, connectivity can be disrupted by stressors such as intensive land uses and road construction. Integrating spatial information on patterns of stressors can be used to assess the status of connectivity. Spencer et al. (2010), with extensive stakeholder involvement including David Graber and Ray Sauvajot of the NPS, conducted a comprehensive GIS assessment of "essential connectivity areas" for the State of California. The CEHC Project first delineated Natural Landscape Blocks (NLBs) for which connectivity areas were to be modeled (Figure 53). These NLBs were identified primarily by large, contiguous areas (greater than 2,000 acres) in good ecological condition. The Ecological Condition Index (ECI) was developed by Davis et al. (2006) based on maps of land conversion, housing density, road effects, and forest structure. The CEHC Project set thresholds in the ECI specific to conditions in ecoregions for delineating NLBs. These initial areas were supplemented with protected areas and areas of high biodiversity where not already included by the ECI criterion. Several NLBs occur within SAMO. Several other small NLBs occur in or on the park-and-buffer boundary; the largest is associated with the Santa Susana Mountains north of State Highway 118. Identifying Essential Connectivity Areas (ECAs) required two basic steps. First a GIS layer of resistance or "cost" to wildlife movement was developed. The most important input to the resistance layer was a score based on land cover, with natural cover types having low resistance and human-modified types having higher resistance. Management status such as protected area had a minor influence on resistance value (Figure 53). Then a least-cost corridor analysis was run for each pair of NLBs, which finds the path of least resistance. Statewide, the CEHC Project identified 192 ECAs. Note that the resistance value used to model ECAs is very generic and was not based on a particular species. Thus the ECA might be considered an antidote to general habitat fragmentation rather than as a migratory or dispersal route for any individual or group of species. For this condition assessment, we summarized the relative proportions of land in the NLBs or ECA at the three reference scales.

Where NLBs and ECAs overlapped, we included the area in the NLB category. We also compare this statewide connectivity assessment with two studies specific to the Santa Monica Mountains.

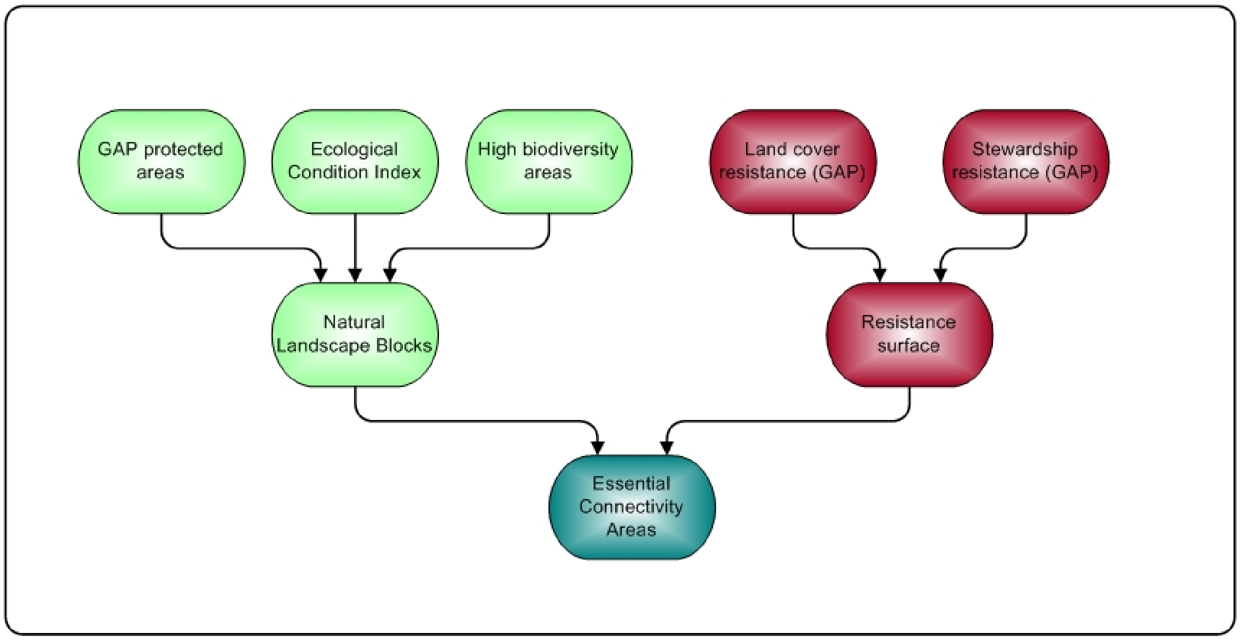


Figure 53. GIS conceptual model of California Essential Connectivity Areas (after Spencer et al. 2010).

For the SAMO condition assessment, the proportions of Natural Landscape Blocks and Essential Connectivity Areas are reported at the regional, park-and-buffer, and park scales. The ownership patterns within the ECA connecting SAMO were assessed by GIS overlay with the California Protected Areas Database.

Data

- California Essential Connectivity Areas
  ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Habitat_Connectivity/

- Protected areas data from Calif. Protected Areas Database, version 1.6
  (www.calands.org)

Status

Much of the higher elevations of the South Coast were incorporated into NLBs, including several nested within the administrative boundary of SAMO (Figure 54). The primary ECA involving SAMO links the Simi Hills NLB with the Santa Susana Mountains, roughly 10 km to the north. The main branch of this ECA runs north along Highway 23 between the cities of Moorpark and Simi Valley, while a narrow branch skirts the western edge of the densely populated San Fernando Valley. This ECA extends north of the Santa Susana Mountains into the Sespe Condor Sanctuary and the Los Padres National Forest. The CEHC analysis found that the ECA is 62% privately owned and unprotected. Overlaying the ECA with the latest version (1.6) of the California Protected Areas Database showed that 33% of the area is in some form of park or open space management (Figure 55), although not necessarily conserved for biodiversity and connectivity. The class of agency managing the largest proportion of land in the ECA is special districts, such as open space, parks and recreation, and water districts. Two-thirds of the ECA is therefore vulnerable to land use change that could further reduce the connectivity value of this area. It is also bisected by state highways 118 and 126. Roughly one-quarter of the ECA overlaps with Critical Habitat (9 federally-listed species) and Essential Habitat (5 species) identified by the US Fish and Wildlife Service. Furthermore, 23 plants and 37 animals tracked by the California Natural Diversity Database are found in the ECA. Thus the ECA appears to have high conservation value in its own right in addition to its value for connectivity. Another ECA connects the Santa Susana Mountains to the Angeles National Forest and the San Gabriel Mountains.

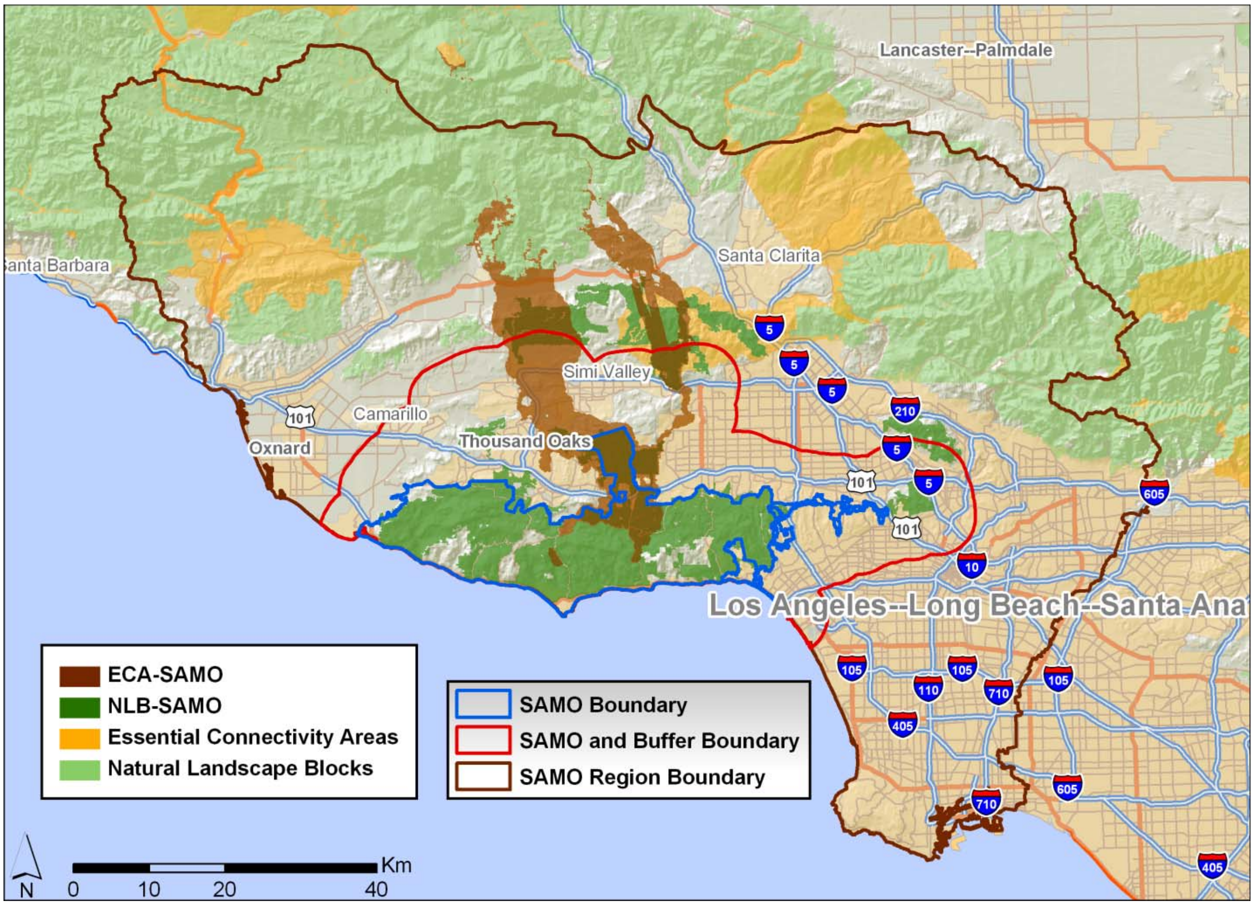


Figure 54. Map of the Natural Landscape Blocks (NLB) and Essential Connectivity Areas (ECA) between them (Spencer et al. 2010) for SAMO and surrounding regions.

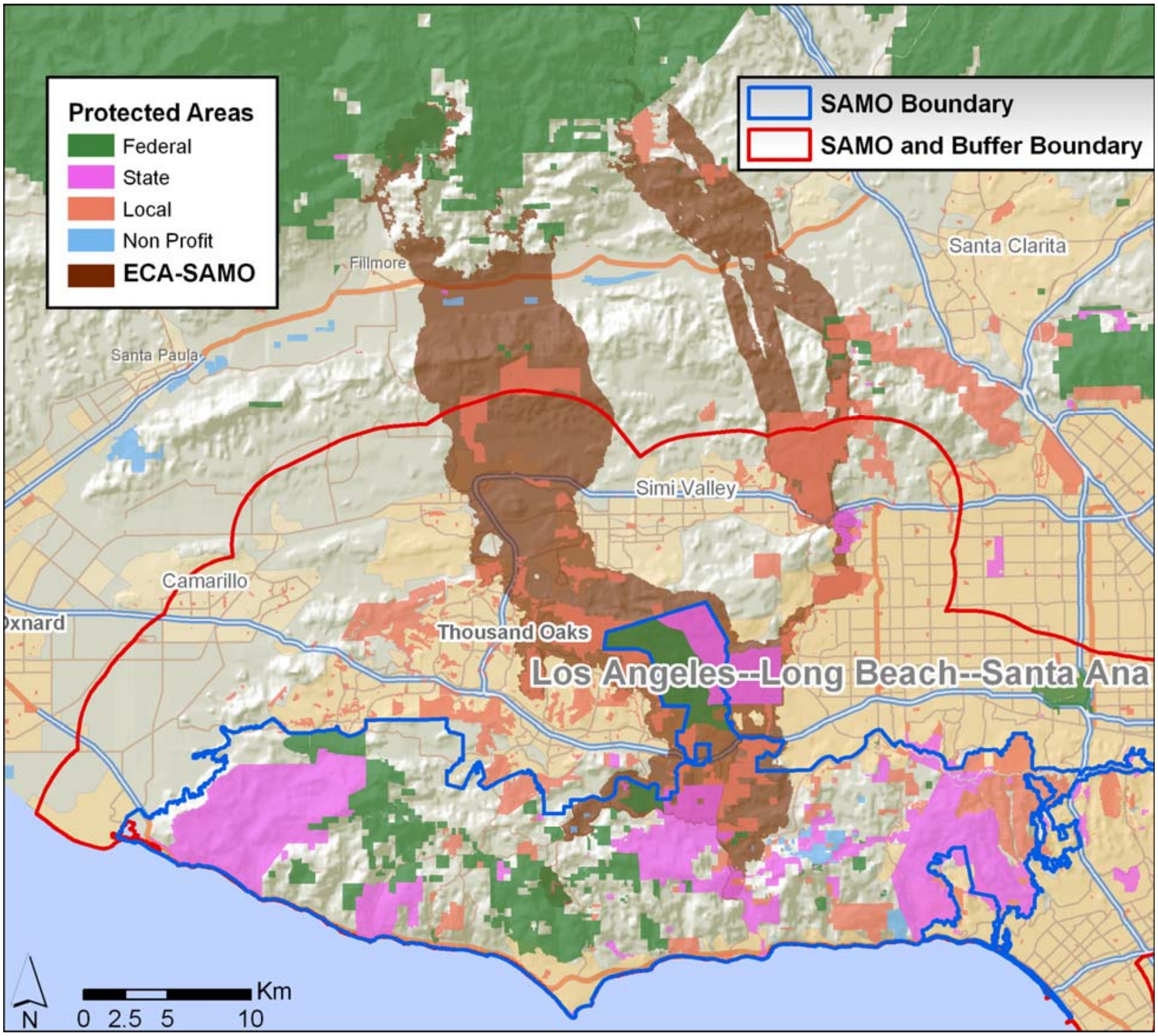


Figure 55. Map of protected areas within the Essential Connectivity Area.

Tabulating percentages of area in NLBs and ECAs quantifies the visual impressions from looking at the map in Figure 54. Nearly 80% of SAMO is within an NLB with some areas excluded in developed coastal watersheds (Figure 56). The park-and-buffer is similar to the regional scale, with more than half the area not included in either an NLB or an ECA. Roughly a third of the land at both scales is within NLBs and about 10% in an ECA.

Table 24. Area and percentage of land in the Essential Connectivity Area by agency.

Agency	Area (km2)	% of ECA
California Department of Parks and Recreation	10.5	2.2
Other State	22.1	4.6
National Park Service	25.4	5.3
US Bureau of Land Management	3.4	0.7
US Fish and Wildlife Service	0.1	0.0
US Forest Service	11.8	2.4
County	15.7	3.3
City	9.3	1.9
Special District	60.7	12.6
Non Governmental Organization	1.2	0.2
Unprotected	321.6	66.8
Total	481.8	100.0

The CEHP connectivity assessment used statewide data and very general criteria to identify essential connectivity areas. No information about the needs of individual species of interest was used to identify ECAs. Two recent studies have analyzed connectivity for species of interest in the Santa Monica Mountains. The South Coast Missing Linkages project designed a linkage based on the requirements and preferences of mountain lions, American badger, and mule deer (Figure 57; Penrod et al. 2006). They refined the design to accommodate 17 additional focal species including plants and invertebrates. The linkages mapped with biological information and local-scale mapping produced connectivity areas very similar to those of the CEHP. Their western branch supported mule deer, while the eastern branch supported all three mammals (although the least-cost paths were slightly different). Delaney and Strelich (2009) did a similar connectivity analysis based on bobcats, mule deer, and side-blotched lizards as part of the Santa Monica Mountains Conservancy comprehensive planning (Figure 58). Their study focused primarily on corridors between a set of core areas within SAMO that were similar to the NLBs of the statewide assessment. They did, however, model another corridor between the Simi Hills and the area on the north side of Highway 118 near the Ventura-Los Angeles county line. Important local corridors include Malibu Creek State Park-Simi Hills area across U. S. Highway 101 (Liberty Canyon), along Mulholland Drive between Interstate 405 and Highway 101 in the Mount Hollywood area, between Point Mugu State Park and Zuma/Trancas Canyon, and a route corresponding to the eastern branch of the state ECA connecting the Simi Hills to the eastern portion of the Santa Susana Mountains NLB. Both the South Coast Missing Linkages project and the Santa Monica Mountains Conservancy study identified an additional connectivity area to the Mountclef Ridge NLB from both Point Mugu State Park and the Simi Hills. The South Coast Missing Linkages project reported that this connectivity area was important as a live-in or move-through area for other focal species: cactus wren, brush rabbit, desert woodrat, and western toad.

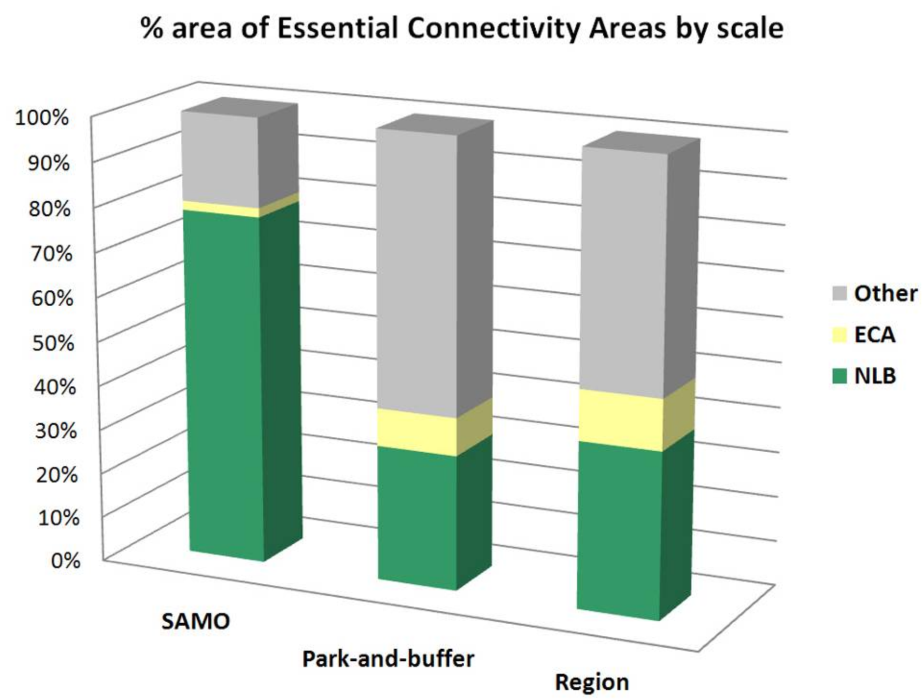


Figure 56. Bar graphs of the relative percentage of Natural Landscape Blocks (NLB), Essential Connectivity Areas (ECA), and all other lands for SAMO, the park-and-buffer landscape, and the region.

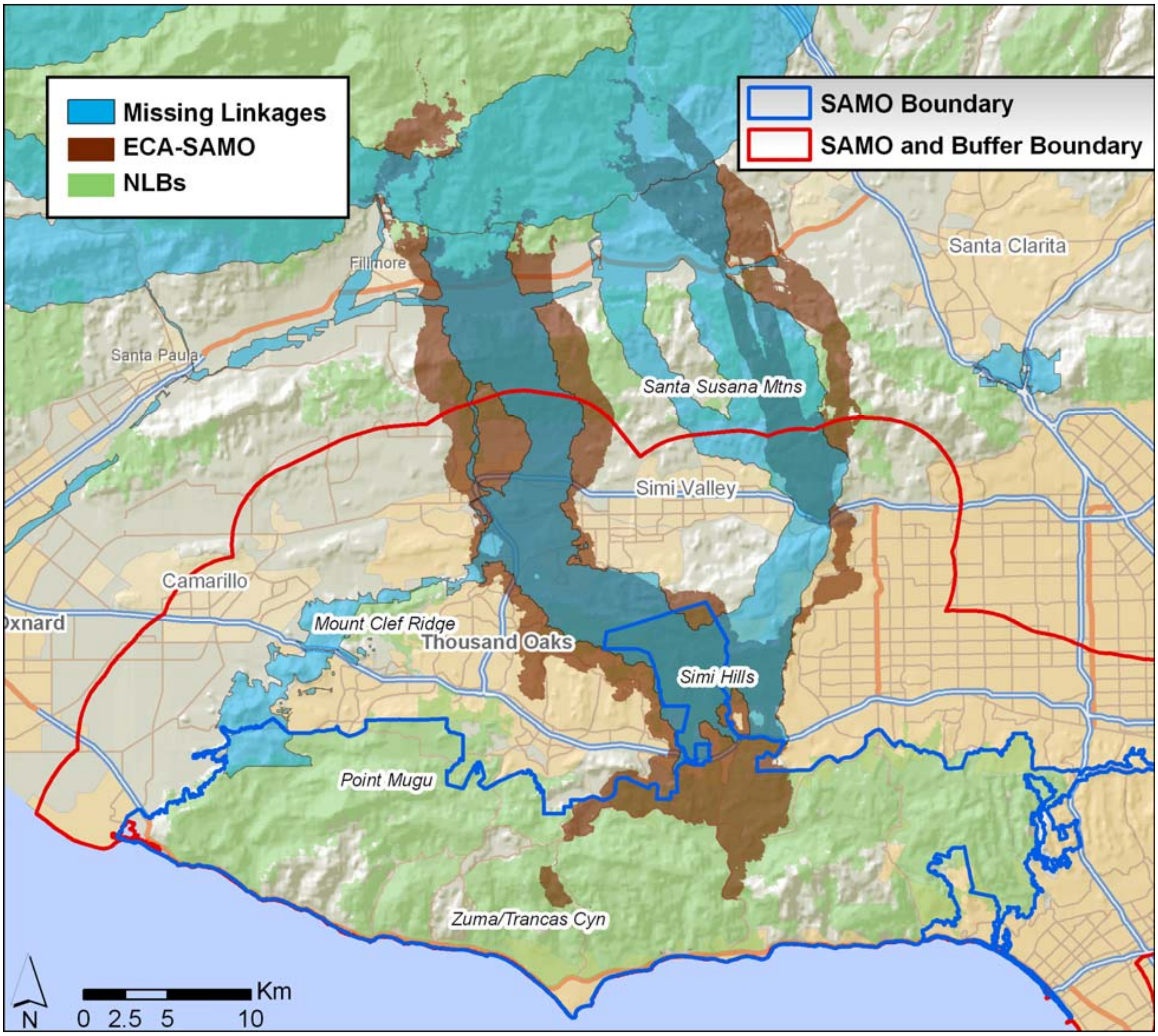


Figure 57. Comparison of CEHC connectivity areas and South Coast Wildlands' Missing Linkages.

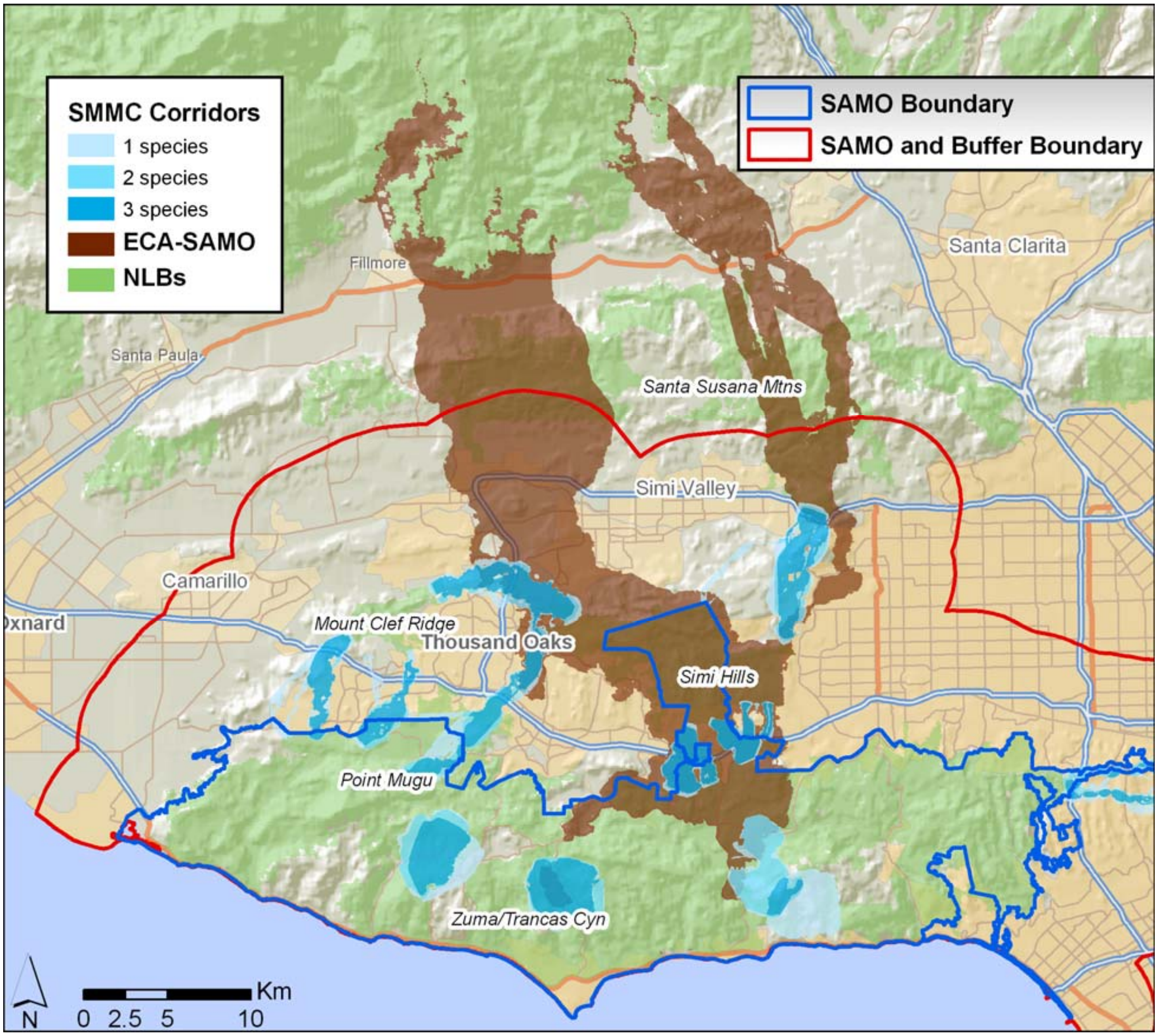


Figure 58. Comparison of CEHC connectivity areas and Santa Monica Mountains Conservancy corridors.

Trends

The CEHC Project was based on current ecological conditions to generate NLBs and ECAs. Thus no temporal trends in connectivity were addressed. Other sections of this condition assessment report show that ecological conditions have declined around SAMO over previous decades. We may speculate that the size of NLBs tends to be relatively smaller now than they would have been in the past, and perhaps some potential ECAs have been lost. Fortunately, SAMO is still linked by an ECA to the network of natural areas remaining in the state.

Emerging Issues

The CEHC Project underscores the growing awareness of the need to manage landscapes for habitat connectivity at scales larger than individual managed areas. SAMO for instance has been shown to be a key NLB in the network of connectivity areas or green infrastructure of the state. Management objectives at SAMO already strive to maintain conditions compatible with the criteria for NLBs. However, the habitat value of SAMO depends in part on its continued connectivity to NLBs to the north. Park managers should be vigilant for land use proposals that might degrade the value of the ECA/missing linkage and work with land owners to mitigate further fragmentation in the connectivity area. Maintaining or enhancing connectivity may be an effective hedging strategy for some isolated species (Baron et al. 2009).

Data Gaps

The CEHC Project identified broad connectivity areas deemed essential across the State of California. The process of necessity used spatial data that were statewide in coverage, and thus could not incorporate more detailed information for specific locales. Moreover the process was of necessity quite generic and did not address distributions or needs of particular species. The Missing Linkages and the Santa Monica Mountains Conservancy corridor analyses highlight the differences in results with increasing spatial resolution and modeling for individual species. These studies identified additional areas of connectivity that the statewide assessment did not.

Key references

Crooks, K. R. and M.A. Sanjayan, editors. 2006. Connectivity Conservation: Maintaining Connections for Nature. Cambridge University Press, Cambridge.

Davis, F. W., C. J. Costello and D. M. Stoms. 2006. Efficient conservation in a utility-maximization framework. *Ecology and Society* 11: 33. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art33/.

Delaney, K. S. and E. Strelich. 2009. Draft Comprehensive Plan, Santa Monica Mountains Conservancy.

Penrod, K., C. Cabañero, P. Beier, C. Luke, W. Spencer, E. Rubin, R. Sauvajot, S. Riley, and D. Kamradt. 2006. South Coast Missing Linkages: A Linkage Design for the Santa Monica-Sierra Madre Connection. South Coast Wildlands in cooperation with National Park Service, Santa Monica Mountains Conservancy, California State Parks, and The Nature Conservancy. Online at http://www.scwildlands.org/reports/SCML_SantaMonica_SierraMadre.pdf.

Spencer, W. D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California, Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration. http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=18366.

Landscapes—Viewscapes—Dark night sky
Summary: Baseline only

Chronic skyglow from urban lights, as well as direct glare and intermittent lights such as car headlights, can create "ecological light pollution" that are known to affect behavior, navigation, reproduction, communication, competition, and predation in some species (Longcore and Rich 2004, Rich and Longcore 2006). SAMO is surrounded on three sides by large urban areas. A model based on population in 1990 quantified the impact of city lights on skyglow in national park units. At that time, SAMO was one of the most affected park units in the nation, relative to conditions before human settlement (Albers and Duriscoe 2001). The model has not been applied with more current census data to identify trends in skyglow, but the number of housing units within SAMO's surrounding region increased 4% from 1990 to 2000 and population by 7%. Therefore we might expect that the skyglow has increased as well. However, new local lighting ordinances may have reversed this trend and darkened skies of the region. Countering that trend is the increasing development within inholdings of SAMO, probably causing greater direct lighting effects in local areas.

Approach
Skyglow is the light reflected back from the night sky (Longcore and Rich 2004). Albers and Duriscoe (2001) modeled skyglow for the United States. The model predicted the skyglow contribution of each city as a function of its population size in the 1990 census and its distance from each location. Overall light pollution or skyglow at each location was calculated as the sum of the maps of skyglow produced by every city, and the sums were then categorized into classes on the Schaaf scale from 1 (most polluted) to 7 (no light pollution). Thus regional urban development is the ultimate driver of light emissions, which are propagated to (and from within) SAMO by atmospheric scattering. This scattering is modulated by air quality and weather conditions, which can also be modified by human activities. Local effects from lighting in campgrounds and similar sources are not incorporated in this assessment.

Data
Regional scale: Albers and Duriscoe (2001) summarized the proportions of major national park units in each of the seven Schaaf classes. We include this in the regional scale assessment because the source of the light pollution is from the external region rather than generated within SAMO itself.

Park scale: Data were not available on permanent lighting within SAMO or on intermittent light from vehicles.

Status
Regional scale: SAMO in embedded within the intense skyglow zone of the southern California metropolitan region (Figure 59). Even in 1990, SAMO was one of the most impacted park units, mapped almost entirely as classes 1-3 (Albers and Duriscoe 2001). Only 7% of the park was mapped in class 4 with none in classes 5-7 (the least impacted zones). The study also computed the proportions of other parks by Schaaf class. Most park units in California had less skyglow than SAMO (e.g., Death Valley, Lassen Volcanic, Redwood, Yosemite, Sequoia-Kings Canyon,

and Pinnacles). Of the California parks, only Golden Gate NRA and Muir Woods in the San Francisco Bay Area had more skyglow.

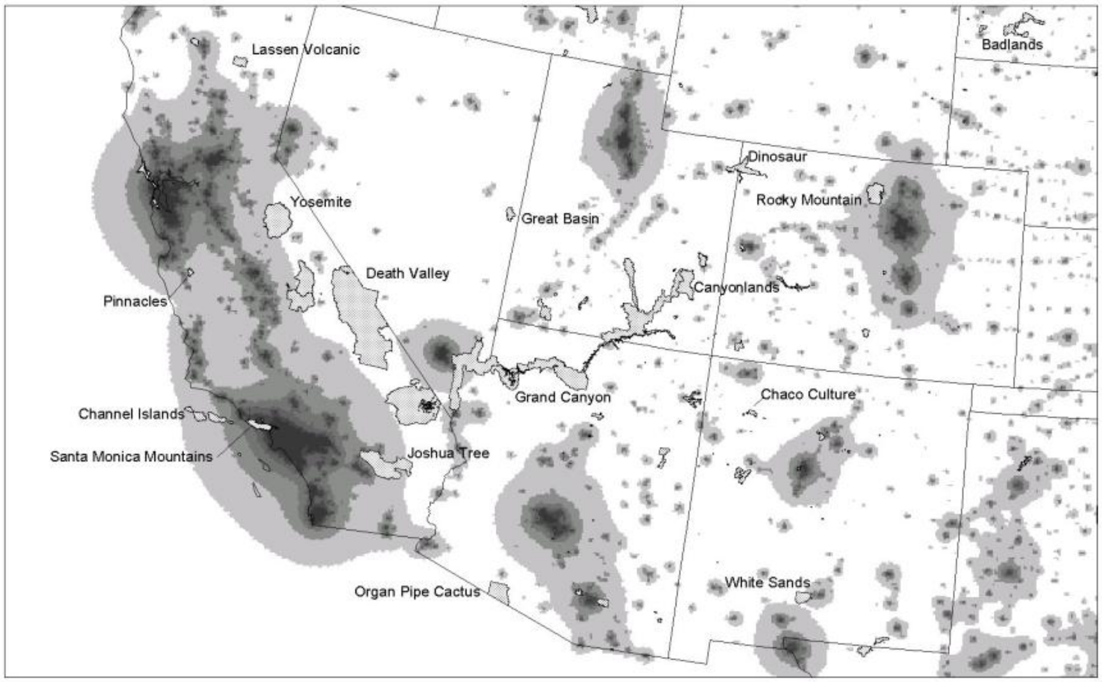


Figure 59. Map of Schaaf scale of light pollution in 1990 in relation to major national park units. Darkest shading is Schaaf class 1 (most impacted) and white is class 7 (no artificial light). Source: Albers and Duriscoe 2001.

Trends

Regional scale: Data are currently only available on skyglow for 1990. The model has not been run again with the 2000 census data or intra-decadal population projections or with future population projections. We know from the housing assessment in this report that the number of housing units in the SAMO region has increased steadily by about 0.4% per year from 1990 to 2000, but population change was at a higher rate (0.7% annually). The effect on light pollution will depend on the relative distance of population growth from SAMO. It is unknown how this increase in average household size will affect the relationship between population and emitted light used for the 1990 analysis. Because of new city and county lighting ordinances, however, the skies are darker at the Mt. Wilson Observatory (in the San Gabriel Mountains northeast of SAMO) than they were a quarter century ago (http://www.mtwilson.edu/skies.php).

Emerging Issues

Astronomical light pollution is currently not a major concern. As the surrounding areas continue to develop, however, the amount of skyglow is likely to increase. Ecological light pollution may emerge as a more significant stressor for a few species as regional population grows, particularly for species already experiencing the compound effects of multiple stressors.

Data Gaps

The primary data gap about light pollution as a stressor is the absence of model results for 2000 or a more recent population estimate so that the trend can be assessed. The model of skyglow used in Albers and Duriscoe (2001) assumed that population was concentrated at the center point of each city, and does not account for effects of low density sprawl. Rural residential development has been increasing throughout the Santa Monica Mountains. This lighting may not be significant in terms of skyglow but can have significant local effects on animal behavior. The model also did not consider spatial variation in cloud cover, which has recently been found to greatly amplify skyglow (Kyba et al. 2011). The world atlas of artificial nighttime sky brightness overcomes many of the limitations of this population-based model by combining observation data of nighttime top-of-the-atmosphere artificial radiance with scattering models that propagate the light through the atmosphere (Cinzano et al. 2001). This approach should give more accurate results than the population-based modeling. Unfortunately, the atlas website (http://www.lightpollution.it/worldatlas/pages/fig1.htm) has only published maps for the late 1990s, and they are only graphic files not suitable for analysis within parks.

The NPS Night Sky Team (http://www.nature.nps.gov/air/lightscapes/team.cfm) was formed in 1999. This team collects field measurements of light pollution and identifies sources (Moore 2001). Data have been collected for many national park units, but none are available online (http://www.nature.nps.gov/air/lightscapes/monitorData/index.cfm) yet for SAMO.

For animals that avoid bright lights, light pollution can disrupt their movement patterns. Nocturnal predators such as owls can lose their night vision and be forced to hunt elsewhere. Less agile bats can become at greater risk from predators whose vision is enhanced with lighting (Travis Longcore, personal communication). Very little is known about the ecological impacts of skyglow and direct lighting on the species and communities that inhabit SAMO.

Key references

Albers, S. and D. Duriscoe. 2001. Modeling light pollution from population data and implications for National Park Service lands. *George Wright Forum* 18: 56-68.

Kyba, C. C. M., T. Ruhtz, J. Fischer and F. Holker. 2011. Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. *PLoS ONE* 6: e17307. doi:10.1371/journal.pone.0017307.

Longcore, T. and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2: 191-198.

Moore, C. A. 2001. Visual estimation of night sky brightness. *The George Wright Forum*, 18(4), 46-55. http://www.georgewright.org/184moore.pdf.

Summary of resource assessments

The status and trends of resource condition indicators is summarized below (Table 25). The trend indicator icons reflect the trend of the indicator and not a positive or negative resource outcome.

Table 25. Summary of status and trends of resource condition.

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
AIR AND CLIMATE					
Air quality	Ozone trend annual fourth highest 8 hour average ozone concentration	77 ppb (0.00 p-value)	75 ppb (EPA); <= 60 ppb is "good condition" (NPS)	Significant Concern since the late 1990's.	
	Total nitrogen deposition	12 kg/ha/yr in 2002 (UC Riverside model)	0.25 kg N/ha/yr is natural background; <1.0 kg N/ha/yr is "good condition" (NPS standards); the critical load for lichen communities in California chaparral = 5.5 kg N/ha/yr; critical load for coastal sage scrub = 7.8 – 10 kg N/ha/yr.	Moderate Condition	
	Sulphur deposition	0.72 kg/ha/yr (average from 1994 – 2009)	0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS standards)	Good Condition	
	Visibility	8.5 deciviews (average 2005-2009)	< 8 deciviews (5 year average deciview values minus estimated deciview values in the absence of human caused degradation)	Significant Concern since 2001 – 2005.	
Climate	Minimum temperature of the coldest quarter Maximum temperature of the warmest quarter	4.5 ºC 32.3 ºC	16.9ºC (mean annual temperature of past 50 years)	Minimum temperature declined 0.25^{o}C per decade during the early part of the 20th century followed by a stronger positive trend of 0.6^{o}C per decade over the last 60 years. Maximum temperature increased by 0.01 ^{o}C per decade.	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
	Mean annual temperature Mean annual precipitation	16.9 ºC 427 mm	427 mm (average of past 50 years)	Downscaled climate models consistently project a 25 – 34% increase in growing degree days (GDD) by 2100 for SAMO, resulting in future conditions that are currently found in the western Mojave. Minimum winter temperatures are projected to increase by 2.1 - 2.8ºC while maximum summer temperatures are projected to increase by 4.0 – 5.3ºC. Precipitation projections are variable, either increasing or decreasing depending on the global climate model (GCM). Projected distributions indicate that under future climates, Valley Oak, *Quercus lobata*, which is at the southernmost part of its distribution at SAMO, will become further restricted to the coolest and wettest sites.	
WATER					
Water quality	NA	NA	NA	Water quality ranks among the most important indicators of ecosystem health. The Los Angeles Regional Water Quality Control Board has identified 38 water quality limited segments (primarily streams and beaches) within or near SAMO that do not meet standards for at least one of 37 pollutants. These pollutants span a range of nutrients, pesticides, pathogens, toxicity, metals, and others. A plan, called a Total Maximum Daily Load or TMDL, is required for each of the 134 segment-pollutant combinations that violate standards. USEPA has currently approved 54 TMDLs, leaving 80 that must still be developed and approved. The most frequent pollutants to be addressed are DDT, PCBs, indicator bacteria, and coliform bacteria.	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
				Segments in Calleguas Creek have as many as 14 pollutants identified. Addressing this large spectrum of water quality issues, which typically involves a contentious, drawn-out planning process, could become extremely burdensome to NPS resource staff. At the same time, these water quality violations represent a large number of stressors and pathways that can impact the aquatic resources at SAMO in complex, synergistic ways.	
BIOLOGICAL INTEGRITY					
Invasive plants	NA	NA	NA	Over 300 non-native plants in more than 10,000 populations have been detected at SAMO. The most vulnerable locations in SAMO tend to be in the lower reaches of the coastal canyons where the invasive populations occur in or near disturbed or highly invasible landscapes.	
LANDSCAPES					
Fire regime	Fire rotation period	34 years	The historical range of variation in fire return frequency in chaparral - dominated landscapes in California is 20-60 years.	The mean fire rotation interval for the Santa Monica Mountains subsection for the period 1946-2008 was 34 years, which is shorter than many chaparral-dominated landscapes in California but still within the historical range of variation typical of many chaparral landscapes. The annual area that re-burned within a decade of the last fire peaked in 1993, but the annual area subjected to such short-interval burning did not increase between 1960 and 2008. However, some localities in the Santa Monica Mountains and the Simi Valley–Santa Susana Mountains are burning at very high frequency,	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
				notably the western Santa Susana Mountains (South Mountain, Oak Ridge, and Oat Mountain), the Simi Hills, and the ocean-facing canyons of the Santa Monica Mountains above Malibu. Trends in fire history data from 1946-2008 do not support the proposition that fire suppression has led to fewer and larger chaparral fires; the time since fire distribution has not changed appreciably over the interval.	
Predicted future fire regime	Frequency of fires > 200 ha in SAMO in 2070-2099 as percent of 1961-1990 period—mean of 3 GCMs for A2 emissions scenarios —mean of 3 GCMs for B1 emissions scenarios	188% 162%	NA	Wildfire is sensitive to climate change and urban growth. Change in fire frequency in SAMO by the end of the century ranges from a 62% increase under a low emissions and growth scenario to 88% under a high emissions and growth scenario. Potential changes in Santa Ana winds were not considered in this projection. Countering the potentially significant impact of increased fire on ecosystems may require substantial increases in fire management resources.	
Habitat connectivity	NA	NA	NA	SAMO contains a set of Natural Landscape Blocks, identified by the California Essential Habitat Connectivity Project. Collectively they are linked by an Essential Connectivity Area with the Santa Susana Mountains into the Sespe Condor Sanctuary and the Los Padres National Forest to the north. Maintaining the park unit's habitat value will depend in part on the functioning of the connectivity area, which primarily crosses private, unprotected land. SAMO staff has already participated in detailed design of habitat linkages for focal species, which	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
				tend to corroborate the more generalized connectivity area. Park planners should remain vigilant about activities proposed by adjoining land owners that may degrade habitat quality within SAMO by increasing its isolation.	
Dark night sky	Mean Schaaf class	2.27	Schaaf class 7 (no artificial light)	A model based on population in 1990 identified SAMO as one of the most affected park units in the nation, relative to conditions before human settlement. As the number of housing units within SAMO's surrounding region has increased, we might expect that the skyglow has increased as well. However, new local lighting ordinances may have reversed this trend and darkened skies of the region. Countering that trend is the increasing development within inholdings of SAMO, probably causing greater direct lighting effects in local areas.	

= baseline only = no significant trend = increasing trend

Chapter 5. Discussion and Conclusions

Answers to Management and Research Questions

The staff at SAMO identified a set of management and research questions (listed in Chapter 3). This NRCA has made progress in answering some of them and identified the limits of our current knowledge. Here we provide brief summaries of what was found.

1. *Can we model or predict future development and land use changes in the region? What work has been done and is there anything we can learn from the results?* Two recent studies modeled future urban growth for the SAMO region. Syphard et al. (2005) modeled urban growth specifically within SAMO, based on historical growth patterns. Scenarios were developed with different maximum slope restriction criteria (25%, 30%, and 60%). The urban footprint increased from 11% of SAMO in 2000 to 26%, 35%, and 47% respectively by 2050. Nearly all available land was projected for development with the 60% slope limit. Growth rates declined to near zero by 2040 as most available land with slopes below the limits became developed. At a national scale, EPA's Integrated Climate and Land Use Scenarios modeled change in housing density along storylines to the end of the 21^{st} century that were consistent with climate change scenarios (U.S. EPA 2009, Bierwagen et al. 2010). Although the area of potential urban development was more restricted than in the Syphard study, all scenarios led to greater densification and loss of rural character within and surrounding SAMO. Both studies therefore indicate a densification of residential use within and surrounding SAMO with all the attendant stressors that entails—habitat fragmentation, wildlife mortality from traffic and domestic pets, exotic plants, fire, lights, water quality and quantity, and air quality.

2. *How will increasing development affect habitat connectivity and habitat quality?* Syphard et al. (2005) used their urban growth scenarios to assess potential impacts on landscape fragmentation. Similar to the findings in this assessment under Road Distance and Accessibility, those investigators also found that most of the native vegetation in SAMO constitutes one large, interconnected habitat patch. In the growth scenarios where development was prohibited above 25% or 30% slopes, that large patch would become more perforated but remain mostly intact. However, with a 60% slope limit, that patch would become fragmented into smaller patches. Over time, interior core habitat would decrease as smaller patches shrank and edge habitat expands. All three scenarios showed future build-out in the neck connecting Cheseboro Canyon to the main portion of SAMO. This site is part of connectivity areas mapped by state, regional, and local studies (see Landscapes-Landscape dynamics-Habitat connectivity section), and would be a critical loss if fully developed.

3. *What were the historic land uses and vegetation patterns and what role has land use had in creating vegetation patterns we see today? Can observed land use changes be mechanistically linked to changes in vegetation and other resources?* To assess land cover change, a map of historical land cover was overlaid with the 2009 vegetation map prepared for SAMO and adjoining area. The Wieslander Vegetation Type Map (VTM) collection is a dataset compiled in the 1920s and 30s, consisting of photos, species inventories, plot maps, and vegetation maps covering most of California. In 1945, the detailed vegetation type maps were compiled and generalized at 1:1 million scale

(http://projects.atlas.ca.gov/frs/download.php/220/veg1945wie.zip). Even at that time, 19% of the area of the 2009 map was already converted to urban and agricultural uses (Table 26). Nearly half of the 2009 map area was chaparral and one quarter was coastal sagebrush. By 2009, these two types had each lost between 22-24% of their area to human-dominated uses. Grass and woodland types were rare in 1945, but a significant fraction of their area has been converted. This comparison is only indicative of the types and magnitude of changes because of the difference in spatial scales of the two maps. A more precise comparison would be possible if desired once the original Vegetation Type Maps are converted into GIS-compatible format for this region (http://vtm.berkeley.edu/).

Table 26. Percent change of vegetation types from 1945 to 2009.

		2009 SAMO Vegetation Map Generalized Classes			
Wieslander 1945 Vegetation Types	**1945 %**	**% Vegetated**	**% Agriculture**	**% Urban/ Disturbed**	**Total % of 1945 type**
Chaparral	48.0	78.0	0.4	21.6	100.0
Coastal sagebrush	25.1	76.2	3.1	20.7	100.0
Grass	5.7	57.8	0.2	41.9	100.0
Woodland (Hardwoods)	2.2	48.1	12.4	39.5	100.0
Cultivated, Urban, Industrial	19.0	41.5	9.8	48.7	100.0
Total	100.0	68.8	3.1	28.1	100.0

4. *Are there species that are particularly likely to be affected by changes in habitat quality and/or configuration? How is the herbaceous flora, particularly the post-fire flora, affected by interaction between fire and competition from non-native invasive species?* SAMO is prone to short-interval fires, especially near major roads and at wildland-urban interfaces. Non-native invasive plants are promoted by short intervals between fires whereas native chaparral and coastal sage scrub plant and animal species tend to be strongly negatively impacted. Intervals less than 10-12 years threaten non-sprouting chaparral shrub species by limiting their ability to replenish the seed bank between burns. Short-interval burns also tend to be cooler than long-interval burns and have higher survivorship of alien seedbanks. As a result, very short intervals of six years or less result in significant reduction in the abundance of native shrubs and post-fire herbs and can lead to the replacement of chaparral and coastal sage scrub by alien-dominated grasslands.

5. *Has the vegetation community structure, distribution, composition, and function changed with changing fire regime and establishment of invasive plant species? Are there other factors affecting vegetation community change? How do these factors interact? How can we monitor this? Are there specific species or species characteristics we should be concerned with—either specific invasive species/characteristics or native species?* This condition assessment was not able to quantify changes in vegetation communities over time or to ascribe the role of specific stressors to that change. In principle, most of the main stressors at SAMO act synergistically to promote changes in structure, distribution, composition, and function. Increasing fire frequency tends to suppress native shrubs and grasses and promote exotic plants. Housing and infrastructure development within the park boundaries disturbs the soil surface, offering further opportunities for plant

invasions. Nitrogen is often a primary limiting nutrient on overall productivity of ecosystems. Continued growth in the Los Angeles region as forecast is likely to continue increasing nitrogen loading at SAMO. Nitrogen deposition causes an increase in non-native annual plants and loss of native plant diversity. This in turn can alter the fire regime, favoring more frequent fires that further retard growth of native plants. Modeled results for total nitrogen deposition were above the upper critical load threshold for coastal sage scrub communities, at which level they become at risk from invasion by exotic annual grasses, decrease in native plant richness, and decrease in arbuscular mycorrhizal spore density (Fenn et al. 2010). Exceeding the critical load for lichen communities in chaparral and oak woodlands is likely to cause a shift in dominance from epiphytic to eutrophic lichen species. Climate change is also expected to increase the frequency of burning, further amplifying the impacts of nitrogen. Monitoring will be challenging. One can either monitor changes in stressors (e.g., fire frequency, climate, nitrogen deposition, invasive plant populations, and land use) or endpoint indicators (e.g., lichen community composition). Because of the interactions of stressors, their synergetic impacts may not be detected from their individual changes. Changes in endpoints may be difficult to quantify and to detect until a tipping point has already been reached. More study is needed on what to monitor and how to do so.

6. *Are there any manageable dimensions to the changes we're seeing due to increased fire frequency and establishment of invasive plant species? Is there any way to offset/mitigate changes/impacts – especially considering elements we have no control over? What are the mechanisms of change and what actions have or have not been successful in managing change?* This question is predicated on the premise that fire frequency is increasing. Trends in fire history data from 1946-2008 examined in this condition assessment do not support the proposition that fire frequency has increased over that period. The time since fire distribution has not changed appreciably over that interval. Fire regime is probably being affected by several countervailing influences including increased ignition frequency due to increased vehicle traffic and human population, increased fuel fragmentation due to development and associated fuel breaks, vegetation changes in areas of high fire frequency, and changing weather and climate associated with regional and global climate change. Except for limited opportunities for fuel management, such as fuel breaks, most of these factors are beyond the direct control of SAMO management. As discussed in the previous management question, nitrogen deposition is one of the interacting stressors affecting invasive plants, but management options to mitigate it are limited (Fenn et al. 2010). Reducing emissions is the only effective strategy for protecting lichen communities in chaparral, but SAMO has little control over emissions. There are several mitigation methods in coastal sage scrub habitat to control the seedbank and thatch cover of exotic annual grasses (e.g., prescribed fire, herbicides, mowing, and grazing), but these may conflict with current NPS policies, park management, or public opinion.

7. *How do we expect fire regime to change with continued development and climate change?* Change in fire frequency in SAMO by the end of the century could range from a 62% increase under the low emissions and growth scenario to 88% under the high emissions and growth scenario; however, this does not account for potential changes in Santa Ana wind frequency, timing, or intensity. High urban growth rates and sprawl

would tend to dampen the rate of increase in fire frequency because it would reduce the proportion of vegetation in the landscape. Lower growth rates with development constrained to agricultural or bare land predicts even higher fire frequency than the sprawl scenario by late-century.

8. *What are the potential effects of changing climate in this region (e.g. rain, temperature, and drought) and what are the implications for the park (changes to fire regime, vegetation distribution, interactions between fire and invasive species, etc.)?* Minimum temperatures increased on average by 0.6^{o}C decade^{-1} over the last 60 years, while maximum temperatures and precipitation barely increased. Precipitation increased only slightly. Climate modeling consistently projects a large increase in growing degree days (GDD) by 2100, resulting in future conditions at SAMO that are currently found in the western Mojave Desert. Minimum winter temperatures are projected to increase by 2.1 - 2.8ºC by 2100 while maximum summer temperatures are projected to increase nearly double that. Precipitation projections are much more variable between GCMs, so it is unclear if SAMO will become warmer and wetter or warmer and drier. Fire frequency may increase dramatically in SAMO by the end of the century, ranging from a 62% increase under a low emissions and growth scenario to 88% under a high emissions and growth scenario. The combination of large projected increases in temperature and relatively modest changes in precipitation can be expected to reduce the growth and recruitment of many plant species at SAMO. Our projection for Valley Oak, which is at the southernmost part of its distribution at SAMO, indicates that under future climates, it will become further restricted to the coolest and wettest sites in increasingly isolated patches. Greater fire frequency will also make SAMO more sensitive to invasions of non-native plants.

9. *Are there other important resource threats we are not considering?* Argentine ants (*Linepithema humile*) have invaded widely throughout Mediterranean climate regions such as SAMO. They can seriously deplete the abundance and diversity of native ant species, such as the common harvester ant (*Pogonomyrmex subnitidus*) by raiding their nest colonies (Zee and Holway 2006). Loss of native ants has at least two secondary impacts—reduction of dispersal of large seeds (Carney et al. 2003) and loss of primary diet for the coast horned lizard (*Phrynosoma coronatum*) (Suarez et al. 2000), a California Species of Special Concern that has been declining in southern California. NPS is aware of the presence of Argentine ants (Villalba and Ward 2002).

10. *What ecosystem elements, species or species groups might be particularly important to monitor in light of current knowledge of resource threats and stressors?* We suggest monitoring be considered for invasive species and for phenological mismatches caused by climate change. Two invasive species, the New Zealand mudsnail and the Argentine ant, may be important to monitor because of their potential to displace native species and disrupt food web dynamics. The mudsnail became quickly established after it first appeared in Malibu Creek and also spread rapidly to other watersheds (Abrams 2009). Because it is a recent invader to SAMO, the ecological impacts are not yet known. Recent studies in southern California have shown that Argentine ants are most successful at invading native ant communities in areas with greater soil moisture and plant cover (Menke and Holway 2006) and within 200m of urban and agricultural land uses

(Mitrovich et al. 2010). Both factors have been spreading at SAMO. Summer flows seem to be increasing in urban streams that were historically intermittent, thus expanding the area of moist soils and riparian plant cover. Urban development continues to encroach further into SAMO and is expected to continue in future growth scenarios. Information about Argentine ant invasion and its ecological impacts in southern California come primarily from studies south of the Los Angeles Basin. The evidence from such studies suggests that the extent of invasion and its consequences could be significant in SAMO as well. One study from SAMO found high correlation between Argentine ant abundance and habitat fragmentation (Villalba and Ward 2002). Monitoring this invasion, or the condition of plant and animal community indicators at risk, is recommended. Climate change is expected to cause shifts in the timing of plant phenology and animal behavior such as nesting or migration. For instance, pollinators may not be available if plants bloom earlier, and conversely the pollinators may not find food unless they can adjust their life cycles to match the plants. We do not have any recommendations for specific species or processes to monitor at this time.

11. *How has the hydrology in the mountains changed over the past century? Can increases in water availability and decreases in water quality be quantified or described with existing data and information? What implications do these changes have for native communities? What information and research is needed to best address these questions?* This assessment did not address water quantity or trends in quality. The focus here was on specific water quality limited segments that currently exceed water quality standards in one or more pollutants. Many of the TMDLs that have been completed are for indicator bacteria that are thought to be associated with pathogens known to affect human health. Although the exposure level of pollutants is known, the effects on native communities and species are not well known.

General Themes of the Assessment

Two fundamental themes permeate this condition assessment: 1) the pervasive ways that anthropogenic drivers affect the key resources at SAMO and 2) the interconnectedness of resources. This final chapter synthesizes these themes from the individual resource assessments, and highlights some key emerging issues and data gaps.

The human enterprise has continued to expand and intensify in the region surrounding SAMO and in private enclaves within it. This expanding human population generates a litany of stressors. More people leads to higher demand for outdoor recreation at SAMO and associated infrastructure. Increased traffic and urban activities has led to air and water quality problems, such as high levels of nitrogen deposition. Development and associated infrastructure increase the sensitivity to invasion by non-native plants and Argentine ants. Roads and infrastructure reinforce the impacts of development to fragment habitats, tending to isolate SAMO from its broader landscape. Globally, the rapid increase in greenhouse gas emissions is projected to lead to profound changes in the local climate.

SAMO's globally-rare Mediterranean climate has been a primary influence in creating its special landscape. Minimum temperatures have been increasing rapidly over the past six decades at SAMO. Modeling predicts that growing degree days at SAMO will become similar to current conditions in the western Mojave Desert. Minimum winter temperatures and maximum summer temperatures are forecasted to increase. Models are less consistent in forecasting precipitation changes. Most ecological resources in SAMO would be affected by these changes in climate. The assessment found that the frequency of wildfire and the area burned annually will almost certainly increase, with consequent effects on invasive plants and wildlife habitats. Climate change is likely to have direct effects on other resources or processes such as plant-pollinator phenology, range shifts of plant and animal species, and added stress on amphibians with changing precipitation and less reliable runoff patterns.

Key Emerging Issues and Data Gaps

The condition assessment identified a number of emerging issues that may become of greater management concern in the future. The most obvious of these is climate change from anthropogenic emissions of greenhouse gases. Modeling predicts that SAMO will become similar to current conditions in the western Mojave Desert in terms of growing degree days. Minimum winter temperatures and maximum summer temperatures are both forecasted to increase. Models are less consistent in forecasting precipitation changes. Climate change is not just another management issue for SAMO; it will tend to amplify many existing stressors and effects (Baron et al. 2009), such as:

- Dramatic increase in the frequency of wildfire and the area burned annually (Westerling et al. 2010), which would probably
    - increase atmospheric particulates that would reduce visibility and increase human health risks (McKenzie et al. 2006)
    - promote conversion of shrubland and woodland to grassland with greater potential for invasion by non-native plants (Cameron et al. 2005)
- Range shifts of plant and animal species (Kueppers et al. 2005, Hannah 2008, Loarie et al. 2008)
- Displacements in time of the phenology of host plants and species that pollinate them or depend on them for food at critical life stages (Murphy and Weiss 1992)
- Increased stress on amphibians with changing precipitation and runoff patterns

We reiterate the recommendations of Baron et al. (2009) that SAMO managers identify and prioritize resources and ecological processes at greatest risk from climate change and adapt monitoring programs for the highest priorities.

Trends of many other drivers are also expected to continue increasing along with the corresponding and interacting stressors. Housing density is predicted to increase. This is likely to increase rodenticide application, irrigation runoff, nitrogen deposition skyglow, noise, road kill, and wildfire risk. These stressors in turn threaten mesopredators, aquatic habitats, gene flow, and native vegetation. Increased nitrogen deposition also favors invasive plants and more frequent fire. Lichen communities would be particularly susceptible with limited mitigation options. Expanding residential areas and increased summer runoff encourages invasion by Argentine ants. They raid nests of native ant species and can seriously deplete their abundance and diversity.

Loss of native ants has at least two secondary impacts—reduction of dispersal of large seeds and loss of primary diet for the coast horned lizard, a California Species of Special Concern that has been declining in southern California. Future development may also imperil SAMOs tenuous connectivity with other blocks of natural landscapes to the north.

Water quality violates acceptable levels in many of the water segments and for many different pollutants in and around SAMO. This leads to temporary closures of popular beaches because of bacteria. Addressing this large spectrum of water quality issues, which typically involves a contentious, drawn-out planning process to determine Total Maximum Daily Loads (TMDLs), could become extremely burdensome on NPS resource staff for both monitoring and compliance and may impose restrictions on park management actions. At the same time, these water quality violations represent a large number of stressors and pathways that can impact the aquatic resources at SAMO in complex, synergistic ways.

The report identifies data gaps that, if filled, would improve the usefulness of the stressor or resource condition indicators assessed in this report. These data would either improve the accuracy of the indicator value or in many cases provide trend information where only baseline values are currently known. Key data gaps include:

- Pesticides affecting amphibians—the volumes applied on agricultural lands are known but the amounts transported into SAMO such as by aerial drift, and the amounts used within SAMO, have not been inventoried or monitored, and the levels in aquatic habitats have not been comprehensively assessed.

- Rodenticides—the volume applied on agricultural lands outside the park is reported. The main use is around structures, some of which are adjacent to or within the park boundary, but this use is generally not reported to the California Department of Pesticide Regulation.

- Air quality—there is a dearth of air quality data sampled within SAMO boundaries. Much of the information for this assessment was obtained from air quality data from nearby monitoring stations.

- Invasive plants—trend data are still too short and too geographically limited to determine whether non-native plants are expanding or whether recent control activities have had the desired impact on invasions. Increased summer flows in intermittent streams are blamed for invasions in riparian habitat, but the exact pathway by which flows are increasing is not fully known.

- Invasive ants—information about Argentine ant invasion and its ecological impacts in southern California come primarily from studies south of the Los Angeles Basin. The evidence from such studies suggests that the extent of invasion and its consequences could be significant in SAMO as well. Monitoring this invasion, or the condition of plant and animal community indicators at risk, is needed.

- The cause of most wildfires is not known or recorded, although SAMO is working to fill this gap to the extent practical. Trends in vegetation structure and composition would also be helpful in interpreting modern fire history data.

- Dark night sky—trends are not well known. Cloud cover is known to strongly affect skyglow but this has not been accounted for. The subdiscipline of light ecology is just emerging, so the species that are most sensitive to light pollution are not known, nor are the specific types of impacts on predators and prey.

Literature Cited

Abramson, M. 2009. Tracking the invasion of the New Zealand mudsnail, Potamopyrgus antipodarum, in the Santa Monica Mountains. *Urban Coast* 1: 1, 21-27. Available at http://www.santamonicabay.org/Documents/UrbanCoastIVol1Issue1.pdf.

Aerial Information Systems (AIS), Environmental Systems Research Institute (ESRI), California Department of Fish and Game, California Native Plant Society and National Park Service. 2007. Spatial Vegetation Data of Santa Monica Mountains National Recreation Area and Environs. USGS-NPS Vegetation Mapping Program, Santa Monica Mountains National Recreation Area, Thousand Oaks, CA.

Albers, S. and D. Duriscoe. 2001. Modeling light pollution from population data and implications for National Park Service lands. *George Wright Forum* 18: 56-68.

Althoen, E. J., E. Chasin, S. Kent, E. Kiyan, and S. Schliemann. 2007. Biology and Management of Non-Native Plant Species in the Santa Monica Mountains National Recreation Area. Masters thesis in Environmental Science and Management, Donald Bren School of Environmental Science & Management, University of California Santa Barbara. Santa Barbara.

Barbour, M. G., T. Keeler-Wolf, and A. A. Schoenherr, editors. 2007. Terrestrial Vegetation of California. University of California Press, Berkeley.

Baron, J. S., L. Gunderson, C. D. Allen, E. Fleishman, D. McKenzie, L. A. Meyerson, J. Oropeza, and N. Stephenson. 2009. Options for national parks and reserves for adapting to climate change. *Environmental Management* 44: 1033-1042.

Barro, S.C. and S.G. Conard. 1991. Fire effects on California chaparral systems: An overview. *Environmental International* 17:135-149.

Bedos, C., Cellier P., Calvet R., Barriuso E. and Gabrielle B. 2002. Mass transfer of pesticides into the atmosphere by volatilization from soils and plants: overview. *Agronomie* 22: 21-33.

Bierwagen, B. G., D. M. Theobald, C. R. Pyke, A. Choate, P. Groth, J. V. Thomas, and P. Morefield. 2010. National housing and impervious surface scenarios for integrated climate impact assessments. *Proceedings of the National Academy of Sciences* 107: 20887-20892.

Biswell, H.H. 1989. Prescribed Burning in California Wildlands Vegetation Management. University of California Press, Berkeley.

Brakes, C.R. and R. H. Smith. 2005. Exposure of non-target small mammals to rodenticides: short-term effects, recovery and implications for secondary poisoning. *Journal of Applied Ecology* 42: 118-128.

California Department of Forestry and Fire Protection. 2008. Mapped fire history database for California; public version and detailed methodology.

California Geological Survey, Seismic Hazard Mapping Program. 1997-2002. Official Maps of Seismic Hazard Zones. Available at http://gmw.consrv.ca.gov/shm (accessed 15 October 2003).

California Regional Water Quality Control Board, Los Angeles Region. 2010. Santa Monica Bay: Nearshore and Offshore Debris TMDL (Draft: July 30, 2010).

Cameron, L., R. Sauvajot, and D. Kamradt. 2005. Mediterranean Coast Network – Vital signs monitoring plan. National Park Service Unpublished Report, Thousand Oaks, California.

Carney, S. E., M. B. Byerley, and D. A. Holway. 2003. Invasive Argentine ants (*Linepithema humile*) do not replace native ants as seed dispersers of *Dendromecon rigida* (Papaveraceae) in California, USA. *Oecologia* 135: 576-582.

Caterino, M. S. and K. J. Hopp. 2009. Toward an insect survey of the Santa Monica Mountains National Recreation Area. Final report submitted to National Park Service by Santa Barbara Museum of Natural History, Santa Barbara, CA.

Cayan, D, M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate Change Scenarios and Sea Level Rise Estimates for California 2008 Climate Change Scenarios Assessment. Sacramento, CA: California Climate Change Research Center. Final report #CEC-500-2009-014-F.

Cinzano, P., F. Falchi, and C. D. Elvidge. 2001. The first World Atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society* 328: 689–707.

Clark, J. P. 1994. Vertebrate Pest Control Handbook (fourth ed.). California Department of Food and Agriculture, Division of Plant Industry, Integrated Pest Control Branch, Sacramento, CA.

Conard, S. G. and D. R. Weise. 1998. Management of Fire Regime, Fuels, and Fire Effects in southern California chaparral: Lessons from the past and thoughts for the future. Pages 342-350 *in* P.L. Pruden and L.A. Brennan, editors, Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription. Tall Timbers Fire Ecology Conference Proceedings, No 20.

Conservation Biology Institute. 2001. On the global and regional biological significance of southern Orange County: Conservation Priorities for a Biodiversity Hotspot. Report prepared for Endangered Habitats League of Los Angeles. San Diego, California.

Crooks, K. R. and M. A. Sanjayan, editors. 2006. Connectivity Conservation: Maintaining Connections for Nature. Cambridge University Press, Cambridge.

D'Antonio, C. M. and B. E. Mahall. 1991. Root profiles and competition between the invasive, exotic perennial, Carpobrotus edulis, and two native shrub species in California coastal scrub. *American Journal of Botany* 78: 885-894

Daszak, P., A. A. Cunningham, and A. D. Hyatt. 2000. Wildlife ecology - Emerging infectious diseases of wildlife - Threats to biodiversity and human health. *Science* 287: 443-449.

Davidson, C. 2004. Declining downwind: amphibian population declines in California and historic pesticide use. *Ecological Applications* 14: 1892–1902.

Davidson, C. and R. A. Knapp. 2007. Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs. *Ecological Applications* 17: 587-597.

Davis, M. A., K. Thompson, and J. P. Grime. 2005. Invasibility: the local mechanism driving community assembly and species diversity. *Ecography* 28: 696–704.

Davis, F. W., C. J. Costello, and D. M. Stoms. 2006. Efficient conservation in a utility-maximization framework. *Ecology and Society* 11: 33. Available at http://www.ecologyandsociety.org/vol11/iss1/art33/.

Davis, F. W. and J. C. Michaelsen. 1995. Sensitivity of fire regime in chaparral ecosystems to global climate change. Pages 435-456 in *Global Change and Mediterranean-type Ecosystems*. W. C. Oechel and J. M. Moreno. New York, Springer-Verlag.

Davis, F. W., D. M. Stoms and P. A. Jantz. 2011. *Natural resource condition assessment: Pinnacles National Monument.* Natural Resource Report NPS/PINN/NRR-20XX/XXX. Fort Collins, Colorado, National Park Service.

DeFries, R., A. Hansen, B. L. Turner, R. Reid, and J. G. Liu. 2007. Land use change around protected areas: Management to balance human needs and ecological function. *Ecological Applications* 17: 1031-1038.

Delaney, K. S., S. P. D. Riley and R. N. Fisher. 2010. A rapid, strong, and convergent genetic response to urban habitat fragmentation in four divergent and widespread vertebrates. *PLoS ONE* 5: e12767. doi:10.1371/journal.pone.0012767.

Delaney, K. S. and E. Strelich. 2009. Draft Comprehensive Plan. Santa Monica Mountains Conservancy.

DeSimone, S. 1995. California's Coastal Sage Scrub. *Fremontia* 23:3-8.

Dorgelo, J. 1987. Density fluctuations in populations (1982-1986) and biological observations of *Potamopyrgus jenkinsi* in two trophically differing lakes. *Hydrobiological Bulletin.* 21: 95-110.

Ehrenfeld, J. G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* 6:503-523.

Emmel, T. C. and J. F. Emmel. 1973. The butterflies of southern California. Natural History Museum of Los Angeles County, *Science* Series 26: 1-48.

Faber, P. M., E. Keller, A. Sands, and B. M. Massey. 1989. The Ecology of riparian habitats of the southern California coastal region: a community profile. *Biological Report* 85 (7.27). U.S. Department of the Interior, Fish and Wildlife Service, Research and Development, National Wetlands Research Center. Washington, D.C.

Fabritius, S. and S. D. Davis. 2000. Manuscript in preparation. Is increasing fire frequency causing vegetation-type conversion among chaparral plant communities of the Santa Monica Mountains?

Fancy, S., J. Gross, and S. Carter. 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* 151: 161-174.

Fenn M. E., J. S. Baron, E. B. Allen, H. M. Rueth, K. R. Nydick, L. Geiser, W. D. Bowman, J. O. Sickman, T. Meixner, D. W. Johnson, and P. Neitlich. 2003. Ecological effects of nitrogen deposition in the western United States. *BioScience* 53: 404-420.

Fenn, M. E., E. B. Allen, S. B. Weiss, S. Jovan, L. H. Geiser, G. S. Tonnesen, R. F. Johnson, L. E. Rao, B. S. Gimeno, and F. Yuan. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *Journal of Environmental Management* 91: 2404-2423.

Fiesler, E. 2009. Family-level Invertebrate Inventory of the Santa Monica Mountains National Recreation Area. Final report submitted to National Park Service by Bioveyda, Torrance, CA. Bioveyda report number SMM-FII-2009-2a.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. *Road Ecology—Science and Solutions*. Washington, DC: Island Press.

Fry, J.A., M. J. Coan, C. G. Homer, D. K. Meyer, and J. D. Wickham, 2009. Completion of the National Land Cover Database (NLCD) 1992–2001 Land Cover Change Retrofit product: U.S. Geological Survey Open-File Report 2008–1379, 18 p. Available at http://pubs.usgs.gov/of/2008/1379/.

Gamradt, S. C. and L. B. Kats. 1996. Effect of introduced crayfish and mosquitofish on California newts. *Conservation Biology* 10: 1155–1162.

Gentile, J. H., M. A. Harwell, W. Cropper, C. C. Harwell, D. DeAngelis, S. Davis, J. C. Ogden and D. Lirman. 2001. Ecological conceptual models: a framework and case study on ecosystem management for South Florida sustainability. *Science of the Total Environment* 274: 231-253.

Goodsell, J. A. and L. B. Kats. 1999. Effect of introduced mosquitofish on Pacific treefrogs and the role of alternative prey. *Conservation Biology* 13: 921–924.

Goudey, C. B. and D. W. Smith, editors. 1994. Ecological Units of California: Subsections. (map) San Francisco, CA. U.S. Department of Agriculture, Forest Service. Scale 1,000,000; colored.

Haidinger, T. I. and J. E. Keeley. 1993. Role of high fire frequency in destruction of mixed chaparral. *Madroño* 40:141-147.

Haines, A. M., M. Leu, L. K. Svancara, J. M. Scott and K. P. Reese. 2008. A theoretical approach to using human footprint data to assess landscape level conservation efforts. *Conservation Letters* 1: 165-172.

Hammer, R. B. S. I. Stewart, R. Winkler, V. C. Radeloff, and P. R. Voss. 2004. Characterizing spatial and temporal residential density patterns across the U.S. Midwest, 1940-1990. *Landscape and Urban Planning* 69: 183-199.

Hannah, L. 2008. Protected areas and climate change. *Year in Ecology and Conservation Biology* 2008. 1134: 201-212.

Hansen A. J. and R. DeFries. 2007. Land use change around nature reserves: Implications for sustaining biodiversity. *Ecological Applications* 17: 972-973.

Hansen, A. J. and J. Rotella. 2002. Biophysical factors, land use, and species viability in and around nature reserves. *Conservation Biology*. 16: 1112 – 1122.

Harnly, M., McLaughlin R., Bradman A., Anderson M. and Gunier R. 2005. Correlating agricultural use of organophosphates with outdoor air concentrations: A particular concern for children. *Environmental Health Perspectives* 113: 1184-1189.

Harwell, M. A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. *BioScience* 49: 543-556.

Hickman, J. C., editor. 1993. The Jepson Manual. University of California Press, Berkeley, California.

Hogue, C. L. 1974. Insects of the Los Angeles Basin. Natural History Museum of Los Angeles County, Los Angeles.

Hogue, C. L. 1993. Insects of the Los Angeles Basin, 2nd ed. Natural History Museum of Los Angeles County, Los Angeles.

Hoots, H. W. 1930. Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California. U. S. Geological Survey Professional Paper 165-C: 83 -134.

Jacobsen, A. L., S. D. Davis, and S. l. Fabritius. 2004. Fire frequency impacts non-sprouting chaparral shrubs in the Santa Monica Mountains of southern California. Pages 1-5 in 10th Medecos Conference. Millpress, Rotterdam, Rhodes, Greece.

Jaeger, J. A. G. 2000. Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. *Landscape Ecology* 15: 115-130.

Jantz, P.A. and F. W. Davis. In preparation. Stable Geographic Units for Assessing Housing and Population Change in the United States from 1990 - 2000.

Johansson, C. 2009. Santa Monica Mountains National Recreation Area invertebrate inventory: tardigrades. Unpublished report submitted to National Park Service by Fresno City College. Fresno, CA.

Kay, B.L., C. F. Walker, J. E. Street, and J. L. Myler. 1958. Progress Report Range Demonstration, University of California Range Management Investigations. Cited in Murry 1968.

Keeler-Wolf, T. 1995. Post-fire emergency seeding and conservation in southern California shrublands. Pages 127-139 *in* J.E. Keeley and T. Scott, editors. Brushfires in California: Ecology and Resource Management. International Association of Wildland Fire, Fairfield, Washington.

Keeler-Wolf, T. and J. M. Evens. 2006. Vegetation classification of the Santa Monica Mountains National Recreation Area and environs in Ventura and Los Angeles Counties, California: Version 1—association level and specific alliances. National Park Service Unpublished Report, Santa Monica Mountains National Recreation Area, Thousand Oaks, California. Available at http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=18243&inline=1.

Keeler-Wolf, T., J. Evans, J. Christian, R. Taylor, E. Reyes, and J. Tiszler. 2007. A vegetation classification for the Santa Monica Mountains *in* Flora and Ecology of the Santa Monica Mountains: Proceedings of the 32nd annual Southern California Botanists symposium, ed. D.A. Knapp, 131-158. Southern California Botanists Special Publication No. 4, Fullerton California.

Keeley, J. E. 1992a. Demographic structure of California chaparral in the long-term absence of fire. *Journal of Vegetation Science* 3:79-90.

Keeley, J. E. 1992b. Recruitment of seedlings and vegetative sprouts in unburned chaparral. *Ecology* 73:1194-1208.

Keeley, J. E., C. J. Fotheringham, and M. Morais.1999. Reexamining fire suppression impacts on brushland fire regimes. *Science* 284:1829-1832.

Keeley, J. E. and C. J. Fotheringham. 2001. The historical role of fire in California shrublands. *Conservation Biology* 15: 1536-1548.

Keeley, J. E., J. G. Pausas, P. W. Rundel, W. J. Bond, and R. A. Bradstock, Fire as an evolutionary pressure shaping plant traits, Trends in Plant Science, In Press, Corrected Proof, Available online 14 May 2011

Keeley, J. E. 2002. Native American impacts on fire regimes of the California coastal ranges. *Journal of Biogeography* 29:303-320.

Keeley, J. E., C. J. Fotheringham, and M. Morais. 1999. Reexamining fire suppression impacts on brushland fire regimes. *Science* 284:1829-1832.

King, W. B. 1985. Island birds: will the future repeat the past? Pages 3-15 *in* P. J. Moors, editor.

Conservation of Island Birds. International Council for Bird Preservation. Cambridge University Press, Cambridge, UK.

Koch, A. L. and V. L. Santucci. 2003. Paleontological resource inventory and monitoring: Mediterranean Coast Network. TIC #D-177. Kemmerer, WY: National Park Service.

Koch, A. L., V. L. Santucci, and T. R. Weasma. 2004. Santa Monica Mountains National Recreation Area paleontological survey. NPS/NRGRD/GRDTR-04/01. Denver, CO: National Park Service, Geologic Resources Division.

Kueppers, L. M., M. A. Snyder, L. C. Sloan, E. S. Zavaleta, and B. Fulfrost. 2005. Modeled regional climate change and California endemic oak ranges. *Proceedings of the National Academy of Sciences of the United States of America* 102 (45): 16281-16286.

Kyba, C. C. M., T. Ruhtz, J. Fischer, and F. Holker. 2011. Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems. PLoS ONE 6: e17307. doi:10.1371/journal.pone.0017307.

Kyriazis, S. 2008. Geologic Summary, Santa Monica Mountains National Recreation Area. Unpublished report. National Park Service, Santa Monica Mountains National Recreation Area.

Lebassi B., J. Gonzalez, D. Fabris, E. Maurer, N. Miller, C. Milesi, P. Switzer P., and Bornstein R. 2009. Observed 1970-2005 cooling of summer daytime temperatures in coastal California. *Journal of Climate* 22: 3558-3573.

LeNoir, J. S., L. L. McConnell, G. M. Fellers, T. M. Cahill, and J. N. Seiber. 1999. Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada Mountain Range. *Environmental Toxicology and Chemistry* 18: 2715–2722.

Lepczyk, C. A., A. G. Mertig, and J. G. Liu. 2003. Landowners and cat predation across rural-to-urban landscapes. *Biological Conservation* 115: 191-201.

Leu, M., S. E. Hanser and S. T. Knick. 2008. The human footprint in the west: A large-scale analysis of anthropogenic impacts. *Ecological Applications* 18: 1119-1139.

Lloret, F. and P.H. Zedler. 1991. Recruitment pattern of *Rhus integrifolia* in periods between fire in chaparral. *Journal of Vegetation Science* 2:217-230.

Loarie, S. R., B. E. Carter, K. Hayhoe, S. McMahon, R. Moe, C. A. Knight, and D. D. Ackerly. 2008. Climate change and the future of California's endemic flora. PLoS ONE 3(6): e2502. doi:10.1371/journal.pone.0002502.

Longcore, T. and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2: 191-198.

Liu, J. G., Daily G. C., Ehrlich P. R. and Luck G. W. 2003. Effects of household dynamics on resource consumption and biodiversity. *Nature* 421: 530-533.

McKenzie, D., S. M. O'Neill, N. K. Larkin, and R. A. Norheim. 2006. How will climatic change affect air quality in parks and wilderness? Pages 186-193 in *People, Places, and Parks: Proceedings of the 2005 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites*. Hancock, Michigan: The George Wright Society.

Manion, B. S. 1993. The Tidewater Goby (*Eucyclogobius newberryi*): Reintroduction of a Geographically Isolated Fish Species Into Malibu Lagoon. California State University, Northridge.

Manion, B. S. and J. H. Dillingham. 1989. Malibu Lagoon: A Baseline Ecological Survey. California State University, Northridge.

Meiler, K. 2007. Invasive *Phalaris aquatica* (harding grass) in the Santa Monica Mountains National Recreation Area. Thesis. Clark University, Worcester, MA.

Menke, S. B. and D. A. Holway. 2006. Abiotic factors control invasion by Argentine ants at the community scale. *Journal of Animal Ecology* 75: 368-376.

Mensing, S.A., J. Michaelsen, and R. Byrne. 1999. A 560-year record of Santa Ana fires reconstructed from charcoal deposited in the Santa Barbara Basin, California. *Quaternary Research* 51:295-305.

Miles, S. R. and C. B. Goudey, compilers. 1997. Ecological subregions of California: section and subsection descriptions. R5-EM-TP-005. San Francisco, CA: USDA Forest Service, Pacific Southwest Region.

Miller, N. L. and N. J. Schlegel. 2006. Climate change projected fire weather sensitivity: California Santa Ana wind occurrence. *Geophysical Research Letters* 33:L15711.

Minnich, R.A. 1983. Fire mosaics in southern California and northern Baja California. *Science* 219:1287-1294.

Minnich, R.A. and R.J. Dezzani. 1998. Historical decline of coastal sage scrub in the Riverside-Perris Plain. *Western Birds* 29:366-391.

Mitrovich, M. J., T. Matsuda, K. H. Pease, and R. N. Fisher. 2010. Ants as a measure of effectiveness of habitat conservation planning in Southern California. *Conservation Biology* 24:1239-1248.

Moore, C. A. 2001. Visual estimation of night sky brightness. *The George Wright Forum*, 18(4), 46-55. http://www.georgewright.org/184moore.pdf.

Moser, B., J. Jaeger, U. Tappeiner, E. Tasser and B. Eiselt. 2007. Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. *Landscape Ecology* 22:447-459.

Moser, S., G. Franco, S. Pittiglio, W. Chou, and D. Cayan. 2009. The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2008-071.

Murphy, D. D. and S. B. Weiss. 1992. Effects of climate change on biological diversity in Western North America: Species losses and mechanisms. Chapter 26 *in* Global Warming and biological diversity, ed. R. L. Peters and T. E. Lovejoy. Hamilton Printing, Castleton, New York.

Nakićenović, N. and R Swart, editors. 2000. Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K.

National Parks and Recreation Act of 1978, Pub. L. No. 95-625, 92 Stat. 3501 (1978).

National Park Service. 1994. Wildland Fire Management Plan, 1994 Revision. An Addendum to the Resource Management Plan for the Santa Monica Mountains National Recreation Area.

National Park Service. 2002. Final General Management Plan & Environmental Impact Statement, Santa Monica Mountains National Recreation Area. Vol. 1 of 2. 439 pp.

National Park Service. 2011. NPScape: monitoring landscape dynamics of US National Parks. Natural Resource Program Center, Inventory and Monitoring Division. Fort Collins, Colorado. Available at http://science.nature.nps.gov/im/monitor/npscape/ (accessed 24 August 2011).

National Park Service, Air Resources Division. 2004. Assessing the risk of foliar injury from ozone on vegetation in parks in the Mediterranean Coast Network. Unpublished report. Available at http://www.nature.nps.gov/air/Pubs/pdf/03Risk/mednO3RiskOct04.pdf.

National Park Service, Air Resources Division. 2009. Air quality in national parks: 2008 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2009/151. National Park Service, Denver, Colorado.

National Park Service, Air Resources Division. 2011. NPS Air Quality Estimates. National Park Service. Denver, CO. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm.

Ng, S. J., J. W. Dole, R. M. Sauvajot, S. P. D. Riley, and T. J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. *Biological Conservation* 115: 499-507.

Natural Resources Conservation Service. 2005. Soil Survey Geographic (SSURGO) database for Ventura Area, California. Fort Worth, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service. Available at http://SoilDataMart.nrcs.usda.gov/.

Natural Resources Conservation Service. 2006. Soil Survey Geographic (SSURGO) database for Santa Monica Mountains Recreation Area, Parts of Los Angeles and Ventura, California. Fort Worth, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service. Available at http://SoilDataMart.nrcs.usda.gov/.

Natural Resources Conservation Service. 2008. Soil Survey Geographic (SSURGO) database for Los Angeles County, California, West San Fernando Valley Area. Fort Worth, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service. Available at http://SoilDataMart.nrcs.usda.gov/.

Orrock, J. L. and M. S. Witter. 2010. Multiple drivers of apparent competition reduce re-establishment of a native plant in invaded habitats. *Oikos* 119:101-108.

O'Leary, J. F. 1995. Coastal sage scrub: threats and current status. *Fremontia* 23:27-31.

Parker, V. T. 1989. Maximizing vegetation response on management burns by identifying fire regimes. Pages 87-91 in N.H. Berg (technical coordinator), Proceedings of the symposium on fire and watershed management. USDA Forest Service General Technical Report PSW-109. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Parmesan, C. and Yohe G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.

Penrod, K., C. Cabañero, P. Beier, C. Luke, W. Spencer, E. Rubin, R. Sauvajot, S. Riley, and D. Kamradt. 2006. South Coast Missing Linkages: A Linkage Design for the Santa Monica-Sierra Madre Connection. South Coast Wildlands in cooperation with National Park Service, Santa Monica Mountains Conservancy, California State Parks, and The Nature Conservancy. Available at http://www.scwildlands.org/reports/SCML_SantaMonica_SierraMadre.pdf.

Moroney, J. R., P. M. Schiffman, and C. A. Brigham. 2011. Invasive European annual plants impact a rare endemic sunflower. *Madrono* 58(2):69-77.

Radke, K.W-H., A.M. Arndt, and R.H. Wakimoto. 1982. Fire history of the Santa Monica Mountains. Pages 438-443 in C.E. Conrad and W.C. Oechel (technical coordinators), Dynamics and Management of Mediterranean-type Ecosystems. USDA Forest Service General Technical Report PSW-58. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Relyea, R. A. 2009. A cocktail of contaminants: how mixtures of pesticides at low concentrations affect aquatic communities. *Oecologia* 159: 363-376.

Rich C., Longcore T. *Ecological Consequences of Artificial Night Lighting*. Washington, DC: Island Press; 2006.

Riitters, K. H. and J. D. Wickham. 2003. How far to the nearest road? *Frontiers in Ecology and the Environment* 1: 125–129.

Riley, S. P. D., C. Bromley, R. H. Poppenga, F. A. Uzal, L. Whited, and R. M. Sauvajot. 2007. Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. *Journal of Wildlife Management* 71: 1874-1884.

Riley, S. P. D., J. P. Pollinger, R. M. Sauvajot, E. C. York, C. Bromley, T. K. Fuller, and R. K. Wayne. 2006. A southern California freeway is a physical and social barrier to gene flow in carnivores. *Molecular Ecology* 15: 1733-1741.

Rundel, P. W. and J. Tiszler. 2007. The Santa Monica Mountains in a Global Context. Pages 17-27 *in* Flora and Ecology of Santa Monica Mountains: Proceedings of 32nd Annual Southern California Botanists Symposium. D. A. Knapp, editor. Pages 173-194. Southern California Botanists Special Publication No. 4, Fullerton, California.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo, and G. Woolmer. 2002. The human footprint and the last of the wild. *BioScience* 52: 891-904.

Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation, Second Edition. California Native Plant Society, Sacramento California.

South Coast Air Quality Management District (SCAQMD). 2003. Air Quality Management Plan. Available at http://www.aqmd.gov/aqmp/AQMD03AQMP.htm.

Science Daily. 2008. Global Carbon Emissions Speed Up, Beyond IPCC Projections. September 28, 2008. Available at http://www.sciencedaily.com/releases/2008/09/080925072440.htm.

Shafer, C.L. 1999. National park and reserve planning to protect biological diversity: some basic elements. *Landscape and Urban Planning* 44: 123 – 153.

Spencer, W. D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. 2010. California Essential Habitat Connectivity Project: A Strategy for Conserving a Connected California, Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration. Available at http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=18366.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, editors. 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Stein, B.A., L.S. Kutner, and J.S. Adams, editors. 2000. Precious heritage: the status of biodiversity in the United States. Oxford University Press.

Stone W. B., J. C. Okoniewski, and J. R. Stedelin. 1999. Poisoning of wildlife with anticoagulant rodenticides in New York. *Journal of Wildlife Diseases* 35: 187-193.

Suarez, A. V., J. Q. Richmond, and T. J. Case. 2000. Prey selection in horned lizards following the invasion of Argentine ants in Southern California. *Ecological Applications* 10: 711-725.

Svancara, L., P. Budde, and J. Gross. 2009. Measure Development Summary: Population and Housing. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, Colorado, USA.

Swenson, J. J. and J. Franklin. 2000. The effects of future urban development on habitat fragmentation in the Santa Monica Mountains. *Landscape Ecology* 15: 713-730.

Syphard, A. D., K. C. Clarke, and J. Franklin. 2005. Using a cellular automaton model to forecast the effects of urban growth on habitat pattern in southern California. *Ecological Complexity* 2: 185-203.

Syphard, A. D., V. C. Radeloff, T. J. Hawbaker, and S. I. Stewart. 2009. Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. *Conservation Biology* 23:758-769.

Tennesen, M. 2007. *Santa Monica Mountains National Recreation Area*. Tucson, AZ: Western National Parks Association.

Theobald, D. M., J. B. Norman, and P. Newman. 2010. Estimating visitor use of protected areas by modeling accessibility: A case study in Rocky Mountain National Park, Colorado. *Journal of Conservation Planning* 6: 1-20.

Tigas, L. A., D. H. Van Vuren, and R. M. Sauvajot. 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. *Biological Conservation* 108: 299-306.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. The Robert H. MacArthur Award Lecture. *Ecology* 80:1455-1474.

Timbrook, J., J. R. Johnson, and D. D. Earle. 1982. Vegetation burning by the Chumash. *Journal of California and Great Basin Anthropology* 4:163-186.

Tobler, W. 1993. Three presentations on geographical analysis and modeling. National Center for Geographic Information and Analysis, University of California, Santa Barbara.

U.S. Census Bureau. (2010). Total Population, U.S. Census Summary File 1. Available at http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?fpt=table (accessed 17 April 2012).

U.S. EPA. 2009. Land-Use Scenarios: National-Scale Housing-Density Scenarios Consistent with Climate Change Storylines (Final Report). EPA/600/R-08/076F, 2009. Washington, DC, Available at http://oaspub.epa.gov/eims/eimscomm.getfile?p_download_id=489947.

U.S. Forest Service. 1993. ECOMAP. National hierarchical framework of ecological units. U. S. Forest Service, Washington, D.C.

U.S. Geological Survey. 1996. USGS Response to an Urban Earthquake: Northridge ’94. Open-File Report 96-263.

Villalba, F. and P. Ward. 2002. The Effects of Urbanization and the Argentine Ant (*Linepithema humile*) on the Native Ant Community in Santa Monica Mountains National Recreation Area. Final Lay Report 02-10. University of California Davis.

Watts, R. D., R. W. Compton, J. H. McCammon and D. S. Ouren. 2003. Intensity of human use, backcountry roads, and analysis of human accessibility. Pages 535-545 *in* Proceedings of the International Conference on Ecology & Transportation, Lake Placid, NY. Center for Transportation and the Environment, North Carolina State University, 2003. Available at http://www.icoet.net/downloads/03TechnologyApps.pdf#page=25.

Weiss, S. B. 2006. Impacts of Nitrogen Deposition on California Ecosystems and Biodiversity. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-165.

Westerling, A. L., B. P. Bryant, H. K. Preisler, H. G. Hidalgo, T. Das, and S. R. Shrestha. 2009. *Climate Change, Growth, and California Wildfire.* CEC-500-2009-046-D. Sacramento, California Energy Commission.

Westerling, A. L., B. P. Bryant, H. K. Preisler, T. P. Holmes, H. G. Hidalgo, T. Das, and S. R. Shrestha. 2010. Climate change and growth scenarios for California wildfire. Available at http://ulmo.ucmerced.edu/pdffiles/10CC_Westerlingetal.pdf.

Whisson, D. A. and T. P. Salmon. 2009. Assessing the effectiveness of bait stations for controlling California ground squirrels (*Spermophilus beecheyi*). *Crop Protection* 28: 690-695.

Wiersma, Y. F., Nudds T. D. and Rivard D. H. 2004. Models to distinguish effects of landscape patterns and human population pressures associated with species loss in Canadian national parks. *Landscape Ecology* 19: 773-786.

Zedler, P. H. 1995. Fire frequency in southern California shrublands: biological effects and management options. Pages 101-112 *in* J.E. Keeley and T. Scott, editors. Brushfires in California: Ecology and Resource Management. International Association of Wildland Fire, Fairfield, Washington.

Zedler, P. H. and C. A. Zammit. 1989. A population-based critique of concepts of change in the chaparral. Pages 73-83 *in* S.C. Keeley (ed.), The California Chaparral: Paradigms Reexamined. Science Series No. 34. Natural History Museum of Los Angeles County, Los Angeles.

Zedler, P. H., C. R. Gautier, and G. S. McMaster. 1983. Vegetation change in response to extreme events: The effect of a short interval between fires in California chaparral and coastal scrub. *Ecology* 64:*8*09-818.

Zee, J. and D. Holway. 2006. Nest raiding by the invasive Argentine ant on colonies of the harvester ant, *Pogonomyrmex subnitidus*. *Insectes Sociaux* 53: 161-167.

Appendix

GIS data layers created for the assessment

The GIS data layers produced for this report (see table below) are available from the Mediterranean Coast Network Research Learning Center (http://www.mednscience.org) **or by contacting the Santa Monica Mountains National Recreation Area.**

Analysis regions	Title of Dataset	GIS layer name	Layer type
Region	Park reference region	SAMO_regional_boundary	shapefile
Park-and_buffer	Park-and_buffer reference region	SAMO_buffer_boundary	shapefile
Indicator theme			
Stressor: Housing Development	Housing density 1940-2000	pbg00v2	shapefile
Stressor: Housing Development	Housing density 1990-2000	brf_region_clip	shapefile
Stressor: Road distance and accessibility	Distance to nearest road	dist2rds	raster
Stressor: Road distance and accessibility	Travel time from park entrance	ttime_min	raster
Stressor: Road distance and accessibility	Average annual daily traffic time series	AADT_Major_Roads	shapefile
Stressor: Pesticides	Pesticide use 1990-2007	pss_pcide	shapefile
Stressor: Rodenticides	Rodenticide use 1990-2007	pss_rcide	shapefile
Water-Water quality	Water Quality Limited Segments	tmdl_impaired_segments	shapefile
Biological Integrity—Invasive species—Non-native invasive plants	Exposure to populations of invasive plants	exposure	raster
Biological Integrity—Invasive species—Non-native invasive plants	Sensitivity to invasion by invasive plants	sensitiv	raster
Biological Integrity—Invasive species—Non-native invasive plants	Vulnerability to non-native invasive plant invasion	vulnerability	raster
Biological Integrity—Invasive species—Non-native invasive plants	Change in vulnerability to non-native invasive plant invasion if 10% highest priority populations were treated	vulndiff90	raster
Landscapes—Fire and fuel dynamics—Fire regime	Number of times burned	burnfreq4608	Raster
Landscapes—Fire and fuel dynamics—Fire regime	Number of short-interval fires (6 years)	tslflt7	Raster
Landscapes—Fire and fuel dynamics—Fire regime	Number of short-interval fires (12 years)	tslflt13	Raster

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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