National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

John Muir National Historic Site

Natural Resource Report NPS/JOMU/NRR—2014/897

ON THE COVER
Mount Wanda, Muir Nature Trails, John Muir National Historic Site
Photograph courtesy of John Muir National Historic Site/NPS/2006

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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.

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Commonly Used Abbreviations

Acronym	Definition
ARD	Air Resources Division (NPS)
BLM	Bureau of Land Management
CARB	California Air Resources Board
CDF&FP	California Department of Forestry and Fire Protection
CEHC	California Essential Habitat Connectivity Project
cfs	cubic foot per second
CLN	Conservation Lands Network (Bay Area Open Space Council)
DTR	Distance to roads
ECA	Essential Connectivity Area
ECI	Ecological condition index
EDRR	Early Detection Rapid Response
EPA	Environmental Protection Agency (US)
EPMT	Exotic Plant Management Team
EUON	Eugene O'Neill National Historic Site
FRAP	Fire and Resource Assessment Program (CDF&FP)
GCM	Global climate model
GFDL	Geophysical Fluid Dynamics Laboratory
GDD	Growing degree days
GHG	Greenhouse gas
GIS	Geographic Information System
GMP	General Management Plan
GOGA	Golden Gate National Recreation Area
HCP	Habitat Conservation Plan
ICLUS	Integrated Climate and Land Use Scenarios (EPA)
IPCC	Intergovernmental Panel on Climate Change
I&M	Inventory & Monitoring (NPS)
JOMU	John Muir National Historic Site
MCB	Modified census block
NCCP	Natural Community Conservation Plan
NLB	Natural Landscape Block
NLCD	National Land Cover Dataset
NPS	National Park Service
PAD	Protected Areas Database
PBG	Partial block group
PCB	Polychlorinated biphenyls
PCE	Primary Constituent Elements
PCM	Parallel Climate Model
PINN	Pinnacles National Monument
PLSS	Public Land Survey System
UCSB	University of California Santa Barbara
USFS	United States Forest Service
USGS	United States Geological Survey
VTM	Vegetation Type Mapping (USFS)
WFMI	Wildland Fire Management Information

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 the John Muir National Historic Site (JOMU) and an evaluation of the threats and stressors that act on these resources. An improved understanding of the state of knowledge regarding the condition of JOMU'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 JOMU. 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 monument and the planning and science perspectives about their management; (3) **Study Approach** outlines 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** synthesizes major themes of the assessment, highlights the emerging threats and data gaps identified, and makes recommendations for future study.

JOMU was established for the purpose of providing an historic site "as a public national memorial to John Muir in recognition of his efforts as a conservationist and a crusader of national parks and reservations." In 1993, the park acquired the rights to the predominantly undeveloped 326-acre Mount Wanda parcel and in 2000 to the Muir Gravesite where Muir, his wife Louisa, two daughters and his in-laws, are currently buried. John Muir National Historic Site was deemed a nationally significant site in part because the contrasting landscapes – 19th-century vernacular adobe to high-style Victorian home, the manipulated mosaic of Mt Wanda, managed agricultural lands, and the streamside setting of the Muir gravesite – express the continuum of California land use and settlement from Native American times to the present. The legislated policy framework encourages the NPS to collaborate and cooperate with various local governments, land managers, non-profit organizations and community members.

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. In some cases the assessment could model endpoints directly from environmental data to gain an understanding of the strength of hypothesized relationships. In many cases, however, where endpoint data were not available, the assessment was done on a midpoint indicator such as on stressors or ecological pathways. 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 JOMU boundary itself. To assess stressors and endpoints at the landscape scale across adjacent lands, we adopted the North East Bay Hills landscape unit delineated for the Upland Habitat Goals Project in order to link the NRCA to regional conservation planning. A set of eight landscape units were aggregated to delineate an appropriate region. This 2500 km^2 East Bay region contains most of Contra Costa County and all but the southeast quadrant of Alameda 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	DATA
STRESSORS				
Housing development	In 2000, nearly half of the region and the buffer area were in urban or suburban housing densities.	NA		High confidence
Human footprint	The footprint is mostly medium intensity within the JOMU boundary due to the proximity of urban development near the park unit. At the park-and-buffer scale, the amount of high intensity increases to one-quarter. The larger region is more intense yet, with nearly equally split between high intensity in the valleys and medium in the hills.	NA		Medium confidence
AIR AND CLIMATE				
Air quality	Ozone trend: Moderate Condition Total nitrogen deposition: Moderate Condition	75 ppb (EPA); <= 60 ppb is "good condition" (NPS) 0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS); 5.5 kg/ha/yr is considered the critical load for lichen communities in California chapparal. 6.0 kg/ha/yr is considered the critical load for grasslands.		High confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	DATA
	Sulphur deposition: Good Condition Visibility: Moderate Condition	0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS standards) 8 deciviews (5 year average deciview values minus estimated deciview values in the absence of human caused degradation)		
Climate	Climate at JOMU is characterized by warm, dry summers and mild, wet winters. Temperatures averaged 15ºC (59ºF) and total annual precipitation averaged 50 cm (19.7 in) over the past 50 years. Minimum temperature exhibited a small positive trend of 0.1ºC decade-1 over the last century; maximum temperature increased by 0.2 ºC decade-1. Precipitation showed no significant trend. Climate models consistently predict warming conditions to the end of this century but vary in predictions of precipitation.	15ºC (mean annual temperature of past 50 years) 500 mm (average of past 50 years)		Medium confidence
WATER				
Water quality	Erosion in Strentzel Watershed and its possible contribution to flooding and sedimentation in Alhambra Creek is one of the most pressing resource management issues at JOMU. Gullying is the central process that has raised concerns about park neighborhoods and resources. This condition assessment investigated some of the potential stressors with other data sources. Most stressors, including landslide susceptibility, annual grasslands, residential development, climatic patterns, and grazing, appear widespread in the North East Bay Hills and not unique to the Mount Wanda area.	NA		Medium confidence
BIOLOGICAL INTEGRITY				
Non-native invasive plants and Sudden Oak Death	About 254 of approximately 496 plant species are non-native (51%). Eighteen of these non-native species are considered invasive, with the potential for creating serious ecological damage (e.g., erosion, fire, and habitat quality) and detracting from the character of the site's native plant community. Invasive plant management is	No invasive populations		High confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	DATA
	intricately interconnected with other stressors and resources in the park and surrounding landscape, such as watershed health. Sudden Oak Death has not been detected in JOMU, but confirmed detections in the past few years in nearby Briones Regional Park suggest that this disease could become a greater threat for the NPS to monitor.	 No infestations		
Alameda whipsnake	JOMU is included in a Critical Habitat designation for the Alameda whipsnake. To date, no confirmed sightings within the park have been made. Habitat modeling in this assessment indicates there is potential core and movement habitat for this species.	The Alameda whipsnake occurs at JOMU. The park appears to contain the proper habitat requirements, though it is unclear if the park supports a population.		Medium confidence
LANDSCAPES				
Fire regime	In the North East Bay Hills landscape unit and region, fire in annual grasslands is believed to be within historical range with minimal disturbance. Grasslands are considered low hazard and fire severity, with relatively high fire frequency. Oak woodland and shrub types within the region were modeled as moderate departure from natural regimes, with associated changes in ecosystem composition and structure that render future fires likely to cause some loss and change in elements and processes. These types are higher hazard and fire severity than grasslands.	Annual grasslands: 0-35 year frequency Oak woodlands and shrublands: 35-100+ year frequency		Medium confidence
Future fire regime	Wildfire is sensitive to climate change and urban growth. Change in fire frequency in North East Bay Hills by the end of the century ranges from a 16% increase under a low emissions and growth scenario to 41% under a high emissions and growth scenario. High urban growth rates and sprawl tend to dampen the rate of increase in fire frequency.	NA		Medium confidence
Habitat connectivity	JOMU is contained in a Small Natural Area identified by the statewide California Essential Habitat Connectivity Project, but was not included in an Essential Connectivity Area. In the Conservation Lands Network developed by the Bay Area Open Space Council, JOMU is connected to a large area considered essential to meet coarse-filter and fine-filter conservation goals for the North East Bay Hills. The Bay Area Critical Linkages Project is developing	NA		Medium confidence

INDICATORS	STATUS	REFERENCE CONDITIONS	TREND	DATA
	focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that could be irretrievably compromised by development projects in the next decade unless immediate conservation actions occur.			

 = baseline only  = no significant trend  = increasing trend

The staff at JOMU and the SFAN I&M program identified a set of management and research questions. Here we provide brief summaries of what was found in the assessment.

1. *What are the effects of air quality (e.g. pollutants) on the park's natural resources?* JOMU has been rated at High Risk from atmospheric nutrient N enrichment relative to other national parks, based on the level of exposure to emissions and ecosystem sensitivity. Modeling indicates that JOMU and its surroundings experience annual deposition rates at or near the critical load threshold for grasslands and lichen communities above which species composition is likely to change.

2. *What have the changes in climatic factors been over the last 50 years (temperature, precipitation)?* Minimum temperature exhibited a small positive trend of 0.1^{o}C per decade over the last century; maximum temperature increased by 0.2 ^{o}C per decade. Precipitation showed no significant trend.

3. *What are the potential effects of changing climate in this region (e.g. rain, temperature, flooding, and drought patterns) and how may this affect local biological diversity, erosion and flooding patterns.* Minimum winter temperatures are projected to increase by 2.3 – 3.6ºC; maximum summer temperatures by 3.0 –3.9ºC. Precipitation projections are variable, either increasing 6% or decreasing 33% depending on the global climate model. 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 JOMU with an expansion of grassland and shrubland. The frequency of large fires in this area is predicted to increase 16-41% by the end of the century depending on the emissions and urban growth scenario.

4. *Is the level of soil erosion on Mount Wanda normal for the soil type?* Primary data from the Strentzel Watershed and similar streams were not available to conduct a comparative analysis of soil erosion rates in this condition assessment. The watershed report (Moore 2006) identified many potential factors that might account for a high erosion rate, gullying, and flooding. A cursory examination did not identify any obvious factors that would make Mount Wanda unique or at unusually high risk for erosion relative to the broader region. Monitoring erosion rates here and in comparable streams in the region is needed to quantify the rates to support an analysis of the causal factors.

5. *What are the effects of current and probable non-native species invasions (plants and animals) along with disease (e.g., Sudden Oak Death)?* Historically, annual grasses have replaced perennials in the grasslands and in the understory of woodlands throughout the region. Along with other invasive weeds, the potential effects include reducing the number of native plants, increasing fire severity, increasing soil erosion, and suppressing recruitment of oaks. Introduced animals such as rats, dogs, and cats, have increased predatory pressure on the Alameda whipsnake, especially where urban development abuts whipsnake habitat. Cats also prey upon the same food sources as whipsnakes, such as lizards. Sudden Oak Death has been detected near JOMU. It selectively kills black oak and coast live oak.

6. *Are there exemplary natural communities or rare or sensitive species that have not been documented on Mount Wanda but can possibly occur? Is there sufficient data available to determine whether Mount Wanda is suitable for supporting viable populations of these species?* The Mount Wanda unit of JOMU lies just inside the Critical Habitat designation and a recovery unit for the Alameda whipsnake. This condition assessment has shown that Mount Wanda has habitat qualities that the whipsnake prefers. Although there has been one confirmed sighting in the park, it is unknown at this time if a whipsnake population truly occurs at JOMU, however. There are two globally and state imperiled plants that occur here—*Calochortus pulchellus* (Mount Diablo fairy-lantern) and *Helianthella castanea* (Diablo helianthella).

7. *What are the ecological effects of long-term fire suppression on Mount Wanda and in the region? How does fire suppression alter vegetation species composition and communities? What is the potential future trend in fire behavior?* The fire regime of the North East Bay Hills has been strongly influenced by human cultures for thousands of years and has changed considerably over the past several centuries. Lightning fires are relatively rare, creating a woodland/shrubland dominated landscape. Intentional burning by Native Americans and intensive grazing in the 19th Century created a grassland-dominated mosaic, which is probably what John Muir experienced. Aggressive fire suppression in the 20th Century has lengthened mean fire-free periods, reversing the process of grassland expansion by allowing chaparral and coastal scrub to recolonize. Climate change is expected to counter this trend. If temperatures get warmer as expected, grassland and shrubland would likely expand.

8. *What is the ecological significance of Mount Wanda in the regional context (landscape and regional level)? What is the park's relative role in habitat connectivity with other park or protected spaces (e.g. East Bay Regional Parks)?* The statewide California Essential Habitat Connectivity Project classified Mount Wanda as a small natural area but did not identify it as part of any Essential Connectivity Area. According to the Bay Area Open Space Council, JOMU is connected to a large area considered essential to meet conservation goals for the North East Bay Hills. The Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that may include JOMU.

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 JOMU will become similar to current conditions in Stockton in the Central Valley in terms of maximum temperature and Bakersfield for growing degree days. Minimum winter temperatures and maximum summer temperatures are both forecasted to increase dramatically. Models are less consistent in forecasting precipitation changes. Climate change is not just another management issue for JOMU; it will tend to amplify many existing stressors and effects, such as: increase fire frequency that would increase particulates and promote conversion to grassland, shift ranges of native species, and change the phenology of host plants and pollinators.

Housing density is predicted to increase with associated increases in ozone, nitrogen deposition, skyglow, noise, invasive plants, road kill, and wildfire risk. If the metropolitan statistical area containing JOMU is designated as nonattainment for ozone by EPA, it will be important for the park to ensure that planned park activities are included in the State Implementation Plan and emissions inventories.

Until recovery planning identifies locations for focus population centers of the Alameda whipsnake, it remains unclear how involved JOMU will need to be in new regional coordination efforts for adaptive management, inventory, monitoring, and planning. In any case, the designation of Critical Habitat raises some possibilities of constraints on management options, such as treating invasive plants.

JOMU has some of the primary hosts for the Sudden Oak Death pathogen, such as California bay laurel and buckeye. It also has black oak and coast live oak that are susceptible to SOD. So far SOD has not been detected within JOMU, but there have been recent confirmed detections only a couple of kilometers away in similar habitat. Vigilance is called for both in monitoring for SOD but also for following best management practices to avoid accidental introduction of the pathogen.

The report identifies data gaps that, if filled, would improve the usefulness of the stressor or resource condition indicators assessed in this report. Key data gaps include:

- The establishing legislation directs the NPS to maintain or restore the Mount Wanda unit to be consistent with conditions during Muir's time. The specifics of those references conditions are not well-documented, however. Work is needed in historical ecology to determine what the vegetation patterns and composition, watershed, fire regime, and so on, were like. Research will be needed to identify how those reference conditions can be maintained or restored in an environment that is warming and urbanizing.

- The designation of Critical Habitat for the Alameda whipsnake by the U. S. Fish and Wildlife Service entrains JOMU into the recovery planning process. An occurance has been confirmed, but future surveys are needed to verify if a population inhabits the park. More detailed analysis of core and movement habitat will be needed, including higher resolution spatial data on critical habitat elements, such as rock outcrops and small mammal burrows.

- State and regional studies found that JOMU has some role in maintaining habitat connectivity in the North East Bay Hills. These general studies need to be supplemented with species-specific modeling that accounts for their individual habitat affinities, as in the Bay Area Critical Linkages.

The added challenge of responding to these emerging trends and filling data gaps will be the increasing need for coordination and collaboration with other agencies, academics, communities, property owners, and other stakeholders. This approach both acknowledges the ecological and social role of JOMU in the broader landscape, but also builds capacity for the small resource staff at the park.

Acknowledgments

We thank Fernando Villalba, Biologist at John Muir National Historic Site, for his guidance and assistance in preparing this report. His help with data sources, contacts with resource staff, and prioritizing of resource issues was indispensable to this project. Marcus Koenen, former Inventory & Monitoring Program Manager of the San Francisco Bay Area Network and Denise Kamradt from the Santa Monica Mountains National Recreation Area organized and managed the contract and provided guidance throughout the assessment process. The report benefited immensely from reviews by Dave Graber, Marsha Davis, Robert Steers, and Lisa Sanders of the National Park Service. A number of colleagues graciously provided data or advice about their area of expertise. We are very grateful to Anthony Westerling from the University of California Merced who made his data available on response of wildfire to climate change and urban growth scenarios. Alan Flint from USGS supplied downscaled data of climate change forecasts. Ryan Branciforte of the Bay Area Open Space Council provided access to their vast GIS database and assisted with understanding how they delineated their landscape units that we employed as reference regions in this assessment.

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. xxii) for more information.

Chapter 1 NRCA Background Information

In 1999 the National Park Service (NPS) Director instituted the Natural Resource Challenge, which ushered in several new NPS programs to apply science-based management to assess the status of natural resources in national parks, and to assure a healthy condition for them—including the Natural Resource Condition Assessment (NRCA) Program. Over the next several years, the NPS plans to fund an NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring (I&M) Program.

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 things identified on a list of potential study resources and indicators.

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

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
- employ hierarchical indicator frameworks
- identify or develop logical reference conditions/values to compare current condition data against
- emphasize spatial evaluation of conditions and GIS (map) products
- summarize key findings by park areas
- 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. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options are outside the project scope.

Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is 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 current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

NRCAs do not establish management targets for study indicators and do not provide management recommendations. Decisions about management targets must be made through sanctioned park planning and management processes. Meant to serve as foundational documents, 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 and help parks report to government

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 accountability measures.

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.

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.

Additional information about the NRCA Program is posted at http://www.nature.nps.gov/water/nrca/index.cfm.

Chapter 2. Park Resource Setting / Resource Stewardship Context

Introduction

John Muir National Historic Site (JOMU) is a unit of the National Park Service (NPS) that protects and manages roughly 140 hectares (345 acres) of land in Martinez, California in the eastern San Francisco Bay Area. The park includes Mount Wanda, the Muir gravesite, and the Muir House property which includes the historic Martinez Adobe and a large 14-room Victorian home where John Muir lived with his family from 1890 until his death in 1914. While living in the area, Muir carried out many of the endeavors that he is still famous for today, including his battle to prevent the damming of Yosemite National Park's Hetch Hetchy Valley, his significant role in the creation of several national parks, and many of his writings that were later used to help set the foundation of conservation in the U.S. and the NPS. JOMU was created to memorialize John Muir and his legacy as an icon for modern environmentalism. In addition to the cultural artifacts, structures and landscapes that JOMU is commonly known for, the park also contains natural resources, including the region's iconic oak and California bay woodlands and forests, intermixed with open grasslands and savannas – all typical of the eastern San Francisco Bay Area. Although the park's natural resources have been heavily impacted by historical and modern disturbances, its landscapes remain for the most part undeveloped and contain a relatively high level of native biological diversity, making it a good candidate to serve as a model for local collaborative conservation of a small NPS unit in an urbanized setting.

Enabling Legislation

John Muir National Historic Site was established in 1964 for the purpose of providing and protecting an historic space "as a public national memorial to John Muir in recognition of his efforts as a conservationist and a crusader of national parks and reservations" (Public Law 88-547). Initially consisting of only the small land parcel that included the Muir House, Martinez Adobe and some surrounding cultivated land, legislation was passed in 1988 to expand the park to include Mount Wanda and the Muir Gravesite. Using this authorization, in 1991 the park acquired the property rights to Mount Wanda, a 132-hectare (326 -acre) parcel of predominantly undeveloped land. In 2000, the NPS acquired the gravesite property, where John Muir, his wife Louisa, one of his daughters, and some of his in-laws are currently buried. The reason for this park expansion was "to preserve the site in its present undeveloped condition and to provide all maintenance of the site," a legacy that John Muir left behind when we decided preserve Mount Wanda from common land use practices of the time, particularly grazing. This Act also authorizes the Interior Secretary, through the Director of the NPS, "to enter into a cooperative agreement with the East Bay Regional Park District of Oakland, California, for the operation and maintenance by such District of trails on lands within the John Muir National Historic Site" (U.S. Congress 1988; Killion 2005).

This policy framework is what guides the park's management decisions today and encourages the NPS to collaborate and cooperate with various local governments, land managers, non-profit organizations and community leaders. Additionally, given the park's unique circumstance – the varied historical, cultural and natural resources that the park is entrusted to protect and interpret; the potential wide-spread relevancy of John Muir's story and legacy; and the proximity to a diverse and populous demographic – park management is in a position to establish and develop partnerships that cut across a rich array of public and private sectors of the communities.

Park Significance

John Muir National Historic Site was deemed a nationally significant site for the following reasons:

- This site preserves the home and a portion of the land holdings where John Muir – one of most prominent naturalists and conservationists – lived for 24 years and wrote many of his most important literary works to encourage U.S. policies protecting wilderness and creating a national park system.

- Through his influence in protecting Yosemite and other famous national parks, John Muir's leadership and accomplishments continue to influence public perception and political action on environmental issues today.

- The contrasting the historic features of JOMU – 19th-century vernacular adobe to high-style Victorian home, the manipulated mosaic of Mt Wanda, managed agricultural lands, and the streamside setting of the Muir gravesite – express the continuum of California land use and settlement from Native American times to the present.

Geographic Setting

John Muir National Historic Site is located in Martinez, California, approximately 40 kilometers northeast of San Francisco, and immediately south of the Carquinez Strait which connects the Suisun and San Pablo bays (Figure 1). Covering over 34 square kilometers (km^2), of which about 2.5 km^2 is water, the city of Martinez has a population of about 36,000. Established in 1876, it is one of the oldest towns in California and is currently the seat for Contra Costa County (www.thecityofmartinez.org). The largest metropolitan cities near JOMU are San Francisco, at approximately 800,000 people, and Oakland, with a population of approximately 300,000 (U.S. Census Bureau, 2010). The park is situated adjacent to two major highways. The parcel that holds the Muir House and Martinez Adobe (to the north) is separated from Mount Wanda and the Muir Gravesite (to the south) by California State Highway 4, while Interstate Highway 680 lies a few kilometers east of the park boundaries.

Figure 1. John Muir National Historic Site (green outline) in relation to the San Francisco and east San Francisco Bay Area.

Although commonly known for its petroleum refinery, due to the presence of the Shell Martinez Plant, Martinez is also popular for its public open space, undeveloped wildlife corridors, accessible waterfronts, recreational parks and hiking trails. In fact, the city has a high per capita of public open space in California. Additionally, the small city is nestled within a series of protected and undeveloped lands – Martinez Regional Shoreline to the north, Carquinez Strait Regional Shoreline to the west, Briones Regional Park to the southwest, and Waterbird Regional Preserve and the Pacheco Marsh to the east (Figure 2). As with much of the east San Francisco Bay Area, East Bay Regional Parks District has a dominant presence in the local area as a land manager and community partner. In total, they administer more than 40,000 hectares of land, including 65 protected areas, 29 inter-park trails, and nearly 2000 kilometers of trails within District lands.

Figure 2. A map showing the open space areas surrounding Martinez and JOMU.

Human and Land Use History

Current evidence suggests that humans first settled what is now California between 10 to 30 thousand years ago (Moratto 1984; Perego et. al. 2009), during a time of turbulent environmental changes associated with the end of the last glacial period. Populations of megafauna, such as mastodons, bison and ground sloths, were declining rapidly and likely near or at extinction during this epoch (Edwards 1992). As Native American groups settled the varied biogeographic regions and the dynamic climate zones of the area, their cultures also diversified, making California one of the most cultural and linguistically diverse areas of the world.

Although hunting and gathering were common methods for acquiring food, native peoples of California also tended large areas of land and vegetation to help increase production and accessibility to food by developing active land stewardship methods and tools. Human-ignited fires, for example, are believed by many scholars to have been so common before European arrival that they played a significant role in shaping California landscapes, especially native grasslands. Perceived to be untouched, pristine wilderness by early European explorers and settlers, much of the land could have also been characterized as managed ecosystems, to a point where many native plant species may have become reliant on human disturbances and care (Anderson 2006).

By the time of European arrival, a large native group named the Ohlone (Costanoan) had already settled the southern region of the San Francisco Bay Area. Divided into eight linguistic subgroups by anthropologists and linguists, the Ohlone people developed a diverse and complex system of villages based on kinship relationships. Locally, one of the least populous of these linguistic subgroups, the Karkin Indians (from the Spanish name Los Carquines), inhabited what is now western Contra Costa County (Burke et al. 1992), including Martinez.

In the mid to late-1700s Spanish explorers, such as Juan Baustista de Anza, began leading settlements into the San Francisco Bay Area. With them, they introduced not only exotic domestic animals but also (intentionally and unintentionally) many non-native plant species. Many of these plants, such as European annual grasses, wild oats (*Avena* spp.), mustards (*Brassica* spp.) and thistles (e.g. *Cirsium* spp., *Carduus* spp.), are now considered invasive species and have come to dominate much of the local landscape, in particular native grasslands and disturbed areas. European explorers and settlers also introduced exotic pathogens (e.g. whooping cough, measles, small pox, etc.) to which native people were lethally susceptible, making death from infectious diseases the largest contributor to the decimation of California Indian populations (Burke et al 1992; Anderson 2006). Additionally, the systematic subjugation of native communities (for example, through the California Mission system) disrupted local cultures, along with their traditional use and knowledge of the land and resources. By the early 1800s, much of the Bay Area had been settled by Europeans and many native communities were either decimated and/or dispossessed of their traditional lands. In the Martinez area alone, 200 Native American villages were estimated to have been present at the time of Spanish contact in the 1790s. By the 1820s, while the European population grew exponentially, all Indian villages were being abandoned to the point where the Indian population consisted of virtually only the hired labor on the local ranches (Hunter et al.1993).

Having just won independence from the Spanish crown in 1821, the Mexican government began implementing a land grant system throughout Alta California which consisted of present-day California, Nevada, Arizona, Utah, western Colorado and southwestern Wyoming. In 1837 Ignacio Martinez received a land grant for El Pinole Ranch (Rancho El Pinole) from the Mexican government of about 1,750 hectares, which encompassed what is now northwestern Contra Costa County, including the JOMU property and most of Martinez. In 1849 the Martinez family hired local labor to construct an adobe house near the northern base of Mount Wanda. Now referred to as the Martinez Adobe, this building is considered a significant historic structure of the area (Killion 2005).

From 1853 to 1874 the ownership of the land changed several times (Burke et al. 1992). Tree harvesting for wood is believed to have begun during this time period, the effects of which are still visible on Mount Wanda, though no commercial logging operations are suspected to have occurred (Hunter et al. 1993). In 1874 Dr. John Strentzel and his family acquired land that includes what is now JOMU a large area surrounding it. Soon after, the Strentzel family started to cultivate fruit orchards (which became a large business for them), built a large Victorian mansion (referred to simply as the Muir House), and established large gardens of ornamental plants. On Mount Wanda, some orchards such as olives and apricots were also planted, but were largely confined to the southwestern foothills (Killion 2005).

Soon afterward, John Muir married into the Strentzel family and later, in 1890, inherited the house upon the death of Dr. Strentzel. Muir continued many of the land activities and business endeavors that the Strentzel family established. Although the land surrounding the Muir House and Martinez Adobe was intensely modified, much of Mount Wanda still remained unconverted for agricultural purposes during Muir's time (Killion 2005; Burke et al 1992). He did have some livestock grazing on this land, but it is uncertain as to how extensive it was (Burke et al. 1992). In 1889, the construction of the train tracks, trestle, and tunnel which are found on the northern-most section of Mount Wanda and still operational today, were completed after John Muir transferred the right-of-way to the San Francisco and San Joaquin Railroad company (Killion 2005).

After Muir's death in 1914, ownership of the property was transferred a few times and split up into variably-sized allotments. Subsequent owners and renters did not develop this small area further, and in fact, the ranch land and orchards around the Muir House and Martinez Adobe were not well maintained during this time. However, grazing did continue on the local land. Although the exact locations are not well-documented, it is probable that the entire site was grazed at some point. Additionally, some natural gas exploration was conducted on Mount Wanda. At least three wells were drilled, the last one in 1954, but no gas was produced and the wells were later capped (Killion 2005).

After the NPS acquired rights to the land some of the historic land activities, such as grazing and wood harvesting, were discontinued. With the exception of the pear orchard at the Muir Gravesite, none of the original orchards are exist. However, the park has planted orchards at the Muir House property and the southwestern base of Mount Wanda in an attempt to recreate the historic landscape to help interpret the story of Muir's time.

Visitation

According to previous reports, onsite visitation at JOMU has fluctuated from 23,000 to 39,000 people per year during the 1990s. Generally, the Muir House property – where the park's visitor center is located – is the most visited compared to Mount Wanda. In more recent years, the park has experienced an increased number of visitors. In Fiscal Year (FY) 2011 (October 1, 2010 to September 31, 2011) the park logged a total of roughly 44,000 visits. Of these, just over 12,000 visitors entered the park for special events, such as the annual John Muir Birthday / Earth Day celebration in late April (the park's largest event), and ranger-led and other educational programs. NPS Public Use Reports show that peak visitation generally occurs in month of April, with nearly 5,000 visitors, and visitation numbers stay relatively even throughout the rest of the year, with a slight decrease during the cool, wet months (generally November - January). Nearly 32,000 of the total visits during FY 2011 were observed at the visitor center, compared to roughly 12,000 visits to the main trail head of Mt Wanda, where there is an automatic motion sensor counter.

It should be noted that visitors who go to both the visitor center and the main trail of Mount Wanda on the same day would be counted twice separately, duplicating some of the visits. However, it is uncertain as to how many duplicate counts there are on an annual basis. Conversely, there are entrance locations to the Mount Wanda parcel, other than the main trail head, where visitors can access its trail system and are not counted. Although it is unknown exactly how many visits go uncounted, it is believed that, if added, these unobserved visits could noticeably increase the overall observed visitation of the park. Also, the Muir Gravesite is currently not accessible to the public due to no public access road. An environmental assessment is expected to be conducted within the next 2 years to develop a visitor access plan for this parcel.

Natural Resources

The resources found at JOMU are typical of those found in the undeveloped, yet disturbed, lands of eastern San Francisco Bay Area. Over the past 150 years, JOMU lands and surrounding landscapes have experienced significant changes – starting with Native American settlement, through European settlement and the time when John Muir resided in Martinez, to now, with the development of neighboring lands. Orchard cultivation, grazing, introduction and spread of exotic species, modifications to hydrogeomorphic features, and population growth, have all played a significant role in shaping of the current landscape and disrupting valuable ecosystem functions. As a result of these changes, air, soil, water, flora, fauna, and natural landscapes are under pressure from past and present human activities, requiring attention from park management to address these issues and attempt to restore some natural ecological processes within and adjacent to park boundaries.

Furthermore, although there have been extensive efforts to analyze the direct human alterations to the land during the park's historical period of significance (roughly from the late 1700s to the early 1900s) – many of which are now considered and maintained as cultural resources – few efforts have analyzed the subsequent changes that have occurred to the natural landscape features since then, whether as a result of these direct manipulations or due to other, independent factors. Thus, many questions still remain regarding the historical ecology of the natural resources of the site. Such information would be invaluable in informing future management decisions. This section does not try to answer these questions; rather, it discusses the basic information of what is already known from the work that has recently been conducted by the NPS and others, while identifying data gaps.

Ecological Units and Watersheds

JOMU is part of the East Bay Hills-Mount Diablo ecological subregion (Figure 3), also referred to as Subsection 261Ac by the US Forest Service (Miles and Goudey 1997). According the Miles and Goudey, in this subregion "[t]he predominant natural plant communities are the coast live oak (*Quercus agrifolia*) series in the East Bay Hills, both the coast live oak series and blue oak (*Q. douglasii*) series on Mount Diablo, and valley oak (*Q. lobata*) series on alluvial plains." Chamise (*Adenostema fasciculatum*) chaparral can be found on shallow soils, though this community is not extensive at JOMU, while the common native plant community on Vertisols soil series is needlegrass (*Stipa* spp.) grasslands. Hillslopes yield rapid runoff which decelerates in alluvial fans, generally in the lower reaches of drainages. With the exception of the larger streams, creeks are typically dry through the last half of the summer, and natural standing bodies of water are not common (Miles and Goudey 1997).

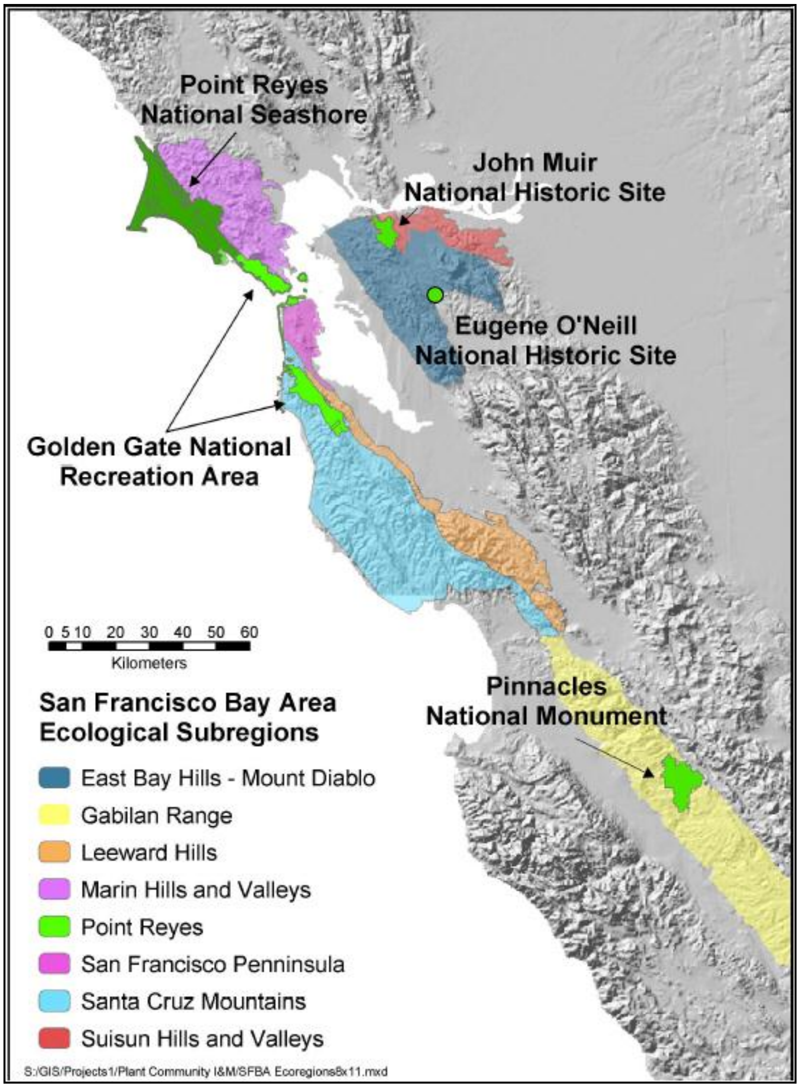


Figure 3. JOMU within the network of San Francisco Bay Area Ecological Subregions. JOMU lie within the East Bay Hills - Mount Diablo ecological sub-region.

The entire park lies within the Alhambra Creek Watershed. The Strentzel Watershed, which drains into Alhambra Creek just south of park boundaries, is located partially within the Mount Wanda parcel of JOMU, and the rest is located on private property west of the park (Figure 4). Much of downtown Martinez is situated within the 100-year flood plain of Alhambra Creek, making it susceptible to periodic flooding, which in recent years has become an increasing concern in the local area, largely due to recent flood events. Some local and county officials and hydrology experts attribute the rising risk of flooding and reduced water quality to deteriorating watershed functions, including accelerated rates of sedimentation and increased area with impervious surfaces. In response to these developments, there have been efforts from local community members, the city of Martinez, and Contra Costa County to address flooding, erosion and sedimentation problems within the Alhambra Creek Watershed. (Alhambra Creek Watershed Planning Group 2001).

Figure 4. Map of Strentzel Watershed (outlined in red) at JOMU (yellow outline) looking northwest. Martinez is on the right-hand side.

After relatively recent flood events at the confluence of Alhambra and Strentzel Creeks, local attention has been focused more on the Strentzel Watershed as a contributing source of sediment to the Alhambra Watershed. In response, the NPS commissioned an assessment of current watershed conditions. One of the products of this was a watershed management report. Completed in 2006, the purpose of this report is to help inform the park on the seriousness of this and related issues, as well as to outline possible management and monitoring options to consider (Moore 2006).

Resource Descriptions

<u>Introduction:</u>

Although there are three separate land parcels that make up JOMU, this section of the report will mainly discuss and reference information relevant to Mount Wanda. Being by far the largest of the three, this parcel remains relatively undeveloped. Thus, it encompasses the grand majority of the natural resources found within in the park boundaries. The other two parcels, the gravesite and Muir House properties, are managed primarily as cultural landscapes per the guidance and recommendations of the park's Cultural Landscape Report (Killion 2005) and the National Register of Historic Places.

Air:

The greater San Francisco Bay Area has a large ratio of open space to urbanized environments, allowing for the protection of a relatively extensive network of airsheds in the region. However, due to several dense metropolitan centers and local industrial activities (e.g. oil refineries and mining operations), maintaining healthy, clean air continues to be local concern. Although air quality has improved significantly in recent decades, the Bay Area is still faced with the issue of low air quality compared to national standards.

The U.S. Environmental Protection Agency (EPA) has identified 52 metropolitan statistical areas in the country as *Non-attainment Areas* under the Clean Air Act based on a history of monitored levels of ground-level ozone above the standard of 0.075 parts per million. These *Non-attainment Areas* encompass 62 NPS units across the country. JOMU is included in the greater San Francisco Bay Area, which has been identified as one of these areas for historically not meeting EPA ozone standards.

Ground-level ozone is typically created through a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, refinery outgassing, and chemical solvents are some of the major sources of NOx and VOC. Breathing ozone can trigger or exacerbate a variety of health problems, particularly long-term respiratory ailments. People with preexisting conditions, such as asthma, are especially at risk. Ground-level ozone also affects plants and animals, causing disruptions in natural ecosystem functions. Ozone molecules can damage tissue in the respiratory system of animals, and can block openings in plant leaves, which in turn slows the rate of photosynthesis and plant growth.

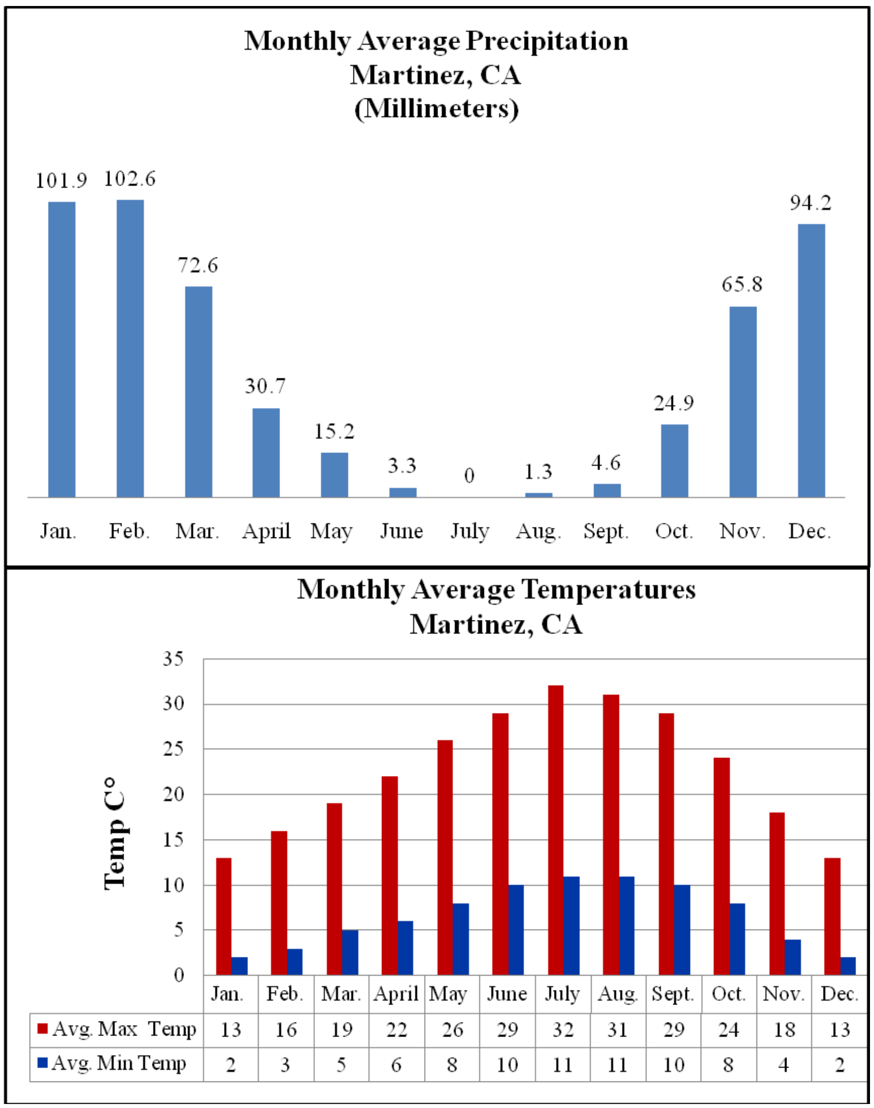
Air Resource Issues Overview:

Being near an urbanized environment, with two major freeways nearby, several ports, and an oil refinery, air quality has been and will continue to be a challenge for the local Martinez area. Ground-level air pollution such as ozone and suspended particular matter are of major concern. This issue will especially be of greater import if demographic trends in the east San Francisco Bay Area lead to increased development, housing density, and fossil fuel-based transportation. Additionally, increased temperatures estimated by climate change predictions (ranging from 1 to 3 C°), which has the potential to further increase ground-level ozone pollution (California Energy Commission 2011), can make matters worse.

Climate:

John Muir National Historic Site and the Martinez area are found within the Mediterranean-type climate zone of central and southern California and northern Baja California region. This climate type only occurs in four other locations around the world and is commonly located on the west side of continents, adjacent to oceans between 30-40 degrees latitude north and south of the equator. Due to the park's proximity, to the coastline, its climate is heavily influenced by the Pacific Ocean, which creates moderate, wet winters and warm, dry summers. Under the Köppen-Geiger classification system, Mediterranean-type climates are generally classified as "dry-summer subtropical" (Peel et. al. 2007).

The California Department of Fish and Game's adapted the Köppen-Geiger system to develop a more localized classification system of sub-regions. According to this local system, JOMU and the surrounding area are within a Mediterranean-type sub-region that experiences relatively mild summers, in contrast to sub-regions with hot summers like those found close to and within California's Central Valley to the east (California Department of Fish and Game 2003). As suggested, summer months in Martinez are relatively dry and warm, with very little rainfall and minimum and maximum temperatures ranging from about 10 to 32 C°. The area experiences relatively infrequent fog and overcast occurrences throughout most of the year, unlike the San Francisco peninsula and other areas closer to the coastline such as Berkeley and Oakland (California Department of Fish and Game 2003). Winter and spring months are typically wet, with an average precipitation of about 520 millimeters (about 20 inches) annually (Figure 5). Snowfall is very rare at the elevations found in the park and local areas.



	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Avg. Max Temp	13	16	19	22	26	29	32	31	29	24	18	13
Avg. Min Temp	2	3	5	6	8	10	11	11	10	8	4	2

Figure 5. Top graph shows the average monthly minimum (blue) and maximum (red) temperatures (in C°) for Martinez, CA. The bottom graph shows the average monthly precipitation (millimeters) for Martinez, CA (The Weather Channel, http://www.weather.com).

Climate Resource Issues Overview:
Climate change continues to be a concern for the NPS, and will likely be one of, if not the, most pressing and complex challenges of the near future for the agency. It is difficult to predict how natural systems and resources will respond to both changing weather patterns and management efforts under predicted future conditions. This poses a challenge for managing natural resources, especially if land managers are looking to implement programs that address resource issues at the ecosystem level.

Current climate change scenarios predict a change in the precipitation temperature regimes of the local area, to a more arid and hotter climate, with an increase in average temperatures of about 1 - 3 C° (California Energy Commission 2011). If this occurs, there would be significant impacts to the natural resources that rely heavily on the already scarce water resources of the site. Furthermore, increased temperatures and carbon dioxide levels are suggested to favor the spread of invasive plants, an issue that is already a difficult challenge to manage. Fire risk is also predicted to rise with increased temperatures and water scarcity, possibly posing a greater danger to resources and people (Luers et. al. 2006).

<u>Geology and soils:</u>
The bedrock geology is composed of marine and near-shore sediments. Older siltstones and mudstones from the Great Valley Sequence overlie younger Tertiary sandstones, indicating that the strata have been overturned. Steeply dipping and overturned strata are common in the highly dynamic tectonic environment of the Coast Range, as well as in proximity to the San Andreas Fault system. The Southampton Fault, a small tectonic feature, strikes across the southwest flank of Mount Wanda, under a cattle pond, and through the steep canyon that drains into Franklin Creek (Dibblee 1980). This fault connects to a series of fault splays of the active Calaveras Fault to the south.

The lowermost formation on Mount Wanda is called the Martinez Formation by Dibblee (1980), and the Lower Vine Hill Formation by Graymer et al. (1994). This rock type, either described as glauconite sandstone or claystone-siltstone-sandstone, has ample fossils of shells and other seafloor creatures, and is of Paleocene age (~ 55 to 65 million years ago (Mya)). The older overlying rocks are of Cretaceous age (~ 65-150Mya) and were formed when the entire Central Valley area was a shallow inland sea that rapidly filled with sediments from the ancestral Klamath Mountains and Sierra Nevada. Although it is difficult to distinguish the various units of the Great Valley Sequence, Dibblee refers to this layer as the Panoche Formation, while Graymer et al. (1994) split it into Assemblage V sandstone and shale, and Assemblage IV quartz arenite. These inconsistencies are typical, given the scale and small land area of the Mount Wanda watershed.

Elevations found at JOMU range roughly from 61 meters (200 ft) to 201 meters (660 ft). Slopes are fairly steep and deeply dissected, with the steepest occurring on the low-elevation flanks of Mount Wanda and in the narrow drainages. Soils are moderately well-developed, brown in color, and slightly acidic. The weathering front is probably 2+ meters below the soil surface, as few rocks are exposed. Soil maps show Mount Wanda to be predominantly Los Gatos series loam (Figure 6). These are rich, well-drained (less likely to saturate) loams to clay-loams, prone to small slope failures when abused and rapid runoff when bare. This soil type is found under oak woodlands and on north-facing slopes. Permeability is moderate, as is shrink/swell potential, and erosion potential is high (Welch 1977).

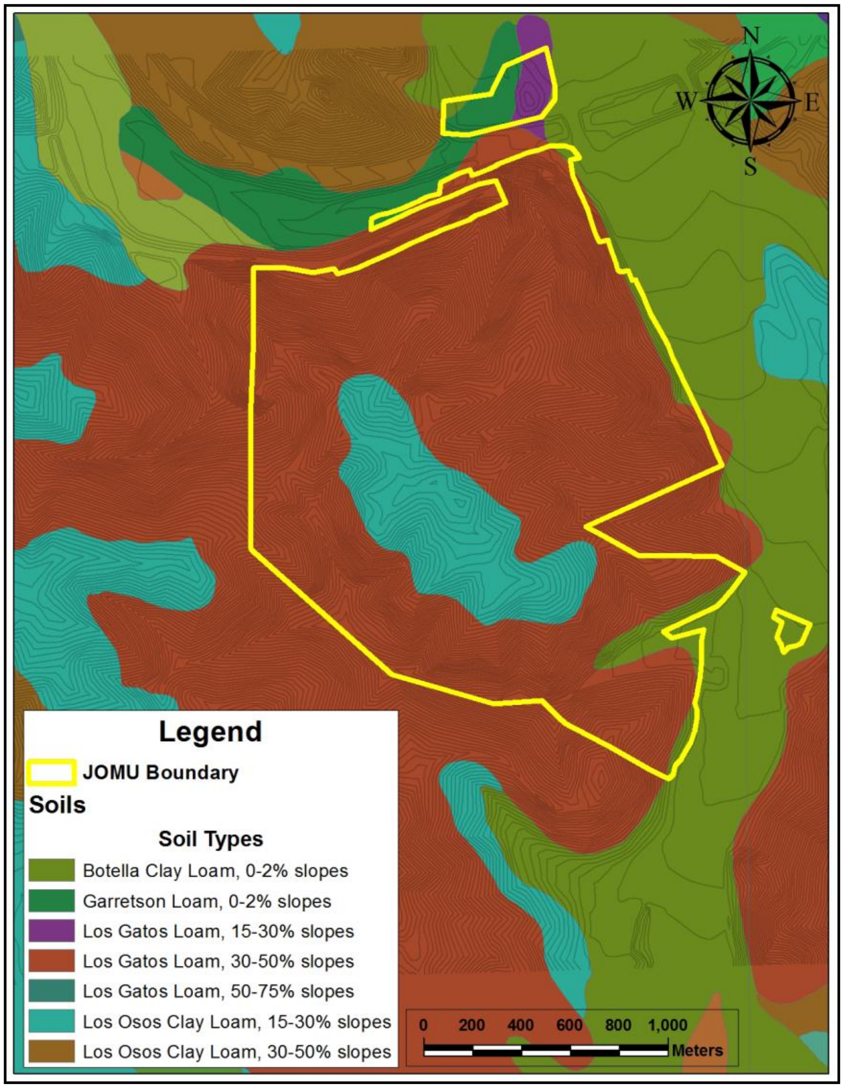


Figure 6. The Soils species and topography found within JOMU and just outside of park boundaries.

Los Osos-series soils are found on the grassy summits and ridges of Mount Wanda and adjacent terrain. Generated from the finer-grained sand and shale of the Great Valley Sequence rocks, these soils have higher clay content, and are classified as clay or clay-loam. They are slightly deeper than the Los Gatos soils, grayish-brown in color, and with medium acidity. Permeability is low, and the clays readily shrink or expand as moisture conditions change, while their erosion potential is high. Locally, the Los Gatos and Los Osos soil types may grade into one another. A third soil type, Botella clay-loam, is found in the lowermost reaches and alluvial plains of Strentzel Canyon as well as on Alhambra Creek floodplains (Welch 1977).

Geology and Soils Resource Issues Overview:

The geological features of Mount Wanda have seen significant changes over the last 150 years, largely due to human activity. For instance, soils continue to be impacted by historic grazing in at least two ways. First, localized terracing from historic grazing is still visible in some areas. It is unclear, however, whether this network of terraces is being sustained by deer populations. Second, many of the wide-spread European annual plants that occur on Mount Wanda, such as wild oats, were introduced to be used for grazing fodder. These plants tend to have shallow roots with low tensile strength, making them poor ground cover for stabilizing soils. Thus, their pervasiveness within the park has likely exacerbated the deterioration of hillslopes and watershed features, leading to the increased risk of slumping and erosion, particularly among the steep slopes of the Strentzel Watershed.

<u>Water:</u>

All of the channels draining Mount Wanda are intermittent or ephemeral. None of them are named on U.S. Geological Survey topographic quadrangles. Although water yields and annual average discharge are unmeasured, flow is a fraction of a cubic meter per second (cms) from December to April, with sharply higher flows during and immediately following rainstorms. A 10-year flow is estimated to be just over 5cms at the mouth of Strentzel Creek (Inglis 2000).

John Muir National Historic Site is located within the 27 square kilometers Alhambra Creek Watershed in mid-western Contra Costa County, and largely within the Martinez city boundaries and adjacent unincorporated areas (Figure 7). Alhambra Creek headwaters originate in the hills of Briones Regional Park southwest of JOMU. Eventually, this creek flows past the John Muir gravesite and continues north into the Carquinez Strait, between Suisun and San Pablo Bays. This watershed is not included in the San Francisco Bay Regional Water Quality Board’s Basin Plan, which "is the Board's master water quality control planning document that designates beneficial uses and water quality objectives for waters of the State, including surface waters and groundwater. It also includes programs of implementation to achieve water quality objectives" (California Regional Water Quality Control Board 2010). Alhambra Creek does not flow within the boundaries of JOMU. However, two of its tributaries do flow through the Site: Franklin Creek and Strentzel Creek.

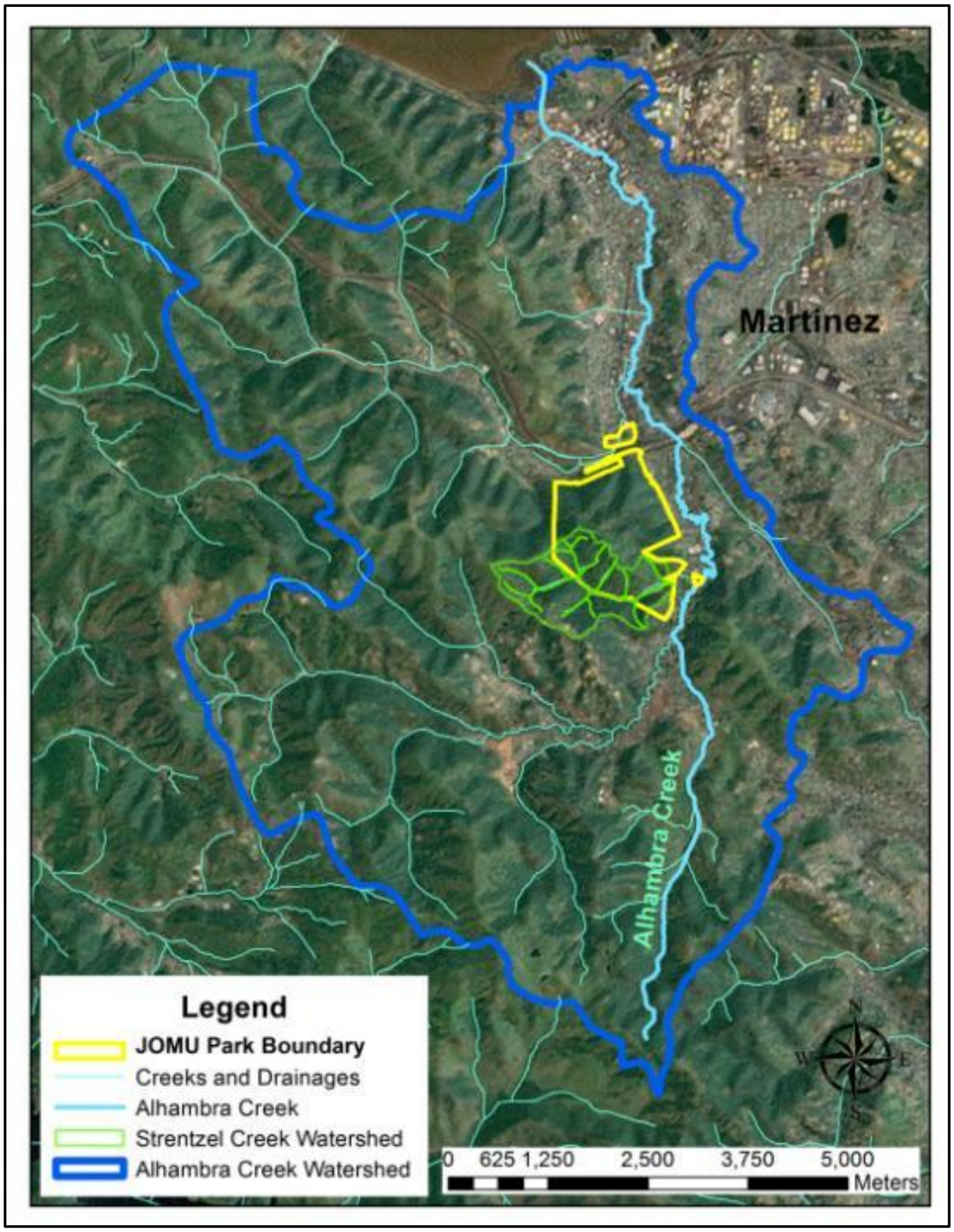


Figure 7. Map of JOMU (yellow) and the Strentzel Creek sub-watershed (green) in relation to the Alhambra Creek Watershed (blue). Martinez is to the top right. The mouth of Alhambra Creek (light blue) leads into the Carquinez Strait at the very top of the image.

The Strentzel Watershed begins in the upper hills of Mount Wanda, flows past a ranch currently occupied by the Strain family (herein called the Strain Ranch), drains underground via a culvert just to the east of the Muir gravesite, and drains into Alhambra Creek. Some tributaries of Strentzel Creek are spring-fed; however, the main stem is ephemeral and only flows during and after storm events, generally starting in early winter and ending in late spring. This watershed area is just over 3 square kilometers. Approximately half of the watershed is outside JOMU boundaries on private land, much of which is currently used for cattle grazing. The Strentzel Canyon is used by visitors for hiking recreation, and provides valuable wildlife habitat. With the exception of a few old stock ponds, it is not used as a water supply. An old unmaintained, decommissioned fire road follows along the eastern side of the creek.

The 8 square-kilometer Franklin Creek is a year-round stream that flows through the Muir House parcel, just west of the house. It begins in Briones Hills overlooking Martinez, flows primarily eastward and drains into Alhambra Creek about a kilometer downstream of the Muir House and about 2 kilometers downstream of the confluence of Strentzel and Alhambra creeks. The current uses of Franklin Creek include municipal and domestic water supply, wildlife habitat, non-contact recreation, and possibly coldwater habitat for large fish. It is believed to have supported historic populations of large anadromous fish such as steelhead trout. Significant gravel beds are still present in the creek, which would provide spawning areas for salmonids. However, there are several migration barriers within the stream – one of which lies at the northern border to the Muir House parcel – and it is uncertain whether the stream currently meets the coldwater temperatures that would maintain sufficient oxygen levels necessary for the survival of these particular fish (Cooprider 2004). At the present, although there have been some anecdotal reports of unidentified large fish, the only fish populations that have been documented within park boundaries are small fish species such as sticklebacks (Brown 2005).

Water Resources Issue Overview:
Significant floods in the 1980s and 1990s, together with the National Park Service purchase of the Mount Wanda lands in 1991, raised community interest of water resources within the park. Strentzel Watershed, partly on NPS land and partly held by private owners, appears at first to be a natural area, but closer examination reveals a long history of varying anthropogenic land uses and manipulations in physical and biotic character. In 2000, Richard Inglis from the NPS Water Resources Division (WRD) completed a condition assessment of this watershed. Inglis concluded that under current conditions, flooding would likely occur in the neighborhoods just downstream of Strentzel Meadow, with any flows above 0.5-1.5 cubic meters per second, finding that the only action that would significantly reduce the risk of flooding downstream would be the installation of a large detention basin in the meadow.

In 2006 Chad Moore, from the NPS Denver Service Office, conducted a geomorphology survey of the Strentzel Watershed. In the process, he also developed a geomorphology chart that details the locations and extent of the most notable erosion points of the watershed (Figure 8). Moore found that sedimentation and runoff were remarkably high in the system. Most notably, the middle section of Strentzel Creek and some of its drainages displayed the greatest number and extent of headcuts, undercuts and downcuts, creating a network of gullies. He also noted that the abandoned earthen dams and their associated trapped sediment pose a moderate risk, while the smaller NPS cattle pond in the upper portion of the watershed shows no significant contribution to runoff or sediment load. Meanwhile, failures of other larger dams in the watershed have contributed to increased erosion and sediment production. A small earthen dam at the meadow of the creek (lower watershed) was removed in 2005. Although the remaining dams are of some concern, the problem appears to have evolved independently (Moore 2006).

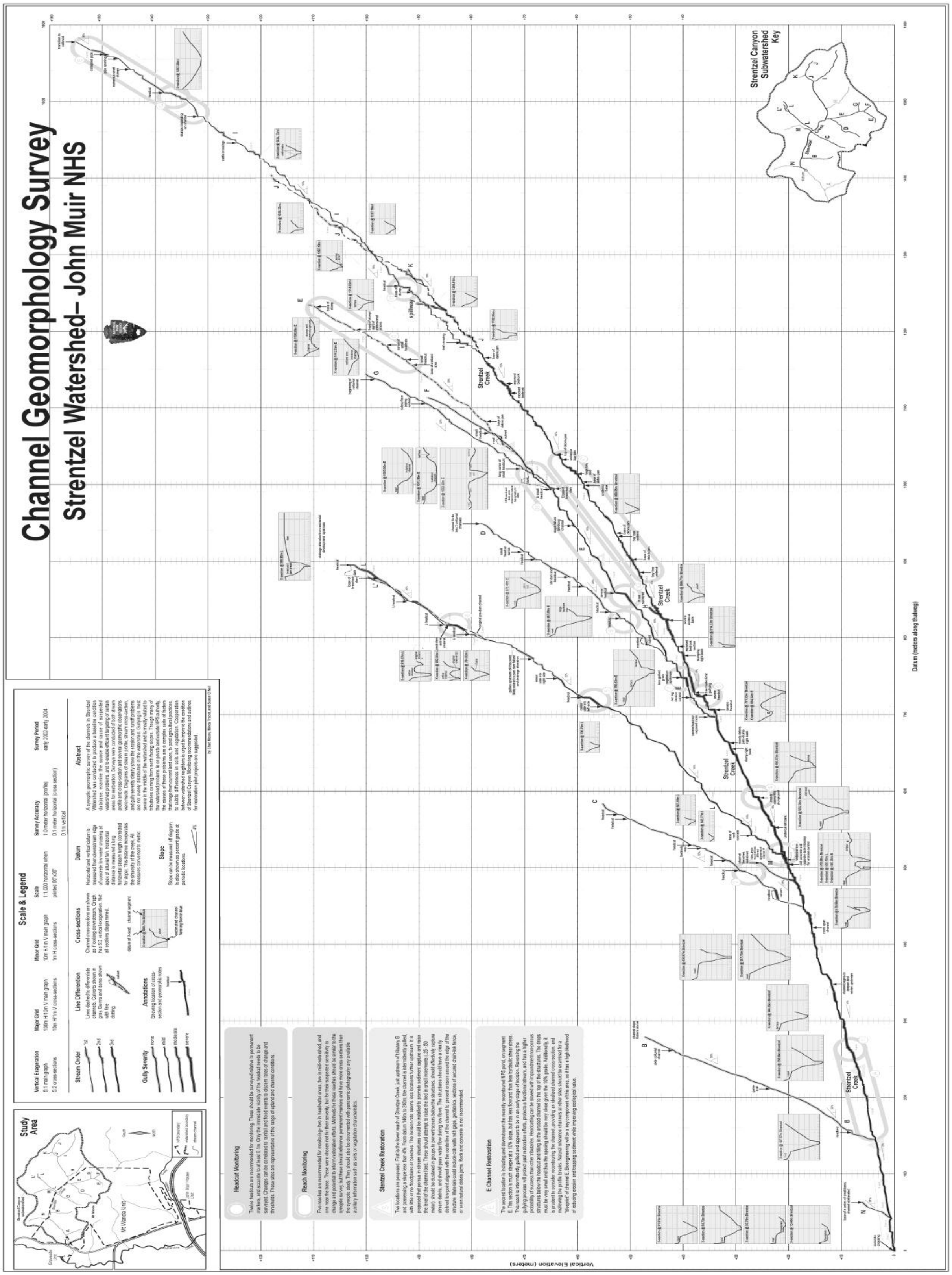


Figure 8. Geomorphology graph of Strentzel Watershed (Moore 2006).

Moore's assessment also revealed that, although there is clear evidence that gullies have naturally developed in the past, the dramatic incising of this streams are likely unprecedented. The expansion of these channels accounts for most of the watershed problems observed downstream, before the channel empties into Alhambra Creek. A simple analysis of sediment sources revealed that the expanding and deepening network of gullies are the primary sediment source, while slumping (slope failures) are secondary. Other tertiary sources of sediment include: dam failures (where the dam itself and the decades of impounded sediment are eroded), the road network (especially the old fire road that runs along the creek), and storm water drainage from residential areas atop the watershed. Measuring the sediment load contributed by Strentzel Creek relative to other tributaries within the Alhambra Creek Watershed was beyond the scope of Moore's assessment, but would be informative (Moore 2006).

In 2004, the NPS collaborated with the city of Martinez and Contra Costa County Flood Control District to install a detention basin at the bottom of Strentzel Meadow, which drains into a large culvert routed under the downstream neighborhood and into Alhambra Creek. JOMU staff continues to work with the local governments and other community partners to mitigate this issue in the interim while a long-term solution is developed. However, planning for the long-term has been delayed since the Strain Ranch site, which lies in the alluvial fan, is currently occupied by the private residence of the Strain family (Figure 9). As per the legal arrangements agreed upon during the acquisition of Mt. Wanda, the NPS will be acquiring full management of this property in 2016. After assuming management of this piece of land, the park can then develop a more holistic management strategy for restoring some of the natural functions of the meadow, along with other important land features in the mid- and upper reaches of the watershed.

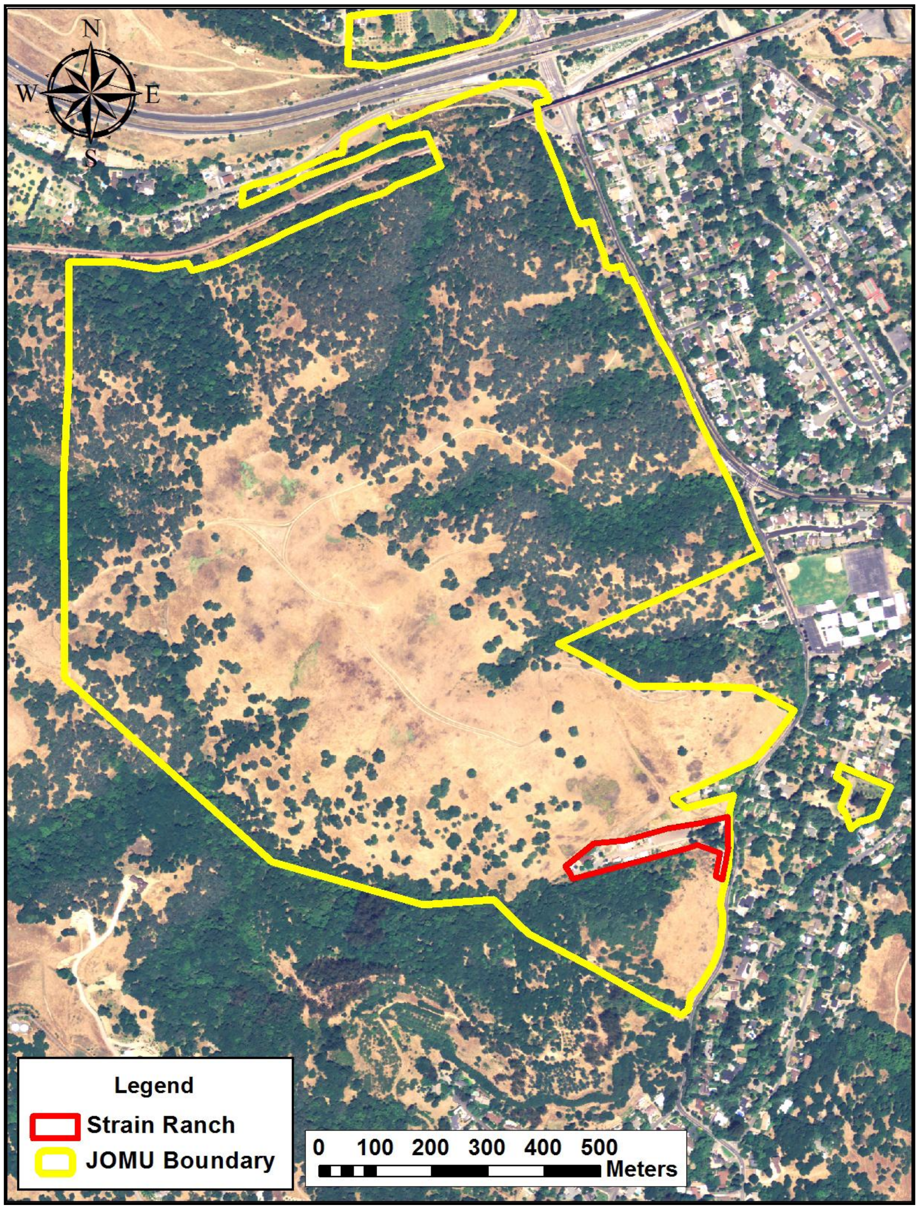


Figure 9. An approximation of the Strain Ranch property within the Mount Wanda parcel.

Since 2004, the NPS Inventory and Monitoring Program staff has been monitoring the water quality of Strentzel and Franklyn creeks. The potential or existing issues in the JOMU watersheds include pollution by fecal coliform bacteria, nutrients, sediment and impacts of flooding. Much of this may be attributed to the cattle grazing that occurs on the south side of the Strentzel Watershed (outside JOMU boundaries) and in the upper reaches of Franklin Watershed. Monitoring by the Friends of Alhambra Creek has detected high levels of fecal coliform. Additional water quality testing will help determine the extent of runoff (or direct inputs) of animal waste into the streams. Other potential sources of pollutants in Franklin Creek include illegal dumping, highway runoff, horse operations, a nursery, and residential septic systems.

Biological Integrity:

California, particularly along the Pacific Coast region, is considered a hotspot for biodiversity because of its large number of unique species found nowhere else in the world (Figure 10). However, this diversity is currently being threatened, predominantly by habitat loss and fragmentation due to human population growth and development in the region (Bay Area Open Space Council 2011). John Muir National Historic Site lies within this ecologically-rich San Francisco Bay Area, which is part of the California Floristic Province and is also valued for its high biological diversity and endemic species. There is a strong latitudinal climate gradient, as well as a strong climatic gradient perpendicular to the coast and influence of the Pacific Ocean. A number of ecoregion delineations have been done that include the JOMU lands, but for the purposes of this document, the California Central Coast system (as defined by The Nature Conservancy) has been selected as being an strong representative of the various zones within the park (The Nature Conservancy 2000).

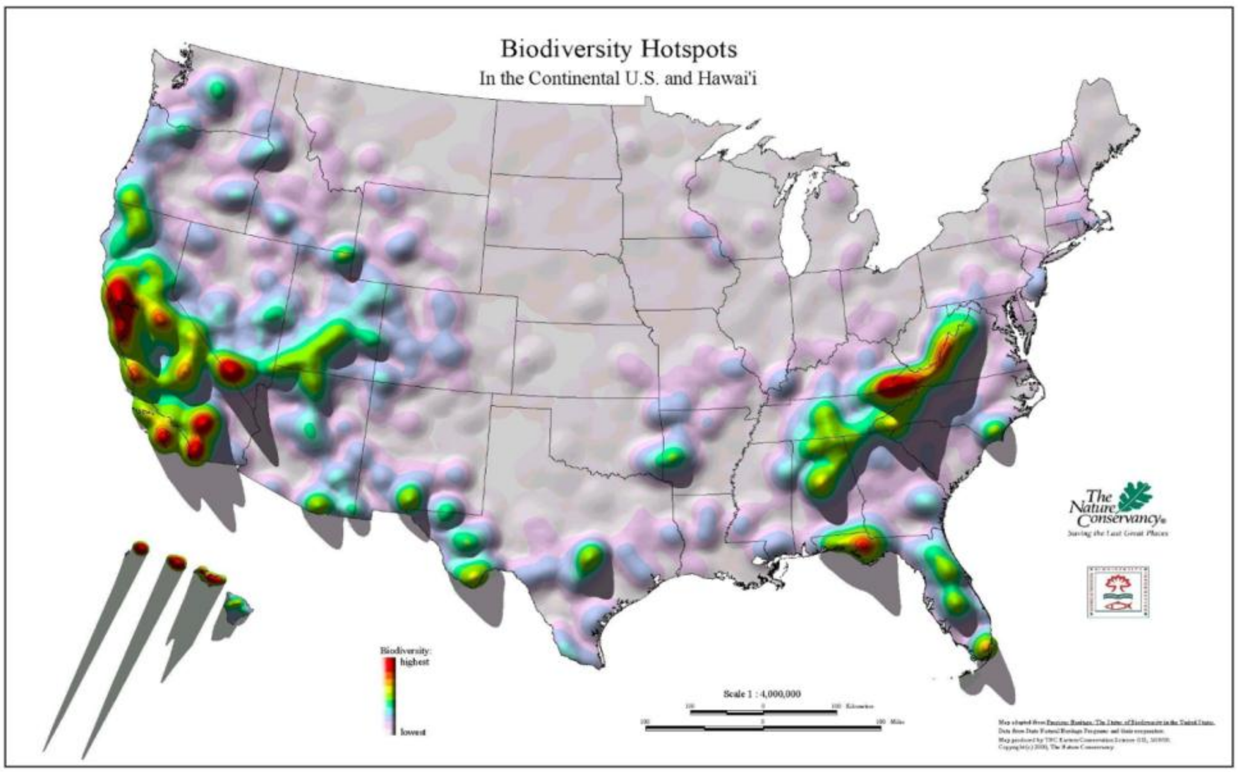


Figure 10. Biodiversity Hotspots in the United States. Map produced by: The Nature Conservancy. 2000. Eastern Conservation Science. Arlington, VA. USA.

Resource Issues Overview:

One of the most, if not the most, immediate threat to the biological integrity at JOMU comes from exotic invasive plants. Having little to no natural predators or diseases to control populations, as well as having the ability to thrive in local environments, invasive species can often outcompete and devastate native biota if left uncontrolled. In particular, the grasslands at JOMU have become heavily infested with non-native plant species. And, although native grass diversity is relatively high in this vegetation community, it has been estimated that only 7 introduced plants dominate and cover over 90% of these patches (Hunter et al. 1993). As a result, some native plant communities – grasslands in particular – are found in small, non-contiguous patches and are at risk of local extirpation. In addition to exotic European annual grasses, various thistle species, predominantly Italian and milk thistles, are common. Thistles are also commonly found in woodland habitats and likely compete with tree seedlings for sunlight and water. Tree of heaven (*Ailanthus altissima*) is also encroaching on these woodlands. Although there was an effort in the early 2000s to remove and contain tree of heaven, the plant still persists on the eastern and southern borders of Mount Wanda, presumably due to a lack of control on adjacent lands. There is major concern that without aggressive and cooperative management of these and other invasive plants in and around JOMU property, the shift towards predominately exotic plant species on the landscape may become irreversible, which in turn would have negative long-term impacts on native fauna as well.

<u>Vegetation:</u>
John Muir National Historic Site is within the Central California Coast (Section 261A) as described by Miles and Goudy (1997). This section is comprised of hills and valleys in the southern Coast Ranges of California. The growing season ranges from 200 to 300 days. Within the Central California Coast section, JOMU is within the East Bay Hills–Mount Diablo subsection (261Ac) consisting of the Diablo Range and steep hills west of Mount Diablo. In this subsection, the marine influence is moderate. The hills tend northwest with rounded ridges, steep sides and narrow canyons. The vegetation for this subsection is described as Coast live oak series in the East Bay Hills, Coast live oak series and Blue oak series on Mount Diablo and Valley oak on alluvial plains. The chamise series is found on shallow soils with sagebrush present on south-facing slopes (Miles and Goudy 1997).

In 1992, Hunter and others surveyed the vascular plants at JOMU and found that there were at least 260 species on Mount Wanda (Hunter et al. 1993). In 2002, another survey found similar results, with investigator finding over 290 species on Mount Wanda alone. At the John Muir House site, over 220 plant species can be found, although many of which are cultivated plants that are contributing features of the cultural landscape. At the John Muir Gravesite 94 species were documented (Jepsen and Murdock 2002). In all, there have been nearly 220 native vascular plant species documented at the park (Appendix A-1).

In 2004, a vegetation map of Mount Wanda was completed. Four dominant vegetation community alliances alliances can be found on Mt Wanda: Wild Oats Grassland (28%), Blue Oak Woodland (26%), Coast Live Oak Live Oak Forest (20%), and California Laurel Forest (14%). Vegetation also consists of Valley Oak Woodland, Woodland, Buckeye Woodland and Chamise Shrubland. A very small percentage of the vegetation is made made up of native grasslands (1.13%), though some isolated populations of native grasses can be found found interspersed among the wild oats and woodlands (O'Neill and Egan 2005) (

Table 1 and Figure 11).

Table 1. Vegetation communities at JOMU.

Formation Name:	Hectares Covered*	Percent of Area*	Number of Polygons
Woodland	49.67	37.65	8
Forest	46.91	35.56	12
Herbaceous (grassland)	38.40	29.11	12
Shrubland	2.39	1.81	4
Alliance Name:	**Hectares Covered***	**Percent of Area**	**Number of Polygons**
Wild oats grassland	36.92	27.98	4
Blue oak woodland	34.98	26.48	3
Coast live oak forest	26.85	20.35	7
California laurel (bay) forest	17.81	13.5	3
Valley oak woodland	10.98	8.32	2
Buckeye woodland	3.75	2.84	3
Olive forest	1.97	1.49	1
Chamise shrubland (chaparral)	1.51	1.15	2
Coyote brush shrubland	0.88	0.67	2
Ryegrass grassland	0.87	0.66	6
Leymus grassland	0.60	0.46	1
Oak forest	0.28	0.21	1
Crypsis grassland	0.02	0.01	1

* Hectares were converted from acres. Data used from O'Neill and Egan 2005.

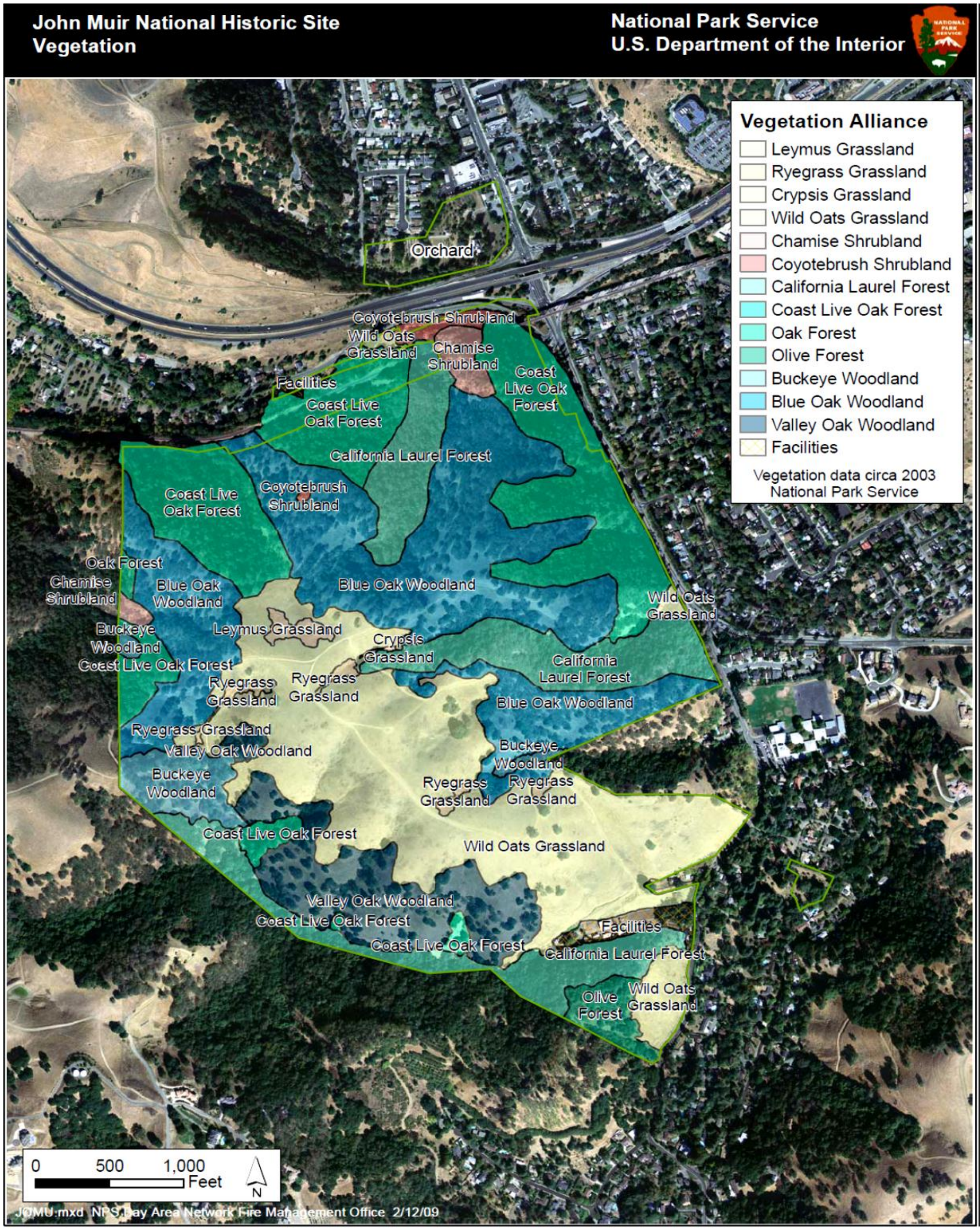


Figure 11. Vegetation communities found at JOMU, based on a mapping project conducted in 2004.

Annual grassland is typically limited to the upper portions of the mountain, covering roughly 37 hectares. Although this one of the most diverse vegetation communities on Mount Wanda, it is dominated by non-native vegetation. In 1992, 74 species were observed in this vegetation community; however the grand majority of this community comprises of only 7 species of exotic annual grasses and forbes (Hunter et al. 1993).

Mixed evergreen forest covers 29 hectares of Mount Wanda, primarily on north and northeast facing slopes and riparian areas in canyon bottoms. This vegetation community has low shrub and herb cover, with the overstory composed of coastal live oak, California bay laurel trees, or a mixture of the two species. Oaks are more common on hillslopes while bay trees are more common in canyon bottoms (Jepsen and Murdock 2002).

Mount Wanda also holds two relatively small plots of chamise chaparral, totaling about 1.5 hectares. One is located close to the northeastern boundary of the parcel, while the other lies just inside the western boundary. These plots predominately consist of chamise (*Adenostoma fasciculatum*), toyon (*Heteromeles arbutifolia*), and California sage brush (*Artemisia californica*). Some sticky monkey flower (*Mimulus aurantiacus*) and scrub oak (*Quercus dumosa*) can also be found.

Vegetation Resources Issues Overview:
Exotic plants have increasingly become one of the most notable features at JOMU, whether as cultural resources or invaders of natural landscapes. Nearly 40 of non-native plant species have been documented at JOMU (Appendix A-2), not including the dozens of other exotic plants that are part of the cultural landscape and maintained by the park. Fortunately, most of the cultural plantings are not considered invasive and are confined to small areas. Of the documented non-native plants, 14 species are categorized as Noxious by the state of California's Department of Food and Agriculture. In particular, grassland communities are likely the most impacted vegetation at JOMU and the surrounding areas, largely pervaded by rip-gut brome (*Bromus madritensis*), Italian ryegrass (*Lolium multiflorum*) and wild oats (*Avena* spp.) (Hunter et al, 1993). Various thistle species, most notably Italian thistle, (*Carduus pycnocephalus*) and milk thistle (*Silybum marianum*) are also very common in these grassland areas, as well as in oak woodlands and the drip line of oak savannas where both water and sunlight are relatively accessible. Also, yellow starthistle (*Centaurea solstitialis*) populations have historically been wide-spread throughout the park's grasslands, though their populations have decreased over the past decade due to ongoing control efforts by the NPS California Exotic Plant Management Team and park staff.

According to data collected in the 2002 plant survey, 15 locally to regionally rare plant species occur at at JOMU (

Table 2). These include the Mount Diablo sunflower (*Helianthella castanea*) which is an endemic species to the San Francisco Bay Area, and California black walnut (*Juglans californica* var.*hindsii*), an endemic species to California. Both of these plants are federally listed as Species of Concern and categorized in the California Rare Plant Rank list as 1B (Plants Rare, Threatened, or Endangered in California and Elsewhere).

Table 2. Rare plant species of JOMU.

Scientific Name	Common Name	Local Status	Federal Status	Property
Asclepias cordifolia	Heart-leafed milkweed	Ua1		JOMU: Wanda
Calochortus venustus	Butterfly mariposa lily	Uw		JOMU: Wanda
Carex aquatilis var. dives	Sitka sedge	Ua2		JOMU: House
Castilleja rubicundula ssp. *lithospermoides*	Cream sacs	Ub		JOMU: Wanda
Clarkia affinis	Chaparral clarkia	Uw		JOMU: Wanda
Collinsia sparsiflora var. *sparsiflora*	Blue-eyed mary	Ub		JOMU: Wanda
Dicentra formosa	Bleeding heart	Ua1		JOMU: Grave
Epilobium ciliatum ssp. *ciliatum*	Willow herb	Uw		JOMU: House
Equisetum telmateia ssp. *braunii*	Giant horsetail	Uw		JOMU: Grave
Helianthella castanea	Mount Diablo sunflower	List 1B, RED-223	Species of Concern	JOMU: Wanda
Juglans californica var. *hindsii*	California black walnut	List 1B, RED-333	Species of Concern	JOMU: Wanda, House, Grave
Linaria canadensis	Blue toadflax	Ub		JOMU: Wanda
Phoradendron macrophyllum	Big-leaf mistletoe	Ub		JOMU: Wanda, House
Platanus racemosa	California sycamore	Ua2		JOMU: Grave
Plectritis congesta	Seablush	Ua2		JOMU: Wanda

Federal Status:

Species of Concern:
Plant species sensitive species that have not been listed, proposed for listing nor placed in candidate status. Species of concern is an informal term used by some but not all U.S. Fish & Wildlife Service offices. Species of concern receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species.

Local Status:

CNPS Rarity Lists:
- List 1A = Plants Presumed Extinct in California;
- List 1B = Plants Rare, Threatened, or Endangered in California and Elsewhere;
- List 2 = Plants Rare, Threatened, or Endangered in California, But More Common Elsewhere;
- List 3 = Plants About Which We Need More Information - A Review List;
- List 4 = Plants of Limited Distribution - A Watch List

CNPS Rarity-Endangerment-Distribution, (R-E-D) Code:

R - Rarity
- 1 = Rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time.
- 2 = Distributed in a limited number of occurrences, occasionally more if each occurrence is small.
- 3 = Distributed in one to several highly restricted occurrences, or present in such small numbers that it is seldom reported.

E = Endangerment
- 1 = Not endangered
- 2 = Endangered in a portion of its range
- 3 = Endangered throughout its range

D - Distribution
- 1 = More or less widespread outside California
- 2 = Rare outside California
- 3 = Endemic to California

Lake’s Unusual and Significant Plants list, (for Alameda and Contra Costa Counties):
- Ua1 = 2 known localities or fewer
- Ua2 = More than 2 localities, but seriously threatened
- Ub = 3-5 localities, threatened but not as seriously
- Uw = Lake’s watch list

There are also several species of native plants at JOMU that are sensitive to ozone (Table 3). Additionally, with climate change predicted scenarios, increased temperatures will have the potential to increase surface-level ozone pollution in the local area. How ozone-sensitive species will respond to these ensuing changes is unclear, but it is an important factor to consider as the park develops strategies for addressing vegetation management issues, among other resources. These plants can serve as bioindicators of ozone levels in the area, which can help understand potential impacts to the local natural resources.

Table 3. Ozone-sensitive Native Plant Species of JOMU.

Scientific Name	**Common Name**
Artemisia douglasiana	Mugwort
Sambucus mexicana	Blue Elderberry
Symphoricarpos albus	Common Snowberry, Snowberry (Common)
Robinia pseudoacacia	Black Locust
Quercus kelloggii	California Black Oak
Pinus ponderosa	Pacific Ponderosa Pine, Ponderosa Pine
Pinus radiata	Monterey Pine
Rubus parviflorus	Western Thimbleberry

Vertebrates:

Megafauna at JOMU are typical of the San Francisco Bay Area wildland–urban interfaces. Bob cat and mountain lion sightings have been reported in the East Bay Hills, and they likely occur occasionally in and around Mount Wanda. Other midsized to large vertebrate species include mule deer, coyote, striped skunk, raccoon, and gray fox (Fellers 2001). Introduced squirrels and feral cats are also present.

Only one coordinated land vertebrate survey has been conducted at JOMU, although it was a preliminary preliminary inventory. In 2003 and 2004 Gary Fellers of the U.S. Geological Survey conducted a preliminary inventory of land vertebrate. In 2002 and 2003 Fellers also conducted a bat inventory using using acoustic surveying methods. Both of these surveys have contributed to the knowledge of mammals, mammals, reptiles and amphibian in the park. To date, 26 mammal species have been documented in the the park, including 9 bat species, 5 reptile species and 5 amphibian species (

Table 4) (NPSpecies). Of these, none are considered a species of management concern. Since past surveys were conducted under limited time frame and scope, and were approached as preliminary inventories, it is probable that more species occur in the park. An inventory of the small mammal and herpetofauna populations may demonstrate a more diverse assemblage of animals.

Table 4. Mammals and Herpetofauna of JOMU.

	Scientific Name	Common Name
Mammals	*Canis familiaris*	Domestic dog, domestic dog (feral)
	Canis latrans	Coyote
	Capra hircus	Domestic goat, goat (feral)
	Didelphis virginiana	Virginia Opossum
	Eptesicus fuscus	Big brown bat
	Equus caballus	Horse, horse (feral)
	Felis catus	Domestic cat, Feral cat
	Lasionycteris noctivagans	Silver-haired bat
	Lasiurus blossevillii	Western red bat
	Lasiurus cinereus	Hoary bat
	Lynx rufus	Bobcat
	Mephitis mephitis	Striped Skunk
	Microtus californicus	California meadow vole
	Mus musculus	House mouse
	Myotis californicus	California myotis, Californis myotis
	Myotis lucifugus	Little brown bat, little brown myotis
	Myotis thysanodes	Fringed myotis
	Myotis yumanensis	Yuma myotis
	Neotoma fuscipes	Dusky-footed woodrat
	Odocoileus hemionus	Mule deer
	Peromyscus boylii	Brush mouse
	Procyon lotor	Common raccoon, northern raccoon, Raccoon
	Reithrodontomys megalotis	Western harvest mouse
	Sciurus niger	Eastern fox squirrel, fox squirrel
	Sus scrofa	Pig, pig (feral), wild boar
	Tadarida brasiliensis	Brazilian free-tailed bat
	Urocyon cinereoargenteus	Common gray fox, gray fox
Amphibians	*Hyla regilla*	Pacific tree frog
	Aneides lugubris	Arboreal Salamander
	Batrachoseps attenuatus	California Slender Salamander
	Ensatina eschscholtzii	Ensatina
	Taricha torosa	California Newt
Reptiles	Elgaria coerulea	Northern alligator lizard
	Contia tenuis	Sharp-tailed Snake
	Lampropeltis getula	Common kingsnake
	Sceloporus occidentalis	Western fence lizard
	Eumeces skiltonianus	Western skink

In 2001, Point Reyes Bird Observatory conducted a bird inventory. Additionally, with the help of local experts, the park has conducted annual bird counts for the past several years. Combined, these efforts have documented 140 bird species at JOMU, which is consistent with the local avian diversity

(Appendix A-3). The park plans to continue these monitoring efforts to help inform future management decision regarding bird distribution and conservation.

Resource Issues Overview:

The park lies within the designated critical habitat of the Alameda whipsnake (*Masticophis lateralis eurxanthus*). This subspecies of the California whipsnake (also named the striped racer) is currently listed as Threatened, both federally and within the state of California. It is a midsized snake with two black lateral stripes. It depends primarily on scrub and chaparral vegetation as core habitat, but it also utilizes oak savannas and woodlands, and generally seeks shelter in rock piles, outcrops and small mammal burrows. It preys largely on lizards, but its diet could include various other vertebrates such as snakes and nesting birds (U.S. Fish and Wildlife Service 2005).

To date, only one documented report has been confirmed for this species, which was found on the southwestern area of Mount Wanda. Although only a few small, non-contiguous patches of scrub and chaparral communities are found on Mount Wanda, oak savannas and woodlands are common, as well as many small mammal burrows. These features leads park staff, as well as local wildlife experts, to believe that JOMU could possibly support a small population of the Alameda whipsnake, or, at very least, serve as a transitional corridor.

Several occurrences of the whipsnake have been documented within a radius of a few kilometers outside of park boundaries, such as at Briones Regional Park and in Pinole Creek just west of the park. The closest documented sighting occurred within half a kilometer from the park, just southeast of the NPS boundary in the Alhambra Hills (California Fish and Game Department 2011) (Figure 12).

Figure 12. Aerial view (looking southeast) showing nearby sightings of the Alameda whipsnake (yellow pins) in the Alhambra Hills. The nearest recorded occurrence outside of the JOMU boundary is within 1/2 kilometer. (Google Earth 2011).

Invertebrates:

The small undeveloped area of Mount Wanda is adequate to support a relatively diverse array of invertebrate populations. However, to date, only two invertebrate groups have been inventoried at JOMU. So far, Lepidoptera (butterflies and moths) and Apoidea (bees and wasps) have been inventoried but no other invertebrate groups.

Since 2003, butterflies have been inventoried annually on Mount Wanda. This has been largely coordinated by the wildlife biologist from Pinnacles National Monument with support and assistance from the SFAN I&M Network. From inventories conducted in 2003 and 2004, at least 35 species of butterflies (Appendix A-4) and 147 species of moths (Appendix A-5) were identified with a high degree of certainty during the study. The presence of five species of swallowtail butterflies during one such butterfly walk in 2003 is noteworthy for such a small area. This was a surprise, given that it is rare to see all five species of CA swallowtails anywhere in the greater San Francisco Bay Area in a single day. The number of butterfly species identified seems low. However, given the Lepidoptera diversity present in Contra Costa Country and the limited timing of trapping and resources available during the survey, it is suspected that more species are likely to occur at JOMU (O'Neil and Johnson 2006).

In 2002-2003, a bee survey was conducted at JOMU by researchers from University of California, Berkeley and Utah State University, and Agricultural Research Service of the U.S. Department of Agriculture (Griswold et al. 2003). Investigators found 70 species of bees, representing 26 genera – relatively high diversity given the small area of the park (Appendix A-6). Similar surveys at the Presidio at Golden Gate National Recreation Area found 56 species, only 11 of which matched those found at JOMU.

Landscapes:

Fire has played a major role in shaping landscapes throughout California (Anderson 2006) and in the San Francisco Bay Area in particular (Keeley 2005). With the use of fire, Native Americans played a significant role in creating and expanding grasslands in the state. European settlers later sustained and expanded much of the grasslands with grazing, though they also modified the composition of this vegetation through the introduction and spread of exotic plants. Considering that lightning fires are rare in the Bay Area and that grassland distribution depends largely on disturbance, it is believed that grassland vegetation was limited in extent before the arrival of people. Now, with an aggressive fire suppression of the 20th century (much of which still occurs today, especially in areas with urban surroundings), coupled with the recent reduction of grazing in the East Bay, local management regimes have favored the conversion of many grassland habitats to shrubland (Keeley 2005).

The top of Mount Wanda is the only location in the park that has a 360 degree view of the surrounding lands (Figure 13). Immediately north and east of Mount Wanda are the most developed landscapes visible from this location; the Martinez Shell Oil Refinery and large ports along the Carquinez Strait can be seen to the north, while the cities of Martinez and Pleasant Hill are apparent to the northeast and east, respectively. Looking south, there is much less development, with interspersed housing visible between Mount Wanda and Briones Regional Park lands. To the west, lands are largely undeveloped.

Figure 13. A view from the top of Mount Wanda. Four corner directions are shown: (A) northeast, (B) southeast, (C) southwest and (D) northwest. NPS Photos, 2012.

Resource Issues Overview:

Very little is known about the use or frequency of anthropogenic fire on park lands or surrounding landscapes prior to European settlement. However, it can be inferred, based on the results of Keeley 2005, that the current lack of anthropogenic disturbances on Mount Wanda landscapes would cause a shift to favor shrubland vegetation expansion into grassland areas. However, given that shrubland is one of the least common vegetation communities in the park, this process would be slow paced. More localized studies would need to be conducted to confirm whether this likely to occur and at what rate.

The viewshed of JOMU has changed in recent decades and varies depending on the direction viewed. Although it is a small NPS unit, the JOMU park boundary has a relatively large proportion of urban-wildland interface along its borders. This situation presents complex challenges in managing the natural landscapes of the park. For example, fire has become more widely accepted as an effective management tool, particularly for grasslands. However, due the close proximity of urban and suburban areas, as well as the concerns over air quality and public safety, it would be difficult and possibly controversial for the park to employ.

Likewise, the management of bordering and other nearby lands has implications for JOMU resources as well. For instance, the harboring of wind-disbursed invasive plants and the grazing of lands within shared watersheds can have significant impacts on the health of ecosystem functions that the park is attempting to maintain and restore. Additionally, the burning of fossil fuels throughout the year, and of wood during the winter, sometimes can also have profound effects on the park's viewshed.

Resource Stewardship

Management Directives and Planning Guidance

Established as an NPS unit in 1964, JOMU is significant for the historic integrity of John Muir's home, and has exceptional value for interpreting a cultural theme (NPS 1991; NPS 2000, Sec. 1.3.1). The Mount Wanda parcel complements these key values by adding a notable natural resource that is linked to the cultural and historic theme that protects and supplements the cultural/ historical landscape, and offers opportunities for public enjoyment and scientific study. As per the guidance and recommendations of the park's Cultural Landscape Report (Killion 2005) and the National Register of Historic Places, the site is to be maintained or restored to the condition of the historic period, in particular during John Muir's time.

John Muir National Historical Site developed a General Management Plan (GMP) in 1991 to address the boundary expansion and subsequent purchase of the Mount Wanda tracts. A GMP is designed to provide long-term guidance to the park for a 15 to 20-year period, linking NPS policies and mandates to specific management directions at the park level. The GMP acknowledged that the park lies in a rapidly developing urban area, and that the Mount Wanda tracts provide the public with a dwindling resource (NPS 1991). Although JOMU is primarily a cultural resource park, it has the opportunity to steward the Mount Wanda lands for natural resource values.

The GMP identified a high priority need for a vegetation management plan to address issues of exotic weed invasion, wildfire, oak regeneration, grassland restoration, and maintaining the natural integrity of the mountain for cultural and ecosystem reasons. It clearly identified the desire to keep and restore the vegetation to earlier pre-development conditions. Baseline conditions were not succinctly identified in the GMP, and there was some discussion about Muir-era conditions as compared to pre-Spanish era conditions. However, the plan clearly demonstrated a desire to improve native biodiversity, preserve the visual structure of the vegetation community contemporaneous with Muir, and manage it as a healthy ecosystem. Specifics were few due to the paucity of research at the time, although vegetation mapping (O'Neil and Egan 2003), soils mapping, oak regeneration (some current research), and fire history (not in progress) projects were identified as needed.

In 2001, the park developed a draft Resource Management Plan for cultural and natural resources. Although the draft was never finalized and was written over ten years ago, it still provides some guidance for strategizing the management of park lands and resources:

- Collaborate and cooperate with local, state and private entities to promote coordinated land management at the landscape and regional scale;
- Implement historic vegetation study and promote historic native flora;
- Establish programmatic floral and faunal inventory and monitoring programs;

- Conduct a study of local fire history;
- Conduct a lichen inventory and survey;
- Develop a programmatic watershed monitoring and enhancement program;
- Establish a long-term invasive plant monitoring and control program.

Status of Supporting Science

Although many cultural activities had already been documented on JOMU land, little to no information about the natural resources was known nor collected when the park first acquired each of the land parcels it manages today. Historically, the park has relied on other NPS offices or outside entities for assistance with such efforts. During the early 2000s, especially with the establishment of the NPS San Francisco Bay Area Inventory and Monitoring (I&M) Network, natural resource program activities increased and a basic understanding of what resources were present was beginning to take shape. Later, from about 2003 to 2007, the I&M Network assigned a Biologist, Susan O'Neill, to help conduct and coordinate natural resource projects at JOMU as part of her duties. During this time, a few baseline surveys were conducted, including a vegetation map, lepidopteran inventory, invasive plant inventory, and native oak survey. The I&M Network also established a few I&M monitoring protocols and programs that have been implemented in the park since.

Overall, however, supporting science, comprehensive species lists, and long-term resource monitoring monitoring has been lacking. Understanding that such efforts would tremendously help the park make make well-informed, long-term management decisions, JOMU requested, and was granted, an increase increase in park base funding to hire its first Natural Resources Management staff member – a permanent, subject-to-furlough Natural Resources Specialist, who was hired on in 2010. Since then, the the park has further assessed resource data gaps (

Table 5). With the help of I&M program and the NPS Pacific Coast Science and Learning Center, JOMU is currently prioritizing these data gaps. Meanwhile, the Resource Specialist is continuing some of inventories that require the least funding, and is seeking soft funding to address some of the more intensive projects.

Table 5. Status of natural resource inventories of JOMU to date.

Project	Taxa	Status
Plants	Lichen	Incomplete
	Oak Woodlands	Complete
	Rare Plants	Incomplete*
	Vascular Plants	Complete
	Invasive Plants	In progress
	Plant Phenology	In progress
Vertebrates	Bats	Complete
	Land birds	Complete
	Small Mammals	Incomplete
	Terrestrial Vertebrates	Preliminary
Invertebrates	Hymenoptera	Complete
	Lepidoptera	Complete
Water	Multi-species riparian	Incomplete
Mapping	Wetland	Incomplete
	Vegetation	Complete
Other	Weather	Complete
	Geomorphology	Incomplete

*Rare plants were documented during a vascular plant inventory in 2002, but no formal inventory has been conducted to specifically survey rare plants within the park.

Chapter 3. Study Approach

Preliminary Scoping

As described in the Resource Stewardship section 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 (Adams et al. 2006). At the outset of this condition assessment, NPS staff provided a ranking of potential themes to be addressed (Table 6). They refined these general themes into the following set of preliminary management or research questions:

1. *What are the effects of air quality (e.g. pollutants) on the park's natural resources?*
2. *What have the changes in climatic factors been over the last 50 years (temperature, precipitation)?*
3. *What are the potential effects of changing climate in this region (e.g. rain, temperature, flooding, and drought patterns) and how may this affect local biological diversity, erosion and flooding patterns.*
4. *Is the level of soil erosion on Mount Wanda normal for the soil type?*
5. *What are the effects of current and probable non-native species invasions (plants and animals) along with disease (e.g., Sudden Oak Death)?*
6. *Are there exemplary natural communities or rare or sensitive species that have not been documented on Mount Wanda but can possibly occur? Is there sufficient data available to determine whether Mount Wanda is suitable for supporting viable populations of these species?*
7. *What are the ecological effects of long-term fire suppression on Mount Wanda and in the region? How does fire suppression alter vegetation species composition and communities? What is the potential future trend in fire behavior?*
8. *What is the ecological significance of Mount Wanda in the regional context (landscape and regional level)? What is the park's relative role in habitat connectivity with other park or protected spaces (e.g. East Bay Regional Parks)?*

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 that NPS staff would find more detailed analysis of some key issues and indicators more helpful than a superficial treatment of everything and that new analysis would be more efficient use of time than compilation of existing material.

Table 6. Priority rank potential focal themes for the natural resource condition assessment (updated version, 7/14/11).

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

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

Study Resources and Indicators

Assessment Framework Used in the Study

The NPS Ecological Monitoring Framework (Table 7) 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 used 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 7. 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	
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	
		Surface Water Dynamics	

Level 1 Category	Level 2 Category	Level 3 Category	Comments
		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	
		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	Catch-all category to be used in rare cases where no other

Level 1 Category	Level 2 Category	Level 3 Category	Comments
		sparingly)	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). 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 and temporal 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 JOMU staff, a societal conceptual model was developed (Figure 14). Four 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., domestic pets from nearby urban areas prey on small wildlife species 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.

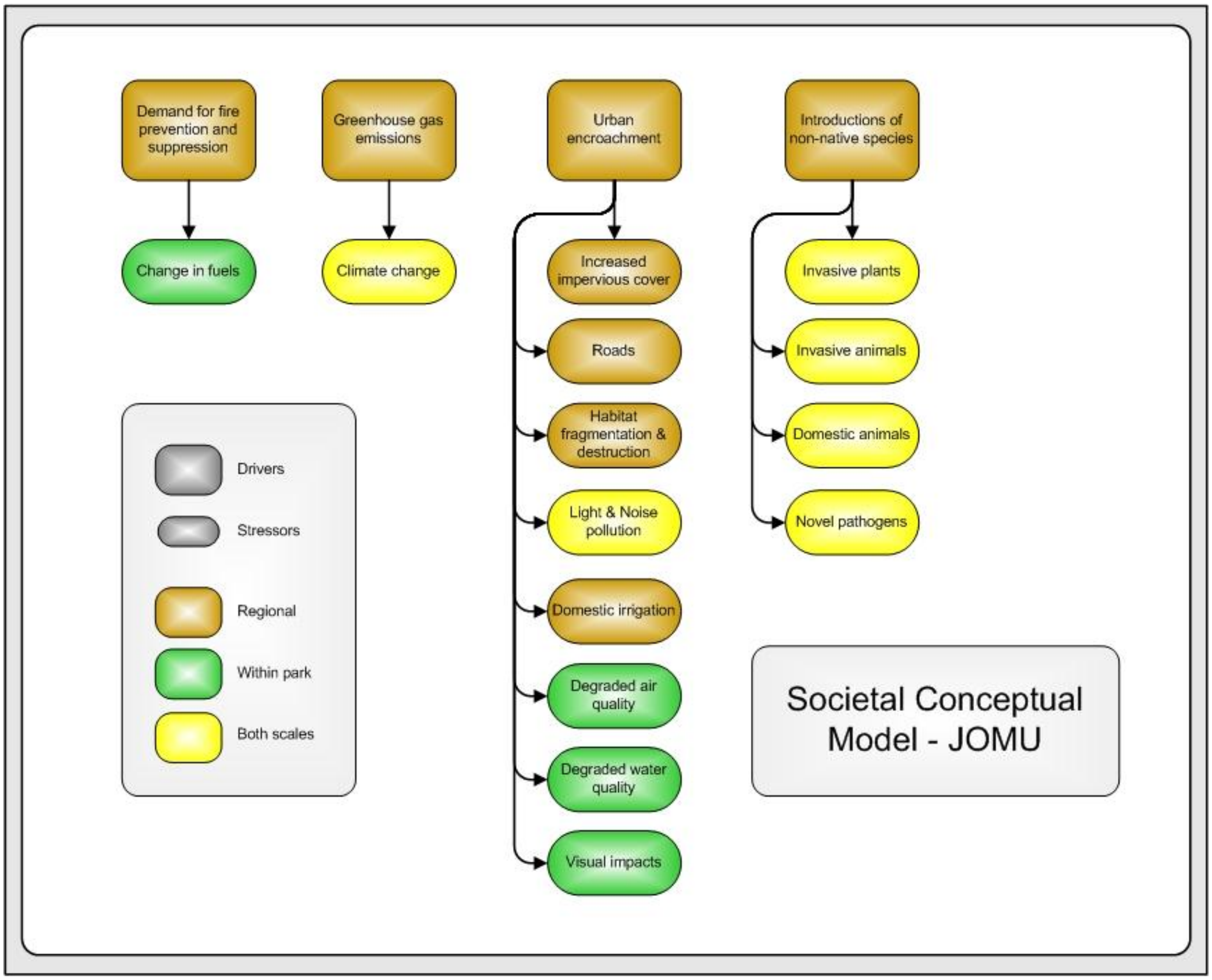


Figure 14. Societal conceptual model of drivers and stressors for JOMU.

Based on the set of management questions and resource indicators described above, second level resource conceptual models were developed (see Figure 15 for an example for the fire regime). 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. This model will be explained in detail in the Fire Regime section of Chapter 4.

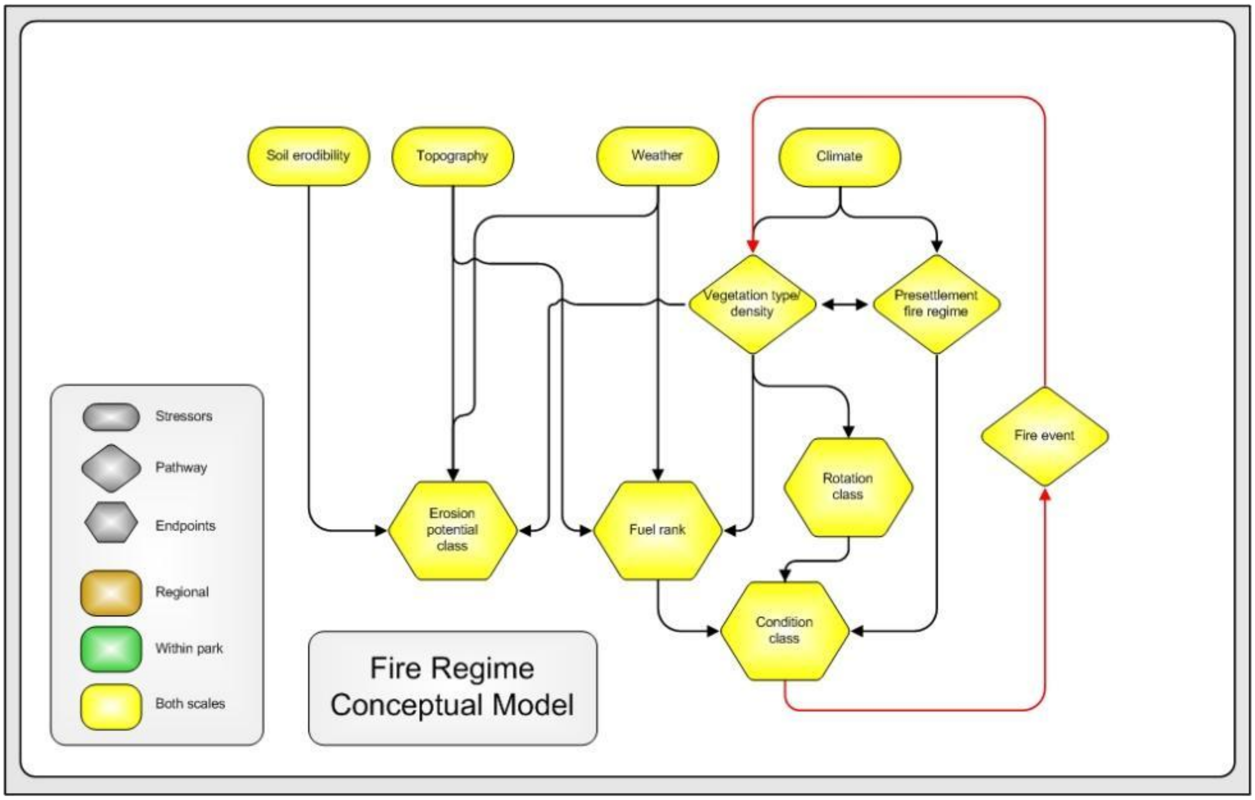


Figure 15. Fire regime conceptual model of stressors, pathways, and endpoint indicators.

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.

Study Methods

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

1. Develop a conceptual model 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. In a few cases where the data were aggregated to park-wide totals (e.g., prairie falcon nests), statistical analysis was used instead of GIS, although GIS may have been used to derive values of independent variables.

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. Air pollution from automobile exhaust within JOMU is virtually non-existent compared to that produced by vehicles in nearby metropolitan areas of the Bay Area. Resource endpoints such as the Alameda whipsnake do occur within JOMU but its survival ultimately depends on management of populations at the landscape and regional scales. 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. To assess stressors and endpoints at the landscape scale across adjacent lands, we adopted the North East Bay Hills landscape unit delineated for the Upland Habitat Goals Project and subsequent Conservation Lands Network (Bay Area Open Space Council, 2011) (Figure 16). That project divided the nine-county Bay region into 34 such landscape units. Major physiographic features, primarily mountain ranges and intervening valleys, were used to demarcate the units. Highway 24 was used to subdivide the North East Bay Hills from the other East Bay Hills landscape units. We refer to this 348 km^2 landscape unit in this report as park-and-buffer scale. Although the landscape unit is larger than we recommended for assessing landscape-scale processes at other parks (Davis et al. in press, Stoms et al. in preparation), being able to link the NRCA to regional conservation planning justified the choice. 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. For the JOMU condition assessment, a set of eight CLN landscape units (Alameda Urban, Contra Costa Urban, Middle East Bay Hills, Mount Diablo Range, North Contra Costa Valley, North East Bay Hills, South East Bay Hills, and Tri-Valley) were aggregated to delineate an appropriate region (Figure 16). This 2500 km^2 East Bay region contains most of Contra Costa County and all but the southeast quadrant of Alameda County. The assessments of specific stressors and indicators were performed at the scale(s) deemed most appropriate. Watershed management is a major issue in the Strentzel Creek Watershed, which is jointly managed by JOMU and neighboring private owners (Figure 4). Because of the importance of resource concerns in this watershed, this subarea was also used for some assessments.

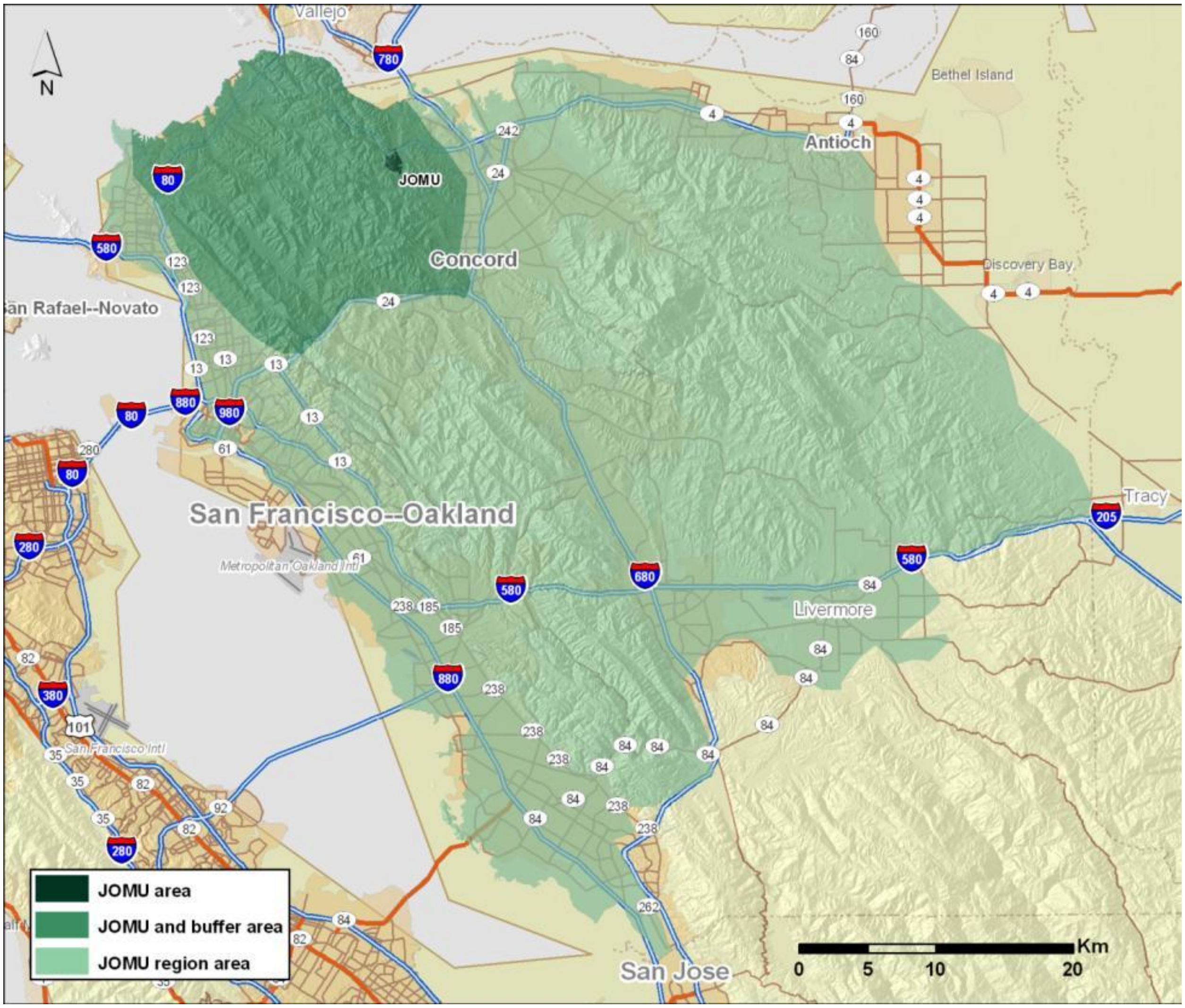


Figure 16. Geographic units for the three scales of condition assessment.

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. 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. A2 is used in the assessment sections on Climate and Future Fire Regime, while B1 is only used for Future Fire Regime.

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 plant species in the Climate section below, climate variables from the A2 scenario that had been downscaled to 270 meters were used as predictor variables. 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. In addition, EPA modeled scenarios of change in housing density that along storylines that are consistent with the IPCC GHG emissions scenarios (U.S. EPA 2009, Bierwagen et al. 2010). These housing scenarios are used in this assessment as part of the Housing Development stressor.

Chapter 4. Natural Resource Conditions

Regional/Landscape Context

Overview of Stressors

The remainder of this section contains assessments of the key stressor indicators. Each assessment follows a similar outline. Each begins with a brief summary of the findings about 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 JOMU. 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. Stressors are reported by their spatial distribution in maps, as statistical summary plots, and in some cases as trends in time-series plots. Each assessment then concludes with the identification of emerging issues and data gaps.

Stressor: Housing Development
Findings: Increasing trend

Housing growth near protected area boundaries decreases effective habitat area, decreases habitat connectivity, increases non-native species introductions, increases exposure to chemical stressors, 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 JOMUs boundary, 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 642,000 units, from 188,000 units to 830,000. Overall housing density for the region increased from 75 units/km^2 to 332 units/km^2. The number of housing units increased by 9% from 1990-2000, population by 15%, and developed land by 3%. Household size increased 4%, from 2.66 people/unit to 2.76 people/unit. At the park-and-buffer scale, overall housing density was 242 units/ km^2 in 2000, and had grown 4%, in the preceding decade. Household size decreased slightly from 2.65 to 2.63 people/unit, whereas the amount of developed land increased 1.4%. Developed land per housing unit decreased 3%. It is expected that new housing units will show a significant increase in the 2010 Census, but the data were not yet available at the time this assessment was conducted. EPA growth scenarios project moderate increases in urban and suburban densities by 2050. The high growth-high sprawl scenario would eliminate most of the rural density land at the regional scale.

Approach

For current status at the region and park-and-buffer scales, we used a year 2000 U.S. Census bureau census block database. 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 that intersected 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 that intersected the regional extent were extracted from the database. Similarly, MCBs that intersected with the park-and-buffer analysis boundary were 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. (See the Appendix A-7 for GIS layers generated for the assessment).

Because housing density is such a powerful indicator of a variety of stressors on JOMUs resources, we also explored how housing density might change in the future. 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 (see Table 8 for definitions and how these differ from those of the Census). Projections were modeled by decade from 2010 to 2100. A commercial/industrial class was included but was held constant in all time periods. Similarly, public lands were excluded from development in the model, and these lands were held constant over all time periods. Undevelopable land constituted 42% in the park-and-buffer area and 30% in the reference region. 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.

Table 8. Definitions of housing density classes used by the US Census and EPA (ICLUS).

Housing density class	Census definition (units/km^2)	ICLUS definition (units/km^2)
Urban	≥ 250	≥ 1000
Suburban	25 - 250	147 - 1000
Exurban	6 - 25	6 - 147
Rural	1 - 6	< 6
Undeveloped	< 1	NA

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 landscape measures (Svancara et al. 2009). The assessment was redone here with the buffer and region boundaries customized for JOMU.

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.
- 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 288 units/km^2, which meets the Census definition for urban. However, housing is heterogeneously distributed in the region with the densest and most extensive settlements along the interstate and major state highways (Figure 20). Twenty-four percent of the region was urban, 21% was suburban, 7% was exurban, and 20% was rural. The remaining 29% of the region was settled at densities lower than 1 unit/km^2 (Figure 17).

Park-and-buffer scale:
In 2000, overall housing density at this scale was 242 units/km^2, with 9% of the area settled at rural densities. Urban, suburban, and exurban areas covered the greatest proportions of the area at 28% and 21%, and 24% respectively.

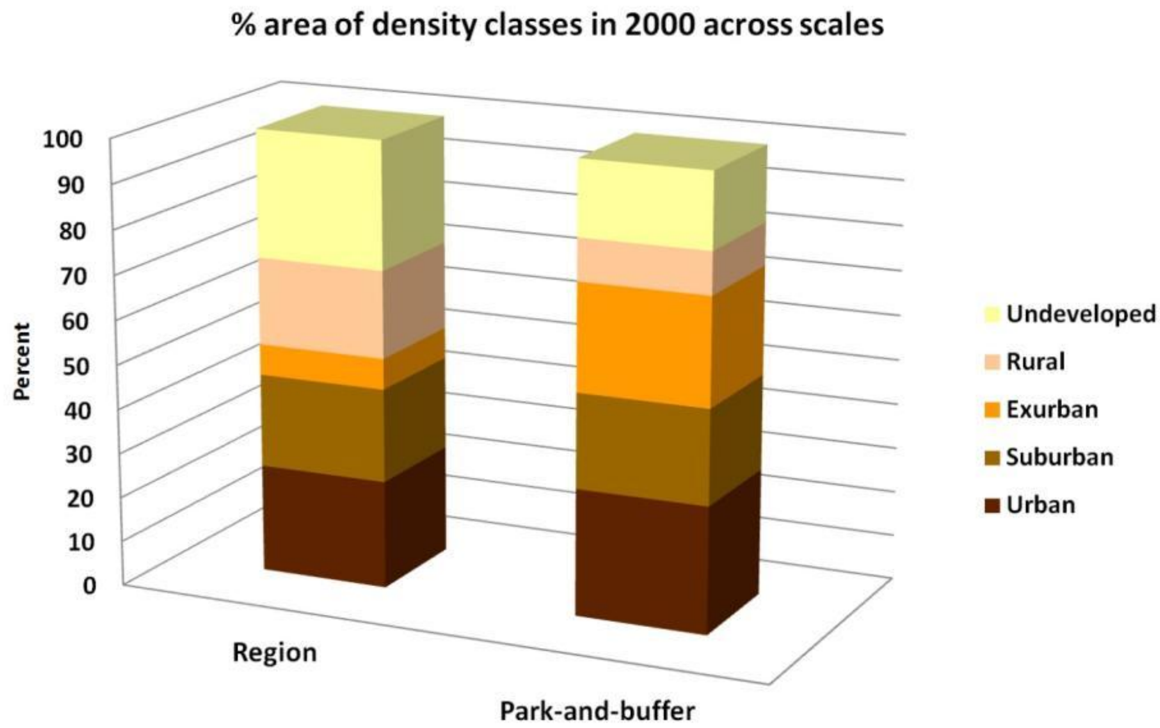


Figure 17. Percentage in each housing density class in 2000 by reference scale. Colors correspond to Figure 19 and Figure 20. Following the U. S. Census classification, Undeveloped < 1 unit/km, Rural = 1- 6 units/km^2, Exurban = 6 - 25 units/km^2, Suburban = 25 - 250 units/km^2, and Urban ≥ 250 units/km^2.

Trends

Regional scale:

About 642,000 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 since the peak of over 130,000 units added in the 1970s to less than 70,000 in the 1990s (Figure 18). The most intense growth occurred along major highways such as Interstate 680 and state highways 4 and 24 (Figure 21). Although there were high density communities such as Lafayette and Pleasant Hill in 1940, urban expansion both filled the gaps along the highways and expanded into the interior of the North East Bay Hills, virtually isolating it from neighboring landscape units.

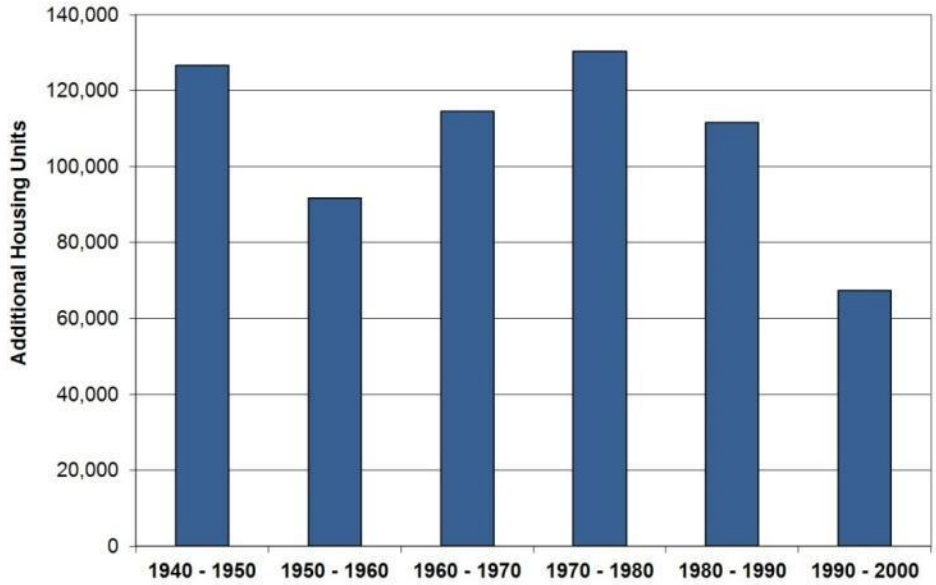


Figure 18. Housing units added per decade at the regional scale. Note the decreased rate in housing development growth in recent decades.

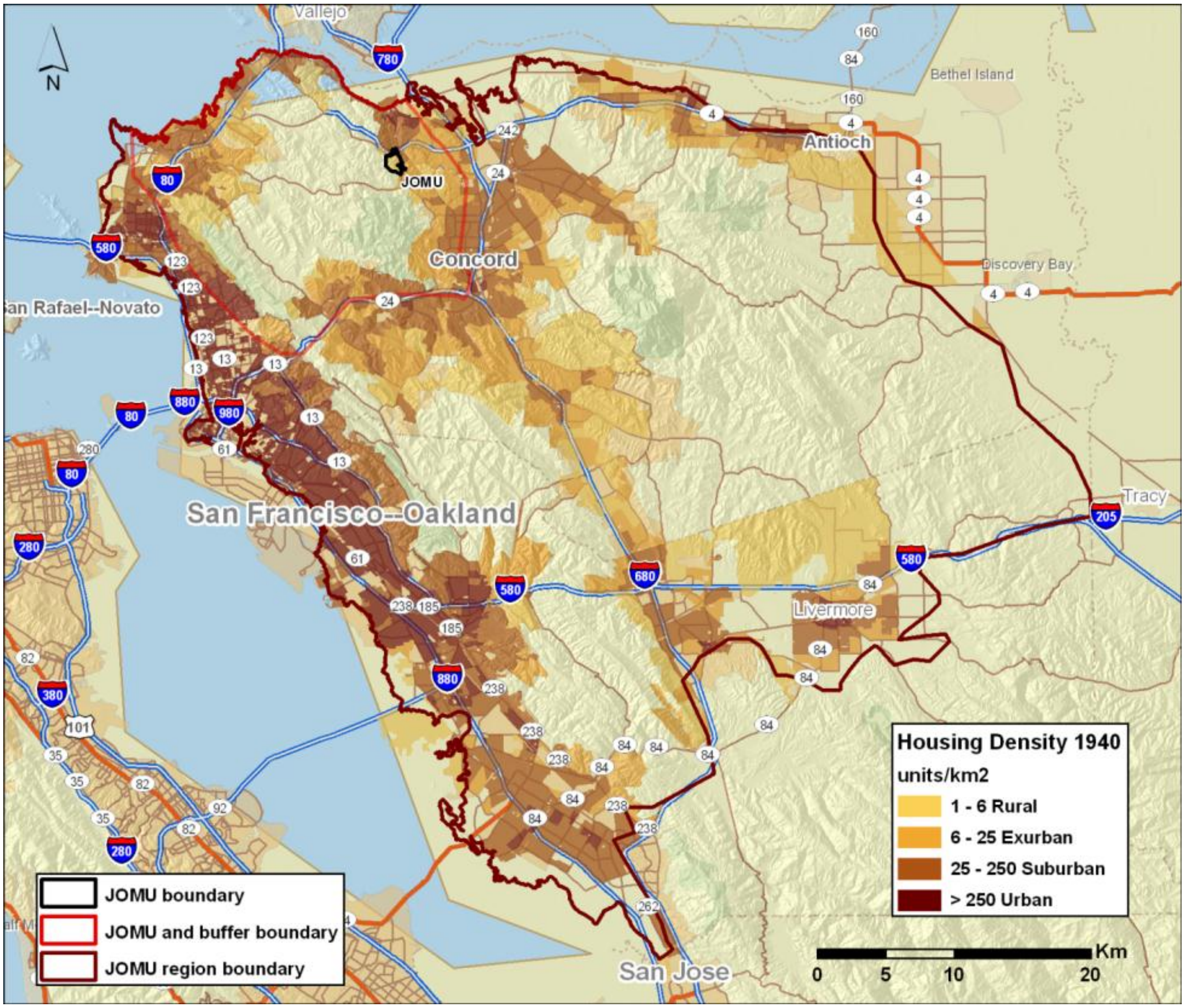


Figure 19. Housing density in 1940 derived from partial block group data at the regional scale.

From 1990 – 2000 at the regional scale, housing increased by 8.75%, while population increased by 15% (

Table 9). Household size increased 3.7% from 2.66 people/unit to 2.76 people/unit, and the amount of developed land increased 3% from 1150 km^2 to 1186 km^2. Developed land per housing unit decreased 8% from 0.16 ha/unit to 0.14.

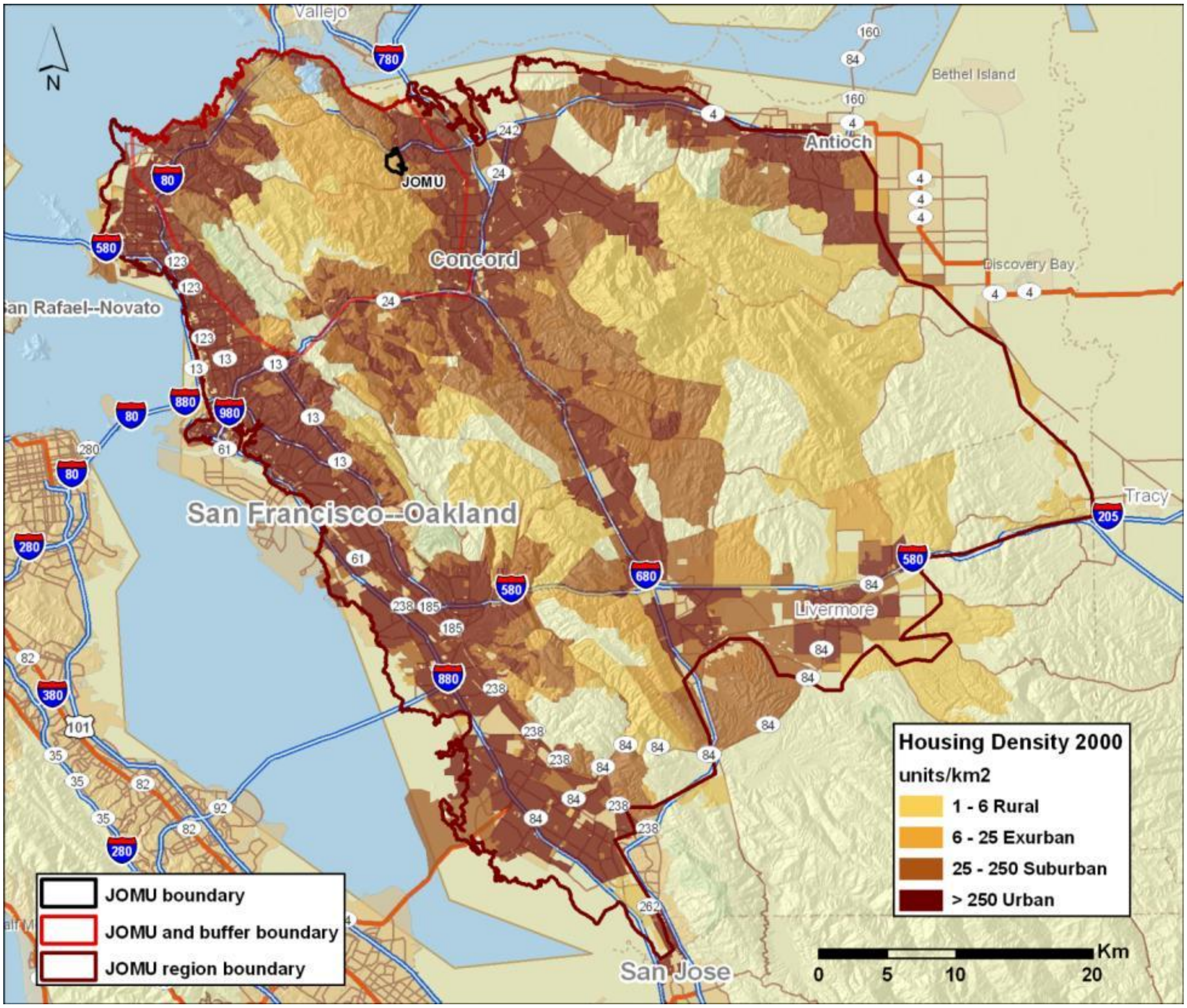


Figure 20. Housing density in 2000 derived from census block data at the regional scale.

Table 9. Percent change in census and land use variables between 1990 and 2000 at region and park-and-buffer scales.

Scale	Population	Housing Units	Occupied Housing Units	Household Size	Developed Land	Developed Land Per Unit
Region	15.0	8.8	10.9	3.7	3.1	-8.1
Park-and-buffer	5.7	4.5	6.2	-0.5	1.4	-3.0

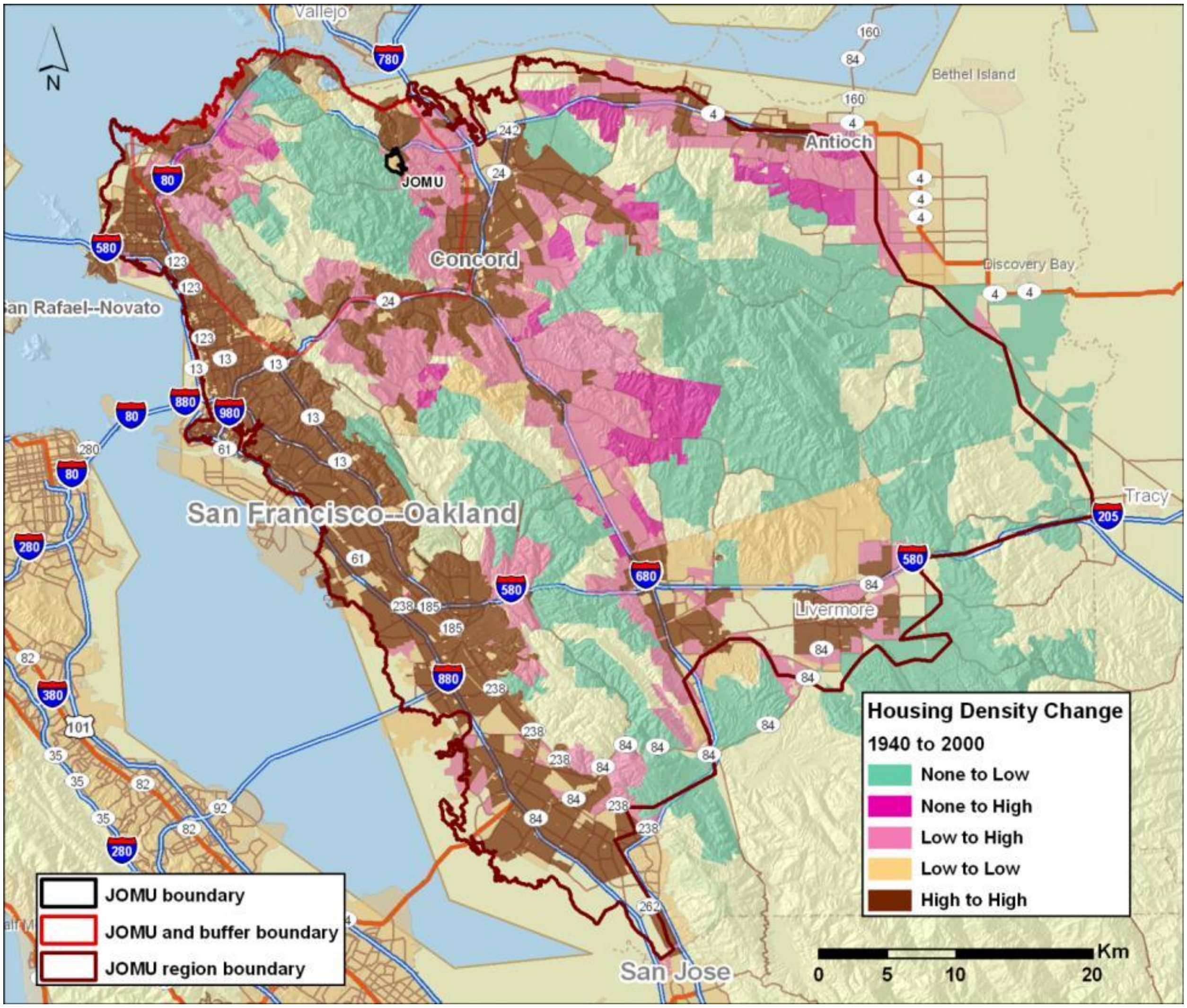


Figure 21. Change in housing density, 1940 to 2000. For simplicity, the density classes have been aggregated: None = undeveloped, Low = Rural or Exurban, High = Suburban or Urban. Density thresholds for these classes are given in Table 8.

A large fraction (30%) of the region was considered undevelopable in ICLUS, whereas 3% is commercial/industrial. The remaining 61% shows a modest shift toward higher housing densities in both scenarios (Figure 22). In both scenarios, the urban class expands about 20% in area, although it only expands to 14% of the region. Suburban area increases 15% in A2, such as just southeast of JOMU, at the expense of the exurban class. Also note that the ICLUS density classes are different than those shown in Figure 19 and Figure 20. Because the published data only identify density classes, it is not possible to project the increase in number of housing units for comparison with Figure 18.

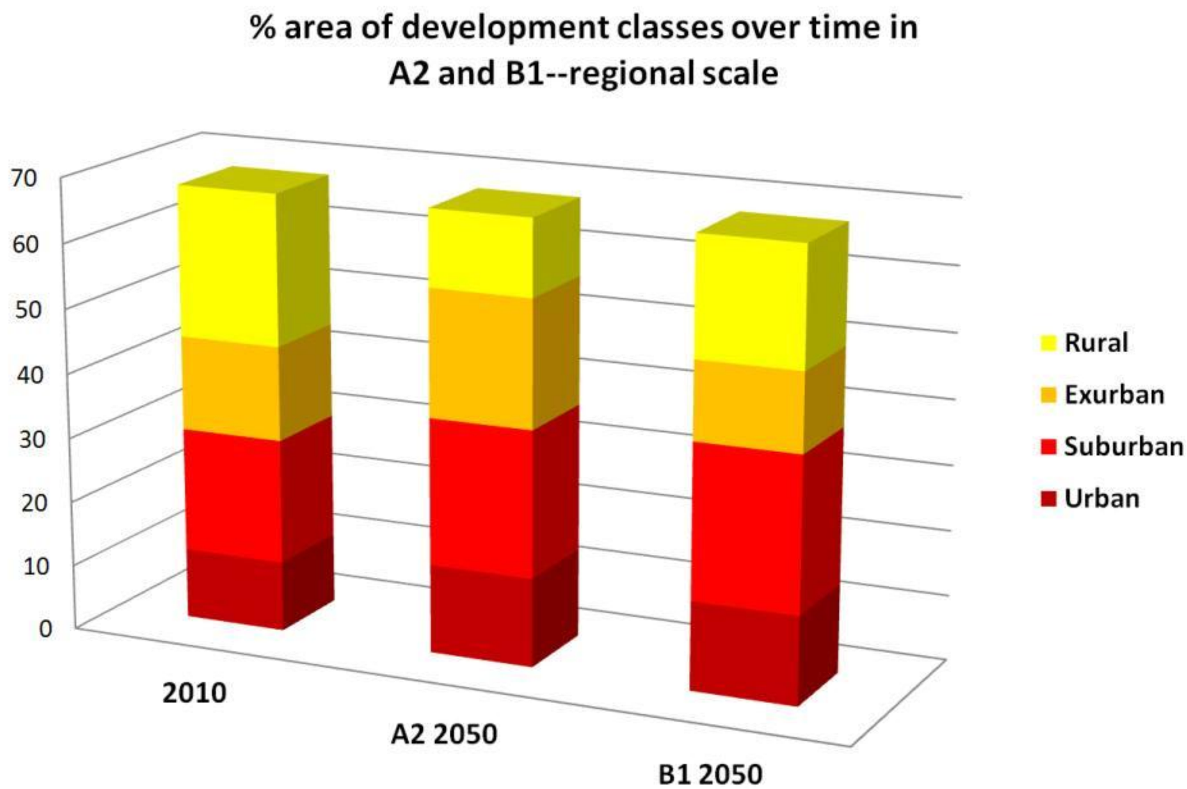


Figure 22. Housing density changes in ICLUS future growth scenarios at the regional scale. An additional 3% of commercial/industrial land and 30% of undevelopable public land in all time periods and scenarios is not shown. Following the ICLUS classification, Rural < 6 units/km^2, Exurban = 6 - 147 units/km^2, Suburban = 147 - 1000 units/km^2, and Urban ≥ 1000 units/km^2. Note the difference in breakpoints from the Census classes (Table 8); hence a different color scheme was used.

Park-and-buffer scale:

In 1940, housing was limited to the periphery of the North East Bay Hills (park-and-buffer), and at relatively low densities (Figure 23). Much of Martinez was still at exurban or even rural density. By 2000, the periphery had been developed to suburban and urban densities, while the core became lightly developed (Figure 24 and Figure 21). From 1990 – 2000, population and housing increased at the park-and-buffer scale by 5.7% and 4.5%, respectively, a rate much lower than that of the regional scale (

Table 9). Household size decreased 0.45% from 2.65 to 2.63 people/unit. The amount of developed land increased 1.4% from 163 km^2 to 166 km^2. Developed land per housing unit decreased 3% from 0.19 ha/unit to 0.18.

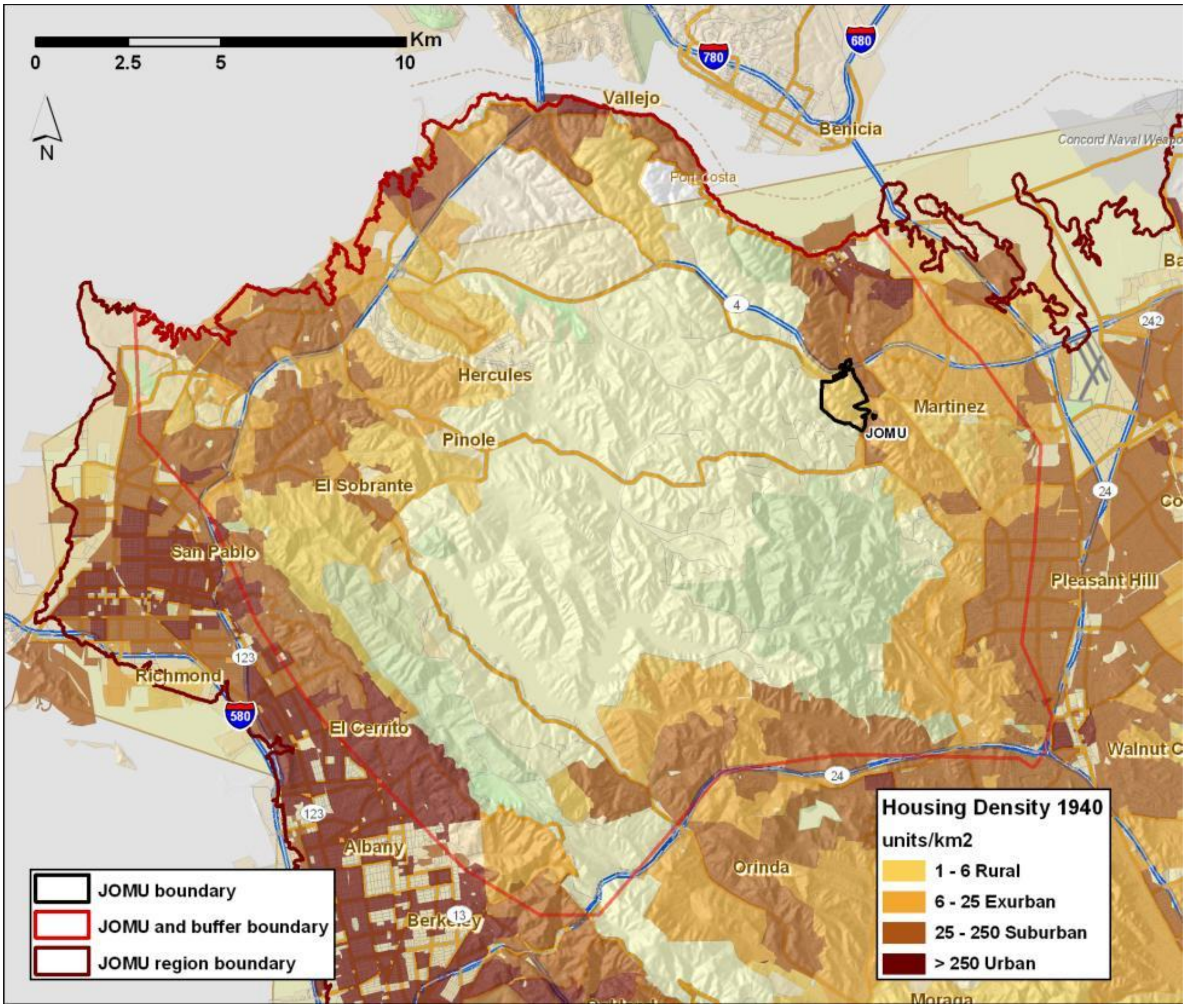


Figure 23. Housing density in 1940 derived from partial block group data at the park-and-buffer scale.

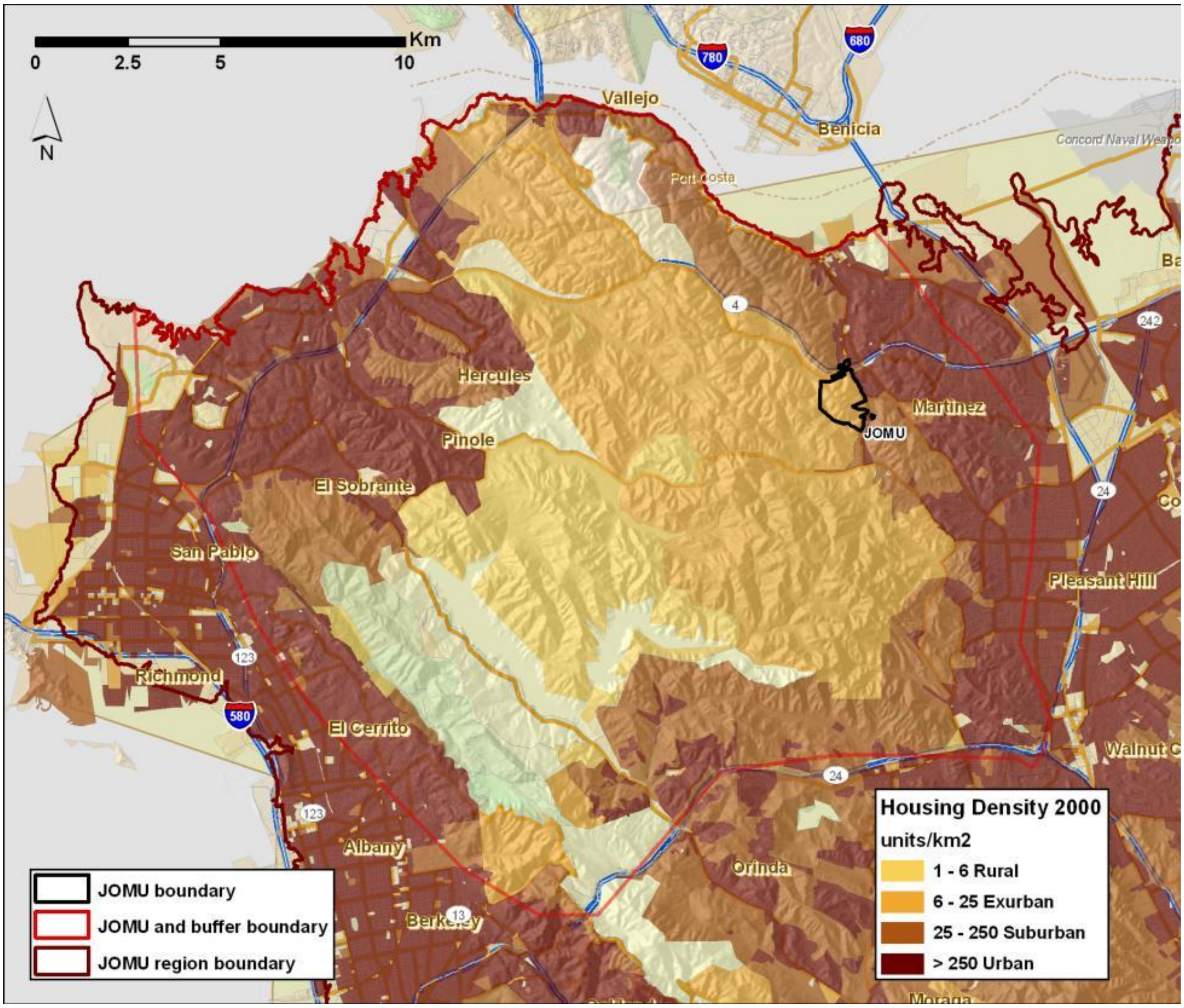


Figure 24. Housing density in 2000 derived from census block data at the park-and-buffer scale.

The ICLUS scenarios for 2050 both show a small trend toward greater housing density (Figure 25). Both the A2 (high growth) and B1 (low growth) scenarios show a small increase in area of urban housing density by 2050. Much of the change comes from intensification from rural to exurban class or exurban to suburban class. Note that in ICLUS, the commercial/industrial class (2%) and undevelopable public lands (42%) are held constant over time and are not displayed in the bar chart.

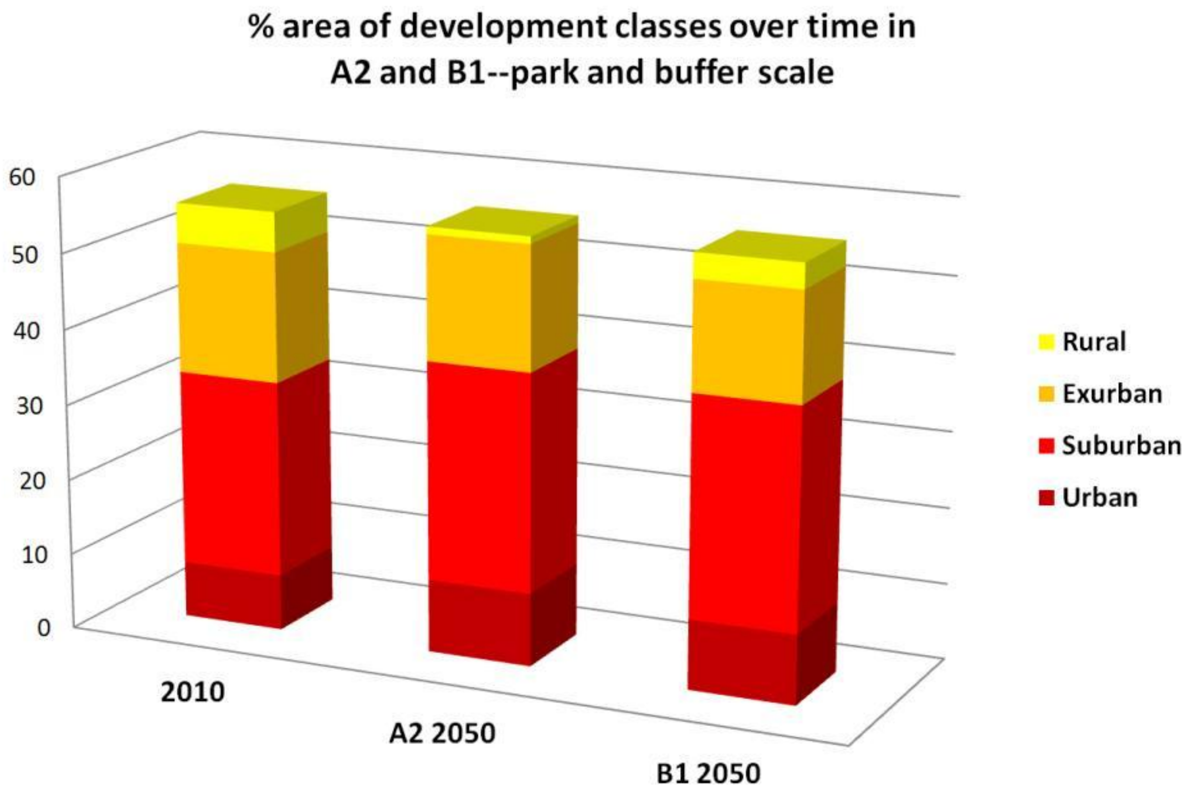


Figure 25. Housing density changes in ICLUS future growth scenarios at the park-and-buffer scale. An additional 2% of commercial/industrial land and 42% of undevelopable public land in all time periods and scenarios is not shown. Following the ICLUS classification, Rural < 6 units/km^2, Exurban = 6 - 147 units/km^2, Suburban = 147 - 1000 units/km^2, and Urban ≥ 1000 units/km^2. Note the difference in breakpoints from the Census classes (Table 8); hence a different color scheme was used.

Emerging Issues

Development 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). The increasing frequency of human-wildlife interactions can cause behavioral changes in wildlife. The development in the second half of the 20th century along Highway 24 and Interstate 680 has virtually isolated the northern population of the Alameda whipsnake from other populations, complicating recovery efforts (see the Alameda whipsnake section below). Runoff from housing developments may contribute to erosion and other watershed problems in Strentzel Canyon within the Mount Wanda tract. Conversely, an increasing urban population in close proximity to the park can limit management options for maintaining or restoring the historical conditions for which JOMU was established. Prescribed fire to maintain grasslands and other objectives is already precluded by the risk to neighboring development. Other practices such as some forms of treatment of invasive species or promotion of public use of Mount Wanda may become less acceptable to the community if more homes are developed in the immediate vicinity of JOMU. Other issues include increasing light pollution, noise pollution, invasive species, and an increase in the number of houses and people in areas of high wildfire risk.

Data Gaps

Most stressors on the natural resources at JOMU are directly associated with human settlement and activity. Housing density is a good synthetic indicator of this suite of stressors. Quantifying the actual effects of urbanization on other stressors and through ecological pathways to the impacts on resources is still an active area of research. Updating the assessment with 2010 Census results should be informative. Predicting future housing development is challenging because of the many factors involved. The ICLUS modeling uses nationwide datasets and rules to predict general trends. Predicting growth at the local scale to predict future impacts on JOMU would require more detailed information.

Key references

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Stressor: Human Footprint
Findings: Baseline only

The Human Footprint model synthesizes information about many stressors into a cumulative indicator of human-caused disturbance. The database for the western states developed by Matthias Leu and colleagues at USGS is categorized into ten classes of footprint intensity or disturbance. JOMU is mostly impacted at the medium intensity level on the edge of a broader such area in the core of the North East Bay Hills park-and-buffer. Over half of the reference region is punctuated with urban development and other disturbance factors. Consequently JOMU is rather heavily impacted for a unit of the national park system. 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 has increased 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 (http://sagemap.wr.usgs.gov/HumanFootprint.aspx) as a standardized product that could be applied to all western park units. The human footprint was derived from seven input models of human-caused disturbance (Figure 26) based on thirteen map layers (t are sensitive to disturbance.

Table 10). Details of the data inputs and methods for compiling this synthetic indicator are provided in Leu et al. (2008). Each model accounted for both the physical area occupied by the feature (e.g., road surfaces) and the ecological effect area that was affected by that feature. 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.

Table 10. Anthropogenic features used as inputs in the Human Footprint of the West model (Leu et al. 2008).

Anthropogenic Feature
Agriculture
Populated areas
Campgrounds
Federal/state highways
Interstate highways
Secondary roads
Fire ignition locations
Landfills
Oil-gas wells
Power lines
Railroads
Rest stops
Irrigation canals

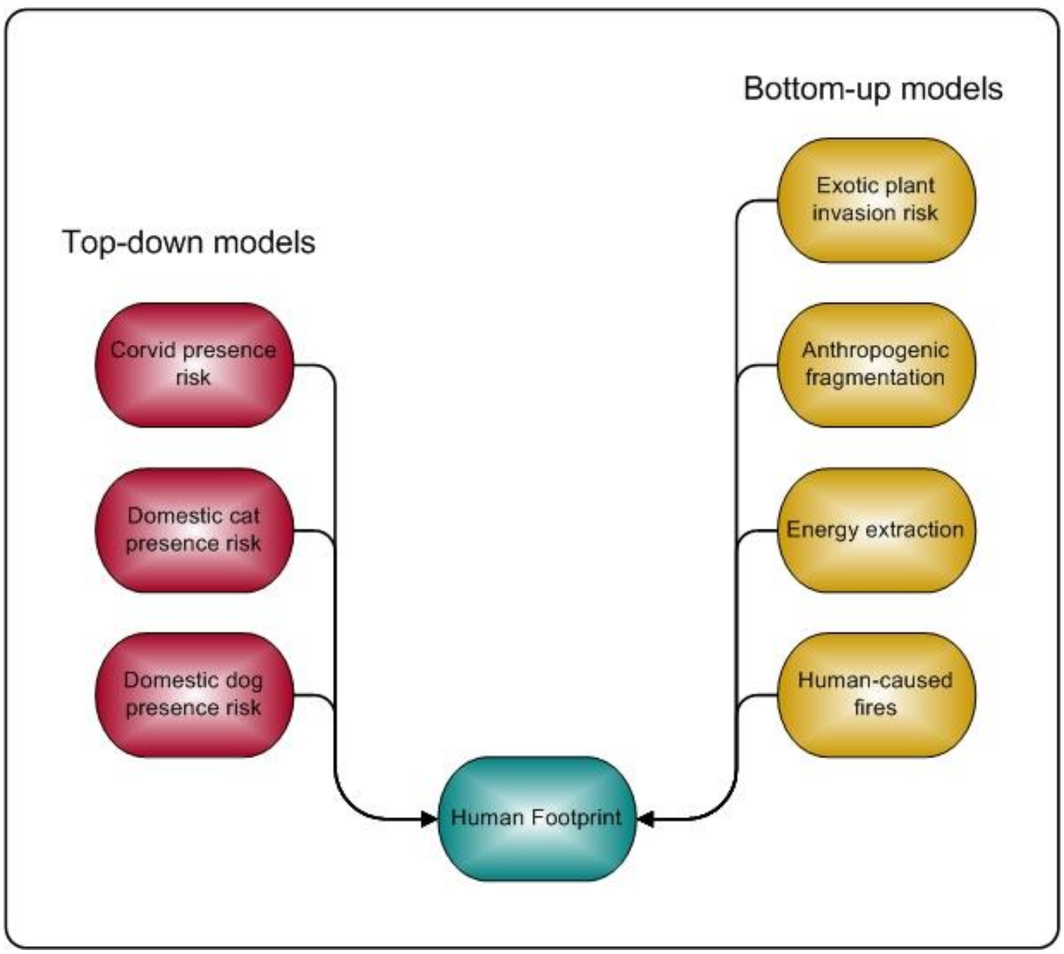

Figure 26. GIS conceptual model of the human footprint (redrawn from Leu et al. 2008). Each input model is based on multiple input factors.

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. The intensity values are assigned to classes rather than numerical values, where a high class number (8-10) represents high intensity human footprint. It is not possible to compute averages or similar summary statistics from ordinal class values. 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.

Data

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

Status

The influence of urban development can be clearly identified in the map of the human footprint (Figure 27). Most of the Mount Wanda unit of JOMU forms part of the edge of a large block of intensity class 5, or medium intensity, in the core of the park-and-buffer North East Bay Hills landscape unit, which is ringed by the highest intensity footprint class. For reference, southern Briones Regional Park is classified as class 4, the lowest intensity class found in the entire region, whereas Mount Diablo State Park falls mostly in class 5 and 6. The larger region is more complex, with bands of high intensity footprint along the urban corridors along interstate freeways and highways 4 and 24. Hilly areas are intersected with roads and urban influences such that they fall into the medium intensity classes. No low intensity classes (1-3) occur within the region, and hence there are none in the buffer or park either.

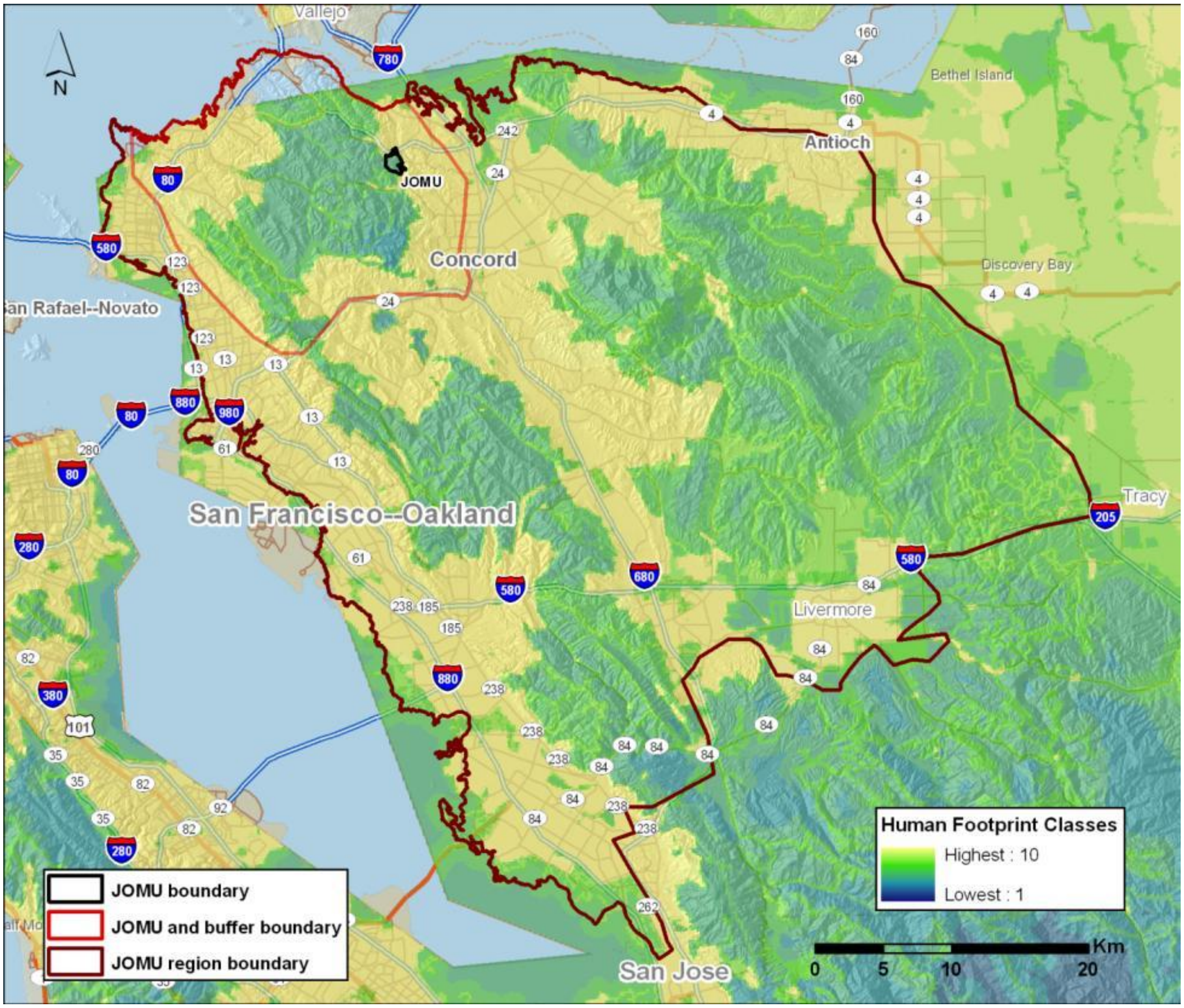

Figure 27. Map of the human footprint intensity (Leu et al. 2008) for JOMU and surrounding regions.

Tabulating percentages of area in each class quantifies the visual impressions from looking at the map in Figure 27. At the smaller scales, the footprint intensity peaks at class 5-6 (medium), with an additional high percentage in class 10, most intense, for the park-and-buffer scale (Figure 28). Inside JOMU, the percentage in high intensity is much less than the other two scales, whereas the percentage in medium classes is greater. Over half of the regional scale is in the high intensity footprint class.

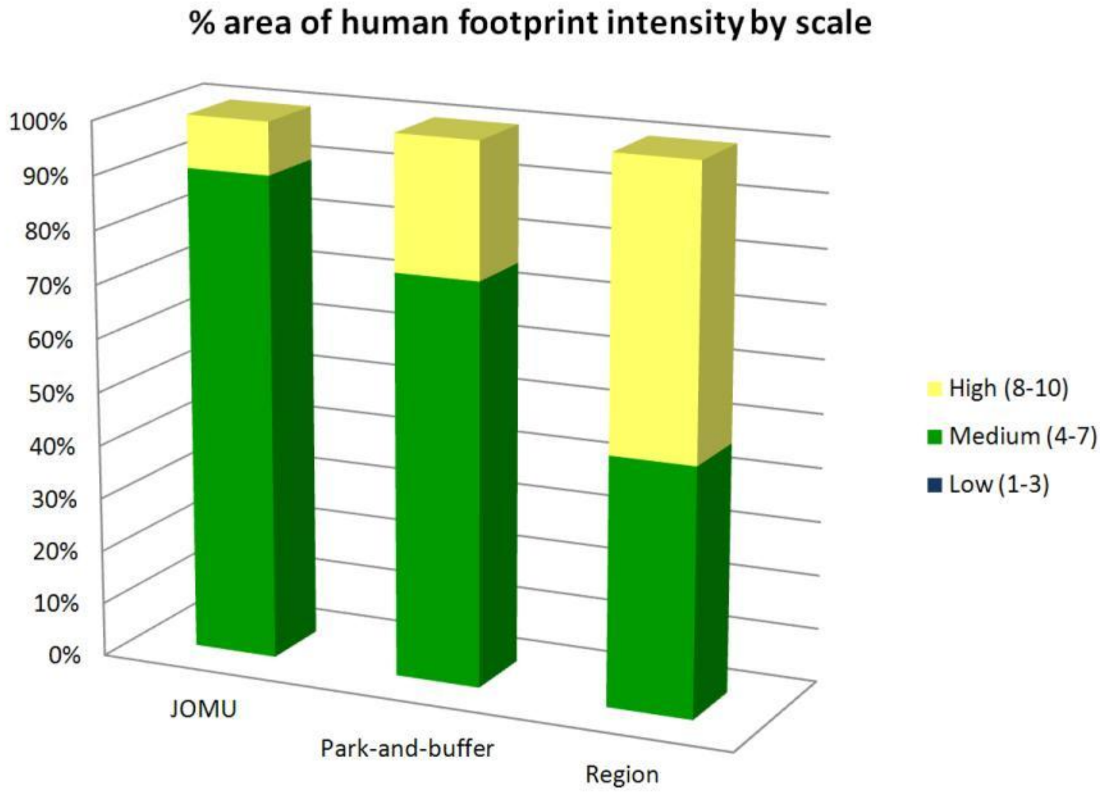

Figure 28. Bar graphs of the relative percentage of human footprint intensity for JOMU, the park-and-buffer landscape, and the region as a percentage of intensity grouped into high, medium, and low categories. Note that no low intensity classes occur within the region, and therefore within the nested reference regions.

Emerging Issues

The Human Footprint synthesizes a broad suite of stressors and serves as a proxy for individual stressors that are not assessed in this report. Most land use drivers of the footprint models (e.g., energy, agriculture, and urbanization) are relatively stable in the vicinity of JOMU. Some intensification from rural or exurban to suburban and urban land use may occur over the next 40 years (see Housing Density section), which may intensify some stressors on the natural resources of JOMU such as exotic plants and animals, domestic pets, and fragmentation. Much of this projected trend could be averted if the lands near JOMU are protected to maintain connectivity and meet conservation targets identified by other groups (see Habitat Connectivity section below).

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. Also, there was a limitation to the assessment done by USGS because it omitted some factors relevant to JOMU, such as livestock grazing. A more detailed assessment (both higher spatial resolution and more specific anthropogenic features) may be helpful to park management in the future.

Key references

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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 JOMU condition assessment report.

STRESSOR	MEASURES	RECENT DATA	STATUS	TREND
Housing development	Regional housing density Park-and-buffer housing density	288 units/km^2 242 units/km^2	In 2000, nearly half of the region and the buffer area were in urban or suburban housing densities.	
Human footprint	Regional area of high (low) intensity Park-and-buffer area of high (low) intensity JOMU area of high (low) intensity	54% (0%) 25% (0%) 10% (0%)	The footprint is mostly medium intensity within the JOMU boundary due to the proximity of urban development near the park unit. At the park-and-buffer scale, the amount of high intensity increases to one-quarter. The larger region is more intense yet, with nearly equally split between high intensity in the valleys and medium in the hills.	

= baseline only = no significant trend = increasing trend

Resource Briefs

Overview of Indicators

The remainder of this section contains assessments of the key resource indicators. Each assessment follows a similar outline. Each begins with a brief summary of the findings about 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 Level 1 Category

Air and Climate—Air quality
Findings: No significant trends

JOMU lies in the San Francisco Bay Area Air Basin. Although located in this heavily developed coastal area, JOMU is designated as a Class II area under the Clean Air Act (Sullivan et al. 2001). However, because of extensive development, the region has historically had problems with high levels of ozone and other pollutants with human health impacts and diminished visitor experience.

The 5 year average (from 2005 – 2009) annual 4th-highest 8-Hour average ozone concentration was 65 ppb, resulting in a rating of Moderate Condition for ozone pollution. A decreasing trend in ozone concentrations from 1999-2009 was detected but not significant.

Condition estimates for nitrogen deposition were not available for JOMU through the NPS Air Resources Division. However, modeled total nitrogen deposition from UC Riverside indicate that the majority of JOMU and its surroundings was moderately high, 5.7 kg ha^{-1} yr^{-1} in 2002. This is near the critical load threshold for invasion by exotic annual grasses in grasslands (6.0 kg N ha^{-1} yr^{-1}) and above the critical load (5.5 kg N ha^{-1} yr^{-1}) in chaparral and oak woodlands where the composition of epiphytic lichen communities shifts to eutrophic lichens. JOMU has been rated at High Risk from atmospheric nutrient N enrichment relative to other national parks, based on the level of exposure to emissions and ecosystem sensitivity. 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 2005 reached Significant Concern and in 2008 dropped to Good Condition.

Dry deposition rates for sulfur were not available. Condition estimates for sulfur deposition were not available for JOMU through the NPS Air Resources Division. Annual sulfur wet deposition from SO4 averaged 0.52 kg ha^{-1} yr^{-1} from 1994 – 2009, consistently in the Good Condition level. As with nitrogen wet deposition, the trend was decreasing but was only assessed qualitatively.

Visibility at JOMU is rated as Moderate Condition as the five-year average visibility index is below the threshold for Significant Concern. However, visibility on the haziest 20% of days and the clearest 20% of days in the period 2005-2009 is poorer than the baseline period of 1999 – 2003.

Approach

JOMU 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. 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 headquarters of JOMU. 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 2009 report. We acquired visibility data and wet nitrogen and sulfur deposition data 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. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. 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 for ozone, wet deposition, dry deposition, and visibility within JOMU.

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 are below the EPA non-attainment standard of 75 ppb, resulting in a rating of Moderate Condition (Figure 29) (National Park Service, Air Resources Division 2010). However, the risk of foliar ozone injury to plants at JOMU is considered high (Kohut 2007). According to the UC Riverside model, total nitrogen deposition is moderately high at JOMU, 5.7 kg ha^{-1} yr^{-1} (Figure 30), compared to the estimated background rate of 0.25 kg ha^{-1} yr^{-1} in the western

U.S (National Park Service, Air Resources Division 2010). The critical load estimate for California grasslands is 6.0 kg N ha^{-1} yr^{-1} (Fenn et al. 2010). Above this threshold, grassland becomes at risk from invasion by exotic annual grasses and reduction in native plant richness (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. The modeled estimates of total nitrogen in 2002 show JOMU at or near these two critical load levels. A recent national study of the National Parks rated JOMU at High Risk from atmospheric nutrient N enrichment relative to other parks, based on the level of exposure to emissions and ecosystem sensitivity (Sullivan et al. 2011). The average annual sulfur deposition rate of 0.52 from 1994 - 2009 is close to two times higher than the natural background deposition rate of 0.25 kg ha^{-1} yr^{-1} (National Park Service, Air Resources Division 2010). Visibility condition at JOMU is below the threshold of 8 deciviews for Significant Concern, and thus is rated Moderate Condition (Figure 32) (National Park Service, Air Resources Division 2010). Visibility conditions at JOMU, relative to reference conditions, are similar to neighboring park units such as Golden Gate National Recreation Area and Point Reyes National Seashore but better than Pinnacles National Monument, which is right at the threshold.

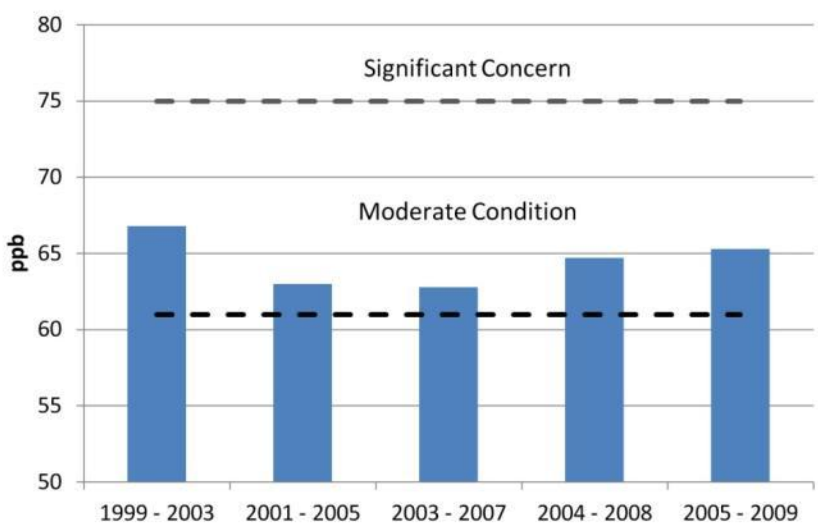

Figure 29. Annual 4th-highest 8-Hour average ozone concentrations, in parts per billion (ppb), averaged over five year intervals. The EPA 75 ppb threshold and NPS threshold for Moderate Condition are indicated by dashed lines. Source: National Park Service, Air Resources Division. 2010.

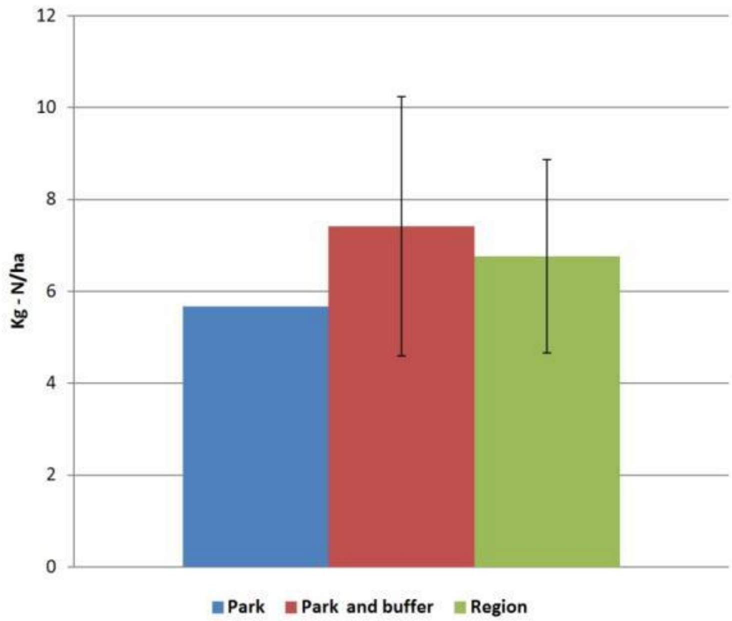

Figure 30. Total nitrogen deposition in kilograms per hectare for the year 2002 at different park scales. Derived from modeled data from U.C. Riverside Center for Conservation Biology. Error bars indicate one standard deviation.

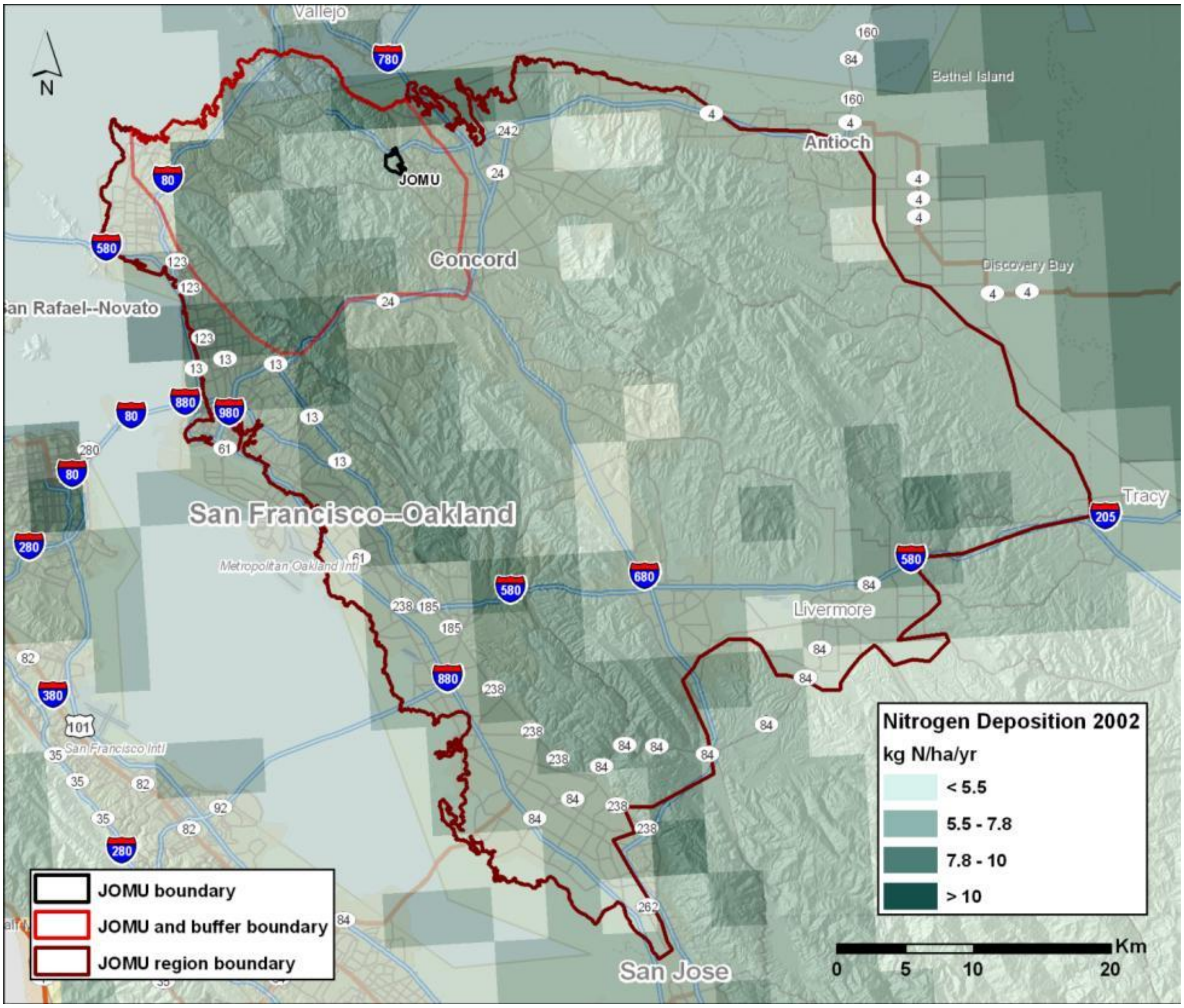

Figure 31. Modeled total nitrogen deposition rates in kilograms N per hectare per year in 2002. Source: U.C. Riverside Center for Conservation Biology.

Park-and-buffer scale:

Nitrogen deposition, at 7.4 kg ha-1 yr-1, is higher than at the park scale, mainly due to the inclusion of developed areas of Martinez just north of the park and Orinda on the southern boundary of this subregion (Figure 30, Figure 31).

Regional scale:

Nitrogen deposition, at 6.8 kg ha-1 yr-1, is in between rates found at the park and park-and-buffer scales. Higher rates of nitrogen deposition in the northern and western edges of the reference region are offset by lower rates in the eastern part (Figure 30, Figure 31).

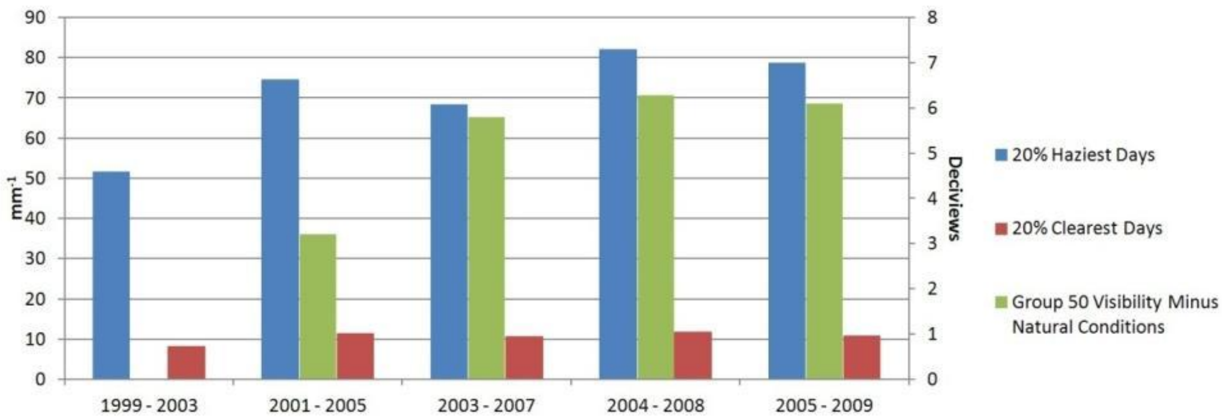

Figure 32. Primary axis: Visibility measured as light extinction for haziest 20% of days and the clearest 20% of days in units of inverse megameters, a measure of the fraction of light attenuation with distance. Higher values indicate more light attenuation and lower visibility. Secondary axis: Visibility 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 would indicate Significant Concern. Source: National Park Service, Air Resources Division 2010.

Trends

Park scale:

No significant trends in ozone concentration have been observed for JOMU although recent concentrations appear to be declining (National Park Service, Air Resources Division 2010). Lack of appropriate data prohibits establishing robust trend estimates for nitrogen and sulfur. However, interpolations of wet deposition rates suggest a downward trend, with wide interannual variation, in nitrogen (Figure 33) and sulfur deposition (Figure 34) over the past decade. Wet nitrogen deposition has typically rated as Moderate Condition, although in 2005 it reached Significant Concern and 2008 dropped to Good Condition (National Park Service, Air Resources Division 2010). The majority of N deposition in California occurs as dry deposition, which might have a different trend. Wet sulphur deposition has consistently occurred within the Good Condition rating (National Park Service, Air Resources Division 2010). Visibility of the clearest days has been improving at a statistically significant rate of 0.21 deciviews per year; that improving trend for the haziest days is not statistically significant (National Park Service, Air Resources Division 2010).

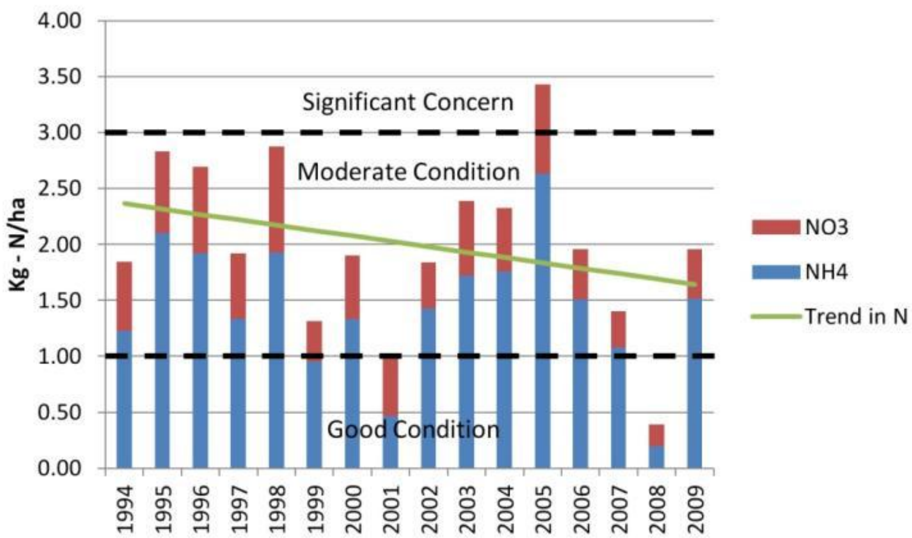

Figure 33. Interpolated wet nitrogen deposition in kilograms per hectare by analyte. The weak linear trend for total nitrogen deposition is shown in green. Derived from modeled data from National Atmospheric Deposition Program.

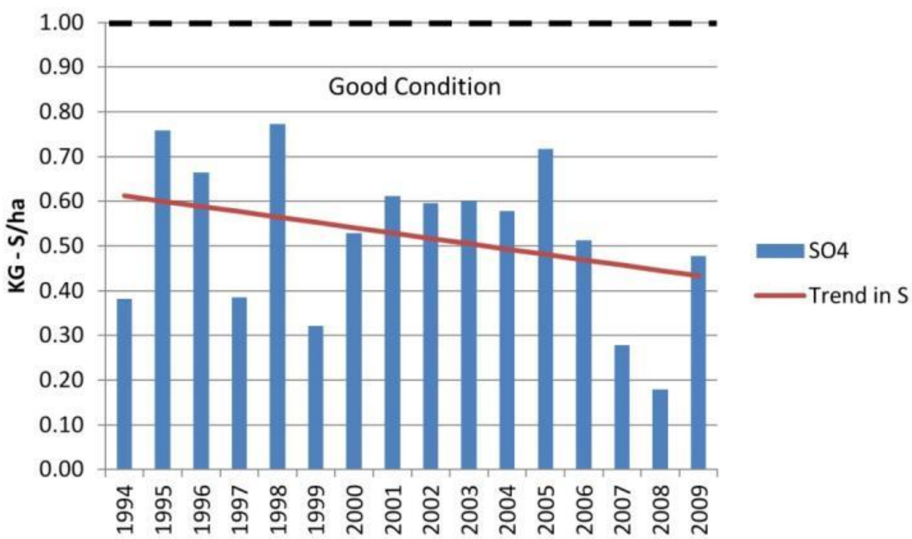

Figure 34. Interpolated wet sulfur deposition in kilograms per hectare. The weak linear trend for sulfur deposition is shown in red. Derived from modeled data from National Atmospheric Deposition Program.

Emerging Issues

EPA has identified a preliminary list of 52 metropolitan statistical areas in the country as nonattainment based on a history of monitored levels of ozone above the standard. JOMU is one of 62 NPS areas located in a proposed area that is "nonattainment" for ozone under the Clean Air Act. Final EPA designations will be determined through the designations process, which will include extensive input and review by the states and an opportunity for public comment. If a nonattainment area is designated, California will be required to develop a State Implementation Plan that will describe strategies for bringing the area into attainment of the standard. During Plan development, it would be important for JOMU to work with the state to ensure that planned park activities are included in the Plan and emissions inventories.

Nitrogenous air pollutants have many sources, including transportation, agriculture, industry, and electricity generation, and are a growing threat to the biodiversity of California (Weiss 2006). In the San Francisco Bay area, most nitrogen deposition comes from mobile sources such as cars, trains, trucks, and airplanes, and most sulfur deposition comes from oil refineries (National Park Service, San Francisco Bay Area Network 2009). Continued growth in the San Francisco Bay region as forecast (see Housing Development section above) is likely to continue increasing nitrogen loading at JOMU. This may be partially offset by tougher standards on vehicle emissions. The effects of increased nitrogen interact with other stressors and ecological processes. Nitrogen is often a primary limiting nutrient on overall productivity of ecosystems, especially in the western United States. 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 JOMU 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 and oak communities, but JOMU has little control over emissions. There are several mitigation methods in grassland habitat, primarily reducing annual grass cover and accumulation of the associated thatch and litter accumulation so that native forbs can coexist (Fenn et al. 2010). These methods include prescribed fire, mechanical treatment, and moderate intensity grazing, all of which would be challenging if not controversial at JOMU.

Data Gaps

There is a dearth of air quality data sampled within JOMU boundaries. Much of the information for this section was obtained from air quality data interpolated for JOMU using nearby monitoring stations. Ironically, one of the potential bioindicator species for ozone risk monitoring is a non-native invasive plant, tree-of-heaven (*Ailanthus altissima*) (Kohut 2007), which is tentatively proposed for management to eradicate it from the park (see the Invasive species and disease indicator section).

Key References

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National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

Air and Climate—Climate

Findings: Significant historical warming trend, increasing trend predicted

Climate at JOMU is characterized by warm, dry summers and mild, wet winters. Temperatures averaged 15^{o}C (59^{o}F) and total annual precipitation averaged 50 cm (19.7 in) over the past 50 years. Minimum temperature exhibited a small positive trend of 0.1^{o}C decade^{-1} over the last century; maximum temperature increased by 0.2 ^{o}C decade^{-1}. Precipitation showed no significant trend.

Downscaled climate models consistently project a 27 – 37% increase in growing degree days (GDD5) by 2100, resulting in future conditions at JOMU that are currently found at Bakersfield in the Central Valley. Minimum winter temperatures are projected to increase by 2.3 – 3.6ºC while maximum summer temperatures are projected to increase by 3.0 –3.9ºC, similar to today's Stockton. Seasonality, measured as the standard deviation of monthly mean temperatures, is projected to increase by 4 – 19%. Precipitation projections are variable, either increasing 6% or decreasing 33% 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 JOMU. Modeled associations with climate and soil indicate that suitability is low across much of the landscape for Blue Oak, *Quercus douglasii*, which is a prominent component of the vegetation in JOMU and the region. Projected distributions indicate that under future climate scenarios, suitability for Blue Oak will decrease within JOMU. Areas surrounding JOMU are also expected to decrease in suitability (even at Mount Diablo), with suitable range contracting westward into the East Bay Hills. These changes could result in decreased cover and forage for the many bird and mammal species that use Blue Oak. In contrast, the chaparral shrub Chamise, *Adenostoma fasciculatum*, is projected to have increased probability of occurrence throughout the East Bay Hills. Chamise is relatively rare in the reference region but is important for some species, such as the Threatened Alameda whipsnake (see section on this species below).

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 headquarters of JOMU. Trends for three climate variables, minimum temperature of the coldest period, maximum temperature of the warmest period, and annual precipitation, were assessed.

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). There are many other GCMs and emission scenarios. The A2 scenario assumes business-as-usual and is not as extreme as some fossil-fuel intensive scenarios. Emissions have been increasing even more rapidly, however, than the most extreme scenarios. It is therefore expected that A2 will be treated by IPCC as a middle-of-the road scenario in future reports (Moser et al. 2009). Our purpose in this section is not to present an exhaustive assessment of all possible scenarios and GCMs, but rather to provide illustrative results to suggest the potential changes in climate and ecological consequences at JOMU.

We transformed the monthly temperature and precipitation data into five ecologically-relevant climate variables: GDD5, 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, GDD5 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 projections to 2100 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 JOMU is climatically from its surrounding region.

To illustrate possible biotic responses to climate change, we compared modeled historic distributions of Blue Oak, *Quercus douglasii*, and Chamise, *Adenostoma fasciculatum*, with their potential future distributions under climate change in the A2 scenario by late century.

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 latitude and longitude of the JOMU headquarters using the PRISM online map application: http://prismmap.nacse.org/nn/.

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.

- Raster surfaces depicting probability of occurrence of *Quercus douglasii* and *Adenostoma fasciculatum* under historic and projected climates at 270 meter resolution. These data were developed by Maki Ikegami of the Biogeography Lab at the University of California Santa Barbara with the MaxEnt model using climate and soils as predictor variables.

Trends

Generalized least squares linear regressions, which adjust significance levels to account for autocorrelation, revealed significant positive trends in minimum temperature (TMIN) from 1895 – 2011 (TMIN: slope = 0.011, $p = 0.004$, std error = 0.004, adj. $r^2 = 0.06$, Figure 35). Maximum temperature showed an even greater rate of increase (TMAX: slope = 0.019, $p = 0.0$, std error = 0.003, adj. $r^2 = 0.30$, Figure 36). No significant trend in annual precipitation was revealed by a least squares linear regression (adj. $r^2 = 0.01$, std error = 0.44, slope = 0.69, $p = 0.12$, Figure 37). No autocorrelation was found in regression residuals (Durbin-Watson, $p = 0.3876$).

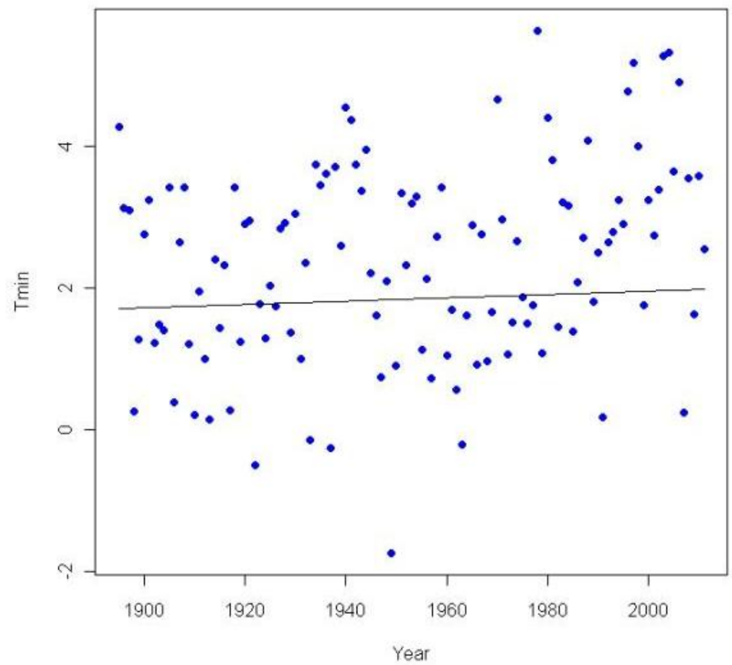

Figure 35. Minimum temperature (Tmin, ^{o}C) with a linear fit indicated by the black line.

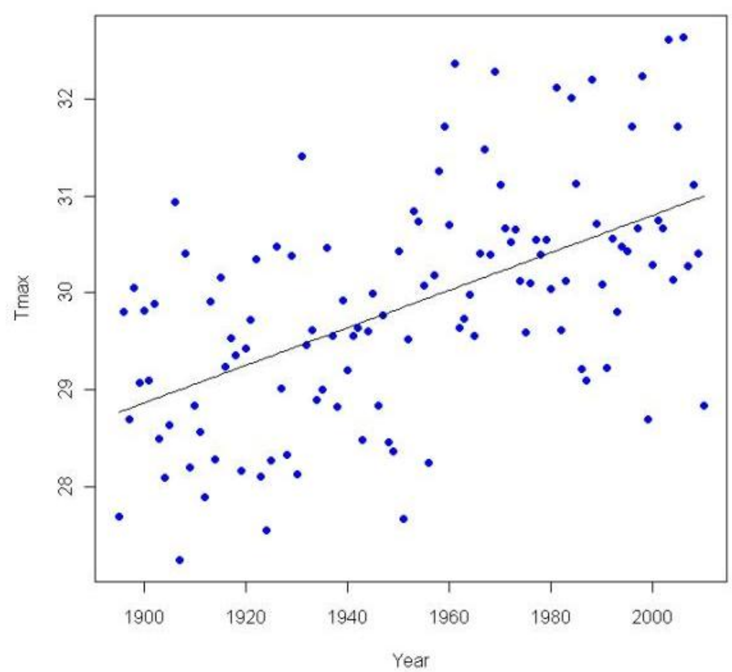

Figure 36. Maximum temperature (Tmax, ^{o}C) with a linear fit indicated by the black line.

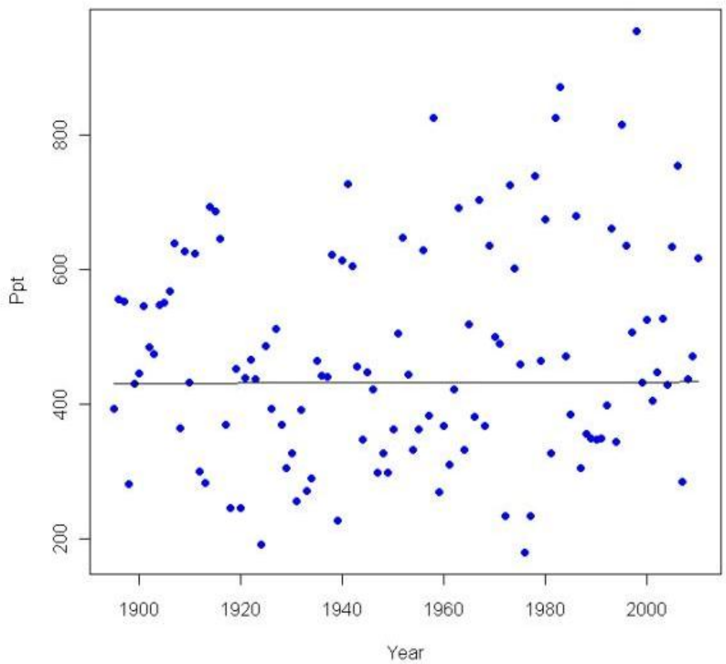

Figure 37. Precipitation (Ppt, in mm) with a linear fit indicated by the black line.

GDD5, minimum and maximum temperatures, and temperature variability are expected to increase from the baseline period (1971 – 2000) to 2100 (Figure 38). For example, minimum temperatures within and around JOMU are expected to increase between 2.3-3.6 ^{o}C; maximum temperatures are projected to increase 3-3.9 ^{o}C. Future maximum temperatures are projected to be similar to those currently found in nearby Stockton, while future GDD5 would be similar to that of Bakersfield. Annual precipitation increases slightly (~7%) in the PCM model over the North East Bay Hills area but decreases dramatically (~33%) in the GFDL model. Trends at the other scales are projected to be similar to those at the park-and-buffer scale. In general, the GFDL model projects a warmer and drier future than the PCM.

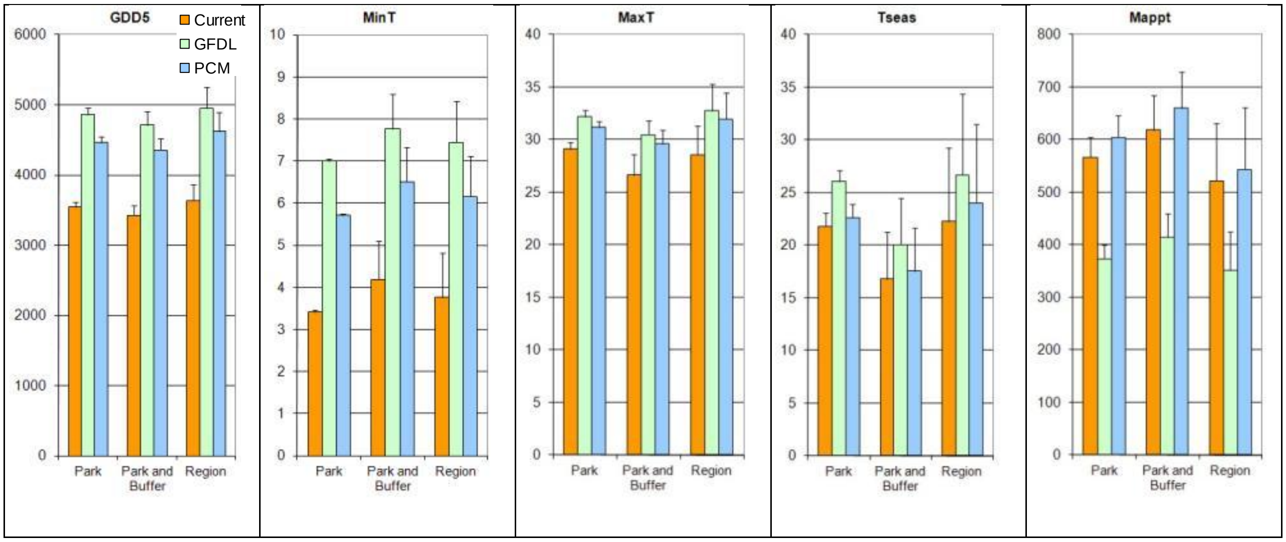

Figure 38. Current (1971 – 2000) and projected (2000 – 2100) values for climate variables summarized by three reference scales. Projected data from the Parallel Climate Model (PCM) and the Geophysical Fluid Dynamics model (GFDL). Error bars show the standard deviation of the spatial data at each scale. Climate variables are coded as follows: GDD5 = growing degree days above 5^{o}C, MinT = minimum temperature of the coldest period in ^{o}C, MaxT = maximum temperature of the warmest period in ^{o}C, Tseas = temperature seasonality (the standard deviation of monthly mean temperatures), MAppt = average annual precipitation in mm.

Occurrence probabilities for *Quercus douglasii* currently average 0.33 across the park. Future probabilities toward the end of this century vary widely between the two GCMs, with a decrease to 0.27 with the PCM and 0.04 with GFDL based on the A2 scenario. From moderately high suitability throughout the region under historical conditions, suitable area may contract dramatically to the East Bay Hills with both models (Figure 39). The Mount Diablo area is expected to become much less suitable for Blue Oak by the end of the century according to both GCMs. The current probability of occurrence for *Adenostoma fasciculatum* at JOMU is similar to that of *Q. douglasii*, at 0.31. However, by late century this average probability is projected to rise slightly to 0.37 in GFDL and 0.40 in PCM. In general the probability increases throughout the East Bay Hills in both GCMs relative to the current situation (Figure 40).

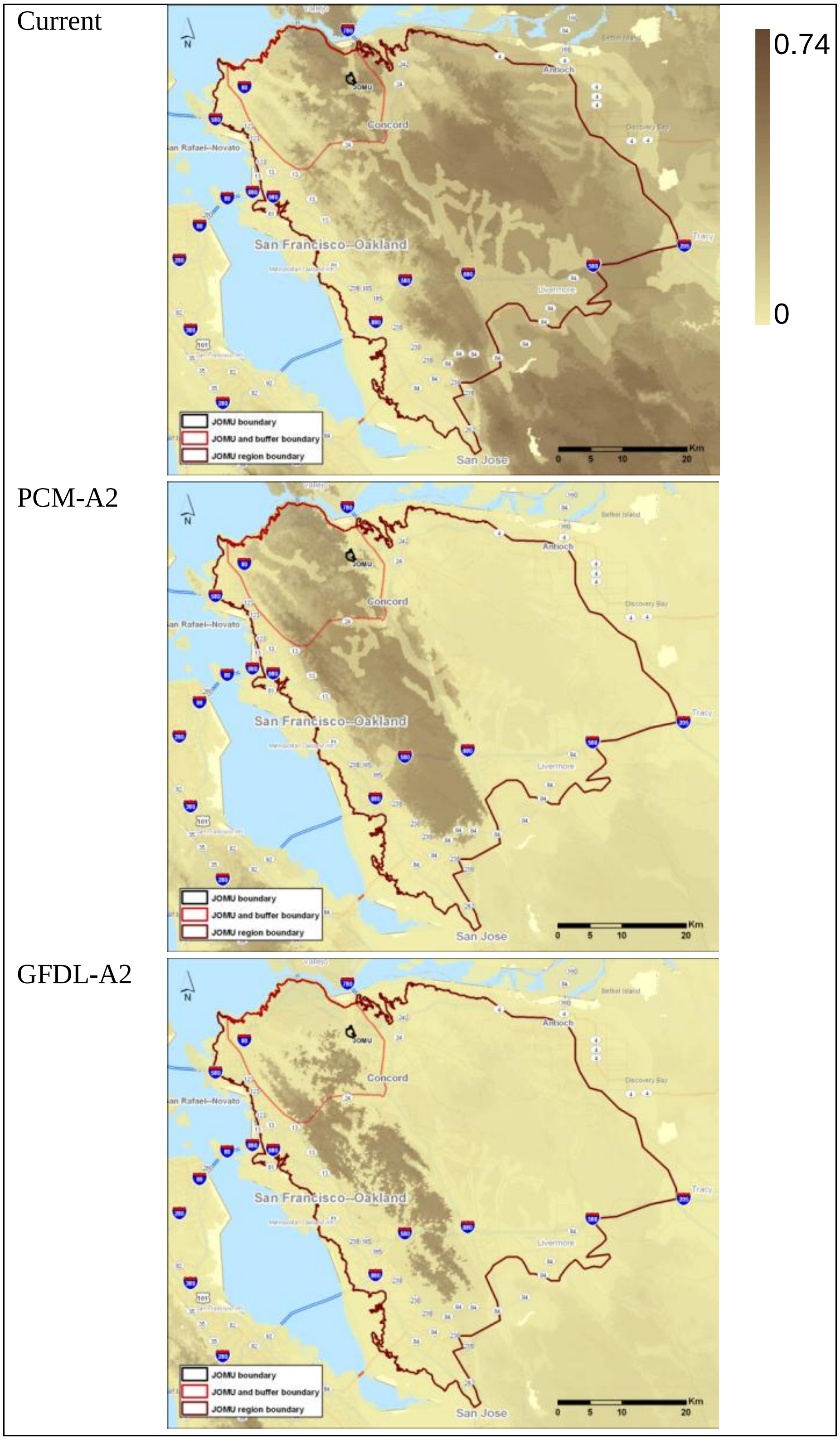

Figure 39. Mapped probability of occurrence for *Quercus douglasii* under historic and projected climate conditions with the A2 scenario in late-21st Century.

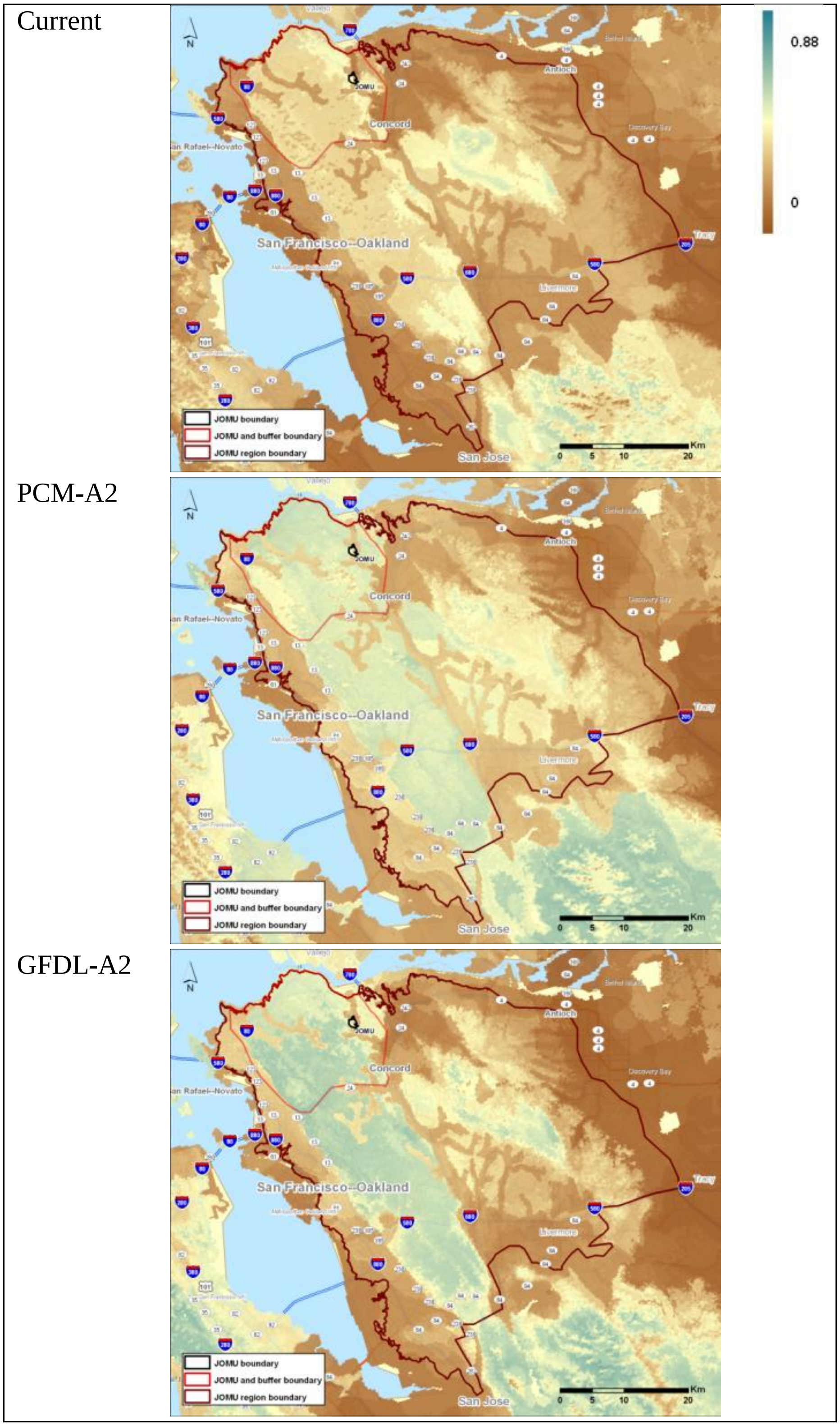

Figure 40. Mapped probability of occurrence for *Adenostoma fasciculatum* under historic and projected climate conditions with the A2 scenario in late-21st Century.

Emerging Issues

Climate change per se is less of an emerging issue than the consequences of that change across-the-board on the socioeconomic and ecological systems in and around JOMU. Some dimensions of climate drive virtually every resource indicator in the park. Plant communities may reassemble in new combinations. As we have shown, one possible outcome would be a dramatic decrease in the probability of Blue Oak with an increase in Chamise as examples. 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 JOMU and surrounding areas (Hannah 2008). Results for Blue Oak distribution showing a loss of suitable land area in JOMU under future climate reflect the findings of Kueppers et al. (2005) that the majority of land suitable for Blue Oak in the future will be outside the boundaries of current protected areas. Changes in climate factors may enhance invasions by non-native plants. Animal species may be directly impacted if conditions move outside their tolerances or indirectly by changes to their habitat. Climate change can also disrupt the co-evolved timing of host plants and pollinators, putting both in greater peril. A warming climate is likely to increase the frequency of large fires although the magnitude of such change is highly uncertain between GCMs and fire modeling assumptions (Westerling et al. 2010). Given JOMU'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. Recent emissions exceeded the most fossil fuel-intensive scenario from IPCC (Moser et al. 2009), so these projected climate changes may be underestimated unless emissions are drastically curbed soon.

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 Blue Oak in the central 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 JOMU. 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 JOMU.

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: 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 Level 1 Category

Water—Hydrology and water quality
Findings: Baseline only

Erosion in Strentzel Watershed and its possible contribution to flooding and sedimentation in Alhambra Creek is one of the most pressing resource management issues at JOMU. Furthermore, because the watershed represents a series of interconnected biotic and abiotic processes and covers such a large portion of JOMU land, improving its health serves well as a comprehensive management goal. Gullying is the central process that has raised concerns about park neighborhoods and resources. A recent report identified the potential stressors that could be causing the increased gullying, but because little data on historical or current conditions has been collected, neither the relative contribution of stressors to the problem nor reference conditions have been determined (Moore 2006). This condition assessment investigated some of the potential stressors with other data sources. No significant trend in annual precipitation was identified that could account for changes in gullying, nor did we uncover any evidence of increase in extreme precipitation events. Vegetation mapping of the Bay Area revealed that 31% of the watershed is non-native annual grassland, especially on the headwalls of the watershed. Annuals tend to be more shallow-rooted than the native perennials they replaced and hence such grassland is more prone to erosion. Most of the watershed was mapped as Most Susceptible to landslides. Data on other stressors such as grazing history were not found. However, most stressors, including landslide susceptibility, annual grasslands, residential development, climatic patterns, and grazing, appear widespread in the North East Bay Hills and not unique to the Mount Wanda area.

Approach

As described in Chapter 2, the primary watershed concerns at JOMU occur in the Strentzel Watershed in the southwestern portion of the Mount Wanda unit and adjoining private lands (Figure 4). An expanding and deepening gullying network in the watershed has caused impacts on rates of sediment delivery and has been attributed to potentially increasing downstream flooding. We synthesized information in the Watershed Management Report (Moore 2006) into a conceptual model of the relationships between stressors, ecological pathways, and resource endpoints specific to the Strentzel Watershed (Figure 41). Because erosion is a normal process even under natural, undisturbed conditions, one of the key management questions for JOMU is whether the level of soil erosion on Mount Wanda is normal for the types of soil found in the park.

Gullying is the central process that has raised concerns about the condition of the watershed and impacts on neighborhoods and resources. The increase in gullying can be caused by a higher volume of stream flow. A wide range of stressors have been suggested as the ultimate source. Upstream land uses, including on-going livestock grazing, remove vegetative cover that would otherwise buffer the energy of water flow. Culverts have redirected and increased runoff. The network of fire roads on Mount Wanda has also been implicated. Invasion of non-native annual grasses that replaced deeper-rooted perennial species changes the erodability of the soil. There may once have been wetlands near some of the headwaters that would have released water gradually. If those were destroyed, the increased rate of runoff may have contributed to gullying. Numerous small dams in the watershed had a similar effect, but some of these have failed and allowed a surge of water to rush downstream and cut channels deeper.

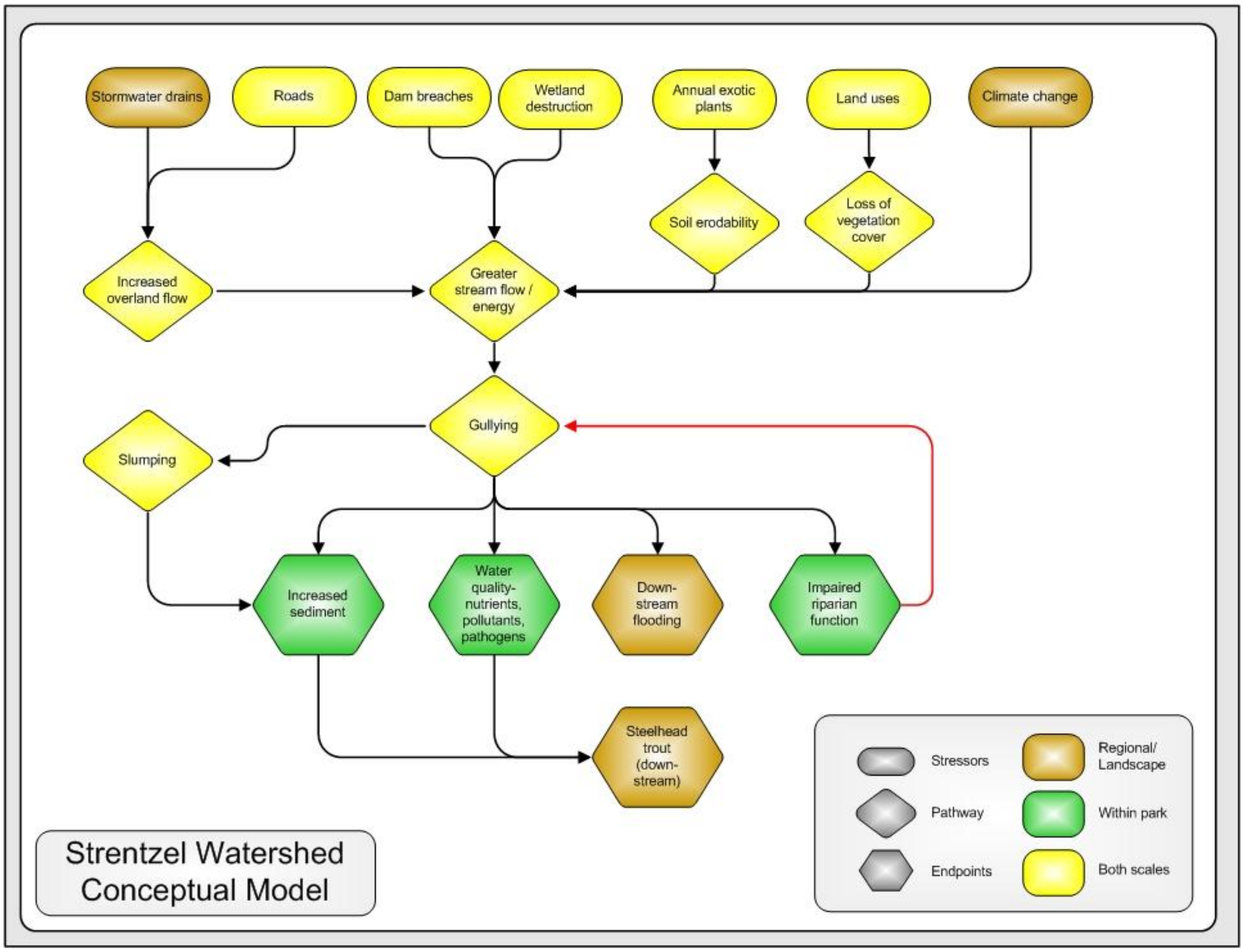

Figure 41. Conceptual model of stressors, ecological pathways, and resource endpoints in the Strentzel Watershed. Based on Moore 2006. The red arrow indicates a positive feedback loop between riparian functioning and gullying.

Gullying in turn causes other impacts, such as increased slumping of hillslopes that become destabilized after channel cutting. These processes combine to increase the sediment load of the creek. Alhambra Creek historically provided habitat for steelhead trout. If sediment loading becomes excessive, it can further degrade habitat by covering spawning beds should the fish return. The stressors that have potentially led to increased gullying also increase the rate that water is discharged following peak rainfall ("flashier") and hence raising the potential of downstream flooding. As water and sediment are more rapidly transported downstream, so are nutrients, pathogens (e.g., fecal coliform), and other pollutants. Gullying also affects the functioning of riparian systems that normally stabilize the channel. This loss of function creates a positive feedback by increasing the potential for gullying in the destabilized channels. An impaired riparian system also allows more nutrients to be transported out of the watershed, especially after fire.

Very little data has been collected to date about resource indicator endpoints and much of the information about stressors is anecdotal or speculative. In the absence of new data to analyze about watershed conditions, we summarize evidence about the stressors that potentially drive the increased gullying process. Much of that evidence comes from the Watershed Management Report itself (Moore 2006), while some is interjected from other sections of this resource condition assessment. GIS summaries of spatial data, such as the area of non-native annual grasslands, were also made.

Data

- Conservation Lands Network Vegetation: cln_veg, http://www.bayarealands.org/gis/all-datasets.php, accessed 07/11/11.

- Williamson Act enrollment status, as of 2007, ftp://ftp.consrv.ca.gov/pub/dlrp/wa/WA%20GIS%20to%202009/shapefile/, Accessed 10/21/11.

- Relative Landslide Susceptibility Map, California Department of Conservation (Haydon 1995).

Status

Summarizing from Moore (2006), sediment and runoff at the mouth of Strentzel Canyon appear to be inordinately high, although historical monitoring data are sparse. These effects are driven by changes in the drainage network, both a deepening of the channels and an expansion of gullies headward. Gullies are the primary source of sediment, with other contributions directly or indirectly from the other stressors and pathways shown in the conceptual model (Figure 41). However, identifying the relative contribution of stressors to the increased gullying has not been fully disentangled. The most severe gullying has been mapped in the middle of the watershed associated with tributaries from north facing slopes outside of JOMU (Moore et al. 2006).

This condition assessment found no statistically significant trend in annual precipitation that corresponds with the accelerated gullying (see Climate section above). However, gullying is coupled to high intensity storm events rather than annual average precipitation. Our assessment did not investigate trends in storm precipitation or intensity. A national study of trends in extreme precipitation events did not detect any significant trends for the California-Nevada region over the past century (Groisman et al. 2004). Whether there were any trends at the scale of the San Francisco Bay Area was not addressed.

The finest resolution of housing data from the US Census over time is partial block groups (see Housing Development section for details).Unfortunately, Strentzel Watershed is only a small fraction of one, 6488 hectare partial block group. There were only 24 housing units here in 1940, which increased 14-fold by 2000. The largest jump in housing units occurred between 1980 and 1990. Given the very small number of housing units in the watershed, it is dangerous to infer too much about the rate and timing of development with respect to changes in gullying in the watershed from these lower resolution data.

The CLN vegetation type map included 31% of the watershed in the Warm Grassland type, which is dominated by annuals with varying amounts of native perennials. In addition, shallow-rooted annuals occur as understory in the woodland type. The grassland types occur on the south-facing slope within JOMU on the northern side of the watershed. According to the JOMU vegetation map (O'Neil and Egan 2004), this is primarily Wild Oats Grassland (*Avena fatua*) on clay soils that was heavily grazed until 1991, three years after NPS assumed management. Warm grasslands also occur near the watershed divide on the north-facing, private lands of the southern side of the watershed. In other words, the headwalls of the watershed are predominately non-native annual grasslands that tend to be more erodible than the native perennials they replaced.

Except for some of the lands on the watershed divide and the mouth of the canyon, Strentzel Watershed was mapped as Most Susceptible in Relative Landslide Susceptibility (Figure 42) (Haydon 1995). Landslides, which are relatively common in this subarea, are generally of the smaller and shallower type, usually less than 5 acres in size, that incorporate colluvium or shallow, fractured bedrock. Slopes are at or close to their stability limits because of their steepness. The materials underlying this area can therefore be expected to fail, locally, when adversely affected by natural processes or man-caused modifications that steepen slopes, increase loads, or remove natural buttresses from the bases of the slopes. This subarea is relatively widespread in the North East Bay Hills (Haydon 1995).

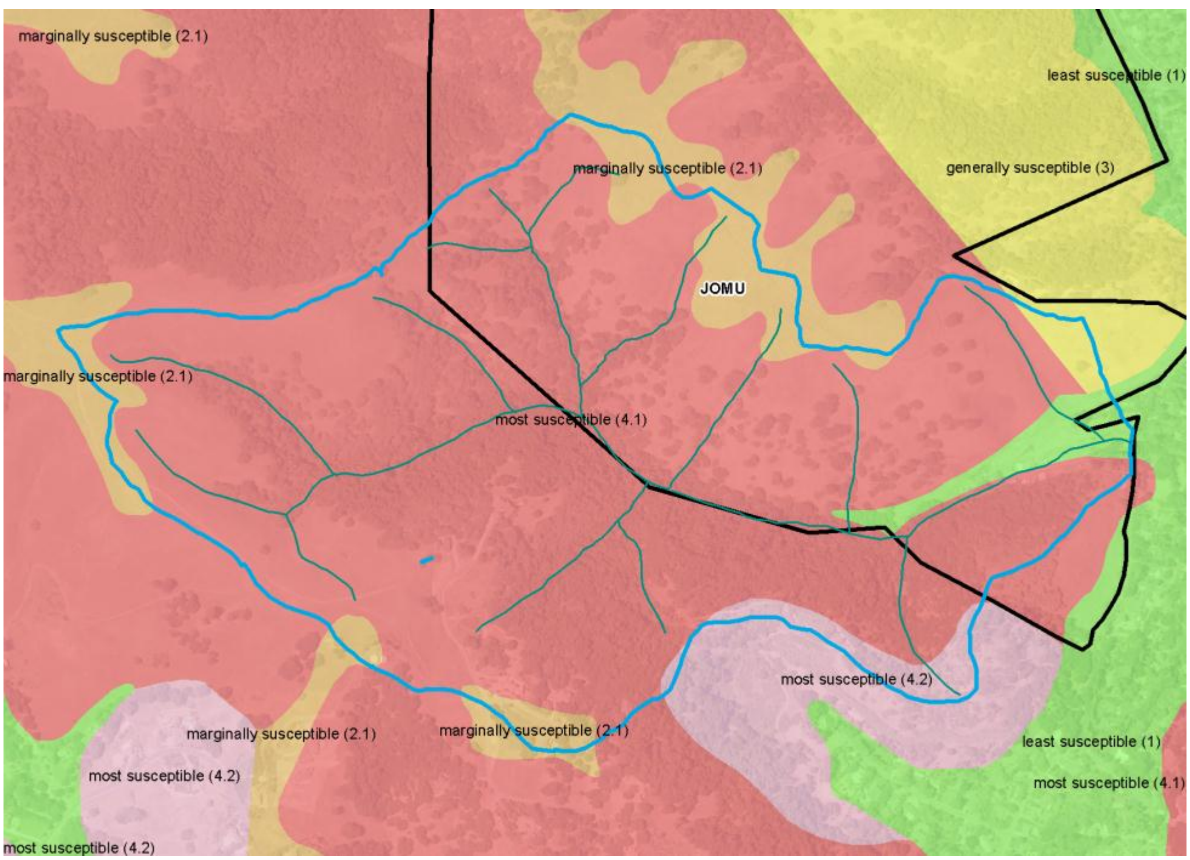

Figure 42. Relative landslide susceptibility areas, by Haydon (1995).

Emerging Issues

Projections of future annual precipitation under the A2 emissions scenario differ between GCMs (+7% in the PCM model, -33% in GFDL) over the North East Bay Hills area (see Climate section above). There is nothing in these projections to suggest that precipitation will change in magnitude as a stressor on the watershed functioning, at least considering average annual amounts. How extreme precipitation events might change in the future have not been predicted at this time.

Parcel 367-210-003 is 272 acres along the western edge of the Mount Wanda unit and covers the western headwaters of Strentzel Watershed. According to a statewide compilation of general plans, the parcel is designated as agriculture, including grazing (California Resources Agency and University of California Davis 2004). In addition, as of 2007, the parcel was enrolled under the Williamson Act (ftp://ftp.consrv.ca.gov/pub/dlrp/wa/WA%20GIS%20to%202009/shapefile/), whereby the owner receives property tax reductions in exchange for preserving their land in agricultural or related open space use for the length of the contract. Should the owner choose not to renew their ten-year contract, there is a ten-year waiting period before the property can be developed. The ICLUS projections of housing density in 2050 (see Housing Development section above) also show no change from the current exurban density. Consequently it does not appear that there is any imminent danger of any additional residential development in the headwaters.

Efforts are already underway to treat invasive plant areas, road-caused erosion, and stormwater runoff. Between these reductions in stressors and the projections of little or no additional stress from land use and climate on the watershed, we might expect that the resource endpoints will begin to stabilize or even improve.

Data Gaps

"Drainage network change is so extensive that it is difficult to determine what natural or prehistoric channel types once existed" (Moore 2006, page 20). Although establishing reference conditions from the time of John Muir will be hard, JOMU is submitting a funding request to conduct a historical ecology study to help better understand historic vegetative and hydrogeomorphic conditions. The current channel geomorphology of the Strentzel Watershed has been accurately mapped as a baseline (Moore et al. 2006). This condition assessment has synthesized current understanding of the stressors and pathways that affect the resource endpoints of concern. The Watershed Management Report (Moore 2006) pulled together many pieces of evidence of the various stressors and endpoints. However, a characterization of reference conditions from John Muir's time still eludes us. In addition, the magnitude of the effects of the various stressors on the intermediate pathways and resource endpoints has not yet been determined. Indeed, there has only been spotty sampling of stream flows and loading in the watershed. According to Moore (2006), flows and impacts were sampled once in 2004 late during one storm hydrograph. The SFAN I&M program could increase monitoring of stream conditions over more storms and throughout the hydrograph. Moore (2006) also suggested attempting to determine reference conditions through historical aerial photos and examining undisturbed watersheds in the vicinity with similar soils and slopes. It may also be possible to document more details of the grazing history of the watershed from local records. With more data on land uses and consequences to the watershed, it should be possible to apply a watershed model such as the Watershed Analysis Risk Management Framework (WARMF) from EPA or the Soil and Water Assessment Tool (SWAT) from Texas A&M and USDA to identify the relative contributions of potential stressors.

Key references

Moore, C. 2006. Watershed Management Report, John Muir National Historic Site, Martinez, California. Natural Resource Technical Report NPS/SFANNRTR—2006/022. National Park Service, Fort Collins, Colorado.

Biological Integrity Level 1 Category

Biological integrity—Invasive species and disease—Non-native invasive plants and Sudden Oak Death
Findings: Baseline only

Invasive weeds are one of the largest threats to biodiversity in the Bay Area (Bossard et al. 2000) and perhaps the most immediate threat on public lands (Bay Area Open Space Council 2011). They affect all Bay Area ecosystems but especially grasslands. At JOMU, about 254 of approximately 496 plant species are non-native (51%, Williams et al. 2009). Eighteen of these non-native species are considered invasive, with the potential for creating serious ecological damage (e.g., erosion, fire, and habitat quality) and detracting from the character of the site's native plant community. The Early Detection Rapid Response program, coordinated by the San Francisco Bay Area Inventory and Monitoring Network of the NPS, provides critical surveillance of new and potentially new invaders, while the Exotic Plant Management Team monitoring and control program addresses more well-established, widespread invasive plants. Invasive plant management is intricately interconnected with other stressors and resources in the park and surrounding landscape, such as watershed health. Efforts are already underway to improve coordination of invasive plant monitoring and management among land managers and citizens. Two key data gaps for JOMU are to establish reference conditions tied to John Muir's time through determining the historical ecology of the site and to set priorities for sites for treatment and restoration. Sudden Oak Death has not been detected in JOMU, but confirmed detections in the past few years in nearby Briones Regional Park suggest that this disease could become a greater threat for the NPS to monitor.

Approach

There are two complementary programs being implemented at JOMU for inventorying, monitoring, and treating invasive plants. The first is the Early Detection Rapid Response (EDRR) program operated by SFAN to locate new, isolated infestations of priority species before they can become entrenched and hard to eradicate (Williams et al. 2009). This program was ranked as the second-highest vital sign priority for inventory and monitoring by SFAN (Adams et al. 2006). The first step in the protocol is to develop a list of target invasive plants, whose priority determines the level of data gathered (Williams et al. 2009). The current lists, grouped by threat level, are shown in Table 12 (high threat) through Table 14 (low threat). The locations of species on List 1 (Table 12) and 2 (Table 13) are always recorded. All occurrences of List 1 species are also "assessed" (i.e., the patch is mapped, data on the cover of the invasive species is recorded, and whether or not the occurrence was treated to eradicate it); those on List 2 are only assessed if the occurrence is less than 100 m^2 in size (i.e., small founding populations called spreading foci). List 3 represents more widespread species, so point occurrences are only recorded when less than 100 m^2 in size. All remaining exotic plants are included on List 4 (not shown). Using these lists, SFAN program staff survey JOMU, document the observed plant species, and treat infestations on the spot if time permits. If the infestation requires further treatment, SFAN staff will notify the park to further remove the plants. The trail network at JOMU has been surveyed annually by the EDRR program since 2009, and the results are entered into a GeoWeed database (Williams et al. 2011). The database consists of GIS shapefiles of the occurrences (points) and assessments (polygons). We combined the threat level from the tables with the shapefiles to display the pattern of invasive threat.

Table 12. List 1 early detection invasive species--high threat. These species primarily occur in cultural landscapes, but concerned about spread into natural areas. Point occurrence and assessment.

Scientific name	Common name
Centaurea calcitrapa	Purple-star thistle
Euphorbia oblongata	Oblong spurge
Eucalyptus globulus	Tasmanian blue gum
Ficus carica	Fig
Lepidium latifolium	Perennial pepperweed
Malvella leprosa	Alkali mallow
Xanthium spinosum	Spiney cocklebur
Not currently in park, but of concern:	
Centaurea melitensis	Napa thistle, Tocalote
Cortaderia jubata	Pampas grass
Senecio mikanioides	Cape ivy
Ulex europaeus	Gorse

Table 13. List 2 early detection invasive species--medium threat. These species occur in natural areas of the park but are not yet widespread. Point occurrence recorded. Assessment if <$100m^2$.

Scientific name	Common name
Arundo donax	Giant reed
Bellardia trixago	Bellardia
Cirsium vulgare	Bull thistle
Conium maculatum	Poison hemlock
Convolvulus arvensis	Bindweed
Cotoneaster franchetii	Cotoneaster
Cynara cardunculus	Artichoke thistle
Foeniculum vulgare	Fennel
Genista monspessulana	French broom
Hirschfeldia incana	Summer/Hoary mustard
Olea europaea	Olive
Phalaris aquatica	Harding grass
Rubus discolor	Himalayan blackberry
Tribulus terrestris	Puncturevine
Zantedeschia aethiopica	Calla-lily

Table 14. List 3 invasive species--low threat. These species are established and widespread and thus are not to be considered on the EDRR watch list and should be addressed through the regular monitoring and control program. Point occurrence recorded if <$100m^2$.

Scientific name	Common name
Annual exotic grasses	
Ailanthus altissima	Tree-of-heaven
Brassica nigra	Black mustard
Carduus pycnocephalus	Italian thistle
Centaurea solstitialis	Yellow star thistle
Silybum marianum	Blessed milk thistle
Vinca major	Periwinkle

The second component is an Exotic Plant Management Team (EPMT) model, developed in 2000 by NPS as part of the Natural Resources Challenge initiative. This program helps NPS to address invasive plant issues at a local level by offering technical and financial support to parks. Currently, there are 16 EPMTs, though two of these teams are not fully active at this time. Teams vary in their structure and composition. However, all teams use or fund highly trained personnel to control invasive plants with the most efficient and effective methods available. Their efforts are focused on priority invasive plant populations that have been identified by the parks they serve. At JOMU they largely concentrate on several thistle species.

JOMU is supported by the California EPMT, based out of Point Reyes National Seashore. Originally, this particular EMPT was designed to provide NPS units in California an invasive plant control service by sending teams of trained seasonal employees to treat priority infestations. More recently, however, this EPMT has adapted into an office that provides financial and technical support to parks through an annual application process. Generally, these funds go towards paying for contractors, seasonal employees and equipment to remove invasive plant populations.

Spatial data have been compiled since the 2005 EPMT survey, with additional surveys in 2010 and 2011. The survey process and the database details have evolved during that period, so the data are not directly comparable between years.

Detecting and monitoring occurrences of invasive plants is only part of the story. These occurrences and species must be managed to protect the cultural and natural resources of JOMU in a manner consistent with the time period or significance, particularly during Muir's time (1800-1915). Furthermore, management should be coordinated among multiple stakeholders and agencies for consistent stewardship. With this in mind, JOMU hosted a workshop among interested parties on June 9-10, 2011, to begin developing strategies for containment and eradication of high-priority species and enhancement of native biodiversity. The workshop participants tentatively agreed to a prioritized list of invasive plants to be managed, including both higher threat species from the EDRR lists and more widespread plants such as thistles and mustard (Table 15). To visualize the pattern of management priorities, we assigned the occurrences from the 2009-2011 EDRR surveys and the 2010-2011 park surveys of other invasives to the proposed priority ranking.

Table 15. Non-native invasive plant species (in alphabetical order by scientific name) proposed for management at JOMU by participants of the June 9-10, 2011 workshop. List indicates the species' priority ranking in the Early Detection Rapid Response program in the previous tables.

Common name	Scientific name	List
Highest Priority (EDRR species)		
Barb goatgrass	*Aegilops triuncialis*	4
Tree-of-heaven	*Ailanthus altissima*	3
Distaff thistle	*Carthamus lanatus*	4
Yellow starthistle	*Centaurea solstitialis*	3
Artichoke thistle	*Cynara cardunculus*	2
Stinkwort	*Dittrichia graveolens*	4
Oblong spurge	*Euphorbia oblongata*	1
Fennel	*Foeniculum vulgare*	2

Common name	Scientific name	List
Highest Priority (EDRR species)		
French broom	*Genista monspessulanas*	2
Ivy	*Hedera sp.*	4
Perennial sweet pea	*Lathyrus latifolius*	4
Perennial pepperweed	*Lepidium latifolium*	1
Olive*	*Olea europaea*	2
Bermuda oxalis	*Oxalis pes-caprae*	4
Harding grass	*Phalaris aquatica*	2
Medusa head	*Taeniatherum caput-medusae*	4
Calla lily	*Zantedeschia aethiopica*	2
High Priority (long term)		
Mustard	*Brassica sp.*	3
Milk thistle	*Silybum marianum*	3
Italian thistle	*Carduus pycnocephalus*	3

*Cultural planting; edge of historic orchard needs to be delineated

Sudden Oak Death (SOD) is a highly virulent disease caused by the pathogen, *Phytophthora ramorum*. First detected in California in 1995, the disease has caused widespread mortality in oak and mixed hardwood forests in the coast ranges of Northern and Central California (Figure 43). A 2002 survey examined 26 transects of 50m length in woodlands and forest at JOMU to determine if SOD was present in the park (O'Neil 2005). Those findings are summarized below. We also queried the database at OakMapper.org, a website created by Maggi Kelly's lab at the University of California Berkeley to collect and distribute spatial information related to the spread of the disease (Connors et al. in press).

Figure 43. Tree mortality caused by Sudden Oak Death. Photo Credit: Marin County Fire Department, http://www.suddenoakdeath.org/library/photos/landscape-photos/, accessed 11/1/2011.

Data

Park scale:

- Early Detection occurrences: Weedoccurrences.shp shapefile from SFAN I&M.
- Park EPMT surveys of invasive plants: JOMU_0310_pt.shp shapefile from JOMU for 2010; JOMU_Invsvs_pt.shp shapefiles for Units 1, 2, 3, and 5 that were appended into a single shapefile for 2011.
- Trails: SFAN I&M supplied a shapefile of the trails for the EDRR surveys.

Status

Park scale:

In general, past land use history and year of establishment have a larger effect on invasion of Bay Area parks than the effects of visitation, miles of roads and trails, and length of perimeter (Table 16, Williams et al. 2009). JOMU, in addition to its historical land use is highly exposed to the effects of neighboring urban development. Its flora is dominated by exotics, and the percent invasive is higher than the relatively undisturbed Pinnacles National Monument (PINN). The managed portion of Golden Gate National Recreation Area (GOGA) is similar to PINN in size and number of natives, but with the number of exotics similar to the tiny JOMU.

Table 16. Apparent influential factors in the extent of invasion at parks (extracted from Williams et al. 2009).

Park Name	Acres in Park	# of Natives	# of Exotics	# of Invasives	% Flora Exotic	% Flora Invasive	Year Established	Prior Use (50 yrs)
JOMU	345	242	254	18	51.2%	6.9%	1964	Home, Ranch
PINN	26,000	540	128	27	19.2%	4.8%	1908	National Monument
GOGA Managed	20,556	514	267	61	34.2%	10.6%	1972	Military, Ranch

The EDRR surveys have detected 51 point occurrences since 2009 (Figure 44). These are congregated mostly in the Muir home site, the entrance on the fire road at Mount Wanda, and along Alhambra Road on the southeastern boundary. Very few occurrences have yet been detected in the core of the Mount Wanda unit; however, inventory is on-going and new infestations are being discovered regularly.

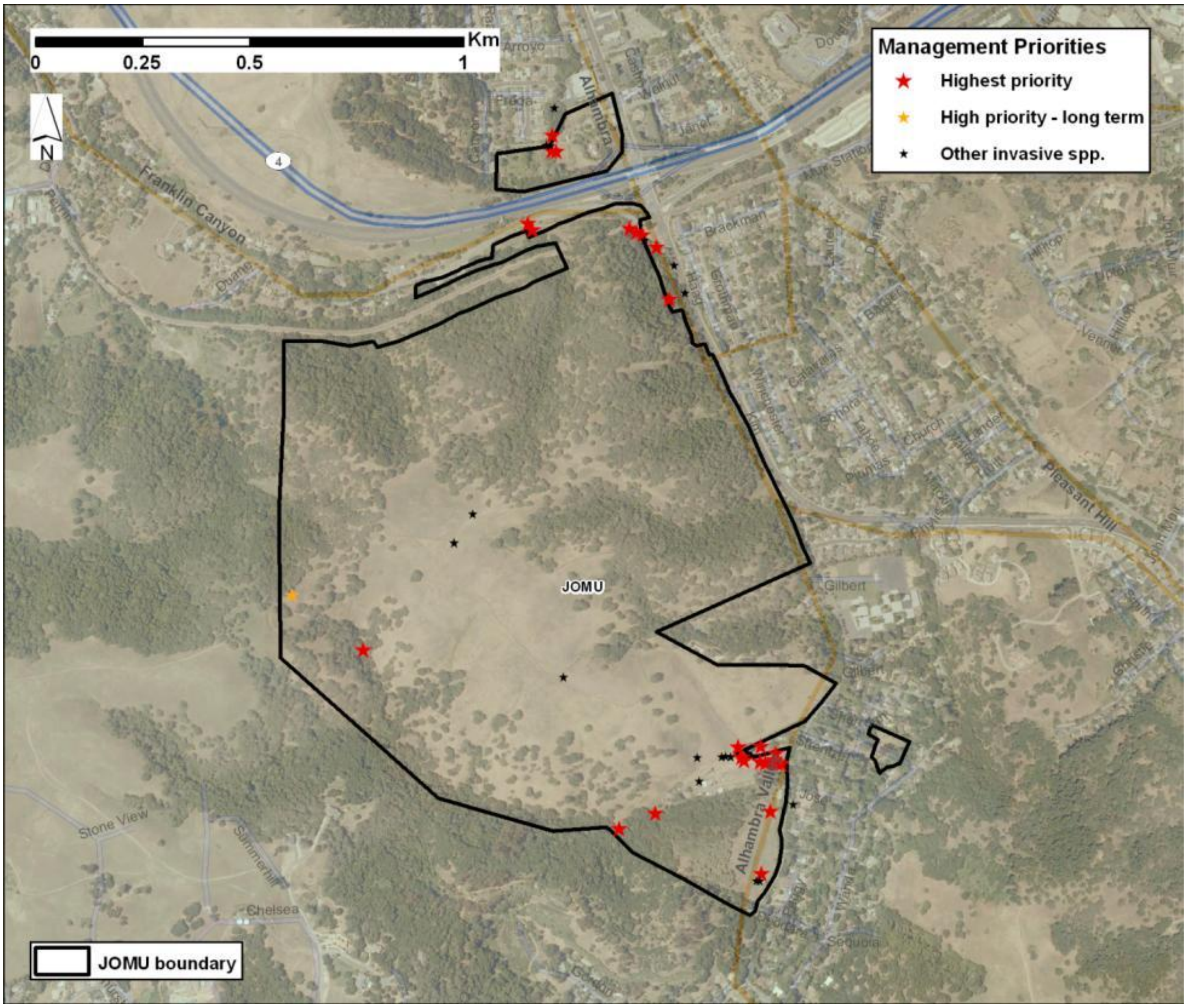

Figure 44. Points from the Early Detection Rapid Response program, 2009-2011, by threat level.

The EPMT surveys focused on more widespread species such as thistles and mustard (Figure 45). In 2005, the surveys and treatments concentrated on milk thistle and tree of heaven (Boughter 2005a and b). The latter was abundant on private properties along Alhambra Valley Road, which are potential seed sources for the east fire road and northern Strain Ranch (Boughter 2005b).

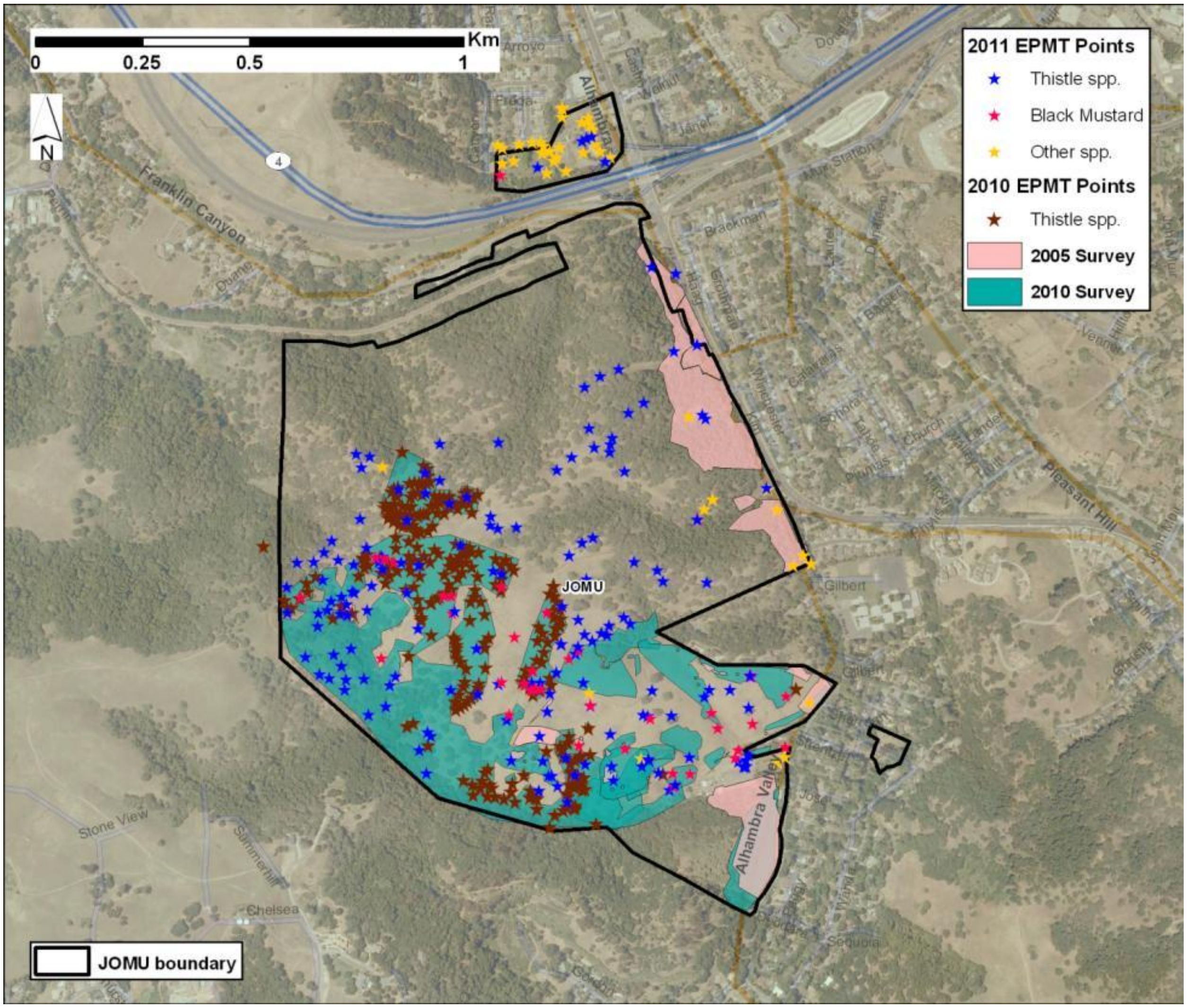

Figure 45. Points and areas for EPMT invasive plant surveys for 2005, 2010, and 2011.

Based on the management priorities for treating invasive plants that were proposed at the June, 2011, workshop, the combined occurrences from the 2009-2011 EDRR and the 2010-2011 EPMT surveys shows that most of the highest priority occurrences are near the park boundaries (Figure 46). The annual grassland in the southern half of the Mount Wanda unit is dominated by various thistles and mustard.

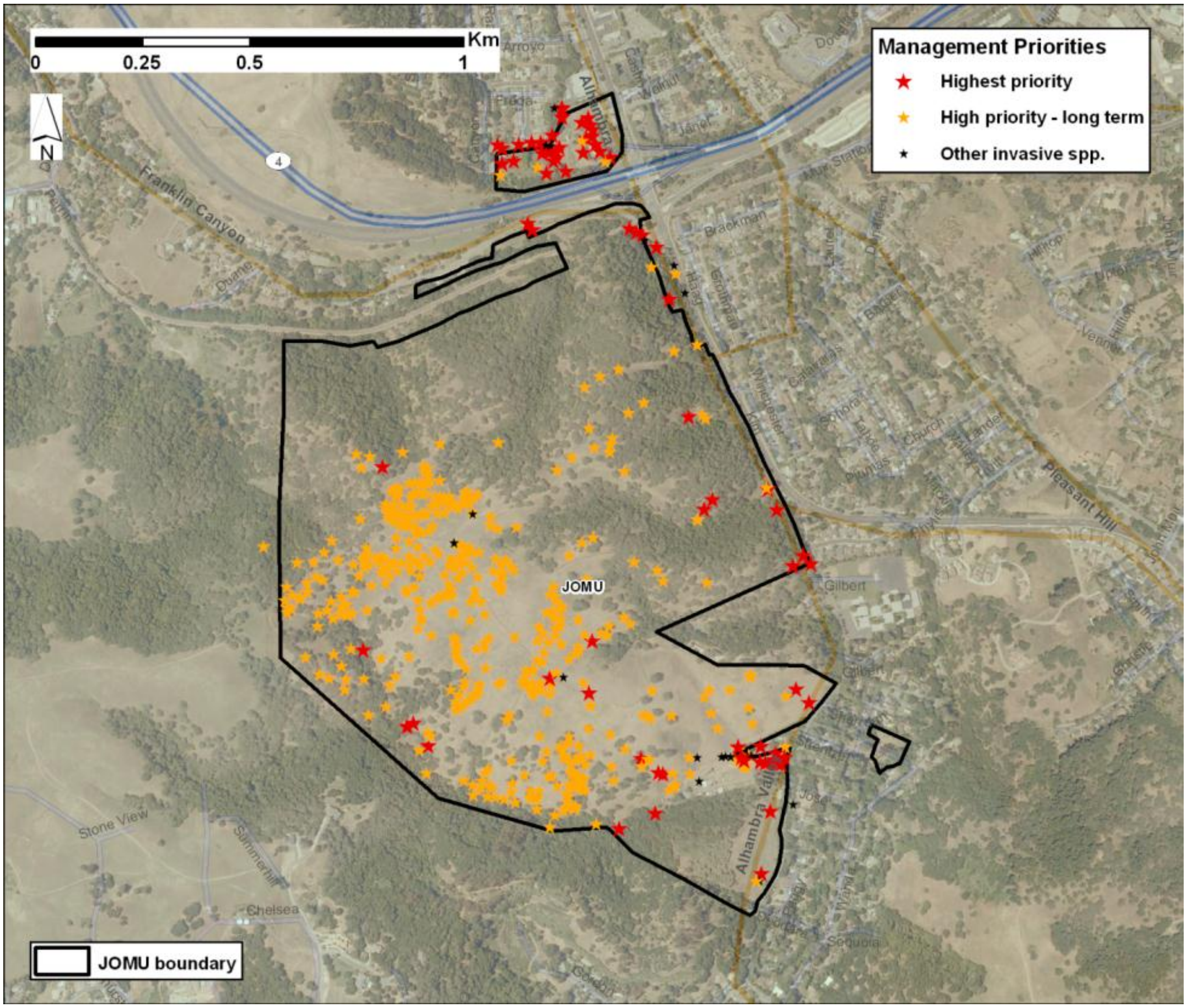

Figure 46. Map of occurrences from the EDRR and EPMT surveys of invasive plants by management priorities proposed at the June, 2011 workshop hosted by JOMU.

P. ramorum especially thrives in cool, wet climates such as coastal evergreen forests and tanoak/redwood forests within the fog belt.The best predictor of *P. ramorum* is the presence of California bay laurel (*Umbellularia californica*), which serves as a host and is abundant at JOMU. Buckeye (*Aesculus californica*), which also is found at JOMU, is another potential host. While hosts generally are not killed by the disease, they serve as a breeding ground for inoculums of *P. ramorum,* which may then be spread through wind-driven rain, water, plant material, or human activity. Wet soil and mud adhering to vehicles, equipment, and boots in infested areas can be a potential carrier of the pathogen. Best management practices call for conducting field operations during the dry season and utilizing paved and graveled roads to the extent possible. Mud and foliage from infested areas should be washed off before traveling to an uninfested area (California Oak Mortality Task Force 2002).

JOMU contains four species of oaks—*Quercus agrifolia* (coast live oak), *Quercus kelloggii* (black oak), *Quercus douglasii* (blue oak) and *Quercus lobata* (valley oak). However, only black oak and coast live oak are known to be vulnerable to SOD. No signs of SOD were detected during the 2002 survey (O'Neil 2005). The OakMapper web site (www.oakmapper.org) shows several confirmed cases of SOD (red dots) in Briones Regional Park in 2008, plus unconfirmed sightings from citizens (yellow dots) in 2002 across from the Briones Horse Center and 2003 just north of Highway 4 in Martinez (Figure 47). The location of JOMU beyond the summer fog-belt may have retarded the invasion of SOD into what is evidently prime vegetative habitat (O'Neil 2005). However, the detections in Briones Regional Park, and a confirmed detection in 2010 as far inland as Las Trampas Regional Wilderness near Danville off Interstate 680, indicates that absence of summer fog is not an assurance of immunity from SOD.

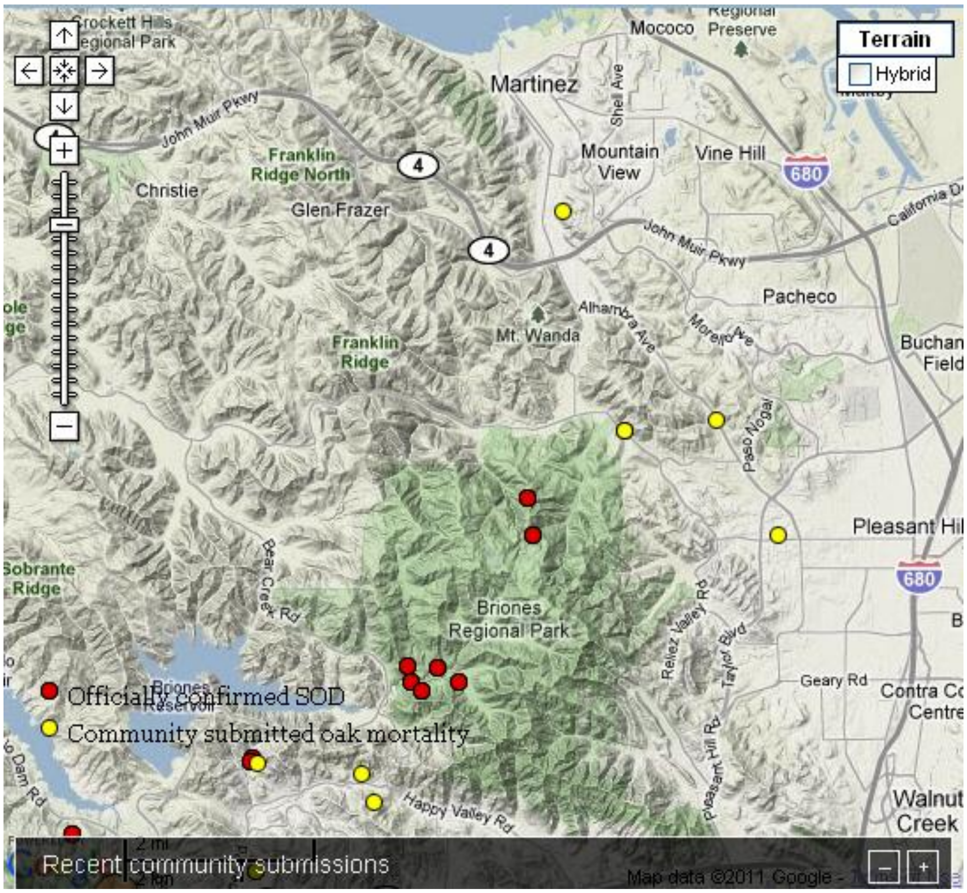

Figure 47. Map of confirmed and reported infestations of Sudden Oak Death. Source: http://www.oakmapper.org/, accessed October 31, 2011.

Emerging Issues

Globalization has increased the rate of redistribution of plants to new environments. As a major international port and destination for millions of immigrants, the San Francisco Bay Area has been a gateway for non-native introductions, including many invasive species, since at least the Gold Rush period. The Bay Area Early Detection Network (http://baedn.org/) is a collaborative partnership of regional land managers (including NPS), invasive species experts, and concerned citizens that formed in 2006 for this purpose across the nine Bay Area counties. They continually review new introductions and rate their invasiveness and priority for control.

Invasive plant management is intricately interconnected with other stressors in this region. Human activities and development disturb the land, which opens niches for invasive plants. Some horticultural and ornamental plants, such as the tree of heaven, that are common on private lands surrounding JOMU, are highly invasive and difficult to treat because they perpetually supply new seeds. Nitrogen deposition from our mechanized society artificially fertilizes invasive plants and gives them a competitive edge over natives. 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. As discussed in the Climate indicator section, temperature is expected to increase substantially in any climate scenario, while the projections for precipitation are less consistent. The section below on Future Fire Regime indicates that fire frequency is predicted to increase at JOMU in response to climate change and urban growth.

Invasive species create problems for other natural resources. They often outcompete and replace the native flora. They tend to have shallower roots than perennial grasses and forbs, and therefore are likely promoting greater erosion, gullying, and flooding, which is a serious issue in Strentzel Watershed. Italian thistle is prevalent in the dripline of oaks where they may outcompete oak seedlings and suppress their recruitment. Management of invasives faces many constraints from other social and environmental concerns. Treatment must be compatible with management of Critical Habitat for the Alameda whipsnake, and ideally should be implemented in concert with native vegetation enhancement efforts. Grazing and prescribed fire are effective tools for some invasive plants but may conflict with current NPS policies, park management, and public opinion.

Managing invasive plants is clearly a landscape-scale issue. As illustrated by the challenge of tree of heaven and thistle populations on neighboring private lands, JOMU cannot successfully treat these plants independently from other land managers. This seed source will continually re-infest the treated areas within the park unless the source itself is addressed. The JOMU staff has initiated a process involving experts and stakeholders to develop a coordinated Invasive Plant Management Strategy for the Mount Wanda unit that takes a wide view beyond park boundaries.

SOD has not been detected within JOMU but has been recently confirmed in Briones Regional Park only a few kilometers to the south. The summer fog belt may be more susceptible to the spread of SOD than drier locations such as JOMU, but the recent confirmed detection in Las Trampas Regional Wilderness suggests that JOMU may not be immune to the pathogen. The California bay laurel and buckeyes in the park are particularly good hosts for *P. ramorum*. Predictive models of areas at risk of SOD have given contradictory results for JOMU. Guo et al. (2005) predicted the woodland of the North East Bay Hills would be at risk, while Meentemeyer et al. (2004) expect relatively low risk in this area. This disease could alter the woodland-forest component of the landscape mosaic, and hence the character, of JOMU. Possible threats if SOD does spread to JOMU include a change in species composition and therefore in ecosystem functioning; loss of food sources for wildlife; a change in fire frequency or intensity; and decreased water quality due to an increase in exposed soil surfaces.

Data Gaps

A key question posed at the June, 2011, workshop was "how do you determine what the historic biodiversity was during John Muir's time?" This question about reference conditions is fundamental both for treating invasive plants and more generally for managing many of the resources at JOMU—fire, watershed, and vegetation. The workshop suggested a study of historical ecology of the park, using Muir's own journals and other accounts, historical photos, and early vegetation studies (e.g., the "Wieslander" vegetation type mapping (VTM) by the U. S. Forest Service in the 1920s and 30s, including plots and photos). The VTM collection is being digitized and made available online (http://vtm.berkeley.edu/).

Just as management of invasive plants needs to be planned at the landscape level, inventory and monitoring of the local distribution and abundance of key weeds across property boundaries will help predict and manage invasions (Bay Area Open Space Council 2011). Core areas of the invasive, and especially spreading foci, should be thoroughly mapped using GPS coordinates.

With the large number of invasives with wide distribution and varying impacts, managers need to prioritize which species to monitor and treat and which places to treat. Between the EDRR program and the results of the invasive management workshop, the species priorities are well-established. New information or new invasions may continually lead to revisions of the priorities. There are still gaps, however, in the information to prioritize places. First, the Bay Area Open Space Council (2011) recommends defining and prioritizing containment zones where the spread of invasives will be stopped, such as sensitive habitats with rare species. The workshop identified the needs to prioritize focus areas for treating Italian thistle and Milk thistle and for sites for pilot plots for native enhancement experiments in conjunction with invasive control. The Bay Area Early Detection Network uses WHIPPET, an analytical model to prioritize eradication targets based on relative impact, invasiveness, and feasibility of eradication, weighing species level, and population specific factors in the ranking (Bay Area Early Detection Network 2011), which could be a useful tool for JOMU, especially if invasive plant data from neighboring lands becomes available.

The EDRR program uses GeoWeed for documenting detection and treatment of high threat invasive plants (Williams et al. 2009). The EPMT monitoring and treatment program in the park uses a different data management approach that has changed from year to year. Invasive species monitoring and management could be more effective if the two programs shared a compatible data model.

Key references

O'Neil, S. 2005. 2002 Oak Survey of Mount Wanda, John Muir National Historic Site. National Park Service, Inventory and Monitoring Program, San Francisco Bay Area Network.

Williams, A. E., S. O'Neil, E. Speith, and J. Rodgers. 2009. Early detection of invasive plant species in the San Francisco Bay Area Network: A volunteer-based approach. Natural Resource Report NPS/SFAN/NRR—2009/136. National Park Service, Fort Collins, Colorado.

Biological Integrity—At risk biota—Alameda whipsnake
Findings: Baseline

The Alameda whipsnake (*Masticophis lateralis euryxanthus*), also known as the Alameda striped racer, is designated as a Threatened subspecies on both federal and California state lists. Its remaining, highly-fragmented distribution is in the East San Francisco Bay Area, where it prefers chaparral and coastal scrub communities interspersed with woodlands and grasslands. Much of the North East Bay Hills landscape unit has been designated as Critical Habitat; the Mount Wanda unit of JOMU lies just within the boundary of the designated area. In the absence of an on-site coordinated monitoring effort, the Alameda whipsnake has only been recorded once at JOMU. Modeling for this assessment suggests that it may serve as a potential core and movement habitat. More detailed spatial information on preferred habitat features (rock outcrops and small mammal burrows) is needed to refine the model. Many of the threats facing the recovery effort are exacerbated in and around JOMU because of its position within the urban-wildland interface. Threats from fire suppression and domestic pets are difficult management issues in such a setting. JOMU could possibly be identified in the future as part of a focus population center, which may involve JOMU in new regional coordination efforts for adaptive management, inventory, monitoring, and planning. However, the designation of Critical Habitat and the Draft Recovery Plan by the U.S. Fish and Wildlife Service did not acknowledge the NPS as one of the public land managers and stakeholders.

Approach

Information about the Alameda whipsnake (Figure 37) and its habitat preferences and threats was excerpted from the Draft Recovery Plan (U.S. Fish and Wildlife Service 2002), and the Federal Register final rule designating critical habitat (U. S. Fish and Wildlife Service 2006). The Alameda whipsnake was federally listed as Threatened on December 5, 1997. It is state-listed as Threatened in 1971. There has been one recorded sighting within JOMU to date. There have been a few individuals documented just adjacent (within approx. 1-2 miles) to JOMU. The preferred habitat types are chaparral and coastal sage scrub, but mosaics with oak woodlands and savanna and grasslands are also used. Rocky outcrops are important habitat features because they provide shelter and large populations of their primary prey, the western fence lizard (*Sceloporus occidentalis*). Preferred slope aspects are east, south, southeast, and southwest, as northerly exposures tend to be moisterwith denser canopy.

Figure 48. Photo of Alameda whipsnake. Source: USGS, WERC http://www.werc.usgs.gov/Project.aspx?ProjectID=220

Regulatory and Planning Background

The U. S. Fish and Wildlife Service designated six units as critical habitat for the Alameda whipsnake on October 2, 2006 (U. S. Fish and Wildlife Service 2006) (Figure 49 and Figure 50). Unit 1 (Tilden-Briones) contains 13,808 ha (34,119 ac) in Alameda and Contra Costa Counties, including the Mount Wanda unit of JOMU. Unit 1 closely corresponds to the core of the North East Bay Hills landscape unit (park-and-buffer area). It contains a complex mosaic of habitat types and special features preferred by the subspecies, is relatively unfragmented, and known to be occupied. Critical habitat designations are based on the best scientific data available about physical and biological features (Primary Constituent Elements, PCE) that are essential to the preservation of the subspecies and that may require special management for its recovery. Three such PCEs were identified for the Alameda whipsnake.

- PCE (1): Scrub/shrub communities with a mosaic of open and closed canopy, including chamise chaparral, which forms core habitat. This mix of sunny and shady sites provides a range of temperatures while also offering refuge from raptors and other predators.
- PCE (2): woodland and grassland plant communities contiguous to land containing PCE 1, which provides foraging, dispersal, and contact with other Alameda whipsnakes.
- PCE (3): lands within or adjacent to PCE 1 and/or PCE 2 containing rock outcrops and talus that provide shelter, hibernacula, and abundant prey; small mammal burrows that provide shelter.

According to the 2004 vegetation map (O'Neil and Egan 2004), the Mount Wanda unit contains two small patches of chamise chaparral (PCE 1) on the northern and western boundaries. Most of the Mount Wanda unit falls into PCE 2, with various oak, laurel, and buckeye stands, and annual grasslands. Burrows of gophers and other small mammals appear to be abundant (Fernando Villalba, personal communication). The critical habitat designation in the Federal Register failed to recognize NPS management in Unit 1, acknowledging only lands managed by the East Bay Regional Park District and the state as non-private (U. S. Fish & Wildlife Service 2006).

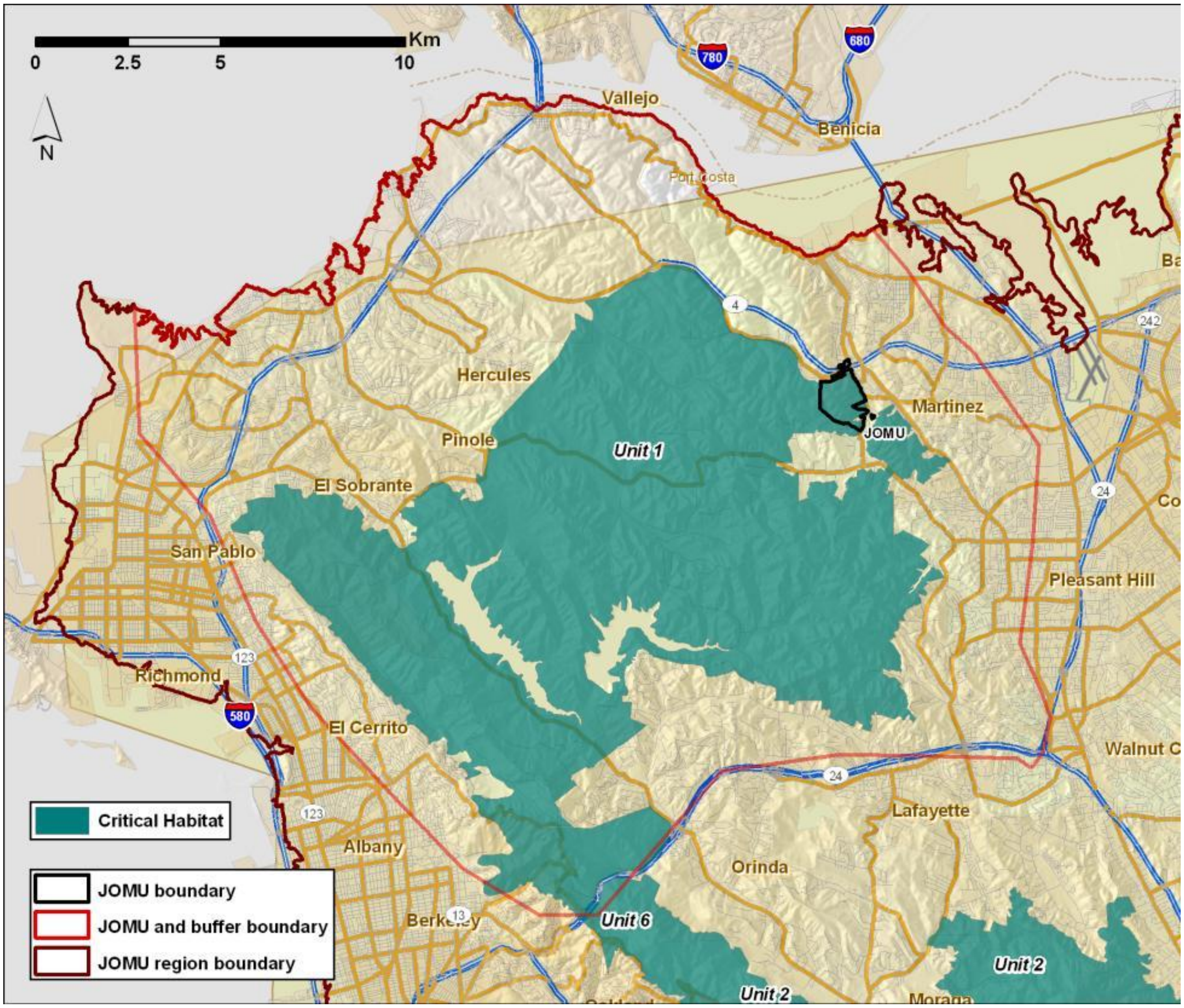

Figure 49. Critical habitat designation (park-and-buffer extent) for the Alameda whipsnake (U. S. Fish & Wildlife Service 2006).

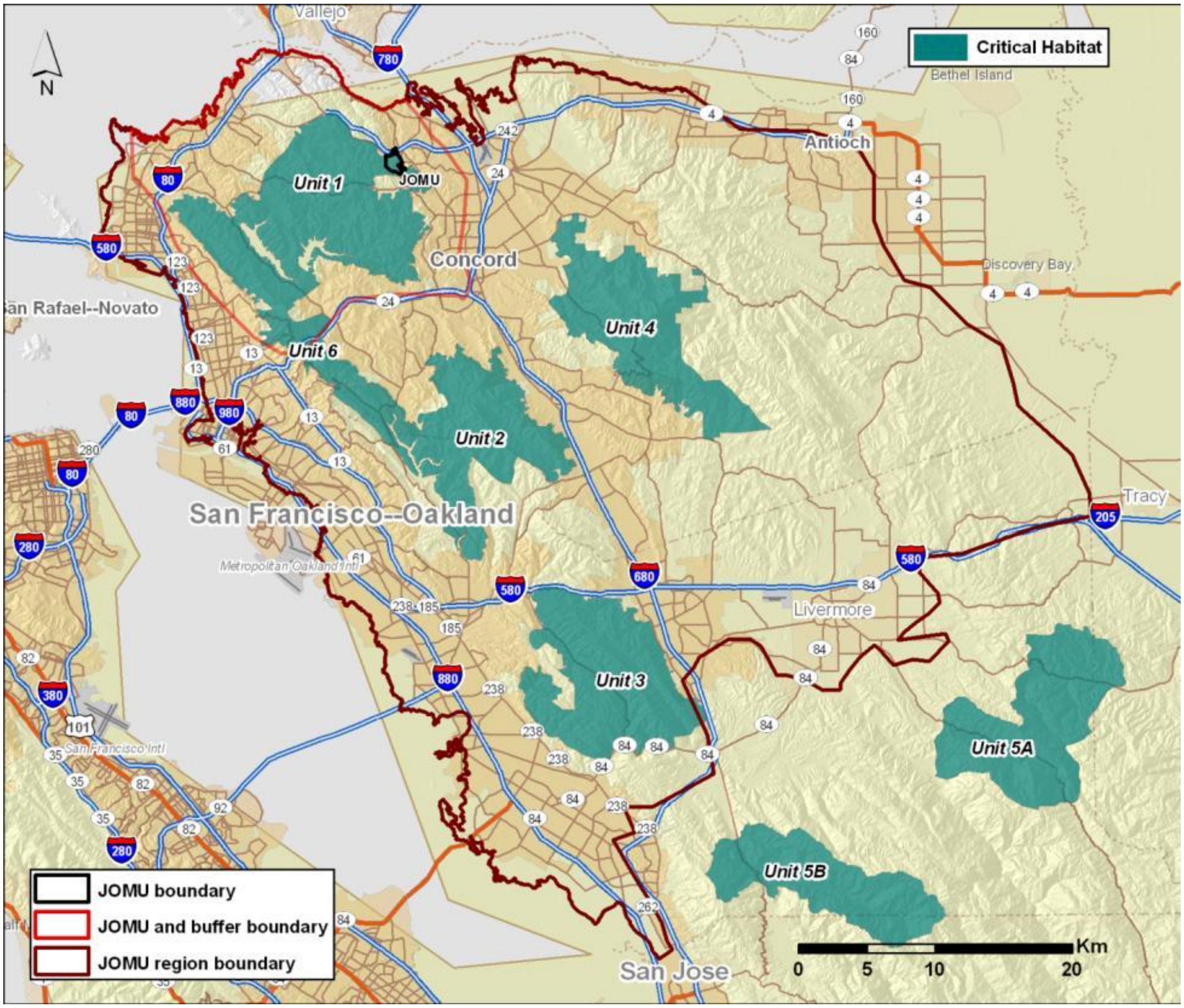

Figure 50. Critical habitat designation (full extent) for the Alameda whipsnake (U. S. Fish & Wildlife Service 2006).

In 2002, the U. S. Fish and Wildlife Service published a draft recovery plan for a suite of species in the chaparral and scrub plant communities of the East Bay region, including the Alameda whipsnake (U. S. Fish and Wildlife Service 2002). This draft plan identified the Tilden-Briones area as Recovery Unit 1 (Figure 49 and Figure 50). Note that a final recovery plan has not yet been approved after nearly a decade since the draft was published.

The East Contra Costa County Habitat Conservation Plan/Natural Communities Conservation Plan (HCP, NCCP) (Jones & Stokes 2006) protects the Alameda whipsnake and many other listed species. The HCP/NCCP area does not extend as far west as JOMU, but some of the directives for future research may provide beneficial opportunities for JOMU and the SFAN I&M program to learn from the work of potential collaborators. Specifically, the HCP/NCCP called for a monitoring approach to identify critical uncertainties about the whipsnake's requirements and behavior.

Population Threats

The various plans and critical habitat designations identify a wide variety of human-caused stressors that have most likely decreased the population of the Alameda whipsnake. The greatest threat is from urban development that destroys core habitat. In conjunction with development, the network of roads has fragmented the range, leading to the semi-isolation of the five discrete populations. Fire suppression is a stressor through two ecological pathways. First is the buildup of fuels that may eventually lead to a catastrophic fire that temporarily degrades habitat and kills individuals. The second pathway of fire suppression is that the shrub canopy becomes closed, at least until the next fire. Trees have encroached into grasslands as a result of fire suppression, leading to more closed canopies and heavier fuel loads. Overgrazing during the era of Euro-American settlement reduced density of grass cover, exposing whipsnakes to greater risk from predators. It also prevented the recolonization of grasslands by chaparral, one of the PCEs mentioned above. However, fire suppression in the late 20th century may be promoting chaparral recolonization (Keeley 2005). Recreation activities can be disruptive. Introduced species have increased predatory pressure on the Alameda whipsnake, including rats, wild pigs, domestic dogs, and feral and domestic cats. This pressure becomes especially acute where urban development abuts whipsnake habitat (U. S. Fish and Wildlife Service 2002), as is the case at JOMU. Cats also prey upon the same food sources as whipsnakes, such as lizards. EPA recently determined that rodenticides such as Bromethalin and zinc phosphide *May Affect* and are *Likely to Adversely Affect* the Alameda whipsnake from chronic toxicity and indirectly from modifying its habitat by reducing prey base and the small mammal population that excavates burrows that it uses for shelter (e.g., Mastrota and Parker 2011, Odenkirhcen and Wente 2011). Diagrammatically shown as a conceptual model, this network of stressors and pathways interact to reduce the population of Alameda whipsnake (Figure 51).

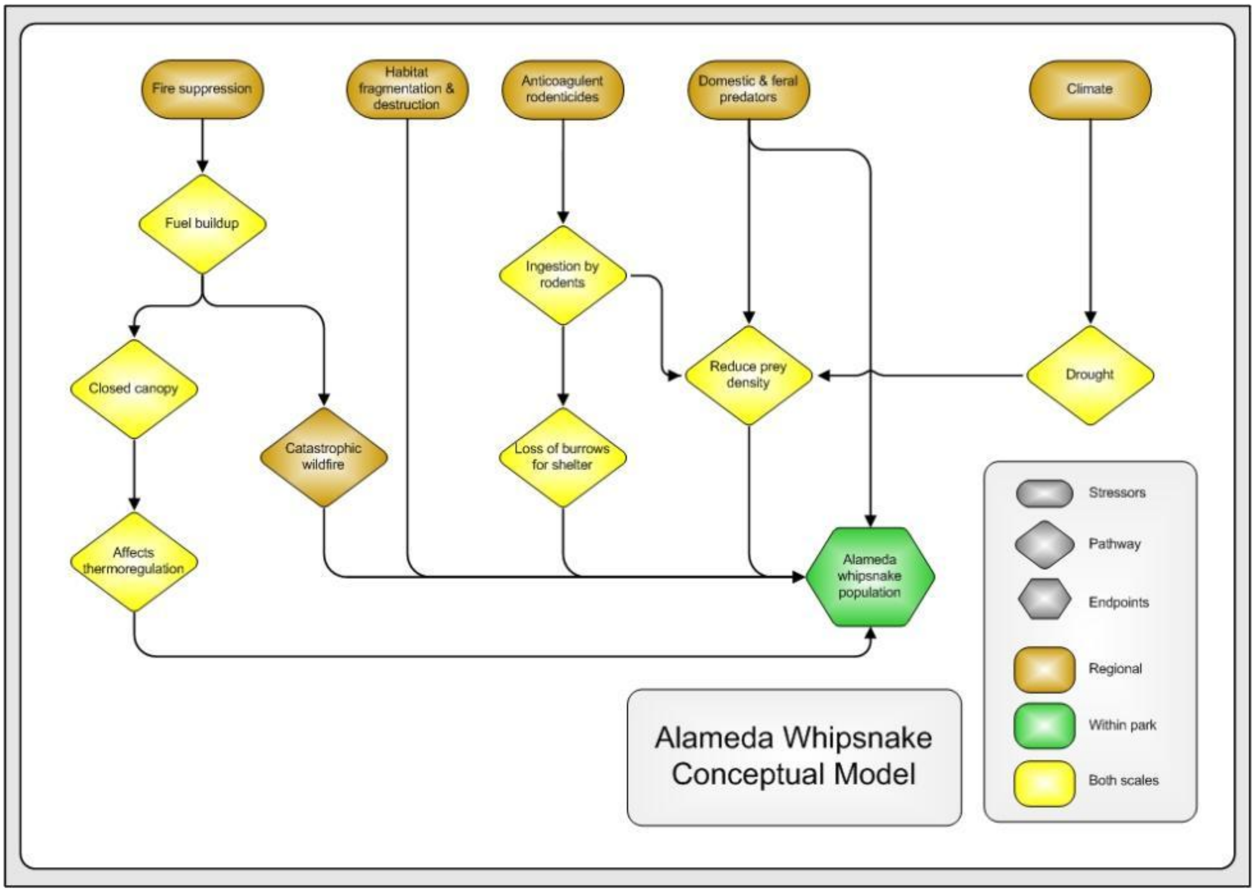

Figure 51. Conceptual model of stressors and pathways that impact the Alameda whipsnake.

Habitat Model

Visual inspection of GIS vegetation and terrain data assessed qualitatively whether JOMU contains PCEs. This assessment also sought to model the potential for core habitats and movement habitats between them. A GIS predictive model was developed for the East Contra Costa County HCP/NCCP (Jones & Stokes 2006), shown conceptually in Figure 52. That HCP/NCCP did not extend as far west as JOMU and the North East Bay Hills, so we emulated that model. Vegetation communities were taken from a regional vegetation map compiled from multiple sources for the Upland Habitat Goals Project of the Bay Area Open Space Council (2011) and the more detailed map for JOMU (O'Neil and Egan 2004). Core areas consisted of any chaparral or coastal scrub communities and a buffer of 150 meters (500 feet) of grassland, savanna or woodland of blue oak, coast live oak, Valley oak and similar types (e.g., buckeye, laurel). Movement habitat was predicted from these same grassland and woodland types, riparian areas, and streams within 1500 meters (1 mile) of core areas. Unfortunately, mapping of rock outcrops, talus, and small mammal burrows (PCE 3) is insufficient at this time to be used in the model. The percentages of core and movement habitat within Critical Habitat Unit 1 and JOMU were then summarized to determine the relative importance of JOMU.

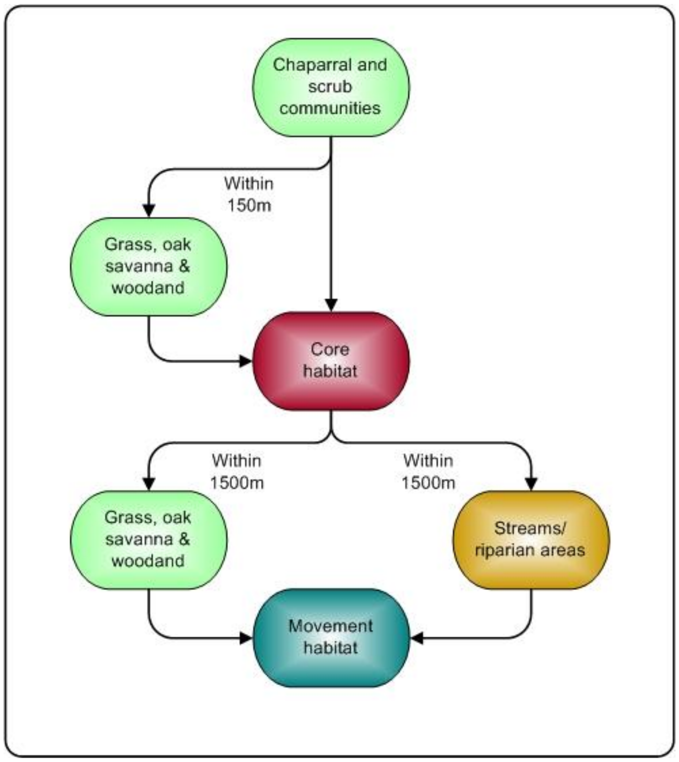

Figure 52. GIS conceptual model of core and movement habitat, based on the East Contra Costa County HCP/NCCP (Jones & Stokes 2006).

Data

- Critical Habitat designation: http://www.fws.gov/sacramento/PDFs/aw_fCH_71FR58175.zip
- CLN Vegetation: cln_veg, http://www.bayarealands.org/gis/all-datasets.php
- JOMU Vegetation: O'Neil and Egan 2004.

Status

Figure 53. Photo of Alameda whipsnake. Source: EPA.

The combined map of vegetation communities derived from JOMU's detailed map and the coarser regional map from the Bay Area Open Space Council shows that the communities most important for the Alameda whipsnake, chaparral and coastal scrub, occur in relatively small, isolated patches in the

North East Bay Hills landscape unit (Figure 54). The grassland and woodland communities of secondary importance for the whipsnake form the landscape matrix surrounding shrub patches. Most of the unsuitable lands ring the landscape unit where development has occurred. The Critical Habitat designation clearly corresponds to the urban-wildland interface, except in the north where grassland and woodland occurs outside the designated area.

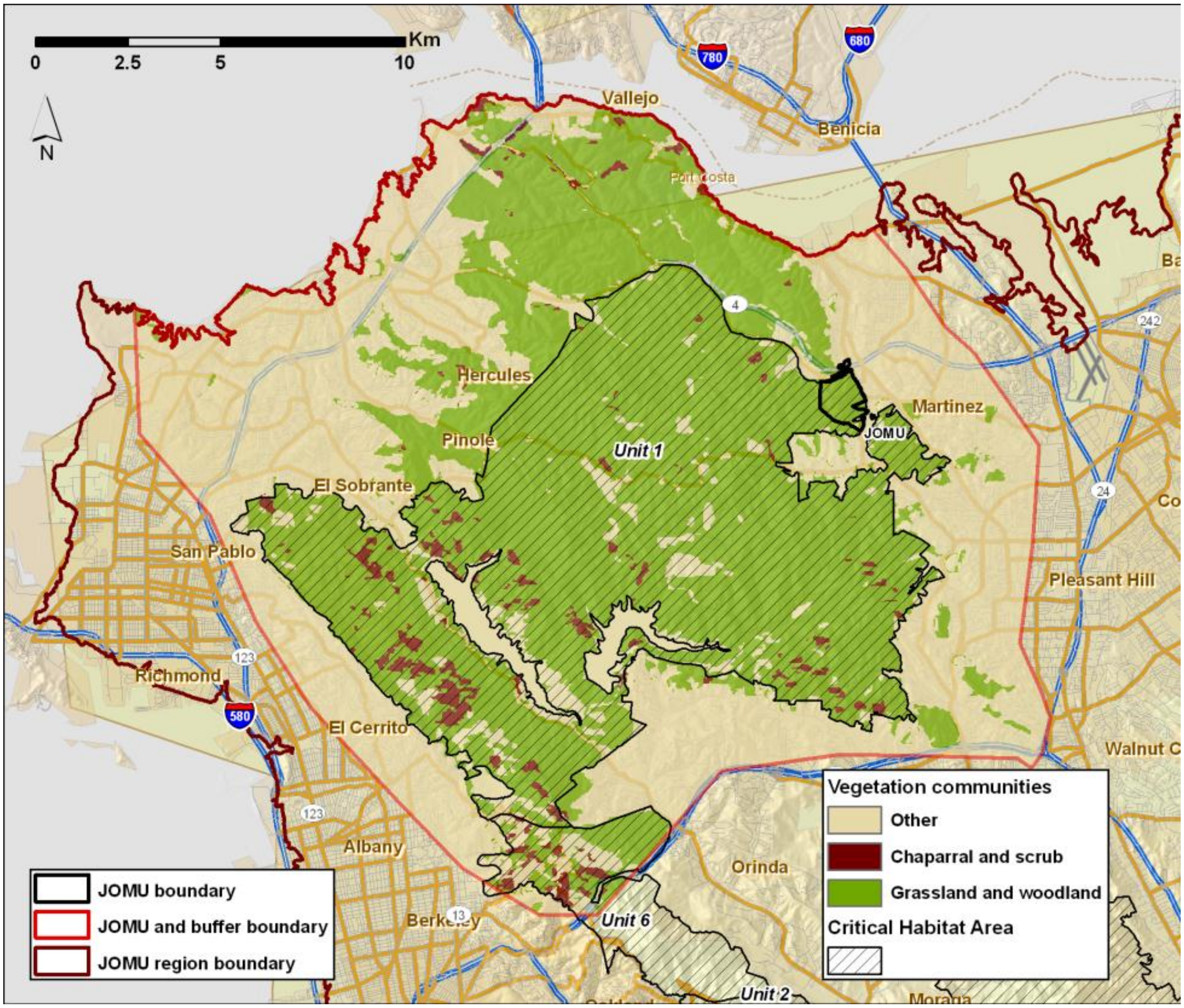

Figure 54. Vegetation communities that are important habitat for the Alameda whipsnake in the North East Bay Hills landscape unit.

The predictive habitat model identified potential core and movement habitats for the Alameda whipsnake based largely on vegetation community types and landscape configuration of patches. Two small core areas were modeled in JOMU, and virtually the rest of the Mount Wanda unit is potential movement habitat (Figure 55). At the park-and-buffer scale, the densest concentration of potential core habitat was found on the western edge in Tilden Regional Park, which the draft recovery plan targeted for one of three populations in Recovery Unit 1 (U.S. Fish and Wildlife Service 2002) (Figure 56). Except for some potential habitat in the north near Hercules and Crockett, most core and movement habitat closely follows the boundary of the Critical Habitat areas. Because of the limited spatial resolution of the vegetation/land cover data, it was not possible to identify PCE 3 features such as rock outcrops or mammal burrows. Nor have core and movement habitats been surveyed to validate GIS modeling. The maps, therefore, are only indicative of sites with potential habitat value for this subspecies. Comparing percentages of habitat classes in JOMU to Critical Habitat Unit 1, the proportion of habitat classes is similar except that JOMU has a lower percentage of core habitat and a larger percentage of movement habitats (Figure 57).

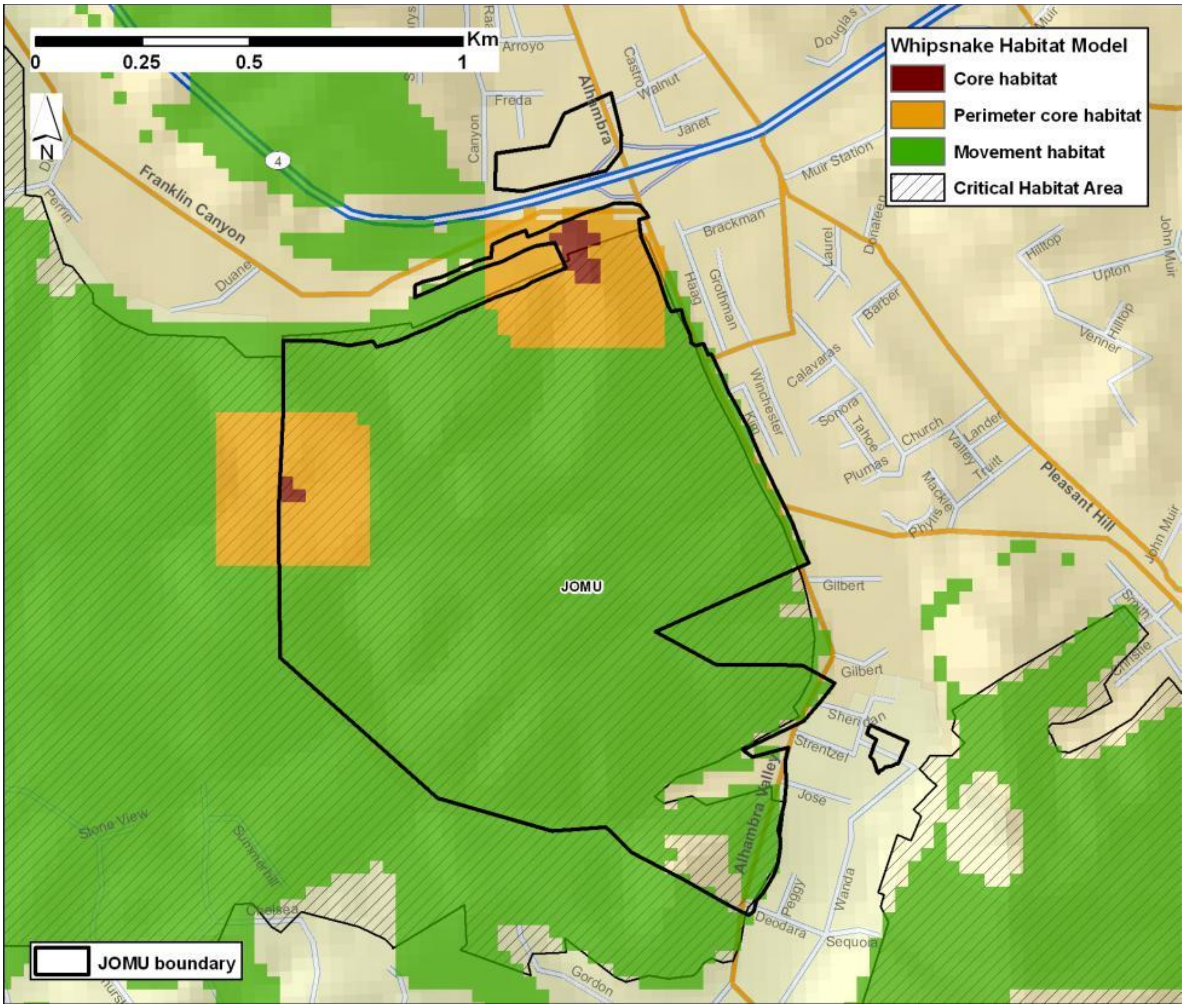

Figure 55. Modeled habitat distribution for the Alameda whipsnake in JOMU.

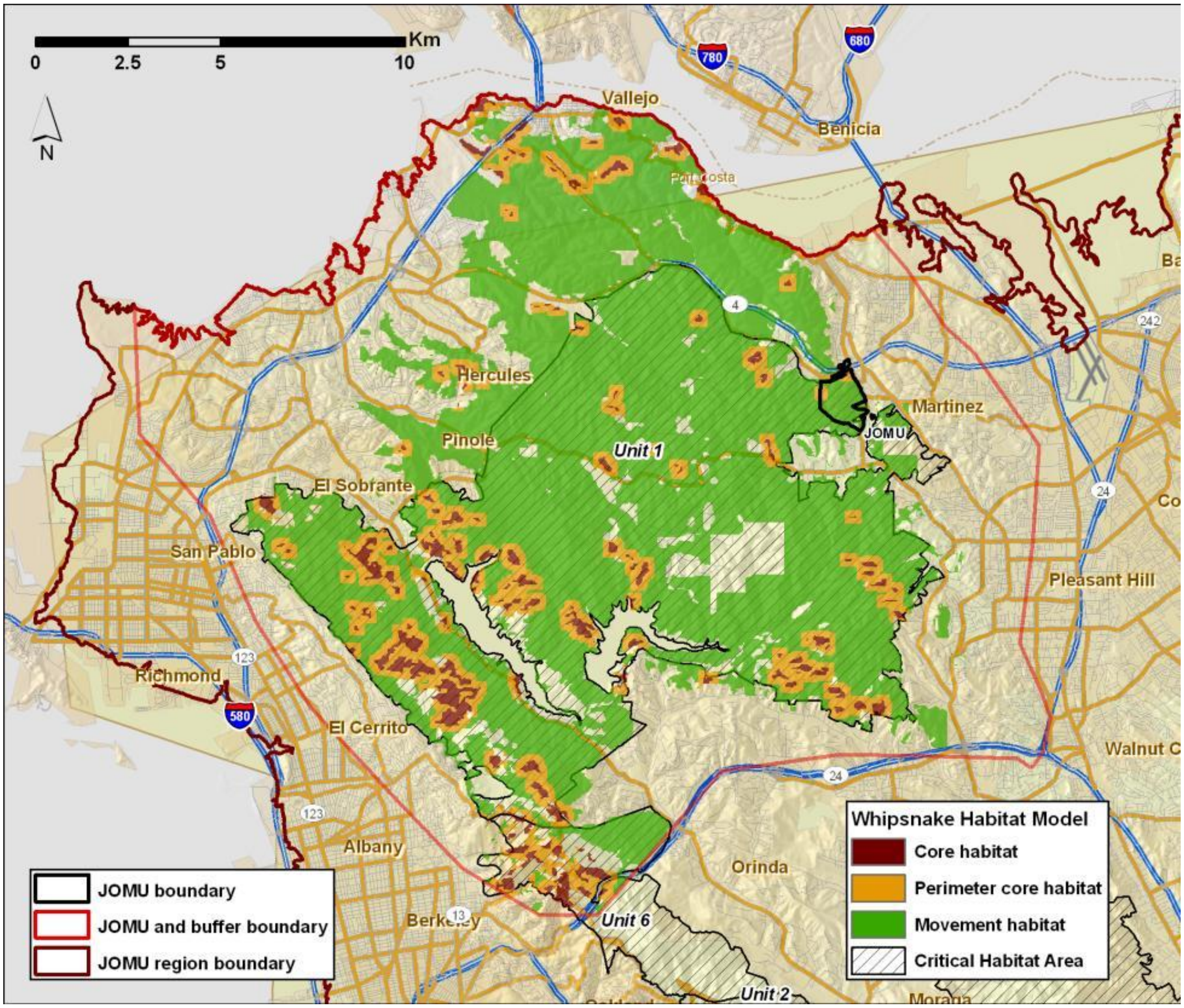

Figure 56. Modeled habitat distribution for the Alameda whipsnake in the North East Bay Hills landscape unit.

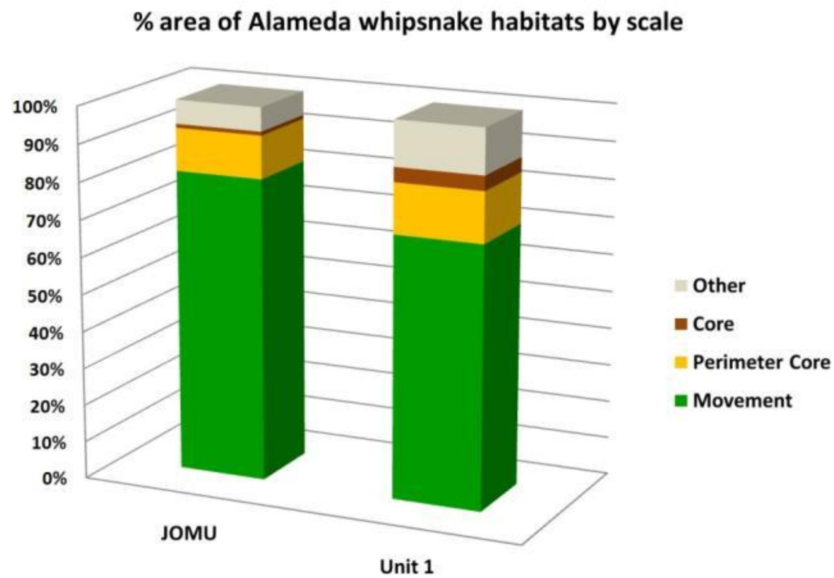

Figure 57. Bar chart of percent area of habitats for the Alameda whipsnake by scales.

The southern half of the Mount Wanda unit contains much of the east to southwest facing slopes preferred by the Alameda whipsnake (U. S. Fish and Wildlife Service 2006), but it tends to be in the southern half of the unit rather than where the potential core habitat occurs (Figure 58). However, as with the vegetation data, the resolution of the terrain data may limit the identification of small suitable slope facets.

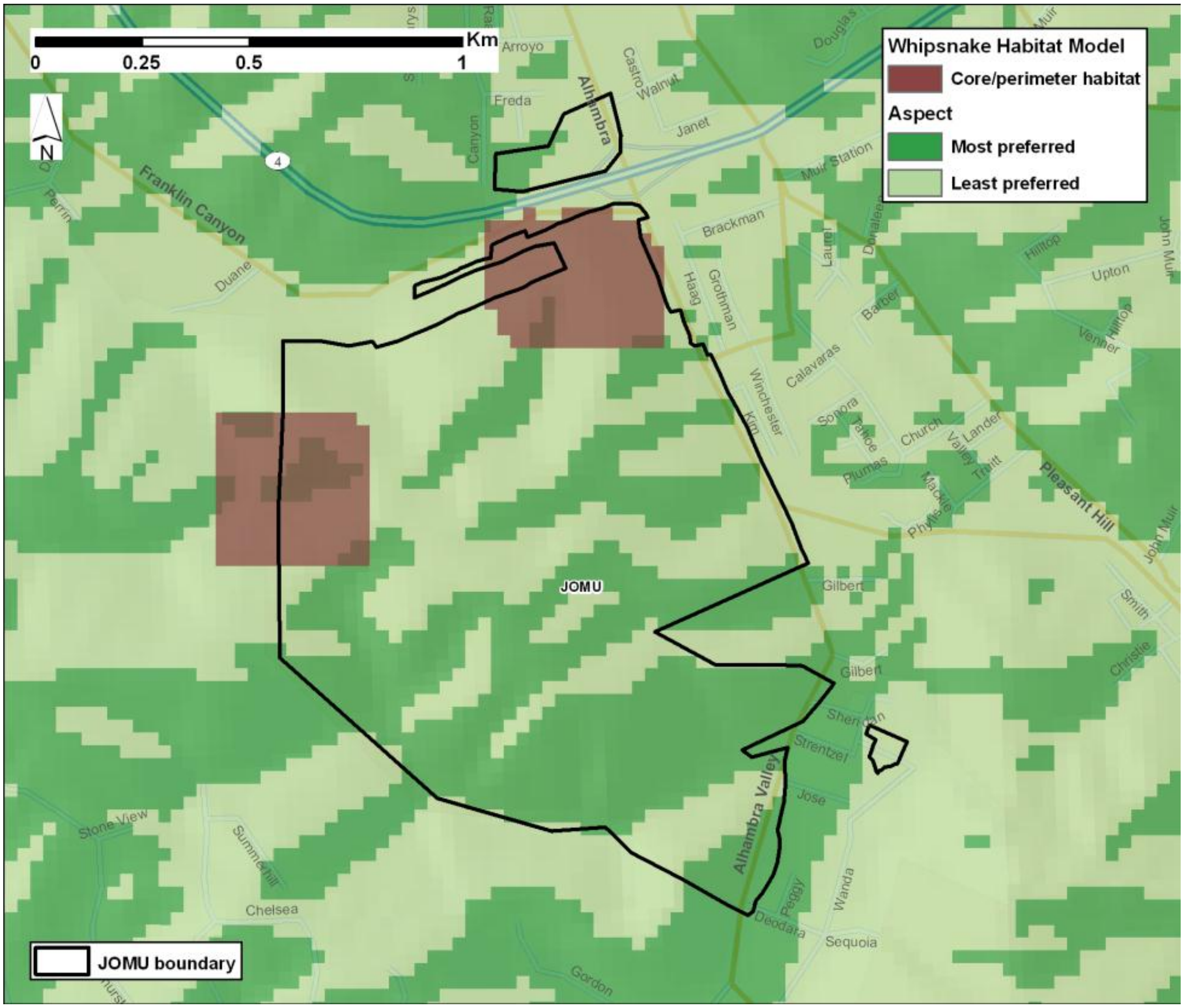

Figure 58. Slope aspects preferred by the Alameda whipsnake in JOMU.

Emerging Issues

The draft recovery plan identified the need for surveys to determine appropriate site-specific areas for recovery actions for the Alameda whipsnake (U. S. Fish & Wildlife Service 2002). In addition to the known Alameda whipsnake population in Tilden Regional Park, the recovery plan calls for two other population centers and linkages between the three centers to be identified through mapping, assessment, and surveying. These focus areas should ideally be on public lands to the extent practical. Lands outside of focus areas may also be essential. Therefore it is possible that JOMU may become an actor in the recovery effort (even though NPS was not listed as a large land manager in Recovery Unit 1), especially given that there has been a recorded occurence with the unit. Being in a Critical Habitat area, and the possibility of being identified in the future as part of a focus population center, may involve JOMU in new regional coordination efforts for adaptive management, inventory, monitoring, and planning. Such a role could obligate JOMU to undertake new management actions or constrain actions to achieve other park objectives such as recreation and education. The critical habitat designation (U. S. Fish & Wildlife Service 2006) identified special management actions to maintain a vegetation mosaic of open/closed canopy habitats and other PCEs. These potential actions include prescribed burning to reduce fuel loads and risk of catastrophic fire caused by fire suppression, and management of introduced predators associated with the urban-wildland interface.

Data Gaps

Only one sighting of the Alameda whipsnake has been documented within JOMU to date. An inventory was conducted at JOMU in 2003 to document vertebrate species, including reptiles, but it is important to note that there has never been a comprehensive survey done at JOMU specifically for reptiles, or for the Alameda whipsnake . Furthermore, the vertebrate inventory conducted in 2003 involved the placement of plywood boards on the ground for surveying reptiles, which is a passive monitoring approach. Previous work and this assessment have shown that JOMU possesses potential habitat for this subspecies, but at this time, it is unknown to whether the species uses park lands to support a resident population or simply as extended foraging habitat and corridor.

The vegetation data in the habitat model adapted from Jones & Stokes (2006) could not discriminate open and closed shrub and tree canopy because of the level of classification used. It is known that the subspecies prefers a mosaic of open and closed canopy, and that homogeneously closed canopy is not desirable. The presence of small rock outcrops has also not been mapped at JOMU or elsewhere in the Critical Habitat unit. Future recovery planning will require this level of detail.

The East Contra Costa County HCP/NCCP proposed refining the Alameda whipsnake model. As noted in the Habitat Connectivity section, the Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity. These and related efforts may help provide improved information for JOMU or be opportunities for collaboration. Similarly, the East Contra Costa County HCP/NCCP outlined a monitoring program for this subspecies in which JOMU and/or the San Francisco Bay Area Network of I&M may wish to collaborate. Specific data gaps that were identified include the use of grassland for foraging/breeding; habitat function of chaparral; and the response to fire and prescribed burning. All plans call for adaptive management because of large uncertainties about the ecology and response of the Alameda whipsnake.

Key references

Jones & Stokes. 2007. East Contra Costa County Habitat Conservation Plan and Natural Community Conservation Plan, with 12/19/06 Corrections and Updates Included. (J&S 01478.01.) San Jose, CA.

U.S. Fish and Wildlife Service. 2002. Draft Recovery Plan for Chaparral and Scrub Community Species East of San Francisco Bay, California. Region 1, Portland, OR. xvi + 306 pp.

U. S. Fish and Wildlife Service. 2006. Designation of Critical Habitat for the Alameda Whipsnake; Final Rule. Federal Register, 71 FR 58176-58231. Online at http://www.gpo.gov/fdsys/search/citation.result.FR.action?federalRegister.volume=2006&federalRegister.page=58176&publication=FR. Accessed 09/06/11.

Landscapes (Ecosystem Pattern and Processes) Level 1 Category

Landscapes—Fire and fuel dynamics—Fire regime
Findings: No significant change

Lightning fires are relatively rare in this region so most fires are human-caused. Only ten mapped fires ≥ 100 acres were recorded in the North East Bay Hills landscape unit since 1961, all human-caused. Aggressive fire suppression limited the burned area to 5175 acres, with the largest fire being 657 hectares. Erosion potential following wildfire is strongly influenced by the expected change in vegetative density. Because erosion in Strentzel Watershed is already a management concern, we examined this indicator in the context of fire as well, although it should only be considered a first approximation of erodibility. The largest percentage of non-urban/water area at all scales is in the Moderate class, but is highest at JOMU. The area of high erosion potential ranges from 4-6% at all scales, so is relatively uncommon in this part of California.

The fire regime of the JOMU area has been strongly influenced by human cultures for thousands of years and has changed considerably over the past several centuries. Pre-European fire frequency is not well documented in the local area, but California Native Americans have been well-documented to periodically apply fire for various reasons, such as promoting grassland-dominated mosaics to improve access to resources such as acorns and other seeds (Anderson 2006). It is thought that similar activities likely occurred on JOMU land before European colonization (Hunter et al. 1993, Moore 2006). With the expansion of Mexican livestock ranching in the early 19th Century, fire frequency probably decreased but heavy livestock grazing maintained a level of disturbance sufficient to prevent grasslands from being recolonized by chaparral. Fires remained common and the frequency of large accidental wildfires increased during the latter half of the 19th Century, associated with increased economic activity and Anglo-American traffic in the region. Since the second quarter of the 20th Century active fire suppression has lengthened mean fire-free periods in all vegetation types compared the 19th Century and Pre-European fire regimes. Reduced frequency of fire in the region has been associated with a reduction in grassland accompanied by expansion of chaparral and coastal scrub (Keeley 2005). Using fire and vegetation patterns during Muir's residency here as reference conditions would be based on high levels of human-caused disturbance from fire and grazing to maintain grasslands. Grazing has recently been suspended in Mount Wanda, and fire policy requires prompt suppression in the wildland-urban interface. Therefore it is not clear how such disturbance can be mimicked today.

Approach

Fire is a complex process, involving climate, weather, terrain, vegetation, and proximity of human settlement. Key factors in a condition assessment include frequency or rotation, degree of deviation from the presettlement or "natural" fire regime representing potential damage to ecosystem processes and health, and the potential erosion vulnerability following wildfire.

Fire history data from 1878 through 2010 were obtained from the California Department of Forestry and Fire Protection (California Department of Forestry and Fire Protection 2011). The fire perimeters include both public and private lands and are consistently recorded for fires larger than 300 acres. The database is considered much less complete prior to 1950, especially for private lands. This database of large fires was supplemented with point locations of small fires from CDF&FP and from the Wildland Fire Management Information (WFMI) database. The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) has also modeled a number of fire-related indicators that are represented as a conceptual model (Figure 59). Several of these indicators were summarized at the three reference scales for the JOMU condition assessment.

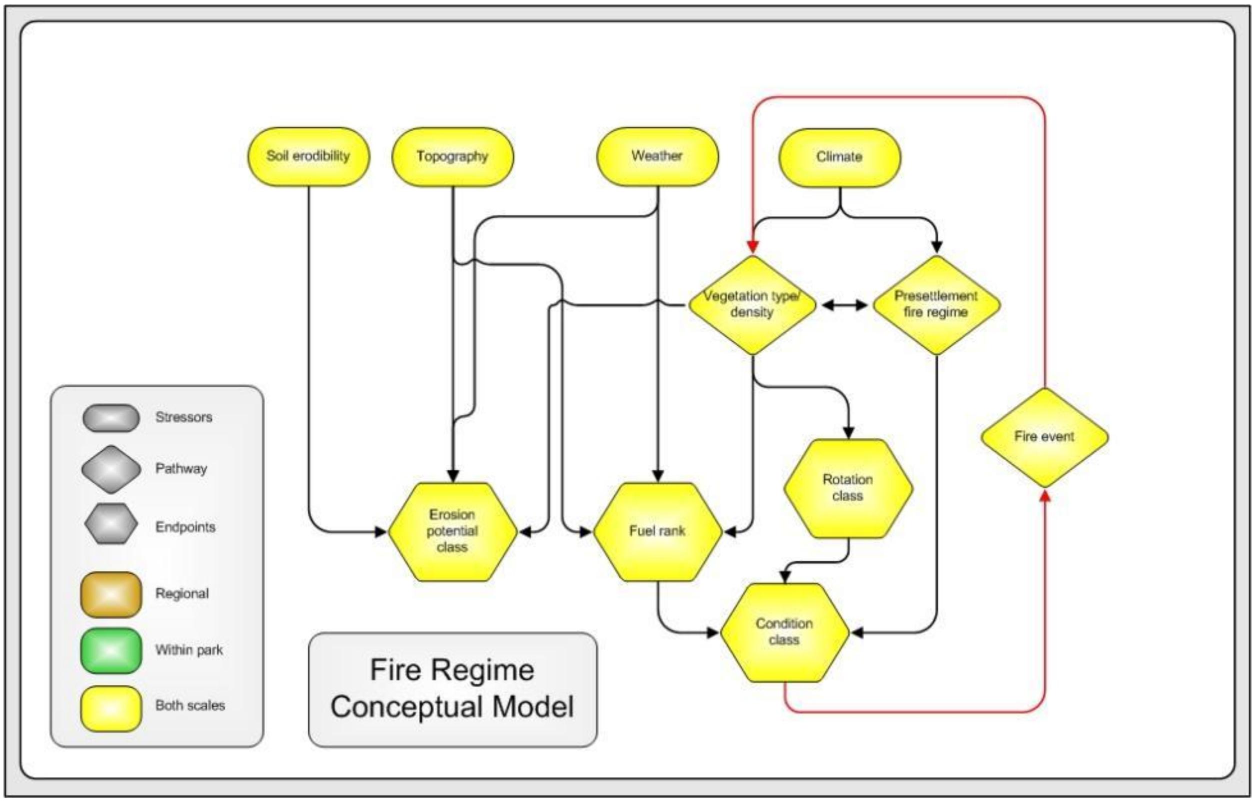

Figure 59. Conceptual model of the fire regime with endpoint indicators, based on modeling by FRAP. The red arrow indicates potential damage to the ecosystem from a fire if the current condition is altered from the presettlement fire regime.

FRAP's followed the National Fire Plan concepts (Schmidt et al. 2002) with spatial data specific to California to describe fire-related risks to ecosystems (Fire and Resource Assessment Program 2003). Fuel Rank assessment methodology assigns ranks based on expected fire behavior for unique combinations of topography and vegetative fuels under a given severe weather condition (wind speed, humidity, and temperature). Rotation Class is based on fire rotation or the number of years it would take for past fires to burn an area equivalent to the area of a given "stratum," defined by vegetation type, climate, and land ownership. Short rotations correspond to high fire frequency. The pre-settlement fire regime is an approximation of the "historical" fire frequency and burn severity that was believed to occur prior to Euro-American settlement, i.e., prior to 1700 (Fire and Resource Assessment Program 2003). It is classified into five regimes, plus classes for non-vegetated lands and water. Condition Class is a qualitative measure that of the departure or deviation of ecosystems from their pre-settlement natural fire regime and can be interpreted as a measure of sensitivity to fire damage to key elements and processes typical of those ecosystems (Table 15). Disruption of fire regimes leads to changes in plant composition and structure, uncharacteristic fire behavior and other disturbance agents (pests), altered hydrologic processes and increased smoke production. Condition Class is useful for determining areas in need of mitigation measures designed to improve ecosystem resilience and health when subjected to effects from wildfire. It is not clear if burning by Native Americans was accounted for explicitly in either the baseline fire regime or as part of the deviation. One of the impacts of fire, particularly in altered ecosystems, is a greater risk of soil erosion when vegetative cover is burned off. FRAP applied the Revised Universal Soil Loss Equation to estimate erosion amount based on soil erodibility, slope, cover, and rainfall-runoff erosivity. Erosion rates were grouped into three classes of Low, Medium, and High potential.

Table 17. Descriptions of Condition Classes developed by FRAP to indicate deviation from presettlement fire regimes and risk of loss to key ecosystem components (indicated by the red arrow in the conceptual model in Figure 59).

Condition Class	Description
1	Fire regime within or near historical range. Risk of key ecosystem component loss low.
2	Fire regime moderately altered from historical range. Risk of key ecosystem component loss moderate.
3	Fire regime significantly altered from historical range. Risk of key ecosystem component loss high.
9	None Assigned (non-wildlands)

Data

All GIS data were accessed from FRAP on 10/24/11.

- Fire perimeters 1895-2010, http://frap.cdf.ca.gov/data/frapgisdata/download.asp?rec=fire, published 2011.
- Wildland Fire Management Information (WFMI) database of fire locations, provided by NPS.
- Fire Rotation, http://frap.cdf.ca.gov/data/frapgisdata/download.asp?rec=frot, published 2006.
- Fire Regime and Condition Class, http://frap.cdf.ca.gov/data/frapgisdata/download.asp?rec=cafrcc, published 2003.
- Post Fire Erosion Potential, http://frap.fire.ca.gov/data/frapgisdata/download.asp?rec=perod, published 2004.

Status

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

Ten mapped fires ≥ 100 ac were recorded in the fire perimeters database completely or partially within the North East Bay Hills landscape unit. These fires burned 2094 hectares (5175 acres), the largest being 657 hectares (Figure 60). No fires were recorded within JOMU from the start of the database in 1878, including the Mount Wanda unit. Seven fires were along State Highway 4 near JOMU, however. All fires were either human-caused from powerlines, railroads, or equipment use, or the source was undetermined or unknown. Thirty-two additional small fires were recorded by CDF&FP between 1994-2006. These fires were less than 170 acres, with a mean of 13.2 acres. A single human-caused fire (0.1 acre) was recorded within JOMU in the WFMI database in 2004 on the northern boundary of the Mount Wanda unit. The FRAP fire rotation map shows that JOMU and most of North East Bay Hills has a 151 year rotation, with annual probability of 0.00661.

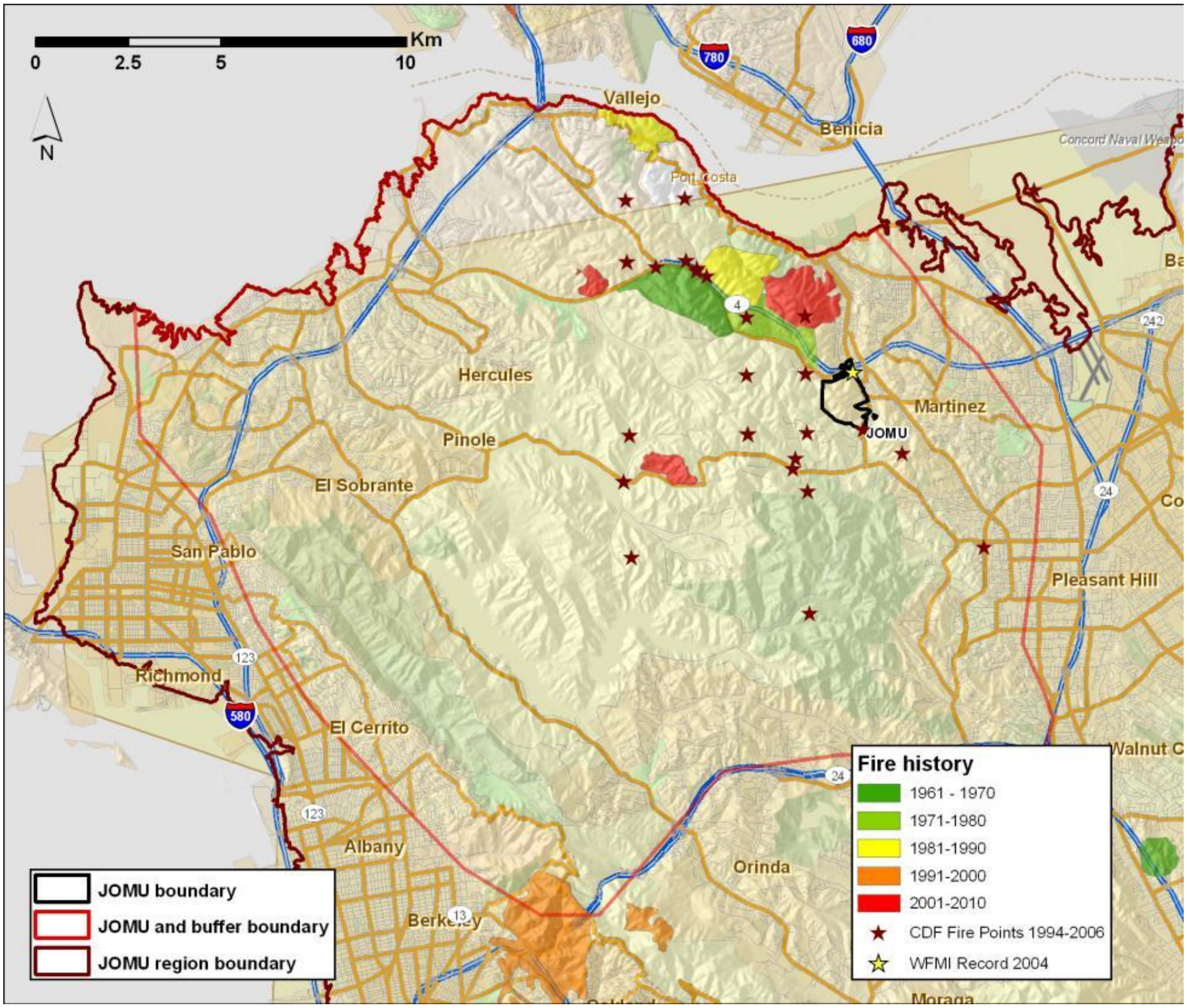

Figure 60. Fires recorded from 1950 through 2010 in the CDF&FP fire perimeters database (California Department of Forestry and Fire Protection 2011), point locations from CDF&FP of small fires from 1994 through 2006, and a single fire location from 2004 within JOMU from the Wildland Fire Management Information database.

The FRAP map of Fire Regime and Condition Class modeled the general deviation of ecosystems from their presettlement natural fire regime (Figure 61), in part based on vegetation type and structure. In the North East Bay Hills landscape unit and region, annual grassland was modeled as Class 1 in which fire was believed to be within historical range with minimal disturbance, even though the plant community itself was highly altered from the native perennial grasses. Grasslands were categorized as low hazard and fire severity because of their simple structure, with relatively high fire frequency (< 35 years, Regime I). Oak woodland and shrub types within the region were modeled as Class 2 or moderate departure from natural regimes, with associated changes in ecosystem composition and structure that render future fires likely to cause some loss and change in elements and processes. These types are higher hazard and fire severity than grasslands, and have a lower fire frequency (35-100+ year, Regime III). Within JOMU, these two classes occur in equal proportions with a small percentage of urban land (Figure 62). At the park-and-buffer scale, the proportions of the two classes are again equal but nearly half the area is non-wildlands/urban. Half of the reference region is also non-wildlands/urban, but a larger proportion is in Class 1 because of the predominance of grassland further inland from the coast. At both these scales, a tiny fraction is also modeled as Class 3 or Significantly Altered in conifer stands, but none occur within JOMU.

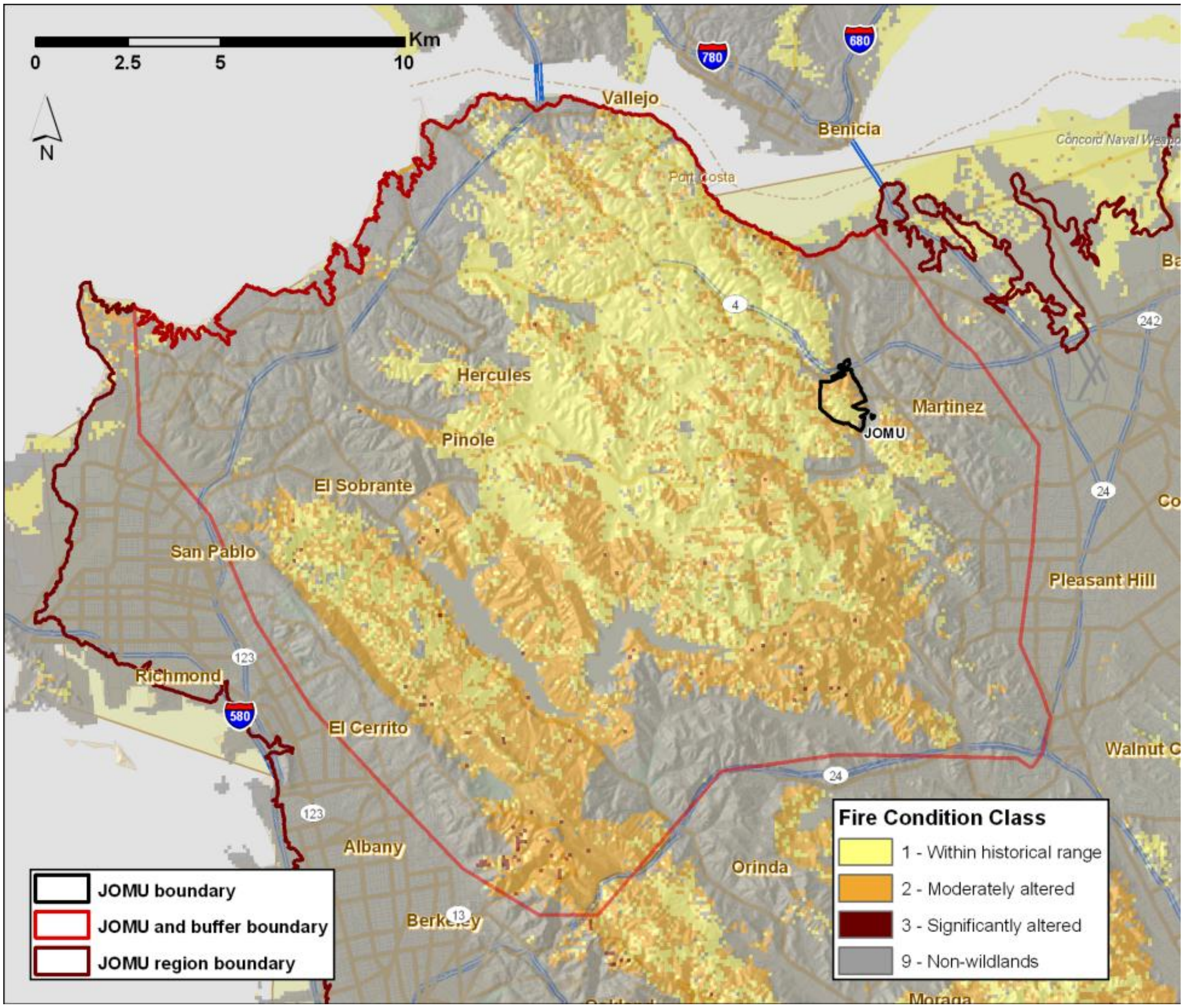

Figure 61. Condition class showing the general deviation of ecosystems from their presettlement natural fire regime at the park-and-buffer scale. See Table 15 for explanation of the classes.

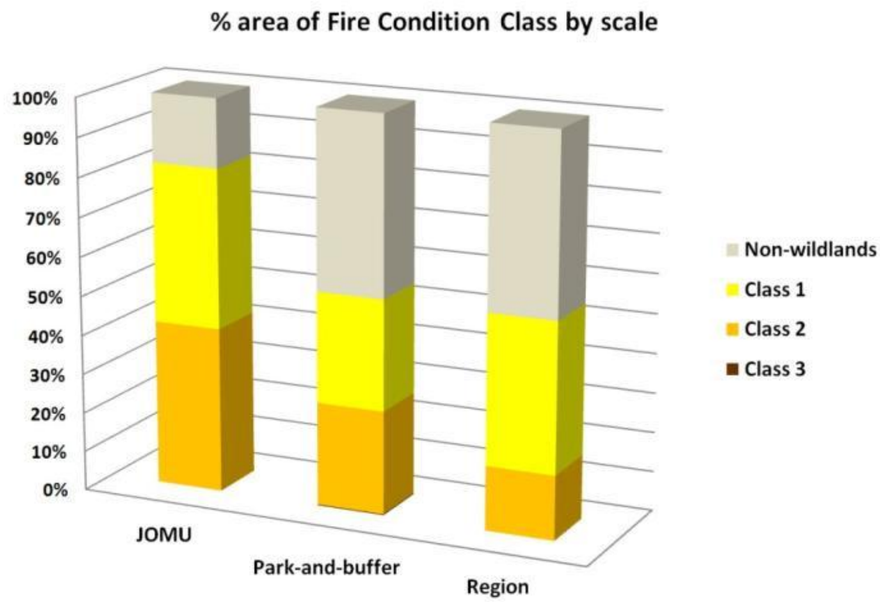

Figure 62. Comparison of Fire Condition Class distribution across scales. See Table 15 for explanation of the classes.

FRAP modeled the erosion potential following wildfire with the Revised Universal Soil Loss Equation. Because erosion in Strentzel Watershed is already a management concern, we examined this indicator in the context of fire as well. The key component related to fire was the change in vegetative density expected from fire. As seen in Figure 63, erosion potential following fire is lowest where slope is relatively flat. The largest percentage of non-urban/water area at all scales is in the Moderate class (Figure 64). High erosion potential ranges from 4-6% at all scales, so is relatively uncommon in this part of California. The FRAP metadata cautions that this model only provides a first approximation of erodibility and only accounts for the direct contribution of wildfire, omitting other land uses that expose soil to rainfall, such as roads.

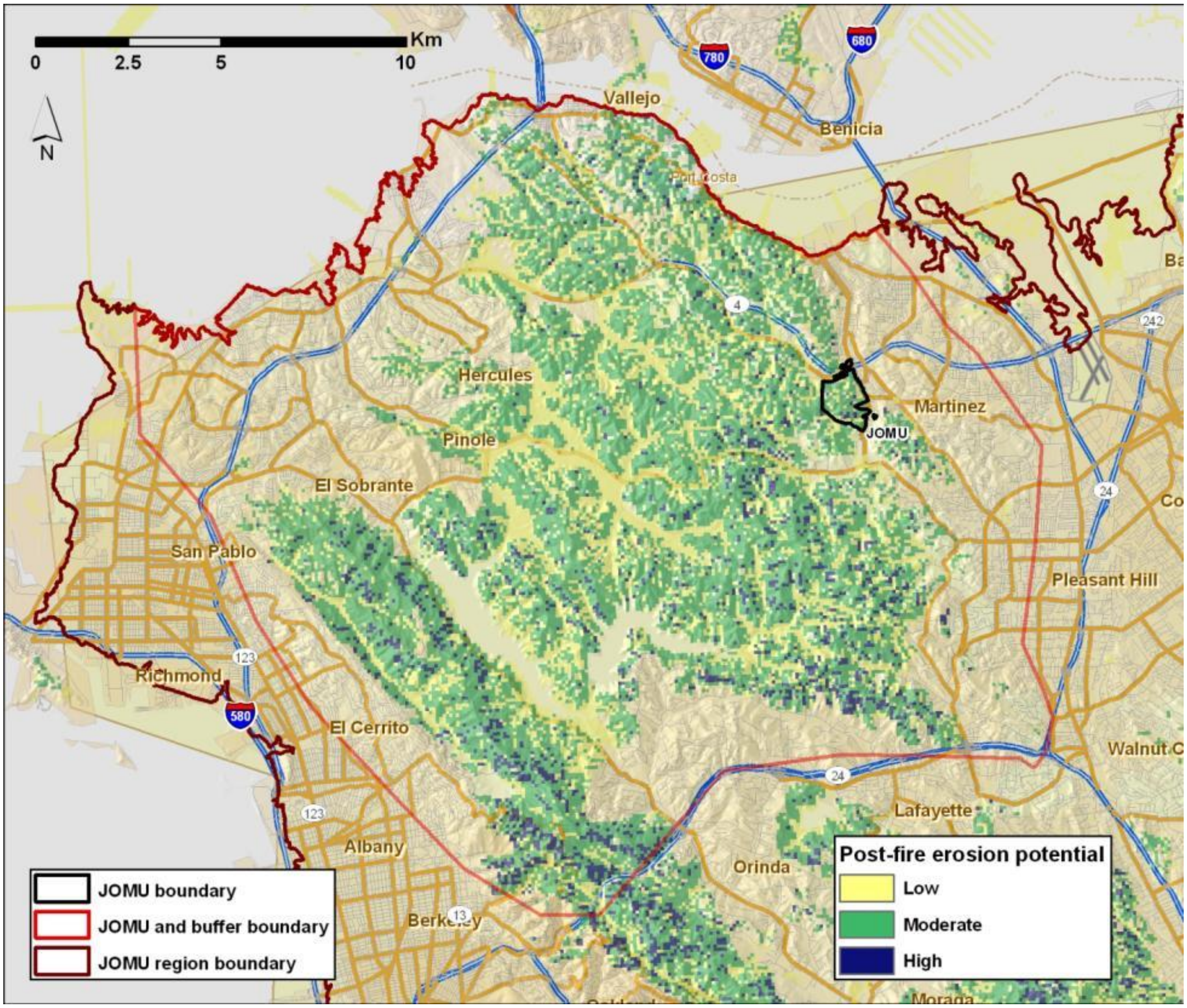

Figure 63. Post-fire soil erosion potential at the park-and-buffer scale.

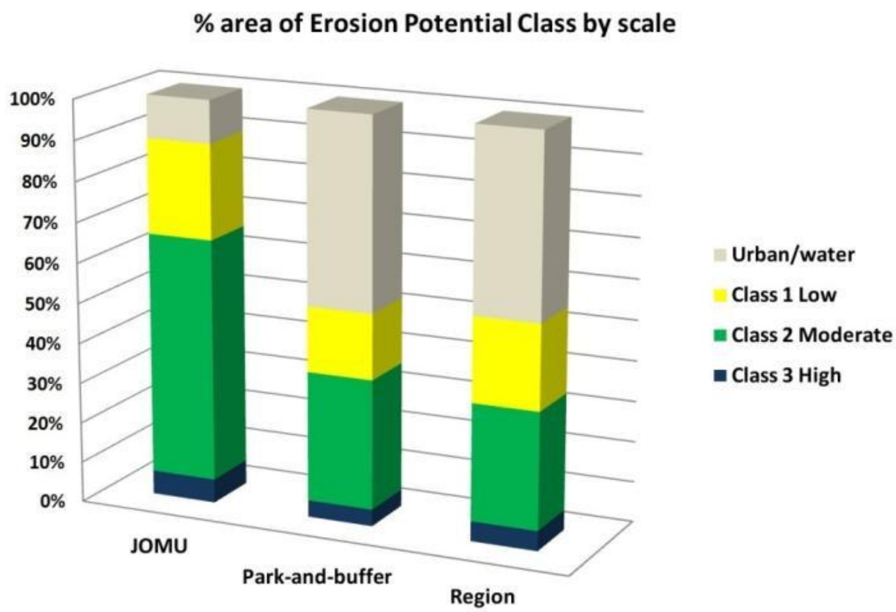

Figure 64. Comparison of postfire erosion potential class distribution across scales.

<u>Park scale:</u>

Zooming in to the park scale, the pattern of Fire Condition Classes becomes clearer (Figure 65). In general, grasslands are classified as Class 1, while woodland-forest and shrubland areas are in Class 2. Some cells around the boundaries of the Mount Wanda unit were mapped as part of the urban and non-wildland class.

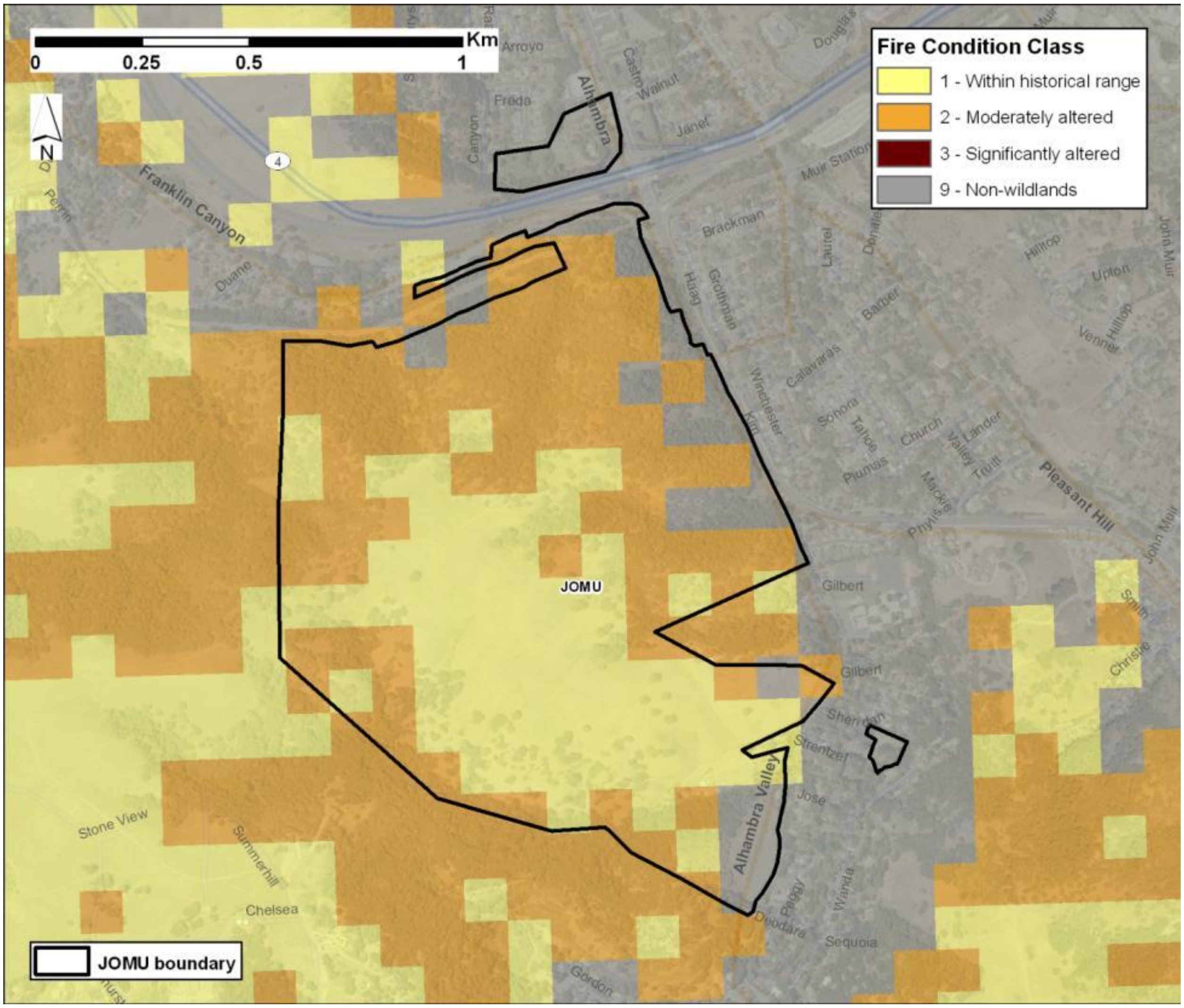

Figure 65. Condition class showing the general deviation of ecosystems from their presettlement natural fire regime at the park scale. See Table 1 for explanation of the classes.

The local pattern of post-fire erosion potential is more complicated (Figure 66) than that of Condition Class. The general rating for Mount Wanda is Moderate, with scattered cells rated Low or High. This heterogeneity is caused by the interaction of factors of soils, slopes, and cover.

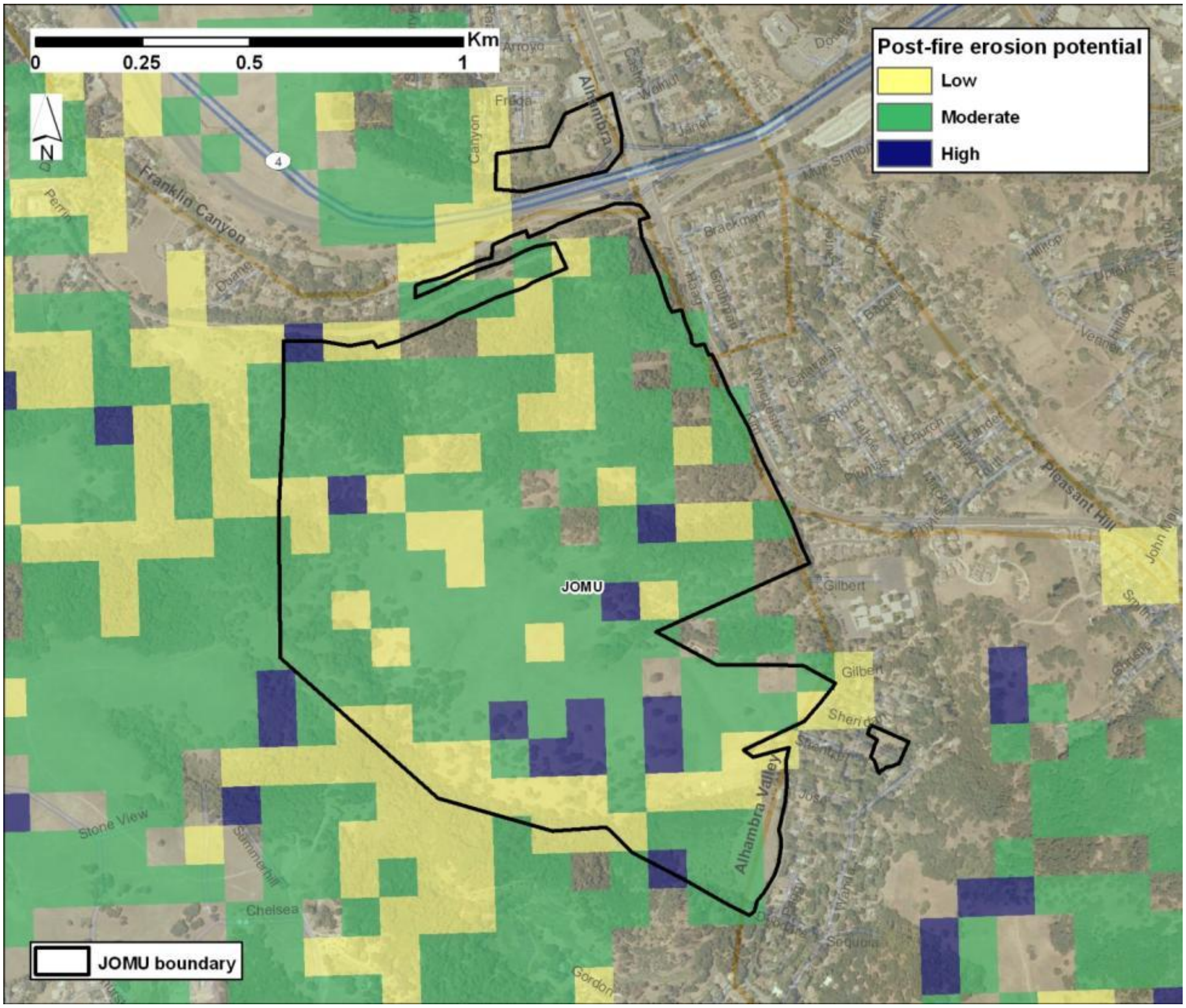

Figure 66. Post-fire soil erosion potential at the park scale.

Trends

Keeley (2005) postulates that grassland in the East Bay counties (Contra Costa, Alameda, Santa Clara) is dependent upon disturbance, either fire, grazing, or both. Up to the mid-Holocene period prior to Native American settlement, the region was more heavily dominated by woodlands, with components of shrublands and grasslands. Lightning-caused fire was rare enough that grasslands remained as small, scattered patches. During the era of relatively high-density occupation by Native Americans, they used frequent burning to shift the landscape to a grassland-dominated matrix to improve access to resources. Frequent fire suppressed the regeneration of woody plants, favoring the replacement with native perennial grasses and annual forbs. European settlement in the 19th century reduced the frequency of intentional fire, but the level of disturbance favoring grasslands was provided by heavy livestock grazing. The grasslands, however, were now dominated by the annual non-native grasses we see today. In the 20th century, increasing urban development led to a steady increase in fires < 4 ha and decrease in fires > 4 ha between 1945 and 2005, reflecting the effectiveness of fire suppression efforts in controlling growing numbers of ignitions from an expanding human population in the region. The expanding network of protected areas brought about a reduction in grazing in the area. With this reduced level of disturbance, Keeley (2005) reports that there is often a gradual recolonization of grasslands by shrubs, initially led by *Baccharis pilularis*.

Emerging Issues

Expansion of shrublands into areas formerly occupied by grasslands could potentially return the landscape to more "natural" vegetation conditions and fire regime, but shrublands produce more intense fires that are harder to suppress than grasslands, which will be a serious concern in this urban landscape. Climate change (Westerling and Bryant 2008) and exurban development (Moritz and Stephens 2008) will probably combine to increase both the risk and cost of wildfires in the area (see Future Fire Regime section below). If climate change does increase fire frequency, this more frequent disturbance may tend to offset some of the shift to shrubland associated with warmer temperatures. On the other hand, an increase in shrubland could be beneficial for recovery of the Alameda whipsnake (see that section above).

Data Gaps

Determining reference conditions prior to or consistent with Muir's time here (1890-1914) will be difficult to determine. This period would probably still show the legacy, if not the contemporary practices, of intentional burning and heavy grazing with an artificially high proportion of grassland in the landscape (Keeley 2005). It is not known how fast the recolonization of grasslands by shrubs might be. Nor is it known how to mimic natural disturbance in this wildland-urban interface to offset shrub colonization and retain grasslands.

Key references

California Department of Forestry and Fire Protection. 2011. Mapped fire history database for California; public version and detailed methodology. http://frap.cdf.ca.gov/data/frapgisdata/download.asp?rec=fire. Accessed October 24, 2011.

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Keeley, J. E. 2005. Fire history of the San Francisco East Bay region and implications for landscape patterns. *International Journal of Wildland Fire* 14:285-296.

Moritz, M. A., and S. L. Stephens. 2008. Fire and sustainability: considerations for California's altered future climate. *Climatic Change* 87:S265-S271.

Westerling, A. L., and B. P. Bryant. 2008. Climate change and wildfire in California. *Climatic Change* 87:S231-S249.

Landscapes—Fire and fuel dynamics —Future fire regime
Findings: Increasing fire frequency predicted

Fire regime and vegetation are tightly coupled, and both are strongly controlled by the Mediterranean climate regime. Thus climate change is likely to affect the frequency of fires, both from a change in flammability and in fuel loading. JOMU has highly flammable vegetation (grasslands and shrublands) and seasonal live fuel moisture deficit toward the end of the summer dry season. Climate change is expected to expand grassland and shrubland as conditions get warmer, and moisture deficit would become more pronounced and last longer during the year. 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 out to the end of the 21st century relative to a 30 year reference or baseline period (1961-1990) at the park-and-buffer and regional scales. For the model combinations we assessed, change in frequency of fires greater than 200 hectares in the JOMU-buffer area by the end of the century increases by 16% under the low emissions and urban growth scenario and 41% under the high emissions and growth scenario. High urban growth rates and sprawl tend to dampen the rate of increase in fire frequency because it would reduce the proportion of vegetative fuel in the landscape.

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 67. 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, such as annual grasses, that may increase the flammability and the length of the fire season of the ecosystem. The Westerling et al. model did not account for such feedbacks.

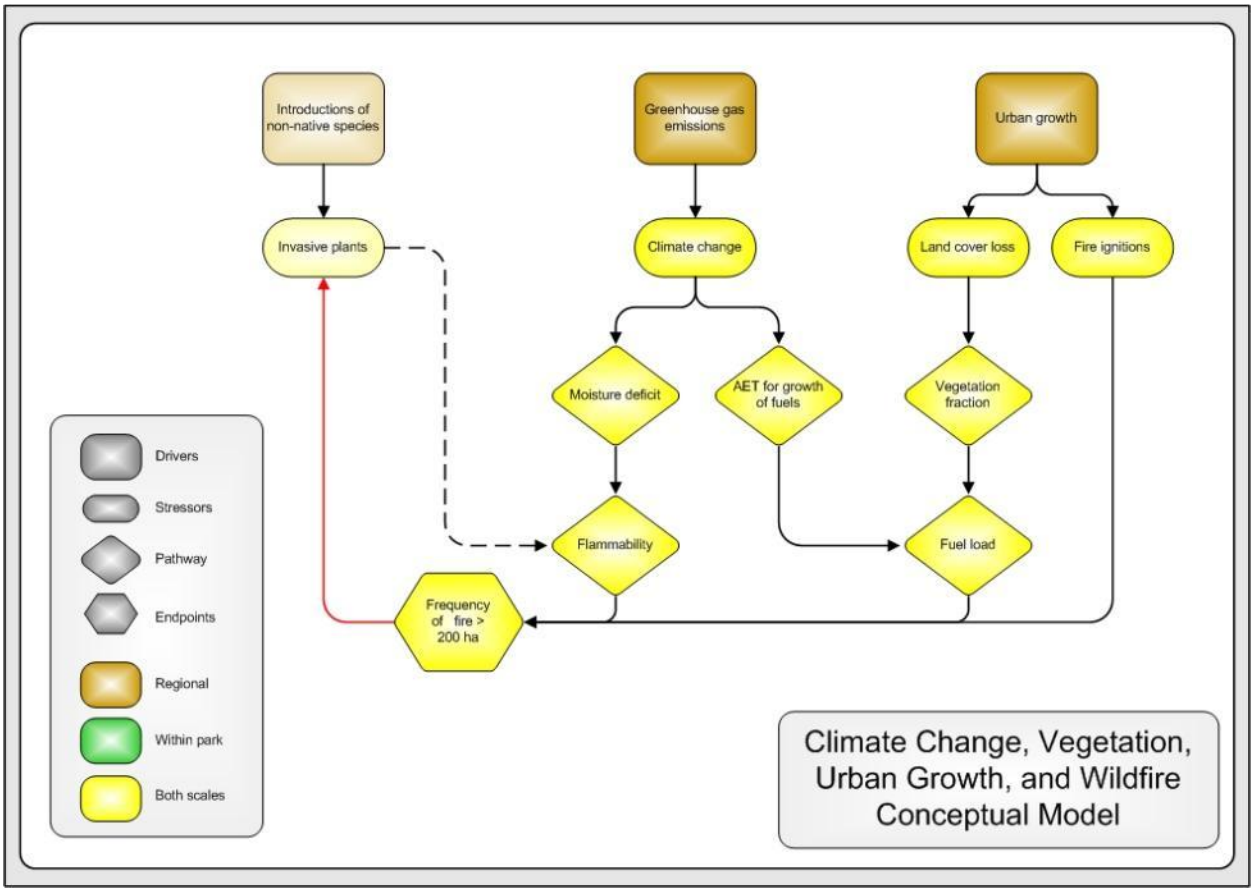

Figure 67. Conceptual model of the response of wildfire frequency to climate change and urban growth underlying the model of Westerling et al. (2010). Lighter colored icons and dashed arrows represent potential drivers and stressors that are not included in the current version of the Westerling model. 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 JOMU 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 km wide by ~14 km high at the latitude of JOMU) 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; see also Housing Development section above). For the high growth scenarios, it was 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 JOMU 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 and park-and-buffer scales. The park-and-buffer scale is represented by a single 1/8 degree cell in the core of the North East Bay Hills, which also encompasses most of JOMU. 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 the relative contributions of climate change and urban growth on future fire regime are intertwined in these basic scenarios, we also summarize the two emissions scenarios with no-growth options at the park-and-buffer scale. 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

- Shapefile of 1/8 degree cells in California with predictions of 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

Both the A2 and B1 emission scenarios lead to forecasts of increasing fire occurrence within the North East Bay Hills (park-and-buffer scale) by the end of the century, but the trends vary between GCMs and emissions (Table 18). Frequency dips under A2 in the short-term in all three GCMs, before climbing after mid-century. It remains relatively stable short-term under B1 before a dip in mid-century and then rising later. The A2 scenario with high population growth leads to an increase of 41% in frequency by late century relative to the baseline period and compared to a more modest 16% increase under B1. 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 18. Predicted frequency of fires > 200 ha at the park-and-buffer 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	85	118	134
GFDL CM21	100	93	107	193
NCAR PCM1	100	86	92	96
Mean	100	88	106	141
B1 emissions scenario—low growth				
CNRM CM3	100	104	94	125
GFDL CM21	100	111	96	134
NCAR PCM1	100	89	85	89
Mean	100	101	92	116

The results in Table 18 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, 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. When growth is ignored, fire frequency increases much more rapidly by mid-century under both emissions scenarios (Figure 68) than for their associated growth scenarios shown in Table 18. For the low-growth options, frequencies are similar between A2 and B1 to mid-century, after which the A2 soars to 180% of baseline while B1 increases slowly. We can presume that with identical growth factors, the increase in frequency is entirely a response to higher emissions in A2. The effect of growth is most noticeable with the B1 emissions scenario at mid-century where frequency increases without growth and decreases with low growth. As defined in Westerling et al. (2010), the high growth assumptions would reduce the vegetation fraction (burnable area) more than low growth. Thus, urban growth around JOMU apparently dampens much of the effect of climate change on fire frequency.

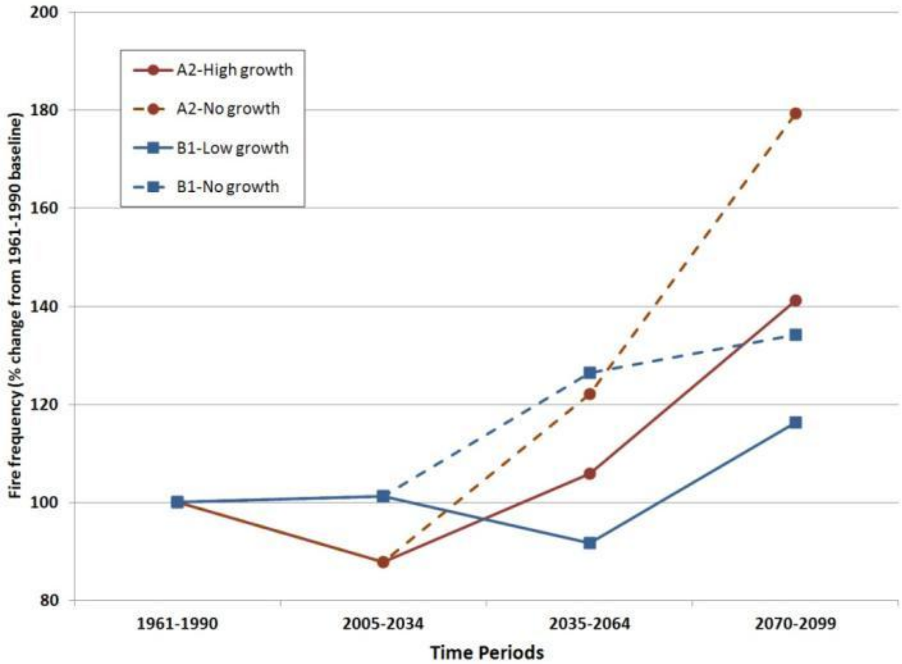

Figure 68. Graph of predicted frequency of fires > 200 ha at the park-and-buffer scale for JOMU for the A2 and B1 emissions scenarios with different urban growth scenarios as a percentage of the 1961-1990 reference period (derived from data from Westerling et al. 2010). Each point represents the average of the three GCMs.

Average fire frequency at the park-and-buffer scale (one 1/8 degree cell) is higher than at the overall region scale (twelve 1/8 degree cells) in the baseline period. The rate of increase is quite higher at the regional scale within each emission scenario than at the park-and-buffer scale (Table 19). This appears to be due to the fact that the North East Bay Hills landscape unit representing the park-and-buffer scale is closer to the marine influence than the majority of the region, which is further inland.

Table 19. Predicted frequency of fires > 200 ha by 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				
Park-and-buffer	100	88	106	141
Region	100	124	189	371
B1 emissions scenario—low growth				
Park-and-buffer	100	101	92	116
Region	100	146	139	182

Emerging Issues

Wildfire is an important process in the ecosystems at JOMU 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 JOMU managers. For instance, the combination of climate and wildfire frequency may convert shrubland and woodland to grassland and promote invasions by non-native plants, although the rates of these potential changes are not known. 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. 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.

Key references

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Landscapes—Landscape dynamics—Habitat connectivity
Findings: Baseline

A functional network of connected wildlands is essential to the continued support of the Bay Area'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 (ECAs) that link Natural Landscape Blocks (NLBs) throughout the state. The Mount Wanda area meets the criteria for NLBs except that its size is smaller than the CEHC threshold for the Bay Area. JOMU was not included in an ECA. In the Conservation Lands Network (CLN) developed by the Bay Area Open Space Council for the nine Bay Area counties, JOMU is connected to a large area considered essential to meet coarse-filter and fine-filter conservation goals for the North East Bay Hills. The Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that could be irretrievably compromised by development projects in the next decade unless immediate conservation actions occur.

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) and refuge from urbanized environments. At a regional scale, connectivity can be disrupted by stressors such as intensive land uses and road construction. 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 69). 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. Other factors that may be relevant for JOMU, such as historic grazing, were not mapped for all of California and were omitted from the ECI. 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. 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 69). 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 counted the area as part of the NLB category. The CEHC Project did not identify ECAs for natural blocks < 2,000 acres in the Bay Area that otherwise meet the criteria for NLBs, but they did compile a GIS layer of these small natural areas for use in regional conservation planning.

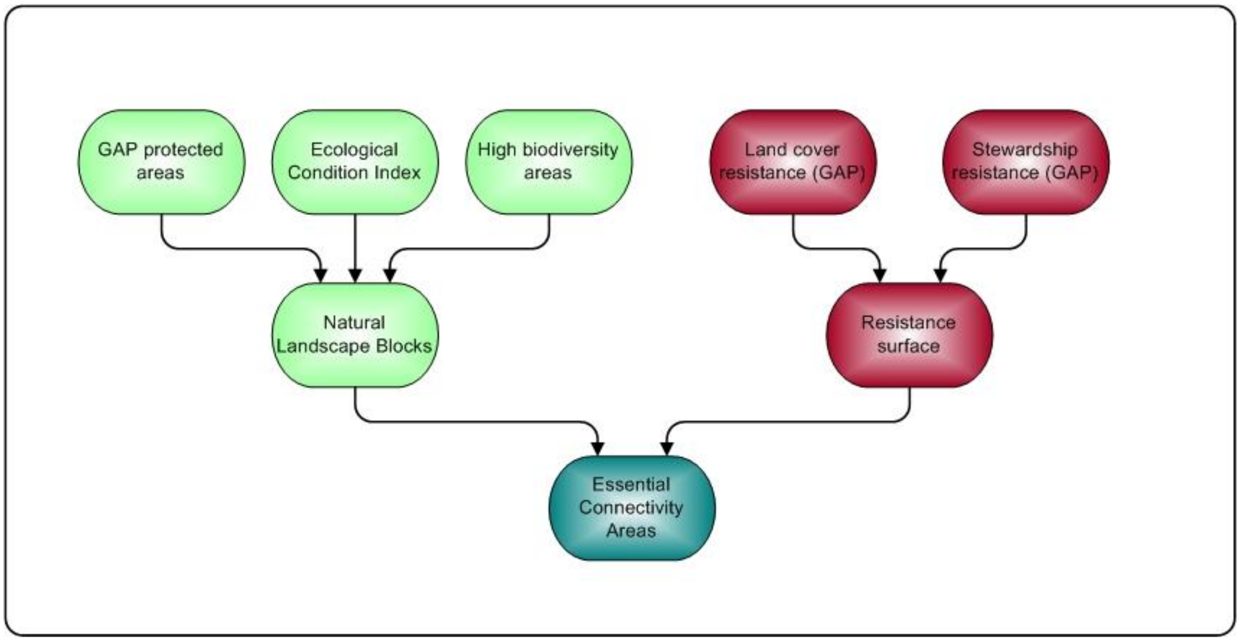

Figure 69. GIS conceptual model of California Essential Connectivity Areas (after Spencer et al. 2010).

For the JOMU condition assessment, the proportions of Essential Connectivity Areas, Natural Landscape Blocks, and small natural areas are reported at the regional, park-and-buffer, and park scales.

The Bay Area Open Space Council conducted its own conservation plan. Their Upland Habitat Goals Project delineated 34 landscape units in the nine counties in the Council's domain. For each unit, a gap analysis identified coarse-filter targets (i.e., vegetation types) that are not adequately protected. Conservation planning software then selected sites that met the goals by building out from existing protected areas on lands with best available ecological integrity. Initial results were then adjusted to ensure protection of fine filter targets such as rare species. The outcome was the Conservation Lands Network (Bay Area Open Space Council 2011). Although not based on connectivity objectives per se, the CLN aimed for a reasonably well-connected network. We examined the relationship of the CLN to JOMU for this assessment.

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)

- Bay Area Open Space Council's Conservation Lands Network (http://www.bayarealands.org/gis/)

Status

JOMU is part of a small natural area (< 2,000 acres) as designated by CEHC Project because it is protected. JOMU is not directly part of a large NLB because the ECI value, driven in this location by housing density of the vicinity, was too low to qualify. Nor was JOMU connected by an ECA with other natural areas. Therefore JOMU is not considered essential for connectivity within California. However, JOMU is less than one mile from two NLBs and the Mt Allison - Briones Hills ECA in the center of the North East Bay Hills park-and-buffer area (Figure 70). This ECA links all the blocks of natural landscapes of the East Bay Hills west of Interstate 680 (Figure 71). No ECA was delineated to connect the JOMU neighborhood to Mount Diablo and other natural landscapes in the eastern half of the region.

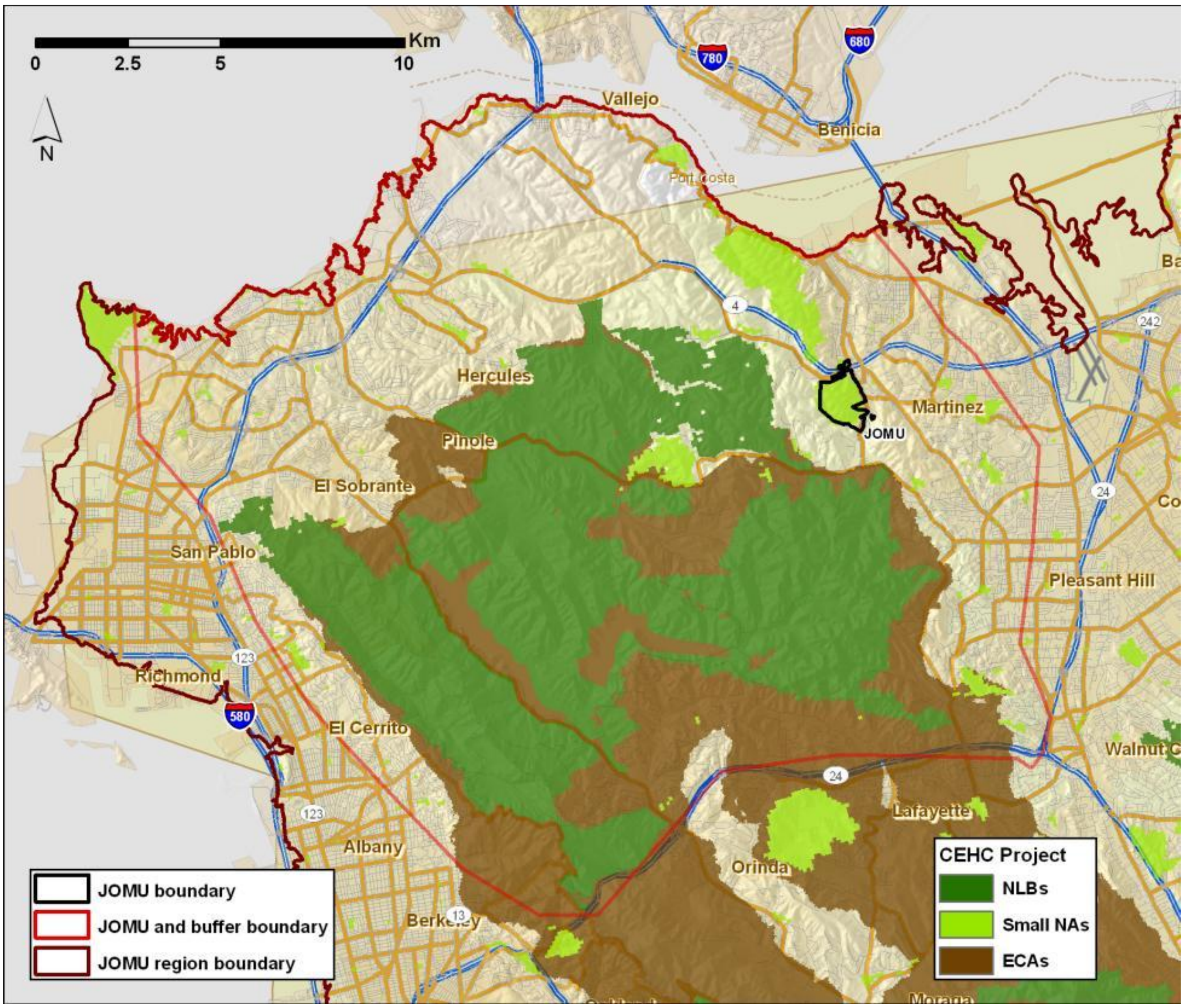

Figure 70. Map of the Natural Landscape Blocks (NLB), small Natural Areas (NA), and Essential Connectivity Areas (ECA) between them (Spencer et al. 2010) for the park-and-buffer area.

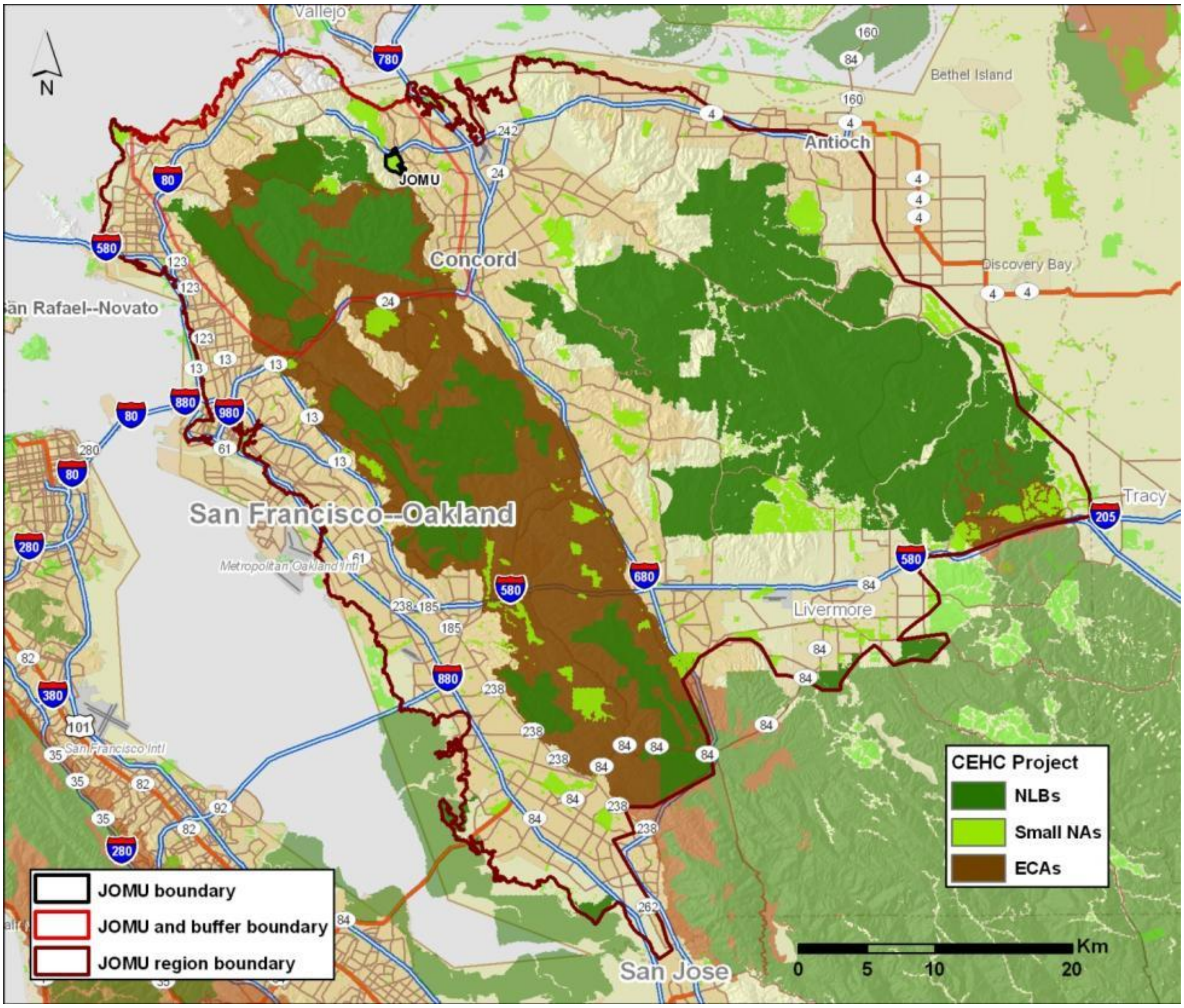

Figure 71. Map of the Natural Landscape Blocks (NLB), small Natural Areas (NA), and Essential Connectivity Areas (ECA) between them (Spencer et al. 2010) for the region.

Tabulating percentages of area in NLBs and ECAs quantifies the visual impressions from looking at the maps in Figure 70 and Figure 71. Eighty-four percent of JOMU is part of a small natural area as designated by CEHC Project (Figure 72). The park-and-buffer is similar to the regional scale, with slightly more land in NLBs and the ECA at the park-and-buffer scale.

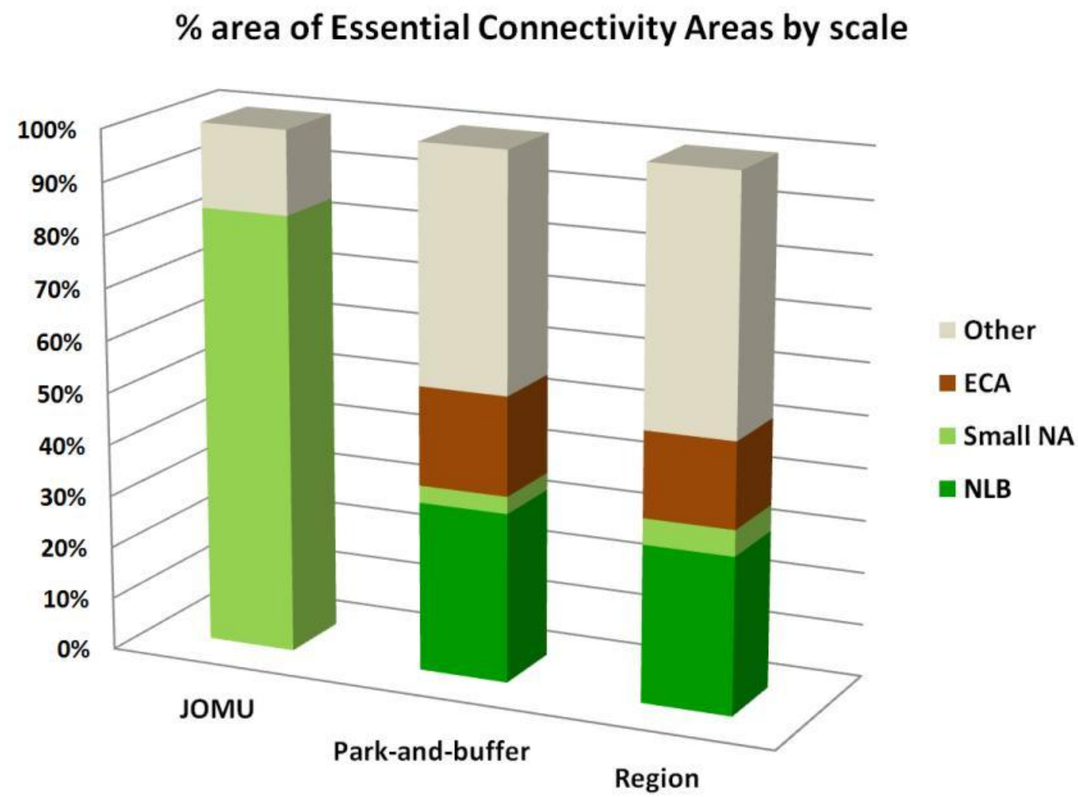

Figure 72. Bar graphs of the relative percentage of Natural Landscape Blocks (NLB), small natural areas (Small NA), Essential Connectivity Areas (ECA), and all other land for JOMU, the park-and-buffer landscape, and the region.

Although the CEHC and CLN results were based on different criteria and methods, the maps in Figure 70 and Figure 73 are remarkably similar. Both projects placed high priority in the core of the North East Bay Hills landscape unit. CEHC provided a greater degree of contiguity across Highway 24 to the south than the CLN. Of primary interest for NPS is that the CLN links JOMU to rest of the core area. The CLN process also identified State Highway 4 west of Alhambra Avenue as a major road barrier for wildlife movement.

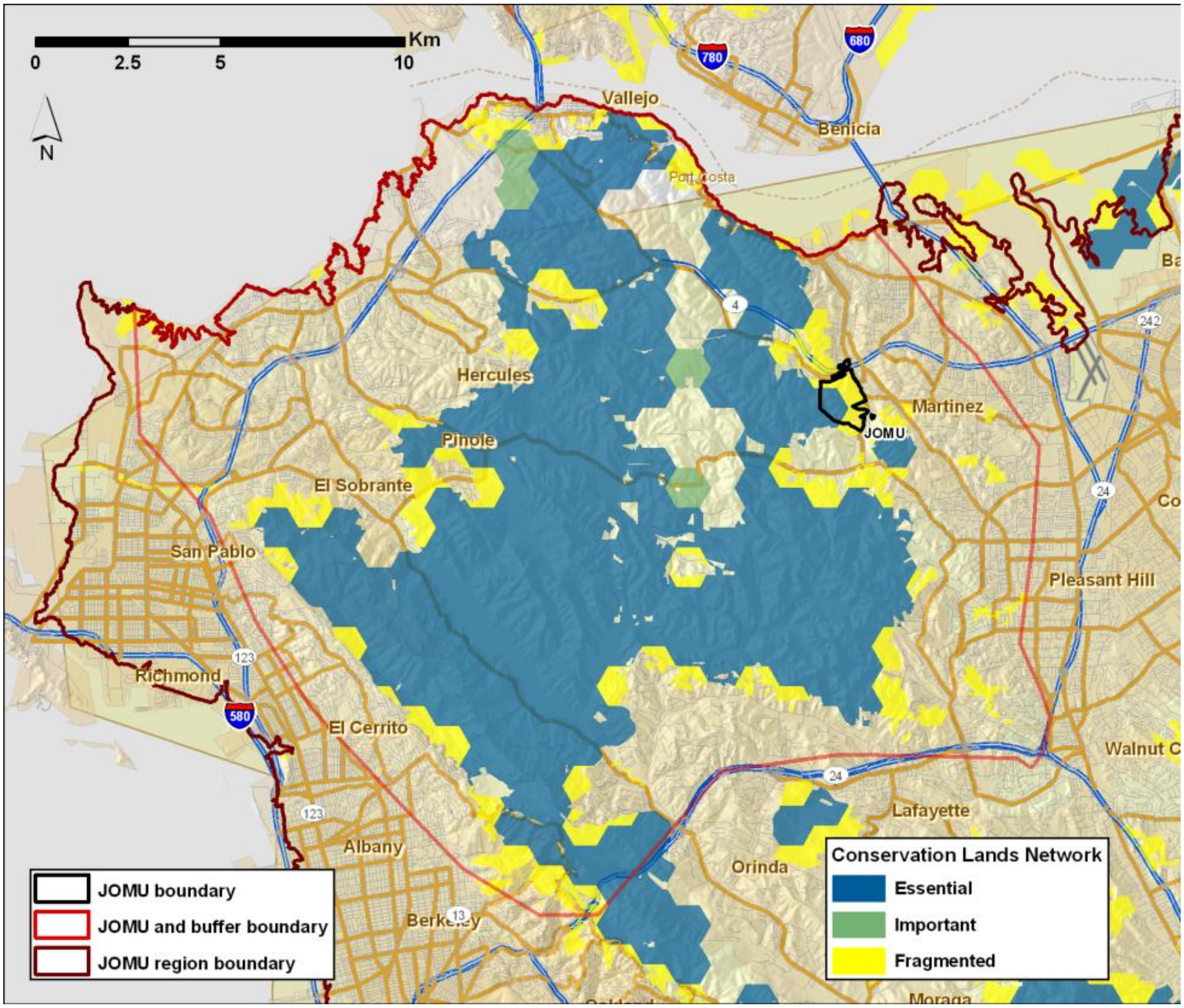

Figure 73. Map of the Conservation Lands Network of the Bay Area Open Space Council, showing how JOMU is linked to a large area of "essential" conservation priority in the North East Bay Hills landscape unit.

Trends

The CEHC Project was based on current ecological conditions both to generate NLBs and ECAs. Thus no temporal trends in connectivity were addressed. The rapid urbanization of the East Bay has probably caused ecological conditions around JOMU to decline. 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 ECA has been lost. On the other hand, the addition of new protected areas over the years has also helped to counter this trend of lost connectivity.

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. Management objectives at JOMU already strive to maintain conditions compatible with the criteria for NLBs. However, the habitat value of JOMU depends in part on its continued connectivity to the green infrastructure of its surroundings. As reported in the Housing Development section above, future urban densification is anticipated, which could tend to undermine that objective. Park managers should be vigilant for land use proposals that might further isolate JOMU. Managers at JOMU may want to consider participating in detailed planning and implementation of the CLN (Bay Area Open Space Council 2011) and other localized efforts.

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. The housing density criterion in the ECI was only mapped at a 5 km resolution, which led to JOMU and its vicinity being filtered out of the process to identify NLBs. Grazing history was not included in the ECI criteria for lack of statewide data. Moreover the process was quite generic and did not address distributions or needs of particular species, such as the Alameda whipsnake. The CLN was based on more detailed biological and land use information for the nine Bay Area counties. It did not consider wildlife corridors or linkages directly but rather promoted contiguity of conservation priority lands with existing protected areas. The Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that could be irretrievably compromised by development projects in the next decade unless immediate conservation actions occur (http://www.scwildlands.org/projects/bayarea.aspx). It is not known at this time whether the Alameda whipsnake will be one of the focal species for modeling critical linkages. This information may be very useful to JOMU managers in future planning efforts.

Key references

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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.

Summary of resource assessments

The status and trends of resource condition indicators is summarized below (Table 20). The trend indicator icons reflect the trend of the indicator and not a positive or negative resource outcome.

Table 20. Summary of status and trends of resource condition indicators.

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
AIR AND CLIMATE					
Air quality	Ozone trend	65 ppb (2005 – 2009 average annual 4th-highest 8-Hour average ozone concentration)	75 ppb (EPA); <= 60 ppb is "good condition" (NPS)	Moderate Condition	
	Total nitrogen deposition	5.7 kg/ha/yr (UC Riverside model)	0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS standards); 5.5 kg/ha/yr is considered the critical load for lichen communities in California chapparal. 6.0 kg/ha/yr is considered the critical load for grasslands.	Moderate Condition	
	Sulphur deposition	0.52 kg/ha/yr (average from1994 – 2009)	0.25 kg/ha/yr is natural background; <1.0 kg/ha/yr is "good condition" (NPS standards)	Good Condition	
	Visibility	6.1 deciviews (average 2005-2009)	8 deciviews (5 year average deciview values minus estimated deciview values in the absence of human caused degradation)	Moderate Condition	
Climate	Minimum temperature of the coldest quarter	3.4ºC (average in JOMU, 1971-2000)	15ºC (mean annual temperature of past 50 years)	Climate at JOMU is characterized by warm, dry summers and mild, wet winters. Temperatures averaged 15ºC (59ºF) and	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
	Maximum temperature of the warmest quarter Temperature seasonality (standard deviation of monthly temperatures) Growing degree days above 5ºC Mean annual precipitation	29.1ºC 21.8 3542 567 mm	500 mm (average of past 50 years)	total annual precipitation averaged 50 cm (19.7 in) over the past 50 years. Minimum temperature exhibited a small positive trend of 0.1ºC decade-1 over the last century; maximum temperature increased by 0.2 ºC decade-1. Precipitation showed no significant trend. Climate models consistently predict warming conditions to the end of this century but vary in predictions of precipitation.	
WATER					
Hydrology and water quality	NA	NA	NA	Erosion in Strentzel Watershed and its possible contribution to flooding and sedimentation in Alhambra Creek is one of the most pressing resource management issues at JOMU. Gullying is the central process that has raised concerns about park neighborhoods and resources. This condition assessment investigated some of the potential stressors with other data sources. Most stressors, including landslide susceptibility, annual grasslands, residential development, climatic patterns, and grazing, appear widespread in the North East Bay Hills and not unique to the Mount Wanda area.	
BIOLOGICAL INTEGRITY					
Sudden Oak Death and Non-native invasive plants	Sudden Oak Death	Not detected (2002)	No infestations	Sudden Oak Death has not been detected in JOMU, but confirmed detections in the past few years in nearby Briones Regional Park suggest that this disease could become a greater threat for the NPS to monitor. About 254 of approximately 496 plant species are non-	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
				native (51%). Eighteen of these non-native species are considered invasive, with the potential for creating serious ecological damage (e.g., erosion, fire, and habitat quality) and detracting from the character of the site's native plant community. Invasive plant management is intricately interconnected with other stressors and resources in the park and surrounding landscape, such as watershed health.	
Alameda whipsnake	NA	NA	NA	JOMU is included in a Critical Habitat designation for the Alameda whipsnake. To date, one confirmed sightings within the park has been made. Habitat modeling in this assessment indicates there is potential core and movement habitat for this species.	
LANDSCAPES					
Fire regime	Fire frequency	Insufficient data	Annual grassland: 0-35 years Oak woodlands and shrublands: 35-100+ years	In the North East Bay Hills landscape unit and region, fire in annual grasslands is believed to be within historical range with minimal disturbance. Grasslands are considered low hazard and fire severity, with relatively high fire frequency. Oak woodland and shrub types within the region were modeled as moderate departure from natural regimes, with associated changes in ecosystem composition and structure that render future fires likely to cause some loss and change in elements and processes. These types are higher hazard and fire severity than grasslands.	
Future fire regime	Frequency of fires > 200 ha in North East Bay Hills (park-and-buffer) in 2070-2099 as	141%	NA	Wildfire is sensitive to climate change and urban growth. Change in fire frequency in North East Bay Hills by the end of the century ranges from a 16% increase under a low	

INDICATORS	MEASURES	RECENT DATA	REFERENCE CONDITIONS	STATUS	TREND
	percent of 1961-1990 period—mean of 3 GCMs for A2 emissions scenarios —mean of 3 GCMs for B1 emissions scenarios	 116%		emissions and growth scenario to 41% under a high emissions and growth scenario. High urban growth rates and sprawl tend to dampen the rate of increase in fire frequency.	
Habitat connectivity	NA	NA	NA	JOMU is contained in a Small Natural Area identified by the statewide California Essential Habitat Connectivity Project, but was not included in an Essential Connectivity Area. In the Conservation Lands Network developed by the Bay Area Open Space Council, JOMU is connected to a large area considered essential to meet coarse-filter and fine-filter conservation goals for the North East Bay Hills. The Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that could be irretrievably compromised by development projects in the next decade unless immediate conservation actions occur.	

 = baseline only  = no significant trend  = increasing trend

Chapter 5. Discussion and Conclusions

Answers to Management and Research Questions

The staff at JOMU and the SFAN I&M program 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. *What are the effects of air quality (e.g. pollutants) on the park's natural resources?* JOMU has been rated at High Risk from atmospheric nutrient N enrichment relative to other national parks, based on the level of exposure to emissions and ecosystem sensitivity. Nitrogen deposition modeled by UC Riverside indicates that the majority of JOMU and its surroundings were subject to average annual deposition rates in 2002 at or near the critical load threshold for grasslands and epiphytic lichen communities in chaparral and oak woodlands. Nitrogen fertilization tends to favor non-native annual grasses and invasive weedy plants over native perennial grasses.

2. *What have the changes in climatic factors been over the last 50 years (temperature, precipitation)?* Temperatures averaged 15^{o}C (59^{o}F) and total annual precipitation averaged 50 cm (19.7 in) over the past 50 years. Minimum temperature exhibited a small positive trend of 0.1^{o}C per decade over the last century; maximum temperature increased by 0.2 ^{o}C per decade. Precipitation showed no significant trend.

3. *What are the potential effects of changing climate in this region (e.g. rain, temperature, flooding, and drought patterns) and how may this affect local biological diversity, erosion and flooding patterns.* Downscaled climate models consistently project a 27 – 37% increase in growing degree days (GDD5) by 2100 at JOMU, resulting in future conditions that are currently found at Stockton in the Central Valley. Minimum winter temperatures are projected to increase by 2.3 – 3.6ºC, while maximum summer temperatures are projected to increase by 3.0 –3.9ºC. Precipitation projections are variable, either increasing 6% or decreasing 33% depending on the GCM. 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 JOMU. Projected distributions indicate that under future climate scenarios, suitability for Blue Oak, which is a prominent component of the vegetation in JOMU and the region, will decrease within JOMU. Areas surrounding JOMU are also expected to decrease in suitability (even at Mount Diablo), with suitable range contracting westward into the East Bay Hills. These changes could result in decreased cover and forage for the many bird and mammal species that use Blue Oak. In contrast, Chamise is projected to have increased probability of occurrence throughout the East Bay Hills. Chamise is relatively rare in the reference region today but is important for some species, such as the Threatened Alameda whipsnake. Climate change is also likely to change flammability of fuels with a longer summer to dry the vegetation. The frequency of fires greater than 200 hectares in JOMU-buffer area is predicted to increase 16-41% by the end of the century depending on the emissions and urban growth scenario. Grassland and shrubland

are likely to expand as conditions get warmer. If climate change also accentuates extreme weather events, more destructive fires and flooding may occur.

4. *Is the level of soil erosion on Mount Wanda normal for the soil type?* Primary data from the Strentzel Watershed and similar streams were not available to conduct a comparative analysis of soil erosion rates in this condition assessment. The watershed report (Moore 2006) identified many potential factors that might account for a high erosion rate, gullying, and flooding. These include soils and their erodability, slope, climate, vegetative cover, land use impacts, grazing, non-native annual plants, wetland destruction, and dam breaches. A cursory examination of data on these correlates of erosion was made in the process of this condition assessment. The soils at Mount Wanda include Los Osos Clay Loam, 15 To 30 Percent Slopes in grassy areas and Los Gatos Loam, 30 To 50 Percent Slopes in the woodlands and forest. Both types are well-drained and are abundant throughout the area. The Mount Wanda unit is primarily rated as Moderate potential of post-fire erosion, as is much of the North East Bay Hills and larger region. No significant trend in annual precipitation was identified that could account for changes in erosion, nor did we uncover any evidence of increase in extreme precipitation events in the Bay Area or that Mount Wanda is more prone to extreme storms than surrounding hills. Fire and land uses have replaced shrubland and woodland with grassland throughout the East Bay, and the grassland has become dominated by shallow-rooted non-native annuals. Most of the landscape was subjected to intensive livestock grazing, but grazing was eliminated from the Mount Wanda unit after its acquisition in the 1990s. Roads and trails permeate the region. In summary, this assessment did not identify any obvious factors that would make Mount Wanda unique or at unusually high risk for erosion. Monitoring erosion rates here and in comparable streams in the region is needed to quantify the rates to support an analysis of the causal factors.

5. *What are the effects of current and probable non-native species invasions (plants and animals) along with disease (e.g., Sudden Oak Death)?* Non-native plants and animals produce a wide range of effects on the ecology and management of JOMU. Historically, annual grasses have replaced perennials in the grasslands and in the understory of woodlands throughout the region. Along with other invasive weeds, this reduces the number of native plants and tends to homogenize the vegetation so that this area becomes more similar to other counties. This shift has had some effect on fire as the annuals form a more continuous cover than perennial bunchgrasses. Because they are more shallow-rooted, they may also be contributing to increased soil erosion. Italian thistle is prevalent in the dripline of oaks where they may outcompete oak seedlings and suppress their already-diminished recruitment. Introduced animals such as rats, dogs, and cats, have increased predatory pressure on the Alameda whipsnake in the North East Bay Hills, especially where urban development abuts whipsnake habitat, as is the case at JOMU. Cats also prey upon the same food sources as whipsnakes, such as lizards. SOD has not been detected at JOMU yet. It selectively kills black oak and coast live oak in areas that it infests that are similar to JOMU. Thus it could cause a change in species composition and therefore in ecosystem functioning; loss of food

sources for wildlife; a change in fire frequency or intensity; and decreased water quality due to an increase in exposed soil surfaces.

6. *Are there exemplary natural communities or rare or sensitive species that have not been documented on Mount Wanda but can possibly occur? Is there sufficient data available to determine whether Mount Wanda is suitable for supporting viable populations of these species?* The Mount Wanda unit of JOMU lies just inside the boundary of Unit 1 of the Critical Habitat designation for the Alameda whipsnake. This has also been identified as Recovery Unit 1 of the draft recovery plan. Our assessment has shown that Mount Wanda has habitat qualities corresponding to a small area of core habitat, but is mostly considered movement habitat. JOMU may become a major land manager in coordinated planning for recovery of the Alameda whipsnake. A documented sighting has confirmed the presence of the subspecies within JOMU. However, it is unknown at this time how many occur and to what extent the whipsnake relys on park lands and resources for survival. The draft recovery plan calls for three focus populations in Unit 1, including one at Tilden Regional Park. Because of the area of chamise chaparral at Mount Wanda is so small, it seems unlikely that JOMU independently could support a viable Alameda whipsnake population. The California Natural Diversity Data Base indicates there are two globally and state imperiled plants that occur in or near JOMU—*Calochortus pulchellus* (Mount Diablo fairy-lantern) and *Helianthella castanea* (Diablo helianthella). Both have an identical Rare Plant Rank (1B.2) from the California Native Plant Society, indicating that they are seriously threatened in California.

7. *What are the ecological effects of long-term fire suppression on Mount Wanda and in the region? How does fire suppression alter vegetation species composition and communities? What is the potential future trend in fire behavior?* The fire regime of the JOMU area has been strongly influenced by human cultures for thousands of years and has changed considerably over the past several centuries. Lightning fires are relatively rare, creating a woodland/shrubland dominated landscape. Küchler's map of "natural" vegetation in the absence of fire or human activity (1977) identifies most of the North East Bay Hills as either Mixed Hardwood Forest (Arbutus-Quercus) or Blue Oak-Digger Pine Forest (Pinus-Quercus). Küchler acknowledged that finer detail of inclusions was not possible at the 1:1,000,000 scale of his map, but that both of these two types included unmapped patches of chaparral. Native Americans may have burned the landscape frequently to create a grassland-dominated mosaic to improve access to resources. With the expansion of Mexican livestock ranching in the early 19th Century, fire frequency probably decreased but heavy livestock grazing maintained a level of disturbance sufficient to prevent grasslands from being recolonized by chaparral or coastal scrub. Fires remained common and the frequency of large accidental wildfires increased during the latter half of the 19th Century, associated with increased economic activity and Anglo-American traffic in the region. Thus the landscape at the time John Muir resided here would have been more open than prior to human settlement. Since the second quarter of the 20th Century aggressive fire suppression for protection of people and property has lengthened mean fire-free periods in all vegetation types compared

to the 19th Century and Pre-European fire regimes. This longer fire interval has begun to reverse the process of grassland expansion by allowing chaparral and coastal scrub to recolonize (Keeley 2005). Climate change is expected to counter this trend. If temperatures get warmer as expected, moisture deficit would become more pronounced and last longer during the year, expanding grassland and shrubland. The modeling by Westerling et al. (2009, 2010) predict that frequency of fires greater than 200 hectares in the North East Bay Hills increases by 16% under the low emissions and urban growth scenario and 41% under the high emissions and growth scenario by the end of the century. High urban growth rates and sprawl may tend to dampen the rate of increase in fire frequency.

8. *What is the ecological significance of Mount Wanda in the regional context (landscape and regional level)? What is the park's relative role in habitat connectivity with other park or protected spaces (e.g. East Bay Regional Parks)?* A functional network of connected wildlands is essential to the continued support of the Bay Area's diverse natural communities in the face of human development and climate change. Two previous studies assessed the pattern of habitat connectivity that can inform JOMU managers. The California Department of Transportation and California Department of Fish and Game commissioned a statewide California Essential Habitat Connectivity (CEHC) Project to delineate Essential Connectivity Areas (ECAs) that link Natural Landscape Blocks (NLBs). The Mount Wanda area meets the criteria for NLBs except that its size is smaller than the CEHC threshold for the Bay Area. JOMU was not included in an ECA. The second study was for the nine Bay Area counties in the domain of the Bay Area Open Space Council. JOMU is connected to a large area considered essential to meet coarse-filter and fine-filter conservation goals for the North East Bay Hills. The Bay Area Critical Linkages Project is developing focal species-based designs to ensure functional habitat connectivity for several priority landscape linkages in the region that could be irretrievably compromised by development projects in the next decade unless immediate conservation actions occur. Until that project is completed, it is not known if JOMU will be part of a critical linkage. This condition assessment showed that JOMU has potential core and movement habitat for the Alameda whipsnake that could be essential for this species' recovery.

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 JOMU will become similar to current conditions in Stockton in the Central Valley in terms of maximum temperature and Bakersfield for growing degree days. Minimum winter temperatures and maximum summer temperatures are both forecasted to increase dramatically. Models are less consistent in forecasting precipitation changes. Climate change is not just another management issue for JOMU; it will tend to amplify many existing stressors and effects (Baron et al. 2009), such as:

- 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

- 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)

We reiterate the recommendations of Baron et al. (2009) that JOMU 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 nitrogen deposition, skyglow, noise, road kill, and wildfire risk. Increased nitrogen deposition also favors invasive plants and more frequent fire. Lichen communities would be particularly susceptible with limited mitigation options. If the metropolitan statistical area containing JOMU is designated as nonattainment for ozone by EPA, it will be important for the park to work with the state and the NPS Air Resources Division to ensure that planned park activities are included in the State Implementation Plan and emissions inventories.

The impact of recovery planning for the Alameda whipsnake on JOMU management is just emerging. NPS is a relatively small actor in a diverse management landscape. Until recovery planning identifies locations for focus population centers, it remains unclear how involved JOMU will be in new regional coordination efforts for adaptive management, inventory, monitoring, and planning. In any case, the designation of Critical Habitat raises some possibilities of constraints on management options, such as treating invasive plants.

JOMU has some of the primary hosts for the Sudden Oak Death pathogen, such as California bay laurel and buckeye. It also has black oak and coast live oak that are susceptible to SOD. So far SOD has not been detected within JOMU, but there have been recent confirmed detections only a couple of kilometers away in similar habitat. Vigilance is called for both in monitoring for SOD but also for following best management practices to avoid accidental introduction of the pathogen. For instance, JOMU staff also manages the Eugene O'Neill National Historic Site (EUON), which borders the Las Trampas Regional Wilderness where a SOD infestation was recently detected. Some of the vehicles that are stored and operated at EUON are also taken up Mt Wanda. The pathogen infesting wet soil or foliage can adhere to vehicles and therefore be dispersed to uninfested areas. Taking extra precautions such as washing vehicles before traveling to Mount Wanda could become necessary in the future.

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:

- The establishing legislation directs the NPS to maintain or restore the Mount Wanda unit to be consistent with conditions during Muir's time. In other words, that era establishes the reference conditions for the park. The specifics of those conditions are not well-documented, however. Work is needed in historical ecology to determine what the vegetation patterns and composition, watershed, fire regime, and so on, were like. This will require an integrated approach using journals, old aerial photos, and early vegetation maps, to support the choice of reference conditions. More research will then be needed to identify how those conditions can be maintained/restored in an environment that is warming and urbanizing. That is, the drivers are changing from what created the reference conditions at the park.
- The designation of Critical Habitat for the Alameda whipsnake by the U. S. Fish and Wildlife Service entrains JOMU into the recovery planning process. Future surveys are needed to confirm how the snake uses park resources and the suitability of these resources to support a viable population. If JOMU is targeted for a focus population center for recovery, more detailed analysis of core and movement habitat will be needed, including higher resolution spatial data on the Primary Constituent Elements, such as rock outcrops and small mammal burrows.
- State and regional studies found that JOMU has some role in maintaining habitat connectivity in the North East Bay Hills. These general studies need to be supplemented with species-specific modeling that accounts for their individual habitat affinities. Knowledge of these affinities needs to be compiled through literature review and consultation with species experts. The Bay Area Critical Linkages Project is currently conducting such an analysis but results are not completed to determine JOMU's role at that level.

The added challenge of responding to these emerging trends and filling data gaps will be the increasing need for coordination and collaboration with other agencies, academics, communities, property owners, and other stakeholders. This approach both acknowledges the ecological and social role of JOMU in the broader landscape, but also builds capacity for the small resource staff at the park.

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Appendix

A-1. Native Vascular Plants of JOMU

Scientific Name	Common Name
Achillea millefolium	Yarrow
Achyrachaena mollis	Blow Wives
Adenostoma fasciculatum	Chamise
Adiantum jordanii	Maidenhair Fern
Aesculus californica	California Buckeye
Agoseris grandiflora	California Dandelion
Agoseris heterophylla	Mountain Dandelion
Agrostis exarata	Spike Redtop
Allium serra	Serrated Onion
Amaranthus blitoides	Prostrate Pigweed
Amsinckia menziesii var. intermedia	Common Fiddleneck
Aphanes occidentalis	Lady's Mantle
Arabis glabra	Tower Mustard
Arctostaphylos manzanita	Common Manzanita, Manzanita
Aristolochia californica	Pipevine
Artemisia californica	California Sagebrush
Artemisia douglasiana	Mugwort
Asclepias cordifolia	Heart-Leafed Milkweed
Asclepias fascicularis	Narrow-Leafed Milkweed
Aster chilensis	California Aster
Aster radulinus	Broad-Leaved Aster, Woodland Aster
Baccharis douglasii	Marsh Baccharis
Baccharis pilularis	Coyote Bush
Berberis aquifolium	Oregon Grape
Berberis nervosa	Cascade Oregongrape
Brodiaea elegans	Elegant Brodiaea
Brodiaea elegans ssp. elegans	Harvest Brodiaea
Brodiaea terrestris	Dwarf Brodiaea
Bromus carinatus var. carinatus	California Brome
Calandrinia ciliata	Red Maids
Calocedrus decurrens	Incense Cedar
Calochortus venustus	Butterfly Mariposa Lily
Calycanthus occidentalis	Western Sweetshrub
Calystegia subacaulis ssp. subacaulis	Hill Morning Glory
Cardamine oligosperma	Bitter Cress
Carex aquatilis var. dives	Sitka Sedge

Scientific Name	Common Name
Castilleja affinis ssp. affinis	Indian Paintbrush
Castilleja attenuata	Valley Tassels
Castilleja exserta ssp. exserta	Purple Owl's Clover
Castilleja foliolosa	Texas Paintbrush
Castilleja rubicundula ssp. lithospermoides	Cream Sacs
Chlorogalum pomeridianum	Soap Plant
Clarkia affinis	Chaparral Clarkia
Clarkia unguiculata	Elegant Clarkia
Claytonia perfoliata ssp. perfoliata	Miner's Lettuce
Collinsia heterophylla	Purple Chinese Houses
Collinsia sparsiflora var. sparsiflora	Blue-Eyed Mary
Conyza canadensis	Canadian Horseweed
Corylus cornuta var. californica	California Hazelnut
Crassula connata	Sand Pygmyweed
Cynoglossum grande	Grand Hound's Tongue
Cyperus eragrostis	Tall Cyperus
Daucus pusillus	Rattlesnake Weed
Delphinium patens	Zigzag Larkspur
Dicentra formosa	Bleeding Heart
Dichelostemma capitatum ssp. capitatum	Blue Dicks
Dichelostemma congestum	Round Tooth Ookow
Dodecatheon hendersonii	Shooting Star
Dryopteris arguta	Wood Fern
Elymus glaucus ssp. glaucus	Blue Wildrye
Epilobium brachycarpum	Annual Fireweed
Epilobium canum ssp. canum	California Fuchsia
Epilobium ciliatum ssp. ciliatum	Willow Herb
Epilobium minutum	Slender Annual Fireweed, Willow Herb
Equisetum telmateia var. braunii	Giant Horsetail.
Eremocarpus setigerus	Turkey Mullein
Erigeron foliosus var. franciscensis	Franciscan Erigeron
Eriogonum nudum var. auriculatum	Nude Buckwheat
Eriophyllum confertiflorum var. confertiflorum	Golden Yarrow
Eschscholzia californica	California Poppy
Euphorbia spathulata	Spatulate Leaved Spurge
Festuca rubra	Red Fescue
Filago californica	Fluffweed
Filago gallica	Fluffweed
Fremontodendron californicum	California Flannelbush, California Fremontia,

Scientific Name	Common Name
	Flannelbush
Galium porrigens var. porrigens	Bedstraw
Garrya elliptica	Coast Silk Tassel
Gaultheria shallon	Salal
Gilia clivorum	Purplespot Gilia
Gnaphalium californicum	California Everlasting
Grindelia camporum var. camporum	Common Gumplant
Helenium puberulum	Sneeze-Weed, Rosilla
Helianthella castanea	Diablo Sunflower
Helianthemum scoparium	Peak Rush-Rose
Hesperevax sparsiflora	Erect Dwarf-Cudweed
Hesperocnide tenella	Western Nettle, Western Stingingnettle
Heteromeles arbutifolia	Toyon
Holocarpha heermannii	Sticky Tarweed
Holodiscus discolor	Oceanspray
Hordeum brachyantherum	HORDEUM, Meadow Barley
Iris douglasiana	Douglas Iris
Juglans californica var. hindsii	California Black Walnut
Juncus bufonius	Toad Rush
Juncus patens	Spreading Rush
Juncus phaeocephalus var. paniculatus	Brownhead Rush
Lagophylla ramosissima ssp. ramosissima	Common Hareleaf
Lathyrus vestitus var. vestitus	Hillside Pea
Lepidium nitidum var. nitidum	Poorman's Pepperweed
Leymus triticoides	Creeping Wild Rye
Linanthus bicolor	Bicolored Linanthus
Linaria canadensis	Blue Toadflax
Lithophragma affine	Common Woodland Star
Lithophragma heterophyllum	Hillside Woodland Star
Lomatium caruifolium	Foothill Lomatium
Lomatium utriculatum	Bladder Parsnip
Lonicera hispidula var. vacillans	Honeysuckle
Lotus humistratus	Hill Lotus
Lotus purshianus var. purshianus	Spanish Lotus
Lotus scoparius var. scoparius	Deer Weed
Lotus wrangelianus	California Lotus, Common Trefoil
Lupinus bicolor	Miniature Lupine
Lupinus formosus var. formosus	Summer Lupine
Lupinus microcarpus var. microcarpus	Chick Lupine, Valley Lupine

Scientific Name	Common Name
Lupinus nanus	Sky Lupine
Lupinus succulentus	Arroyo Lupine
Luzula comosa	Wood Rush
Luzula comosa var. congesta	Woodrush
Madia elegans ssp. densifolia	Common Tarweed
Madia exigua	Threadstem Madia
Madia gracilis	Slender Tarweed
Marah fabaceus	California Manroot
Melica californica	California Melic
Melica torreyana	Torrey Melic
Micropus californicus var. californicus	Slender Cottonweed
Microseris elegans	Elegant Silverpuffs
Mimulus aurantiacus	Sticky Monkey Flower
Monardella villosa ssp. villosa	Coyote Mint
Myrica californica	Pacific Wax Myrtle
Nassella lepida	Foothill Needlegrass
Nassella pulchra	Purple Needlegrass
Nemophila heterophylla	Canyon Nemophila
Nemophila maculata	Fivespot
Oemleria cerasiformis	Oso Berry
Orobanche uniflora	Naked Brown Rape
Osmorhiza chilensis	Wood Cicely
Paspalum dilatatum	Dallis Grass
Pellaea andromedifolia	Coffee Fern
Pentagramma triangularis ssp. triangularis	Goldback Fern
Perideridia kelloggii	Yampah
Phlox gracilis	Slender Phlox
Phoradendron macrophyllum	Big Leaf Mistletoe, Big-Leaf Mistletoe, Big-Leafed Mistletoe
Phoradendron villosum	Oak Mistletoe
Picea sitchensis	Sitka Spruce
Pinus ponderosa	Pacific Ponderosa Pine, Ponderosa Pine
Pinus radiata	Monterey Pine
Platanus racemosa	California Sycamore
Plectritis brachystemon	Short-Spurred Plectritis
Plectritis ciliosa ssp. ciliosa	Long-Spurred Seablush
Plectritis congesta	Seablush
Poa secunda ssp. secunda	One Sided Bluegrass, One-Sided Bluegrass
Polypodium californicum	California Polypody

Scientific Name	Common Name
Polystichum munitum	Western Sword Fern
Populus fremontii ssp. fremontii	Fremont Cottonwood
Potentilla glandulosa ssp. glandulosa	Sticky Cinquefoil
Prunus lyonii	Catalina Cherry
Pseudotsuga menziesii	Douglas Fir
Psilocarphus tenellus var. tenellus	Wooly Head
Ptelea crenulata	Hoptree
Quercus agrifolia	Coast Live Oak
Quercus douglasii	Blue Oak
Quercus garryana	Oregon White Oak
Quercus kelloggii	California Black Oak
Quercus lobata	Valley Oak
Ranunculus californicus	California Buttercup
Rhamnus californica ssp. californica	California Coffeeberry
Rhus ovata	Sugar Bush
Ribes californicum var. californicum	Hillside Gooseberry
Ribes speciosum	Fuchsia Flowered Gooseberry
Romneya coulteri	Matilija Poppy
Rorippa nasturtium-aquaticum	Water Cress
Rosa californica	California Rose
Rosa gymnocarpa	Dwarf Rose, Wood Rose
Rubus ursinus	California Blackberry
Rupertia physodes	California Tea
Salix laevigata	Red Willow
Salix lasiolepis	Arroyo Willow
Salvia clevelandii	Cleveland Sage
Salvia columbariae	Chia
Salvia leucophylla	Purple Sage
Salvia mellifera	Black Sage
Salvia sonomensis	Sonoma Sage
Sambucus mexicana	Blue Elderberry
Sanicula bipinnatifida	Purple Sanicle
Sanicula crassicaulis	Pacific Snakeroot
Satureja douglasii	Yerba Buena
Saxifraga californica	California Saxifrage
Scientific Name	Common Name
Scirpus maritimus	Prairie Rush
Scrophularia californica ssp. californica	Figwort
Scutellaria tuberosa	Skullcap

Scientific Name	Common Name
Sequoia sempervirens	Coast Redwood, Redwood
Sequoiadendron giganteum	Giant Sequoia
Sisyrinchium bellum	Blue-Eyed Grass
Solanum americanum	Small-Flowered Nightshade
Solanum umbelliferum	Blue-Witch Nightshade
Solidago californica	California Goldenrod
Stachys ajugoides var. rigida	Hedge Nettle, Ridgid Hedge Nettle
Symphoricarpos albus var. laevigatus	Snowberry
Thysanocarpus curvipes	Fringepod
Toxicodendron diversilobum	Western Poison Oak
Trifolium bifidum var. decipiens	Deceiving Clover
Trifolium ciliolatum	Foothill Clover
Trifolium gracilentum var. gracilentum	Pinpoint Clover
Trifolium microcephalum	Smallhead Clover
Trifolium microdon	Valparaiso Clover
Trifolium oliganthum	Fewflower Clover
Trifolium willdenovii	Tomcat Clover
Triphysaria pusilla	Dwarf Owl's Clover
Triteleia laxa	Ithuriel's Spear
Typha angustifolia	Narrow-Leafed Cattail
Umbellularia californica	California Bay
Uropappus lindleyi	Silver Puffs
Urtica dioica ssp. holosericea	Hoary Nettle, Hoary Nettle, Stinging Nettle
Vicia americana var. americana	American Vetch
Vulpia microstachys var. pauciflora	Common Hairyleaf Fescue
Wyethia angustifolia	Narrow Leaf Mule Ears
Wyethia helenioides	Grey Mule Ears
Xanthium spinosum	Spiny Cocklebur
Xanthium strumarium	Cocklebur

A-2. Target Non-Native Species of JOMU

Latin Name	Common Name	Cal-IPC Rating	CDFA Rating
Ailanthus altissima	Tree of heaven	A-2	
Arundo donax	Giant reed	A-1	
Avena barbata	Slender wild oat	G	
Avena fatua	Wild oat	G	
Bellardia trixago	Bellardia	B	
Brassica nigra	Black mustard	B	
Bromus diandrus	Rip-gut brome	G	
Bromus madritensis ssp. *rubens*	Foxtail chess, Red brome	A-2	
Carduus pycnocephalus	Italian thistle	B	NOX-C
Carpobrotus edulis	Ice plant, Sea fig	A-1	
Centaurea calcitrapa	Purple star thistle	B	NOX-B
Centaurea melitensis	Tocalote	B	NOX-Non-Rated
Centaurea solstitialis	Yellow star thistle	A-1	NOX-C
Cirsium vulgare	Bull thistle	B	NOX-Non-Rated
Conium maculatum	Poison hemlock	B	
Convolvulus arvensis	Bindweed	?	NOX-C
Cotoneaster franchetii	Francheti cotoneaster	N	
Cotoneaster lacteus	Big-leafed cotoneaster	A-2	
Cynara cardunculus	Artichoke thistle	A-1	NOX-B
Cynodon dactylon	Bermuda grass		NOX-C
*Eucalyptus globulus***	Tasmanian blue gum**	A-1	
Euphorbia lathyris	Caper spurge	N	
Euphorbia oblongata	Oblong spurge		NOX-B
*Ficus carica***	Fig**	A-2	
Foeniculum vulgare	Fennel	A-1	
Genista monspessulana	French broom	A-1	NOX-C
Hedera canariensis	Algerian ivy	N	
*Hedera helix***	English ivy**	B	
Hirschfeldia incana	Hoary mustard	N	
Lepidium latifolium	Perrenial pepperweed	A-1	NOX-B
Lolium multiflorum	Italian rye grass	G	
Malvella leprosa	Alkali mallow		NOX-C
Medicago polymorpha	California bur clover	?	
Nerium oleander	Oleander	?	
*Olea europaea***	Olive**	B	
Oxalis pes-caprae	Bermuda buttercup	N	
Phalaris aquatica	Harding grass	B	
Phyla nodiflora var. *nodiflora*	Common lippia	N	
Picris echioides	Bristly ox-tongue	?	
Piptatherum miliaceum	Smilo grass	N	
*Prunus cerasifera***	Cherry plum**	N	
Rubus discolor	Himalaya blackberry	A-1	
Salsola soda	Russian thistle	N	
Senecio vulgaris	Groundsel		NOX-Non-Rated
Silybum marianum	Milk thistle	?	
Vinca major	Periwinkle	B	
Tribulus terrestris	Puncturevine		NOX-C

Latin Name	Common Name	Cal-IPC Rating	CDFA Rating
Xanthium spinosum	Spiny cocklebur	?	
Zantedeschia aethiopica	Calla-lily	?	

** = Historic/potentially historic plantings

California Invasive Plant Council (Cal-IPC) Ratings:
A-1 = Most Invasive Wildland Pest Plants, Widespread
A-2 = Most Invasive Wildland Pest Plants, Regional
B = Wildland Pest Plants of Lesser Invasiveness
N = Need More Information
G = Other Annual Grasses of Concern
? = Considered but Not Listed

California Department of Food and Agriculture (CDFA) Ratings:
NOX-C = Extremely Widespread (Containment Efforts Not Recommended);
NOX-B = Widespread (Potentially Containable);
NOX-Non-rated = Weeds without an Established Rating

A-3. Birds of JOMU

Abbreviations:

CalPIF = California Partners in Flight listed;

Spp. of C = California Species of Concern (Shuford and Garaldi 2008)

Scientific Name	Common Name	CalPIF	Spp. of C
Accipiter cooperii	Cooper's Hawk		
Accipiter striatus	Sharp-shinned Hawk		
Aeronautes saxatalis	White-throated Swift		
Agelaius phoeniceus	Red-winged Blackbird		
Anas platyrhynchos	Mallard		
Aphelocoma californica	Western scrub-jay	X	
Aphelocoma coerulescens	Florida Scrub Jay, Florida Scrub-Jay, Scrub Jay		
Ardea herodias	Great Blue Heron		
Baeolophus inornatus	Oak titmouse	X	
Bombycilla cedrorum	Cedar Waxwing		
Branta canadensis	Canada Goose		
Bubo virginianus	Great Horned Owl		
Buteo jamaicensis	Red-tailed Hawk		
Buteo lineatus	Red-shouldered Hawk		
Buteo regalis	Ferruginous Hawk	X	
Callipepla californica	California Quail, Californian Quail		
Calypte anna	Anna's Hummingbird		
Carduelis lawrencei	Lawrence's Goldfinch		
Carduelis pinus	Pine Siskin		
Carduelis psaltria	Lesser Goldfinch		
Carduelis tristis	American Goldfinch		
Carpodacus mexicanus	House Finch		
Carpodacus purpureus	Purple Finch		
Cathartes aura	Turkey Vulture		
Catharus guttatus	Hermit Thrush		
Catharus ustulatus	Swainson's Thrush	X	
Certhia americana	brown creeper	X	
Chamaea fasciata	Wrentit	X	
Chondestes grammacus	Lark Sparrow		
Circus cyaneus	Northern Harrier	X	X
Colaptes auratus	Northern Flicker		
Columba fasciata	Band-tailed Pigeon		
Columba livia	Common Pigeon, Rock Dove, Rock Pigeon		

Scientific Name	Common Name	CalPIF	Spp. of C
Contopus cooperi	Olive-sided Flycatcher	X	X
Contopus sordidulus	Western Wood Pewee, Western Wood-Pewee		
Corvus brachyrhynchos	American Crow		
Corvus corax	Common Raven, Northern Raven	X	
Cyanocitta stelleri	Steller's Jay		
Dendroica coronata	Yellow-rumped Warbler		
Dendroica nigrescens	Black-throated Gray Warbler, Black-throated Grey Warbler	X	
Dendroica occidentalis	Hermit Warbler		
Dendroica petechia	American Yellow Warbler, Yellow Warbler	X	
Dendroica townsendi	Townsend's Warbler		
Elanus caeruleus	white-tailed kite		
Elanus leucurus	white-tailed kite		
Empidonax difficilis	Pacific-slope flycatcher		
Falco columbarius	Merlin		
Falco sparverius	American Kestrel		
Hirundo rustica	Barn Swallow		
Icterus cucullatus	Hooded Oriole		
Icterus galbula bullocki	Bullock's Oriole		
Ixoreus naevius	Varied Thrush		
Junco hyemalis	Dark-eyed Junco	X	
Melanerpes formicivorus	Acorn Woodpecker	X	
Meleagris gallopavo	Wild Turkey		
Melospiza melodia	Song Sparrow	X	
Mimus polyglottos	Northern Mockingbird		
Myiarchus cinerascens	Ash-throated Flycatcher	X	
Otus kennicottii	Western Screech-Owl		
Pandion haliaetus	Osprey		
Parus inornatus	Plain Titmouse		
Parus rufescens	Chestnut-backed chickadee		
Passer domesticus	House Sparrow		
Passerculus sandwichensis	Savannah Sparrow	X	
Passerella iliaca	Fox Sparrow	X	
Passerina amoena	Lazuli Bunting		
Petrochelidon pyrrhonota	Cliff swallow		
Phalacrocorax auritus	Double-crested Cormorant		
Pheucticus melanocephalus	Black-headed Grosbeak	X	
Picoides nuttallii	Nuttall's Woodpecker	X	
Picoides pubescens	Downy Woodpecker		

Scientific Name	**Common Name**	**CalPIF**	**Spp. of C**
Picoides villosus	Hairy Woodpecker		
Pipilo crissalis	California towhee		
Pipilo maculatus	Spotted towhee		
Piranga ludoviciana	Western Tanager		
Poecile rufescens	Chestnut-backed Chickadee		
Polioptila caerulea	Blue-gray Gnatcatcher, Blue-grey Gnatcatcher	X	
Psaltriparus minimus	American Bushtit, Bushtit		
Regulus calendula	Ruby-crowned Kinglet		
Regulus satrapa	Golden-crowned Kinglet	X	
Sayornis nigricans	Black Phoebe		
Sayornis saya	Say's Phoebe		
Selasphorus rufus	Rufous Hummingbird		
Selasphorus sasin	Allen's Hummingbird		
Sialia mexicana	Western Bluebird	X	
Sitta carolinensis	White-breasted Nuthatch		
Sphyrapicus ruber	Red-breasted Sapsucker		
Spizella passerina	Chipping Sparrow		
Stelgidopteryx serripennis	Northern Rough-winged Swallow		
Sturnella neglecta	Western Meadowlark	X	
Sturnus vulgaris	Common Starling, European Starling		
Tachycineta bicolor	Tree Swallow	X	
Tachycineta thalassina	Violet-green Swallow		
Thryomanes bewickii	Bewick's Wren		
Toxostoma redivivum	California Thrasher		
Troglodytes aedon	House Wren		
Turdus migratorius	American Robin		
Tyto alba	Barn Owl, Common Barn-Owl		
Vermivora celata	Orange-crowned Warbler		
Vireo cassinii	Cassin's vireo		
Vireo gilvus	Warbling Vireo	X	
Vireo huttoni	Hutton's Vireo		
Wilsonia pusilla	Wilson's Warbler	X	
Zenaida macroura	Mourning Dove		
Zonotrichia atricapilla	Golden-crowned Sparrow		
Zonotrichia leucophrys	White-crowned Sparrow		

A-4. Butterflies of JOMU

Scientific Name	Common Name
Battus philenor	Pipevine swallowtail
Papilio zelicaon	Anise swallowtail
Papilio rutulus	Western tiger swallowtail
Papilio multicaudata	Two-tailed swallowtail
Papilio eurymedon	Pale swallowtail
Pieris rapae	Cabbage white
Euchloe ausonides	Large marble
Anthocharis sara	Sara orange-tip
Colias eurytheme	Orange sulphur
Colias eurydice	California dogface
Lycaena xanthoides	Great copper
Satyrium auretorum	Gold-hunter's hairstreak
Callophrys augustinus	Brown elfin
Strymon melinus	Gray hairstreak
Celastrina ladon	Spring azure/echo blue
Plebejus acmon	Acmon blue
Agraulis vanillae	Gulf fritillary
Chlosyne palla	Northern checkerspot
Phyciodes mylitta	Mylitta crescent
Phyciodes campestris	Field crescent
Euphydryas chalcedona	Variable checkerspot
Nymphalis antiopa	Mourning cloak
Vanessa virginiensis	American lady
Vanessa cardui	Painted lady
Vanessa atalanta	Red admiral
Junonia coenia	Common buckeye
Adelpha bredowii	California sister
Limenitis lorquini	Lorquin's admiral
Coenonympha tullia	Common ringlet
Cercyonis sthenele	Great Basin wood nymph
Danaus plexippus	Monarch
Erynnis propertius	Propertius duskywing
Erynnis tristis	Mournful duskywing
Pyrgus communis	Common check'd-skipper
Ochlodes agricola	Rural skipper
Poanes melane	Umber skipper

A-5. Moth Species List of JOMU

Family	Subfamily/Species Name
Tineidae	*Nemapogon granella*
Acrolophidae	*Ptilopsaltis confusella*
Acrolophidae	*Amydria sp.*
Acrolophidae	*Amydria new sp. "c"*
Acrolophidae	*Acrolophus laticapitanus*
Tineidae	*Tinea niveocapitella*
Gracillariidae	*Caloptilia agrifoliella*
Gracillariidae	*Marmara*
Gracillariidae	*Phyllonorycter*
Oecophoridae	*Agonopterix oregonensis*
Oecophoridae	*Esperia sulphurella*
Oecophoridae	*Pleurota albastrigulella*
Blastobasidae	*Hypatopa/Holcocera*
Blastobasidae	*Blastobasis glandulella*
Cosmopterigidae	*Walshia miscecolorella*
Gelechiidae	*Isophrictis*
Gelechiidae	*Aristotelia adenostomae*
Gelechiidae	*Evippe laudatella*
Gelechiidae	*Leucogoniella californica*
Gelechiidae	*Xenolechia*
Gelechiidae	*Exceptia sisterina*
Gelechiidae	*Chionodes sp.*
Gelechiidae	*Chionodes*
Gelechiidae	*Chionodes ochreostrigella*
Gelechiidae	*Filatima*
Gelechiidae	*Mirificarma eburnella*
Carposinidae	*Bondia comonana*
Epermeniidae	*Epermenia cicutaella*
Plutellidae	*Euceratia securella*
Plutellidae	*Plutella vanella*
Plutellidae	*Ypsolopha sp.*
Plutellidae	*Ypsolopha cervella*
Tortricidae	*Endothenia hebesana*
Tortricidae	*Eucosma avalona*
Tortricidae	*Eucosma subflavana*
Tortricidae	*Epinotia siskiyouensis*
Tortricidae	*Cydia pomonella*
Tortricidae	*Cydia latiferreana*
Tortricidae	*Cnephasia longana*
Tortricidae	*Decodes basiplaganus*
Tortricidae	*Decodes fragarianus*
Tortricidae	*Argyrotaenia citrana*
Tortricidae	*Archips argyrospila*

Family	Subfamily/Species Name
Tortricidae	*Clepsis peritana*
Tortricidae	*Amorbia cuneana*
Tortricidae	*Henricus umbrabasanus*
Crambidae	*Cosipara sp.*
Crambidae	*Eudonia sp.*
Crambidae	*Eudonia rectilinea*
Crambidae	*Hellula rogatalis*
Crambidae	*Dicymolomia metalliferalis*
Crambidae	*Pyrausta volupialis*
Crambidae	*Pyrausta perrubralis*
Crambidae	*Lineodes integra*
Crambidae	*Mecyna mustelinalis*
Crambidae	*Mimorista subcostalis*
Crambidae	*Herculia*
Crambidae	*Diastictis fracturalis*
Crambidae	*Pediasia sp.*
Crambidae	*Euchromius ocellus*
Crambidae	*Arta epicoenalis*
Pyralidae	*Galleria mellonella*
Pyralidae	Phycitinae
Pyralidae	*Acrobasis tricolorella*
Pyralidae	*Acrobasis comptella*
Pyralidae	*Trachycera caliginoidella*
Pyralidae	*Apomyelois bistriatella*
Pyralidae	*Etiella zinckenella*
Pyralidae	*Dioryctria sp*
Pyralidae	*Homoeosoma electellum*
Pyralidae	*Phycitodes mucidella*
Pyralidae	*Ephestiodes gilvescentella*
Pyralidae	*Vitula edmandsii*
Pyralidae	*Ephestia kuehniella*
Pyralidae	*Bandera*
Geometridae	*Alsophila pometaria*
Geometridae	*Elpiste marcescaria*
Geometridae	*Semiothisa sp.*
Geometridae	*Semiothisa muscariata*
Geometridae	*Semiothisa californiaria*
Geometridae	*Hulstina sp.*
Geometridae	*Hulstina wrightiaria*
Geometridae	*Pterotaea sp.*
Geometridae	*Cochisea sinuaria*
Geometridae	*Phigalia plumogeraria*
Geometridae	*Paleacrita longiciliata*
Geometridae	*Erannis tiliaria vancouverensis*

Family	Subfamily/Species Name
Geometridae	*Pero macdunnoughi*
Geometridae	*Thallophaga sp.*
Geometridae	*Neoterpes edwardsata*
Geometridae	*Sicya morsicaria*
Geometridae	*Plataea personaria*
Geometridae	*Pherne sp.*
Geometridae	*Synaxis pallulata*
Geometridae	*Synaxis cervinaria*
Geometridae	*Prochoerodes truxaliata*
Geometridae	*Nemoria leptalea*
Geometridae	*Nemoria pulcherrima*
Geometridae	*Dichorda illustraria*
Geometridae	*Synchlora aerata*
Geometridae	*Cyclophora dataria*
Geometridae	*Dysstroma sp.*
Geometridae	*Dysstroma brunneata*
Geometridae	*Hydriomena edenata*
Geometridae	*Hydriomena albifasciata*
Geometridae	*Hydriomena nubilofasciata*
Geometridae	*Stamnodes gibbicostata*
Geometridae	*Epirrhoe plebeculata*
Geometridae	*Zenophleps lignicolorata*
Geometridae	*Venusia duodecemlineata*
Geometridae	*Operophtera occidentalis*
Geometridae	*Operophtera danbyi*
Geometridae	*Eupithecia sp.*
Geometridae	*Eupithecia nevadata complex*
Geometridae	*Eupithecia/Nasusaria*
Lasiocampidae	*Phyllodesma americana*
Lasiocampidae	*Malacosoma californicum*
Sphingidae	*Arctonotus lucidus*
Notodontidae	*Nadata gibbosa*
Notodontidae	*Schizura unicornis*
Arctiidae	*Leptarctia californiae*
Arctiidae	*Spilosoma vestalis*
Arctiidae	*Grammia (Apantesis) ornata*
Arctiidae	*Hemihyalea edwardsii*
Lymantriidae	*Orgyia cana*
Noctudae	*Abagrotis sp.*
Noctudae	*Mesogona subcuprea*
Noctudae	*Mesogona olivata*
Noctudae	*Pseudorthosia variabilis*
Noctudae	*Idia americalis*
Noctudae	*Noctua pronuba*

Family	Subfamily/Species Name
Noctudae	*Noctuidae sp.*
Noctudae	*Hemeroplanis finitima*
Noctudae	*Synedoida edwardsi*
Noctudae	*Caenurgia togataria*
Noctudae	*Catocala aholibah*
Noctudae	*Catocala ilia zoe*
Noctudae	*Catocala verilliana*
Noctudae	*Autographa californica*
Noctudae	*Nola minna*
Noctudae	*Eumicremma minima*
Noctudae	*Acronicta marmorata*
Noctudae	*Apamea cinefacta*
Noctudae	*Oligia marina*
Noctudae	*Cobalos franciscanus*
Noctudae	*Aseptis paviae*
Noctudae	*Properigea albimacula*
Noctudae	*Pseudobryomima fallax*
Noctudae	*Amphipyra pyramidoides*
Noctudae	*Protoperigea posticata*
Noctudae	*Spodoptera exigua*
Noctudae	*Spodoptera praefica*
Noctudae	*Cosmia calami*
Noctudae	*Agrochola purpurea*
Noctudae	*Agrochola purpurea*
Noctudae	*Pleromelloida cinerea*
Noctudae	*Lacinipolia sp.*
Noctudae	*Lacinipolia sp.*
Noctudae	*Lacinipolia cuneata*
Noctudae	*Lacinipolia pensilis*
Noctudae	*Lacinipolia stricta cinnabarrina*
Noctudae	*Lacinipolia strigicollis*
Noctudae	*Lacinipolia quadrilineata*
Noctudae	*Dargida procincta*
Noctudae	*Faronta terrapictalis*
Noctudae	*Pseudaletia unipuncta*
Noctudae	*Leucania oaxacana*
Noctudae	*Orthosia erythrolita*
Noctudae	*Orthosia erythrolita ?*
Noctudae	*Orthosia sp.*
Noctudae	*Orthosia transparens*
Noctudae	*Orthosia praeses*
Noctudae	*Orthosia behrensiana*
Noctudae	*Orthosia macona*
Noctudae	*Orthosia arthrolita*

Family	Subfamily/Species Name
Noctudae	*Orthosia pacifica*
Noctudae	*Egira hiemalis*
Noctudae	*Egira crucialis*
Noctudae	*Egira februalis*
Noctudae	*Egira rubrica*
Noctudae	*Egira perlubens*
Noctudae	*Homorthodes communis*
Noctudae	*Homorthodes fractura*
Noctudae	*Homorthodes hanhami*
Noctudae	*Protorthodes alfkeni*
Noctudae	*Zosteropoda hirtipes*
Noctudae	*Tricholita fistula*
Noctudae	*Agrotis ipsilon*
Noctudae	*Euxoa*
Noctudae	*Peridroma saucia*
Noctudae	*Xestia adela*
Noctudae	*Anomogyna infimatis*
Noctudae	*Adelphagrotis indeterminata*
Noctudae	*Parabrogrotis insularis*

A-6. Bees of Mount Wanda (JOMU)

Genus / Family*	Species
Andrena	*angustitarsata*
	caerulea
	piperi
	sladeni
	sola
	suavis
Tortricidae*	
Panurginus	*nigrihirtus*
Anthophora	*californica*
	edwardsii
	urbana
Habropoda	*tristissima*
Apis	*mellifera*
Bombus	*californicus*
	edwardsii
	griseocollis
	vosnesenskii
Ceratina	*acantha*
	nanula
	sequoiae
Diadasia	*bituberculata*
Doeringiella	*sp. 1*
Eucera	*actuosa*
	cordleyi
	frater
	virgata
Melissodes	*lupina*
	stearnsi
Svastra	*obliqua*
Tetraloniella	*pomonae*
Nomada	*sp. A*
Xylocopa	*tabaniformis*
Colletes	*fulgidus*
Hylaeus	*coloradensis*
	granulatus?
Agapostemon	*angelicus/texanus*
Halictus	*farinosus*
	tripartitus
Lasioglossum	*incompletus*
	mellipes
	ruidosensis
	sp. 1
	sp. 16
	sp. B
	sp. E

Genus / Family*	Species
Lasioglossum	*titusi*
Stelis	*montana*
Megachile	*apicalis*
	fidelis
	montivaga
Ashmeadiella	*bucconis*
	californica
Hoplitis	*albifrons*
	howardi
Osmia	*atrocyanea*
	californica
	coloradensis
	cyanella
	gabrielis
	glauca
	granulosa
	laeta
	lignaria
	montana
	nemoris
	pusilla
	texana
	tristella
Protosmia	*rubifloris*

A-7. GIS data layers created for the assessment

Analysis regions	Title of Dataset	GIS layer name	Layer type
Region	Park reference region	JOMU_regional_ boundary	shapefile
Park-and_buffer	Park-and_buffer reference region	JOMU_buffer_bo undary	shapefile
Indicator theme	**GIS layer topic**	**GIS layer name**	**Layer type**
Stressor: Housing Development	Housing density 1940-2000	pbg00v2	shapefile
Stressor: Housing Development	Housing density 1990-2000	brf_region_clip	shapefile
Biological Integrity—At-risk biota—Alameda whipsnake	Core and movement habitat model of Alameda whipsnake	whipsnake	raster

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