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A VEGETATION CLASSIFICATION FOR THE SANTA MONICA MOUNTAINS

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ABSTRACT: The vegetation of the entire Santa Monica Mountains and adjacent area north to the Simi Hills was systematically sampled to develop a detailed vegetation classification. This classification will form the basis for a detailed vegetation map and provide a baseline data set for the long-term monitoring and management of the area's natural resources. In this 320,000-acre region, over 4,100 individual vegetation surveys were allocated based on a Geographic Information Systems (GIS) biophysical model, which identified seven ecological zones defined via climatic, geologic, and topographic conditions. The California Native Plant Society (CNPS) Rapid Assessment protocol was used to obtain the majority of the data. The field data were analyzed using TWINSPAN and agglomerative cluster analysis. The final analysis relied on a set of 254 species and 3,912 samples. These samples were partitioned into 84 alliances or unique stands, 204 associations, and 73 phases. The rapid assessment method compared favorably to relevé and other methods of sampling vegetation for classification. The robustness and level of detail of the classification is unsurpassed in California vegetation classification.

KEYWORDS: Vegetation classification, Santa Monica Mountains, vegetation map, Rapid Assessment Vegetation Sampling Protocol, vegetation alliance, vegetation association, vegetation phase

INTRODUCTION

The Santa Monica Mountains and adjoining Simi Hills are not only the most accessible and largest piece of natural land adjacent to the western Los Angeles Basin but also play an important role in the panoply of vegetation in southern coastal California (Figure 1). Fire history, differences in soil, moisture, and temperature regimes, and topography all combine to create complex patterns of woodland, chaparral, coastal scrub, and grassland vegetation. The mountains

Figure 1. Topography including slope position, steepness, and exposure has a strong influence on vegetation patterning in the Santa Monica Mountains. In this view are stands of *Quercus agrifolia, Q. berberidifolia, Adenostoma fasciculatum, Ceanothus megacarpus, Ceanothus spinosus,* and *Platanus racemosa* alliances, Upper Solstice Canyon, facing southeast.

are home to several locally common but regionally restricted species (such as *Ceanothus spinosus, C. megacarpus, Eriogonum cinereum,* and *Coreopsis gigantea*); each because of its high sociability and abundance defines its own suite of vegetation types. Other alliances defined by *Encelia californica, Salvia leucophylla, Juglans californica,* and *Rhus integrifolia* are regionally distributed in southern, coastal California and display a more concentrated distribution and a broader variation of vegetation associations here than anywhere else.

The Santa Monica Mountains are the westernmost and lowest of the Transverse Ranges of southern California. They have small stands of higher-elevation chaparral alliances such as *Quercus wislizeni* var. *frutescens* and *Arctostaphylos glandulosa,* remnants of a cooler and perhaps moister climate. They also are tall enough to sustain a more extensive presence of some higher-elevation chaparral alliances such as *Ceanothus oliganthus* and *Adenostoma sparsifolium*. In addition, they contain the southernmost stands of *Quercus lobata* woodlands in California and among the largest remaining woodlands of *Juglans californica*. The seaward bases of the mountains have succulent coastal scrub like that of Baja California, including stands of *Opuntia littoralis, O. oricola,* and *O. prolifera* along with drought deciduous scrubs such as *Salvia leucophylla, Artemisia californica,* and the largely insular *Coreopsis gigantea.* The core of the mountains covers thousands of acres and includes varied examples of *Ceanothus spinosus* and *C.*

megacarpus alliances, both representing the center of their world distribution (Figure 2). Riparian vegetation includes extensive woodlands of *Platanus racemosa, Salix lasiolepis,* and *S. laevigata,* which often interface with lower slope woodlands of *Quercus agrifolia, Juglans californica,* and *Umbellularia californica.* Further south, the latter two alliances diminish significantly, thus signifying the biogeographic role of the Santa Monica Mountains as crossroads between northern and southern California coast range vegetation.

The National Park Service, Santa Monica Mountains National Recreation Area (NPS) undertook development of a new vegetation classification and map in 2001. NPS entered into a contract with Environmental Systems Research Institute, Inc. (ESRI), to develop a vegetation classification and map. ESRI subcontracted with CNPS via the California Heritage Program ecologist (housed at California Department of Fish and Game, CDFG), representing NatureServe in California. ESRI also subcontracted with Aerial Information Systems, Inc. (AIS), to produce a map driven by the classification developed by CNPS and CDFG. Primary responsibility for development of the classification was assigned to Todd Keeler-Wolf (CDFG California Heritage Program senior vegetation ecologist) and Julie Evens (CNPS senior vegetation ecologist). Edward Reyes (AIS) was the lead photo-interpreter and vegetation mapper. NPS assumed responsibility for field data collection, vegetation database management, and statistical analyses. With supervision from John Tiszler, field data were collected during a continuous two-year effort and managed by Julie Christian from 2002 to 2004.

Figure 2. The *Ceanothus spinosus* Alliance (foreground and left-center) has its center of distribution in the Santa Monica Mountains.

The primary motivation for this project was to produce a new vegetation classification and map that meet NPS and U.S. National Vegetation Classification (USNVC) standards and to provide the information base necessary to develop effective fire hazard management strategies while fully protecting natural resource values. In addition, the classification and map will have many uses for the numerous public planning and land conservation agencies with jurisdiction in the Santa Monica Mountains and Simi Hills. For example, the classification and map will provide a highly detailed spatial assessment of native vegetation and, as such, will be a valuable planning tool where habitat connectivity, sensitive vegetation types, and protection of designated Ecologically Significant Habitat Areas are of concern. The results will improve the capacity to make local vegetation management and other land-use decisions.

This article provides our methods for sampling and classification, a listing of the vegetation types defined, and a brief description of the broad ecological zones of the Santa Monica Mountains that we determined in the course of our study.

METHODS

Study Area

The area of study was the Santa Monica Mountains and its environs, including the Simi Hills and Montcleff Ridge. The area encompasses approximately 225,000 acres, from Griffith Park in Los Angeles in the east to Point Mugu State Park in the west and from Simi Valley in the north to the Malibu Coast (Figure 3). Of that area, approximately 75,000 acres is developed, including the cities of the Conejo Valley and the City of Malibu. We excluded these areas from the survey.

Standards and Protocols

This vegetation classification follows the U.S. National Vegetation Classification (USNVC) guidelines (Grossman et al. 1998). Refinements to the classification have been occurring in the application process, leading to ongoing proposed revisions that are reviewed both locally and nationally (http://www.natureserve.org/explorer/). Vegetation mapping in national parks has been undertaken under the auspices of the NPS Inventory and Monitoring Program, in close cooperation with the USGS-Biological Resources Division (BRD). The mapping is done in accordance with standards established by the Federal Geographic Data Committee (FGDC) for vegetation mapping on federal lands. The FGDC Web site (http://www.fgdc.gov/ standards/standards_publications/index_html) explains the development of the classification standards currently used for mapping and classifying vegetation in national parks. The USGS-BRD/NPS Vegetation Mapping project Web site (http://biology.usgs.gov/npsveg /standards.html) contains additional information on vegetation mapping in national parks.

This project was the first effort to extensively employ the CNPS Rapid Assessment Vegetation Sampling Protocol, which is an abbreviated plotless (stand-based) survey technique that relies on visual estimates of cover of the predominant species in each of the vegetation strata of a stand (see http://www.cnps.org/programs/vegetation /protocol.htm for full description).

This technique was selected, in addition to the standard relevé sampling protocol used regularly by the National Park vegetation programs, because of its ability to represent large numbers of vegetation stands quickly, thus increasing the sample size and range of sampling locations for all types of vegetation. This rapid assessment protocol provided an efficient way to inventory many

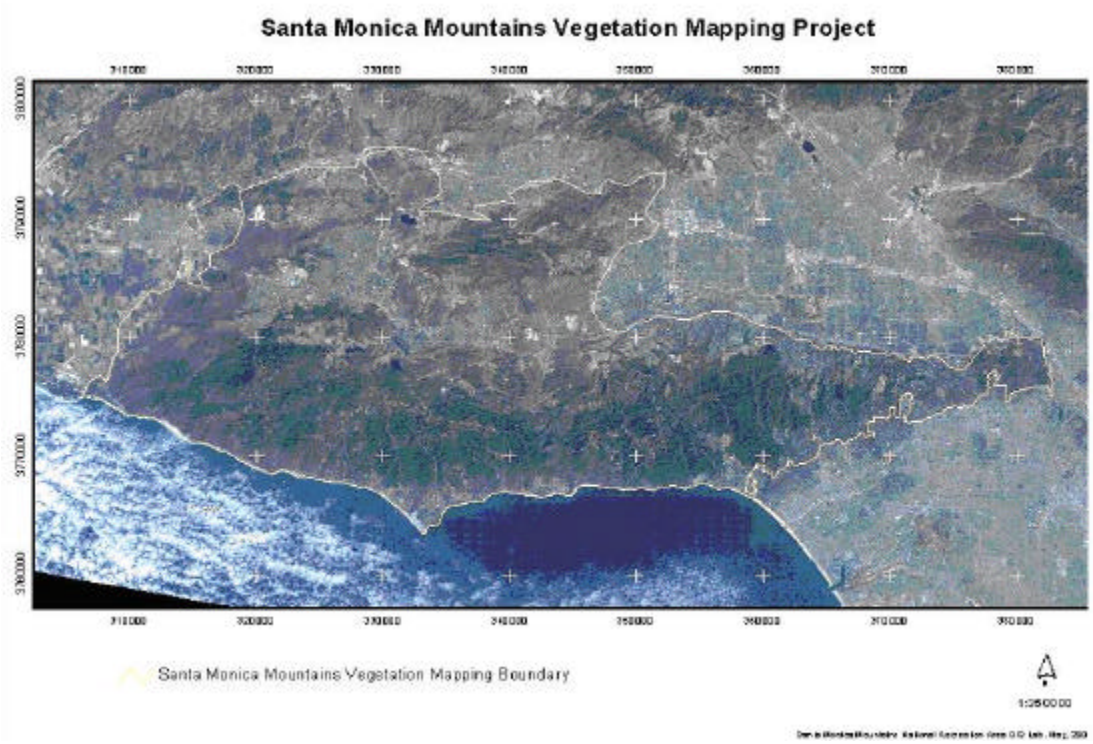

Figure 3. Study area of the Santa Monica Mountains and environs.

dense and difficult to penetrate stands of chaparral and coastal scrub, where the species indicative of particular ecological settings were primarily in the shrub layer and not in the understory herbaceous layer. It was used extensively in surveying virtually all types of vegetation in this project except for the species-rich riparian, oak, and other hardwood woodlands, coastal sage scrub, and grasslands in which relevés were conducted to augment the samples. The diversity of species and the more significant variation of understory species in these situations required a full sample of all species recorded to more accurately classify and understand the variations in these types of vegetation.

Field Sampling

The locations of stand samples were driven by a selection of representative landscapes using a biophysical model of the area (for details see full report in Keeler-Wolf and Evens 2006). A GIS analysis was conducted by park staff based on identification of driving variables for vegetation distribution. Specifically, a March solar radiation layer was separated into three classes (based on slope and aspect), then layers were classified and combined for:

a) fire history,
b) geology,
c) average annual precipitation, and
d) average maximum July temperature.

Field crews were directed to sampling locations identified through the GIS analysis and refined their sample locations based on the principles of stand homogeneity and accessibility (see CNPS rapid assessment protocol online, op cit.).

Data Analysis

The sample data set used for the classification included 3,790 vegetation rapid assessments, which were completed year-round from July 2002 to April 2004, and 122 relevé samples, which were completed from February to June 2003 (in the phenologically active periods of spring and summer). The very large number of samples collected for this project far exceeded any previous study for a given National Park unit. We used database queries to display the details of the cluster groupings on a plot-by-plot basis. This allowed us to visually inspect the relationships between species and their cover within the statistically determined groupings. Interim analysis about half-way through the field data collection allowed further re-focusing of sampling needs prior to the completion of the field work.

We used the PC-ORD software suite of classification and ordination tools (McCune and Mefford 1997, McCune and Grace 2002) for the initial analysis. PC-ORD performs a set of different multivariate analyses to place vegetation sample units (including both rapid assessment and relevé) into a formalized classification of vegetation types. Using analyses in the suite such as cluster analysis and ordination indicates similarities in species composition and abundance among samples. The data sets are inherently complex and more than one environmental axis may be correlated with the patterns of plot samples. We used a hierarchical agglomerative cluster analysis technique with Sorenson distance and flexible beta linkage method at -0.25. This technique is based on abundance (cover) values converted to seven different classes using the following modified Braun-Blanquet (1932/1951) cover categories: 1 (< 1%), 2 (1-5%), 3 (>5% - 15%), 4 (>15%-25%), 5 (>25%-50%), 6 (>50%-75%), and 7 (>75%). The majority of the species values fell within the first four cover classes. Prior to these analyses, data were screened for outliers (extreme values of sampled stands or species), and these outliers were removed to reduce heterogeneity and increase normality in the data set. We removed samples that were more than three standard deviations away from the mean and species that occurred in fewer than three plot samples using outlier analysis.

Because of the size and heterogeneity of the initial data set, we used a first-order cluster analysis to partition it into more distinct and manageable subsets of around 100–200 samples. Teams of two to three ecologists then analyzed the smaller subsets that usually included distinctly different vegetation types or habitats. We applied cluster analysis to both rapid assessment and relevé data, but analyzed these data sets separately because the species data were recorded differently (i.e., data on all species found in defined plots for relevés as compared to data on up to 20 main species found in stands for the rapid assessments). After the cluster analyses, we used Indicator Species Analysis (ISA) from the PC-ORD suite to determine which species had the highest fidelity for a particular proposed vegetation type using the statistical test developed by Dufrene and Legendre (1997).

ISAs were used to evaluate the total number of significant indicator species (p-value = 0.005) within each group level and the mean p-value for all species. The group level that had the highest number of significant indicators and lowest overall mean p-value was selected for the final community classification evaluation (McCune and Grace 2002). At this grouping level, plant community names within floristic classes were applied to the samples of the different groups.

Vegetation Type Hierarchy

Naming conventions follow the National Vegetation Classification System (Grossman et al. 1998) and the CNPS system (Sawyer and Keeler-Wolf 1995, and updates from Sawyer et al. 2007 ms). Both recognize the plant association as the fundamental unit of classification. We define an

association as a group of vegetation samples with a suite of dominant and characteristic (indicator) species identified through ISA. The membership rules were defined by species constancy, indicator species, and species cover values. This group of floristically similar samples is also correlated with a particular environmental setting, described in this effort by a summarization of the environmental variables collected at each sample location. Formal ordination of these environmental variables was not systematically conducted for all groupings, because of the generalized nature of most of the environmental data collected (see below). However, Bray-Curtis ordination (McCune and Grace 2002) was used to differentiate some groups. A set of similar associations are grouped hierarchically to the next level in the classification, the alliance. Alliances are generic units of vegetation classification, usually defined by the dominant and/or characteristic plant species in the upper layer of vegetation (Figure 4).

Figure 4. *Quercus agrifolia* (Coast Live Oak) Alliance has a broad range in understory variation defining different associations.

The environmental field data collected on rapid assessment surveys is basic and tends to focus on general "hard" variables such as elevation, slope, aspect, soil texture, geology, and so forth. Associations are usually differentiated by environmental factors as well as floristic characteristics. In vegetation, the arrangement of certain groups of species defining a category of vegetation correlates with a particular set of ecological situations, which may include "hard" or specific climatic and other environmental differences related to temperature, moisture, or soil nutrition; however, it may also imply more vague ecological characteristics such as mode, frequency, and intensity of disturbance. As definitions were developed, the data analysis team

used the correlates to ascertain environmental variables, or lack thereof, to help determine whether or not a particular cluster grouping should be ranked as an association.

As many of the vegetation types defined in this classification related to the "softer" variables that may be correlated with history following fire or other disturbance, it was difficult to draw specific, strong environmental correlations with many of the types. In cases where a group of vegetation samples appeared somewhat floristically distinct but shared the same environmental characteristics with a larger group of samples, the term "phase" was used. A phase is an informal unit of classification accommodating local floristic variation that tends to not have obvious correlations with certain environmental conditions, and is best considered a part of a more definitive association. Most defined phases are probably the result of localized variation in climate or site history associated with local relief, soil texture, geology, and fire history.

Each sample was revisited within the context of the cluster to which it had been assigned in order to quantitatively define membership rules for each association. Upon revisiting each sample, a few samples were found to be misclassified in earlier fusions of the cluster analysis, and these samples were reclassified based on the membership rules. The set of data collected throughout the study area was used as the principal means for defining the association composition and membership rules; however, existing classifications of similar vegetation elsewhere in the state were consulted to locate analogous/similar classifications or descriptions of vegetation.

ECOLOGICAL REGIONS

In the process of creating the vegetation classification and map, we defined seven broad ecological regions for the Santa Monica Mountains (Figure 5). We arrived at a determination of these zones by formal and informal means: through a Gradient Directed Sample Allocation (GRADSECT) (Austin and Heyligers 1991); analysis of the environmental factors likely to drive the distribution of the principal vegetation associations in the area (geology, precipitation, temperature, and solar insolation [based on slope and aspect]); and through the assessments of the field ecologists and photo-interpreters based on observations made during field data gathering and vegetation mapping. In addition, the GRADSECT analysis assisted in selecting survey locations in a stratified random process.

The following descriptions serve as brief characterizations of each of these seven regions. Each region is given a descriptive name based on our observations.

Region 1: Western Fog Zone (Coastal Sage Scrub on Volcanics)

General Location:	Far west end of range as hits Oxnard Plain
Ave-Hi/Low Summer Temp:	75/55 (Camarillo)
Ave-Hi/Low Winter Temp:	65/45, Records below 32
Fog Description:	Often foggy, possible year-round
Precipitation:	10–15", lower than Region 2
Geology:	Igneous > Quaternary >> Low Sedimentary
Soil:	Incomplete, Coastal Sage > Igneous Chaparral
Elevation Range:	0–1800'

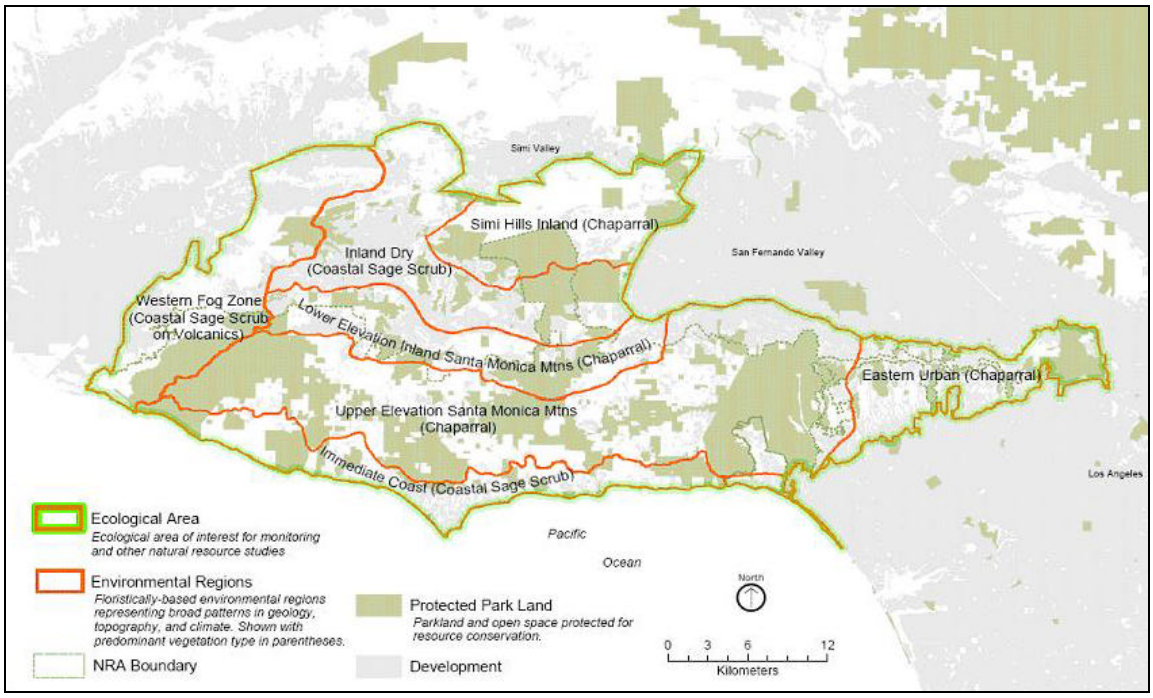

Figure 5. Ecological regions identified for vegetation assessment.

Region 2: Immediate Coast (Coastal Sage Scrub)

General Location:	East-west band along immediate coast, south-facing Slopes
Ave-Hi/Low Summer Temp:	70/60 (Malibu)
Ave-Hi/Low Winter Temp:	65/50, No record lows below 32
Fog Description:	Often foggy, possible year-round
Precipitation:	15–18", higher than Region 1
Geology:	Sedimentary >> Quaternary ~ Igneous
Soil:	Coastal Sage > Sedimentary Chaparral > Coastal Terrace > Sandstone Chamise/Chaparral > Igneous Chaparral
Elevation Range:	0–1500'

Region 3: Upper Elevation Santa Monica Mountains (Chaparral)

General Location:	South-facing slope of mountains, mid to top
Ave-Hi Summer Temp:	82 (extrapolated)
Ave-Low Winter Temp:	41 (extrapolated), frequent radiative freezing
Fog Description:	Mostly Spring
Precipitation:	18–23", 28" at highest elevations
Geology:	Sedimentary > Igneous >> Quaternary
Soil:	Sedimentary Chaparral ~ Sandstone Chamise/Chaparral ~ Igneous Chaparral
Elevation Range:	1000–3100'

Region 4: Lower Elevation Inland Santa Monica Mountains (Chaparral)

General Location:	North-facing slope of mountains, mid-lower
Ave-Hi/Low Summer Temp:	80/50 (Newbury Park), record highs in 100s
Ave-Hi/Low Winter Temp:	70/40, record lows in lower 20s

Fog Description:	Usually in Spring
Precipitation:	18"
Geology:	Igneous > Sedimentary > Quaternary
Soil:	Incomplete, Igneous Chaparral > Marine Sedimentary >> Coastal Terrace
Elevation Range:	1000–2000'

Region 5: Inland Dry (Coastal Sage Scrub)

General Location:	South-facing slope of Simi Hills, lower slope
Ave-Hi/Low Summer Temp:	90/55 (Thousand Oaks + Moorpark), record highs in 110s
Ave-Hi/Low Winter Temp:	70/40, record lows in 20s (Moorpark is a bit more mild)
Fog Description:	Spring only
Precipitation:	13–18"
Geology:	Sedimentary > Quaternary > Igneous
Soil:	Incomplete, Marine Sedimentary
Elevation Range:	900–1800'

Region 6: Simi Hills Inland (Chaparral)

General Location:	Simi Hills, mid to top slope
Ave-Hi Summer Temp:	85 (extrapolated)
Ave-Low Winter Temp:	39 (extrapolated)
Fog Description:	Spring, early Summer
Precipitation:	18"
Geology:	Almost exclusively Sedimentary >>> Igneous = Quaternary
Soil:	Incomplete, Marine Sedimentary
Elevation Range:	900–2400'

Region 7: Eastern Urban (Chaparral)

General Location:	Far east, urban
Ave-Hi/Low Summer Temp:	75/60 (Beverly Hills), record highs in 100s
Ave-Hi/Low Winter Temp:	65/50, record lows in mid 30s
Fog Description:	Spring, early Summer (clearing early in the day; extrapolated)
Precipitation:	18–22"
Geology:	Sedimentary > Igneous > Metamorphic >> Quaternary
Soil:	Incomplete, Sedimentary Chaparral/Urban Land, Urban Land
Elevation Range:	400–1750'

RESULTS

The final agglomerative cluster analyses for the classification used data from 3,912 of 4,014 sites sampled, and it included the 254 most abundant of 544 species sampled in the rapid assessments.

In total, 84 vegetation alliances or unique stands and 204 associations or phases were defined for the project. Of these, 177 types (at the alliance, association, and phase levels) have been fully described in Keeler-Wolf and Evens (2006). Rare stands that were not classified are also described.

We can summarize the vegetation of the Santa Monica Mountains area by inspecting the coarse levels of the cluster analysis. As the cluster analysis proceeds, all of the field sample data is agglomerated into fewer and fewer main clusters (envision cutting back all of the fine branches of the cluster diagram back to the main few that split off from the base). These fundamental groups

reflect their relationships to general patterns in regional climate, soil, and disturbance history and thus, show the general relationships of the entire range of vegetation types within the area. Species identified as significant indicators of these groups are those that tend to have high cover and high fidelity to these groups, and are thus often also used to name vegetation alliances. We selected the top group of 10 clusters in the data set to provide such an example (Figure 6). These 10 groups are arrayed along a complex gradient of temperature, moisture, soil texture, and disturbance history. The following brief narrative descriptions are arranged in the order in which the groups were arranged in the cluster analysis. The names of the groups are not numerically sequential, but are named based on the order in which they split from one another in the analysis. The most highly significant indicator species ($p < 0.002$) are listed.

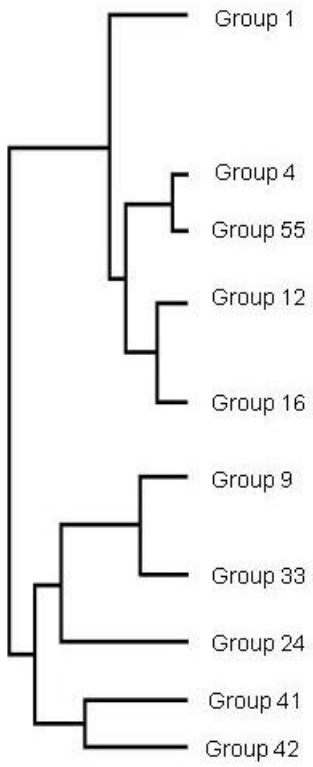

Figure 6. Cluster diagram of the 10 major groupings representing 3,912 samples. Similarity distance has been distorted to facilitate graphic representation. See text for explanation of each group.

At the most basic level, these groups are divisible into two major branches. The first group (including groups 1, 4, 55, 12, and 16 in Figure 2) includes coastal scrub shrubs and herbaceous vegetation of lower elevations, as well as wetland and riparian herbs and woody species. The second large group (including groups 9, 33, 24, 41, and 42) primarily represents the sclerophyll chaparrals and evergreen and deciduous oak woodlands.

Group 1 is made up of many species which tolerate frequent disturbance. The disturbance may be primarily fire-driven or water-driven. Many non-native herbaceous species occur here, but also

native woody species such as *Baccharis pilularis* and *Salix lasiolepis*. This group is distinct from its neighbors and represents the single largest number of samples. At a slightly finer level of division (when 13 major groups are identified instead of just 10) the wetland group separates from the non-wetland group. The following wetland species are among the significant indicators of this group: *Artemisia douglasiana, Baccharis salicifolia, Distichlis spicata, Frankenia salina, Salix lasiolepis, Salicornia virginica,* and *Typha* sp. The following herbaceous or early seral woody species are indicative: *Atriplex lentiformis, Bromus diandrus, Brassica nigra, Baccharis pilularis, Carpobrotus edulis, Foeniculum vulgare, Hazardia squarrosa, Hirschfeldia incana, Lolium* sp., *Nassella pulchra,* and *Phalaris aquatica*.

Group 4 represents a major part of the local coastal sage scrub vegetation characterized by drought-deciduous shrubs and associated herbs, some of which are non-native. The species in this group tend to occur at lower elevations in the maritime zone on heavy soils. Significant indicator species include: *Artemisia californica, Eriogonum cinereum, Centaurea melitensis,* and *Salvia leucophylla*.

Group 55 is related to the previous Group 4 and is composed of stands of vegetation characterized by early seral species usually associated with recent fire, within the coastal scrub zone. The most significant two indicators are the short-lived drought-deciduous shrub *Malacothamnus fasciculatus* and the perennial native grass *Leymus condensatus*.

Group 12 is distinguished by species associated with steep coastal slopes within the summer fog zone. The most significant species in this group are woody shrubs that may be drought-deciduous, succulent, or sclerophyllous. Group 12 is most closely related to the next group (16) and includes the following principle indicators: *Encelia californica, Salvia mellifera, Rhus integrifolia, Opuntia littoralis, Yucca whipplei,* and *Isomeris arborea*.

Group 16 has the widespread xerophyte shrubs *Malosma laurina* (a sclerophyll) and *Eriogonum fasciculatum* (a facultative drought deciduous shrub) as the primary indicators. This is a very well represented group locally, probably because stands dominated by its principle indicators do well with the currently prevalent high fire frequencies, and warm, well drained soils that do not experience cold winters.

Group 9 is defined by the significant presence of the major upper elevation and cold tolerant chaparral species of this region including *Arctostaphylos glandulosa, Cercocarpus betuloides, Ceanothus crassifolius,* and *C. oliganthus*. Both resprouter and obligate seeder sclerophyll shrubs are significant. These vegetation types are typical of upper slopes and/or relatively high elevations and interior locations in the region.

Group 33 is related to group 9 and has *Adenostoma fasciculatum* and *Lotus scoparius* as the strongest indicators. These are, respectively, the most ubiquitous long-lived species of the xeric upper slope chaparral, and its most characteristic early seral woody species. Other significant indicators include *Arctostaphylos glauca, Eriodictyon crassifolium,* and *Trichostema lanatum*. The first species is a significant member of the more inland hot summer chaparral, while the other two are early seral associates of the same settings.

Group 24 has a single very strong indicator, the chaparral shrub *Ceanothus megacarpus*. This species dominates many of the moderately xeric slopes with intermediate disturbance regimes throughout the Santa Monica Mountains, but not in the more inland Simi Hills. It is endemic to the chaparral of the south coast of California.

Group 41 is represented by resprouting chaparral shrubs or shrubby tree species which tend to occur in relatively warm but mesic settings such as northerly facing slopes throughout the region. Significant mesophyllic shrub indicator species include: *Ceanothus spinosus, Heteromeles arbutifolia, Prunus ilicifolia* and *Rhus ovata*. This group also includes some of the mesic upland woodlands represented by the significant indicator trees *Juglans californica* and *Umbellularia californica*. The vine *Marah macrocarpus* is also an indicator of this group, which is closely related to the following group.

Group 42 represents the coastal woodlands in all stages from recently disturbed to mature. Thus, along with the two main oak tree species, shrubs and herbs associated with the understories or seral openings of these woodlands are also among the principle indicators. The most significant indicators in order of importance value are: *Quercus agrifolia, Toxicodendron diversilobum, Mimulus aurantiacus, Platanus racemosa, Rhamnus ilicifolia, Sambucus mexicana, Dryopteris arguta, Quercus lobata, Keckiella cordifolia, Bromus carinatus, Carduus pycnocephalus, Rubus ursinus,* and *Venegasia carpesioides*. It is interesting to note that *Platanus racemosa* sorts out here, suggesting a closer relationship to oak woodlands than to the strictly riparian vegetation including *Salix* spp., *Alnus rhombifolia*, and others found in Group 1.

Vegetation Types

We present here a listing of the vegetation types defined for the Santa Monica Mountains and environs. These are the result of naming the finer branches of the main cluster groups described above using the methods defined. Alliances and associations (with their phases) that are marked by an asterisk (*) are fully described in the report *Vegetation classification of the Santa Monica Mountains National Recreation Area and environs in Ventura and Los Angeles Counties, California* (Keeler-Wolf and Evens 2006). An electronic copy of this report may be obtained free of charge (see Literature Cited for details). Full descriptions of alliances not described in this report may be found in the second edition of the *Manual of California Vegetation* (Sawyer et al. 2007).

Definitions

Alliance: The generic unit of vegetation classification in the National Vegetation Classification system. An alliance is defined usually by the dominant and characteristic plant species in the layer of vegetation with the highest cover. For example, in the California Sycamore alliance, California sycamore is conspicuous or dominant in the tree canopy (with canopy =10% absolute cover). However, it may occur along with other tree species such as oaks and willows, and with numerous other shrub and herb species. Those other species typically cover less ground and/or are less characteristic of the alliance than is the sycamore.

Association: The fundamental unit of classification in the National Vegetation Classification system. This is analogous to the species in organismal taxonomy. Associations tend to be localized to a particular geographic subregion (such as a certain mountain range) and are clearly associated with a certain environmental setting. Associations are built up into the larger units of alliances based on constant patterns of subordinate species within an overall pattern of constant species dominance. For example, although the California Sagebrush Alliance is widespread in coastal central and southern California, the California Sagebrush-Ashy Buckwheat Association is only found in the Santa Monica Mountains.

Phase: An informal unit of classification accommodating local floristic variation that tends not to have obvious correlations with particular environmental conditions. It probably results from particularly localized environmental conditions, site history, or fire history.

Symbols: A dash (-) is used in a classification unit to define more than one species in the same layer of vegetation. A slash (/) is used in a classification unit to separate species that are found in more than one layer of vegetation. Thus, the *Platanus racemosa-Quercus agrifolia/Baccharis salicifolia/Artemisia douglasiana* Association is defined by two trees, one shrub, and an herb.

TREE OVERSTORY VEGETATION

***Alnus rhombifolia* Woodland/Forest Alliance**
- *Alnus rhombifolia-Platanus racemosa* Woodland/Forest Association*

Eucalyptus* Woodland/Forest Alliance

***Juglans californica* Woodland/Forest Alliance**
- *Juglans californica/*Annual Grass-Herb Woodland/Forest Association*
- *Juglans californica/Artemisia californica/Leymus condensatus* Woodland/Forest Association*
- *Juglans californica/Ceanothus spinosus* Woodland/Forest Association*
- *Juglans californica/Heteromeles arbutifolia* Woodland/Forest Association*
- *Juglans californica/Malosma laurina* Woodland/Forest Association*

***Platanus racemosa* Woodland/Forest Alliance**
- *Platanus racemosa South Coast Intermittent Stream* Woodland/Forest Association*
- *Platanus racemosa/*Annual Grass-Herb Woodland/Forest Association*
- *Platanus racemosa-Quercus agrifolia South Coast* Woodland/Forest Association*
- *Platanus racemosa-Quercus agrifolia/Baccharis salicifolia/Artemisia douglasiana South Coast* Woodland/Forest Association*
- *Platanus racemosa-Quercus agrifolia-Salix lasiolepis* Woodland/Forest Association*

***Quercus agrifolia* Woodland/Forest Alliance**
- *Quercus agrifolia South Coastal* Woodland/Forest Association*
- *Quercus agrifolia/Adenostoma fasciculatum* Woodland/Forest Association*
- *Quercus agrifolia/*Annual Grass-Herb Woodland/Forest Association*
- *Quercus agrifolia/Ceanothus spinosus* Woodland/Forest Association*
- *Quercus agrifolia/Heteromeles arbutifolia* Woodland/Forest Association*
  - *Quercus agrifolia/Heteromeles arbutifolia* Phase
  - *Quercus agrifolia/Malosma laurina* Phase
- *Quercus agrifolia/Quercus berberidifolia* Woodland/Forest Association*
- *Quercus agrifolia/Salvia leucophylla-Artemisia californica* Woodland/Forest Association*
- *Quercus agrifolia/Toxicodendron diversilobum* Woodland/Forest Association*
  - *Quercus agrifolia/Toxicodendron diversilobum* Phase
  - *Quercus agrifolia/Mimulus aurantiacus* Phase
- *Quercus agrifolia-Juglans californica* Woodland/Forest Association*
  - *Quercus agrifolia-Juglans californica* Phase
  - *Quercus agrifolia-Juglans californica /Toxicodendron diversilobum* Phase
- *Quercus agrifolia-Salix lasiolepis* Woodland/Forest Association*
- *Quercus agrifolia-Umbellularia californica* Woodland/Forest Association*
  - *Quercus agrifolia-Umbellularia californica* Phase
  - *Quercus agrifolia-Umbellularia californica/Toxicodendron diversilobum* Phase
- *Quercus agrifolia-Umbellularia californica/Ceanothus oliganthus* Woodland/Forest Association*

***Quercus lobata Woodland Forest* Alliance**
*Quercus lobata/*Annual Grass-Herb Woodland/Forest Association*
*Quercus lobata-Quercus agrifolia/*Annual Grass-Herb Woodland/Forest Association*
Quercus lobata-Salix lasiolepis Woodland/Forest Association*
***Salix laevigata Woodland Forest* Alliance**
Salix laevigata-Salix lasiolepis* Woodland/Forest *Sub*-Alliance
*Salix laevigata-Salix lasiolepis/Artemisia douglasiana-Rubus ursinus/*Annual Grass-Herb Woodland/Forest Association*
Salix laevigata-Salix lasiolepis/Baccharis salicifolia Woodland/Forest Association*
Salix lasiolepis* Woodland/Forest Alliance
Salix lasiolepis/Baccharis salicifolia Woodland/Forest Association*
Salix lasiolepis/Malosma laurina Woodland/Forest Association*
Schinus molle* Woodland/Forest Alliance
***Umbellularia californica* Woodland/Forest Alliance**
Umbellularia californica/Ceanothus oliganthus Woodland/Forest Association*
Umbellularia californica-Alnus rhombifolia Woodland/Forest *(*provisional*)* Association*
Umbellularia californica-Juglans californica/Ceanothus spinosus Woodland/Forest Association*
Umbellularia californica-Platanus racemosa Woodland/Forest Association*

SHRUB OVERSTORY VEGETATION

***Adenostoma fasciculatum* Shrubland Alliance**
Adenostoma fasciculatum Shrubland Association*
Adenostoma fasciculatum-Ceanothus megacarpus Shrubland Association*
Adenostoma fasciculatum-Eriogonum fasciculatum Shrubland Association*
*Adenostoma fasciculatum-Eriogonum fasciculatum /*Annual Grass-Herb Phase
Adenostoma fasciculatum-Lotus scoparius-Dendromecon rigida Phase
Adenostoma fasciculatum-Malosma laurina Shrubland Association*
*Adenostoma fasciculatum-Malosma laurina-Eriodictyon crassifolium/*Annual Grass-Herb Shrubland Association*
Adenostoma fasciculatum-Mimulus aurantiacus Shrubland Association*
Adenostoma fasciculatum-Salvia leucophylla Shrubland Association*
***Adenostoma fasciculatum-Adenostoma sparsifolium* Shrubland Alliance**
Adenostoma fasciculatum-Adenostoma sparsifolium-Ceanothus crassifolius Shrubland Association*
***Adenostoma fasciculatum-Arctostaphylos glandulosa* Shrubland Alliance**
Adenostoma fasciculatum-Arctostaphylos glandulosa Shrubland Association*
Adenostoma fasciculatum-Arctostaphylos glandulosa Phase
Adenostoma fasciculatum-Ceanothus megacarpus-Arctostaphylos glandulosa Phase
***Adenostoma fasciculatum-Arctostaphylos glauca* Shrubland Alliance**
Adenostoma fasciculatum-Arctostaphylos glauca Shrubland Association*
***Adenostoma fasciculatum-Ceanothus crassifolius* Shrubland Alliance**
Adenostoma fasciculatum-Ceanothus crassifolius-Malosma laurina Shrubland Association*
***Adenostoma fasciculatum-Ceanothus cuneatus* Shrubland Alliance**
Adenostoma fasciculatum-Ceanothus cuneatus-Salvia mellifera-Malosma laurina Shrubland Association*
***Adenostoma fasciculatum-Salvia mellifera* Shrubland Alliance**
Adenostoma fasciculatum-Salvia mellifera Shrubland Association*
Adenostoma fasciculatum-Salvia mellifera-Malosma laurina Shrubland Association*

Adenostoma fasciculatum-Salvia mellifera-Rhus ovata Shrubland Association*
Adenostoma sparsifolium* Shrubland Alliance
Arctostaphylos glandulosa* Shrubland Alliance
Arctostaphylos glauca* Shrubland Alliance
***Artemisia californica* Shrubland Alliance**
Artemisia californica Shrubland Association*
*Artemisia californica/*Annual Grass-Herb Phase
Artemisia californica-Malosma laurina Phase
Artemisia californica-Salvia leucophylla Phase
Artemisia californica/Leymus condensatus Shrubland Association*
Artemisia californica-Eriogonum cinereum Shrubland Association*
Artemisia californica-Eriogonum cinereum Phase
Artemisia californica-Eriogonum cinereum-Mimulus aurantiacus/Melica imperfecta Phase
Artemisia californica-Mimulus aurantiacus Shrubland Association*
***Artemisia californica-Eriogonum fasciculatum* Shrubland Alliance**
*Artemisia californica-Eriogonum fasciculatum/*Annual Grass-Herb Shrubland Association*
Artemisia californica-Eriogonum fasciculatum-Salvia leucophylla Shrubland Association*
Artemisia californica-Eriogonum fasciculatum-Salvia mellifera Shrubland Association*
Atriplex lentiformis* Shrubland Alliance
***Baccharis pilularis* Shrubland Alliance**
*Baccharis pilularis/*Annual Grass-Herb Shrubland Association*
Baccharis pilularis-Artemisia californica Shrubland Association*
Baccharis pilularis-Artemisia californica Phase
Baccharis pilularis-Artemisia californica-Salvia leucophylla Phase
Baccharis pilularis-Malosma laurina-Artemisia californica Phase
***Baccharis salicifolia* Shrubland Alliance**
Baccharis salicifolia Riparian Shrubland Association*
***Ceanothus crassifolius* Shrubland Alliance**
Ceanothus crassifolius Shrubland Association*
Ceanothus crassifolius-Malosma laurina Shrubland Association*
***Ceanothus cuneatus* Shrubland Alliance**
Ceanothus cuneatus-Quercus berberidifolia Shrubland Association*
***Ceanothus megacarpus* Shrubland Alliance**
Ceanothus megacarpus Shrubland Association*
Ceanothus megacarpus-Adenostoma fasciculatum Shrubland Association*
Ceanothus megacarpus-Adenostoma fasciculatum Phase
Ceanothus megacarpus-Adenostoma fasciculatum-Salvia mellifera Phase
Ceanothus megacarpus-Adenostoma sparsifolium Shrubland Association*
Ceanothus megacarpus-Cercocarpus betuloides Shrubland Association*
Ceanothus megacarpus-Malosma laurina Shrubland Association*
Ceanothus megacarpus-Malosma laurina Phase
Ceanothus megacarpus-Malosma laurina-Adensotoma fasciculatum Phase
Ceanothus megacarpus-Salvia mellifera Shrubland Association*
***Ceanothus oliganthus* Shrubland Alliance**
Ceanothus oliganthus Shrubland Association*
Ceanothus oliganthus-Adenostoma sparsifolium Shrubland Association*
Ceanothus oliganthus-Heteromeles arbutifolia-Rhus ovata Shrubland Association*
Ceanothus oliganthus-Quercus berberidifolia Shrubland Association*
***Ceanothus spinosus* Shrubland Alliance**
Ceanothus spinosus Shrubland Association*

Ceanothus spinosus Phase
Ceanothus spinosus-Malosma laurina Phase
Ceanothus spinosus-Heteromeles arbutifolia-Prunus ilicifolia Phase
Ceanothus spinosus-Ceanothus megacarpus Shrubland Association*
***Cercocarpus betuloides* Shrubland Alliance**
Cercocarpus betuloides Shrubland Association*
Cercocarpus betuloides-Adenostoma fasciculatum Shrubland Association*
Cercocarpus betuloides-Ceanothus spinosus Shrubland Association *
Cercocarpus betuloides-Malosma laurina-Artemisia californica Shrubland Association*
Cercocarpus betuloides-Malosma laurina-Artemisia californica Phase
Cercocarpus betuloides-Artemisia californica/Melica imperfecta Phase
***Coreopsis gigantea* Shrubland Alliance**
Coreopsis gigantea-Artemisia californica-Eriogonum cinereum Shrubland Association*
Coreopsis gigantea-Ericameria ericoides-Encelia californica Shrubland Association*
Dendromecon rigida* Shrubland Alliance
***Encelia californica* Shrubland Alliance**
Encelia californica Shrubland Association*
Encelia californica Phase
Encelia californica-Eriogonum fasciculatum Phase
Encelia californica-Artemisia californica Shrubland Association*
Encelia californica-Eriogonum cinereum Shrubland Association*
Encelia californica-Malosma laurina-Salvia mellifera Shrubland Association*
Encelia californica-Rhus integrifolia Shrubland Association*
***Eriogonum cinereum* Shrubland Alliance**
Eriogonum cinereum Shrubland Association*
*Eriogonum cinereum/*Annual Grass-Herb Phase
Eriogonum cinereum-Malacothamnus fasciculatus/Leymus condensatus Phase
***Eriogonum fasciculatum* Shrubland Alliance**
Eriogonum fasciculatum Shrubland Association*
Eriogonum fasciculatum Phase
Eriogonum fasciculatum-Lotus scoparius Phase
Eriogonum fasciculatum-Salvia mellifera-Malosma laurina Shrubland Association*
Eriogonum fasciculatum-Salvia apiana* Shrubland Alliance
***Hazardia squarrosa* Shrubland Alliance**
Hazardia squarrosa/Nassella pulchra-Hemizonia fasciculata Shrubland Association*
Hazardia squarrosa-Artemisia californica Shrubland Association*
*Hazardia squarrosa/*Annual Grass-Herb
Hazardia squarrosa-Artemisia californica/Leymus condensatus
***Heteromeles arbutifolia* Shrubland Alliance**
Heteromeles arbutifolia-Malosma laurina Shrubland Association*
Heteromeles arbutifolia-Malosma laurina Phase
Heteromeles arbutifolia Phase
Heteromeles arbutifolia-Cercocarpus betuloides Phase
Heteromeles arbutifolia-Salvia mellifera Phase
Heteromeles arbutifolia-Artemisia californica-Mimulus aurantiacus Phase
Lepidospartum squamatum* Shrubland Alliance
***Lotus scoparius* Shrubland Alliance**
Lotus scoparius Shrubland Association*
*Lotus scoparius-Artemisia californica/*Annual Grass-Herb Phase
Lotus scoparius-Malacothamnus fasciculatus-Adenostoma fasciculatum-Salvia mellifera Phase

***Malacothamnus fasciculatus* Shrubland Alliance**
Malacothamnus fasciculatus Shrubland Association*
Malacothamnus fasciculatus-Ceanothus megacarpus Shrubland Association*
Malacothamnus fasciculatus-Ceanothus spinosus Shrubland Association*
Malacothamnus fasciculatus-Malosma laurina Shrubland Association*
Malacothamnus fasciculatus-Salvia leucophylla Shrubland Association*
Malacothamnus fasciculatus-Salvia mellifera Shrubland Association*
***Malosma laurina* Shrubland Alliance**
Malosma laurina Shrubland Association*
Malosma laurina Phase
*Malosma laurina/*Annual Grass-Herb Phase
Malosma laurina-Artemisia californica Shrubland Association*
Malosma laurina-Artemisia californica Phase
Malosma laurina-Artemisia californica-Salvia leucophylla Phase
Malosma laurina-Eriogonum cinereum Shrubland Association*
Malosma laurina-Eriogonum cinereum Phase
Malosma laurina-Eriogonum cinereum-Lotus scoparius Phase
Malosma laurina-Eriogonum cinereum-Salvia mellifera Phase
Malosma laurina-Malacothamnus fasciculatus-Eriogonum cinereum-Salvia mellifera Phase
Malosma laurina-Rhus integrifolia-Eriogonum cinereum-Artemisia californica Phase
Malosma laurina-Eriogonum fasciculatum Shrubland Association*
Malosma laurina-Eriogonum fasciculatum Phase
*Malosma laurina-Eriogonum fasciculatum-Artemisia californica/*Annual Grass-Herb Phase
Malosma laurina-Eriogonum fasciculatum-Heteromeles arbutifolia-Ceanothus megacarpus Phase
Malosma laurina-Rhus ovata-Ceanothus megacarpus Shrubland Association*
Malosma laurina-Salvia mellifera Shrubland Association*
Mesembryanthemum* spp.-*Carpobrotus* spp. *Semi-natural* Shrubland Alliance
***Mimulus aurantiacus* Shrubland Alliance**
Mimulus aurantiacus Shrubland Association*
Mimulus aurantiacus-Malosma laurina Phase
Mimulus aurantiacus-Salvia leucophylla Phase
***Opuntia* spp. Shrubland Alliance**
Opuntia spp.-*Mixed Coastal Sage Scrub* Shrubland Association*
***Prunus ilicifolia* Shrubland Alliance**
Prunus ilicifolia-Heteromeles arbutifolia Shrubland Association*
***Quercus berberidifolia* Shrubland Alliance**
Quercus berberidifolia Shrubland Association*
Quercus berberidifolia Phase
Quercus berberidifolia-Adenostoma fasciculatum Phase
Quercus berberidifolia-Heteromeles arbutifolia Phase
Quercus berberidifolia-Ceanothus spinosus Shrubland Association*
***Quercus berberidifolia-Adenostoma fasciculatum* Shrubland Alliance**
Quercus berberidifolia-Adenostoma fasciculatum Shrubland Association*
***Quercus berberidifolia-Cercocarpus betuloides* Shrubland Alliance**
Quercus berberidifolia-Cercocarpus betuloides Shrubland Association*
Quercus wislizeni* var. *frutescens* Shrubland Alliance
Rosa californica* Shrubland Alliance
***Rhus integrifolia* Shrubland Alliance**

Rhus integrifolia Shrubland Association*
Rhus integrifolia Phase
Rhus integrifolia-Heteromeles arbutifolia Phase
Rhus integrifolia-Malacothamnus fasciculatus Phase
Rhus integrifolia-Artemisia californica-Eriogonum cinereum Shrubland Association*
Rhus integrifolia-Artemisia californica-Salvia leucophylla Phase
Rhus integrifolia-Eriogonum cinereum-Yucca whipplei-Coreopsis gigantea Phase
Rhus integrifolia-Opuntia spp.-*Eriogonum cinereum* Shrubland Association*
***Rhus ovata* Shrubland Alliance**
Rhus ovata Shrubland Association*
Rhus ovata-Salvia leucophylla-Artemisia californica Shrubland Association*
Salix exigua* Shrubland Alliance
***Salvia leucophylla* Shrubland Alliance**
Salvia leucophylla Shrubland Association*
Salvia leucophylla-Artemisia californica Phase
Salvia leucophylla- Artemisia californica-Malacothamnus fasciculatus Phase
Salvia leucophylla/Leymus condensatus Phase
Salvia leucophylla/Nassella spp. Phase
Salvia leucophylla- Artemisia californica Shrubland Association*
Salvia leucophylla- Artemisia californica Phase
Salvia leucophylla- Artemisia californica/Leymus condensatus Phase
Salvia leucophylla-Artemisia californica-Eriogonum cinereum/Nassella spp. Shrubland Association*
Salvia leucophylla-Artemisia californica-Eriogonum cinereum/Nassella spp. Phase
Salvia leucophylla-Artemisia californica-Malosma laurina/Nassella spp. Phase
Salvia leucophylla-Artemisia californica-Mimulus aurantiacus Phase
*Salvia leucophylla-Eriogonum cinereum/*Annual Grass-Herb Shrubland Association*
***Salvia mellifera* Shrubland Alliance**
Salvia mellifera Shrubland Association*
Salvia mellifera Phase
Salvia mellifera-Adenostoma fasciculatum Phase
Salvia mellifera-Eriogonum fasciculatum Phase
Salvia mellifera- Malacothamnus fasciculatus Phase
Salvia mellifera-Eriogonum cinereum Shrubland Association*
Salvia mellifera-Malosma laurina Shrubland Association*
Salvia mellifera-Malosma laurina Phase
Salvia mellifera-Artemisia californica-Rhus integrifolia Phase
Salvia mellifera-Rhus ovata Shrubland Association*
Salvia mellifera-Artemisia californica Shrubland Association*
***Sambucus mexicana* Shrubland Alliance**
Sambucus mexicana/Leymus condensatus-Annual Herb Shrubland Association*
*Sambucus mexicana-Heteromeles arbutifolia/*Annual Grass-Herb Shrubland Association*
Spartium junceum* Shrubland Alliance
***Toxicodendron diversilobum* Shrubland Alliance**
Toxicodendron diversilobum-Artemisia californica/Leymus condensatus Shrubland Association*
Toxicodendron diversilobum-Mimulus aurantiacus Shrubland Association*
Venegasia carpesioides* Shrubland Alliance

HERBACEOUS VEGETATION

Arundo donax* Herbaceous Alliance
***Avena* spp. Herbaceous Alliance**
Avena fatua Herbaceous Association*
California Annual Grassland/Herbaceous Alliance*
Brassica nigra Herbaceous Association*
Brassica nigra-Bromus diandrus Herbaceous Association*
Brassica nigra-Centaurea melitensis Herbaceous Association*
Bromus diandrus Herbaceous Association*
Bromus diandrus-Avena spp. Herbaceous Association*
***Distichlis spicata* Herbaceous Alliance**
Distichlis spicata-Ambrosia chamissonis Herbaceous Association*
Distichlis spicata-Salicornia virginica-Jaumea carnosa Herbaceous Association*
Distichlis spicata-Salicornia virginica-Jaumea carnosa Phase
Distichlis spicata-Jaumea carnosa Phase
Euphorbia terracina* Herbaceous *Stands*
Foeniculum vulgare* Herbaceous Alliance
Frankenia salina* Herbaceous Alliance
Frankenia salina-Limonium californicum-Monanthochloe littoralis-Salicornia spp. Herbaceous Association*
Juncus effusus* Herbaceous Alliance
***Lepidium latifolium* Herbaceous Alliance**
Lepidium latifolium Herbaceous Association*
***Leymus condensatus* Herbaceous Alliance**
Leymus condensatus Herbaceous Association*
Leymus triticoides* Herbaceous Alliance
***Lolium multiflorum* Herbaceous Alliance**
Lolium multiflorum Herbaceous Association*
Nassella lepida* Herbaceous Alliance
Nassella pulchra* Herbaceous Alliance
Nassella pulchra-Hazardia squarrosa Herbaceous Association*
Pennisetum setaceum* Herbaceous Alliance
Pennisetum setaceum-Coreopsis gigantea-Yucca whipplei-Malosma laurina Herbaceous Association*
Phalaris aquatica* Herbaceous Alliance
Salicornia virginica* Herbaceous Alliance
Salicornia virginica/Algae Herbaceous Association*
Salicornia virginica-Brassica nigra Herbaceous Association*
*Salicornia virginica-Frankenia salina-Suaeda taxifolia (*synonym *Suaeda californica* var. *taxifolia)* Herbaceous Association*
Salicornia virginica-Frankenia salina-Suaeda taxifolia Phase
Salicornia virginica-Frankenia salina-Batis maritime Phase
Salicornia virginica-Suaeda taxifolia Phase
Salicornia virginica-Salicornia subterminalis Herbaceous Association*
Scirpus acutus-Scirpus californicus* Herbaceous Alliance
***Selaginella bigelovii* Herbaceous Alliance**
Selaginella bigelovii/Eriogonum fasciculatum Association*
Typha* spp. Herbaceous Alliance

DISCUSSION

Overview of the Santa Monica Mountains Vegetation Patterns

In reviewing the 10 major vegetation groups described above, a general portrait of the current vegetation conditions of the area is unveiled. Since the sample allocation is representative of the array of all vegetation conditions throughout the area, these main groupings show the organizing principles of the vegetation of the region. Significant among them are the importance of both the strong temperature and moisture gradients, indicated by groups restricted to either largely maritime (groups 4, 12, and 16) or upland-continental (group 33) settings, or hot and dry (groups 16, 24, 33) versus moist and shady conditions (groups 4, 41, and 42). Groups defined primarily by recent disturbance or early seral conditions (groups 1, 16, and 55) are also prominent. The close ecological relationship of mesic (north-slope) chaparral and woodlands characterized by oaks and other species is also shown in the cluster groupings. The California walnut and bay woodlands are more similar to mesic chaparral than they are to the coast live oak woodlands.

The overwhelming presence of upland settings within the Santa Monica Mountains area is suggested by the inclusion of most major wetland vegetation (including salt marsh and fresh water types) within a larger group of herbaceous and early seral species at this basic level of differentiation. This is unlike many other regional vegetation classification analyses, where wetland types tend to split very early from other upland types. The complete integration of many non-native species into the list of indicator species for several of these groups underscores the reality that these species are now deeply imbedded members of the local flora and ecology of the region.

Philosophy of Vegetation Classification Used in this Analysis

The developing philosophy of vegetation classification in California has benefited from a large number of recent classification projects centered in southern coastal California (DeSimone and Burk 1992, Gordon and White 1994, White and Padley 1997, Borchert et al. 2004, Evens and San 2005, Klein and Evens 2005). These, in conjunction with a growing understanding of statewide vegetation, have enabled the classification of the vegetation in the current project to proceed within a broader and better framework than would have been possible as little as five years ago. The natural development of most taxonomies, whether they be of species or vegetation, work their way through what can be called an expansive phase and then a synthetic phase. The first is characterized by the proliferation of many taxa based on local description without the benefit of broad comparison of related types. The second is based on a retrospective and broader view of more studies where related taxa can be compared and often shown to be related, thus ultimately synonymized. This latter phase has begun to take place in much of California, especially with the preparation of the second edition of *A Manual of California Vegetation* (Sawyer et al. 2007).

For example, chaparral alliances defined in previous studies included several mixed species types including the *Eriogonum fasciculatum-Encelia farinosa* type (Gordon and White 1994), *Ceanothus megacarpus-Cercocarpus betuloides,* and *Ceanothus megacarpus-Rhamnus ilicifolia* types (Borchert et al. 2004). These were named by the characteristic co-dominance of shrub species and were thought initially to represent fundamentally different entities than stands of vegetation dominated singly by individual species, for example, *Encelia farinosa* (without significant cover of *Eriogonum fasciculatum*) or *Ceanothus megacarpus* (without significant cover of *Cercocarpus betuloides*). However, now with a broader regional perspective, it is becoming clear that these entities are really more generally defined by the presence of a single characteristic species that may or may not have shared dominance with a less characteristic

species. In the above examples, the *Eriogonum. fasciculatum-Encelia farinosa* type has been subsumed under the *Encelia farinosa* alliance, while the *Ceanothus megacarpus-Cercocarpus betuloides* alliance and the *Ceanothus megacarpus-Rhamnus ilicifolia* alliance have been subsumed under the *Ceanothus megacarpus* alliance.

There are various lines of reasoning used to make these decisions. However, central to most of them is a broader understanding of both the geographic distribution and internal variation of each association defined within these alliances. A mixed alliance should have a broad regional distribution of the co-dominant species with further sub-regional variations of the associations to be substantiated as a co-dominant alliance. One example of this is the *Artemisia californica–Eriogonum fasciculatum* Alliance, which occurs from San Diego County and northwestern Baja California, north to the Diablo Range of Alameda County.

One of the great benefits of collecting so many samples of vegetation stands in this current project is that we can now see a more complete approximation of the range in cover of species and environmental conditions for each alliance and association. We have a better sense of where the important "breaks" in species composition are in these patterns. We can also compare vegetation samples from similar areas away from the Santa Monica Mountains and determine if the characteristics are indeed different or similar. Using these kinds of comparisons for many parts of southern California, we have begun to synthesize some of the complicated patterns described in earlier quantitative efforts and, in some cases, simplify them.

For example, although *Salvia leucophylla* forms stands where it is the only dominant as well as mixed stands with *Artemisia californica* in the Santa Monica Mountains, we now believe that both of these situations can be encapsulated within the *Salvia leucophylla* Alliance, rather than establishing a separate alliance for the single dominant and co-dominant situations. This is a result of *Salvia leucophylla* being relatively geographically restricted, whereby it only dominates in the "Venturan" coastal scrub zone between Santa Barbara and Orange counties (Westman 1981, Malanson 1984). When *S. leucophylla* makes up an important component of the shrub cover, whether it is the dominant species or is co-dominant with another species, it is sufficient to define the alliance (Figure 7). On the other hand, a mixed alliance with *Artemisia californica and Salvia mellifera* has a much broader distribution up and down the California Coast Ranges and into Baja California. It occurs under different ecological conditions than either of the single species alliances dominated by *Salvia mellifera* or *Artemisia californica.* For example, in the Central Coast Ranges, there is an association of *A. californica and S. mellifera* defined by co-dominance of the two shrubs (Evens and San 2004). This same association is also defined for western Riverside (Klein and Evens 2005) and Orange counties (DeSimone and Burke 1992). The wide-ranging consistency of this vegetation is a strong factor in maintaining it as a separate entity from either the *Artemisia californica* or the *Salvia mellifera* Alliance.

The philosophy of this classification is consistent with other classifications produced for national parks in California. We require a relatively large number of samples to set high confidence for the existence of an association. In general, we have accepted n = 10 or more as a threshold for high confidence. Any less would set lower confidence, unless the same characteristics of species composition and environmental variables have been previously well defined in studies elsewhere.

Further revisions are bound to occur in the California state classification as more data are analyzed and compared. As a result of relatively rigorous definitions at the association level, it is likely that these modifications will be made at the alliance level as well. The associations that are defined currently in this classification are well substantiated by large sample sizes with consistent species compositions and relative cover values. The separation of associations into different

Figure 7. *Salvia leucophylla* (Purple Sage) Alliance with the nominate species as a dominant or co-dominant shrub.

alliances would only be reasonable if we found major environmental differences in these alliances. Further revisions could also occur as datasets from different regions are analyzed together to identify and differentiate major environmental patterns of the alliances. One further refinement of the classification rules realized in this project was the treatment of large "emergent" shrubs. In earlier efforts in the California deserts and desert transition areas (Keeler-Wolf et al. 1998, Thomas et al. 2004), tall shrubs or "dwarf trees," such as *Juniperus californica, Rhus ovata, Cercidium florida, Olneya tesota,* and others were emphasized in numerical classification when they occurred in association with shorter-stature drought-deciduous desert and semi-desert shrubs such as *Encelia farinosa, Salvia apiana, Viguiera parishii,* and *Eriogonum fasciculatum*. Thus, despite a possible higher overall cover of individuals of the shorter drought-deciduous species, the larger, evenly spaced emergent species were found to "drive" the classification by their presence rather than by their total percent cover in a stand. This meant alliances and associations were often named by the larger, less dense emergent species.

Structurally similar situations exist in the Santa Monica Mountains where *Rhus ovata* and especially *Malosma laurina* occur at relatively low density and cover over a shorter, but higher cover layer of drought-deciduous shrubs such as *Artemisia californica, Encelia californica, Eriogonum cinereum, E. fasciculatum, Salvia mellifera,* and *S. leucophylla*. The initial classification developed for the Santa Monica Mountains before extensive data analysis stressed

the presence of such species as *Malosma laurina,* even if they had a much lower cover than the associated shorter drought-deciduous shrubs.

This structural relationship was not borne out in the first phase of data analysis. Instead, it became clear that the presence of shrubs such as *Malosma laurina* was often ubiquitous, occurring in many situations that were better defined in many cases by the associated shorter-stature drought-deciduous shrubs. The concept of the *M. laurina* Alliance was refined to include only those stands where *M. laurina* was dominant or co-dominant with other shrubs (regardless of their stature) in the stand (Figure 8). This is one of many cautionary tales revolving around vegetation classification assumptions based on extrapolating data from seemingly similar situations in different geographies and environments.

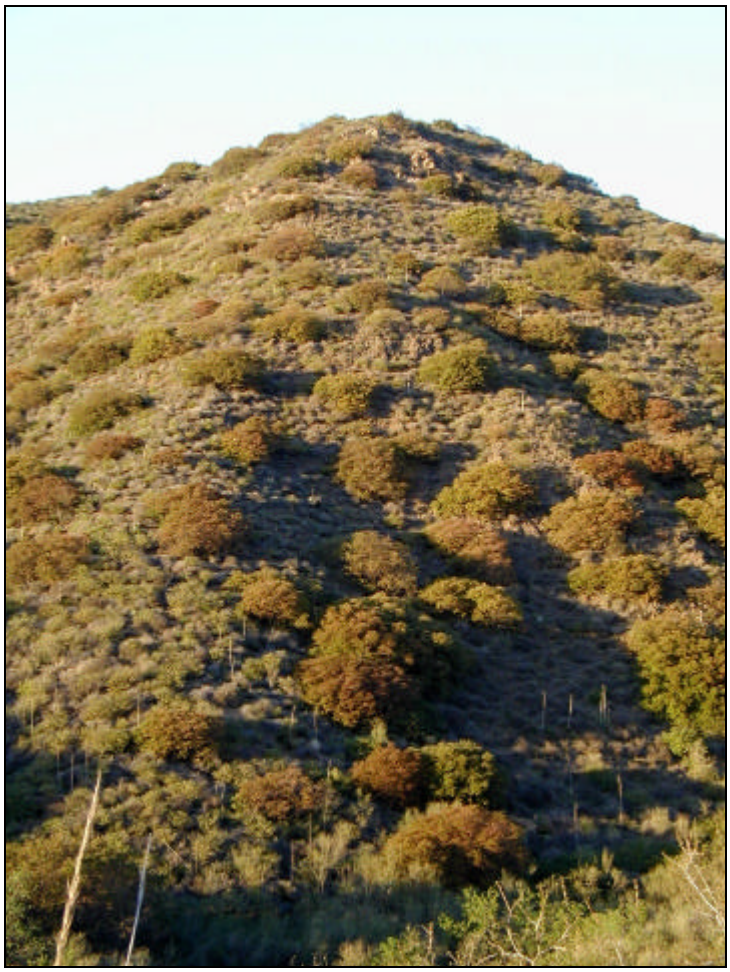

Figure 8. *Malosma laurina* (Laurel Sumac) Alliance is recognized when the species is dominant or strongly co-dominant with other coastal sage scrub species.

CONCLUSIONS AND LESSONS LEARNED FROM THIS APPROACH

The Santa Monica Mountains vegetation project has been the most data-intensive mapping effort to date for any U.S. National Park Service vegetation inventory. Most samples were Vegetation

Rapid Assessments (RAs). To conclude, we briefly touch upon four major points relating to the techniques used in this project:

1) How well did rapid assessments capture the diversity of the vegetation in the park?
2) Did the large sample size help or hinder the classification effort?
3) Did the large sample size help or hinder the mapping and monitoring effort?
4) Did sampling throughout the year hinder analysis and interpretation of the results due to phonological variation?

Capturing the diversity of vegetation

Some vegetation types were underrepresented in the sampling effort. The full spectrum of vegetation in the area was not surveyed because the study area had mixed ownership and accessibility. For these reasons, adequate data may not be available for all vegetation types. However, samples representing unusual species groupings in the study area are considered important, and worthy of additional sampling. These types are classified at a more generic alliance/habitat level or as unique stands.

Large numbers of samples were allocated both by the parameters of the GRADSECT analysis and by the on-the-ground analysis of field crew leaders and photo-interpreters when we encountered new and unusual vegetation. In general, the coordination of rapid assessment and relevé sampling was successful and the concordance in the classification between rapid assessments (where a partial list of up to 20 major species were listed within the stand assessed) and relevés (where full species data were collected in a plot) was high. Several other sampling projects (e.g., Borchert et al 2004, Gordon and White 1994, Thomas et al 2004) have confirmed that sampling woody chaparral and scrub in southern California is not driven strongly by herbaceous species in the understory. Thus, for rapid assessments, the reduced emphasis on inventorying the full component of the shrubland understory in favor of the woody species in the overstory did not appear to affect the results of the classification.

In addition, samples were conducted using relevés for vegetation types with particularly high species diversity and with notable herbaceous components. Capturing the variety of herb-dominated vegetation in the park was less critical to fire managers, and it understandably has been a much more difficult task due to the strong inter- and intra-seasonal variation in vegetation mainly characterized by annual species. This latter issue remains a problem with all types of vegetation sampling currently conducted in California.

Large sample size and classification

The exceptionally robust data set, collected in a standard way by the same crew of botanists within a two-year period, increased the reliability of the data. In contrast to many earlier park efforts, where retrospective data were combined with a small dataset of newly collected information for a classification, this current approach was preferable. No complaints have arisen about the quality of the data because the high sample sizes are enviable in most cases. The plant associations were defined by an average of about 20 samples, substantially higher than the average for any other parks assessed in California. However, the large data set lead to more detailed analysis due to the predilection for more samples to be more finely divided through clustering techniques.

We still believe that this project tended to over-divide some types despite the rational and tempered approach we used in the classification, based on comparison in scale and resolution of

plant associations defined in other parts of southern California. This over-division was noticed in addition to the informally defined phases, which are clearly minor subdivisions of associations. Part of the issue in this park's process revolved around collecting multiple samples of all successional phases of vegetation, and so many of the definitions describe seral stages of vegetation that could perhaps be more broadly defined. This approach was clearly advantageous to the park managers, as they needed to obtain information on the post-fire stages for mapping purposes. However, it may be more detailed than other national vegetation classification standards. In the full report, comments are made on which associations are best defined floristically and which ones may be more minor variants of other broader types.

One certainty was that the huge amount of data collected required substantially more time for analysis and description than was predicted. This would not have been possible without thorough collaboration between park staff and contractors in data collection, analysis, and description phases of the project. Without innovative approaches such as the development of queries of the database and automation of the report writing process, this project would have gone much more over budget than it did. We recommend that the projected amount of analysis and description time could be essentially doubled for future projects where such detail is required.

Large samples for monitoring and modeling

All collaborators on the project have agreed that the variety and numbers of samples collected generally strengthened the utility of this project for the classification and map accuracy. The robust data set also increased the potential for a variety of field-based monitoring and modeling projects, both structural and floristic. Despite the temporary nature of the samples, Global Positioning Systems technology with accurate and complete location information will enable the re-location of most samples for time sequence analysis.

Year-round sampling

One final question was whether the decision to sample vegetation in chaparral and coastal scrub vegetation throughout the year had any major influence on the results of the classification. Certainly because there were drought- or seasonally-deciduous species of *Salvia*, *Eriogonum*, *Artemisia*, and others in coastal scrub, sampling the same stand in April versus August likely yielded much higher cover of these species. Likewise, sampling a stand of *Juglans californica* in December versus June yielded much lower cover of that winter deciduous tree. Our range of cover estimates for these deciduous species was higher than if we standardized data collection during peak phenology. However, this required us to put broader requirements of membership on many of the vegetation types, a characteristic which tempered proliferation of vegetation types based on range of cover alone. We have not noticed a general trend in the data to average somewhat lower cover estimates for many of these deciduous species, compared to other studies. Thus, again the large sample size (many of which were collected in high phenology periods) appeared to ameliorate the range of variance. The value of year-round sampling increased substantially the efficiency of the crews and also logistically enabled the same personnel to remain on the project throughout the duration, vastly improving the consistency and reliability of the data collected through the project.

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