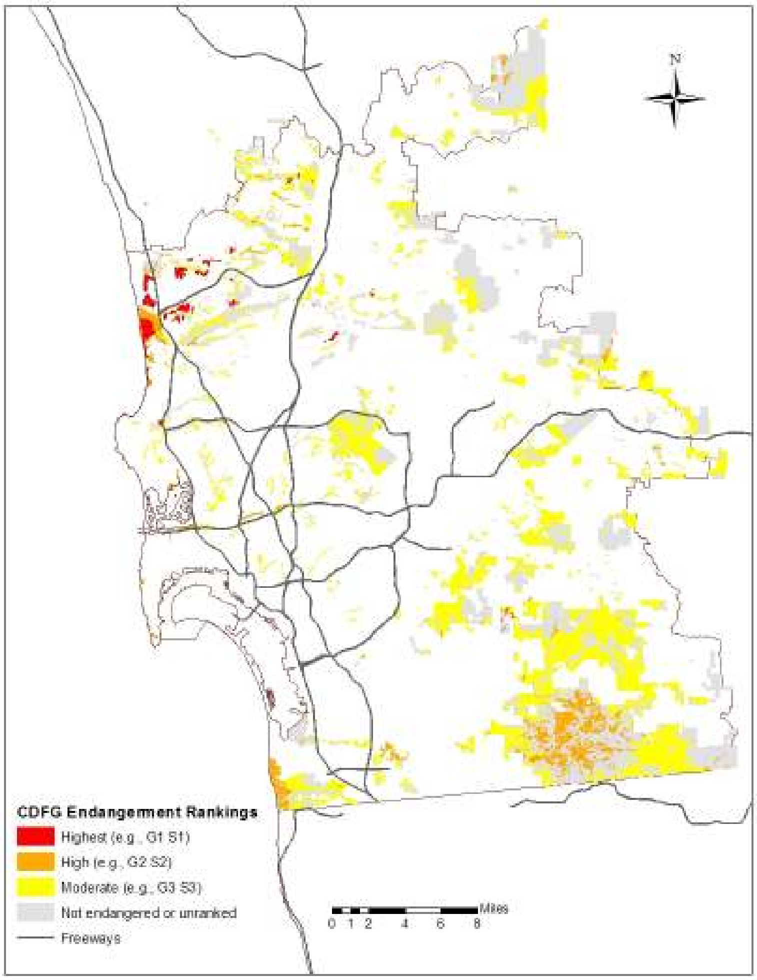
Grouping and Prioritizing Natural Communities for the San Diego Multiple Species Conservation Program

For Task B2 of Local Assistance Grant #P0450009



Prepared for: **California Department of Fish and Game**
Grant Coordinator: Dr. Brenda S. Johnson

Prepared by: **Department of Biology, San Diego State University**
Dr. Janet Franklin, Lauren A. Hierl,
Dr. Douglas H. Deutschman, and Dr. Helen M. Regan

Table of Contents

List of Tables

List of Figures

I. Executive Summary

Current State of the San Diego Multiple Species Conservation Program Preserve
A spatial analysis of mapped plant communities and physical landscape variables in the Multiple Species Conservation Program (MSCP) Region, the planned conservation area (Multi-Habitat Planning Area – the footprint of the preserve) and the currently conserved lands (about 65% of the planned conservation area) provides a context for prioritizing plant communities for monitoring.

We found that among the extensive plant communities in the preserve, chaparral is already well-represented in the currently conserved lands relative to the region, while a greater proportion of coastal sage scrub (CSS) has yet to be acquired within the planned conservation area. Of the less extensive habitats and plant communities in the preserve, grassland and salt water/coastal habitats occur in a smaller proportion of the planned conservation area than the region. Further, grassland and salt water/coastal habitats are more fragmented in the planned conservation area than the region – they occur in smaller, more widely dispersed patches. This is not surprising because representativeness of all plant communities was not used as a strict design criterion during MSCP planning, while protection of coastal shrubland communities was an important criterion. <u>However, it is important to understand the extent and spatial configuration of all communities in the preserve because it affects the design of a monitoring plan for communities.</u> Most plant communities are to some extent more fragmented in the preserve than the region simply because of the configuration of the preserve boundary – they comprise fewer patches, are further apart, and have greater edge density, especially in the case of CSS. On the other hand, some rare plant communities are found almost entirely within the preserve in clustered patches that reflect their natural (or historical) distribution – Torrey Pine woodland and Tecate Cypress woodland.

A limitation of our analyses of representation and landscape patterns is that they are based on a map of vegetation that does not have an up-to-date categorical accuracy evaluation. It is well known that landscape pattern assessment is strongly influenced by map accuracy and spatial resolution (scale). Another consideration is that the available vegetation map was created in the 1990s, after extensive development and land alteration in the past century, and therefore does not allow us to compare the planned conservation area to the historical distribution of plant communities in the MSCP region.

Natural Community Assemblages, Landscape Stratification, and other Classification Systems
While it has been suggested that assemblages of natural communities could be defined for the purpose of monitoring and conceptual modeling, the concept of a natural community assemblage is not defined or supported in the scientific literature. Alternative approaches to landscape stratification that we explore include land system classification, Ecological Systems, and stratification based on physical habitat factors. However, these classification systems are too coarse-scale to apply to the small MSCP preserve. We stratified the MSCP planned conservation area based on physical habitat factors, which allowed us to quantify the degree to which environments are well-protected versus underrepresented on the preserved lands relative to the region. Not surprisingly, coastal environments with more maritime climates and flat sites are

poorly represented primarily because they are already urbanized. However, land units delineated on the basis of physical habitat variables are not intuitive or easy to interpret or define for the purposes of community monitoring.

Therefore, we conclude the hierarchical aggregation of plant community categories based on existing classifications (Holland, CNPS) is the best alternative if communities must be grouped.

Prioritization of Ecological Communities Based on their Endangerment
Prioritization of communities for monitoring was based on the following criteria: representativeness, extent, fragmentation, endangerment and threats. Aggregated communities that received high priority rankings based on several criteria include CSS and meadows & freshwater wetlands. Communities with high endangerment or threats should also receive high priority and include: Southern foredunes, Southern coastal salt marsh, Southern coastal bluff scrub, Maritime succulent scrub, Diegan coastal sage scrub, Southern maritime chaparral, Valley needlegrass grassland, Cismontane alkali marsh, Southern arroyo willow riparian forest, Southern willow scrub, Engelmann oak woodland, Torrey Pine forest, and Tecate Cypress forest.

II. Introduction

This report describes the results of Task B2 from Local Assistance Grant P0450009, Implement Step 4: Strategically subdivide the system and prioritize for monitoring program development.

ii. Group natural communities into natural community assemblages. The current monitoring plan does not define natural community assemblages, and they need to be defined and prioritized for habitat monitoring (which is one of the elements of the current monitoring plan). Groupings developed by Atkinson (2004) will be evaluated and revised if necessary. Grantees will bring relevant land classification systems (California Native Plant Society vegetation classification, National Vegetation Classification System) and approaches (Franklin and Woodcock 1997, Franklin 2003) to bear on this.

This report will: describe the current state of the MSCP Preserve (section III), discuss natural community assemblages and alternative vegetation community classifications for the MSCP (section IV), describe the use of landscape stratification based on environmental variables as an alternative to vegetation classification (section V), discuss the grouping of communities for the monitoring program (VI), and prioritize natural communities for monitoring protocol development (section VII).

III. State of the MSCP Preserve

Assessing the current composition and distribution of landscape components in the MSCP preserve, while not an explicit charge under Task B, is an essential preliminary step to prioritizing, grouping, developing conceptual models, and making monitoring recommendations for communities. As noted in our first report (Hierl et al. 2005) synthesis and assessment of existing data are lacking for the MSCP, in part because the reserve design is being implemented over a number of years. Vegetation communities are a component of the MSCP that must be monitored (Ogden 1996), so it is important to examine the current distribution of vegetation types and other landscape elements in the Preserve.

The most current map of existing vegetation for San Diego County, including the MSCP Region, (available from SANDAG at http://www.sandag.org/resources/maps_and_gis/gis_downloads/senlu.asp) is based on the Holland classification (Holland 1986), referred to in some documents as the CNDDB classification, with revisions from Oberbauer (1996). We used this map to analyze the current distribution of vegetation types in the MSCP currently conserved lands. The effect of spatial data accuracy on this assessment will be discussed.

For the purposes of this report we refer to the MSCP Region (i.e. the planning region whose species and habitats the MSCP is intended to preserve) as the "region," the Multi-Habitat Planning Area (MHPA), i.e. the perimeter of the preserve as described in the planning process, as the "planned conservation area," and those lands already acquired and currently protected within the preserve as the "currently conserved" lands.

According to the data presented in the MSCP plan (Ogden 1998), and our overlay of the vegetation map for the County with the MHPA boundary, there are more than 60 natural or semi-natural vegetation types or land use/land cover types (including urban) mapped within the planned conservation area. We aggregated these vegetation communities (Table 1) for the purpose of summarizing their proportional representation and landscape pattern within the planned conservation area and the region. We also compared the currently conserved lands (SANDAG 2004) to the planned conservation area and to the MSCP region of southwestern San Diego County (see Figure 1). This type of comparison is usually used to determine if a preserve is representative of the region during the reserve design stage (Margules and Pressey 2000). However, it is also useful for determining risk and therefore prioritizing for monitoring. A vegetation community that is underrepresented or greatly fragmented within the preserve relative to the region as a whole may be at greater risk for degradation and receive higher priority for monitoring. Further, comparing the currently conserved lands to the planned conservation area is essential because this preserve is being assembled, through land acquisition and dedication, over a period of decades, not by instantaneous fiat. Therefore, the configuration of currently conserved lands affects the design and implementation of a monitoring plan.

Note that although Vernal Pools are a vegetation class defined in the Holland system (44000), and are of high priority for conservation in the MSCP plan (Ogden 1998), they are not delineated in the map of existing vegetation archived by SANDAG, and are therefore not included in the present analysis. Also note that some currently conserved lands lie outside the planned conservation area (see Figure 1) due to pre-existing parcel boundaries, so several vegetation class' acreages are higher in the currently conserved lands than the planning area (see Table 1).

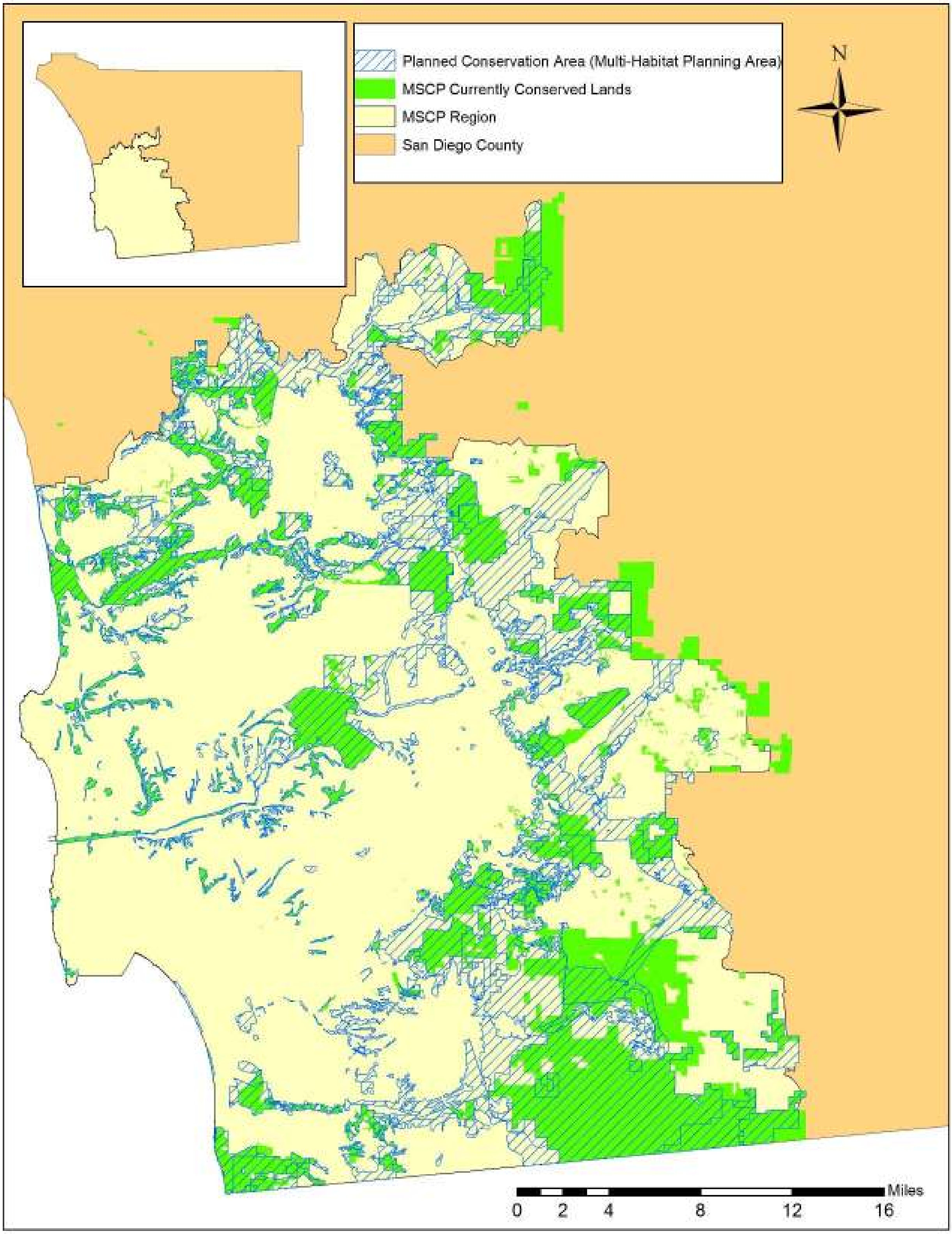


Figure 1. The currently conserved lands and planned conservation area (Multi-Habitat Planning Area) within the MSCP region of San Diego County.

Table 1. Classes occurring within the MSCP's planned conservation area and currently conserved lands based on the map of existing vegetation for San Diego County (SANDAG 1995), using the Holland classification (attribute Holland95), and an example of categorical grouping to more general vegetation and land cover classes. Acreages of grouped and disaggregated classes are shown.

* - These classes are mapped at a broader level of categorical resolution than other similar classes, e.g., may contain other classes present in the map as a result of aggregating data from several mapped sources.

Holland Code	Vegetation Description	Ranking	Planned Conservation Area (acres)	Currently Conserved Lands as of 2004 (acres)	Group Name	Grouped Planned Conservation Area (acres)	Grouped Currently Conserved Lands as of 2004 (acres)
11100	Eucalyptus woodland		357.28	212.18	Urban/Disturbed (11000s-12000s)	9982.74	4505.08
11200	Disturbed wetland		368.28	259.93			
11300	Disturbed habitat		5776.86	2547.75			
12000	Urban/Developed		3480.32	1485.21			
13111	Subtidal		3.45	2.42	Salt Waters/ Coastal (13000s/ 21230/52120)	3039.99	2001.27
13112	Intertidal		14.41	3.82			
13123	Shallow bay		369.50	131.77			
13130	Estuarine		208.58	204.06			
13131	Subtidal		11.97	11.97			
13300	Salt pan/mud flats		241.28	203.27			
13400	Beach		469.22	155.78			
21230	Southern foredunes	G2 S2.1	134.24	94.53			
52120	Southern coastal salt marsh	G2 S2.1	1587.35	1193.65			
13140	Fresh water		4308.29	556.91	Fresh Waters	5178.31	634.14
13200	Non-vegetated channel, floodway, lakeshore fringe		870.02	77.23			
18000	General agriculture*		90.40	40.92	Agriculture (18000s)	4206.59	3761.72
18100	Orchards and vineyards		574.17	97.63			
18200	Intensive agriculture		340.49	330.79			
18300	Extensive agriculture		3197.13	3283.80			
18310	Field/Pasture		0.00	4.18			
18320	Row crops		4.40	4.40			
31200	Southern coastal bluff scrub	G1 S1.1	145.57	142.67	Coastal Sage Scrub (31000s-32000s)	81847.11	44356.27
32400	Maritime succulent scrub	G2 S1.1	958.70	774.80			
32500	Diegan coastal sage scrub	G3 S3.1	80742.83	43438.80			

Holland Code	Vegetation Description	Ranking	Planned Conservation Area (acres)	Currently Conserved Lands as of 2004 (acres)	Group Name	Grouped Planned Conservation Area (acres)	Grouped Currently Conserved Lands as of 2004 (acres)
37000	Chaparral*		41439.95	32354.95	Chaparral (37000s)	63989.10	53208.15
37120	Southern mixed chaparral	N/A	13954.80	9735.21			
37121	Granitic southern mixed chaparral	G3 S3.3	417.58	1587.25			
37122	Mafic southern mixed chaparral	G3 S3.2	0.00	325.66			
37130	Northern mixed chaparral	N/A	149.91	264.59			
37131	Granitic northern mixed chaparral	N/A	1196.06	2454.60			
37200	Chamise chaparral*	G4 S4	3634.58	1787.14			
37210	Granitic chamise chaparral	N/A	40.72	295.78			
37220	Mafic chamise chaparral	N/A	0.00	595.13			
37900	Scrub oak chaparral	G3 S3.3	122.77	49.04			
37C30	Southern maritime chaparral	G1 S1.1	1104.69	947.92			
37G00	Coastal sage/chaparral scrub	G3 S3.2	1927.86	2810.89			
37K00	Flat-topped buckwheat	N/A	0.18	0.00			
42000	Valley and foothill grasslands*		7331.96	4349.91	Grasslands (42000s)	10813.37	6807.89
42100	Native grassland	G3 S3.1	28.25	0.00			
42110	Valley needlegrass grassland	G1 S1.1	229.42	131.43			
42200	Non-native grassland	G4 S4	3223.75	2326.54			
45300	Alkali meadows and seeps	N/A	1.83	0.00	Meadows/ Freshwater Wetlands (45000s/52000s)	599.78	250.04
45320	Alkali seep	G3 S2.1	0.00	2.62			
45400	Freshwater seep	G4 S4	4.79	3.43			
52300	Alkali marsh	N/A	0.00	2.41			
52310	Cismontane alkali marsh	G1 S1.1	239.30	46.90			
52400	Freshwater marsh	G4 S4	8.91	13.42			
52410	Coastal and valley freshwater marsh	G3 S2.1	344.94	181.26			

Holland Code	Vegetation Description	Ranking	Planned Conservation Area (acres)	Currently Conserved Lands as of 2004 (acres)	Group Name	Grouped Planned Conservation Area (acres)	Grouped Currently Conserved Lands as of 2004 (acres)
60000	Riparian and Bottomland Habitat*		30.55	22.88	Riparian/Riparian Woodlands (60000s-63000s)	8827.66	5137.50
61000	Riparian forest*		0.60	0.37			
61300	Southern riparian forest	N/A	970.82	615.00			
61310	Southern coast live oak riparian forest	G4 S4	2923.32	1672.62			
61320	Southern arroyo willow riparian forest	G2 S2.1	21.69	18.39			
61330	Southern cottonwood-willow riparian forest	G3 S3.2	217.19	151.58			
62400	Southern sycamore-alder riparian woodland	G4 S4	580.22	530.72			
63300	Southern riparian scrub	G3 S3.2	3496.92	2050.17			
63310	Mule fat scrub	G4 S4	36.82	20.49			
63320	Southern willow scrub	G3 S2.1	171.62	49.14			
63810	Tamarisk scrub	G5 S4	377.53	6.09			
63820	Arrowweed scrub	G3 S3.3	0.38	0.05			
71100	Oak woodland*	N/A	41.86	39.22	Oak Woodlands (71000s)	3224.14	1709.20
71160	Coast live oak woodland	G4 S4	448.01	138.17			
71162	Dense coast live oak woodland	N/A	2447.17	1177.83			
71180	Engelmann oak woodland	G2 S2.1	1.11	0.95			
71181	Open Engelmann oak woodland	G2 S2.2	285.99	322.83			
71182	Dense open Engelmann oak woodland	G2 S2.1	0.00	30.21			
83140	Torrey pine forest	G1 S1.1	144.51	144.50	Torrey Pine	144.51	144.50
83230	Southern interior cypress forest	G2 S2.1	5654.09	5470.77	So. Int. Cypress	5654.09	5470.77
Grand Total:			197507.39	127986.53		197507.39	127986.53

We used these aggregated classes to summarize the areal extent of vegetation classes (Figures 2a, 2b; Table 2) within the perimeters of the MSCP Region, the planned conservation area (MHPA), and the currently conserved lands (SANDAG 2004) (see Figure 1). While area per se may not be an important criterion for ranking communities for monitoring (as discussed in later section), it is one factor affecting the level of monitoring effort required.

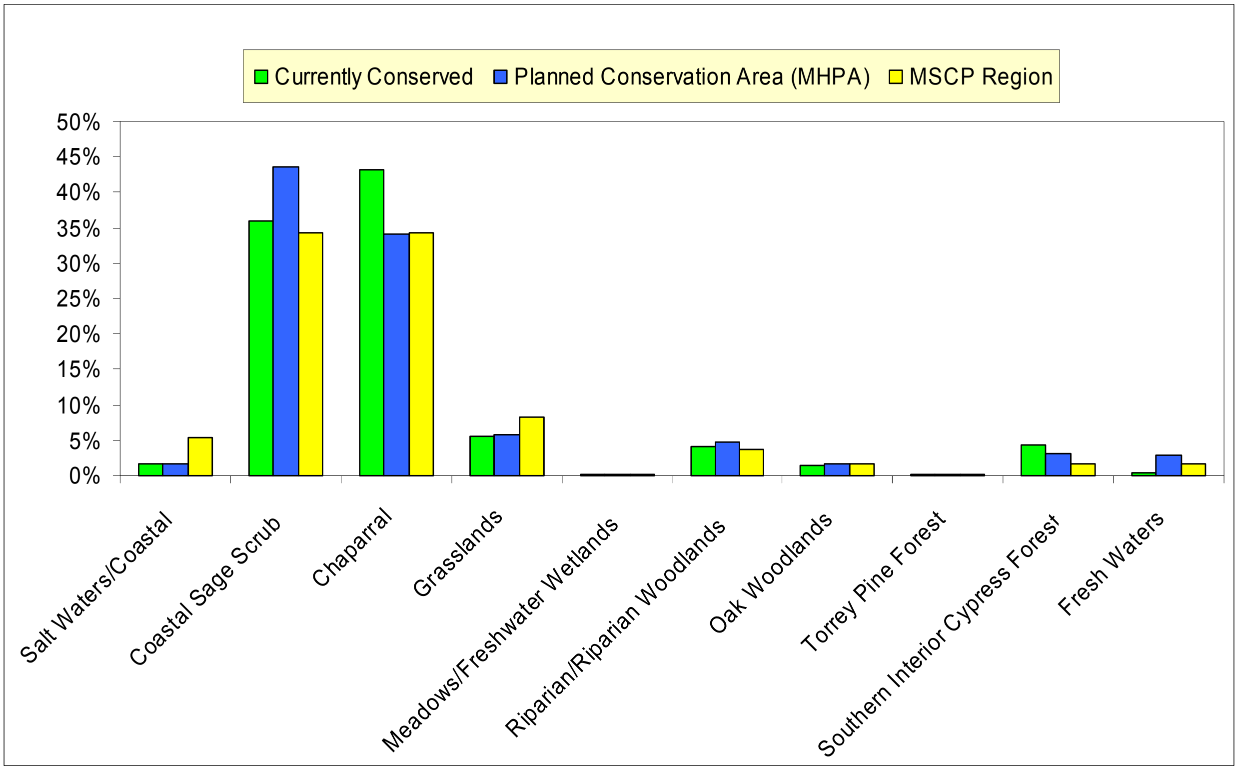


Figure 2a. Percent of the non-urban area of each aggregated vegetation or land cover class occurring in the MSCP currently conserved lands, planned conservation area (MHPA), and the MSCP region.

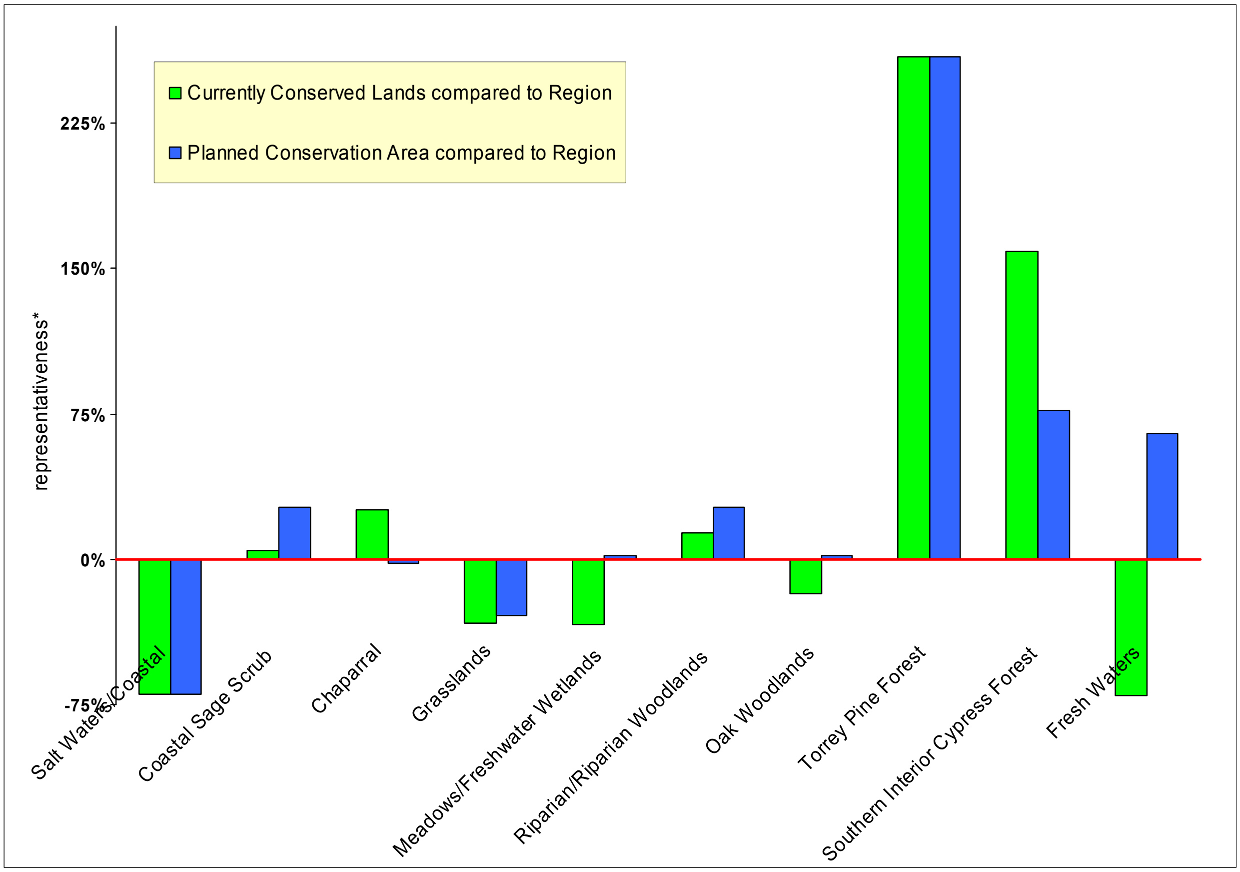


Figure 2b. Representativeness of each aggregated vegetation class, comparing the % area found in each class in the currently conserved lands to that found in the region, and the planned conservation area compared to the region. Values > 0 are well-represented in the planned or currently conserved lands, and values <0 are under-represented.

$$\text{* representativeness} = \frac{(\text{\% currently conserved OR planned conservation area - \% in Region})}{\text{\% in Region}}$$

It is interesting to note the proportion of each class occurring in the planned conservation area (MHPA) and the currently conserved lands vs. the MSCP Region (Figures 2a, 2b; Table 2). Coastal Sage Scrub (CSS) is underrepresented in the currently conserved lands relative to the planned conservation area, while Chaparral shows the opposite pattern. In other words, during the first decade of assembling the preserve we have been slightly more successful at acquiring Chaparral than CSS within the planned conservation area boundary. Meadows & Freshwater Wetlands, Fresh Waters, and Oak Woodlands are underrepresented in the currently conserved lands vs. the Region, showing that important areas of these habitats have yet to be acquired within the planned conservation area during the ongoing assembly of this preserve. Riparian, Torrey Pine Forest and Cypress Forest are well-represented in the currently conserved lands (essentially the entire extent of these communities within the region is included in the currently conserved lands). Notably, Salt Water/Coastal habitats and Grasslands are underrepresented in the planned conservation area relative to the region (blue bars below the zero line in Figure 2b). Again, this information is more useful at the reserve design stage, but it is useful to know that these plant communities and habitats may be of higher priority for monitoring because of their limited extent.

Table 2. Proportion of non-urban MSCP lands in each vegetation class (same data as in Figure 2b). Underrepresented classes indicated in red, well-represented classes in bold black.

Vegetation/Land Cover Class	Currently Conserved	Planned Conservation Area	MSCP Region
Salt Waters/Coastal	**1.6%**	**1.6%**	5.3%
Coastal Sage Scrub	**35.9%**	**43.6%**	34.4%
Chaparral	**43.1%**	**34.1%**	34.4%
Grasslands	**5.5%**	**5.8%**	8.2%
Meadows and Freshwater Wetlands	**0.2%**	**0.3%**	0.3%
Riparian and Riparian Woodlands	**4.2%**	**4.7%**	3.7%
Oak Woodland	**1.4%**	**1.7%**	1.7%
Torrey Pine Forest	**0.1%**	**0.1%**	0.0%
Southern Interior Cypress Forest	**4.4%**	**3.0%**	1.7%
Fresh Waters	**0.5%**	**2.8%**	1.7%
Total Acres	127,987	197,507	582,356

This comparison was based on the existing vegetation map, which raises an important issue. Any evaluation of the quantity, spatial pattern or location of vegetation classes (communities) is based on spatial data represented at a particular scale (grain and extent). Further, **because a map is a model of the landscape, it always has some degree of spatial generalization as well as error**. That error should be quantified and acknowledged in subsequent analyses. It is unquantified for this vegetation map. The original vegetation map developed during MSCP planning and archived by SANDAG was assessed using standard methods for evaluating thematic map accuracy (Stow et al. 1993). They found that overall map accuracy (percent correct classification) was 77% for nine vegetation classes that occupy most of the map area. Most confusion was between structurally similar classes (sparse oak woodland mapped as dense oak woodland) and the "mixed" class Coastal Sage/Chaparral was almost always labeled Chaparral in the map. Other categories (CSS, Chaparral, Grassland, Oak Woodland) were mapped with 80-90% overall accuracy.

In the last decade, as the conserved lands have been acquired, more detailed vegetation mapping has been conducted as part of baseline inventory of the parcel. These vegetation maps tend to be more spatially and categorically detailed than the original map evaluated in 1993. Apparently, over time some of these maps have been merged into the county-wide vegetation map archived by SANDAG. **An "index" map showing the source and date of each part of the map would be a very useful tool for determining how, and to what extent this map should be used as a basis for monitoring**, for example to allocate a stratified random sample of monitoring locations.

Another analysis of map error was conducted more recently (presumably using a product of mixed provenance), with a focus on just two of the map classes, by Winchell and Doherty (2006) as part of a California gnatcatcher study. They compared field vegetation records to vegetation classes depicted in the SANDAG 1995 map and found an overall accuracy of 66% (Table 3) for

Coastal Sage Scrub and CSS/Chaparral ecotone vegetation categories. This illustrates that most of the error detected was between the categorically similar classes that were examined. However, if these categories are known to differ in important ways in their species composition or habitat quality, this may be a notable error, again affecting the usefulness of the map as a stratification tool for monitoring.

	Map Class			
True Class	Coastal Sage Scrub	Scrub/ Chaparral Ecotone	Total	**% Accurate**
Coastal Sage Scrub	126	5	131	**96**
Scrub/Chaparral Ecotone	67	30	97	**31**
Other	7	0	7	**0**
Total	200	35	235	
% Accurate	**63**	**86**		**66**

Table 3. Comparison of field and GIS vegetation classifications for surveyed points in San Diego County, California (excerpted from Winchell and Doherty 2006).

Another way to evaluate the current state of plant communities in the MSCP in order to inform monitoring is to compare the spatial patterning of vegetation classes within the Region, planned conservation area, and currently conserved lands (Figure 3). We used the landscape pattern analysis software FragStats (McGarigal and Marks 1995).

Coastal Sage Scrub and Chaparral are the largest classes in the planned conservation area in terms of area, number of patches and Largest Patch Index[1]. Due to the large number of patches, both classes also have the highest Edge Density[2], but because there are so many patches, they tend to be relatively close together (low Euclidian Nearest Neighbor Distance[3]).

Other vegetation classes, such as Meadows and Freshwater Wetlands, Oak Woodland, and Riparian, have both a low number of patches and small patches (low area and low Largest Patch Index). These classes tend to be farther apart on the landscape (highest Euclidian Nearest Neighbor Distance), and due to the small area of the patches, these classes also have a lot of edge (high Perimeter-Area Ratio[4]).

Interestingly, Coastal Sage Scrub has lower total area in the currently conserved lands than in the planned conservation area or region, but has less edge (lower Edge Density) there than the planned area, so the CSS that has been conserved to date is in larger patches on average than those planned for acquisition within the MHPA. However, a very large patch in the planned conservation area is not yet preserved, as seen in the lower Largest Patch Index. Additionally, all classes except Torrey Pine, Tecate Cypress, and Salt Water/Coastal also have higher

[1] Largest Patch Index = an index that quantifies the percentage of total landscape area comprised by the largest patch, so it is a simple measure of dominance.
[2] Edge Density = the sum of the lengths of all edge segments of a patch type, divided by the total landscape area.
[3] Euclidian Nearest Neighbor Distance = the distance to the nearest neighboring patch of the same type, based on shortest edge-to-edge distance.
[4] Perimeter-Area Ratio = the ratio of the patch perimeter to area, it is a simple measure of shape complexity.

Euclidian Nearest Neighbor Distances (are farther apart on average from like patches) in the currently preserved lands than in the region as a whole or in the planned conservation area. This is not surprising given the extent (22%) and convoluted shape of the currently conserved lands (narrow strips of habitat, lots of edge) relative to the region (Figure 1), but these landscape metrics give us a way to quantify these patterns.

More detailed results of the landscape patterns analysis and metric definitions are provided in Appendix 3.

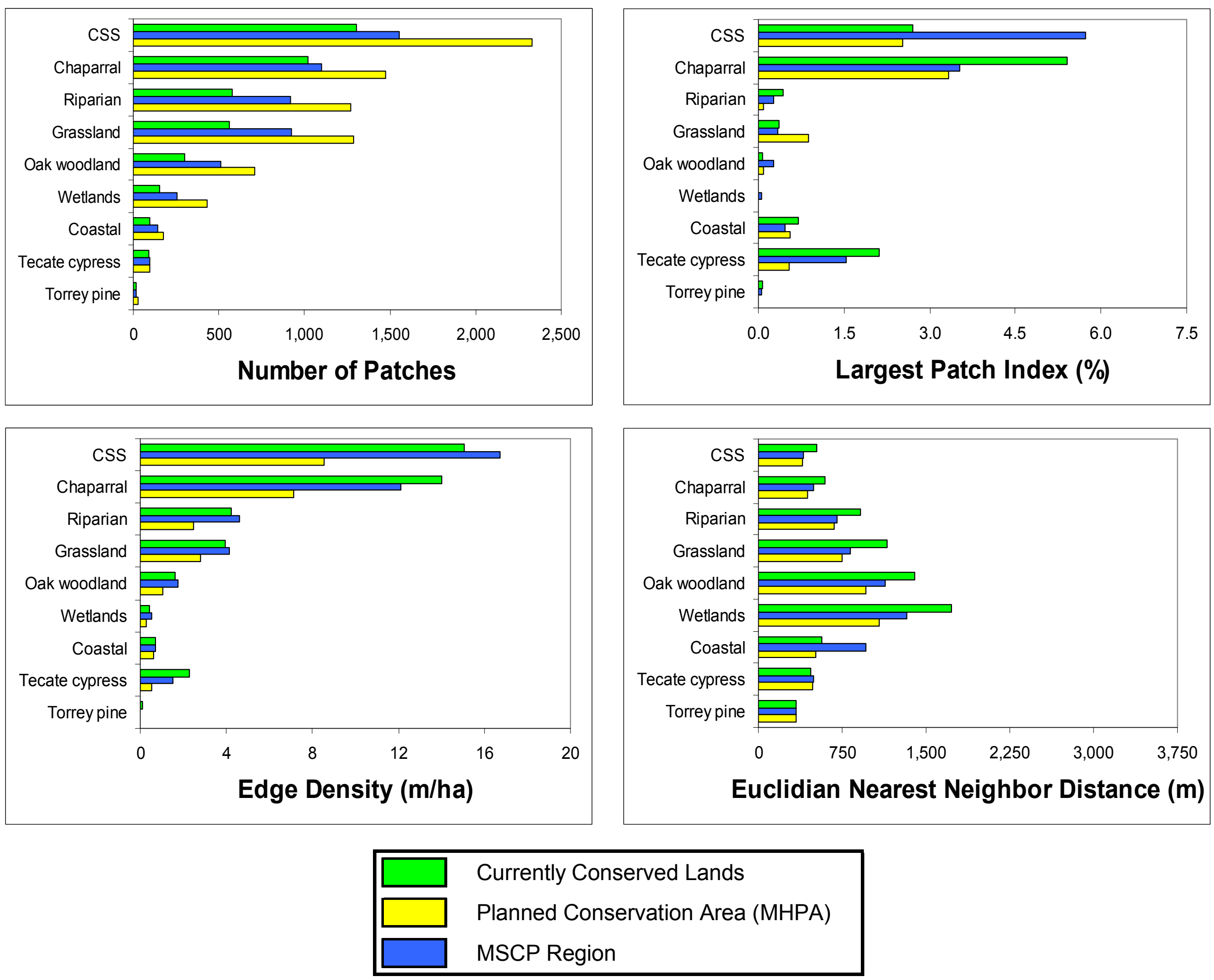


Figure 3. Number of Patches, Largest Patch Index, Edge Density, and Euclidian Nearest Neighbor Distances for 10 aggregated vegetation classes in the MSCP currently conserved lands, planned conservation area (MHPA), and MSCP region. Metrics were calculated using FragStats (McGarigal and Marks 1995). See Appendix 3 for metric definitions.

Taken together these metrics indicate that the planned conservation area will include large blocks of most plant communities (Largest Patch Index in Figure 3) but that, inevitably, those communities will consist of fewer patches, further apart, and with greater edge density, simply due to the overall configuration of the preserve within the region and the intervening developed lands. Further, reinforcing the analysis of class area, Chaparral communities occur in a few large patches that are relatively close together in the currently conserved lands, while Coastal Sage Scrub acquired to date is more fragmented within the currently conserved lands than the planned conservation area or the region. Some communities (Tecate Cypress, Torrey Pine) naturally occur in isolated patches most of which are encompassed in the planned conservation area and are already acquired, while other small classes (Meadows and Freshwater Wetlands, Oak Woodlands) are represented by disproportionately small and/or isolated patches in the planned conservation area.

Finally, it must be emphasized that all of these comparisons of the preserve to the larger region are based on the current land use status of the region. In other words, a more stringent criterion of representativeness could be based on a comparison with the potential distribution, or pre-Euroamerican distribution of vegetation communities (Sprugel 1991). For example, the distribution of coastal sage scrub throughout its extent in southern California is estimated to have declined by 80-90% due to development and land conversion (Westman 1981).

Now that the extent and pattern of vegetation communities in the planned and currently conserved lands have been described, we can move forward with grouping and prioritizing the natural communities for monitoring.

IV. Natural Community Assemblages

Although the terms "ecological community," "natural community," "habitat type," "vegetation type" and "plant community" are often used interchangeably, <u>the MSCP Plan (Ogden 1998) specifically identifies **vegetation communities** as elements of biodiversity that are to be protected under the plan (page 3-8)</u>.

If terrestrial plant communities are **elements of biodiversity** then they can be ranked or prioritized for conservation and monitoring, just as species were in our previous report (Regan et al. 2006) based on a) current status (endangerment) and b) threats. <u>Monitoring the community for this purpose requires defining reference conditions of species composition and vegetation structure, and comparing composition and structure at monitoring sites to that reference</u>.

Plant communities are also used to represent **habitat for covered species**, and in the previous report we provided a priority ranking of community monitoring based on the number of covered species dependent on that habitat and the level of threat experienced by those covered species. We reemphasize that <u>monitoring communities for this purpose should emphasize both area monitoring ("HabiTrak") and monitoring the factors that constitute threats to the covered species</u>.

Atkinson et al. (2004) recommended that natural communities should be grouped into "natural community assemblages" when a monitoring program is being designed, but they make no clear link between this recommendation and monitoring design and implementation. The report refers to two purposes for grouping. The first is to identify communities that are affected by the same biological and physical processes and same general set of pressures (threats). They may also share (provide habitat for) some covered species, but not others. Therefore, grouping communities is intended to lead to the subsequent design steps of identifying landscape level issues and developing conceptual models of these assemblages.

Their second reason is related to prioritization. If certain communities targeted for protection are very limited in extent, or provide habitat for very few covered species, it is reasoned that they could be "lumped" with other communities for the purposes of monitoring, or they could go unmonitored (receive lower priority). Lumping may make sense purely from a sampling point of view (spatial stratification), but it is not logical in terms of biological monitoring protocols. If, for example, vernal pools are very limited in extent and almost always found adjacent to oak woodland, it would not be practical to monitor plant communities using any procedure that would be the same in oak woodland and vernal pools. Also, certain rare and at-risk communities may require monitoring for their own sake, just like rare and at-risk species.

An ecological community is defined by geography as organisms living in the same place. While the terms plant- or vegetation community are commonly used to refer to the plant members of an ecological community, some prefer the term "plant assemblage" to describe a taxonomic subset of the entire community of all organisms (Gurevich 2002). This makes the term "natural community assemblage" particularly confusing. Further, the term "community assemblage" is not commonly used by terrestrial plant ecologists, although it does seem to be used in aquatic ecology. However, it appears to be synonymous with community.

Atkinson et al. (2004) cite two other Habitat Conservation Plans in Southern California that have recently implemented this concept of "natural community assemblages," the North San Diego County Multiple Habitat Conservation Program and Coachella Valley Multiple Species Habitat Conservation Plan. However, the term "natural community assemblage" is not generally used in the published ecological literature, nor do any of these reports cite any literature in support of the approach.

We therefore recommend using a more scientifically robust alternative to the "natural community assemblage" concept. Two alternative approaches to landscape stratification, "land system classification" and "landscape stratification based on environmental variables" were considered and are reviewed below.

V. Landscape Stratification

A. Land System Classification

Atkinson et al. (2004) note that some communities grade into each other over space and time as a result of natural disturbance (succession) and anthropogenic disturbance (pressures, threats). They allude to the idea that fixed vegetation community types are somewhat artificial because plant communities are dynamic in time and space. According to Gleason (1926), each species has its own environmental tolerances, and within the range of environmental conditions a species can tolerate, chance events determine what species are found together at any given location. This "individualistic" model of species distributions predicts gradual changes in community composition over space except where there are abrupt environmental boundaries (Whittaker 1973, Austin and Smith 1989).

In contrast to categorical (floristic) vegetation classification, landscape unit or land system classification defines spatially-discrete landscape units. For example, the ecoregion classification system developed by the Forest Service defines hierachical, spatially nested landscape units. A land system is composed of different terrain types that recur in spatial association with each other on the landscape in a more or less regular pattern.

More generally, the purpose of defining ecological land units (ELUs) is to provide a classification of the capabilities of the land so that the effects of ecosystem management can be assessed (Franklin 2003). Ecological units are designed to represent combinations of factors of the physical and/or biological environment that are relatively stable (over decades to centuries) and define potential conditions for ecosystems (Rowe and Sheard 1981, Sims et al. 1996). **They can be used to allocate stratified samples for ecosystem monitoring** (Arnold et al. 1996, Cleland et al. 1997).

A land system classification could provide an alternative approach to landscape stratification for community monitoring. An advantage to this approach is that it would not rely on an existing vegetation map of unknown accuracy and perhaps of inappropriate scale to evaluate the extent and landscape pattern of communities. It might allow a sample of monitoring sites to be allocated more effectively across environmental gradients within the MCSP. However, though a number of hierarchical systems of land classification have been developed for the US, Canada and elsewhere (ECOMAP, Gap Analysis) (Bailey 1980, Omernik 1987, Marshall et al. 1996, Robitaille and Saucier 1996, Marshall and Schut 1999, Bourgeron et al. 2001), in each of these the landscape units are too coarse to be useful at the scale of the MSCP.

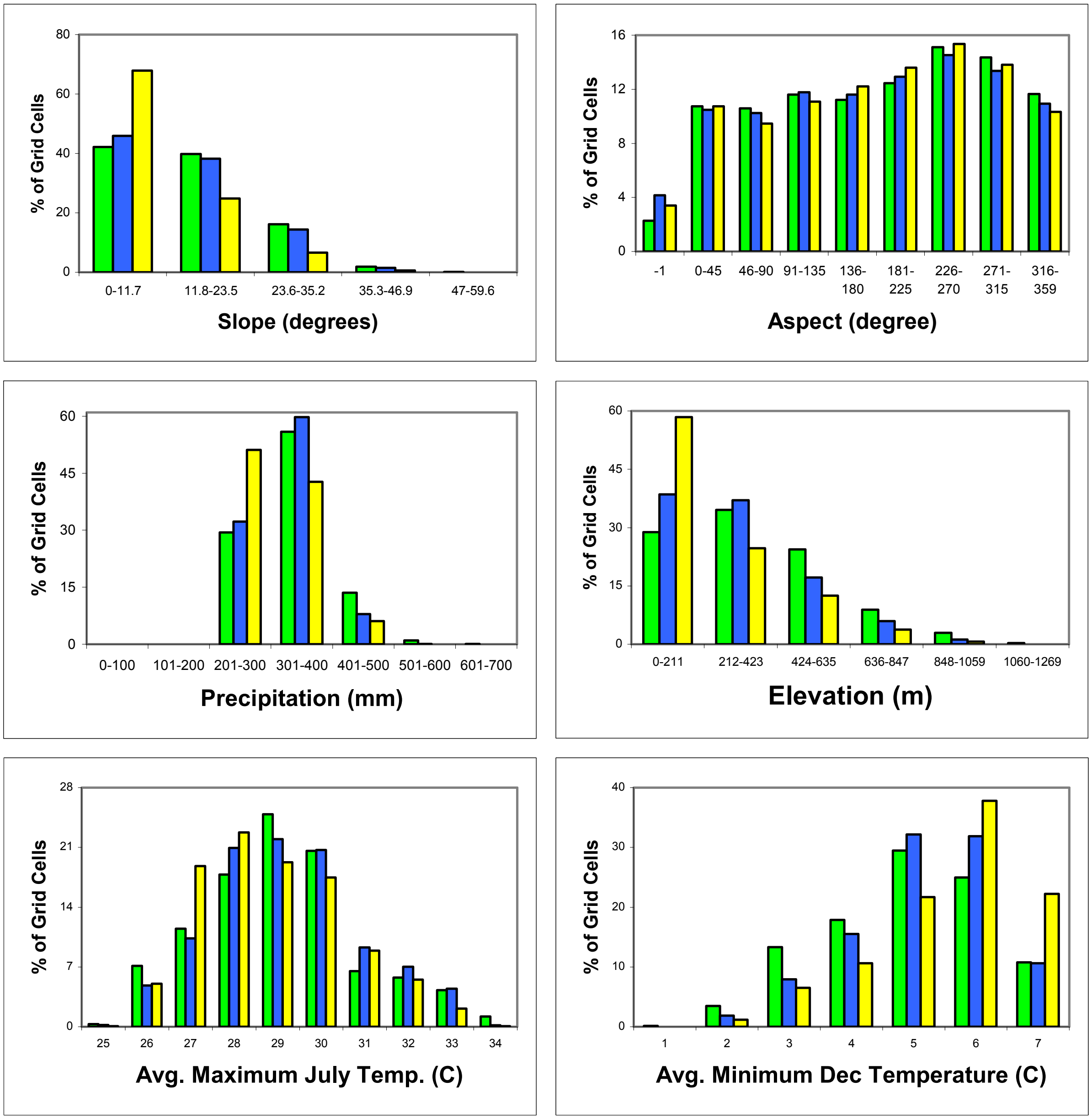
B. Stratification of the MCSP Based on Physical Habitat Factors

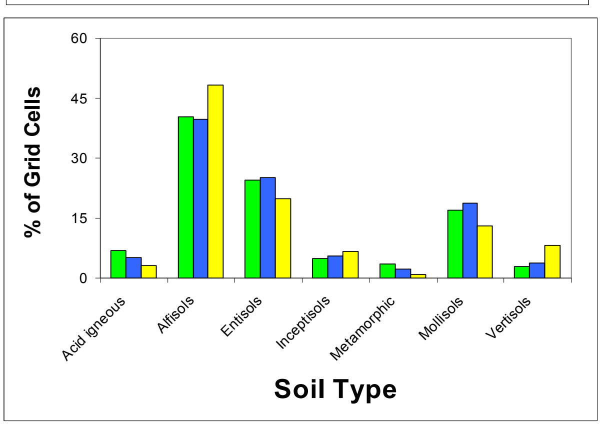
Where a classification of landtypes is not available at an appropriate scale, landscape stratification based on stable characteristics of the physical environment can be used to define land classes for the purposes of biodiversity (baseline) surveys, reserve design, landscape modeling and monitoring (Gillison and Brewer 1985, Austin and Heyligers 1989, 1991, Goedickemeier et al. 1997, Wessels and van Jaarsveld 1998).

Figure 4 shows the distribution of physical habitat variables in the planned conservation area (MHPA) compared to the region (and for comparison, the currently conserved lands) based on existing GIS data (source: SANDAG). In these histograms the continuous variables are divided into ordinal classes. These variables could be combined to form land classes based on co-occurrence of physical habitat factors by overlay (Boolean combination using intersection) (as in Franklin et al. 2001), or by unsupervised clustering (Franklin 2003).

For example, if each variable were divided into 3 equal-area classes and 7 soil classes were retained, almost 5000 unique combinations could result from the overlay (intersection) of these seven variables. Many fewer combinations would actually occur because of multicolinearity among these factors, but clearly the resulting land classes would more finely divide the landscape than the existing vegetation map. Again, assumptions of this approach are that the resulting classes represent the ecological potential of the landscape, and that the GIS data adequately represent abiotic (physical) landscape variables (at an appropriate scale and accuracy).

This descriptive analysis also provides a comparison of the physical environments in the planned conservation area (and the currently conserved lands) to those found throughout the region, similar to our analysis of mapped plant communities above. Comparing the blue and green bars (currently conserved and planning areas) to yellow (region), the planned conservation area underrepresents lower elevations, flatter slopes, lower precipitation, higher winter minimum temperatures, lower summer maximum temperatures (e.g., coastal areas), and alfisol and vertisol soil orders. Inland areas (relatively higher elevation, lower minimum and higher maximum monthly temperatures) are well-represented in the currently conserved lands. While this may be intuitive and obvious to those working closely with the MSCP planning process, this analysis documents these patterns quantitatively based on the physical geography of the landscape.





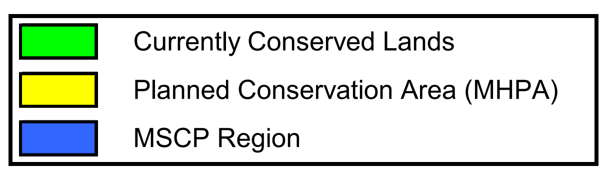


Figure 4. Representativeness of physical variables in the MSCP currently conserved lands, planned conservation area (MHPA), and MSCP region.

.

VI. Classification Systems and Categorical Aggregation

Though landscape stratification based on physical habitats is a powerful tool for allocating a stratified sample of locations for monitoring, one problem with the approach is that the resulting classes are not very intuitive or useful for managers. NatureServe cites this as one reason they used the Ecological System classification approach.

Plant communities themselves are also appropriate entities to group and prioritize for MSCP preserve monitoring because they have been well-defined by a variety of state and national sources including the project sponsor (Cal Fish & Game), the California Native Plant Society, and the National Vegetation Classification (NVC) System. Many of these classifications have also been used as a basis for mapping, including Holland for the MSCP region. Additionally, these vegetation classes have endangerment rankings that we can use in the prioritization process (next section of report).

NatureServe (http://www.natureserve.org/getData/USecologyData.jsp) developed "a new mid-scale ecological classification… for use in conservation and environmental planning" (Comer et al. 2003). They define Ecological Systems as: "a group of plant community types (associations) that tend to co-occur within landscapes with similar ecological processes [such as fire or flooding], substrates, and/or environmental gradients. A given system will typically manifest itself in a landscape at intermediate geographic scales of tens to thousands of hectares and will persist for 50 or more years" (p. iv).

NatureServe felt a new classification system was required for the following reasons (Comer et al. 2003, p. 1): "Ecoregional approaches often provide multiple levels of spatial scales, but typically the resolution is quite coarse, and the units are unique subsets of the geographic space, with varying degrees of heterogeneity." Their approach is to define ecological systems that are more categorically aggregated than NVC Associations and Alliances but below the Formation level, which they find too generalized for community mapping and conservation planning at intermediate scales.

If there were a many-to-one (nested) relationship between plant communities and NatureServe Ecological Systems within the MCSP region, then the NatureServe classification could be used to aggregate communities for monitoring. However, the MSCP preserve is small in relation to the intended mapping scale of the NatureServe Ecological Systems classification (mapping units from 10s to 1000s of hectares), and therefore it may not be appropriate to aggregate plant communities for monitoring within the MCSP preserve.

Many vegetation and ecosystem classification systems are hierarchical, meaning that, like taxonomic classification, finer categorical divisions of species composition are nested within a broader one. However, categories are not necessarily spatially contiguous. Vegetation communities are usually distributed discontinuously across many stands or patches (Urban et al. 1987, Franklin and Woodcock 1997).

The MSCP Plan identified vegetation communities based on the Holland (1986) classification system because that was the system used to map existing vegetation for the MSCP region when the plan was developed (available from SANDAG as already noted; http://www.sandag.org/resources/maps_and_gis/gis_downloads/senlu.asp). This classification is hierarchical and so the communities can easily be grouped according to that hierarchy (Table 1), and can be cross-referenced to classes defined in the more recent and widely accepted CNPS classification for California (Sawyer and Keeler-Wolf 1995) (Appendix 1), or the National Vegetation Classification Standard (http://biology.usgs.gov/npsveg/nvcs.html).

Table 4 shows that vegetation communities mapped as biodiversity elements for the MSCP are defined at Levels 3 or 4 (most detailed) in the Holland system. Table 1 showed one way the 62 vegetation and land cover classes occurring in the vegetation map for the MCSP planned conservation area could be grouped, primarily by aggregating to level 2, with an even greater level of aggregation in some cases.

Table 4. Example of hierarchical grouping of vegetation communities identified for protection in the MSCP region (Table 3.3, Ogden 1998), shown in bold, according to the Holland (1986) classification system.

Level 1	**Level 2**	**Level 3**	**Level 4**
20000 Dune communities	21000 Coastal Dunes	21200 Foredunes	**21230 Southern Foredunes**
30000 Scrub and Chaparral	31000 Coastal bluff scrub	**31200 Southern coastal bluff scrub**	
	32000 Coastal Scrub	**32400 Maritime Succulent Scrub**	
		32500 Diegan Coastal Sage Scrub	

To summarize, for the MSCP monitoring program, we are reliant on the original vegetation map developed for MSCP planning that uses the Holland classification system (as revised by T. Oberbauer in 1996). It is our understanding that more recent mapping of parcels acquired as part of the preserve also uses the Holland classification for baseline delineation and inventory of plant communities. Because this system is hierarchical, vegetation classes can be grouped or aggregated according to that hierarchy if it is necessary to do so for monitoring. We anticipate that some narrowly defined vegetation classes that are highly endangered may receive high priority for monitoring as community elements of biodiversity (next section). However, in designing a sampling scheme for monitoring, aggregating certain classes (such as coastal sage scrub community types) that tend to grade into each other (gradual turnover in composition along environmental gradients) may facilitate community monitoring at the MSCP-wide landscape scale.

VII. Prioritization of Ecological Communities Based on their Endangerment

National classification systems and rankings of national and global endangerment have been developed for ecological communities using systems analogous to those used to rank species, and can be used to help prioritize them for monitoring in the MCSP.

For example, the USGS in their report "*Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation*" (http://biology.usgs.gov/pubs/ecosys.htm) (Noss et al. 1995) identified the following threatened and endangered ecosystems that occur in the MSCP region, according to the criterion of historical loss of extent (percent decline):

Critically Endangered (>98% decline) Ecosystems

- Native grasslands (all types) in California.
- Coastal strand in southern California.

Endangered (85-98% decline)

- Coastal sage scrub (especially maritime) and coastal mixed chaparral in southern California.
- Vernal pools in the Central Valley and in southern California.
- Freshwater marsh and coastal salt marsh in Southern California.

Threatened (70-84% decline)

- Coastal wetlands in California.

Notably, NatureServe defines the Global (G) Conservation Status (Rank) of an ecological community in exactly the same way it is defined for a species, based on the rangewide status of that community (see Appendix 4). These NatureServe rankings, as well as Statewide (S) rankings, are included in the CNPS documents (available at: http://davisherb.ucdavis.edu/cnpsActiveServer/hollandlist.asp) for California plant communities. The rankings are currently being reviewed and updated by CDFG scientists (Keeler-Wolf *pers. comm.* 2006). The endangered classes found in the MSCP region are shown in Table 5.

			Planned Conservation Area			Currently Conserved Lands		
Holland Code	Holland Name	NDDB Status	Acres	Number of Patches	Largest Patch Size (acres)	Acres	Number of Patches	Largest Patch Size (acres)
52310	Cismontane alkali marsh	G1 S1.1	239.30	24	119.49	46.90	12	17.69
42110	Valley needlegrass grassland	G1 S1.1	229.42	116	24.39	131.43	51	23.38
31200	Southern coastal bluff scrub	G1 S1.1	145.57	18	105.25	142.67	11	105.25
83140	Torrey pine forest	G1 S1.1	144.51	22	88.18	144.50	20	88.18
37C30	Southern maritime chaparral	G1 S1.1	1104.69	101	253.23	947.92	114	253.23
32400	Maritime succulent scrub	G2 S1.1	958.70	120	165.97	774.80	75	115.34
71180	Engelmann oak woodland	G2 S2.1	1.11	7	0.74	0.95	6	0.22
61320	Southern arroyo willow riparian forest	G2 S2.1	21.69	8	13.81	18.39	9	6.73
71182	Dense Engelmann oak woodland	G2 S2.1	0.00	0	0.00	30.21	3	22.83
21230	Southern foredunes	G2 S2.1	134.24	15	51.84	94.53	20	22.31
52120	Southern coastal salt marsh	G2 S2.1	1587.35	460	261.04	1193.65	452	261.04
83230	Southern interior cypress forest	G2 S2.1	5654.09	136	2604.52	5470.77	139	2521.34
71181	Open Engelmann oak woodland	G2 S2.2	285.99	26	76.75	322.83	37	68.07
45320	Alkali seep	G3 S2.1	0.00	0	0.00	2.62	1	2.62
63320	Southern willow scrub	G3 S2.1	171.62	144	18.89	49.14	76	4.64
52410	Coast and valley freshwater marsh	G3 S2.1	344.94	259	32.76	181.26	146	19.52
	Total area in endangered classes:		11023.23			9552.56		
	% of planned or currently conserved lands in endangered classes:		5.58%			7.46%		

Table 5. Endangerment rankings, total area, number of patches, and largest patch size for the most endangered Holland vegetation classes found in the MSCP planned conservation area and currently

conserved lands (G1-G2 and/or S1-S2). Appendix 2 contains a complete list of Holland classes found in the MSCP Region cross-referenced with California Native Plant Society series.

In addition to endangerment rankings, landscape pattern analysis could be used as an indicator of risk or threats to further prioritize or rank communities for monitoring. Both the extent and spatial pattern of a plant community in the preserve are important measures of its at-risk status. Communities of very limited extent and/or those that comprise smaller more dispersed patches are subjected to negative fragmentation and edge effects (of course, these too should be measured against some reference condition). Wetlands (including vernal pools) and oak woodlands meet these criteria.

Prioritization could be based on largest areal extent in the planned conservation area or currently conserved lands, which would give Chaparral and Coastal Sage Scrub highest priority. Alternatively, classes that are under-represented in the currently conserved lands compared to the region and/or conservation planning area could be given higher priority, which would include Coastal Sage Scrub, Grasslands, Meadows and Freshwater Wetlands (including vernal pools), Salt Marsh, and Oak Woodlands.

Vegetation/Land Cover Class	Underrepresented	Extent	Fragmentation	Endangerment
Salt Waters/Coastal	1	3	3	2
Coastal Sage Scrub	1	1	2	1
Chaparral	3	1	3	3
Grasslands	2	3	2	2
Meadows and Freshwater Wetlands	2	3	1	2
Riparian and Riparian Woodlands	3	2	1	3
Oak Woodland	2	3	1	2
Torrey Pine Forest	3	3	3	1
Southern Interior Cypress Forest	3	2	3	1

Table 6. Prioritization for monitoring (higher to lower, 1 to 3) for each criterion. Ranking for endangerment based on number of communities included within the aggregated vegetation class that have high rankings – G1-G2 and/or S1-S2 – and their proportional area.

Comparing these priorities based on the landscape assessment to those determined from our covered species habitat/threat analyses, Coastal Sage Scrub, Chaparral, and Grasslands were consistently high priority.

Communities with high endangerment or threats should also receive high priority and include: Southern foredunes, Southern coastal salt marsh, Southern coastal bluff scrub, Maritime succulent scrub, Diegan coastal sage scrub, Southern maritime chaparral, Valley needlegrass grassland, Cismontane alkali marsh, Southern arroyo willow riparian forest, Southern willow scrub, Engelmann oak woodland, Torrey Pine forest, and Tecate (Southern Interior) Cypress forest (Table 5).

VIII. Summary of Recommendations

A spatial analysis of mapped plant communities and physical landscape variables in the MSCP Region, planned conservation area, and currently conserved lands provided context and background for prioritizing plant communities for monitoring.

We found that among the extensive classes, chaparral is already well-represented in the currently conserved lands relative to the region, while a greater proportion of CSS has yet to be acquired within the planned conservation area. Of the less extensive habitats and plant communities in the preserve, meadows and freshwater wetlands, fresh water habitats and oak woodland are underrepresented in the currently conserved lands, but they will occur in the planned conservation area in the same proportion as the region when all conservation lands have been acquired. However grassland and salt water/coastal habitats occur in a smaller proportion of the planned conservation area than the region. This is not surprising because representativeness of all plant communities was not used as a strict design criterion during MSCP planning. However, it is important to note because it affects the design of a monitoring plan for communities. Further, grassland and salt water/coastal habitats, are more fragmented in the planned conservation area than the region – they occur in smaller, more widely dispersed patches. However, most plant communities are to some extent more fragmented in the preserve than the region simply because of the configuration of the preserve boundary – they comprise fewer patches, are further apart, with greater edge density, especially in the case of CSS. On the other hand, some rare plant communities are found almost entirely within the preserve in clustered patches that reflect their natural (historical) distribution – Torrey Pine forest and Tecate Cypress forest.

A major limitation of our analyses of representation and landscape patterns is that they are based on a map of vegetation that does not have an up-to-date categorical accuracy evaluation. It is well known that landscape pattern assessment is strongly influenced by map accuracy and spatial resolution (scale).

While it has been suggested that assemblages of natural communities could be defined for the purpose of monitoring and conceptual modeling (based on shared risks), the concept of a natural community assemblage is not defined or supported in the scientific literature. Alternative approaches to landscape stratification that we explored included land system classification (Ecological Land Units), Ecological Systems (NatureServe) and stratification based on physical habitat factors. Existing Ecological Land Units and Ecological System classifications were intended for mapping landscape units from 100s to 1000s ha in size and are too coarse-scale to apply to the small MSCP. The currently conserved lands are about 50,000 ha, and the planned extent is 79,000 ha with the largest mapped habitat patch about 1000 ha, and most patches much smaller. Stratification based on physical habitat factors allowed us to quantify the degree to which environments are well-protected versus underrepresented on the preserved lands relative to the region. Not surprisingly, coastal environments with more maritime climates and flat sites are poorly represented, primarily because they are already urbanized. However, land units delineated on the basis of physical habitat variables are not intuitive or easy to interpret or define for the purposes of community monitoring.

Therefore, we conclude the hierarchical aggregation of plant community categories based on existing classifications (Holland, CNPS) is the best alternative if communities must be grouped. That was in fact the approach we used for the landscape spatial analysis presented in this report.

Prioritization of communities for monitoring was based on the following criteria: representativeness, extent, fragmentation, endangerment and threats. The last two are defined by NatureServe and CNPS (Global and State) for ecological communities. Aggregated communities that received high priority rankings based on several criteria include CSS and Meadows and Freshwater Wetlands. Communities with high endangerment or threats should also receive high priority and include: Southern foredunes, Southern coastal salt marsh, Southern coastal bluff scrub, Maritime succulent scrub, Diegan coastal sage scrub, Southern maritime chaparral, Valley needlegrass grassland, Cismontane alkali marsh, Southern arroyo willow riparian forest, Southern willow scrub, Engelmann oak woodland, Torrey Pine forest, and Tecate Cypress forest.

IX. Literature Cited

Arnold, D. H., G. W. Smalley, and E. R. Buckner. 1996. Landtype-forest community relationships: a case study on the Mid-Cumberland Plateau. Environmental Monitoring and Assessment **39**:339-352.

Atkinson, A. J. 2004. MSCP Monitoring Plan Development - Status and next steps. Notes prepared for U.S. Geological Survey, California Department of Fish and Game, and U.S. Fish and Wildlife Service.

Atkinson, A. J., P. C. Trenham, R. N. Fisher, S. A. Hathaway, B. S. Johnson, S. G. Torres, and Y. C. Moore. 2004. Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans. US Geological Survey, California Department of Fish and Game, and US Fish and Wildlife Service.

Austin, M. P., and P. C. Heyligers. 1989. Vegetation survey design for conservation: gradsect sampling of forests in North-eastern New South Wales. Biological Conservation **50**:13-32.

Austin, M. P., and P. C. Heyligers. 1991. New approach to vegetation survey design: gradsect sampling. Pages 31-36 *in* C. R. Margules and M. P. Austin, editors. Nature conservation: cost effective biological surveys and data analysis. CSIRO, East Melbourne, Australia.

Austin, M. P., and T. M. Smith. 1989. A new model for the continuum concept. Vegetatio **83**:35-47.

Bailey, R. G. 1980. Descriptions of the ecoregions of the United States. Miscellaneous Publication 1391, USDA Forest Service, U.S. Government Printing Office, Washington, D.C.

Bourgeron, P. S., C. J. Humphries, and M. E. Jensen. 2001. General data collection and sampling design considerations for integrated ecological assessment. Pages 92-107 *in* G. Lessard, editor. An integrated ecological assessment protocols guidebook. Springer-Verlag, New York, NY.

Cleland, D. T., P. E. A. Avers, W. H. McNab, M. E. Jensen, R. G. Bailey, T. King, and W. E. Russell. 1997. National hierarchical framework of ecological units. Pages 181-200 *in* A. Haney, editor. Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources. Yale University Press, New Haven & London.

Franklin, J. 2003. Clustering versus regression trees for determining Ecological Land Units in the southern California mountains and foothills. Forest Science **49**:354-368.

Franklin, J., T. Keeler-Wolf, K. Thomas, D. A. Shaari, P. Stine, J. Michaelsen, and J. Miller. 2001. Stratified sampling for field survey of environmental gradients in the Mojave Desert Ecoregion. Pages 229-253 *in* A. Millington, S. Walsh, and P. Osborne, editors. GIS and remote sensing applications in biogeography and ecology. Kluwer Academic Publishers, Netherlands.

Franklin, J., and C. E. Woodcock. 1997. Multiscale vegetation data for the mountains of Southern California: spatial and categorical resolution. Pages 141-168 *in* D. A. Quattrochi and M. F. Goodchild, editors. Scale in remote sensing and GIS. CRC/Lewis Publishers Inc., Boca Raton, FL.

Gillison, A. N., and K. R. W. Brewer. 1985. The use of gradient directed transects or gradsect in natural resources survey. Journal of Environmental Management **20**:103-127.

Gleason, H. A. 1926. The individualistic concept of the plant association. Bulletin of the Torrey Botanical Club **53**:7-26.

Goedickemeier, I., O. Wildi, and F. Kienast. 1997. Sampling for vegetation survey: some properties of a GIS-based stratification compared to other statistical sampling methods. Coenoses **12**:43-50.

Gurevich, J. 2002. The Ecology of Plants. Sinauer Associates, Sunderland, on p. 236 cites Fauth et al. 1996 American Naturalist 147:282-28.

Hierl, L. A., H. M. Regan, J. Franklin, and D. H. Deutschman. 2005. Draft Assessment of the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program. San Diego State University, Prepared for California Department of Fish and Game.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game, Sacramento, CA.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature **405**:243-253.

Marshall, I. B., and P. H. Schut. 1999. A national ecological framework for Canada. http://res.agr.ca/CANSIS/NSDB/ECOSTRAT/.

Marshall, I. B., C. A. Smith, and C. Selby. 1996. A national ecological framework for monitoring and reporting on the environmental sustainability in Canada. Pages 25-38 *in* R. Sims, editor. Global to local: ecological land classification. Kluwer Academic Publishers, Netherlands.

McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. http://www.umass.edu/landeco/research/fragstats/documents/Metrics/Metrics%20TOC.htm.

Noss, R. F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered Ecosystems of the United States: A preliminary assessment of loss and degradation. Biological Report 28, National Biological Service, U.S. Department of the Interior, Washington, D.C.

Ogden Environmental and Energy Services. 1996. Biological Monitoring Plan for the Multiple Species Conservation Program. Prepared for City of San Diego, California Department of Fish and Game, and US Fish and Wildlife Service.

Ogden Environmental and Energy Services. 1998. Final Multiple Species Conservation Program: MSCP Plan.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers **77**:118-125.

Regan, H., L. Hierl, J. Franklin, and D. Deutschman. 2006. Grouping and Prioritizing the MSCP Covered Species. Technical Report to California Dept. of Fish and Game. San Diego State University, San Diego, CA.

Robitaille, A., and J. P. Saucier. 1996. Land district, ecophysiographic units and area: the landscape mapping of the Ministere des Ressources Naturelles du Quebec. Environmental Monitoring and Assessment **39**:127-148.

Rowe, J. S., and J. W. Sheard. 1981. Ecological land classification: a survey approach. Environmental Management **5**:451-464.

SANDAG. 2004. HabiTrak GIS Layer.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento, CA.

Sims, R. A., I. G. W. Corns, and K. Klinka. 1996. Global to local: Ecological land classification. Kluwer Academic Publishers, Netherlands.

Sprugel, D. G. 1991. Disturbance, equilibrium, and environmental variability: what is 'natural' vegetation in a changing environment? Biological Conservation **58**:1-18.

Stow, D., J. O'Leary, and A. Hope. 1993. Accuracy Assessment of MSCP GIS Vegetation Layer. San Diego State University, Prepared for Ogden Environmental and Energy Services, San Diego, CA.

Urban, D. L., R. V. O'Neill, and H. H. Shugart, Jr. 1987. Landscape ecology. Bioscience **37**:119-127.

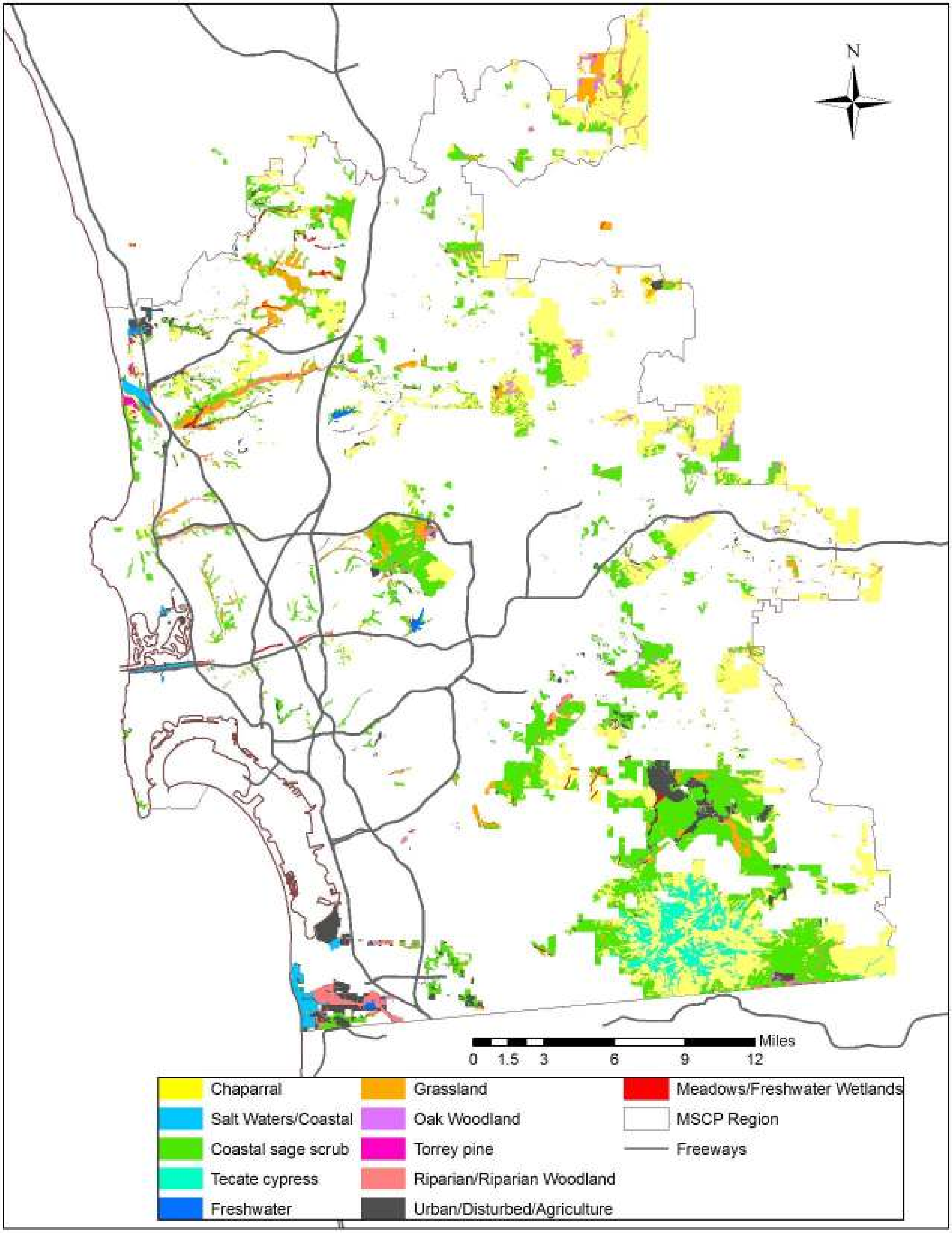
Wessels, K. J., and A. S. van Jaarsveld. 1998. An evaluation of the gradsect biological survey method. Biodiversity and Conservation **7**:1093-1121.

Westman, W. E. 1981. Factors influencing the distribution of species of California Coastal Sage Scrub. Ecology **62**:439-455.

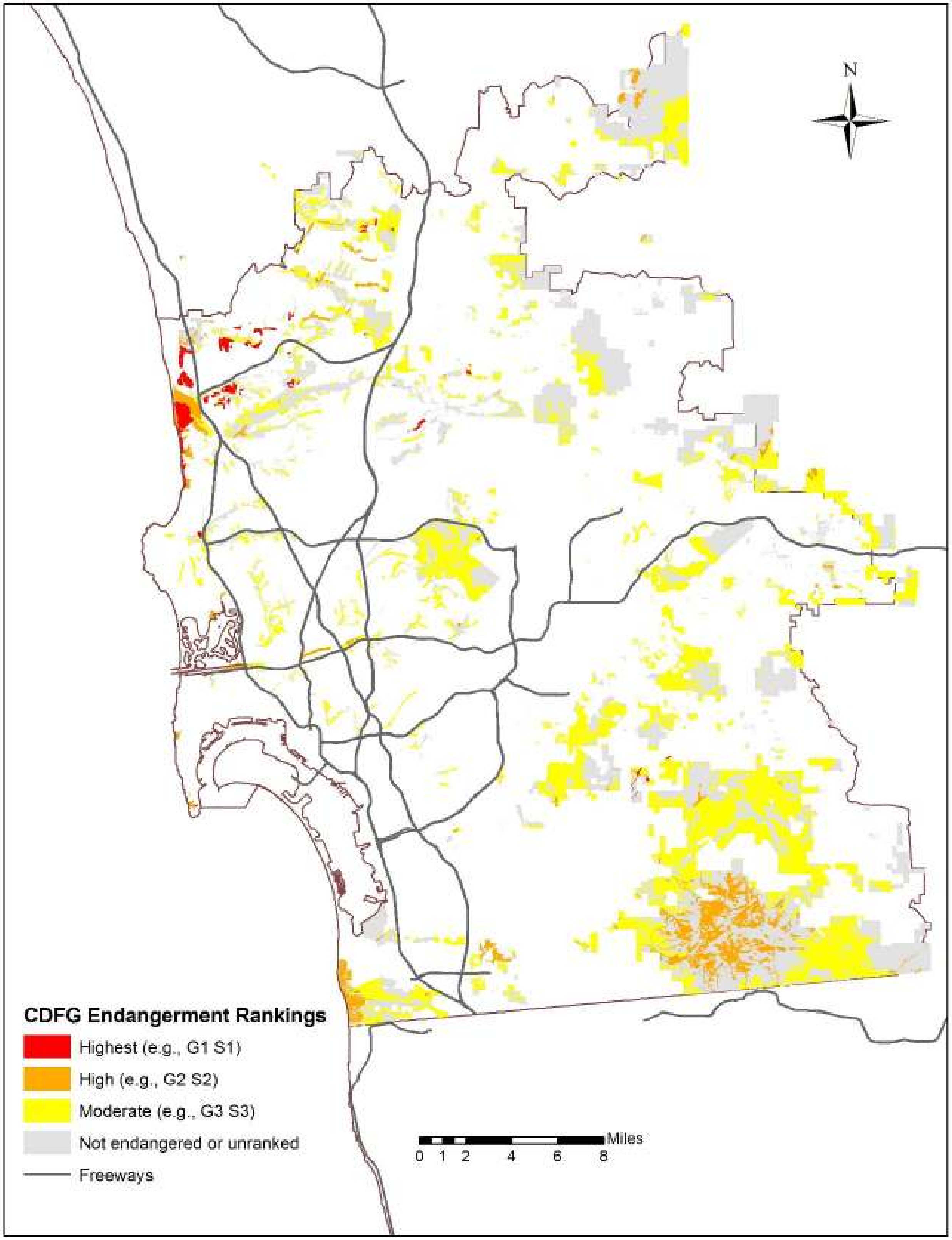
Whittaker, R. H. 1973. Direct gradient analysis. Pages 9-50 *in* R. H. Whittaker, editor. Handbook of Vegetation Science 5: Ordination and Classification of Communities. Junk, The Hague.

Winchell, C., and P. Doherty. 2006. Estimation of California Gnatcatcher Pair Abundance and Occupancy Rates. U.S. Fish and Wildlife Service, Prepared for California Department of Fish and Game, Sacramento, CA.

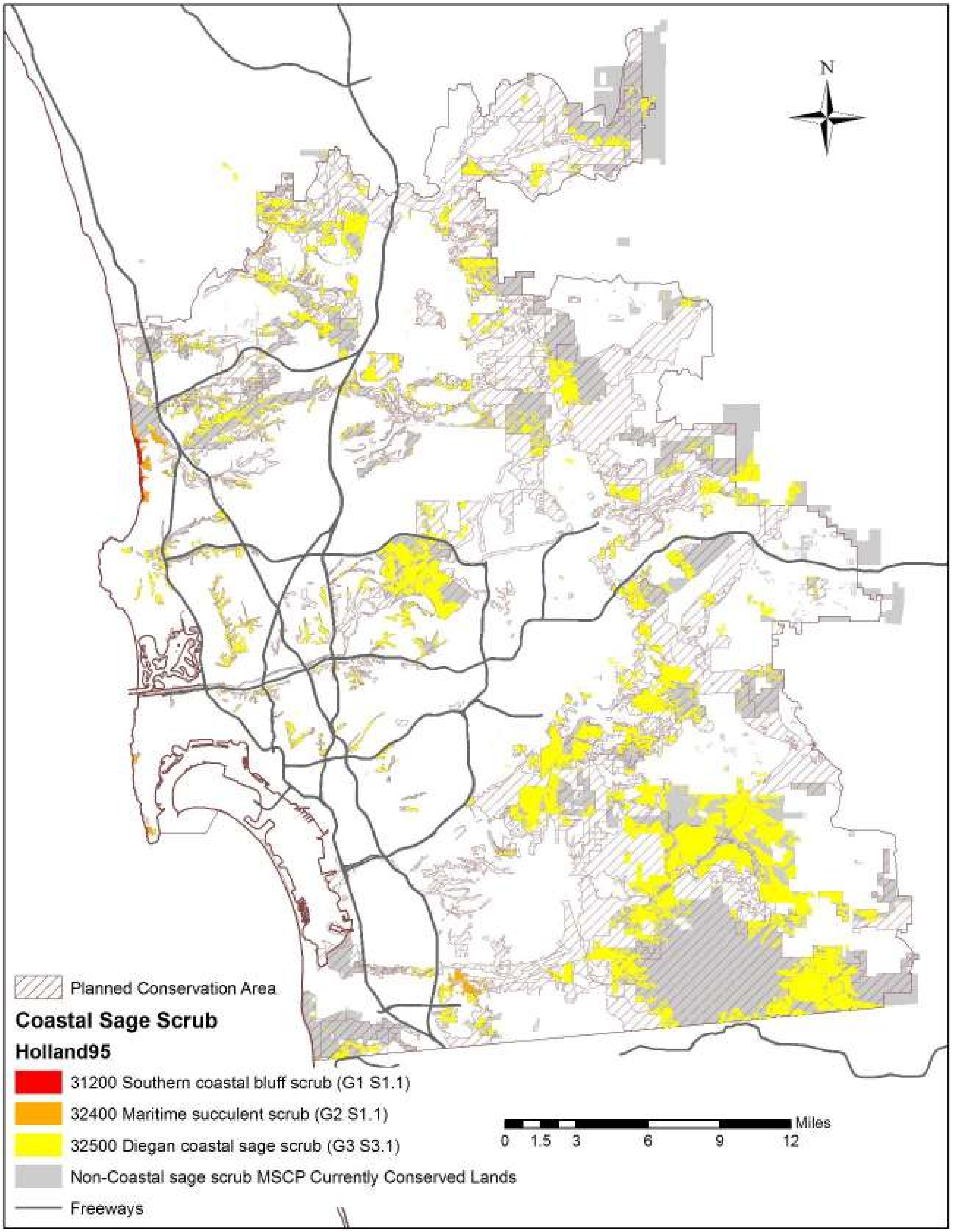
Appendix 1: Maps of vegetation communities in the San Diego Multiple Species Conservation Program's currently conserved lands

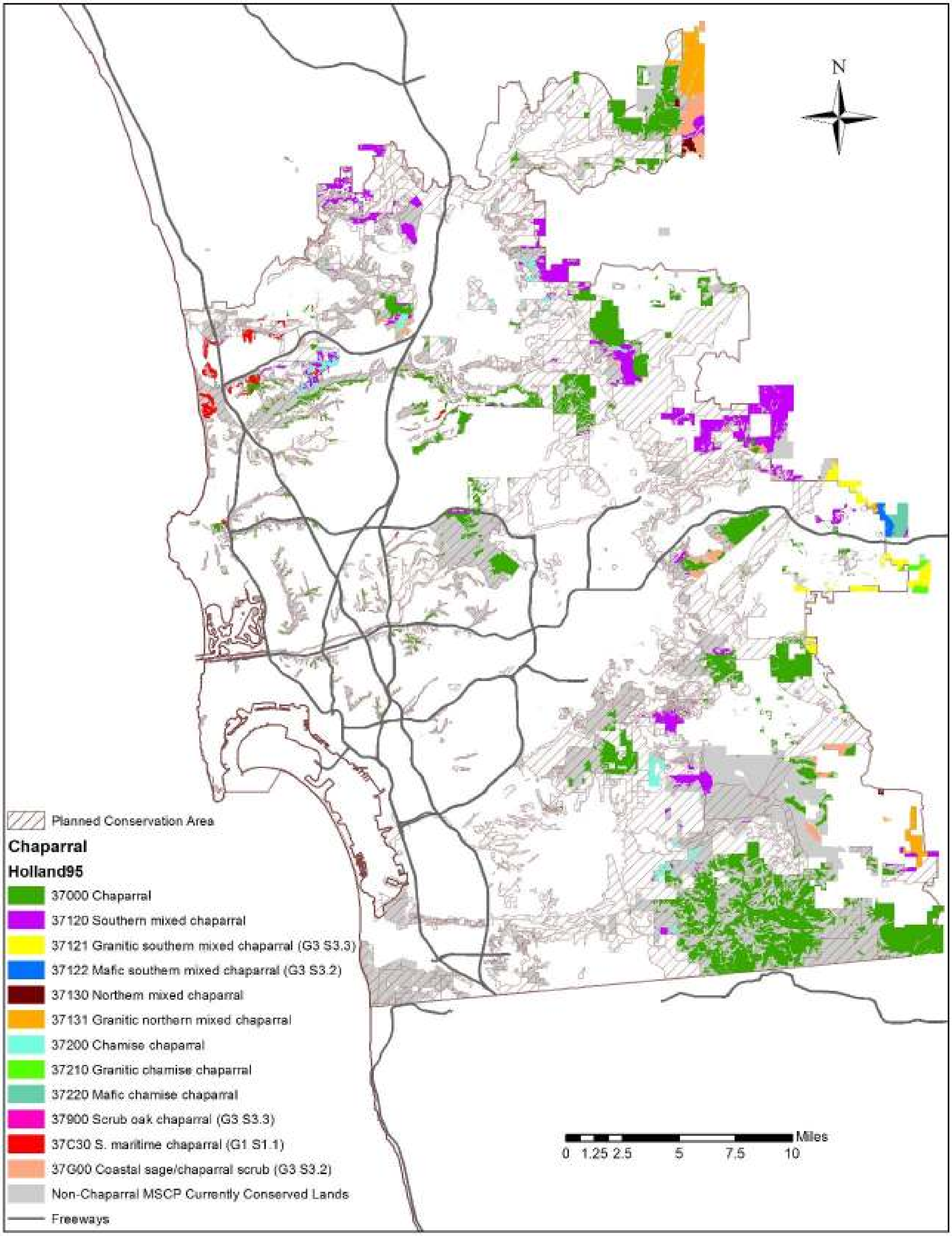


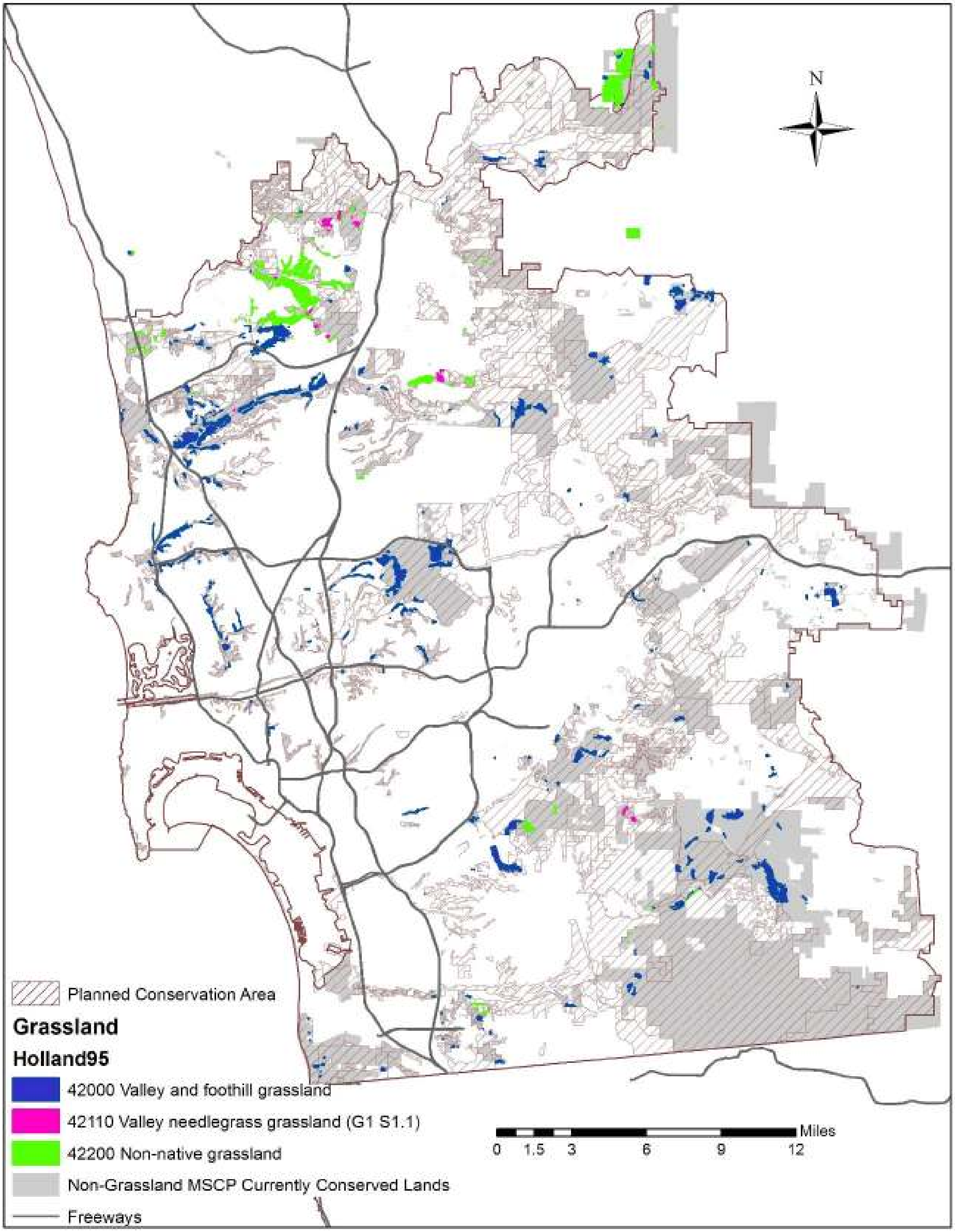
Grouped vegetation communities (as aggregated in Table 1).

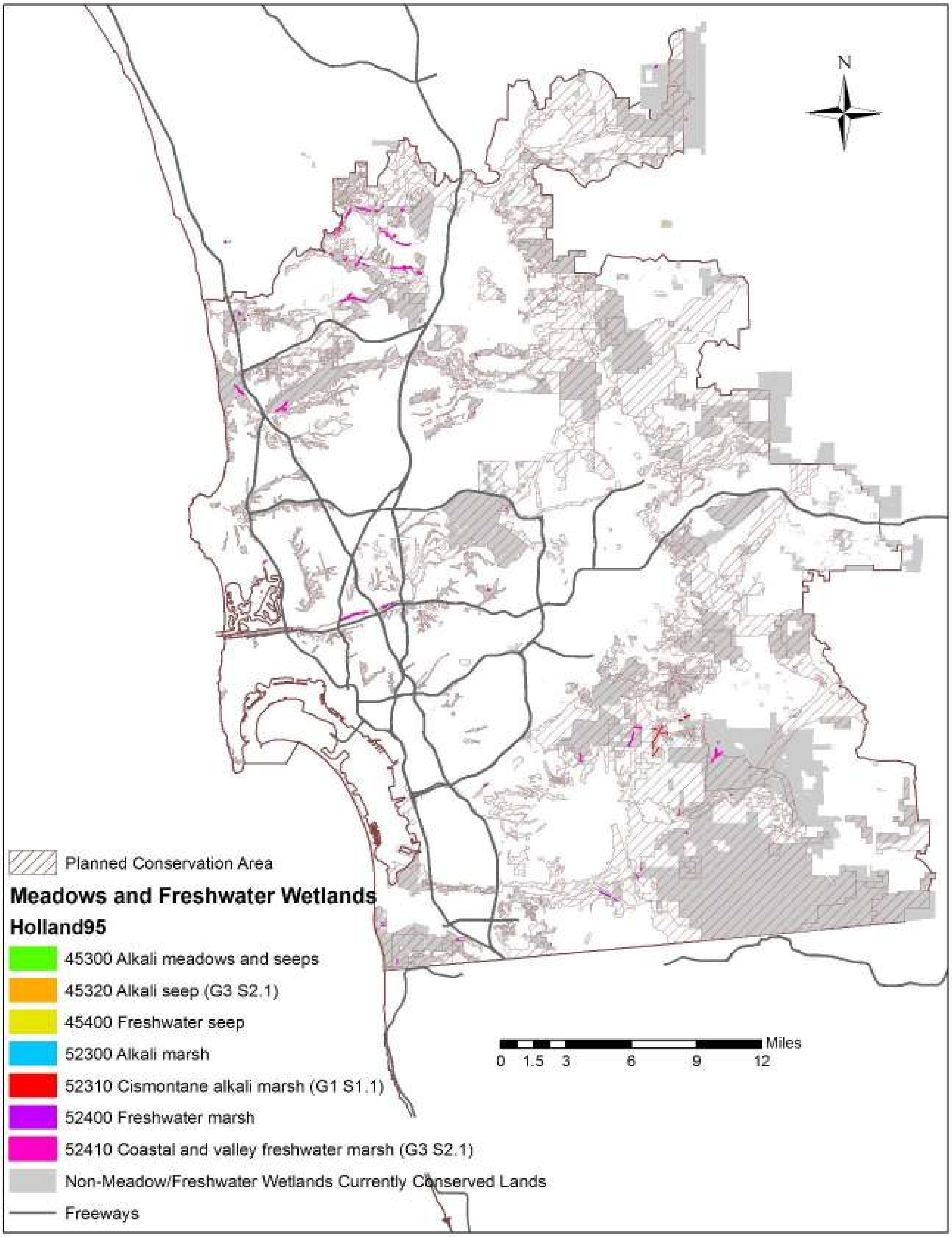


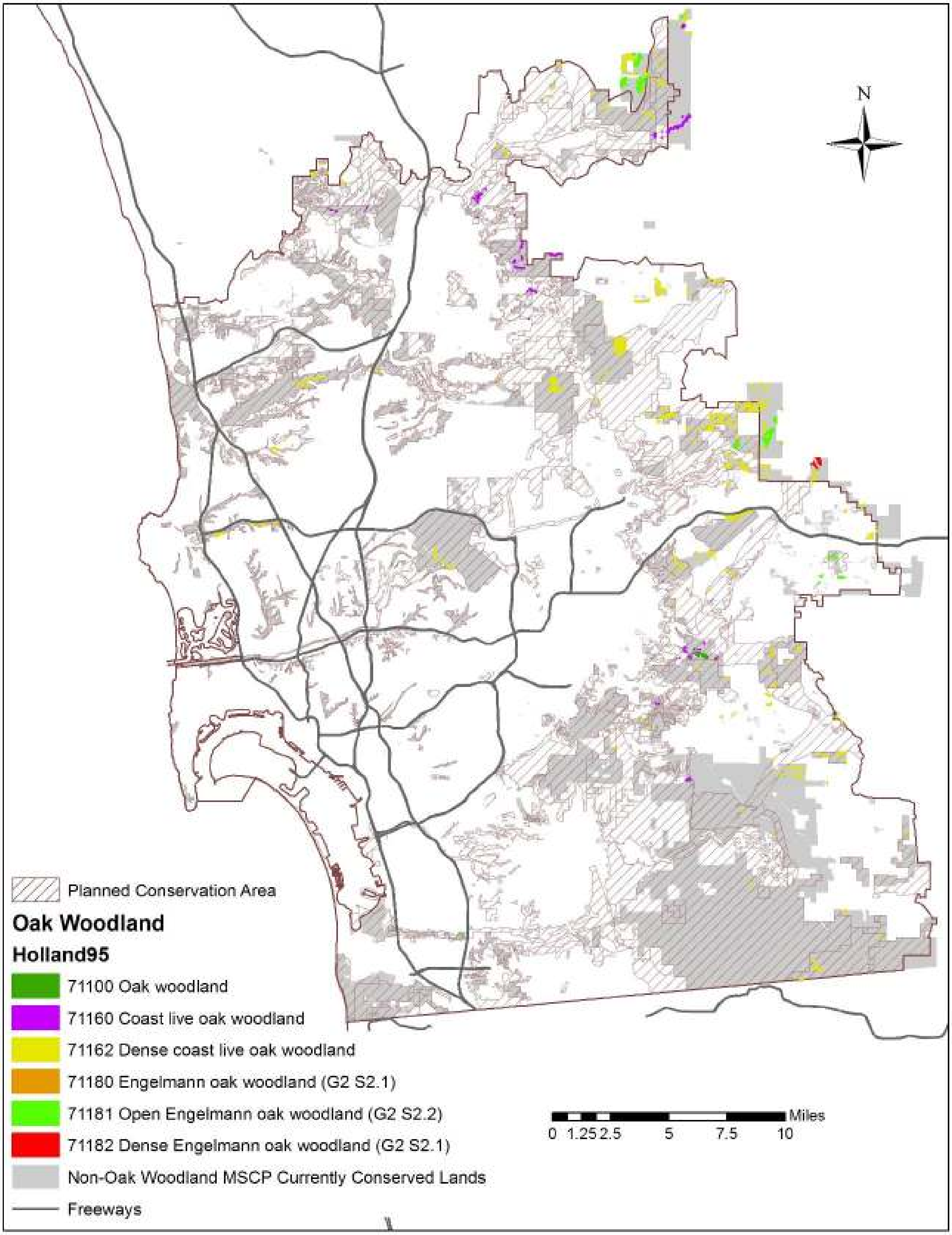
Endangered community types in the MSCP's currently conserved lands, based on California Department of Fish and Game Heritage Program rankings (see Appendix 4).

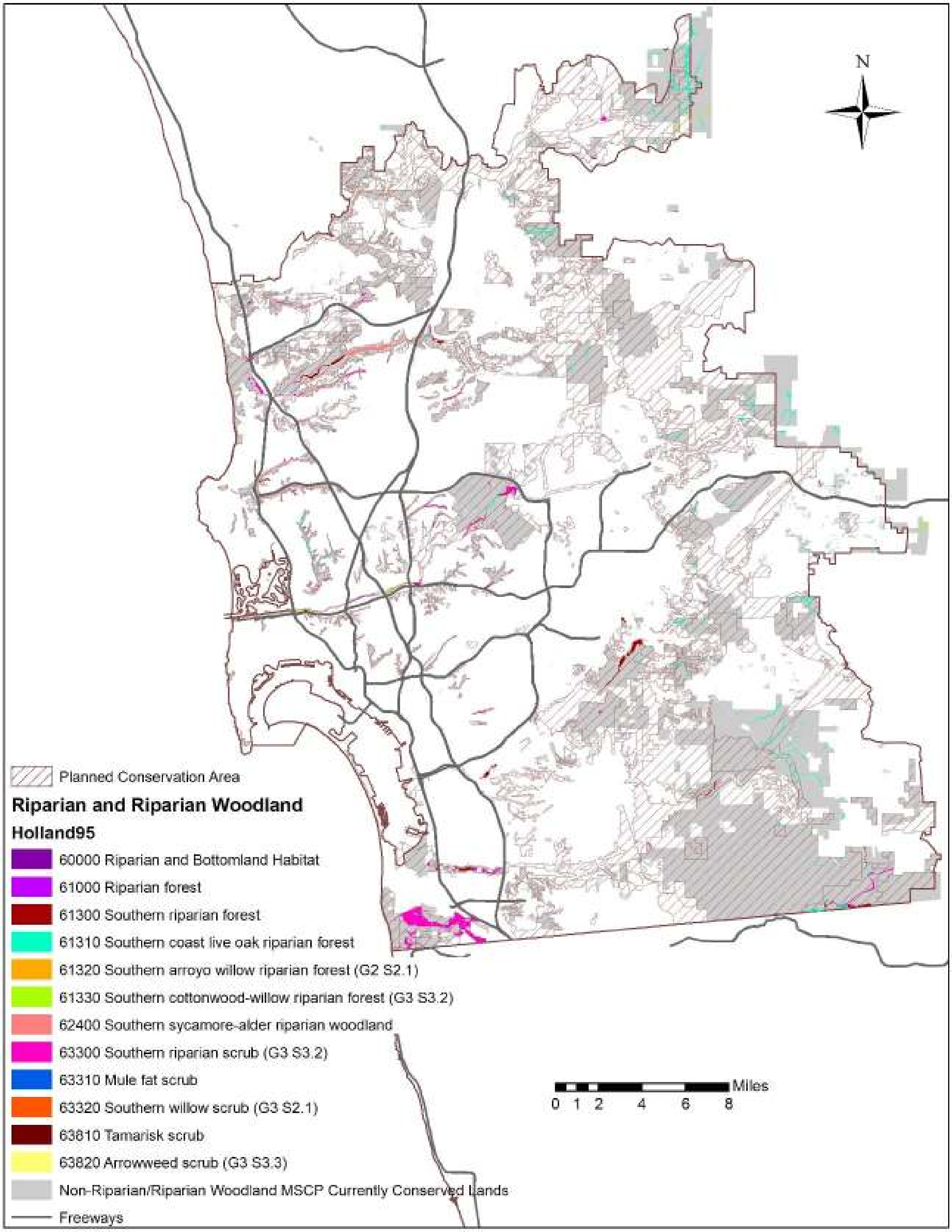

N
Planned Conservation Area
Coastal Sage Scrub
Holland95
31200 Southern coastal bluff scrub (G1 S1.1)
32400 Maritime succulent scrub (G2 S1.1)
32500 Diegan coastal sage scrub (G3 S3.1)
Non-Coastal sage scrub MSCP Currently Conserved Lands
Freeways
Miles
0 1.5 3 6 9 12

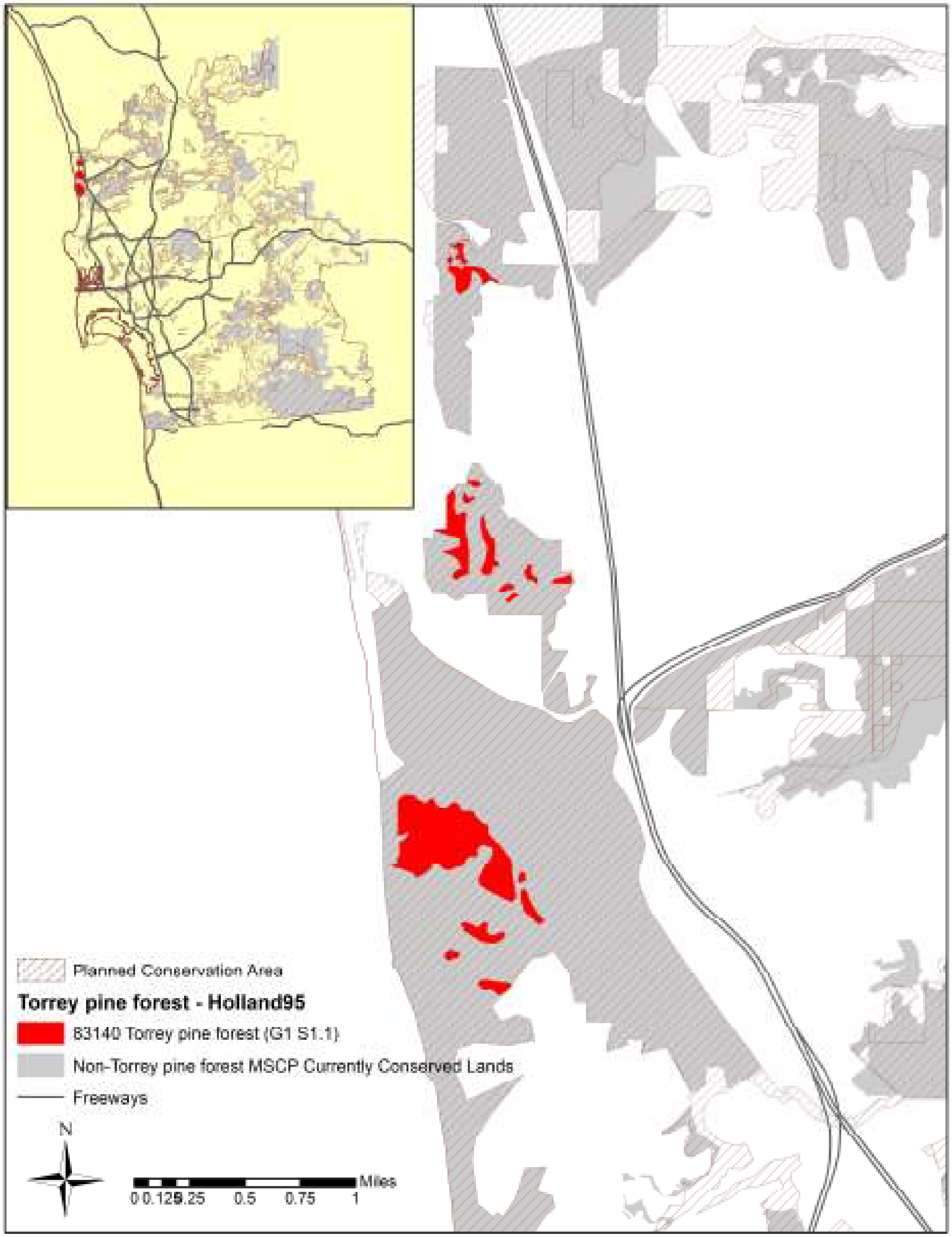

N
Planned Conservation Area
Chaparral
Holland95
37000 Chaparral
37120 Southern mixed chaparral
37121 Granitic southern mixed chaparral (G3 S3.3)
37122 Mafic southern mixed chaparral (G3 S3.2)
37130 Northern mixed chaparral
37131 Granitic northern mixed chaparral
37200 Chamise chaparral
37210 Granitic chamise chaparral
37220 Mafic chamise chaparral
37900 Scrub oak chaparral (G3 S3.3)
37C30 S. maritime chaparral (G1 S1.1)
37G00 Coastal sage/chaparral scrub (G3 S3.2)
Non-Chaparral MSCP Currently Conserved Lands
Freeways
Miles
0 1.25 2.5 5 7.5 10

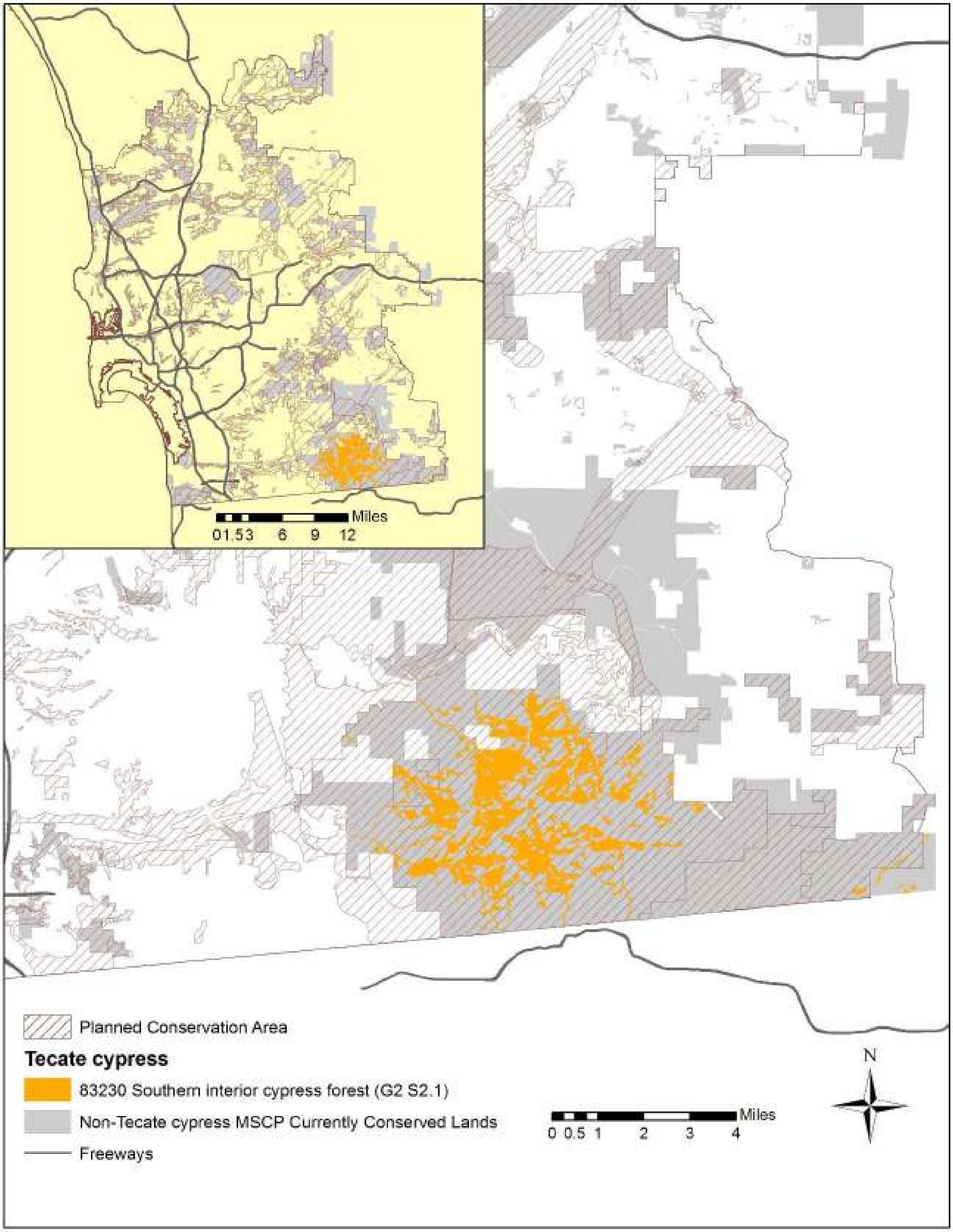

N
Planned Conservation Area
Grassland
Holland95
42000 Valley and foothill grassland
42110 Valley needlegrass grassland (G1 S1.1)
42200 Non-native grassland
Non-Grassland MSCP Currently Conserved Lands
Freeways
Miles
0 1.5 3 6 9 12

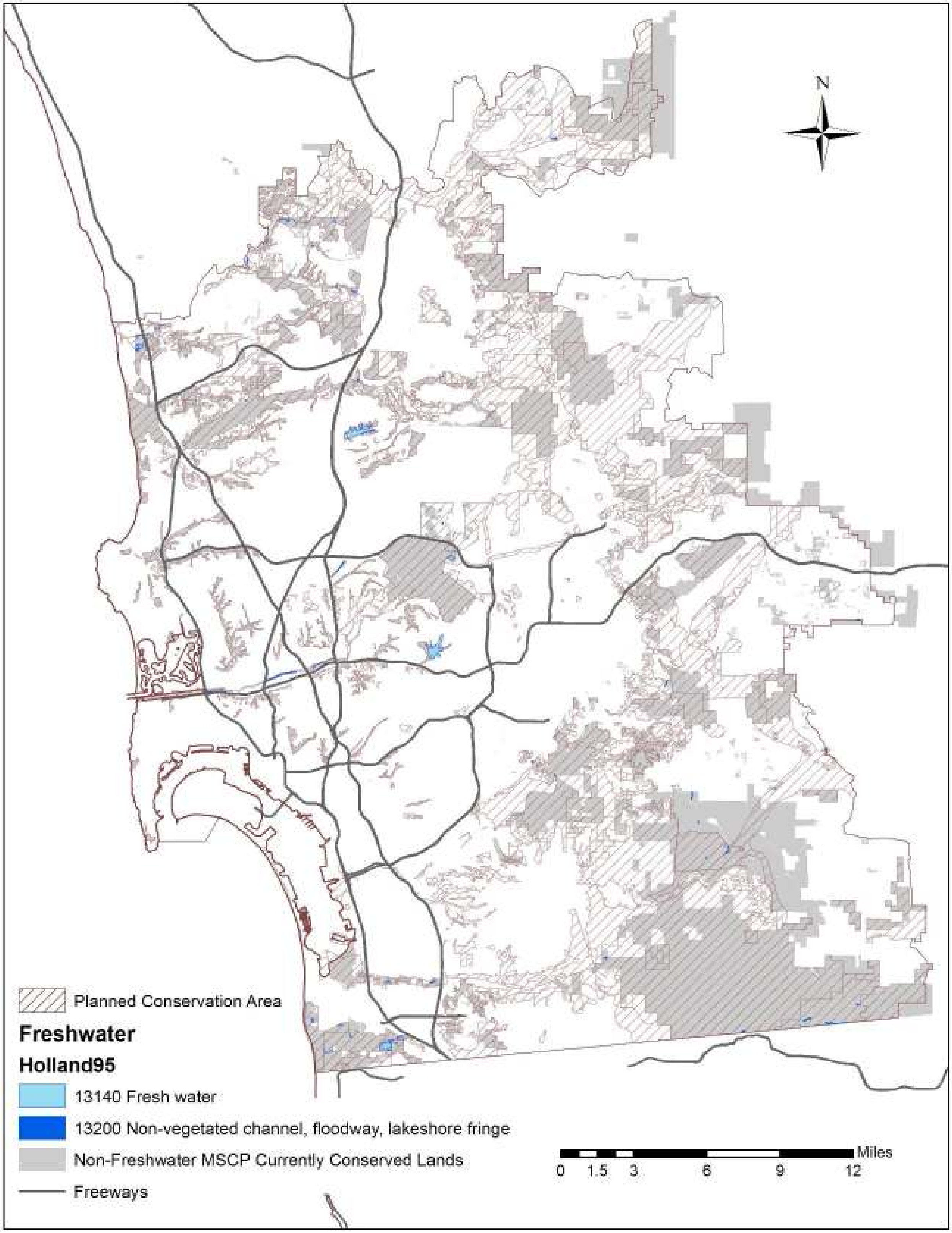

N
Planned Conservation Area
Meadows and Freshwater Wetlands
Holland95
45300 Alkali meadows and seeps
45320 Alkali seep (G3 S2.1)
45400 Freshwater seep
52300 Alkali marsh
52310 Cismontane alkali marsh (G1 S1.1)
52400 Freshwater marsh
52410 Coastal and valley freshwater marsh (G3 S2.1)
Non-Meadow/Freshwater Wetlands Currently Conserved Lands
Freeways
Miles
0 1.5 3 6 9 12

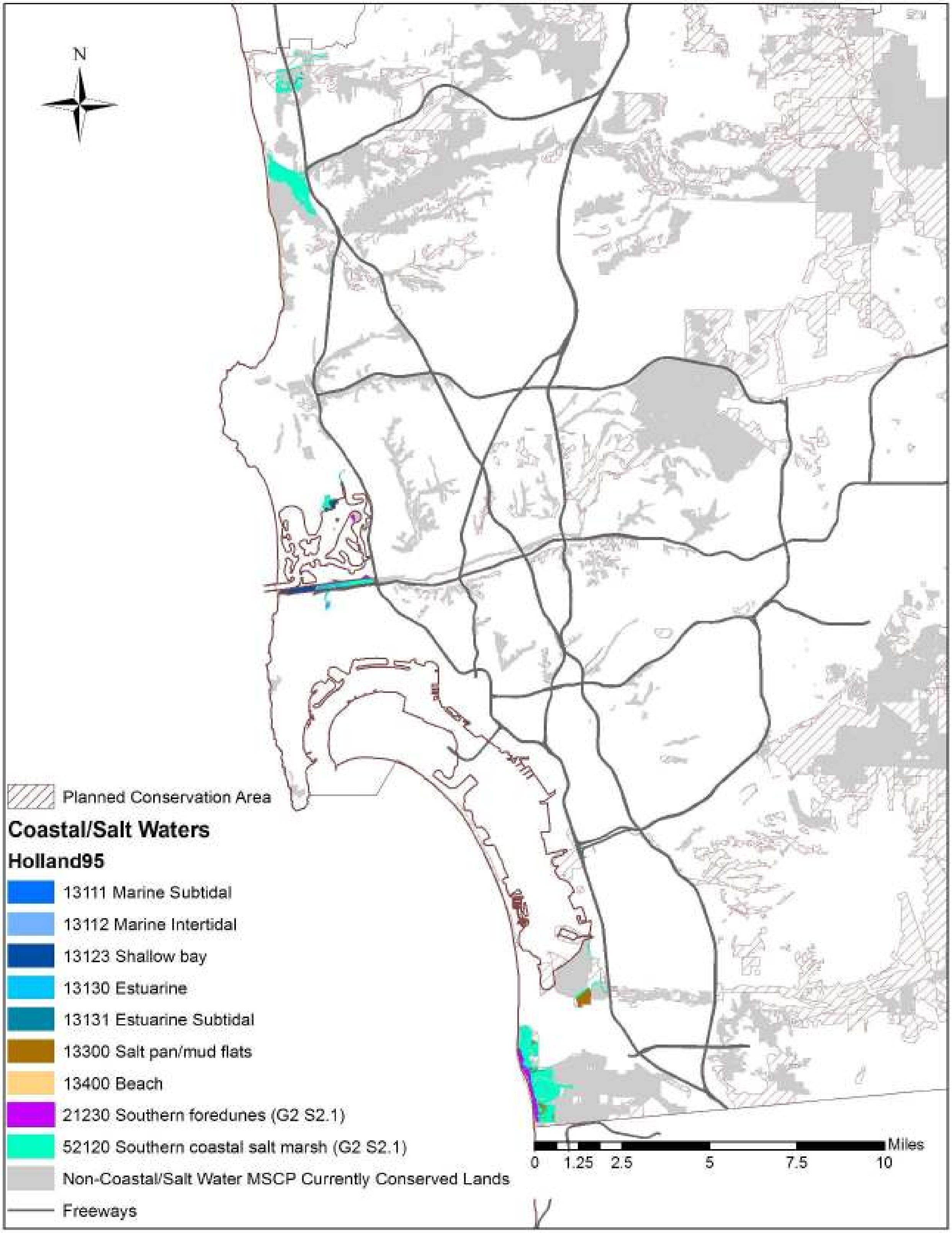

N
Planned Conservation Area
Oak Woodland
Holland95
71100 Oak woodland
71160 Coast live oak woodland
71162 Dense coast live oak woodland
71180 Engelmann oak woodland (G2 S2.1)
71181 Open Engelmann oak woodland (G2 S2.2)
71182 Dense Engelmann oak woodland (G2 S2.1)
Non-Oak Woodland MSCP Currently Conserved Lands
Freeways
Miles
0 1.25 2.5 5 7.5 10

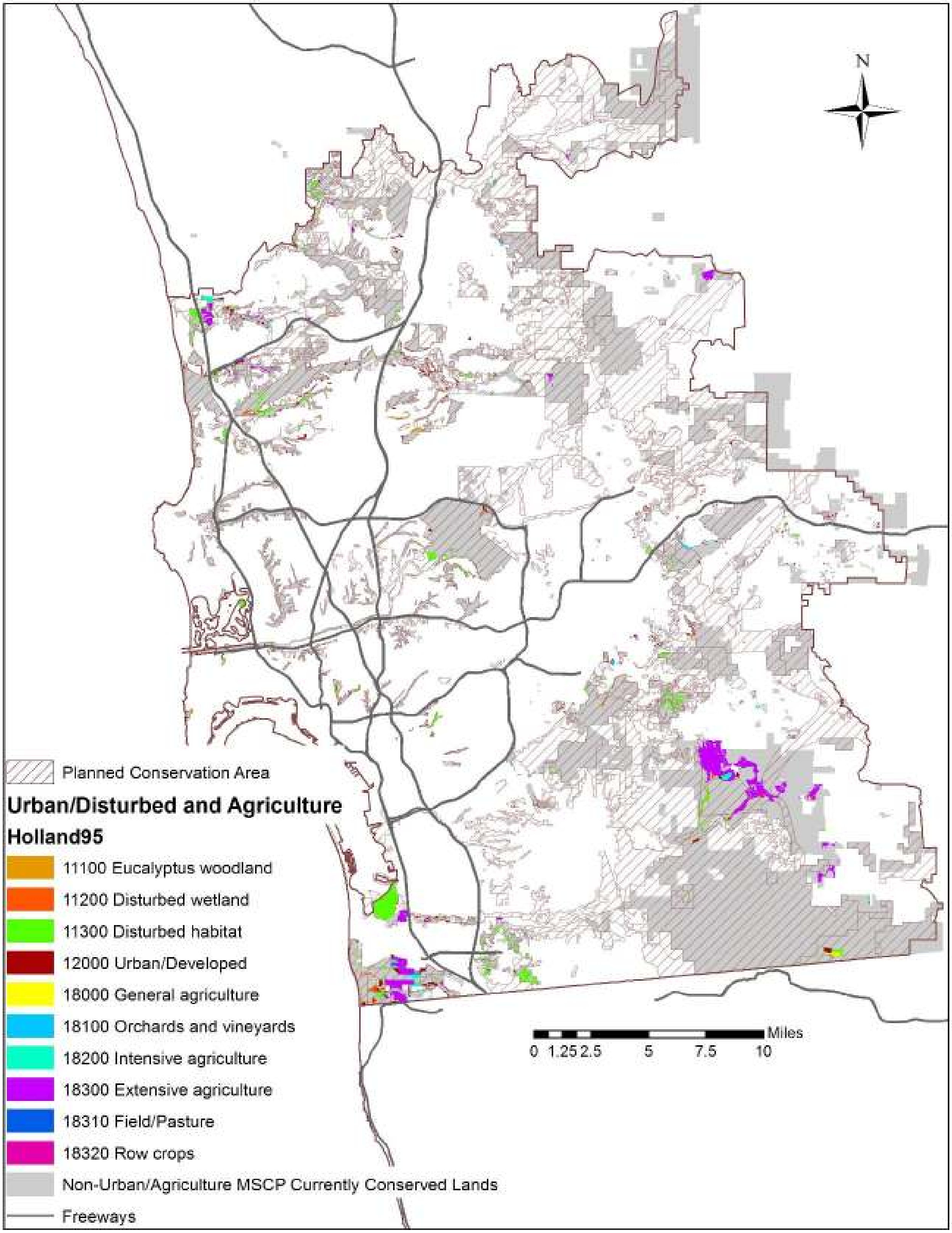

N
Planned Conservation Area
Riparian and Riparian Woodland
Holland95
60000 Riparian and Bottomland Habitat
61000 Riparian forest
61300 Southern riparian forest
61310 Southern coast live oak riparian forest
61320 Southern arroyo willow riparian forest (G2 S2.1)
61330 Southern cottonwood-willow riparian forest (G3 S3.2)
62400 Southern sycamore-alder riparian woodland
63300 Southern riparian scrub (G3 S3.2)
63310 Mule fat scrub
63320 Southern willow scrub (G3 S2.1)
63810 Tamarisk scrub
63820 Arrowweed scrub (G3 S3.3)
Non-Riparian/Riparian Woodland MSCP Currently Conserved Lands
Freeways
Miles
0 1 2 4 6 8


Planned Conservation Area
Torrey pine forest - Holland95
83140 Torrey pine forest (G1 S1.1)
Non-Torrey pine forest MSCP Currently Conserved Lands
Freeways
N
0 0.125 0.25 0.5 0.75 1
Miles


Miles
0 1.5 3 6 9 12
Planned Conservation Area
Tecate cypress
83230 Southern interior cypress forest (G2 S2.1)
Non-Tecate cypress MSCP Currently Conserved Lands
Freeways
0 0.5 1 2 3 4
Miles
N


N
Planned Conservation Area
Freshwater
Holland95
13140 Fresh water
13200 Non-vegetated channel, floodway, lakeshore fringe
Non-Freshwater MSCP Currently Conserved Lands
Freeways
0 1.5 3 6 9 12
Miles


N
Planned Conservation Area
Coastal/Salt Waters
Holland95
13111 Marine Subtidal
13112 Marine Intertidal
13123 Shallow bay
13130 Estuarine
13131 Estuarine Subtidal
13300 Salt pan/mud flats
13400 Beach
21230 Southern foredunes (G2 S2.1)
52120 Southern coastal salt marsh (G2 S2.1)
Non-Coastal/Salt Water MSCP Currently Conserved Lands
Freeways
0 1.25 2.5 5 7.5 10 Miles


N
Planned Conservation Area
Urban/Disturbed and Agriculture
Holland95
11100 Eucalyptus woodland
11200 Disturbed wetland
11300 Disturbed habitat
12000 Urban/Developed
18000 General agriculture
18100 Orchards and vineyards
18200 Intensive agriculture
18300 Extensive agriculture
18310 Field/Pasture
18320 Row crops
Non-Urban/Agriculture MSCP Currently Conserved Lands
Freeways
Miles
0 1.25 2.5 5 7.5 10

Appendix 2. Holland vegetation classes and equivalent California Native Plant Society (CNPS) series found in the MSCP region

(Adapted from: http://davisherb.ucdavis.edu/cnpsActiveServer/hollandlist.asp)

Holland Code	Holland Name	CNPS Series	NDDB Status
31200	Southern coastal bluff scrub	Black sage series	G1 S1.1
31200	Southern coastal bluff scrub	California buckwheat series	G1 S1.1
31200	Southern coastal bluff scrub	California encelia series	G1 S1.1
31200	Southern coastal bluff scrub	California sagebrush series	G1 S1.1
31200	Southern coastal bluff scrub	Coast prickly-pear series	G1 S1.1
31200	Southern coastal bluff scrub	Mixed sage series	G1 S1.1
31200	Southern coastal bluff scrub	Purple sage series	G1 S1.1
37C30	Southern maritime chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	G1 S1.1
37C30	Southern maritime chaparral	Chamise series	G1 S1.1
42110	Valley needlegrass grassland	Desert needlegrass series	G1 S1.1
42110	Valley needlegrass grassland	Nodding needlegrass series	G1 S1.1
42110	Valley needlegrass grassland	One-sided bluegrass series	G1 S1.1
42110	Valley needlegrass grassland	Purple needlegrass series	G1 S1.1
52310	Cismontane alkali marsh	Bulrush series	G1 S1.1
52310	Cismontane alkali marsh	Bulrush-cattail series	G1 S1.1
52310	Cismontane alkali marsh	Cattail series	G1 S1.1
52310	Cismontane alkali marsh	Ditch-grass series	G1 S1.1
83140	Torrey pine forest	Torrey pine stands	G1 S1.1
32400	Maritime succulent scrub	Coast prickly-pear series	G2 S1.1
21230	Southern foredunes		G2 S2.1
52120	Southern coastal salt marsh	Cordgrass series	G2 S2.1
52120	Southern coastal salt marsh	Pickleweed series	G2 S2.1
52120	Southern coastal salt marsh	Saltgrass series	G2 S2.1
61320	Southern arroyo willow riparian forest	Arroyo willow series	G2 S2.1
61320	Southern arroyo willow riparian forest	Mixed willow series	G2 S2.1
71180	Engelmann oak woodland		G2 S2.1
71182	Dense Engelmann oak woodland	Engelmann oak series	G2 S2.1
83230	Southern interior cypress forest		G2 S2.1
71181	Open Engelmann oak woodland	Engelmann oak series	G2 S2.2
45320	Alkali seep	Ditch-grass series	G3 S2.1
52410	Coast and valley freshwater marsh	Bulrush series	G3 S2.1
52410	Coast and valley freshwater marsh	Bulrush-cattail series	G3 S2.1
52410	Coast and valley freshwater marsh	Cattail series	G3 S2.1
52410	Coast and valley freshwater marsh	Duckweed series	G3 S2.1
52410	Coast and valley freshwater marsh	Mosquito fern series	G3 S2.1
52410	Coast and valley freshwater marsh	Pondweeds with floating leaves series	G3 S2.1
52410	Coast and valley freshwater marsh	Pondweeds with submerged leaves series	G3 S2.1
52410	Coast and valley freshwater marsh	Yellow pond-lily series	G3 S2.1
63320	Southern willow scrub	Arroyo willow series	G3 S2.1
63320	Southern willow scrub	Black willow series	G3 S2.1
63320	Southern willow scrub	Mixed willow series	G3 S2.1
63320	Southern willow scrub	Pacific willow series	G3 S2.1
63320	Southern willow scrub	Red willow series	G3 S2.1
32500	Diegan coastal sage scrub	California buckwheat series	G3 S3.1
32500	Diegan coastal sage scrub	California buckwheat-white sage series	G3 S3.1
32500	Diegan coastal sage scrub	California encelia series	G3 S3.1
32500	Diegan coastal sage scrub	California sagebrush-California buckwheat series	G3 S3.1
32500	Diegan coastal sage scrub	Coast prickly-pear series	G3 S3.1
32500	Diegan coastal sage scrub	Mixed sage series	G3 S3.1
32500	Diegan coastal sage scrub	Purple sage series	G3 S3.1
32500	Diegan coastal sage scrub	White sage series	G3 S3.1
42100	Native grassland		G3 S3.1

Holland Code	Holland Name	CNPS Series	NDDB Status
37122	Mafic southern mixed chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	G3 S3.2
37122	Mafic southern mixed chaparral	Chamise-Eastwood manzanita series	G3 S3.2
37122	Mafic southern mixed chaparral	Mixed scrub oak series	G3 S3.2
37122	Mafic southern mixed chaparral	Scrub oak - birchleaf mountain-mahogany series	G3 S3.2
37122	Mafic southern mixed chaparral	Sumac series	G3 S3.2
37G00	Coastal sage-chaparral scrub	Chamise-black sage series	G3 S3.2
37G00	Coastal sage-chaparral scrub	Chamise-white sage series	G3 S3.2
61330	Southern cottonwood-willow riparian forest	Arroyo willow series	G3 S3.2
61330	Southern cottonwood-willow riparian forest	Black willow series	G3 S3.2
61330	Southern cottonwood-willow riparian forest	Fremont cottonwood series	G3 S3.2
61330	Southern cottonwood-willow riparian forest	Mixed willow series	G3 S3.2
61330	Southern cottonwood-willow riparian forest	Pacific willow series	G3 S3.2
63300	Southern riparian scrub		G3 S3.2
37121	Granitic southern mixed chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	G3 S3.3
37121	Granitic southern mixed chaparral	Mixed scrub oak series	G3 S3.3
37121	Granitic southern mixed chaparral	Scrub oak - birchleaf mountain-mahogany series	G3 S3.3
37121	Granitic southern mixed chaparral	Sumac series	G3 S3.3
37900	Scrub oak chaparral	Mixed scrub oak series	G3 S3.3
37900	Scrub oak chaparral	Scrub oak - birchleaf mountain-mahogany series	G3 S3.3
63820	Arrowweed scrub	Arrow weed series	G3 S3.3
37200	Chamise chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	G4 S4
37200	Chamise chaparral	Chamise series	G4 S4
37200	Chamise chaparral	Chamise-bigberry manzanita series	G4 S4
37200	Chamise chaparral	Chamise-black sage series	G4 S4
37200	Chamise chaparral	Chamise-cupleaf ceanothus series	G4 S4
37200	Chamise chaparral	Chamise-Eastwood manzanita series	G4 S4
37200	Chamise chaparral	Chamise-wedgeleaf ceanothus series	G4 S4
37200	Chamise chaparral	Chamise-white sage series	G4 S4
42200	Non-native grassland	California annual grassland series	G4 S4
45400	Freshwater seep	Beaked sedge series 45400 .	G4 S4
45400	Freshwater seep	Nebraska sedge series	G4 S4
45400	Freshwater seep	Rocky Mountain sedge series	G4 S4
45400	Freshwater seep	Sedge series	G4 S4
45400	Freshwater seep	Spikerush series	G4 S4
52400	Freshwater marsh	Quillwort series	G4 S4
61310	Southern coast live oak forest	Coast live oak series	G4 S4
62400	Southern sycamore-alder riparian woodland	California sycamore series	G4 S4
62400	Southern sycamore-alder riparian woodland	White alder series	G4 S4
63310	Mulefat scrub	Mulefat series	G4 S4
71160	Coast live oak woodland	Coast live oak series	G4 S4
63810	Tamarisk scrub	Tamarisk series	G5 S4
Unranked Classes & Classes Not Included in Prioritization (e.g., disturbed/agriculture)			
11100	Eucalyptus woodland		
11200	Disturbed wetland		
11300	Disturbed habitat		
12000	Urban/Developed		
13111	Marine Subtidal		
13112	Intertidal		
13121	Deep bay		
13122	Intermediate bay		
13123	Shallow bay		
13130	Estuarine		
13131	Estuarine Subtidal		

Holland Code	Holland Name	CNPS Series	NDDB Status
13140	Fresh water		
13200	Non-vegetated channel, floodway, lakeshore fringe		
13300	Salt pan/mud flats		
13400	Beach		
18000	General agriculture		
18100	Orchards and vineyards		
18200	Intensive agriculture		
18300	Extensive agriculture		
18310	Field/Pasture		
18320	Row crops		
37000	Chaparral	Bigberry manzanita series	
37000	Chaparral	Bigpod ceanothus - birchleaf mountain-mahogany series	
37000	Chaparral	Bigpod ceanothus series	
37000	Chaparral	Bigpod ceanothus-hollyleaf redberry series	
37000	Chaparral	Birchleaf mountain-mahogany - California buckwheat	
37000	Chaparral	Birchleaf mountain-mahogany - California buckwheat	
37000	Chaparral	Birchleaf mountain-mahogany series	
37000	Chaparral	Blue blossom series	
37000	Chaparral	Blue blossom series	
37000	Chaparral	Brewer oak series	
37000	Chaparral	Brewer oak series	
37000	Chaparral	Bush chinquapin series	
37000	Chaparral	Bush chinquapin series	
37000	Chaparral	California buckwheat-white sage series	
37000	Chaparral	California buckwheat-white sage series	
37000	Chaparral	Canyon live oak shrub series	
37000	Chaparral	Canyon live oak shrub series	
37000	Chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	
37000	Chaparral	Chamise - mission-manzanita - woollyleaf ceanothus	
37000	Chaparral	Chamise series	
37000	Chaparral	Chamise series	
37000	Chaparral	Chamise-bigberry manzanita series	
37000	Chaparral	Chamise-bigberry manzanita series	
37000	Chaparral	Chamise-black sage series	
37000	Chaparral	Chamise-black sage series	
37000	Chaparral	Chamise-cupleaf ceanothus series	
37000	Chaparral	Chamise-cupleaf ceanothus series	
37000	Chaparral	Chamise-Eastwood manzanita series	
37000	Chaparral	Chamise-Eastwood manzanita series	
37000	Chaparral	Chamise-wedgeleaf ceanothus series	
37000	Chaparral	Chamise-wedgeleaf ceanothus series	
37000	Chaparral	Chamise-white sage series	
37000	Chaparral	Chamise-white sage series	
37000	Chaparral	Chaparral whitethorn series	
37000	Chaparral	Chaparral whitethorn series	
37000	Chaparral	Coyote brush series	
37000	Chaparral	Coyote brush series	
37000	Chaparral	Cupleaf ceanothus-fremontia-oak series	
37000	Chaparral	Cupleaf ceanothus-fremontia-oak series	
37000	Chaparral	Deerbrush series	
37000	Chaparral	Deerbrush series	
37000	Chaparral	Eastwood manzanita series	
37000	Chaparral	Eastwood manzanita series	
37000	Chaparral	Greenleaf manzanita series	
37000	Chaparral	Greenleaf manzanita series	

Holland Code	Holland Name	CNPS Series	NDDB Status
37000	Chaparral	Hoaryleaf ceanothus series	
37000	Chaparral	Hoaryleaf ceanothus series	
37000	Chaparral	Huckleberry oak series	
37000	Chaparral	Huckleberry oak series	
37000	Chaparral	Interior live oak shrub series	
37000	Chaparral	Interior live oak shrub series	
37000	Chaparral	Interior live oak-canyon live oak shrub series	
37000	Chaparral	Interior live oak-canyon live oak shrub series	
37000	Chaparral	Interior live oak-chaparral whitethorn shrub series	
37000	Chaparral	Interior live oak-chaparral whitethorn shrub series	
37000	Chaparral	Interior live oak-scrub oak shrub series	
37000	Chaparral	Interior live oak-scrub oak shrub series	
37000	Chaparral	Ione manzanita series	
37000	Chaparral	Ione manzanita series	
37000	Chaparral	Leather oak series	
37000	Chaparral	Leather oak series	
37000	Chaparral	Mixed scrub oak series	
37000	Chaparral	Mixed scrub oak series	
37000	Chaparral	Mountain whitethorn series	
37000	Chaparral	Mountain whitethorn series	
37000	Chaparral	Red shank - birchleaf mountain-mahogany series	
37000	Chaparral	Red shank - birchleaf mountain-mahogany series	
37000	Chaparral	Red shank series	
37000	Chaparral	Red shank series	
37000	Chaparral	Red shank-chamise series	
37000	Chaparral	Red shank-chamise series	
37000	Chaparral	Sadler oak series	
37000	Chaparral	Sadler oak series	
37000	Chaparral	Salal-black huckleberry series	
37000	Chaparral	Salal-black huckleberry series	
37000	Chaparral	Scalebroom series	
37000	Chaparral	Scalebroom series	
37000	Chaparral	Scrub oak - birchleaf mountain-mahogany series	
37000	Chaparral	Scrub oak - birchleaf mountain-mahogany series	
37000	Chaparral	Sumac series	
37000	Chaparral	Sumac series	
37000	Chaparral	Tobacco brush series	
37000	Chaparral	Tobacco brush series	
37000	Chaparral	White sage series	
37000	Chaparral	White sage series	
37000	Chaparral	Whiteleaf manzanita series	
37000	Chaparral	Whiteleaf manzanita series	
37000	Chaparral	Woollyleaf manzanita series	
37000	Chaparral	Woollyleaf manzanita series	
42000	Valley and foothill grasslands	Alkali sacaton series	
42000	Valley and foothill grasslands	California annual grassland series	
42000	Valley and foothill grasslands	Creeping ryegrass series	
42000	Valley and foothill grasslands	Desert needlegrass series	
42000	Valley and foothill grasslands	Foothill needlegrass series	
42000	Valley and foothill grasslands	Kentucky bluegrass series	
42000	Valley and foothill grasslands	Nodding needlegrass series	
42000	Valley and foothill grasslands	One-sided bluegrass series	
42000	Valley and foothill grasslands	Purple needlegrass series	

CNPS SERIES & RANKINGS NOT CURRENTLY AVAILABLE			
Holland Code	**Holland Name**	**CNPS Series**	**NDDB Status**
37120	Southern mixed chaparral		
37130	Northern mixed chaparral		
37131	Granitic northern mixed chaparral		
37210	Granitic chamise chaparral		
37220	Mafic chamise chaparral		
37K00	Flat-topped buckwheat		
45300	Alkali meadows and seeps		
52300	Alkali marsh		
61300	Southern riparian forest		
71100	Oak woodland		
71162	Dense coast live oak woodland		

Appendix 3: Landscape pattern metrics for MSCP currently conserved lands ("MSCP Preserve"), planned conservation area ("MHPA"), and MSCP Region

Metrics calculated using FragStats, with metric definitions from McGarigal and Marks (1995) below.
(Available at: http://www.umass.edu/landeco/research/fragstats/documents/Metrics/Metrics%20TOC.htm)

	Total Class Area (ha)		
Class	MSCP Preserve	MHPA	MSCP Region
Agriculture	16,619.18	18,392.29	127,217.21
Chaparral	227,882.32	278,416.53	510,411.23
Coastal	8,466.15	12,355.56	48,891.96
CSS	191,828.71	353,241.11	510,146.57
Tecate cypress	23,822.14	24,650.05	24,964.15
Freshwater	2,682.45	22,371.86	24,946.70
Grassland	29,551.56	46,563.36	122,185.80
Oak woodland	7,343.54	14,041.43	25,004.87
Riparian	22,147.91	37,842.24	54,926.75
Torrey pine	636.92	636.92	712.54
Urban	21,105.76	48,649.60	1,052,875.18
Wetlands	1,087.72	2,606.83	4,208.36
Total	553,174.37	859,767.78	2,506,491.32

Total (Class) Area	
$CA = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10,000} \right)$	a_{ij} = area (m^2) of patch ij.
Description	CA equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.
Units	Hectares
Range	CA > 0, without limit. CA approaches 0 as the patch type becomes increasing rare in the landscape. CA = TA when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Comments	*Class area* is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type. In addition to its direct interpretive value, class area is used in the computations for many of the class and landscape metrics.

Class	Number of Patches MSCP Preserve	MHPA	MSCP Region
Agriculture	192	496	422
Chaparral	1,023	1,100	1,472
Coastal	97	144	176
CSS	1,306	1,556	2,331
Tecate cypress	91	95	96
Freshwater	107	237	382
Grassland	561	924	1,288
Oak woodland	300	509	711
Riparian	581	920	1,268
Torrey pine	17	17	26
Urban	2,256	4,710	2,061
Wetlands	153	255	432
Total	6,684	10,963	10,665

Number of Patches

$$NP = n_i$$

n_i = number of patches in the landscape of patch type (class) i.

Description	NP equals the number of patches of the corresponding patch type (class).
Units	None
Range	$NP \geq 1$, without limit. NP = 1 when the landscape contains only 1 patch of the corresponding patch type; that is, when the class consists of a single patch.
Comments	*Number of patches* of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type. Although the number of patches in a class may be fundamentally important to a number of ecological processes, often it has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

Class	Largest Patch Index (%) MSCP Preserve	MHPA	MSCP Region
Agriculture	0.85	0.22	1.01
Chaparral	5.41	3.52	3.33
Coastal	0.69	0.47	0.55
CSS	2.70	5.73	2.53
Tecate cypress	2.11	1.55	0.53
Freshwater	0.13	0.51	0.18
Grassland	0.36	0.34	0.87
Oak woodland	0.08	0.28	0.09
Riparian	0.43	0.28	0.10
Torrey pine	0.07	0.05	0.02
Urban	0.51	0.52	37.67
Wetlands	0.02	0.06	0.02
Total	5.41	5.73	37.67

Largest Patch Index

$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$$

a_{ij} = area (m^2) of patch ij.

A = total landscape area (m^2).

Description	LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	$0 < LPI \leq 100$ LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.
Comments	*Largest patch index* at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

	Patch Area Mean ± SD (ha)		
Class	MSCP Preserve	MHPA	MSCP Region
Agriculture	86.55 ± 449.44	37.08 ± 135.99	301.46 ± 1,510.08
Chaparral	222.75 ± 1,320.08	253.10 ± 1,577.28	346.75 ± 3,112.58
Coastal	87.28 ± 436.69	85.80 ± 390.94	277.80 ± 1,661.25
CSS	146.88 ± 751.72	227.02 ± 1,612.67	218.85 ± 1,945.91
Tecate cypress	261.78 ± 1,305.50	259.47 ± 1,432.36	260.04 ± 1,424.82
Freshwater	25.07 ± 95.14	94.40 ± 454.79	65.31 ± 361.32
Grassland	52.68 ± 170.35	50.39 ± 166.68	94.86 ± 669.50
Oak woodland	24.48 ± 45.28	27.59 ± 114.71	35.17 ± 110.02
Riparian	38.12 ± 154.94	41.13 ± 143.48	43.32 ± 149.69
Torrey pine	37.47 ± 90.04	37.47 ± 90.04	27.41 ± 74.85
Urban	9.36 ± 67.32	10.33 ± 85.38	510.86 ± 20,791.68
Wetlands	7.11 ± 13.25	10.22 ± 36.39	9.74 ± 32.35
Total	82.76 ± 649.51	78.42 ± 812.81	235.02 ± 9,270.96

Patch Area	
$AREA = a_{ij}\left(\frac{1}{10,000}\right)$	a_{ij} = area (m^2) of patch ij.
Description	AREA equals the area (m^2) of the patch, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	AREA > 0, without limit. The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Comments	The *area* of each patch comprising a landscape mosaic is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but patch area has a great deal of ecological utility in its own right. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

Class	Edge Density (m/ha) MSCP Preserve	MHPA	MSCP Region
Agriculture	1.45	1.60	1.56
Chaparral	14.03	12.10	7.14
Coastal	0.70	0.72	0.61
CSS	15.05	16.71	8.53
Tecate cypress	2.30	1.54	0.54
Freshwater	0.42	1.19	0.53
Grassland	3.93	4.16	2.82
Oak woodland	1.63	1.77	1.05
Riparian	4.21	4.61	2.49
Torrey pine	0.09	0.06	0.03
Urban	5.21	7.05	7.96
Wetlands	0.44	0.54	0.30
Total	32.29	32.62	17.08

Note: Edge Density metric includes borders as edge

Edge Density

$$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A}(10,000)$$

e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i.

A = total landscape area (m^2).

Description	ED equals the sum of the lengths (m) of all edge segments involving the corresponding patch type, divided by the total landscape area (m^2), multiplied by 10,000 (to convert to hectares). If a landscape border is present, ED includes landscape boundary segments involving the corresponding patch type and representing ‘true’ edge only (i.e., abutting patches of different classes). If a landscape border is absent, ED includes a user-specified proportion of landscape boundary segments involving the corresponding patch type. Regardless of whether a landscape border is present or not, ED includes a user-specified proportion of internal background edge segments involving the corresponding patch type. Note, total landscape area (A) includes any internal background present.
Units	Meters per hectare
Range	ED $\geq$ 0, without limit. ED = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of the corresponding patch type and the user specifies that none of the landscape boundary and background edge be treated as edge.
Comments	*Edge density* at the class level has the same utility and limitations as Total Edge (see Total Edge description), except that edge density reports edge length on a per unit area basis that facilitates comparison among landscapes of varying size.

	Perimeter-Area Ratio Mean ± SD		
Class	MSCP Preserve	MHPA	MSCP Region
Agriculture	246.79 ± 125.91	268.01 ± 123.36	125.17 ± 97.88
Chaparral	185.23 ± 116.80	176.24 ± 112.15	165.15 ± 102.31
Coastal	280.98 ± 114.92	279.54 ± 118.65	286.40 ± 123.82
CSS	193.02 ± 117.58	184.70 ± 114.26	175.54 ± 104.27
Tecate cypress	169.37 ± 96.25	179.35 ± 100.17	178.10 ± 100.20
Freshwater	282.45 ± 112.84	251.69 ± 126.98	247.54 ± 121.18
Grassland	216.52 ± 117.25	211.63 ± 116.34	181.32 ± 108.34
Oak woodland	213.97 ± 97.16	229.50 ± 105.45	212.60 ± 101.27
Riparian	256.64 ± 105.67	255.06 ± 108.59	250.42 ± 104.37
Torrey pine	205.90 ± 97.59	205.90 ± 97.59	225.30 ± 91.49
Urban	321.46 ± 96.24	333.20 ± 94.92	249.51 ± 125.00
Wetlands	317.72 ± 85.94	314.36 ± 89.41	311.23 ± 91.88
Total	250.44 ± 122.55	267.37 ± 123.61	208.53 ± 117.62

Perimeter-Area Ratio	
$$\mathrm{PARA} = \frac{p_{ij}}{a_{ij}}$$	p_{ij} = perimeter (m) of patch ij. a_{ij} = area (m^2) of patch ij.
Description	PARA equals the ratio of the patch perimeter (m) to area (m^2).
Units	None
Range	PARA > 0, without limit.
Comments	*Perimeter-area ratio* is a simple measure of shape complexity, but without standardization to a simple Euclidean shape (e.g., square). A problem with this metric as a shape index is that it varies with the size of the patch. For example, holding shape constant, an increase in patch size will cause a decrease in the perimeter-area ratio.

Class	Euclidean Nearest Neighbor Distance Mean ± SD (m)		
	MSCP Preserve	MHPA	MSCP Region
Agriculture	1,720.73 ± 5,721.85	1,045.63 ± 3,256.27	1,275.81 ± 2,044.48
Chaparral	591.75 ± 964.71	497.10 ± 747.31	439.04 ± 578.16
Coastal	563.96 ± 1,405.14	956.27 ± 4,606.77	508.55 ± 865.06
CSS	519.56 ± 806.77	400.49 ± 609.40	393.00 ± 412.92
Tecate cypress	462.62 ± 638.52	494.42 ± 651.90	482.69 ± 649.69
Freshwater	3,433.30 ± 8,037.08	1,575.22 ± 2,681.64	1,645.95 ± 2,807.20
Grassland	1,152.90 ± 5,159.86	820.67 ± 1,416.60	747.98 ± 1,010.11
Oak woodland	1,397.42 ± 3,783.25	1,135.96 ± 2,447.38	958.21 ± 1,986.10
Riparian	912.05 ± 1,505.18	701.24 ± 1,239.51	673.06 ± 1,039.25
Torrey pine	340.25 ± 175.46	340.25 ± 175.46	342.74 ± 184.16
Urban	574.26 ± 937.87	399.72 ± 484.08	398.81 ± 517.71
Wetlands	1,725.98 ± 3,090.33	1,324.60 ± 3,090.33	1,076.18 ± 2,212.82

Euclidean Nearest-Neighbor Distance

$$ENN = h_{ij}$$

h_{ij} = distance (m) from patch ij to nearest neighboring patch of the same type (class), based on patch edge-to-edge distance, computed from cell center to cell center.

Description	ENN equals the distance (m) to the nearest neighboring patch of the same type, based on shortest edge-to-edge distance. Note that the edge-to-edge distances are from cell center to cell center.
Units	Meters
Range	ENN > 0, without limit. ENN approaches 0 as the distance to the nearest neighbor decreases. The minium ENN is constrained by the cell size, and is equal to twice the cell size when the 8-neighbor patch rule is used or the distance between diagonal neighbors when the 4-neighbor rule is used. The upper limit is constrained by the extent of the landscape. ENN is undefined and reported as "N/A" in the "basename".patch file if the patch has no neighbors (i.e., no other patches of the same class).
Comments	*Euclidean nearest-neighbor distance* is perhaps the simplest measure of patch context and has been used extensively to quantify patch isolation. Here, nearest neighbor distance is defined using simple Euclidean geometry as the shortest straight-line distance between the focal patch and its nearest neighbor of the same class.

Class	Clumpiness Index: MSCP Preserve	Clumpiness Index: MHPA	Clumpiness Index: MSCP Region
Agriculture	0.88	0.82	0.92
Chaparral	0.86	0.87	0.89
Coastal	0.90	0.88	0.93
CSS	0.84	0.83	0.87
Tecate cypress	0.87	0.87	0.87
Freshwater	0.80	0.89	0.87
Grassland	0.81	0.80	0.85
Oak woodland	0.70	0.74	0.74
Riparian	0.74	0.73	0.72
Torrey pine	0.84	0.84	0.81
Urban	0.66	0.68	0.92
Wetlands	0.47	0.57	0.57

Clumpiness Index

$$\text{Given } G_i = \left(\frac{g_{ii}}{\left(\sum_{k=1}^{m} g_{ik}\right) - \min e_i} \right)$$

$$CLUMPY = \begin{bmatrix} \frac{G_i - P_i}{P_i} \text{ for } G_i < P_i \,\&\, P_i < .5, \text{ else} \\ \frac{G_i - P_i}{1 - P_i} \end{bmatrix}$$

g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the *double-count* method.

g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method.

min-e_i = minimum perimeter (in number of cell surfaces) of patch type (class) i for a maximally clumped class.

P_i = proportion of the landscape occupied by patch type (class) i.

Description

CLUMPY equals the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution. If the proportion of like adjacencies (G_i) is less than the proportion of the landscape comprised of the focal class (P_i) and $P_i < 0.5$, then CLUMPY equals G_i minus P_i, divided by P_i; else, CLUMPY equals G_i minus P_i, divided by 1 minus P_i. Note, it can be shown that G_i equals 1 when the patch type is maximally clumped, but this requires adjustment for the perimeter of the class. If a_i is the area of class i (in terms of number of cells) and n is the side of a largest integer square smaller than a_i, and $m = a_i - n^2$, then the minimum perimeter of class i (i.e.,

	when it is maximally clumped), min-e_i, will take one of the three forms (Milne 1991, Bogaert et al. 2000): min-e_i = 4n, when m = 0, or min-e_i = 4n + 2, when $n^2 < a_i \leq n(1+n)$, or min-e_i = 4n + 4, when $a_i > n(1+n)$. Note, g_{ii} in the numerator includes only internal like adjacencies; like adjacencies involving cells in the border are not included. The sum of g_{ik} in the denominator includes all adjacencies involving the focal class, including adjacencies involving background and all adjacencies involving the landscape boundary, regardless of whether a border is present or not. Cell adjacencies are tallied using the *double-count* method in which pixel order is preserved. Note, P_i is based on the total landscape area (A) including any internal background present.
Units	None
Range	$-1 \leq \text{CLUMPY} \leq 1$ Given any P_i , CLUMPY equals -1 when the focal patch type is maximally disaggregated; CLUMPY equals 0 when the focal patch type is distributed randomly, and approaches 1 when the patch type is maximally aggregated. Note, CLUMPY is undefined and reported as N/A in the output files when the class consists either of a single cell, comprises all but 1 cell, or comprises the entire landscape, because it is impossible to distinguish between clumped, random and dispersed distributions in these cases.
Comments	*Clumpiness index* is calculated from the adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. Clumpiness is scaled to account for the fact that the proportion of like adjacencies (G_i) will equal P_i for a completely random distribution (see previous discussion). The formula is contingent upon G_i and P_i because the minimum value of G_i has two forms which depend on P_i. Specifically, when $P_i \leq 0.5$, $G_i = 0$ when the class is maximally disaggregated (i.e., subdivided into one cell patches) and is 1 when the class is maximally clumped. However, when $P_i \geq 0.5$, $G_i = 2P_i - 1$ when the class is maximally disaggregated and approaches 1 when the class is maximally clumped.

Appendix 4: California Department of Fish and Game and The Nature Conservancy Heritage Program's Community Endangerment Ranking Guidelines

(Available at: http://davisherb.ucdavis.edu/cnpsActiveServer/intro.html#tnchp)

Global ranks

G1: Fewer than 6 viable occurrences worldwide and/or 2000 acres

G2: 6-20 viable occurrences worldwide and/or 2000-10,000 acres

G3: 21-100 viable occurrences worldwide and/or 10,000-50,000 acres

G4: Greater than 100 viable occurrences worldwide and/or greater than 50,000 acres

G5: Community demonstrably secure due to worldwide abundance

State ranks

S1: Fewer than 6 viable occurrences statewide and/or less than 2000 acres

S2: 6-20 viable occurrences statewide and/or 2000-10,000 acres

S3: 21-100 viable occurrences statewide and/or 10,000-50,000 acres

S4: Greater than 100 viable occurrences statewide and/or greater than 50,000 acres

S5: Community demonstrably secure statewide

Threat ranks

0.1: Very threatened

0.2: Threatened

0.3: No current threats known