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Assessing and Prioritizing Ecological Communities for Monitoring in a Regional Habitat Conservation Plan

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Abstract In nature reserves and habitat conservation areas, monitoring is required to determine if reserves are meeting their goals for preserving species, ecological communities, and ecosystems. Increasingly, reserves are established to protect multiple species and communities, each with their own conservation goals and objectives. As resources are always inadequate to monitor all components, criteria must be applied to prioritize both species and communities for monitoring and management. While methods for prioritizing species based on endangerment or risk have been established, approaches to prioritizing ecological communities for monitoring are not well developed, despite a long-standing emphasis on communities as target elements in reserve design. We established guidelines based on four criteria derived from basic principles of conservation and landscape ecology—extent, representativeness, fragmentation, and endangerment—to prioritize communities in the San Diego Multiple Species Conservation Plan (MSCP). The MSCP was one of the first multiple-species habitat conservation areas established in California, USA, and it has a complex spatial configuration because of the patterns of surrounding land use, which are largely urbanized. In this case study, high priority communities for monitoring include coastal sage scrub (high endangerment, underrepresented within the reserve relative to the region, and moderately fragmented), freshwater wetlands, and coastal habitats (both have high fragmentation, moderate endangerment and representativeness, and low areal extent). This framework may be useful to other conservation planners and land managers for prioritizing the most significant and at-risk communities for monitoring.

Keywords Biodiversity · Endangerment · Fragmentation · Multispecies · Representativeness · Reserve · Protected area

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It is fundamental to conservation biology that preserving species and ecological processes requires protecting the space that they occupy. Identification of geographical gaps in biodiversity protection (Davis and others 1995; Scott and others 1993) and design of nature reserves or protected areas (Margules and Pressey 2000; Possingham and others 2006) have frequently targeted both species and ecosystems for conservation (Noss 1990), commonly referred to as fine and coarse filters (Noss 1987). When species are the focus of reserve design or management actions, those at high risk of extinction or extirpation are often given greatest priority. Species and speciation are typically the ultimate targets of biodiversity protection (Wilson 1992). However, ecosystems—ecological communities and their physical habitat—by definition comprise all species in a community, not just rare ones, and provide habitat for constituent species. Thus, they are used as elements in gap analysis and reserve design.

A specific kind of protected area, the Habitat Conservation Plan (HCP), is increasingly being implemented in the United States (Rahn and others 2006). Approved at the federal level under the U.S. Endangered Species Act (ESA), multiple-species HCPs are being promoted over single-species HCPs because they encourage integrated ecosystem management and can potentially protect entire suites of species before they warrant listing under the ESA. These are features presumed to improve the conservation value of these plans (Franklin 1993; U.S. Fish and Wildlife Service 1996). The number of HCPs that cover multiple species has increased steadily over time. As of January 2007, 484 HCPs were permitted across the United States, 40 of which cover 10 or more species (U.S. Fish and Wildlife Service 2007). Because of their growing prevalence there is substantial interest in how to monitor the success of multispecies HCPs.

While traditional HCPs were designed to manage and preserve habitat for a single-species, multispecies HCPs are intended to conserve both target species and broad-level ecosystem components and processes. Conservation of ecological communities is in fact mandated in California's Natural Community Conservation Planning Act (California Department of Fish and Game 2003), which oversees a statewide program of multispecies HCPs. Communities are thus a second element of biodiversity, along with covered species, with specific conservation targets. Ecological communities provide habitat for targeted species but are also valuable monitoring elements because they can be used as a gauge of ecosystem function and diversity (Jewell 2000).

Much of the literature on landscape-scale conservation has focused on methods of optimal reserve design (Margules and others 1988; Pressey and others 1999; Wilson and others 2006). However, successful conservation requires more than establishing an optimally designed reserve. Long-term management and monitoring are crucial to determining if species and communities are actually being protected in the reserve, particularly given the high level of landscape fragmentation found in many regions (Barrows and others 2005; Scott and others 2005). In addition to biologically sound reserve design and land acquisition, a conservation program needs a baseline inventory, clearly defined goals and objectives, conceptual models to assist in collating knowledge and understanding ecosystems, and a management and monitoring plan for covered species and communities (Atkinson and others 2004; Mulder and others 1999). Community monitoring in this context typically assesses ecological condition, including diversity and function. Monitoring as part of an adaptive management framework should identify when management interventions may be needed and monitor the success of those interventions at achieving previously defined conservation goals.

Unfortunately, resources are often inadequate to monitor all covered species and all ecological communities to the same degree, so it is necessary to prioritize elements that should be the primary focus of monitoring efforts. Formal prioritization techniques have been developed for at-risk species (Andelman and others 2004; Purvis and others 2000), and some studies have classified at-risk communities for conservation planning purposes (Noss 1996; Rodriguez and others 2007). However, we found few published methods specifically aimed at prioritizing communities for monitoring (Nicholson and Wilcove 2007). In addition, reserves may be assembled over a period of decades, and the final footprint of the reserve may be somewhat different from that envisioned in the original plan. Given the incremental nature of land acquisition, it may also be important to assess the extent and configuration of communities incorporated into the reserve to determine if the plan's original targets have been met.

The San Diego Multiple Species Conservation Plan (MSCP) established an almost 52,000-ha reserve within an approximately 2300-km^2 region in southwestern San Diego County (Fig. 1). The region has high biological diversity and a varied landscape spanning mountains to coastal strand. Southern California has been designated a biodiversity "hotspot" (Brooks and others 2002; Medail and Quezel 1999; Myers and others 2000; Rubinoff 2001) and the large number of endemic and rare species that occur there are at considerable risk of habitat loss owing to high levels of human population growth and pressure for land development (e.g., Shearer and others 2006). Approved in 1997, the MSCP was one of the first multispecies HCPs designated in California under the state's Natural Community Conservation Planning (NCCP) program, and it was viewed as "a major milestone in America's conservation history and a model plan for communities nationwide" (U.S. Department of Interior Secretary, Bruce Babbitt; quoted in Hanna 1997). In addition to covering 85 endangered, threatened, and rare plant and animal species, the San Diego MSCP aims to protect a variety of ecological communities, including coastal sage scrub, its flagship plant community.

In this paper we develop a comprehensive approach to assessing and prioritizing ecological communities within a biodiversity reserve at the landscape scale which we apply to the San Diego MSCP. Our specific objectives in this paper are (1) to assess the extent and configuration of the San Diego MSCP reserve's land acquisition in light of the original targets set in its reserve design process and (2) to apply a framework to prioritize ecological communities for monitoring that relies on landscape pattern analysis and published community endangerment rankings. This framework, used to prioritize the most at-risk communities for monitoring, may be useful to other conservation planners and land managers. This study focuses specifically on ecological communities themselves as conservation elements. In a separate study we address habitat requirements of covered species vis-à-vis these community types (Regan and others 2008).

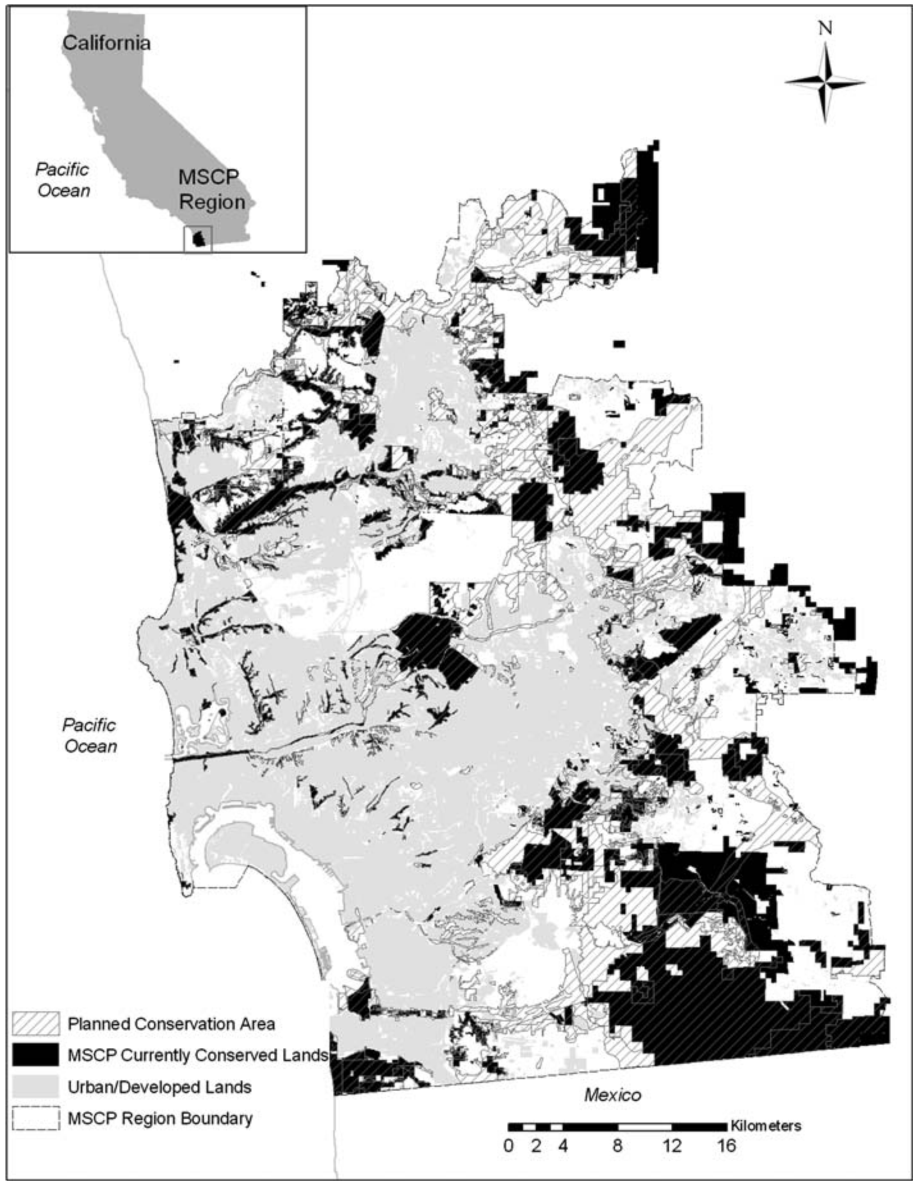


Fig. 1 The study area. (**A**) Currently conserved lands and planned conservation area within the Multiple Species Conservation Plan (MSCP) region of San Diego County. (**B**) Grouped ecological communities (as aggregated in the Appendix). (**C**) Endangered community types in the MSCP's currently conserved lands, based on NatureServe rankings. See Table 3 for definitions

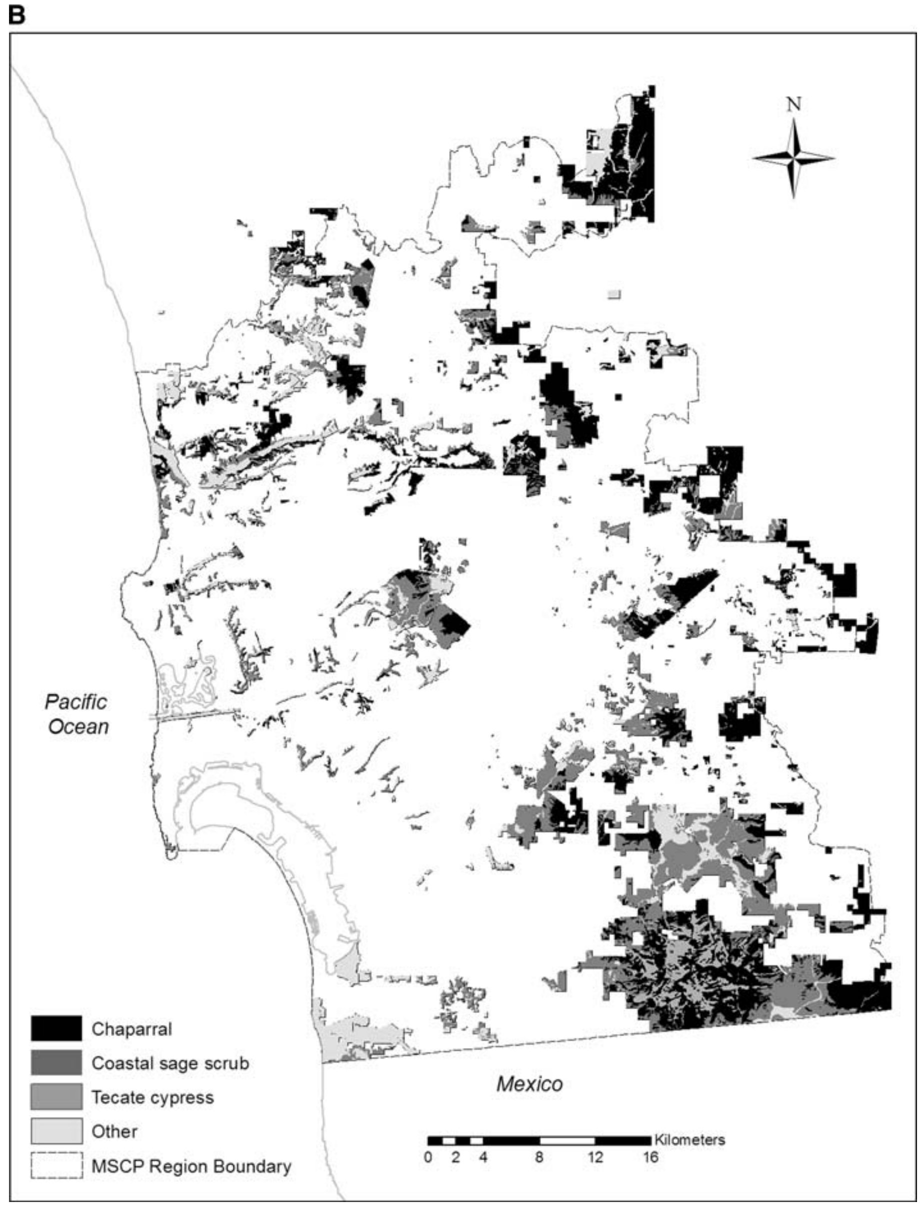
Materials and Methods

Study Area and Data

Located in the southwestern corner of San Diego County, California, USA (Fig. 1), the San Diego MSCP reserve includes lands in the City of San Diego and 11 other jurisdictions. The region is bordered by Mexico to the south, the Pacific Ocean to the west, U.S. National Forest Service lands to the east, and the San Dieguito River Valley to the north (Greer 2004). The two dominant community types in the region are coastal sage scrub and chaparral, but communities range from coastal types (e.g., beaches, salt pans, bluffs) to grasslands, oak woodlands, riparian areas, and freshwater wetlands such as vernal pools (Appendix). Elevation ranges from sea level to approximately 1200 m, and the region experiences a mild Mediterranean climate with warm dry summers and cool wet winters.

For the purposes of this paper we refer to the MSCP region (i.e., the planning region whose species and communities the MSCP is intended to preserve) as the "region," the targeted Multi-Habitat Planning Area (i.e., the perimeter of the reserve as described in the planning process) as the "planned conservation area," and those lands already acquired and currently protected within the reserve as "currently conserved lands" (Fig. 1A). The term "ecological communities" is used to refer to mapped vegetation types (i.e., the spatial representation of terrestrial plant communities) with the understanding that they

Fig. 1 continued

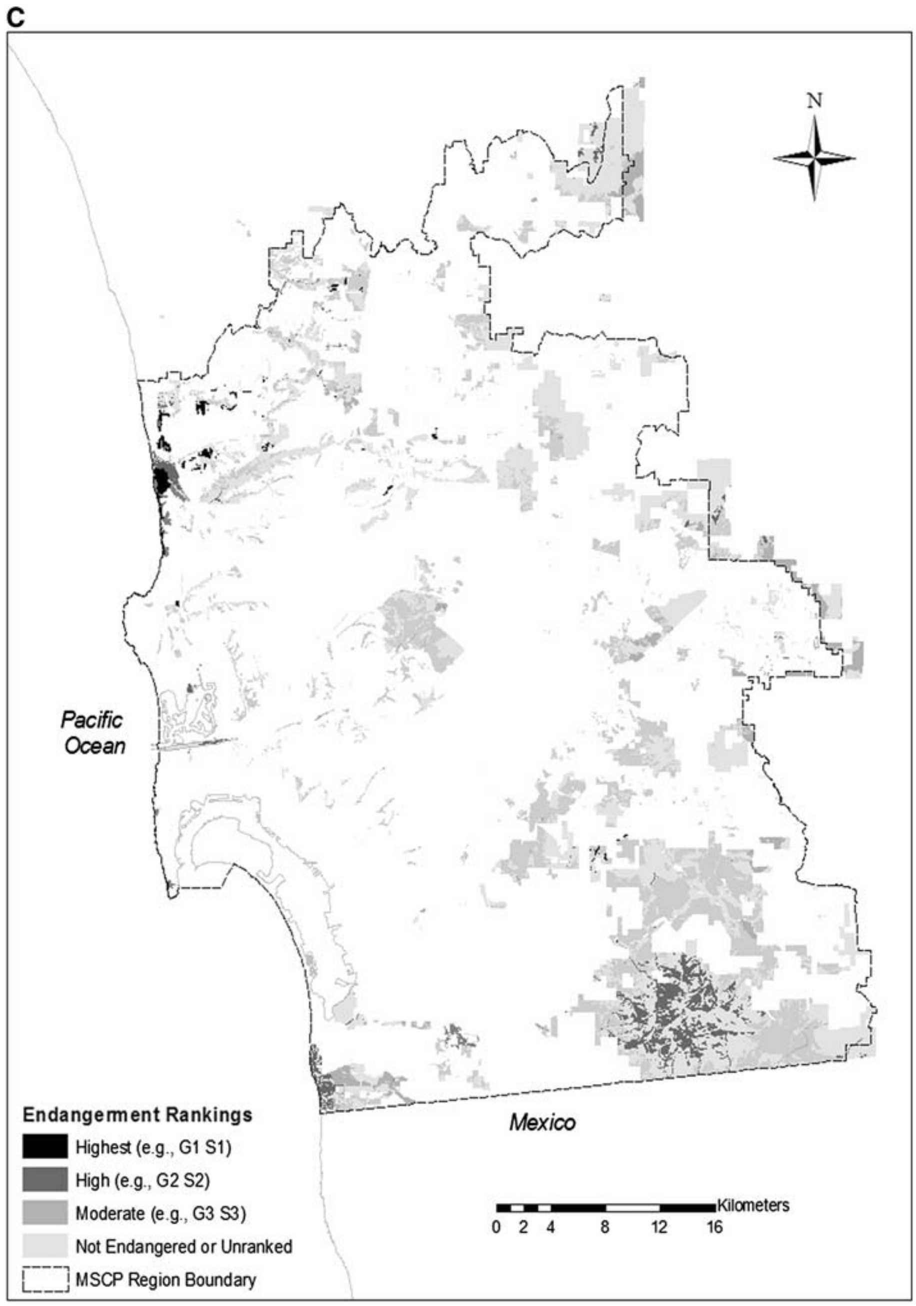


are surrogates for ecosystems and ecological processes that occur there.

A digital map of the ecological communities of San Diego County was initially compiled in geographic information system (GIS) format by the San Diego Association of Governments (SANDAG) in 1995 (scale, 1:24,000) when the MSCP was designed. Sections of the map have been updated with more detailed air photo-based mapping since 1995 as lands have been added in the reserve and surveyed. Also, multidate panchromatic satellite images have been used to identify and revise habitat information in areas that have been converted to land uses such as agriculture or urban. The map is based on the Holland vegetation classification system (Holland 1986) with updates as described in the SANDAG metadata. This classification system is hierarchical, allowing for aggregation to more general vegetation classes, as was done for analyses in this study (Appendix). The Holland classification can also be cross-referenced to the more recently established California Native Plant Society (CNPS) classification for California (Sawyer and Keeler-Wolf 1995), to be consistent with the National Vegetation Classification Standard (Grossman and others 1998).

Stow and others (1993) assessed the accuracy of the original 1995 map using standard methods (Stehman and Czaplewski 1998). They randomly selected a proportional sample of 239 map polygons, stratified by vegetation type, and visited in the field or by helicopter by at least two experts. Observed versus mapped class labels were analyzed in a contingency table (confusion matrix). Overall

Fig. 1 continued



map accuracy (percentage correct classification) was 77% for the nine vegetation classes that occupy most (>80%) of the map area (Stow and others 1993). Most confusion was between structurally similar classes (e.g., sparse oak woodland mapped as dense oak woodland), and the ecotonal "mixed" class coastal sage/chaparral was almost always labeled chaparral in the map. Other categories (coastal sage scrub, chaparral, grassland, oak woodland) were mapped with 80%–90% overall accuracy. A more recent assessment restricted to coastal sage scrub, ecotonal, and chaparral communities found similar results, with an overall accuracy of 66% and the highest error in mapping the most structurally similar classes (Winchell and Doherty 2006).

A geographic database of the lands acquired for the MSCP reserve is maintained through HabiTrak, a SANDAG software program that tracks land acquisitions and losses to development in the MSCP region. Also available from HabiTrak were the MSCP region boundary and a map of the Multi-Habitat Planning Area, i.e., the planned conservation area. Several parcels of currently conserved lands have boundaries that extend beyond the original MSCP region boundaries, resulting in a few vegetation class areas being higher in the currently conserved lands than the planned conservation area (Appendix).

Assessment Criteria

In practice, plant communities or mapped vegetation types are often used as surrogates for ecosystems in terrestrial settings, e.g., in gap analysis (Chattin and others 2006; Davis and others 1995; Scott and others 1993). Multiple criteria for prioritizing species and land during the planning stages of reserve design have been well documented (Margules and Usher 1981; Margules and Pressey 2000; Moffett and Sarkar 2006; Regan and others 2007; Scott and Sullivan 2000), but to our knowledge they have not been used to prioritize ecological communities for monitoring within an established reserve. We used criteria based on extent, representativeness, fragmentation, and endangerment to assess and prioritize communities. We argue that, given the scarcity of funding for monitoring activities in nature reserves, available resources should be focused on communities that are (1) of large extent, that is, comprising much of the reserve and providing habitat for many covered species (Margules and Usher 1981; Noss 1990), (2) underrepresented in the reserve in proportion to their area in the region (Austin and Margules 1984; Margules and Pressey 2000; Margules and Usher 1981), (3) fragmented in the landscape and, therefore, at risk of negative effects of edges and isolation (Fahrig 2002; Noss 1990), and/or (4) endangered according to published endangerment rankings (Andelman and others 2004; Fahrig 2002; Keith 1998; Noon and others 1999).

We assessed each of these four criteria for the terrestrial communities in the San Diego MSCP (Appendix). We excluded agriculture, urban, and freshwater classes from our prioritization, as these were not considered community monitoring or management targets. However, these classes were included in the reserve's planning goals and make up a small proportion of the currently conserved lands. We established and applied decision rules to rank each community as High, Moderate, or Low priority for each criterion (Table 1). To prioritize them, we then ranked the communities by the number of high, then moderate, then low rankings for the four criteria. We used an unweighted ranking. Methods exist for weighting multiple criteria in conservation decision-making (Anselin and others 1989; Figueira and others 2005; Pereira and Duckstein 1993; Regan and others 2006), but agency personnel and other experts we consulted advised against weighting (e.g., all four criteria were regarded as equally important). Each criterion and its calculations are described below.

To evaluate the extent and configuration of ecological communities in the currently conserved lands and planned conservation area compared to both the region and the MSCP targets, we overlaid the vegetation community map for San Diego County with the boundaries of each area (Fig. 1A) in ArcGIS 9.0 (ESRI, Redlands, CA). We aggregated the 68 mapped vegetation communities and land use classes in the region to 11 general communities to facilitate analysis and interpretation (e.g., Figs. 1B and 2). For extent, we summed the areas of each community type that made up an aggregated class to determine the total area of that class in the region and in the currently conserved lands. We then compared the extent of the currently conserved lands to the acquisition targets described in the MSCP planning documents, expressed as percentages of the region to correct for small variations between the planning document, and map-derived areas. As described above, each of the aggregated communities, excluding urban, agricultural, and strictly aquatic (freshwater) cover

Table 1 Decision rules applied to rank communities on each criterion

For each community

1. Calculate extent (area) of community.
   a. If >10% of currently conserved lands, priority based on extent = High.
   b. If 1%–10% of currently conserved lands, priority based on extent = Moderate.
   c. If <1% of currently conserved lands, priority based on extent = Low.
2. Calculate ratio of extent (% currently conserved lands) to targets (% planned conservation area) and normalized ratio value: (% currently conserved lands – % region)/% region.
   a. If ratio <60% or normalized value <0, priority based on representativeness = High.
   b. If ratio 60%–90% or normalized value ~0, priority based on representativeness = Moderate.
   c. If ratio >90% or normalized value >0, priority based on representativeness = Low.
3. Calculate all six landscape metrics, and rank metric for all communities from a value of 1, indicating low fragmentation (low edge density, high largest and mean patch size, low number of patches, low average distance between patches, low perimeter-to-area ratio), to a value of 10, indicating high fragmentation. Average the six rankings and group according to natural break points in the distribution of each metric (clusters of values) when examined in rank order for each community.
   a. If average score >6.5, fragmentation = High.
   b. If average score 5–6.5, fragmentation = Moderate.
   c. If average score <5, fragmentation = Low.
4. Find NatureServe endangerment ranking for community or for subcommunities comprising it.
   a. If majority (>50%) of area is in communities rated G1S1 and/or G2S2, endangerment = High.
   b. If majority of their area is in communities rated G3S3 and higher, endangerment = Moderate.
   c. If majority of area is in communities rated G4S4 or G5S5, or unranked, endangerment = Low.

types, were assigned a priority ranking of High, Medium, or Low based on their extent (large extent = High ranking). Rankings were based on natural breaks in the distributions of these criteria when each was examined in rank order for the communities. For example, large extent and therefore High priority was assigned when a class was >10% of the region, and small extent (Low priority) was <1% (see Table 1 for decision rules). The number of MSCP covered species that use each community (Regan and others 2008) was evaluated to confirm our assumption that extensive communities provide habitat for a majority of covered species.

Communities were also assigned prioritization rankings based on the representativeness of currently conserved lands compared to their proportional area in the region and success in meeting planning targets (underrepresented = High ranking). For example, High priority was assigned to classes that have met less than 60% of their targeted acquisition, or when their representativeness, normalized for area within the region (Table 1), was <0; low priority was assigned when >90% of targeted acquisition has occurred, or when the normalized value was greater than 0.

We used FragStats software (McGarigal and Marks 1995) to calculate several landscape pattern metrics for each of the aggregated vegetation classes. The extensive literature on landscape pattern analysis suggests that there is considerable redundancy among the numerous landscape metrics available (McGarigal 2002; O'Neill and others 1988; Riitters and others 1995), and their use as indicators of habitat fragmentation is still being evaluated (e.g., McAlpine and others 2002; Olsen and others 2007). We used the following measures of community fragmentation: number of patches, largest patch index, mean patch area, edge density, mean perimeter-area ratio, and mean euclidian nearest neighbor distance (described in Table 2). These fragmentation metrics quantify different aspects of pattern (size distribution, shape and isolation of habitat patches) and/or have been used effectively at the urban-wildland interface and other areas with high levels of human disturbance (e.g., Luck and Wu 2002; Olsen and others 1999). This analysis was then used to assess the overall spatial patterning of the vegetation classes in the MSCP reserve. Communities with metric values that indicated they were relatively more fragmented (smaller patches, further apart, and/or more edge) received High priority rankings, and those whose metric values indicated they were less fragmented overall were assigned a Moderate or Low priority ranking. The specific decision rules are described in Table 1.

We compiled Global and State endangerment rankings for ecological communities developed by NatureServe and the California Department of Fish and Game and available from the CNPS. These rankings are analogous to systems

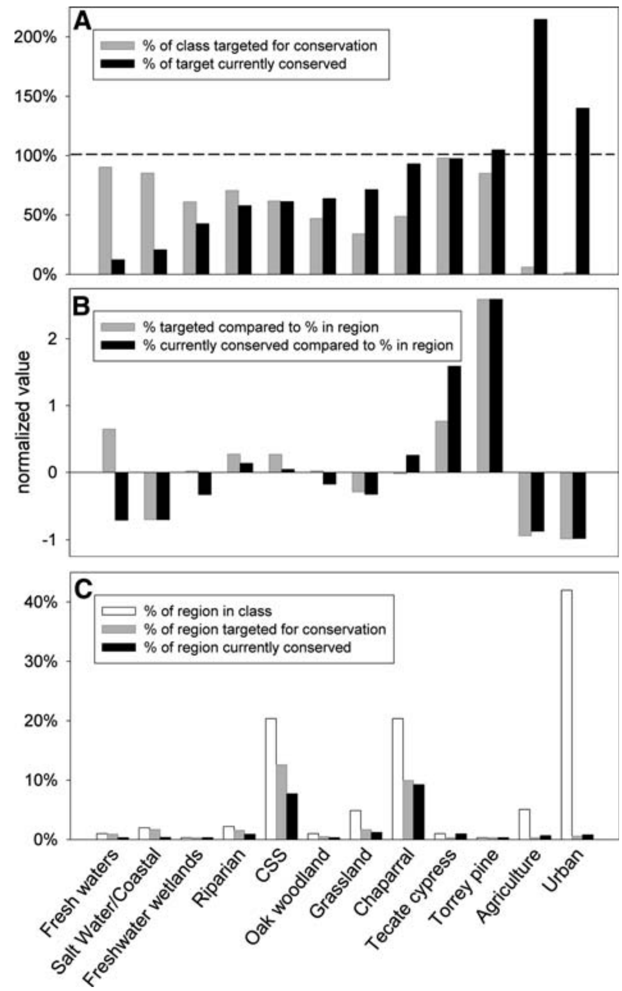


Fig. 2 Summary of the reserve by aggregated ecological community or land cover class. (**A**) Percentage of community type targeted for conservation within the Multiple Species Conservation Plan (MSCP) region in the original planning documents versus percentage of target currently conserved. (**B**) Normalized ratio: (% currently conserved lands – % region)/% region, as described in Table 1. (**C**) Percentage land area of each community in the MSCP currently conserved lands, planned conservation area, and MSCP region

used to rank species endangerment levels, with specific criteria based on the number of occurrences and/or total area of that community found globally or statewide (Table 3). The rankings are cross-referenced from CNPS vegetation alliances to Holland vegetation communities. As there is not a 1:1 relationship between these vegetation classes, some Holland communities found in the MSCP region were not classified for their endangerment level. Additionally, only the more specific Holland hierarchy levels 3 and 4 (and occasionally 2) are ranked, leaving more general classes unranked. For example, general communities such as "coastal sage scrub" are unranked, but more narrowly defined communities such as "Southern coastal bluff scrub" are ranked. The San Diego community map includes all hierarchical levels of classification because different parts of it were mapped to different levels of detail based on available data, as noted above. We assigned each aggregated community a priority endangerment ranking, with the specific decision rules described in Table 1. Those aggregated communities with the majority of area comprising unranked communities were denoted as less certain, because some unranked classes may actually include endangered communities.

Results

Extent and Representativeness of Currently Conserved Lands

Comparing currently conserved lands to the targets set in the original MSCP planning documents (Fig. 2A), the ecological communities that have best met their targets in the reserve are Torrey pine (104% of target currently conserved), Tecate cypress (97%), and chaparral (93%). The most underrepresented communities (Fig. 2A, B) are salt water/coastal and freshwater wetlands. Communities that provide habitat for the highest number of MSCP covered species have not yet met their conservation targets. These include grassland (12 species; 71% of target met), coastal sage scrub (8 species; 61% of target met), and freshwater wetlands (8 species; 43% of target met). Coastal sage scrub is currently protected at levels below those planned for in the MSCP (Fig. 2A) but it is not proportionally underrepresented compared to the region as a whole (Fig. 2B). The most extensive community, chaparral, is proportionally represented in currently conserved lands, and it supports the largest number of covered (36) and at-risk (20) species (Regan and others 2008).

Landscape Pattern Metrics for Land Cover Classes

Coastal sage scrub and chaparral are the largest communities in the planned conservation area in terms of extent (Figs. 1B and 2B), number of patches, and largest patch index (Fig. 3). Both communities also have the highest edge density (interface with other classes) because they are so extensive, but have relatively low average euclidian nearest neighbor distances between patches. Freshwater wetlands, oak woodlands, and riparian areas have a low number of patches, small area, and a low largest patch index. These communities have higher euclidian nearest neighbor distances and high perimeter-area ratios, indicating widely dispersed patches with complex shapes (Fig. 3).

Coastal sage scrub (Fig. 1B) has lower total area in currently conserved lands than in the planned conservation area or the region (Fig. 2B), but has a lower edge density in the conserved than in the planned area (Fig. 3), so coastal sage scrub that has been conserved to date comprises larger patches on average than those still planned for acquisition.

Table 2 Descriptions of landscape metrics used in this study

Landscape metric (unit)	Brief description[a]
Number of patches	Number of patches in the vegetation or land use class
Mean patch area (ha)	Sum of the area of all patches in a class divided by the number of patches in that class
Mean euclidian nearest neighbor distance (m)	Sum of the distance to the nearest-neighboring patch of the same class, using the shortest edge-to-edge distance, for each patch in the class, divided by the number of patches in the class
Mean perimeter-area ratio (m)	Sum of the ratios of the patch perimeter to area, divided by the number of patches in the class
Edge density (ha)	Sum of the lengths of all edge segments involving the corresponding patch type, divided by the total landscape area, multiplied by 10,000 to convert to hectares
Largest patch index (%)	Percentage of the landscape comprised by the largest patch

[a] Excerpted from McGarigal and Marks (1995)

Table 3 NatureServe and California Department of Fish and Game community endangerment ranking guidelines

Rank	
Global	
G1	<6 viable occurrences worldwide and/or 810 ha
G2	6–20 viable occurrences worldwide and/or 810–4047 ha
G3	21–100 viable occurrences worldwide and/or 4047–20,230 ha
G4	>100 viable occurrences worldwide and/or >20,230 ha
G5	Community demonstrably secure due to worldwide abundance
State	
S1	<6 viable occurrences statewide and/or 810 ha
S2	6–20 viable occurrences statewide and/or 810–4047 ha
S3	21–100 viable occurrences statewide and/or 4047–20,230 ha
S4	>100 viable occurrences statewide and/or >20,230 ha
S5	Community demonstrably secure statewide
Threat	
0.1	Very threatened
0.2	Threatened
0.3	No current threats known

Available from the California Native Plant Society at: http://davisherb.ucdavis.edu/cnpsActiveServer/intro.html#tnchp

Additionally, all communities except Torrey pine, Tecate cypress, and salt water/coastal have higher euclidian nearest neighbor distances (i.e., are farther apart on average from similar patches) in currently conserved lands than in the planned conservation area or in the region as a whole (Fig. 3). As parcels are added to the reserve within the footprint of the planned conservation area, the distance between patches is reduced. The three exceptional classes occur in limited, clumped distributions.

Endangerment and Prioritization of Communities

Communities with high endangerment or threats according to NatureServe rankings, and also underrepresented in the reserve, include cismontane alkali marsh and native Valley needlegrass grassland (Table 4). Unfortunately, nonnative (low conservation value) and native (high conservation value) grasslands were not consistently differentiated in the vegetation map, so overall prioritization of grasslands at the aggregated level is uncertain (Table 5). At the aggregated level, by applying the rules described in Table 1, salt water/coastal habitats, Tecate cypress, and Torrey pine are all highly endangered (Fig. 1C, Table 5).

Assessing the overall prioritization of communities based on assigned levels of priority (High, Moderate, or Low) for each criterion—areal extent, fragmentation, representativeness in the reserve versus planning area, and endangerment rankings—resulted in high priority communities of coastal sage scrub (high endangerment, large areal extent, underrepresented, and moderately fragmented), freshwater wetlands, and salt water/coastal (moderate to high fragmentation, endangerment rankings and representativeness, and low areal extent) (Table 5). Based on these criteria, Torrey pine forests and chaparral communities had relatively lower priority, with Torrey pines having a high ranking only for endangerment and chaparral having a high ranking only for extent. Grasslands were assigned low priority owing to high uncertainty about the amount and location of native grassland within this mapped community.

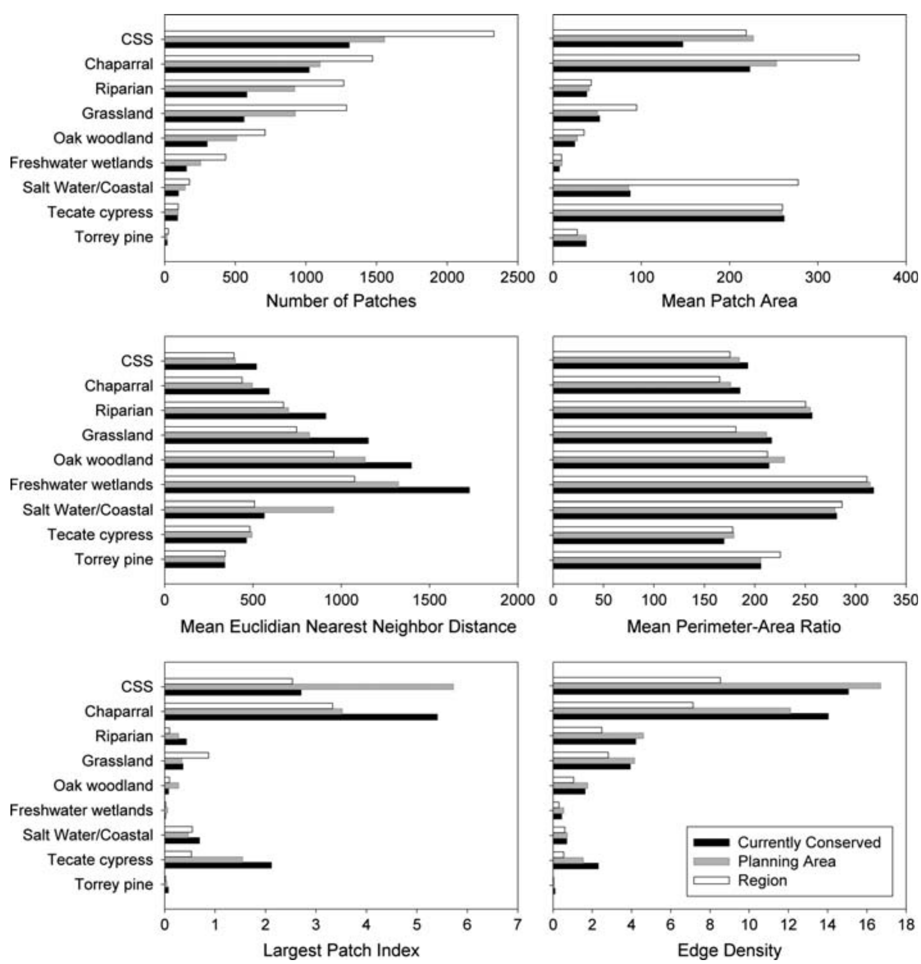


Fig. 3 Number of patches, mean patch area, mean euclidian nearest neighbor distance, mean perimeter-to-area ratio, largest patch index, and edge density for aggregated communities in the Multiple Species Conservation Plan's currently conserved lands, planned conservation area, and region. Metrics were calculated using FragStats (McGarigal and Marks 1995)

Table 4 Endangerment rankings, targeted conservation area, area currently conserved, and percentage of conservation target met for the most endangered communities found in the San Diego Multiple Species Conservation Plan

Holland code	Ecological community	NatureServe ranking	Targeted extent (ha)	Currently conserved extent (ha)	% target currently conserved
52310	Cismontane alkali marsh	G1 S1.1	70	19	27
42110	Valley needlegrass grassland	G1 S1.1	93	53	57
31200	Southern coastal bluff scrub	G1 S1.1	55	58	105
83140	Torrey pine forest	G1 S1.1	56	58	104
37C30	Southern maritime chaparral	G1 S1.1	392	384	98
32400	Maritime succulent scrub	G2 S1.1	359	314	87
71180	Engelmann oak woodland	G2 S2.1	1	0	0
61320	Southern arroyo willow riparian forest	G2 S2.1	11	7	64
71182	Dense Engelmann oak woodland	G2 S2.1	0	12	—
21230	Southern foredunes	G2 S2.1	50	38	76
52120	Southern coastal salt marsh	G2 S2.1	644	483	75
83230	Southern interior (Tecate) cypress forest	G2 S2.1	2271	2214	97
71181	Open Engelmann oak woodland	G2 S2.2	132	131	99
45320	Alkali seep	G3 S2.1	0	1	—
63320	Southern willow scrub	G3 S2.1	84	20	24
52410	Coast and valley freshwater marsh	G3 S2.1	141	73	52
	Total area in endangered classes		4359	3866	
	% of currently conserved lands in endangered classes		5.58%	7.46%	

G1–G3 and/or S1–S2; definitions in Table 3

Discussion

Science in support of biological monitoring for nature reserves has advanced considerably in recent years, especially in the areas of defining goals and objectives (Slocombe 1998), developing conceptual models (Noon 2003), identifying monitoring variables and designing sampling programs (Yoccoz 2001), and prioritizing species (Andelman and others 2004). However, in spite of the continuing emphasis on communities as elements in biodiversity planning (e.g., Regan and others 2007), we found few specific examples of community prioritization schemes for monitoring established reserves. The approach we used in this case study used criteria derived from fundamental principles of conservation biology (i.e., representativeness and endangerment) and landscape ecology (i.e., extent and fragmentation).

As is the case with individual species management, where priority is often given to rare and at-risk species, we would expect communities that are rare (limited local extent) and endangered (limited global extent) to be at high risk of loss of ecological integrity (function) and, therefore, of high priority for monitoring. However, endangerment rankings for communities are not yet as well developed or comprehensive as those for species. In addition, in contrast with some other kinds of protected areas, the MSCP (Fig. 1) is composed of a network of patches within a matrix of urban development (e.g., Mazzotti and Morgenstern 1997; Stenhouse 2004). Therefore, landscape pattern measures indicating that communities are represented by small, widely dispersed patches in the reserve, with a high edge-to-interior ratio, are useful for identifying communities that should be prioritized for monitoring because they are at risk of negative fragmentation and edge effects (Laurance 2000; Leyva and others 2006; McAlpine and others 2002).

Our prioritization scheme, based on multiple criteria, was able to distinguish those communities that are globally rare but well represented in the MSCP reserve (Tecate cypress and Torrey pine) from those that are underrepresented in the reserve, and that often occur in small patches distant from sites supporting similar communities (freshwater wetlands, oak woodlands, salt water/coastal habitats, riparian). These two groups of communities may require different kinds of monitoring focusing on different monitoring variables, for example, population status of an indicator species versus threats such as invasive species abundance.

Further, a surprising result was that the MSCP's flagship ecological community, coastal sage scrub, which encompasses several endangered subcomponents, has only met 61% of its targeted acquisition. Based on moderate to high rankings on all four criteria, it was given higher priority for monitoring than chaparral, although chaparral also includes

Table 5 Rankings of High (H, shown in bold), Moderate (M), or Low (L) for each community prioritization criterion, with aggregated communities in order from top to bottom, from higher to lower priority for monitoring

Ecological community	Extent	Representativeness	Fragmentation	Endangerment ranking
Coastal sage scrub (35.9%)	**H**	**H**	M	M
Saltwater/coastal (1.6%)	L	**H**	L	**H**
Freshwater wetlands (0.2%)	L	M	**H**	M
Tecate cypress (4.4%)	M	L	L	**H**
Riparian (4.2%)	M	L	**H**	L
Oak woodland (1.4%)	L	M	**H**	L[a]
Torrey pine (0.1%)	L	L	L	**H**
Chaparral (43.1%)	**H**	L	L	L[a]
Grasslands (5.5%)	L[b]	M	M	L[a]

Percentage of currently conserved lands given in parentheses

[a] These endangerment rankings are less certain because more than 50% of the land in these classes was unranked

[b] Grassland includes combined area of native and nonnative grasslands which differ greatly in conservation value and endangerment, and so extent was given a lower rating

endangered subcomponents. However, chaparral is the most extensive community and supports the highest number of covered species (Regan and others 2008), and so priority monitoring for chaparral might emphasize habitat quality in the context of species monitoring as opposed to community pattern and process.

One important caveat is that the analyses of extent, representativeness, and landscape pattern were based on the best available community map for San Diego County, initially assembled in 1995, with some more detailed mapping merged into the map subsequently. Any evaluation of the quantity, spatial pattern or location of communities is based on spatial data represented at a particular scale (Turner and others 1989). Since a map is a model of the landscape, it always has some degree of spatial generalization and error (Franklin and others 2001; Goodchild and Gopal 1989; Goodchild 1994; Lowell and Jaton 1999; O'Neill and others 1988). The effect of that error on subsequent analyses has not been comprehensively quantified for all map classes.

It is important to acknowledge the success of the MSCP in reaching a size of 51,800 ha in just over 10 years in a region with intense urban development pressure. Although the majority of lands have already been acquired for the reserve, the program is still acquiring land; hence opportunities exist to fill the gaps identified in this study. Decision makers and conservation planners can use the results of these analyses to strategically target future acquisitions to those communities currently underrepresented in the reserve. It should be noted, however, that all of these comparisons are based on the current land use status of the region. A more stringent criterion of representativeness could be based on a comparison with the potential distribution, or pre-Euroamerican distribution of ecological communities (Sprugel 1991). For example, the distribution of coastal sage scrub throughout its extent in southern California is estimated to have already declined by 80%–90% due to development and land conversion (Westman 1981).

Our approach yields spatially explicit information on where monitoring, habitat management, or additional land acquisition is most needed. High priority communities should receive monitoring attention to determine if the MSCP is meeting its goal of preserving function and diversity of the reserve's ecosystems. Monitoring within an adaptive management framework can also identify when management interventions may be needed, and assess the success of management at achieving conservation goals. Community monitoring does not substitute for species monitoring but can instead answer different questions about a reserve. This community prioritization framework could be useful for other conservation planners who need to prioritize communities as a result of limited monitoring and management resources. The study also illustrates a proactive approach for assessing the status of communities in regional reserves that are undergoing a protracted period of land acquisition.

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Appendix

Table A1 Disaggregated and aggregated communities in the San Diego multiple species conservation plan (MSCP)

Holland code	Disaggregated community description	NatureServe ranking	Class extent in MSCP region (ha)	Extent of targeted conservation area (ha)	Extent of currently conserved lands (ha)	Aggregated group name	Aggregated target conservation, ha (% of region)	Aggregated currently conserved lands, ha (% of region)
11100	Eucalyptus woodland	n/a	665	133	86	Urban/ disturbed	1,303 (0.6)	1,823 (0.8)
11200	Disturbed wetland	n/a	218	174	105			
11300	Disturbed habitat	n/a	9,055	996	1,031			
12000	Urban/developed	n/a	87,876	0	601			
13111	Subtidal	n/a	219	200	1	Salt water/ coastal	3,912 (1.7)	810 (0.3)
13112	Intertidal	n/a	28	26	2			
13123	Shallow bay	n/a	2,897	2,636	53			
13130	Estuarine	n/a	94	85	83			
13131	Estuarine subtidal	n/a	5	4	5			
13300	Salt pan/mud flats	n/a	108	98	82			
13400	Beach	n/a	457	169	63			
21230	Southern foredunes	G2 S2.1	77	50	38			
52120	Southern coastal salt marsh	G2 S2.1	700	644	483			
13140	Fresh water	n/a	1,925	1,751	225	Fresh waters	2,095 (0.9)	257 (0.1)
13200	Nonvegetated channel, floodway, lakeshore fringe	n/a	395	344	31			
18000	General agriculture	n/a	167	10	17	Agriculture	709 (0.3)	1,522 (0.7)
18100	Orchards and vineyards	n/a	1,587	95	40			
18200	Intensive agriculture	n/a	1,153	69	134			
18300	Extensive agriculture	n/a	8,905	534	1,329			
18310	Field/pasture	n/a	6	0	2			
18320	Row crops	n/a	2	0	2			
31200	Southern coastal bluff scrub	G1 S1.1	80	55	58	Coastal sage scrub	29,305 (12.6)	17,950 (7.7)
32400	Maritime succulent scrub	G2 S1.1	764	359	314			
32500	Diegan coastal sage scrub	G3 S3.1	46,598	28,891	17,579			
37000	Chaparral	n/a	26,549	13,009	13,094	Chaparral	23,131 (9.9)	21,533 (9.2)
37120	Southern mixed chaparral	n/a	12,956	6,348	3,940			
37121	Granitic southern mixed chaparral	G3 S3.3	1,318	646	642			
37122	Mafic southern mixed chaparral	G3 S3.2	63	31	132			
37130	Northern mixed chaparral	n/a	811	397	107			
37131	Granitic northern mixed chaparral	n/a	1,277	626	993			
37200	Chamise chaparral	G4 S4	2,019	989	723			
37210	Granitic chamise chaparral	n/a	27	13	120			
37220	Mafic chamise chaparral	n/a	0	0	241			
37900	Scrub oak chaparral	G3 S3.3	54	26	20			
37C30	Southern maritime chaparral	G1 S1.1	633	392	384			
37G00	Coastal sage/chaparral scrub	G3 S3.2	1,703	647	1,138			
37K00	Flat-topped buckwheat	n/a	11	5	0			

Table A1 continued

Holland code	Disaggregated community description	NatureServe ranking	Class extent in MSCP region (ha)	Extent of targeted conservation area (ha)	Extent of currently conserved lands (ha)	Aggregated group name	Aggregated target conservation, ha (% of region)	Aggregated currently conserved lands, ha (% of region)
42000	Valley and foothill grasslands	n/a	6369	2,165	1,760	Grasslands	3,862 (1.7)	2,755 (1.2)
42100	Native grassland	G3 S3.1	64	22	0			
42110	Valley needlegrass grassland	G1 S1.1	274	93	53			
42200	Nonnative grassland	G4 S4	4,650	1,581	942			
45300	Alkali meadows and seeps	n/a	1	0	0	Freshwater wetlands	238 (0.1)	101 (0.0)
45320	Alkali seep	G3 S2.1	0	0	1			
45400	Freshwater seep	G4 S4	36	22	1			
52300	Alkali marsh	n/a	0	0	1			
52310	Cismontane alkali marsh	G1 S1.1	115	70	19			
52400	Freshwater marsh	G4 S4	7	4	5			
52410	Coastal and valley freshwater marsh	G3 S2.1	231	141	73			
60000	Riparian and bottomland habitat	n/a	16	13	9	Riparian	3,597 (1.5)	2,079 (0.9)
61000	Riparian forest	n/a	0	0	0			
61300	Southern riparian forest	n/a	483	391	249			
61310	Southern coast live oak riparian forest	G4 S4	2,116	1,206	677			
61320	Southern arroyo willow riparian forest	G2 S2.1	13	11	7			
61330	Southern cottonwood-willow riparian forest	G3 S3.2	99	80	61			
62400	Southern sycamore-alder riparian woodland	G4 S4	296	237	215			
63300	Southern riparian scrub	G3 S3.2	1,758	1,406	830			
63310	Mule fat scrub	G4 S4	35	28	8			
63320	Southern willow scrub	G3 S2.1	105	84	20			
63810	Tamarisk scrub	G5 S4	175	140	2			
63820	Arrowweed scrub	G3 S3.3	0	0	0			
71100	Oak woodland	n/a	17	8	16	Oak woodlands	1,084 (0.5)	692 (0.3)
71160	Coast live oak woodland	G4 S4	200	94	56			
71162	Dense coast live oak woodland	n/a	1807	849	477			
71180	Engelmann oak woodland	G2 S2.1	1	1	0			
71181	Open Engelmann oak woodland	G2 S2.2	282	132	131			
71182	Dense open Engelmann oak woodland	G2 S2.1	0	0	12			
83140	Torrey pine forest	G1 S1.1	66	56	58	Torrey pine	56 (0.02)	58 (0.03)
83230	Southern interior (Tecate) cypress forest	G2 S2.1	2,318	2,271	2,214	Tecate cypress	2271 (1.0)	2,214 (1.0)

See Table 3 for definitions of NatureServe Rankings. n/a: the endangerment ranking was not available

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