Evaluating the Potential Impact of the Proposed Land Development on Coastal Sage Scrub in Northern Orange County, California

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Abstract

Southern California's coastal sage scrub vegetation, found in limited coastal lowlands, is directly threatened by habitat loss due to urban sprawl. The West Coyote Hills, located in the city of Fullerton, California, is one of the last existing open coastal scrublands remaining undeveloped in northern Orange County, but it has been proposed for housing development. The objective of this study was to evaluate the potential impact of the proposed land development on the remaining coastal sage scrub habitat in the West Coyote Hills area. The analysis was based on a map of vegetation communities, developed from the classification of field inventory data, and a map of the proposed housing tracts from the Revised Environmental Impact Report for the study area. FRAGSTATS was used in conjunction with these maps to quantify the possible changes in landscape composition and spatial configuration. The results indicated that the landscape would become highly fragmented with a great amount of loss of scrub vegetation. The remaining vegetation patches would become smaller, more isolated, and less contiguous. Both coastal sage scrub (CSS) and disturbed coastal sage scrub (dCSS) were examined at the class and patch levels. The results showed that 84 CSS patches over 45 ha and 78 dCSS patches over 9 ha would be lost to the development. The changes in patch extent and patch size distribution of CSS would be more substantial than those of dCSS. Many large CSS patches would be reduced, and the allowable distance for organisms to move within the patches would decrease.

Keywords: landscape structure, landscape metrics, coastal sage scrub, habitat fragmentation, FRAGSTATS

Introduction

Located within the California Floristic Province, one of the world's thirty-four biodiversity hotspots, southern California's coastal sage scrub (CSS) vegetation is concentrated between Point Conception, California, and Northern Baja California, on the interior and exterior sides of the Coast Range. It is usually found in coastal lowlands adjacent to the Chaparral adapted to the semi-arid Mediterranean climate. The vegetation is characterized by the dominance of drought-deciduous shrubs with shallow roots, soft leaves, and a fairly open canopy (Westman 1981a, 1981b, 1983; O'Leary and Westman 1988).

The CSS vegetation has been considered as an endangered plant community due to human disturbances and land-use change (Underwood et al. 2009). The human disturbances of habitat, from the Spanish explorers' development of ranchos in the late eighteenth century to the early settlement of the European-Americans in the nineteenth century, have made it difficult to determine the original range of CSS (Riordan and Rundel 2009). But it was estimated that the direct and indirect effects of human activities have diminished nearly 90% of the original CSS habitat (Riordan and Rundel 2009).

Land-use change is another main contributor to the elimination of native vegetation, including CSS (Kowarik 1995). The landscape of southern California has transitioned through conservation, utilization, and replacement, and is currently predominantly in the final land-use phase of removal (Mooney and Hobbs 2000). Direct habitat loss, caused by urban development and the demands for new housing communities, has become an important issue in southern California (McKinney 2002). Much of the native CSS vegetation in southern California has been converted into freeways, housing communities, and strip malls (South Coast Wildlands 2008). When permanent structures are built over a landscape, the previous vegetation in the area is lost and unable to be restored (Riley et al. 2003; Markovchick-Nicholls et al. 2007). In Orange County, California, the Department of Forestry reported that 6,216 ha of CSS vegetation was destroyed between 1945 and 1980 (Bowler 1990).

A limited habitat can support only a limited number of organisms. Besides, when habitat loss occurs, the landscape breaks up into smaller pieces; this is known as habitat fragmentation. Fragmentation of a natural landscape creates patches of habitats. A fragmented habitat can remain healthy if the patches are large in scale and well connected (Bastin and Thomas 1999; Swenson and Franklin 2000; Williams, Mc Donnell, and Seager 2005; Oneal and Rotenberry 2008). Habitat patches that are intact will have greater species populations, species survival rates, and biodiversity. If habitat patches are disconnected and grow smaller in size, biodiversity will decline drastically. The isolation of habitat patches will eventually lead to inbreeding and the extinction of species (MacDonald 2003). Therefore, in growing urban areas, such as the few remaining open spaces in southern California, it is critical to protect biological diversity by keeping habitat patches intact.

The West Coyote Hills (WCH) is one of the last existing open coastal shrubland remaining undeveloped in northern Orange County, but it has been proposed for a housing development. The objective of this study was to evaluate the potential impact of the proposed land development on the entire WCH landscape and remaining vegetation communities, including both CSS and disturbed coastal sage scrub (dCSS). The specific questions asked in relation to the impact of development are: How much CSS and dCSS would be removed and lost? How would the landscape composition and spatial configuration be affected by habitat loss? Would the development disrupt current wildlife corridors or habitat patches?

Study Area

The WCH is located in the city of Fullerton, Orange County, California (Figure 1). Within the city of Fullerton, the WCH is located on the northwest side of the city limits, between Rosecrans Avenue and Euclid Avenue. The WCH is part of a range of low hills connecting from the east in Yorba Linda to the west in Santa Fe Springs. The elevations vary from around 91 m near the southern boundary to 186 m at the top of the northern hill. Past oil-field activities have altered the natural landscape and topography with well pads, graded roads, canyon fills, and sheer cuts into slopes.

The WCH encompasses 235.6 ha of open space and is the largest undeveloped section of land in northern Orange County. For eighty-seven years, from 1907 to 1994, the WCH was used for oil production. Since the closure of the oil fields, maintenance procedures have taken place, such as reducing brush to prevent fire hazards. Chevron currently owns the WCH property. The hired developer for the property, Pacific Coast Homes, has proposed building a maximum of 760 homes within 72.8 ha of the property; 556 of these homes will be single-family, detached homes; the remaining 204

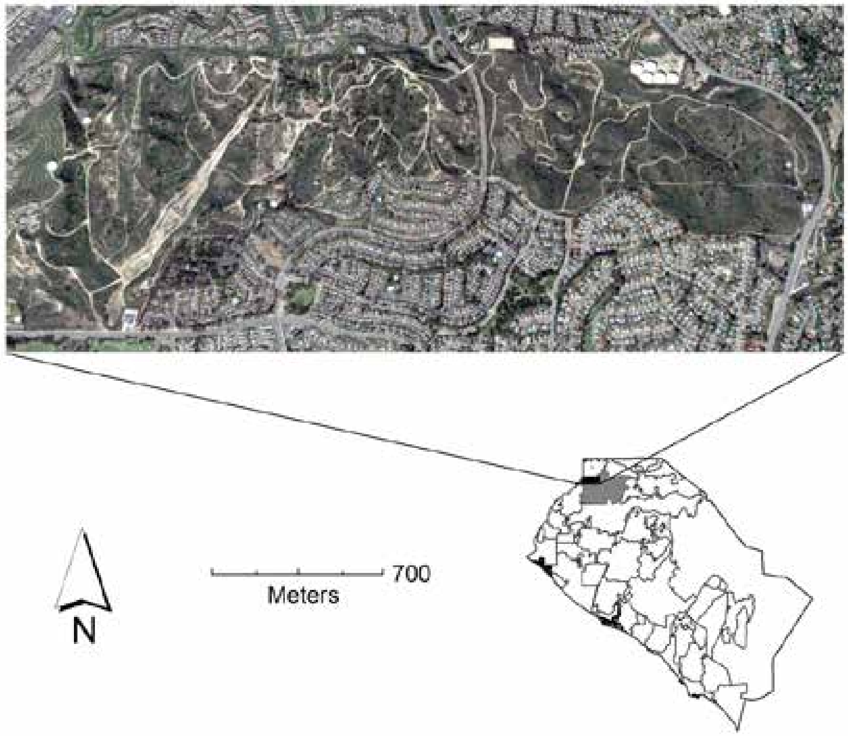

Figure 1.—Map displaying the West Coyote Hills (Google Earth Image 3/7/2011), located in the city of Fullerton, Orange County, CA.

homes will be single-family, attached units (Figure 2). There is also a plan for a commercial center, recreational areas, and open space. The proposed development also includes 29.3 ha of the Robert E. Ward Nature Preserve, which is part of the WCH (Keeton Kreitzer Consulting 2006).

The area has not been incorporated in the Natural Community Conservation Program or any type of habitat conservation plans by the Federal Endangered Species Act (FESA). However, the U.S. Fish and Wildlife Service has been in negotiations over this property due to its identification as a critical habitat for California gnatcatchers (Dudek and Associates Inc. 2003). The California gnatcatcher is one of the species included in the FESA, and thus 25.9 ha of this study site has been designated for this species.

Typical to Mediterranean climates, the study area has dry, hot summers, with most rainfall occurring in the mild winter months. The study area receives about 340 mm of precipitation per year, mostly

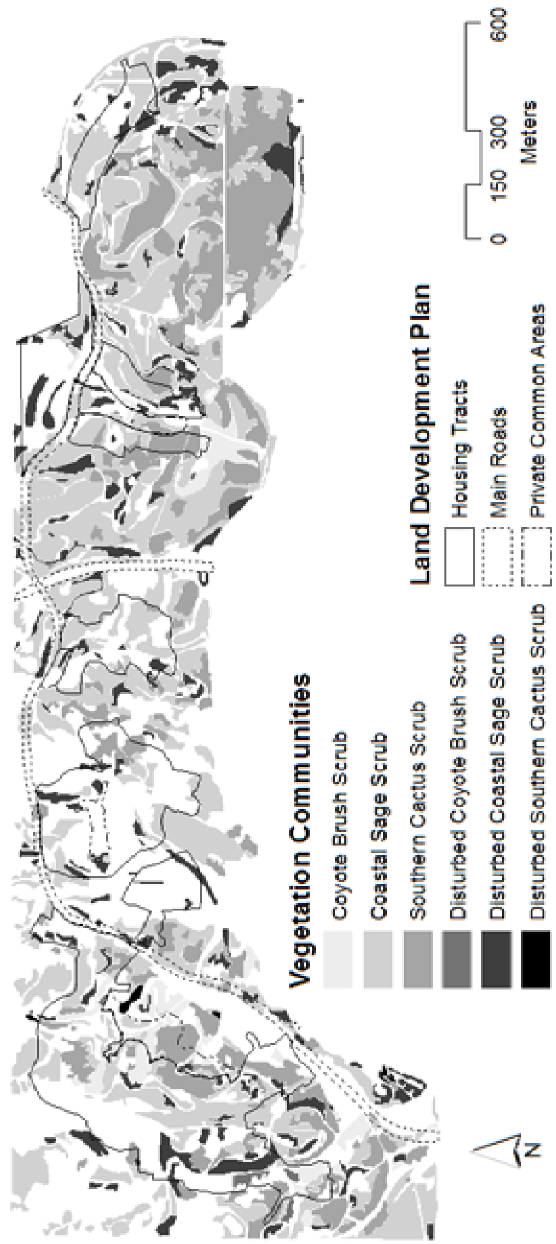

Figure 2.—Vegetation communities of the West Coyote Hills and the proposed land-development plan. Both were digitized and classified from the data in the 2008 Recirculated Revised Draft Environmental Impact Report (Keeton Kreitzer Consulting 2008).

as rainfall from north Pacific storms. In the summer, temperature characteristically ranges from 10 to 31°C, with occasional days surpassing 38°C. The winter high temperature ranges from 10 to 21°C, and the winter low temperature ranges from -1 to 10°C, with a no-frost period of approximately 220 to 300 days per year. The winds in the area alternate from strong spring and fall coastal winds to dry, hot, eastern Santa Ana winds at the end of fall and early winter.

Data and Methods

Vegetation and Land Development Maps

The main data used in this study were a vegetation community's map and a map of the proposed land development from the 2008 Recirculated Revised Draft Environmental Impact Report (RRDEIR) (Keeton Kreitzer Consulting 2008) (Figure 2). A second vegetation community's map was developed for the area under the scenarios of the proposed land development.

The biological resources documented in the Environmental Impact Report (EIR) were recorded from a literature review, field reconnaissance, unofficial consultation with species experts from the U.S. Fish and Wildlife Service, California Department of Fish and Game, U.S. Forest Service, TW Biological Service, and Dudek and Associates, Inc. Field reconnaissance started in 1992 and was completed by Dudek and Associates, Inc. (2003) in the 2003 EIR. The Dudek biologists visited the site around 220 times to monitor maintenance procedures and field closures, and they mapped the change of vegetation communities from February 1994 to July 2003. In June of 2003, the biological consultant of the City of Fullerton peer-reviewed the vegetation map and confirmed it was accurate. Due to no recent impact from oil-field closures, the vegetation map has not been revised in 2008 RRDEIR.

The vegetation classifications used in this study for reporting the plant communities were based on Holland (1986). Seventeen vegetation communities were documented with the total area coverage of 131 ha. However, only six types were recorded on the map, due to their significance. They are coastal sage scrub (CSS), disturbed coastal sage scrub (dCSS), southern cactus scrub, disturbed southern cactus scrub, coyote brush scrub, and disturbed coyote brush scrub. Both CSS and dCSS were evaluated in this study, due to their abundance and endangered status. A large portion of the study site supports CSS (74.2 ha) and dCSS (15.8 ha). The vegetation mostly consists of California sagebrush (*Artemesia californica*), smaller amounts of flat-top buckwheat (*Eriogonum fasciculatum*), white sage (*Salvia apiana*), bush monkey-flower (*Mimulus aurantiacus*), poison oak (*Toxicodendron diversilobum*), and Mexican elderberry (*Sambucus mexicana*).

Map Digitization and Georeferencing

Both the vegetation community's map and the proposed land-development map were digitized and georeferenced. The finalized vegetation map was added as a layer on a 2008 Google Earth image (August 27, 2008), concurrent with the RRDEIR, and every vegetation community was digitized and converted to polygons. The proposed land-development map was also overlaid on the same Google Earth image, and then digitized as a second polygon layer. The polygon layers for the vegetation communities and land development were saved as the Google Earth KMZ files, which were then converted to GIS shapefiles separately with Quantum GIS 1.8.0.

To develop a second layer for vegetation communities under scenarios of the proposed land development, vegetation communities that interfered with the proposed development layer were removed. The vector data for the vegetation communities were selected within the development vector data by location in ArcGIS 10.0. The vegetation layer was the selected feature for the target layer, while the development layer was the source layer. The chosen method for spatial selection was "target layer(s) features intersect the source layer." Basically, all of the vegetation communities that overlap the proposed development were selected. The selected vegetation communities were then deleted from the map with the editor tool. The updated vector data displayed the remaining vegetation communities after the proposed land development.

The polygon vector data for the vegetation communities before and after the proposed development were converted to raster data with 1 m spatial resolution and the UTM projection. The raster data contained 3,337 columns and 1,188 rows and were used as input grids in FRAGSTATS (version 4), a spatial pattern-analysis program for categorical maps (McGarigal, Cushman, and Ene 2012), for the vegetation communities before and after the proposed land development, respectively.

Selected Landscape Metrics

FRAGSTATS uses landscape metrics to quantify landscape composition and spatial configuration (McGarigal, Cushman, and Ene 2012).

Landscape composition refers to the abundance and the variety of different patch types, while landscape configuration provides information about the spatial characteristics, arrangement, orientation, or position of patches within a land-cover class or the entire landscape mosaic (Leitao et al. 2006). Both landscape composition and configuration were quantified in this study because both are important to the understanding of ecological processes, interactively and independently.

Landscape metrics describe the spatial structure of habitat patches, patches in each class, and patch mosaics as a whole (Leitao et al. 2006). Three levels of landscape metrics were used to quantify landscape composition and spatial characteristics of CSS and dCSS patches before and after the proposed land development. Landscape level metrics were calculated for the entire WCH, since the WCH as a whole can be considered one habitat patch with dispersed scrub vegetation. The selected landscape-level metrics for quantifying landscape composition included total area (TA), number of patches (NP), largest patch index (LPI), and Simpson's diversity index (SIDI). The selected metrics for quantifying landscape configuration included total edge (TE), mean patch area (AREA_MN), area-weighted mean patch area (AREA_AM), median patch area (AREA_MD), range in patch area (AREA_RA), standard deviation of patch area (AREA_SD), coefficient variance of patch area (AREA_CV), mean patch area radius of gyration (GYRATE_MN), area-weighted mean patch radius of gyration (GYRATE_AM), mean similarity index (SIMI_MN), and area-weighted mean similarity index (SIMI_AM) (McGarigal, Cushman, and Ene 2012).

At the class level, the collective properties of all the patches belonging to CSS and dCSS were determined. The selected class level metrics were nearly the same as those at the landscape level. The composition metrics included class area (CA), percentage of land (PLAND), NP, and LPI. The configuration metrics included TE, AREA_MN, AREA_AM, AREA_MD, AREA_RA, AREA_SD, AREA_CV, GYRATE_MN, GYRATE_AM, SIMI_MN, and SIMI_AM.

At the patch level, only CSS patches were estimated for this study. The AREA metric was used to identify patches that were larger than or equal to 1 ha before and after the proposed land development. The purpose was to determine how many large individual CSS patches were able to maintain their coverage after the proposed development because of the species reliance on native vegetation and space for survival and persistence.

Results and Discussion

Landscape-Level Changes

After the proposed land development, many vegetation patches would be reduced in size or completely lost to development, although all six vegetation classes would remain. The landscape-level composition metrics showed a great loss in scrub vegetation after the development. Both TA and NP would be significantly reduced (Table 1). TA would lose about 70 ha, and NP would lose 213. Because of the significant loss in habitat area coverage and the disproportionate alteration of the size of patches covering the landscape, LPI would increase from 8.53% to 10.77%, and the patch type diversity, estimated by SIDI, would increase slightly by 0.03.

Table 1: Landscape-level composition metrics, before and after the proposed land development.*

LANDSCAPE METRICS	BEFORE	AFTER
TA (ha)	130.95	61.40
NP	484	271
LPI (%)	8.53	10.77
SIDI	0.59	0.62

*****_TA, NP, LPI, and SIDI refer to total area, number of patches, largest patch index, and Simpson's diversity index, respectively._

Variable changes were found in the landscape-level configuration metrics. Patch TE would decrease significantly by 170,128 m due to the loss of TA (Table 2). After the proposed land development, patches would be reduced in size across the landscape, as indicated by the first-order statistics for AREA. AREA_MN, AREA_AM, and AREA_MD would decrease by 0.05 ha, 0.75 ha, and 0.02 ha, respectively. These decreases displayed potential habitat loss and increased fragmentation, post-development.

The second-order statistics also demonstrated a decrease in patch variability. After the proposed land development, many large patches would disappear or be reduced in size. AREA_RA, AREA_SD, and AREA_CV would decrease by 4.56 ha, 0.2 ha, and 31.98%, respec-

Table 2: Landscape-level configuration metrics, before and after the proposed land development.*

LANDSCAPE METRICS	BEFORE	AFTER
TE (m)	174,968	4,840
AREA_MN (ha)	0.27	0.22
AREA_AM (ha)	2.11	1.36
AREA_MD (ha)	0.10	0.08
AREA_RA (ha)	11.17	6.61
AREA_SD (ha)	0.70	0.50
AREA_CV (%)	259.25	227.27
GYRATE_MN (m)	22.19	20.45
GYRATE_AM (m)	63.10	53.34
SIMI_MN	6,842.55	4,400.96
SIMI_AM	12,215.83	9,120.11

**TE, AREA, GYRATE, and SIMI refer to total edge, patch area, patch radius of gyration, and similarity index, with a search radius of 50 m and a similarity weight of 0.5, respectively. MN, AM, MD, RA, SD, and CV refer to mean, area-weighted mean, median, range, standard deviation, and coefficient variance, respectively.*

tively. The large values of these configuration metrics showed high variability and heterogeneity of the landscape.

The mean and area-weighted mean for GYRATE and SIMI would also decrease in value after the proposed land development. GYRATE_MN and GYRATE_AM would decrease by 1.74 m and 9.76 m, respectively, while GYRATE_AM is a more accurate index representing the average traversability of the landscape, due to the high probability of wildlife inhabiting larger patches. The potential loss of landscape connectivity was shown in the results of SIMI. With a search radius of 50 m and a similarity weight of 0.5, SIMI_MN and SIMI_AM would decrease by 2,441.59 and 3,095.72, respectively. Changes in both GYRATE and SIMI indicated less continuity and more fragmentation in patch distribution across the landscape after the proposed land development.

Table 3: Class-level metrics for coastal sage scrub before and after the proposed land development.*

CLASS METRICS	BEFORE	AFTER
CA (ha)	74.18	28.81
NP	189	105
LPI (%)	8.53	3.88
PLAND (%)	56.65	46.92
TE (m)	95,578	4,243
AREA_MN (ha)	0.39	0.27
AREA_AM (ha)	2.75	0.91
AREA_MD (ha)	0.14	0.11
AREA_RA (ha)	11.17	2.38
AREA_SD (ha)	0.96	0.41
AREA_CV (%)	245.13	152.54
GYRATE_MN (m)	27.31	24.29
GYRATE_AM (m)	74.31	50.14
SIMI_MN	4,569.62	5,825.49
SIMI_AM	10,161.77	8,055.38

**CA, NP, LPI, PLAND, TE, AREA, GYRATE, and SIMI refer to class area, number of patches, largest patch index, percentage of land, total edge, patch area, patch radius of gyration, and similarity index, with a search radius of 50 m and a similarity weight of 0.5, respectively. MN, AM, MD, RA, SD, and CV refer to mean, area-weighted mean, median, range, standard deviation, and coefficient variance, respectively.*

Class-Level Changes

Changes of Coastal Sage Scrub

As the vegetation matrix for this study area, CSS currently covers 57% of the landscape (PLAND) with the largest CA, the highest NP, and the greatest amount of TE among the six vegetation classes (Table 3). However, after the proposed land development, the results showed a great amount of habitat loss. A vegetation matrix would no longer be present due to the PLAND of CSS being reduced below 50%. CA, NP, and TE would be reduced correspondingly by 45.37 ha, 84, and 91,335 m, respectively. With only 28.81 ha of CSS remaining and fragmented, this amount of vegetation probably will not be large enough to support native vertebrate species for more than a few decades in arid habitats (Soule, Alberts, and Bolger 1992).

In addition to the considerable reduction of CSS composition, the spatial configuration of CSS was found to be changed as well. As quantified by LPI, the percentage of total landscape area comprised by the largest patch would decrease from 8.53% to 3.88%. Thus the decline in CSS patch dominance is expected. In fact, all of the CSS patches would become smaller and closer in size, post proposed development, as indicated by the first- and second-order statistics of AREA. Before the proposed land development, AREA_AM is 2.36 ha greater than AREA_MN and 2.61 ha greater than AREA_MD. This means there are many small CSS patches that were factored into the calculation of AREA_MN and AREA_MD. After the proposed development, AREA_MN and AREA_MD would be reduced slightly by 0.12 ha and 0.03 ha, respectively. But the AREA_AM would be reduced significantly by 1.84 ha due to the decrease of LPI. Thus the differences between AREA_AM and AREA_MN or AREA_MD would be only 0.64 ha and 0.8 ha, respectively.

The same trend of change was shown in the significant reduction of AREA_RA, AREA_SD, and AREA_CV. CSS currently has the largest AREA_RA and is the most variable vegetation class in size as indicated by the large values of AREA_SD and AREA_CV. However, after the proposed development, AREA_RA, AREA_SD, and AREA_CV would be reduced significantly by 8.79 ha, 0.55ha, and 92.59%, respectively. The estimates of the radius of gyration and similarity index showed that the reduced CSS patches would also become further dispersed and isolated. After the proposed land development, GYRATE_AM and SIMI_AM would decrease by 24.17 m and 2,106.39, respectively.

Changes of Disturbed Coastal Sage Scrub

Disturbed coastal sage scrub covers only about 12% of the landscape, which is much smaller than that of CSS (i.e., 57%) (Table 4). But dCSS has almost as many patches as CSS, though the patches were not significant in size, as indicated by NP and AREA. After the proposed land development, dCSS would be reduced by 8.82 ha and lose 78 NP.

With the decrease of area coverage of dCSS, TE would decrease by 34,287 m but LPI would increase by 0.7% because most patches lost in the development will be relatively small in size. As a result, after the proposed development, AREA_MN would be reduced only slightly, by 0.01ha, and AREA_AM and AREA_MD would stay the same. No or little change was also observed in the second-order statistics for AREA. AREA_RA and AREA_SD would not change, while AREA_CV would increase only slightly. These insignificant alterations of the spatial configuration of dCSS indicated that in comparison to CSS, dCSS would not change much in patch size distribution.

GYRATE metrics showed that the dCSS patch extent would not change much, as well. After the proposed development, GYRATE _MN and GYRATE_AM would be reduced by only 1.13 m and 1.52 m, respectively. However, from the landscape mosaic perspective, dCSS patches would become more isolated, as indicated by SIMI.

Table 4: Class-level metrics for disturbed coastal sage scrub before and after the proposed land development.*

CLASS METRICS	BEFORE	AFTER
CA (ha)	15.8	6.98
NP	155	77
LPI (%)	0.62	1.32
PLAND (%)	12.06	11.38
TE (m)	35,094	807
AREA_MN (ha)	0.1	0.09
AREA_AM (ha)	0.23	0.23
AREA_MD (ha)	0.06	0.06
AREA_RA (ha)	0.81	0.81
AREA_SD (ha)	0.11	0.11
AREA_CV (%)	113.06	125.46
GYRATE_MN (m)	16	14.87
GYRATE_AM (m)	25.66	24.14
SIMI_MN	7,502.73	3,126.62
SIMI_AM	9,223.1	7,252.07

**CA, NP, LPI, PLAND, TE, AREA, GYRATE, and SIMI refer to class area, number of patches, largest patch index, percentage of land, total edge, patch area, patch radius of gyration, and similarity index, with a search radius of 50 m and a similarity weight of 0.5, respectively. MN, AM, MD, RA, SD, and CV refer to mean, area-weighted mean, median, range, standard deviation, and coefficient variance, respectively.*

SIMI_MN and SIMI_AM would decrease by 4,376.11 and 1,971.03, respectively, after the proposed development.

Patch-Level Changes

The results showed significant decline in CSS patch dominance (Table 5). However, it was difficult to quantify how each patch would change, because there was no correspondence between patch identification numbers in FRAGSTATS outputs between before and after the proposed land development.

Table 5: Patch Identification (PID) for large coastal sage scrub (CSS) patches (patch area ≥ 1ha), before and after the proposed land development.

CSS BEFORE DEVELOPMENT		CSS AFTER DEVELOPMENT	
PID	AREA (ha)	PID	AREA (ha)
1	1.25	1	1.25
9	11.17	59	1.87
47	1.98	84	2.19
65	1.69	112	2.38
91	1.60	246	1.60
116	1.15		
131	3.68		
144	3.55		
151	2.93		
181	1.94		
202	2.14		
248	2.27		
250	1.20		
456	1.60		

Currently, CSS contains 189 habitat patches (Table 3), among which 13 habitat patches are over one ha (Table 5). After the proposed development, 105 CSS patches would remain, but only five patches would remain over one ha. For these five patches, only two patches would not be altered in size after the proposed land development and three would be reduced from existing larger patches. For instance, the present largest CSS patch would be reduced from 11.17 ha to 2.38 ha after the proposed development.

Conclusions

Surrounded by densely populated urban matrix, the West Coyote Hills is the last habitat remnant in northern Orange County, California. We evaluated the potential impact of the proposed land development on the remaining habitat at the landscape, class, and patch levels. Various possible changes were revealed in landscape composition and spatial configuration.

At the landscape level, if the study area were to be developed, the landscape would become highly fragmented, with a great amount of loss of scrub vegetation. More than 53% of habitat area and more than 44% of habitat patches would be lost after the proposed land development. The remaining patches would become smaller, more uniform in size, more isolated, and less contiguous. Thus, the similarity between the patches and the allowable distance for organisms to travel within the patches would decrease, and the habitat corridors could be disturbed due to the land development.

At the class and patch levels, for the 131 ha of scrub vegetation in 484 patches, CSS and dCSS contain the most patches. CSS covers 74 ha in 189 patches, and dCSS covers 16 ha in 155 patches. After the proposed land development, CSS and dCSS would lose 61% and 56% of the coverage, respectively. A vegetation matrix would not be present within the urban matrix of northern Orange County.

The results indicated that the changes of the CSS landscape composition and spatial configuration would be particularly significant. After the proposed development, 84 CSS vegetation patches (45 ha) would be completely lost and many large patches would be reduced. The remaining CSS patches would become further fragmented and isolated. Thus, there is a high probability that the CSS would slowly transform into dCSS.

With lesser area coverage and a high number of patches, dCSS patches are already highly fragmented and much smaller than CSS. With the proposed land development, although the changes in dCSS patch extent and patch size distribution would be insignificant, a great amount of dCSS vegetation could be lost and the connectivity between the patches would be further reduced. Thus, the remaining dCSS vegetation would be less likely to be restored after the proposed land development.

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