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RESEARCH ARTICLE

A Conservation Design for the Central Coast of California and the Evaluation of Mountain Lion as an Umbrella Species

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ABSTRACT: Conservation planners use several methods to select conservation target areas. These include the use of umbrella species for large area requirements, site-specific locations of important biodiversity elements, and indications of ecosystem health. We tested the adequacy of using an umbrella species to represent finer-scale biodiversity elements on 45,205 km^2 of the central coast of California. A network of core and linkages for mountain lion (*Puma concolor* [Kerr]) was developed and 22,069 km^2, or 49% of the region, was selected. We analyzed network representation of a variety of biodiversity elements. The conservation network contained between 8% and 27% of five different endangered species locations in the region. It captured 77% of mapped serpentine rock, a surrogate for rare plants, 88% of the old-growth redwood (*Sequoia sempervirens* [(D. Don) Endl.]), 55% of the The Nature Conservancy conservation portfolio areas, a surrogate for biodiversity, a majority of three types of oak woodlands, and 79% of the watersheds with extant steelhead (*Oncorhynchus mykiss)* populations. The mountain lion network more than proportionally represented most of the biodiversity elements examined. However, endemic amphibian, reptile, and mammal populations were less than proportionally represented, suggesting the need for testing levels of biodiversity representation in conservation designs that are based on carnivore habitat. We discuss implications for conservation plans based on this approach, and the potential synergies of linking aquatic health assessments with terrestrial umbrella species for conservation planning. Finally, we discuss the rankings of cores and corridors in the region.

Index terms: regional conservation plan, representation analysis, umbrella species

INTRODUCTION

The central coast of California is a mixed region, with large urban populations, extensive agriculture, and relatively pristine natural areas. It is 75% privately held (Davis et al. 1998) and 6.9 million people live in the region (U.S. Census Bureau 2000). Projected population growth is 26%, to 8.7 million, by 2020 (California Dept. of Finance 1998). Increasing habitat fragmentation due to urban development (Noss and Cooperrider 1994, Stoms 2000), road building (Forman and Alexander 1998), and agriculture (Brooks et al. 1999, Merenlender 2000) is expected to negatively impact the natural environment. The need for a long-term blueprint for conservation and restoration for the area is similar to the needs of California as a whole, and is recognized by agency scientists and academics (Penrod et al. 2000, Pollack 2001, Thorne et al. 2002). We developed a replicable conservation network design (Noss and Soulé 1999, Margules and Pressey 2000, Noss 2003), intended as the first step in the iterative regional conservation design process (e.g., Hoctor et al. 2000).

The conservation network used mapped favorable mountain lion habitat to select large core areas for an umbrella species (in the sense of Beier 1993, Noss and Cooperrider 1994, Carroll et al. 2001). Habitat linkages are an important component of conservation design (Beier and Noss 1998, Carroll et al. 2004). Therefore, the core areas were analyzed for their most efficient inter-connections (here called habitat linkages) using a least cost path analysis (Wikramanayake et al. 2004), which integrated least distance, best habitat, and lowest road density.

The assumption, using umbrella species' needs as the basis for a conservation design effectively incorporates other biodiversity elements in proposed protected areas, is still being evaluated (see Chase et al. 2000 for small mammals, Carroll et al. 2001 for carnivore representation, Roberge and Anglelstam 2004 for a review). We tested our core/habitat linkage network for representation of other biodiversity elements, including five endangered terrestrial vertebrates (California Dept. Fish and Game 2001b): the (1) California tiger salamander (*Ambystoma californiense* [Gray]), (2) California red-legged frog (*Rana aurora draytonii* [Baird and Girard]), (3) blunt nosed leopard lizard (*Gambelia sila* [Baird and Girard]), (4) giant kangaroo rat (*Dipodomys ingens* [Merriam]) and (5) San Joaquin kit fox (*Vulpes macrotis mutica* [Merriam]). We tested representation of serpentine outcrops as surrogates for rare and endemic plants, The Nature Conservancy portfolio conservation areas (TNC PCA), which were originally identified to represent the region's terrestrial and aquatic biodiversity, and a variety of vegetation types, including old-growth redwood (*Sequoia sempervirens* [(D. Don) Endl.]) stands.

Opinion on the effectiveness of using umbrella species in conservation planning is mixed (Lambeck 1997, Simberloff 1998, Andelman and Fagan 2000, Fleishman et al. 2001, Roberge and Angelman 2004). Our results illustrate the strengths of this approach, inherent limitations due to the availability of spatial data, and the differences in conservation challenges for core and habitat linkages. We also present descriptions of identified risks to each core and habitat linkage as observed in the field, and discuss implementation strategies for a region where land ownership is mostly private.

Study Area

The study area occupies 45,205 km^2 (12.2%) of California extending along the central Coast Ranges from San Francisco to Santa Barbara (Figure 1). The region has a Mediterranean climate with rainfall ranging from 33 cm/year in the interior to 229 cm/year on the coast. Coastal fog influences coastal vegetation (Henson and Usner 1993, Dawson 1998). Prominent geographic features include the Transverse Ranges, the Big Sur region (Santa Lucia Mountains), the agricultural Salinas River valley, the Santa Cruz Mountains, and northern and southern interior Coast Ranges (Figure 2).

The California Gap Analysis (Davis et al. 1998) identified three regionally dominant vegetation types: (1) interior chaparral (26% of the region); (2) oak forests, woodlands, and savannas (15%); and (3) nonnative grasslands (24%). Other vegetation types of conservation concern in the region include coast chaparral (~1%), mixed evergreen and bay forests (4%), redwood forests (<2%), riparian habitats (<0.5%), and wetland habitats (<0.2).

Approximately 75% of the region is private land. Public lands are held under a variety of agencies. The U.S. Forest Service (USFS) manages 11.6%, the Bureau of Land Management (BLM) 4.2%, military bases 3.2%, and state and county agencies 4.7% (Figure 3, Davis et al. 1998). Designated wilderness areas occupy 3268 km^2, or about 6% of the region (Davis et al. 1998). About 19% of the region has been converted to human uses (Davis et al. 1998, Vogelmann et al. 2001).

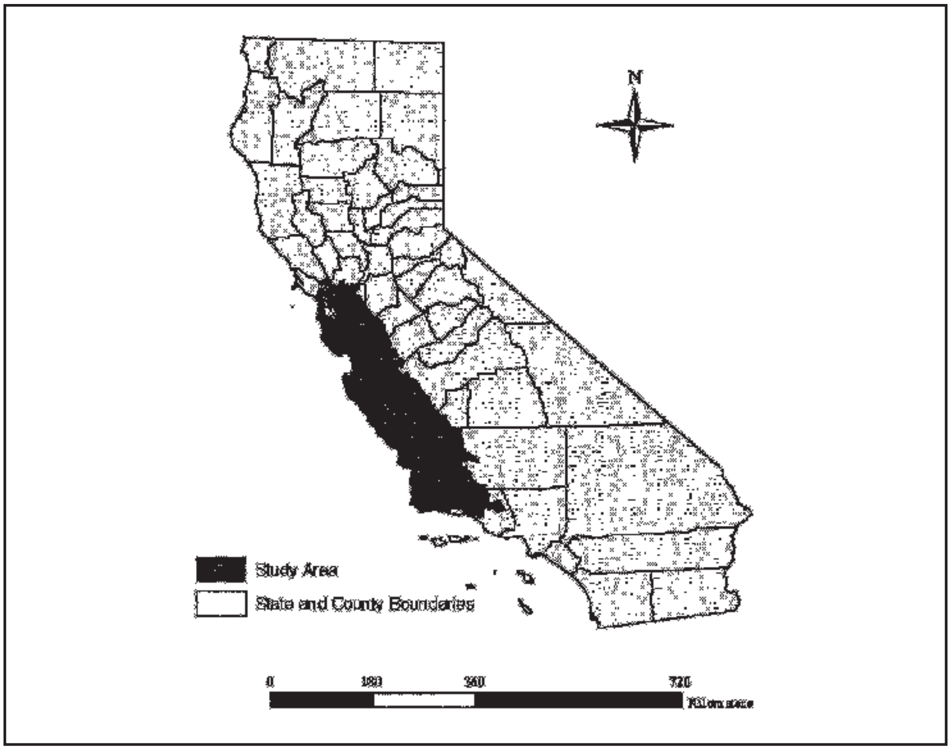

Figure 1. Study area map. This map shows the extent of California's central coast included in the study.

The San Francisco Bay (S.F. Bay) area is the largest urban area in the study area. Other urban areas include San Luis Obispo, Arroyo Grande, Salinas, Santa Maria, and the growing towns on the Monterey Peninsula and Monterey Bay shore. Commercial agriculture, vineyards, and ranching are the dominant activities outside urban areas.

Selection of Mountain Lion as a Focal Species

We selected the mountain lion (*Puma concolor* [Kerr]) as the primary focal species because of its large area requirements, its need for buffering from human interactions, and its potential to be an umbrella species (Noss and Cooperrider 1994, Torres and Lupo 2000). Mountain lions are sensitive to human activities (Torres et al. 1996) and habitat fragmentation (Crooks 2001), and tend to avoid areas of high human population density (Beier 1995).

Mountain lion is a wide-ranging species. They are found throughout the state, but are most abundant where there are high numbers of deer and enough cover for hunting. An adult male's home range is often over 260 km^2 (100 square miles); female home ranges are smaller. Mountain lion densities vary, with high densities around 10 adults per 260 km^2 in areas with high deer concentrations, to one adult per 2600 km^2 in desert regions (Torres and Bleich 2000).

Mountain lions can reproduce at any time of year, producing litters of 2-4 cubs. The young disperse to establish their own home ranges (Torres and Bleich 2000, California Dept. Fish and Game 2001a). Dispersal helps maintain stability in mountain lion populations because local population recruitment occurs by juvenile immigration (Seidensticker et al. 1973). Beier (1995) found dispersing mountain lions will use corridors located along natural travel routes that have ample woody cover, incorporate road crossings at high-speed roads, lack artificial outdoor lighting, and have low

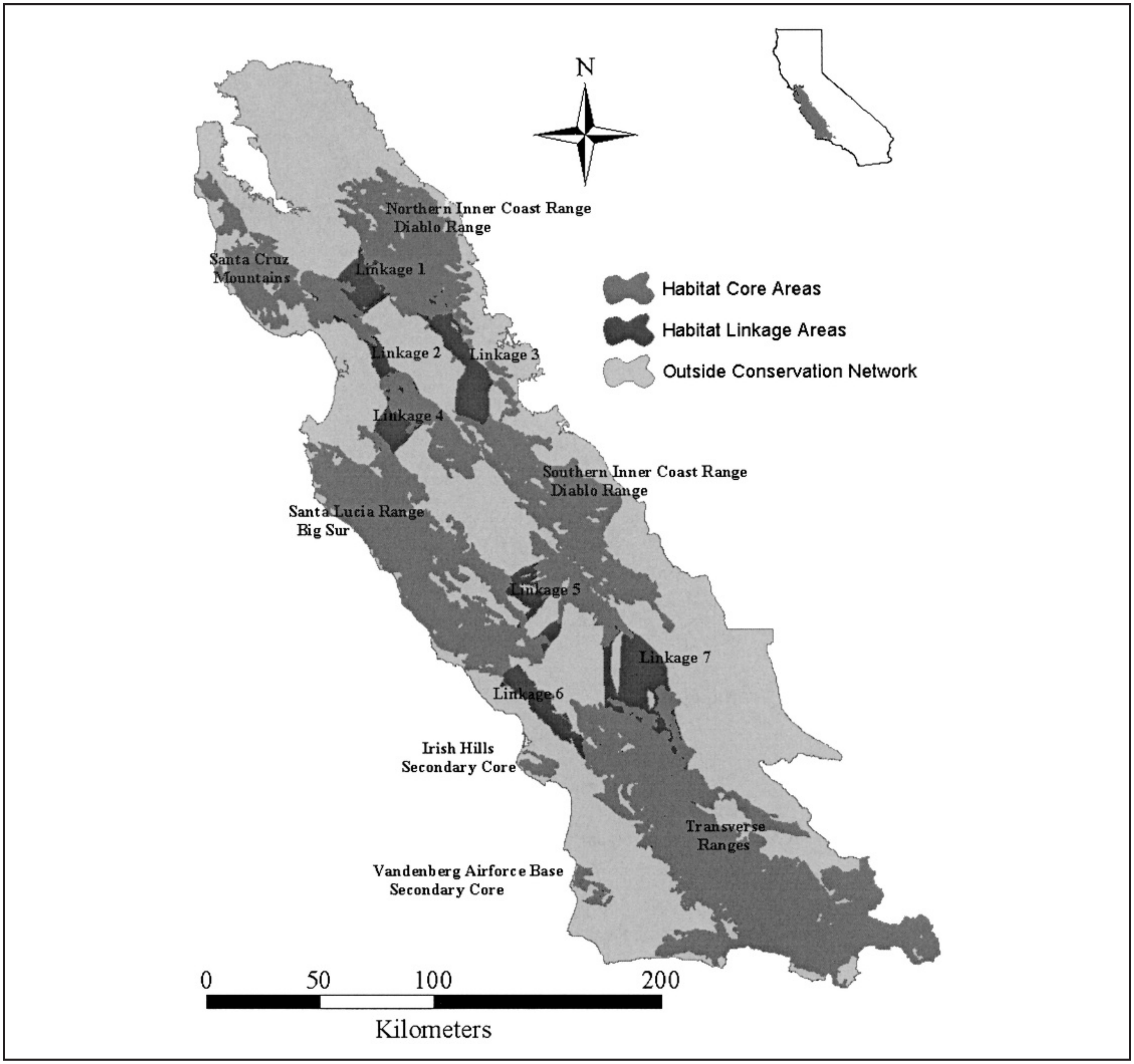

Figure 2. Map of the conservation network design for the central coast of California. The grey areas represent cores, the black areas the habitat linkages, and the light colored areas are outside the conservation network. Labels are referred to in the text.

human population density. This dispersal behavior makes the mountain lion an appropriate species for habitat linkage design.

Habitat fragmentation is a concern for mountain lion populations in rapidly growing areas (Beier 1993, Torres and Lupo 2000, Hunter et al. 2003). Human activities in the study area are fragmenting once-continuous mountain lion habitat and limiting their movement (Hopkins 1989), indicating the need for a regional conservation plan. Fragmented habitats undoubtedly increase lion mortality through direct interactions with people, roads, toxins, and other related risks. Protection and restoration of habitat linkages between mountain lion populations is one objective of a number of conservation organizations (Hunter et al. 2003).

METHODS

The study area is defined by the central coast region in the California flora (Hickman 1993). Watersheds not completely included in the flora were added in their entirety using the California Watershed Map (California Department of Fish and Game 1999). East draining watersheds were restricted to those parts above the

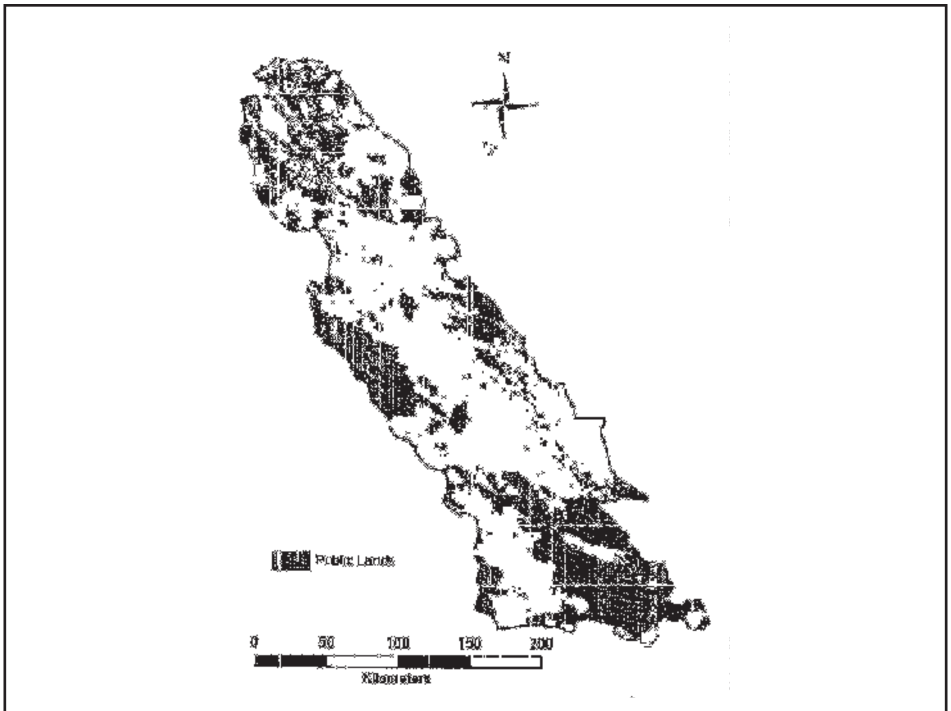

Figure 3. Map of public lands in the study area. This map shows all public lands, including military bases, national forests, state parks, and county parks.

San Joaquin valley floor.

Study Framework – Map Data

Maps used were the: (1) California Gap Analysis vegetation map (Davis et al. 1998), (2) USGS National Land Cover Database (NLCD, Vogelmann et al. 2001) for modeling mountain lion habitat, and (3) Hardwoods Vegetation Map (Pillsbury 1991, California Department of Forestry and Fire Protection 1994) for habitat representation. Species locality records came from the California Natural Diversity Database (CNDDB, California Department of Fish and Game 2000, Bittman 2001), serpentine rock locations were extracted from the statewide geology layer (California Department of Mines and Geology 2000), and steelhead (*Oncorhynchus mykiss*) population condition records (by watershed) were derived from a compilation of State Fish and Game reports (Titus et al., in press). Land management status came from the California Gap Analysis (Davis et al. 1998). We also used locations of TNC PCAs (The Nature Conservancy, unpubl. data) and old growth redwood maps (Pacific Biodiversity Institute, unpubl. data; Singer, unpubl. data).

Select Core Areas for Mountain Lion

Our selected minimum core size was 40,460 ha. This is below the estimated 220,000 ha minimum size core area for a self-sustaining mountain lion population (Beier 1993), but captures some of the relatively undeveloped tracts of land left in the study area, which may be high in deer density and support more lions (Bleich and Taylor 1998). Five cores were identified; two additional, smaller core areas were added later because they represent high quality habitat areas that fell outside the network of large of habitat cores. Core areas are composed of a combination of Gap Analysis vegetation types and NLCD classes whose habitat suitability rankings using the California Wildlife Habitat Relationship (CWHR) classification identify suitable habitat for mountain lions (California Department Fish and Game 2001a).

Least Cost Path Analysis to Identify Potential Habitat Linkages

We used a least cost path analysis (Walker and Craighead 1997, ESRI 1999, Wikramanayake 2004) to model potential habitat linkages between cores. This analysis created a cumulative cost surface, incorporating factors related to distance, habitat quality, road density, and forest cover. Cost in this sense refers to the cumulative friction or resistance to animal movement presented by landscapes of increasing fragmentation and human use. The algorithm identified the area connecting two cores with the least distance, fewest roads, and best habitat. Each identified linkage is not a linear path, but an area of potential permeability for mountain lions. "High cost" areas such as human development, roads, and agriculture negatively influence animal movement; "low cost" areas are comprised of high quality habitat.

Each core was labeled as a source – to or from which a least cost path analysis was made. Core choice defined the assumed origin and destination of the model animal. We modeled habitat linkages between the five large cores. Linkages to the small cores were not included in the network because they occupied far more space than the small cores themselves, which we thought would suggest unrealistic policy scenarios.

Vegetation/Habitat Cost Model

The model assumes mountain lions prefer habitat with few roads and high forest cover. We used CWHR habitat classifications of the California GAP vegetation map to create the cost surface. CWHR habitat values for each pixel were weighted (Table 1). The CWHR map was then refined with road density and forest cover data. All grids were scaled to 4 ha for the modeling, which got rid of high contrast edges from the original GAP polygons, and made the least cost path analysis perform better.

Road Impact Cost Grid

Road influences on mountain lions were weighted by class of road (Table 2). Trails and four-wheel drive roads received a weight of 1 rather than 0, as human access may influence mountain lion behavior. Using the weighted roads grid, we applied LINEDENSITY (ESRI 1999), which

Table 1. Mountain lion habitat suitability cost values, derived from the California Gap analysis. Increasing habitat value was assigned to decreasing cost value.

GAP/CWHR Value	Dispersal Cost Value	Mountain Lion Habitat Quality/Suitability
5	0	High
4	2	Medium to High
3	6	Low to High
1,2	9	Low
0	10	None

tallied the line length of all road classes within a search radius (500 m) and applies that value to the cell. LINEDENSITY was used to create the road cost grid: the more roads per cell, the higher the cell number. Output road grid costs were scaled to the range of the CWHR cost grid creating a road costs scale from 1-11.

Forest Cover Cost Grid

Mountain lions prefer coniferous, mixed, and deciduous tree vegetation types (California Dept. of Fish and Game 2001a). These were extracted from the NLCD map (Vogelmann et al. 2001) to create a new, 4 ha grid. We used these data to refine the CWHR habitat model, which was originated from the spatially coarser GAP vegetation map (Davis et al. 1998). Forest and woodland cover types were selected from the NLCD layer and assigned a cost value of 1, and non-forested areas were given a cost value of 6. The resulting two-class grid was smoothed using a spatial averaging filter to minimize the artificially high edge contrasts and approximate forest density.

Table 2. Road/trail classes and weights, derived from USGS digital line graphs (1:100,000). Road classes from Digital Line Graphs were translated into costs (weight column) which were applied in the least cost path analysis. Larger road features were assigned higher cost values, with divided roads' costs the highest at 8.

Road Class	Least Cost Model Weight	Description
10	6	Primary Route – Undivided
11	7	Primary Route – Divided by Centerline
12	8	Primary Route – Divided, Lanes Separated
20	4	Secondary Route – Undivided
22	5	Secondary Route – Divided, Lanes Separated
30	3	Thoroughfares, Couty Roads – Mostly Paved
40	2	Residential Roads, Unimproved, Unpaved
50	1	Trails
51	1	4WD Vehicle Trails
60	7	Interchanges
70	1	Other USGS Classification
80	1	Rest Areas
90	2	Caltrans Digitized (not many of these)

Compile Conservation Network Linkages

Each habitat linkage was defined separately. A source core and a target core were identified, and the least cost path analysis run between them. When all potential linkages were identified, they were combined with the cores to portray a regional conservation network.

Representation Analysis of Other Biodiversity Elements

The designed regional conservation network was used as a spatial template to assess conservation representation of other biodiversity elements. The distributions of selected habitat types and biodiversity elements were overlaid on the network, and the degree to which they fell within the conservation network was recorded. We present results for: (1) known populations of selected endangered species – California red-legged frog, California tiger salamander, blunt-nosed leopard lizard, giant kangaroo rat, and San Joaquin kit fox (California Department of Fish and Game 2001b); (2) serpentine rock locations as a surrogate for rare and endemic plants; (3) The Nature Conservancy Portfolio Conservation Areas as surrogate for biodiversity; (4) ranking of streams by steelhead population status; and (5) old-growth redwood stands and oak woodland types.

RESULTS

Area in Cores and Habitat Linkages

The total area selected for potential mountain lion habitat and linkages was 22,069 km^2 (49%) of the study area (Figure 2). Cores occupy 19,473 km^2. The seven habitat linkages cover 2,596 km^2.

The five primary cores are: the Santa Cruz Mountains 1524 km^2; the Santa Lucia and Transverse Ranges Cores (connected still by suitable habitat so lumped in area) 11,390 km^2; the northern Inner Coast ranges 2411 km^2; and the southern Inner Coast ranges 3922 km^2. Secondary Core areas measured 104 km^2 (the Irish Hills) and 122 km^2 (Vandenberg Air Force Base) (Figure 2).

Habitat linkages cover 2596 km^2. Habitat linkage areas are as follows: linkage one 316 km^2; linkage two 117 km^2; linkage three 585 km^2; linkage four 204 km^2; linkage five 312 km^2; linkage six 311 km^2; and linkage seven 750 km^2 (Figure 2).

Biodiversity Elements Represented in Conservation Network

The degree to which biodiversity elements are represented in the conservation network is summarized in Table 3. All five terrestrial vertebrates examined were less than proportionally represented. Biodiversity elements represented by TNC portfolio conservation areas were proportionally represented. Those represented by serpentine rock were more than proportionally represented; the network more than proportionally represented both healthy and degraded steelhead populations. Of the habitat types examined, the network did not proportionally represent Valley Oak Woodlands and Grasslands, but more than proportionally represented the other six habitat types. Lakes and urban areas were mostly excluded at 5.1% and 8% within the network.

DISCUSSION

Area Selected

Forty nine percent of the region was included in the area selected for the conservation network for mountain lions. This is likely more area than can be conserved, but we wanted a conservative design, selecting all areas of highest value to the mountain lion. The percent selected is similar to the amount identified for a multispecies conservation design for Florida (Hoctor et al. 2000) that was adopted for implementation. Carroll et al. (2004) suggest that preserving connectivity in the early phases of landscape degradation can be one of the most important contributions to the persistence of large carnivores – a condition applicable to parts of our study area.

Core Areas

The core areas represent the highest quality habitat and most contiguous landscape elements for mountain lion persistence and movement, but their boundaries are somewhat arbitrary, as often there were no clear breaks in habitat. The five main core areas give a sense of some of the conservation challenges facing each (Figure 2).

The Santa Cruz Mountains comprise the smallest of the main cores (1316 km^2), and is below Beier's (1993) estimated cut-off for viable mountain lion populations. It runs a high risk of isolation, as the Santa Clara Valley to the east is being rapidly developed. To the south, urban encroachment along U.S. H129 also threatens to isolate the core. This core contains a number of large state and county parks set in a matrix of increasingly dense rural housing. Connecting protected areas within the heart of the core would be a good step towards preserving it.

The Santa Lucia (Big Sur) and the Transverse Ranges to the south are the largest cores in the region. These cores are predominantly on state and federal lands and are in relatively pristine condition. The habitat linkage connecting them is mostly intact. These cores could be further protected by obtaining conservation easements on private lands adjoining the federal lands and by implementing appropriate resource management strategies on the Fort Hunter Liggett Military reservation.

The Northern and Southern Inner Coast Ranges are predominantly on private lands. These areas are mostly grazed lands in varying ecological condition. The area is generally rural and under less development pressure than the other regions, with the exception of the west side of the northern core, which borders the San Francisco Bay (S.F. Bay) area and the Santa Clara Valley. Conservation strategies for these areas could include obtaining development rights (conservation easements) on private land parcels closer to roads/urban areas, which could potentially help prevent urban development from spreading into the region.

Habitat Linkages

Habitat linkages significantly increased the area selected in our study because the least cost path algorithm selects a wide swath of area that met the selected criteria. Within these broad swaths, potentially successful inter-core dispersal is presumed higher. These linkage zones are priorities for conservation and further refinement and mapping, as they represent areas that will be lost to development sooner than most areas within the cores. The linkage extending south of the Santa Cruz Mountains is likely the most at risk, because the encroaching urban development from east and west have left only a narrow ridge still in native vegetation. The linkage connecting the Big Sur to the Transverse Ranges is the most critical, since it connects the largest protected habitats remaining and is experiencing fragmentation. Initiating conservation activities in the linkage will help maintain mountain lion population connectivity.

Representation of Other Biodiversity Elements

We measured network representation effectiveness by whether a proportional extent (49%) of each element was selected. More than proportional representation of a biodiversity element was considered successful representation.

Vegetation types were used to predict mountain lion habitat, so it is expected that woodlands and forests (including redwoods) would be well represented since those compose good habitat. Other species associated with woodlands and forests would therefore be expected to be well represented. Most oak tree species were well represented (Table 3), a positive factor, as they are an important wildlife food source (Block et al. 1990) and are candidates for conservation in California (Thomas 1997). However, valley oak (*Quercus*) woodlands, a very restricted type, were not proportionally represented. While present elsewhere in the state, this type is generally greatly reduced from its original extent.

Collection of unpublished distribution data for rare plants was beyond the scope

Table 3. Results of the Representation Analysis. This table shows the percentage of different elements of biodiversity that were found in the core regions, in the linkages, and outside of the conservation network. The four parts to the table represent: 1) Test focal species whose recorded populations were in the CNDDB database, 2) surrogate approaches to rare and endemic plants (serpentine geology) and biodiversity (TNC sites), 3) steelhead population status by watershed, and 4) habitat types as defined by vegetation.

Listed Endangered Species	Recorded Populations inRegion	Populations Represented in Cores	Percent in Cores	Populations in Linkages	Percent in Linkages	Populations not in Network	Percent not in Network
California Red-Legged Frog	702	156	22.2	36	5.1	510	72.6
California Tiger Salamander	520	73	14.0	44	8.5	403	77.5
Blunt Nosed Leopard Lizard	96	7	7.3	1	1.0	88	91.7
Giant Kangaroo Rat	48	6	12.5	1	2.1	41	85.4
San Joaquin Kit Fox	119	10	8.4	11	9.2	98	82.4
Biodiversity Elements	**Total km^2 in Region**	**km^2 in Cores**	**Percent in Cores**	**km^2 in Linkages**	**Percent in Linkages**	**km^2 not in Network**	**Percent not in Network**
Serpentine Rock	540.8	358.0	66.2	21.8	4.0	154.0	28.5
The Nature Conservancy selected areas	95.0	41.0	43.2	8.4	8.8	45.6	48.1
Percent Watersheds in Steelhead Database by Steelhead Population Status	**Total km^2 per Steelhead Population Status Class**	**km^2 in Cores**	**Percent in Cores**	**km^2 in Linkages**	**Percent in Linkages**	**km^2 not in Network**	**Percent not in Network**
4% present at historical levels (best remaining)	1258.6	972.3	77.3	13.3	1.0	273.0	21.7
63.24% present at reduced levels	19884.6	8903.6	44.8	1901.6	9.6	9079.4	45.7
12.1% present historically, current status unknown	3805.0	1584.3	41.6	580.5	15.3	1640.2	43.1
0.12% steelhead not present in known geologic history due to barrier at mouth	38.5	0	0	12.0	31.3	26.5	68.7
19.8% obstructed	6225.7	4497.2	72.2	417.2	6.7%	1311.3	21.1
7.31% historical and contemporary status unknown	230.0	69.2	30.1	2.3	1.0	158.4	68.9

continued

Table 3. Continued.

Selected Habitat Types	Total km^2 in Region	km^2 in Cores	Percent in Cores	km^2 in Linkages	Percent in Linkages	km^2 not in Network	Percent not in Network
Old Growth Redwood	129.7	113.2	87.3	1.2	0.9	15.4	11.9
Blue Oak Woodland	4419	2878	65.1	241	5.4	1300	29.4
Blue Oak / Foothill Pine	1638	1450	88.5	29	1.7	159	9.7
Coastal Oak Woodland	4243	2937	69.2	359	8.5	946	22.3
Valley Oak Woodland	209	152	72.7	7	15.3	43	20.5
Conifer vegetation type	1381	1191	86.2	20	1.4	170	12.3
Grass vegetation type	15291	3115	20.4	1537	10.1	10639	69.6
Shrub vegetation type	6647	5035	75.7	191	2.9	1421	21.4
Urban area	763	54	7.1	5	0.7	704	92.2

of this project, so we used representation of serpentine outcrops as a surrogate for some rare plant types, particularly since Kruckeberg (1984) identifies 64 endemic and 40 indicator plant species on serpentine in counties of the study area. Serpentine rock was well represented (70%), which was not expected, given that these vegetation types generally provide undesirable mountain lion habitat. Serpentine plant conservation challenges include off-road vehicle recreation at the largest serpentine outcrop in the region, New Idria.

Target listed species records were less than proportionally represented, ranging from 8% inclusion for blunt-nosed leopard lizards to 27% for California red-legged frog. This implies the umbrella species approach should be used in conjunction with other conservation planning approaches, corroborating multi-species conservation planning recommendations advocated by many conservationists (e.g., Lambeck 1997, Noss et al. 1997). The species records used represent the surveyed populations, reflecting the level of survey effort, which may not be complete. Surveys are often done in conjunction with planned development near existing roads and habitation, so survey data may also be more likely to be collected in locations we deem relatively unsuitable for the mountain lion.

TNC Conservation Portfolio Areas represent land identified in the 1997 Central Coast Ecoregional Plan to represent that region's biodiversity (The Nature Conservancy, unpubl. data). These areas were proportionally represented, at 52%. Grasslands are the largest vegetation type not represented in our network. TNC areas designated for grassland habitat were not selected using our method. While TNC conservation areas are proportionally represented, the area in their portfolio covers much less area than the conservation network proposed here. This is partly because the TNC ecoregional plan focused on identifying biodiversity on private lands and did not as intensively map resources on public land because of the lower threat of habitat loss. In this region (and many across the western United States), upland mountainous habitat is often in public land and lower elevation land is often private. Because the TNC portfolio focused on private land, the conservation areas are biased on lower elevations away from better mountain lion habitat in the foothills and mountains. The TNC PCAs are less extensive because they are not designed for maintaining landscape connectivity for wide-ranging species, for which our network is a first iteration.

High quality steelhead habitat was well represented in the network (78%), but only 4% of all streams in the region have steelhead runs equaling historic levels (Titus et al., in press). Many of the rivers that need fish habitat restoration are in potential habitat linkage areas, such as some streams in the agricultural Salinas Valley. Restoration of riparian vegetation along creeks that descend from the hills on either side of the valley and join at the main stem would be useful for steelhead habitat. It might also provide cover for dispersing mammals. Selecting riparian vegetation restoration efforts that facilitate linking one side of a valley to the other may increase the biological value of the restoration effort. This combination of conservation and restoration in a multi-species regional design is also an economic necessity, considering land values. This strategy could be applied to several areas in the study region, including small streams in the Santa Clara Valley.

Incorporation of an anadromous species in the regional design raised a discussion of preserving ecosystem functions on a landscape, something that can be done without actually acquiring lands. For example, if the restoration of good stream conditions for steelhead is begun in a watershed, this may involve restoration of riparian vegetation and a change in land use practices to minimize erosion. Such change in land use practice need not be done on public land. Zoning laws, tax incentives, conservation grants to farms and ranches, and other legal mechanisms can be used to encourage landowners to follow appropriate land use practices. Terrestrial species may be able to take advantage of these newly restored habitats. Integration of ecosystem process-based restoration practices with habitat-based conservation planning provides many possibilities.

Regional Boundaries

The study region boundaries are somewhat artificial when considering mountain lion habitat needs. To the south, suitable habitat extends beyond the areas in this study. Another conservation assessment using mountain lions has been developed for the southern coastal ecoregion of California (Hunter et al. 2003). The two plans should be linked for comprehensive conservation even though the methods used are different.

There is less suitable mountain lion habitat to the east, through the vast extent of the Central Valley of California. Anecdotal evidence suggests that individual lions occasionally move long distances along Central Valley riparian corridors. Genetic studies indicate stronger connectivity across the central valley than to the south (Ernest et al. 2000, 2003). Developing corridors for this region would likely need to focus on riparian vegetation because it offers wildlife cover and it traverses predominantly privately owned agricultural lands.

To the north, the Sacramento River and the SF Bay-Delta separate the Central Coast from adjoining habitat. Urbanization and the water barriers now presumably isolate lion populations north and south of the Bay and Delta.

Implications for Umbrella Focal Species

The designed single species umbrella network provides a view of what connectivity at the landscape level might look like for one of the most wide-ranging species still living in the region. This level of connectivity may well be required to maintain population viability, although the data and analysis to show that are beyond the scope of this paper. The network captured proportional representation of most broad-scale biodiversity elements examined. However, poor representation of other target-endangered species argues for a multi-species conservation approach.

Mountain lion, as a single focal species, did not adequately represent the endangered terrestrial vertebrates analyzed. This may be partially due to the high levels of beta diversity found in Mediterranean climates in comparison to more northern latitudes where much previous carnivore modeling had been done. In more homogenous landscapes, a single umbrella species approach would be expected to better capture all components of a landscape. Yet, research in those ecosystems has also shown that a suite of focal species will better represent a region's diversity.

Strategies to abate threats based only on umbrella species are responsive to area concerns but not necessarily to ecosystem functions, one of the reasons planners will use a multiple focal species approach. Conservation planning with umbrella species is also limited because it generally addresses a single type of threat to biodiversity (loss of intact and connected habitat). In reality, other threats in the same region may affect different biodiversity elements, so threat abatement strategies need to be developed using more species, site, and ecosystem-process-specific information.

We examined fine-scale biodiversity elements via surrogates such as TNC conservation areas and serpentine outcrops, but more could be done to identify biologically important small areas in the region. Representation analysis using survey records, such as the red-legged frog populations, need to be treated with care as they may not represent all the populations in the region, and some of the identified populations may no longer be in existence. This is a common challenge to conservation planners. This likely accounted for some of the poor representation of these observational records by the mountain lion network.

Various optimization techniques for site selection (Davis et al. 1999, Margules and Pressey 2000, Possingham et al. 2000) could be applied, but require more data, such as the records of collected rare plants found in the herbaria of California. The digital development of those data will eventually permit another spatial level of modeling. Optimizing a network of conservation areas to meet the needs of several biodiversity elements using site-selection algorithms also better accounts for the trade-offs inherent to planning across scales and taxa.

The umbrella species network included the remaining healthy populations of steelhead as well as most of the streams that still had degraded runs. This finding was probably due in part to the remote location of the only streams that still host healthy fish populations, and the fact that these remote areas are also suitable for cores.

Implications for Conservation Strategy Implementation

Regional planning efforts have many limitations, the lack of site detail among the most critical. Nevertheless, they provide a regional perspective that allows individual projects to be brought into a larger framework. We feel that this work can be useful in providing context for such a plan.

Maintaining connectivity for mountain lion is currently more critical than protecting the cores, because of development pressures in the lower elevations, especially river valleys and riparian areas. Yet, linkage conservation represents many challenges for traditional conservation activities, primarily because of the contingencies and the high risks involved. For example, linkage only needs to be severed once to fail to provide connectivity, but needs to be protected often with great cost involving several separate conservation actions over long periods of time (Morrison and Reynolds, in press).

The core areas we identified are similar to those identified by the California Fish and Game habitat (Torres and Lupo, 2000). The degree to which these modeled cores contain viable mountain lion populations is unknown, although mountain lions are known to be in these areas. Four of our cores meet Beier's estimated minimum areas need for mountain lion populations, but we cannot say whether the populations found in any of them will be viable in the long term.

It is well established that some dispersal between populations is necessary. It is possible that the smaller cores may support viable populations where deer densities are high (Torres and Bleich 2000), but they can also contribute to the persistence of a metapopulation, even if they are subject to local extinction and re-colonization. However, long-term protection of large core areas is likely necessary for mountain lion persistence. The two core areas predominantly on public lands could be managed to maintain the qualities characteristic of prime habitat. The three core areas mostly on private lands should become the focus of private conservation efforts, including voluntary stewardship agreements and conservation easements, since acquisition of a large proportion of the core areas is neither economically feasible nor necessarily ecologically desirable.

Private land stewardship activities that are predator friendly and enhance wildlife permeability could be used to create buffers around cores. Yet, habitat quality can vary between properties, so conservation strategies will have to be adaptive and suited to the conditions in specific areas. Since some sites are very remote, conservation easements closer to the outer edges of the cores might help buffer areas further inside. Given high land costs in the region, available money for acquisition should be allocated to preserving lands in the habitat linkages and smaller elements of biodiversity, such as amphibian populations outside of the network, which are at higher levels of risk from imminent development.

Species that are habitat specialists, such as steelhead, may require the use of geophysical units (such as watersheds) in planning their conservation. With only 4% of streams supporting historic levels of steelhead, restoration efforts as well as conservation are indicated for the majority of streams in this region. Our inventory corroborates Frissell's findings (1993) that rivers in our study area had from one to five fish species either extinct or endangered. The size of the region's streams varies considerably, from steep coastal creeks to the four major rivers: Salinas, Pajaro, Santa Maria, and Santa Ynez. Community groups can likely effectively work on the smaller watersheds, but the larger rivers will require long-term governmental support to get restoration work done. Watershed restoration groups should coordinate with terrestrial conservation planning groups; their goals may frequently coincide, as in the case of riparian vegetation restoration, which could supply connectivity for dispersing mammals across the Salinas Valley.

Correct prioritization of conservation activity could potentially be enhanced by defining the level of sensitivity of different plant communities to a variety of development pressures in the region (Stoms 2000). Since our study area was small, compared to the scale at which reserve design is often conducted, the guidelines we identify may work well in conjunction with local knowledge for conservation plan development.

Despite the large numbers of people in the region, good opportunities for conservation exist. Much of the upland habitat is either in public land or relatively large ownerships, and many of the linkage barriers are not completely severed. Probably the most critical data gap for the next analysis is a map of parcel boundaries for the whole region to analyze the level of potential fragmentation in cores and linkages. The network of parks in the San Francisco Bay Area offers an opportunity to explore how to integrate an urban park system into a regional conservation framework.

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