Title
Regional analysis for transportation corridor planning

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Regional Analysis for Transportation Corridor Planning

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Abstract: Developing regional assessments of environmental needs can help streamline the environmental-review process for transportation projects, thus leading to faster and less-costly reviews and more effective biological or ecological mitigation. This study is a demonstration of a rapid-assessment approach using a high-resolution vegetation map derived from agency data to model 12 endangered or threatened species' potential occurrence on 6638 polygons. Those units, occurring on 44 capacity-improvement sites along the 315-km of State Highway 99 in the study, were classed to measure their degree of similarity, thus permitting estimates of the potential for multi-project mitigation planning.

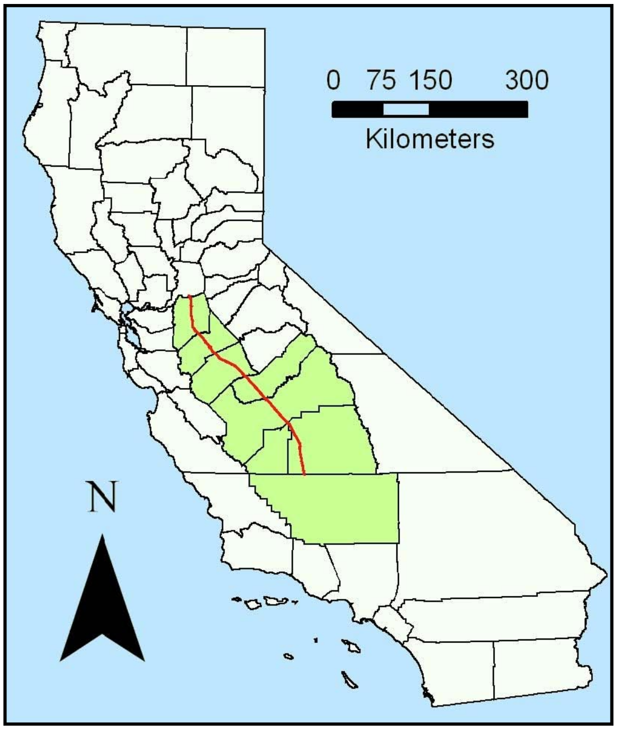
Introduction

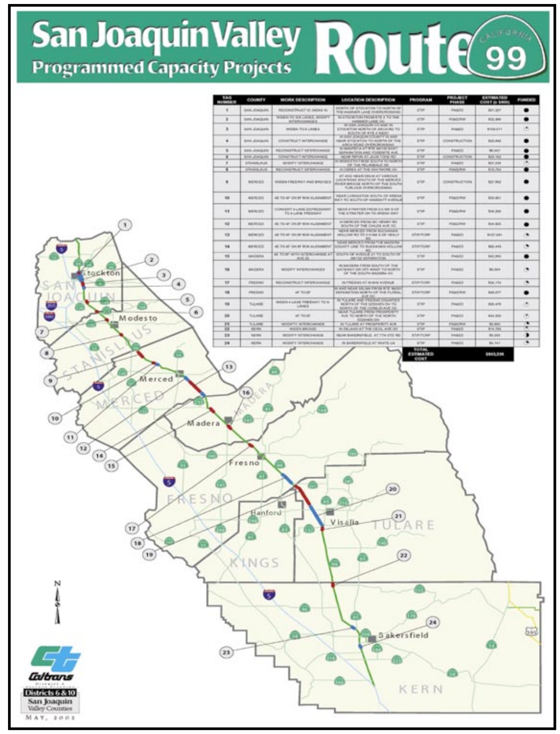
Land use and natural resources planning in the United States is often conducted project by project. Through this practice, we fail to assess cumulative impacts of sequential transportation projects or to plan comprehensively for natural resources, for land use, and for the transportation demand associated with land use on a regional basis. Similarly, environmental-mitigation planning for transportation projects is generally conducted piecemeal, although some efforts are underway to use regional contexts to inform the planning process. Interesting examples may be found in Florida (Florida Department of Transportation 2001); Oregon (Oregon Bridge Delivery Partners 2005); San Diego, California (San Diego Association of Governments 2005); and Merced County, California (McCoy and Steelman, ICOET Conference Proceedings 2005).

In California, 7,868 individual transportation projects with potentially adverse environmental impact were conducted in 1999. Of these, 436 were serious enough to require full Environmental Impact Reports (EIRs) and 2,700 relied on some exemption to regulation. In 2,000 projects, negative declarations were filed, claiming that each project would have no significant environmental impact (CEQANet Database 2005). The pressures of growth have not lessened in the intervening years: to date in 2005, 8,826 projects have been registered (CEQANet 2005), foreshadowing a yearly total of over 10,000.

Our interest was to explore how developing contextual biological information could potentially aid in streamlining of environmental review, decreasing costs associated with environmental review, and improving the quality of mitigation projects for a subset of the current projects. We examined a 315-km stretch of State Highway 99 in the San Joaquin Valley on which 150 projects are currently planned (figures 1 and 2). Of these, 18 are programmed and valued at about $1 billion. An additional 26 projects are planned and 44 projects are capacity enhancing (California Transportation Information System (CTIS) 2005). State Highway 99 is one of the oldest and most heavily used highways in California and was the location of the first highway divider (Dr. June Carroll painted a white line down the middle of the road) ever built (Wikipedia 2005). It carries the majority of the long-distance traffic in the western San Joaquin Valley of California, spanning seven counties. State Highway 99 represents one of the most productive agricultural regions in the world and serves a number of rapidly growing cities (Sacramento, Stockton, Modesto, Fresno, Turlock, Visalia, and Bakersfield) and the southern Sierra Nevada mountains (CalTrans 2005).

We used a high-resolution (from one-square-foot imagery) vegetation map (derived from California Department of Transportation (CalTrans) DHIPP inventory imagery) that spans 1 km to either side of the highway. We used the vegetation types in the map to model the potential distribution of 12 endangered or threatened species using a multiple-logistic regression approach. The number and composition of potential species at each of the 44 capacity-improvement highway sites was determined. Using a clustering algorithm, the degree to which the capacity sites contained similar modeled species was calculated. This permitted an early assessment of which sites might have similar mitigation requirements, potentially allowing contextual planning of mitigation activities that will have greater ecological value to the target species than mitigation projects conducted on a site-by-site basis.





Figures 1 and 2. Study Area. The study uses the section of the Highway 99 landcover map found in Fresno and Madera Counties, California. The maps show the southern extent of Highway 99, the seven counties in which the identified projects are happening, and the location of the modeling efforts presented in red. Fig. 2 courtesy of the California Department of Transportation.

Methods

We digitized polygons from 1-ft resolution ortho-rectified digital imagery using heads-up digitizing (figure 3; ESRI 2005). The polygons were then labeled with vegetation types according to the Manual of California Vegetation (Sawyer and Keeler-Wolf 1995, Thorne et al. 2004). In addition, USGS Anderson landcover classes were used for Urban and Agriculture (Anderson et al. 1976). The resulting landcover map had 38 landcover classes. These landcover classes were then used for modeling potential species ranges or habitats.

Twelve species were chosen in consultation with state and federal wildlife agencies for the initial assessment to represent both species of the greatest policy concern to conservationists and regulators and a diversity of ecological characteristics. The 12 species selected for modeling represented a variety of taxa, including:

- Two amphibians, the western spadefoot toad (*Spea hammondii*) and the California tiger salamander (*Ambystoma californiense*)
- Two reptiles, the giant garter snake (*Thamnophis gigas*) and the blunt-nosed leopard lizard (*Crotaphytus wislizeni silus*)
- Two birds, the burrowing owl (*Speotyto cunicularia*) and the Swainson's hawk (*Buteo swainsoni*)
- Two mammals, the San Joaquin kit fox (*Vulpes macrotis mutica*) and the Tipton kangaroo rat (*Dipodomys nitratoides nitratoides*)
- Two plant species, Colusa grass (*Neostapfia orcuttii*) and Heartscale (*Atriplex cordulata*)
- Two invertebrate species, the vernal pool fairy shrimp (*Branchinecta lynchii*) and the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*).

While this is not a complete list of species of concern in the region, the combined habitat needs of these species represents a broad set of habitats in the study area.

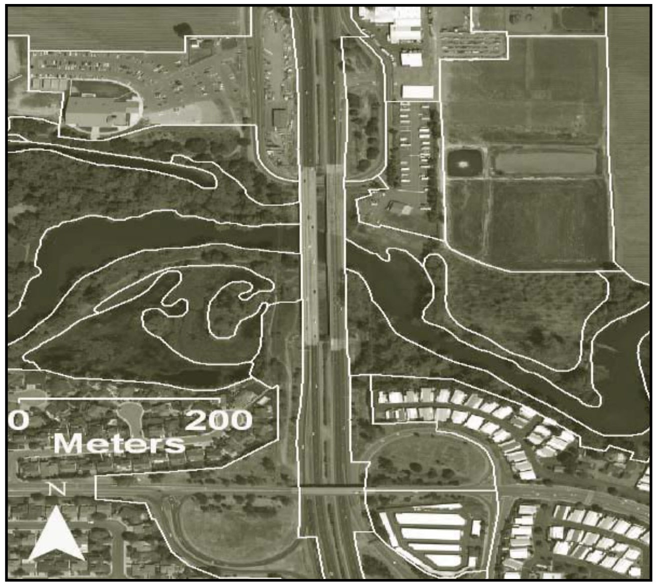


Figure 3. A section of imagery, with the polygon layer superimposed.

Species modeling was a two-step process. In the first phase, we developed a statewide range map for each species, using a logistic regression (Carrol et al. 1999; Guisan and Zimmermann 2000; Thorne et al. unpublished). In this process, we overlaid species-occurrence data (at least 20 occurrences per species) from the California Natural Diversity Database (California Department of Fish and Game, 2004) on a raster stack of 11 environmental-predictor variables. The environmental-predictor variables included five climate layers (annual precipitation, January minimum temperature, July maximum temperature, July precipitation, and summer relative humidity) derived from the PRISM climate data set (Climate Source 2000), five soils layers derived from the STATSGO (U.S. Department of Agriculture 1994) soils dataset for California (soils pH, soil organic matter content, and indices for loam, sand, and clay content), and a 100-meter digital-elevation model. This overlay gave a table of environmental variables associated with the species occurrences. Because the CNDDB database does not contain information on species absences, we simulated species-absence information by determining the values of the environmental variables at a set of random locations throughout California. We developed a logistic-regression model separating the known occurrence points from the random points and returning a probability value for species occurrence given the values of the environmental variables. By applying the logistic-regression model to the raster stack of environmental variables, we created a probabilistic statewide range map for each modeled species.

In the second phase, we assigned habitat-quality values ranging from 0 to 1 for each species to the vegetation polygons in the Highway 99 map. These habitat-quality values were based on the California Wildlife Habitat Relationships model (California Department of Fish and Game 2002) for the terrestrial vertebrates, and by review of the life-history literature for the invertebrates and plant species. For each polygon in the Highway 99 map, we then calculated for each species its potential of occurrence and the habitat-quality value by the probabilities from the statewide range map to give an index ranging from 0 to 1. To determine species presence from these indices, they needed to be normalized across taxa. We normalized these values by comparing the ranked values for each species across every polygon. We counted a species as present in a polygon if its index was in the top two-thirds of the ranked values after eliminating all the zero values.

We then developed a Jaccard similarity analysis (McCune and Grace, 2002) to measure similarity of species composition between the 44 CalTrans capacity improvement projects.

Results

The landcover, or vegetation map, comprised 6683 polygons across 630 km2. Nine of the 12 species modeled were predicted to occur in the study region (Table 1). The area each species potentially covers is the first set of information that could be used in planning, because it identifies the relative rarity of each species. We also show how many sites each species is found at and the number of polygons occupied by the species (Table 2). Figure 3 shows potential species richness along the highway corridor, derived by summing the probability of each species for every mapped polygon in our map. Since the probability of a rare species occurring in a sub- km2 polygon is typically much less than 100 percent, the maximum estimated richness (the most likely number of target species probably found within the polygon) is 4.075, representing some combination of the modeled species at that location. Areas with the highest species richness may become candidate areas for mitigation.

Each of the 44 sites identified from CalTrans plans was then examined and a list of those potential species found at each compiled (Table 3). The lists from all 44 sites were then compared using the Jaccard similarity coefficient (figure 4). Four sets of five or more sites were found to have exactly the same potential species. These sets of sites, mapped in figure 5, are candidates for regional planning of mitigation activities.

Table 1. The potential spatial extent of 12 modeled species by spatial extent along 315 km of State Highway 99, California

Species Name	Percent of study region area at 10% probability	Percent of study region area at 50% probability	Area at 10% probability (sq km)	Area at 50% probability (sq km)	Primary Landcover Class	Secondary Landcover Class
Blunt-nosed leopard lizard	10.7	0	12.4	0	California annual grasslands	Ruderal forbs and grasses
Tipton kangaroo rat	0	0	0	0	Cropland and pasture	California annual grasslands
Colusa grass	0	0	0	0	Temporarily flooded vernal pools	None
Heartscale	0.004	0.004	0.005	0.005	Shrub and brush rangeland	None
Valley elderberry longhorn beetle	0.22	0.22	0.26	0.26	Fremont cottonwood - mixed willow riparian forest	Valley oak forest and woodland
Western spadefoot toad	53.9	10.42	62.5	12.1	Cropland and pasture	Orchards, groves, vineyards, nurseries
Vernal pool fairy shrimp	0	0	0	0	Temporarily flooded vernal pools	None
California tiger salamander	11.37	7.23	13.2	8.4	California annual grasslands	Ruderal forbs and grasses
Burrowing owl	29.1	28.52	33.8	33.1	Cropland and pasture	California annual grasslands
Giant garter snake	0.2	0	0.2	0	California annual grasslands	Canals
San Joaquin kit fox	10.9	10.6	12.7	12.4	California annual grasslands	Ruderal forbs and grasses
Swainson's hawk	27.8	16.4	32.2	19	Cropland and pasture	California annual grasslands

Table 2. The potential presence of 12 modeled species by highway project along 315 km of State Highway 99, California

Species	Planned Projects	Programmed Projects	Polygons in Planned Project	Polygons in Programmed Project	Total Polygons Occupied by Species
Atriplex cordulata	0	0	0	0	1
Blunt-nosed Leopard Lizard	16	10	135	66	541
Burrowing Owl	22	10	184	111	1149
Colusa Grass	0	0	0	0	21
California Tiger Salamander	20	13	149	81	690
Giant Garter Snake	16	13	127	95	745
San Joaquin Kit Fox	21	13	141	77	598
Western Spadefoot Toad	22	14	148	82	730
Swainson's Hawk	20	14	187	93	1094
Tipton Kangaroo Rat	9	9	80	89	563
Valley Elderberry Longhorn Beetle	8	6	18	9	84
Vernal Pool Fairy Shrimp	0	0	0	0	14

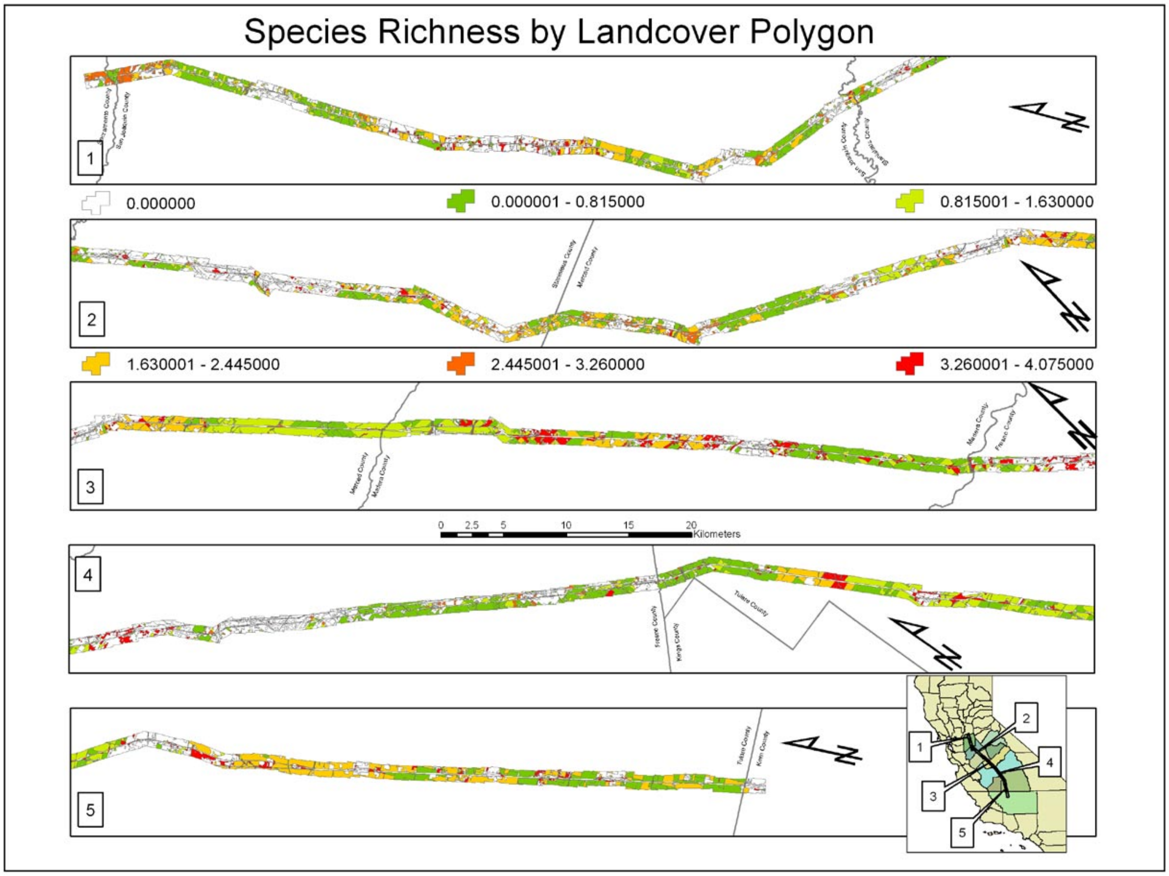


Figure 3. Potential species richness along the Highway 99 corridor. The sum of probabilities of presence for 12 modeled species was calculated for each of the 6683 map units in the landcover map. Red indicates the potentially highest species richness locations.

Table 3. Modeled species presence at each of 44 capacity improvement project sites on State Highway 99, California. This table shows which species were identified at which sites by the species modeling.

Transportation Project Title	Species Name	Atriplex cordulata	Blunt-nosed Leopard Lizard	Burrowing Owl	Colusa Grass	California Tiger Salamander	Giant Garter Snake	San Joaquin Kit Fox	Western Spadefoot Toad	Swainson's Hawk	Tipton Kangaroo Rat	Valley Elderberry Longhorn Beetle	Vernal Pool Fairy Shrimp
SR120/99 INTERCHANGE IMPROVEMENTS		0	0	0	0	0	0	0	0	0	0	0	0
43 EXPRESSWAY		0	1	0	0	1	0	1	1	0	0	0	0
JENSEN TO CENTRAL WIDENING		0	1	1	0	1	0	1	1	0	0	0	0
JENSEN WIDENING		0	1	1	0	1	0	1	1	1	0	0	0
ROEDING AUX LANES		0	1	1	0	1	0	1	1	0	0	0	0
RAMP UPGRADES		0	1	1	0	1	0	1	1	0	1	0	0
WIDENING AVE 7 TO AVE 12		0	1	1	0	1	1	1	1	1	1	1	0
AVE 16 TO AVE 21 1/2 WIDENING		0	1	1	0	1	1	1	1	1	0	1	0
SR 99/SR152 SB AUXILIARY LANE		0	1	1	0	1	0	1	1	1	0	0	0
NORTH MADERA WIDENING		0	1	1	0	1	1	1	1	1	0	1	0
ISLAND PARK 6-LANE		0	1	1	0	1	1	1	1	1	1	1	0
SR 49 16th Street/Oliver Ave. Widening		0	0	1	0	0	1	0	0	1	0	1	0
99/140 INTERCHANGE IMPROVEMENTS		0	0	0	0	0	0	0	0	0	0	0	0
SR-99 WIDENING - WESTSIDE BLVD. TO HUNTER RD.		0	1	1	0	0	1	0	1	1	1	0	0
SR 99 Hammatt IC to Merced River Bridge		0	0	1	0	1	1	1	1	1	1	0	0
SR99 AT MARIPOSA AND FARMINGTON		0	0	1	0	1	1	1	1	1	0	0	0
SR 99/WILSON/MARCH LANE INTERCHANGE		0	0	1	0	1	1	1	1	1	0	0	0
SR 99/MORADA LANE INTERCHANGE		0	0	1	0	1	1	1	1	1	0	0	0
SR 99/EIGHT MILE ROAD RECONSTRUCTION		0	0	0	0	0	0	0	0	1	0	0	0
SR 99 ARCH RD.-SR120 WIDENING		0	0	1	0	1	1	1	1	1	0	0	0
SR 99 WIDENING/CERES TO KIERNAN		0	1	1	0	1	1	1	1	1	0	1	0
SR132 EAST INTERCHANGE		0	1	1	0	1	1	1	1	1	0	1	0
SR 190 PASSING LANES		0	1	1	0	1	0	1	1	1	1	0	0
AIRPORT WIDENING		0	1	1	0	1	1	1	1	1	1	1	0
FARM SHOW INTERCHANGE		0	1	1	0	0	0	1	1	1	1	0	0
PROSPERITY WIDENING		0	1	1	0	1	1	1	1	1	1	0	0
Kingsburg to Selma 6-lane freeway		0	1	1	0	1	1	1	1	1	1	0	0
South Madera & Gateway Improvement Proj		0	1	1	0	1	1	1	1	1	1	0	0
Fairmead Interchange & 6-lane Freeway		0	1	1	0	1	0	1	1	1	0	0	0
Mission Ave Interchange/Freeway		0	1	1	0	1	1	1	1	1	1	0	0
Atwater Freeway		0	0	1	0	0	1	0	1	1	1	0	0
Livingston Stage II Freeway		0	0	1	0	1	1	1	1	1	1	0	0
Freeway Upgrade & Plainsburg Road I/C		0	1	1	0	1	1	1	1	1	1	1	0
Arboleda Road Freeway		0	1	1	0	1	1	1	1	1	1	1	0
Bradley Overhead widening (from 2 to 4-lane)		0	0	0	0	0	0	0	0	0	0	0	0
Route 59 Widening		0	0	1	0	0	1	0	0	1	0	1	0
Castle Highway		0	1	1	0	1	1	1	1	1	0	1	0
Central Galt Interchange		0	0	1	0	1	1	1	1	1	0	0	0
Route 99 Widening in South Stockton		0	0	1	0	1	1	1	1	1	0	0	0
Route 132 Expressway		0	0	0	0	0	0	0	0	0	0	0	0
Route 219 4-lane expressway		0	0	0	0	0	0	0	0	0	0	0	0
Pelandale Interchange Reconstruction		0	1	1	0	1	1	1	1	1	0	0	0
Goshen/Kingsburg 6-Lane		0	1	1	0	1	1	1	1	1	1	1	0
Tagus Ranch 6-lane freeway		0	1	1	0	1	0	1	1	0	1	1	0

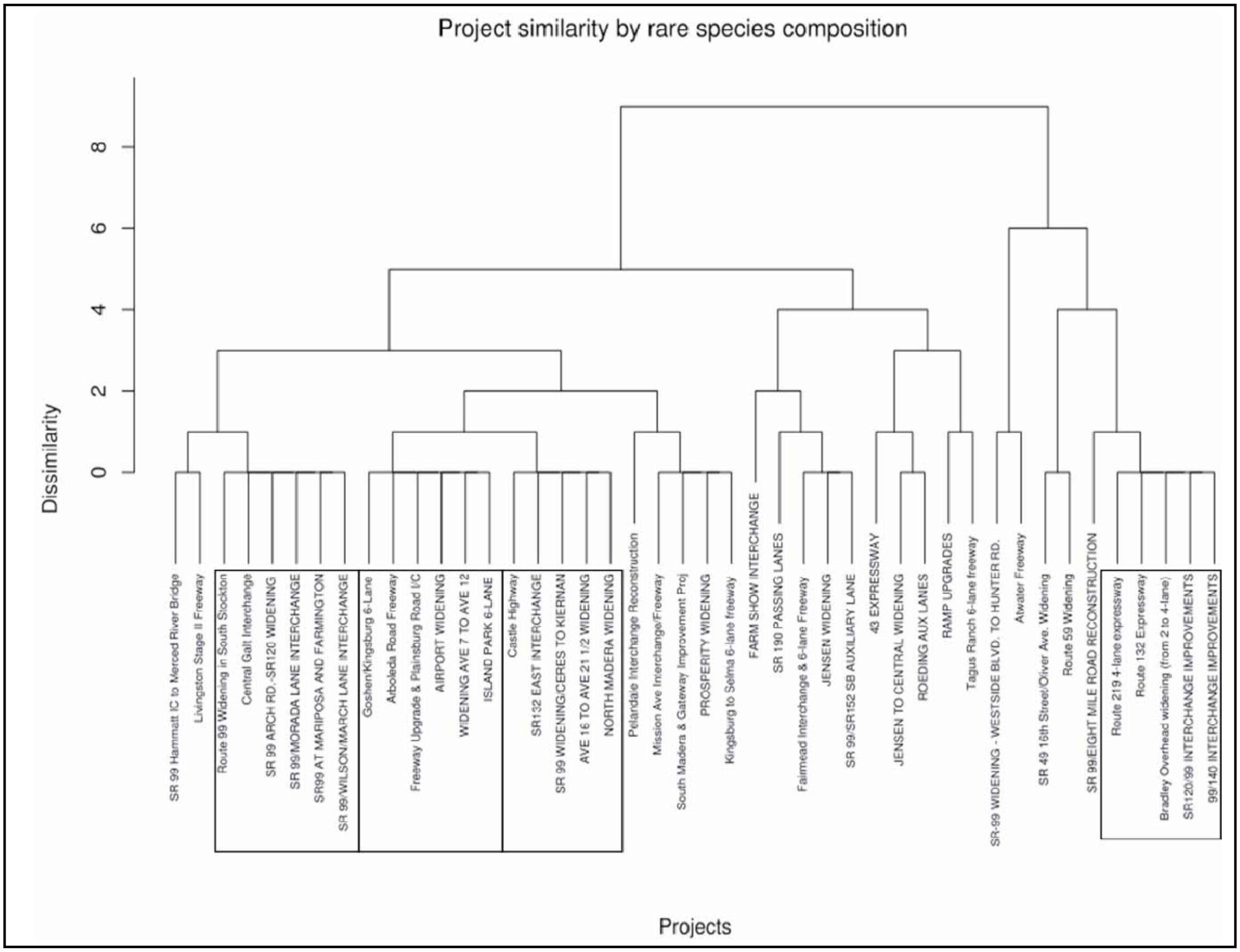


Figure 4. The degree of similarity between 44 capacity-enhancement projects on State Highway 99, California. Project similarity was measured using a Jaccard similarity coefficient, based on modeled species shared or not shared at each site. Four sets of at least five sites shared all modeled species identified and are represented in the boxes of the diagram.

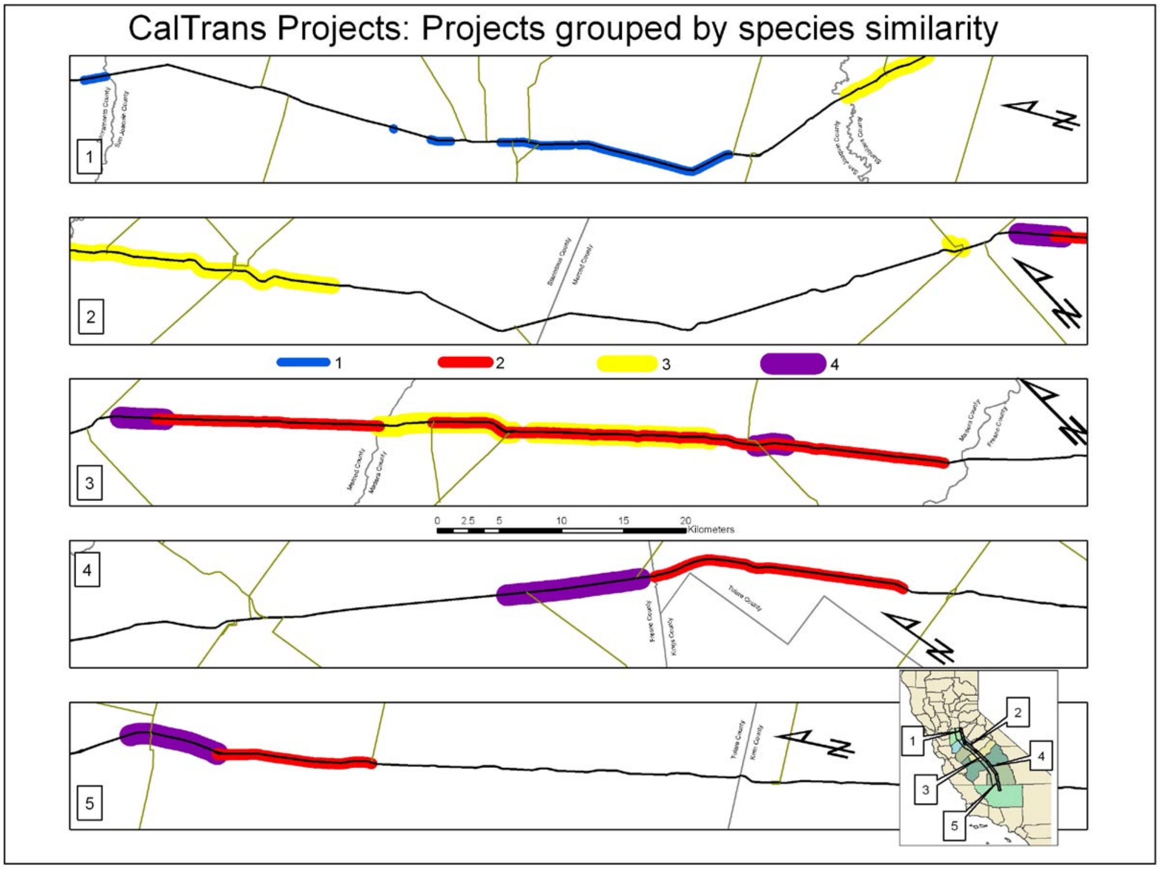


Figure 5. Physical location of four sets of capacity enhancement sites that share endangered species.

Discussion

This pilot project is a demonstration of how transportation agencies can assemble regional data that would help in environmental review and in effective mitigation planning. The value of multi-species, multi-project planning is threefold:

- It permits faster environmental review.
- It can reduce the costs of environmental review.
- It offers the possibility of more environmentally effective mitigation planning, such as combining partial costs from multiple projects to protect a resource at an off-site location which might not be effectively protected or restored using on-site techniques.

This example could be made more thorough by increasing the number of species modeled, by including ecosystem processes in the modeling, and by the development of policy regarding vegetation types or habitats in addition to individual species. Further expansion could involve the inclusion of other human activities on the landscape, such as urban buildout models (e.g. Johnston et al. 2003), and the use of a more regional, rather than linear base vegetation map.

For this approach to be effective, some initial outlays in cost are required. Specifically, the agencies need to assure adequate base data to support species modeling. The development of these data can be made more effective by identification of the size area being considered. Effective environmental planning uses a variety of types of information, including critical habitat level maps, which likely will have to be developed; species presence and absence data; and a wide range of transportation-development plans. The integration of this information can serve a wide range of needs once it is developed.

Another need for the adoption of this type of approach is agency support for flexible, proactive programmatic mitigation and the finance mechanisms to implement identified solutions. Biologists, planners, and GIS personnel need to work together to develop these scenarios and these activities that will require department support, since these collaborations are not always considered part of the work flow.

The next steps are to develop an understanding of regional environmental priorities; to secure adequate environmental data from all relevant spatial scales; and to support flexible policy and finance mechanisms.

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Biographical Sketch: Jim's professional interests include biogeography, conservation biology, and ecology. He has done several studies that focus on incorporation of biological data to county-level planning.

Mike McCoy is the co-founder of the Information Center for the Environment at the University of California, Davis. He leads research teams focusing on the use of modeling urban growth in resource-rich regions and the use of social-network analysis for the study of collaborative planning processes.

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