Proceedings of the Sierra Azul Wildlife Connectivity Workshop

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Please note: the information presented in this document represents the Elkhorn Slough Coastal Training Program's best attempt at summarizing the discussions from the Sierra Azul Wildlife Connectivity Workshop. If errors are present, please contact the Elkhorn Slough Coastal Training Program.

Introduction

On October 11th, 2006, the Sierra Azul Wildlife Connectivity Workshop featured recent advances in science to inform regional land use planning that is compatible with wildlife migration patterns. The Silicon Valley Land Conservancy and the Elkhorn Slough Coastal Training Program sponsored the workshop, which included scientists discussing current data pertaining to biological connectivity issues in the Sierra Azul region of the Santa Cruz Mountains. The Sierra Azul includes the southern portion of the Santa Cruz Mountains, from Highway 17 southwards, an area thought to be important for wildlife migration and habitat connectivity, between the Santa Cruz Mountains on the west with the Diablo and Gabilan mountain ranges to the east and south. Urbanization and road building surrounding this area increasingly threaten the viability of habitat corridors in the Sierra Azul area, thus many think it prudent for scientific analysis of the area's opportunities and constraints for wildlife corridors and habitat connectivity (referred to collectively as 'biotic connectors').

The workshop was convened because of the unique opportunities for conserving biotic connectors presented by the current Santa Clara Valley habitat conservation plan and natural community conservation plan (HCP/NCCP). Among the regulatory requirements of an NCCP are 1) conserving ecological integrity of large habitat blocks, ecosystem function, and biodiversity; 2) providing for the conservation of covered species in the plan area; 3) providing linkages among reserves and outside areas; 4) supporting sustainable populations of covered species; 5) and sustaining movement of species among reserves; wildlife connectivity is essential to all of these requirements (California Department of Fish and Game 2002). The workshop was also convened out of concern about the Coyote Valley Specific Plan proposals potential impacts to existing corridors.

The goals of this workshop included bringing together the latest scientific information to inform the design and management of biotic connectors in the Sierra Azul region and to make that information available in a way that positively affects regional decision making. Speakers presented information on the movement patterns of Bay checkerspot butterfly, California tiger salamander, California red-legged frog, American badger, and mountain lion, and the workshop allowed scientific experts on these species to network. In so doing, we hope to have helped to form a group dedicated to working together to address future issues of biotic connectors in this region.

Background

This workshop was part of ongoing work focusing on landscape-level conservation planning in central California. Efforts include eco-regional planning by The Nature Conservancy, ongoing dialogues within the California Department of Fish and Game, and new levels of regional coordination between land trusts. In 2003, the Elkhorn Slough Coastal Training Program sponsored a workshop featuring the California Wilderness Coalition's landscape-level analysis for wildlife migration in central California. This report still forms the basis for biotic connectivity discussions, and so provided an important framework for discussions during the workshop. The following sections outline the findings of this report as well as the theoretical and scientific rational for biotic connectivity in general.

Corridors in the Sierra Azul Region

The California Wilderness Coalition's 2002 report "Wildlands Conservation in Central Coast Region in California" is the only available scientific study of corridors in the Sierra Azul region (Thorne et al. 2002). Authors of the report concluded, based on expert opinion, that the linkage to the east of the Sierra Azul, between the Northern Diablo Range and the Southern Diablo Range, was mostly intact and fairly available to large vertebrate migration. A critical area for biotic connectivity there straddles the east and west flanks of Pacheco Pass, along Highway 152. But, that analysis identified two linkages between the Santa Cruz Mountains and areas of the Diablo Range that are of more critical concern, especially with respect to the integrity of the mountain lion population in the Santa Cruz Mountains. The first linkage, between the Sierra Azul and the northern Diablo Range, is across Coyote Valley in southern Santa Clara County. There is also a biotic connector between the Santa Cruz Mountains and the southern Diablo Range and Gabilan Range at Chittenden Gap, along highway 129. Both linkages are very important and in danger of being lost due to urbanization, development, and other land use changes. These two corridors represent the last remaining biotic connectors between the Santa Cruz Mountains and other mountain ranges in the region.

Definition of Corridor

In order to better implement The California Wilderness Coalition's conclusions and move forward with a more detailed plan for corridors in the Sierra Azul, it is important to understand the most current science on biotic connectivity. To address this need, the workshop featured Dr. Bill Lidicker, Professor of Integrative Biology, Emeritus, at the University of California, Berkeley and co-author of a recently published book "Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation" (Hilty et al. 2006). Dr. Lidicker provided the scientific framework for evaluating biotic connectors, helping to set the tone for the day's meeting. We gleaned the following information from his presentation but we encourage readers who wish to explore these concepts more deeply to refer to his recent book.

A wildlife corridor connects fragmented habitats and, by doing so, helps to increase movement and gene flow between core habitat areas resulting in improved fitness for a species. Corridors are designed both structurally and functionally. Purely structural considerations of corridors focus on the shape and design of the corridor itself and do not consider its use by particular species. Structurally, corridors are determined by several factors, including: habitat shape (linearity), connection of patches of similar communities, degree of habitat distinctiveness from the adjacent matrix, which may be visible on aerial photographs. On the other hand, a functional definition of a corridor focuses on its use rather than its structure. With this definition, a corridor must *function* as a corridor by enhancing movement, regardless of its structural considerations (Hilty et al. 2006).

Preserving wildlife connectivity through corridors has many potential advantages. Most importantly, corridors may decrease the chance of both local and global extinction for species by improving movement between populations. Global extinction usually results by gradual loss of individual populations (Hilty et al. 2006). Corridors may allow a 'rescue effect' to take place where immigration prevents the local extinction of any given population of a species or allows re-establishment through colonization. They increase the probability that a species is able to inhabit more patches of habitat at any given time, decreasing the chance that a catastrophe will wipe out all populations, leading to total extinction (Hilty et al. 2006). Extinction due to genetic drift and inbreeding depression may also be reduced by increasing connectivity (Hilty et al. 2006).

Corridors also come with possible disadvantages. Corridors often have characteristics typical of ecotones or edges of habitat that are different from the types of habitats that occur further in the interior of blocks of habitat (Hilty et al. 2006). For instance, forest edges have higher wind, more light, and different plant species than the interior of forested patches. Therefore, corridors may not be suitable for the movement of species preferring interior habitat, or they may increase the impact of predators or competitors more associated with edges (Hilty et al. 2006). Corridors may also allow the movement of exotic species, pathogens, and deleterious native species between the areas of habitat they connect (Hilty et al. 2006). If corridors lead from an area of good habitat to an area of poor habitat, they can act as 'demographic sinks' and actually increase the possibility of extinction for a species (Hilty et al. 2006). For instance, roadrunners (birds) may move from areas *without* housecats to areas *with* housecats, where they face certain early death; in such a case, there may be an overall decrease in roadrunner numbers in an area. Finally, corridors can disrupt synergistic relationships between species in an isolated community by allowing some species (such as the more mobile ones) to persist while others become extinct. Such changes in community composition may lead to a cascade of extinctions (Hilty et al. 2006). For example, if a species of plant important to a local herbivore were to go extinct in a patch because it is unable to utilize a corridor that may be suitable for other species, then the herbivore might decrease in numbers or even become extinct in that patch leading to the loss of predators and parasites that prey on that herbivore.

Biotic Connectivity: a Focus on Individual Wildlife Species

In order to more clearly understand concerns about biotic connectivity, the workshop featured in depth information on wildlife species where there have been specific concerns raised by the scientific and conservation communities. The focus was on wildlife instead of plants and biotic communities because the science with animals is easier to understand and plan for. Larger wildlife species, in particular, have been more thoroughly addressed by science; their migration patterns are more easily studied than with the slower-moving plants, and much information has been gathered to establish vertebrate home ranges and landscape-scale migration requirements. In addition, others argue that because wildlife species have larger area and habitat requirements than plants, then plants will be covered by adequately addressing wildlife movement needs. Literature is also available for plants and plant communities, and we hope to feature this information at some later date, in another workshop addressing important concerns for floral migration in the Sierra Azul region.

This workshop was very important in highlighting new studies on American badger populations and migration in the Sierra Azul region. Information was also presented on Bay checkerspot butterfly, California tiger salamander, California red-legged frog, and mountain lion. In each case, the following sections summarize ecological relationships of each species which determine the degree to which humans must plan at the landscape level for conservation. Also, we summarize workshop findings on biotic connectivity design concerns for each species.

American Badger

Species Status and Ecological Considerations for Migration

Badgers are listed as a 'species of special concern' in California (Williams 1986) and are highly sensitive to fragmentation and human development (Crooks 2002, Lay unpublished data, Quinn unpublished data). Populations throughout California, especially in the Santa Cruz Mountain region, are in decline (Williams 1986, Lay unpublished data). They are associated with grasslands and open habitats, and they are semi-fossorial creatures (Lindzey 1982, Long 1983, Apps et al. 2002). Movement patterns of American badgers vary greatly. Their home ranges can be as small as 2 km^2 or as large as 250 km^2 (Lindzey 1978, Messick & Hornocker 1981, Apps et al. 2002, Hoodicoff 2003). However, even when they have small home ranges, badgers have been documented dispersing up to 100 km (Messick & Hornocker 1981).

According to recent research at Fort Ord on badger movements done by radio tracking, badgers can move up to 2 km per night. This study found home range sizes ranging from 2.81 km^2 to 20.85 km^2, with male ranges larger than female ranges. In addition, radio tracking indicated that badgers were willing to cross busy roads. They often place their home ranges at the edge of woodlands but spend most of their time in grasslands. Fort Ord is a 15,000 acre habitat island, and it seems to be supporting a self-sustaining badger population up until this point, though the trajectory for the population is unknown (Quinn, pers. comm.). However, the badger's historical range seems to have contracted statewide, and some local extirpations are suspected (Larsen 1987).

Corridor Design

As with many wildlife species, the density of roads determines the viability of a badger population in a given area (Forman & Alexander 1998). Because they are semi-fossorial (adapted to burrowing) badgers are vulnerable to even low barriers such as road median dividers, which deer and other large vertebrates could traverse. Badgers are much more likely to use culverts and underpasses than the vegetated bridges sometimes created for wildlife migration over roads. Culverts are used even when flowing with water as badgers are able swimmers. Fences have been used to guide badgers to culverts and keep them off of roads, and have been shown to increase dispersal (Federal Highway Administration 2000). On either side of a culvert, corridors must be designed to be fairly wide to take into account the badgers' large home ranges and dispersal patterns (Penrod et al. 2005, Hilty et al. 2006).

San Jose State graduate student Tanya Diamond has worked with a "Least-Cost Path" computer model (ArcView 9.1 ESRI; Craighead et al. 2001) using geographic information systems (GIS) technology to identify potential badger corridors from the Santa Cruz Mountains to the Diablo Range. The model includes analysis factors indicative of habitat use and movement of badgers including records of live and road kill badgers, soil type, vegetation community, hill slope percentage, roads and their level of use, and human development patterns (Diamond pers. comm.). Diamond's work suggests potential badger habitat and corridors running from Henry Coe Park in the Diablo Range down Metcalf Canyon to Tulare Hill and into the Santa Teresa Hills and the Santa Cruz Mountains. Her work suggests that the Coyote Valley represents an important corridor for central California's populations of American badger.

Mountain Lion

<u>Species Status and Ecological Considerations for Migration</u>

Mountain lions are listed as a specially protected mammal by the California Department of Fish and Game (protects lions from sport hunting). Because of the keystone role these large predators play in ecosystems, their conservation has been recognized as being of critical importance (Soule 1987, Noss 1991, Hornocker 1992, Beier 1993). Mountain lions require large habitat patches and are susceptible to fragmentation and human development. The Santa Cruz Mountains are comprised of approximately 1400 mi^2 and support three counties (San Mateo, Santa Clara, and Santa Cruz). To date, it is unknown how much potential lion habitat exists in the entire range. However, in 2000, Santa Cruz County (445 mi^2) had 258 mi^2 of potential mountain lion habitat. Of this, approximately 130 mi^2 was considered core habitat (Korpos 2000 unpublished data). Beier (1993) determined the minimum area necessary to sustain a mountain lion population as 386 – 849 mi^2 of useable habitat. Thus, the Santa Cruz Mountains, within Santa Cruz County, are unlikely to contain enough habitat to support a viable population of mountain lions in the long term without immigration from other areas in the course of any given decade. Without such immigration, there is a high probability of regional extinction of the species (Beier 1993, Korpos 2000 unpublished data).

Juvenile mountain lions disperse between 15 to 22 months and may roam up to 35 miles to establish their home range. Juvenile male lions must find an area that is not inhabited by a resident male. Thus, dispersing lions likely move outside the Santa Cruz Mountains in the southern range, and currently may move into the Gabilan and Santa Lucia Ranges and possibly into the Diablo Range (Korpos pers. comm.). Movement to these areas is dangerous to lions as they must cross major roads and highways to access areas outside the Santa Cruz Mountains. Research indicates that there are only several areas where this movement may occur, and these open space areas could be greatly diminished or disappear in the near future due to urbanization.

<u>Corridor Design</u>

The Circuit Theoretical Model has been used to study mountain lion movements in Southern California, and could provide valuable information informing migration routes for lions in the Sierra Azul region. The model examines wildlife connectivity in a holistic approach identifying multiple pathways rather than considering a single pathway between core habitat areas. It assumes that greater connectivity will be maintained between core areas if connected by multiple, wide corridors rather than single, narrow corridors. The approach is statistically based and uses a weighted model to show conductance levels between each core area (Hopkins pers. comm.).

The utility of this model was illustrated at the workshop using an example from southern California. Rick Hopkins and others first developed a landscape-scale suitability model based on a weighted compilation of vegetation, topographic position index, distances of major highways, and density of roads. As a result, they identified 11 core habitat areas and used the circuit theory model to show possible movements between all the core habitat areas. Connectivity was illustrated by the model in a regional context and single corridors can be compared with others. This approach helps better inform policy decisions by comparing conservation values between various core areas and showing the effectiveness of different corridors. It is easily expandable to new parts of the state and can be modified to examine regional connectivity for any species. While it has currently only been used as a single-species model, the circuit theory approach could potentially overlay the modeling results from several individual species to create a multi-species approach to corridor design.

Bay Checkerspot Butterfly

<u>Species Status and Ecological Considerations for Migration</u>

Bay checkerspot butterflies are found only in serpentine grasslands in the San Francisco Bay region. Because they are listed as endangered under the federal Endangered Species Act they have received a great deal of conservation attention. Serpentine grasslands are naturally patchy but highly fragmented, and so the migration of the butterflies between remaining patches of habitat is of critical importance to their long term survival.

The Bay checkerspot displays two modes of movement. Locally, butterflies move short distances (also known as “random walk”) among nectar sources, host plants and mates. The species also moves greater distances in a “dispersal-mode,” which is more directional with fewer turns and faster flight. Bay checkerspot butteflies display a reluctance to leave serpentine habitat, but if their “random walks” take them outside of serpentine grasslands, they switch to “dispersal-mode” movement (Weiss pers. comm.).

Within continuous habitat, the butterflies exhibit sedentary behavior. For instance, on Coyote Ridge above the Coyote Valley, scientists have found fewer than 5% of butterflies move over 500 m and less than 0.1% over 1500 m (Sisk 1992). Local distributions are strongly affected by topography – butterflies are least abundant on south-facing slopes (where surface temperatures reach 40+°C at mid-day), and most abundant on moderate N-facing slopes where temperatures are cooler.

At Jasper Ridge Biological Preserve, transfer rates between two small habitat patches (5 and 20 acres) separated by chaparral and oak woodland were on the order of 0-2% per year over a 35 year period (Sisk 1992). At Edgewood Natural Preserve, butterflies have dispersed across Highway 280 and mixtures of chaparral and grassland between subpopulations, at similar rates to those at Jasper Ridge corrected for distance (Sisk 1992).

Harrison (1989) experimentally released groups of 100 females at 10 different distances from an isolated target patch near Gilroy, in a largely agricultural setting. One out of 100 females released at 10 km was subsequently found on the serpentine patch and higher fractions were found from groups released closer.

Long-distance dispersal from Coyote Ridge to the smaller serpentine outcrops west of Coyote Valley is inferred from occupancy patterns (Harrison et al. 1988). These small populations went extinct in the severe 1975-77 drought, but by 1987 only those closest to Coyote Ridge were occupied. This distance effect implies that Coyote Ridge (aka Morgan Hill) serves as a "reservoir population" that supports the "satellite" populations.

Serpentine habitat on Tulare Hill, at the northern end of the Coyote Valley, serves as one of these satellite populations. The Tulare Hill population of Bay checkerspot butterflies were absent from 1990-1995 but reappeared in 1995, strong evidence of dispersal across Coyote Valley from a large population on serpentine grasslands north of Metcalf Canyon, 1000-2500 m away. Intervening land cover includes a mix of railroad tracks, Highway 101, percolation ponds, open grassland, and PG&E facilities. By 2002, more than 1000 butterflies occupied Tulare Hill. From 2003 to 2006, the population crashed to <<100 butterflies because of lack of grazing and subsequent deterioration of the habitat (Weiss and CH2M Hill 2006).

Corridor Design

In Coyote Valley, Coyote Ridge, with greater than 6000 acres of serpentine grassland, serves as the largest core population complex for Bay checkerspot butterflies, with populations in the tens of thousands to low millions. Smaller satellite populations, ranging from 10 to several thousand, have existed on other patches of serpentine soil ranging from 5-400+ acres. These smaller populations often go extinct in times of drought and must then be recolonized by dispersal from the core population. Without recolonization of these smaller serpentine habitats, the geographic range of the checkerspot butterfly would contract. Maintaining this extinction-recolonization dynamic is a goal stated in the USFWS Recovery Plan.

The ability of Bay checkerspot butterflies to cross developed urban and suburban areas is not known. Because the butterfly inhabits open grasslands, it should be assumed that low vegetation, grasslands, shrublands, and low crops are preferred corridor composition.

California Tiger Salamander and Red-Legged Frog

Species Status and Ecological Considerations for Migration

The California tiger salamander (*Ambystoma californiense*) in the Sierra Azul is federally listed as a threatened species, and populations have been reported in both the Diablo Range and the foothills of the Santa Cruz Mountains. This species primarily occupies grassland and oak woodland/savannah uplands. Although they breed and develop from egg through metamorphosis in temporary and permanent ponds, juveniles are completely terrestrial and adults return to ponds only to breed. This species has been documented moving 1-2 km into upland habitat and dispersing between ponds up to 670 meters apart (Trenham et al. 2001, Trenham and Shaffer 2005, Trenham unpublished data).

The California red-legged frog (*Rana draytonii*) is listed as a federally threatened species throughout its range. Records of this species exist from sites throughout the

Diablo Range and Santa Cruz Mountains. California red-legged frogs are most commonly found in permanent ponds and reservoirs that lack fishes and bullfrogs, but they are also regularly observed in temporary ponds, springs, seeps, and in some streams (U.S. Fish and Wildlife Service 2002). Larvae are aquatic and juveniles and adults usually remain close to water. Bulger et al. (2003) showed that most non-migrating individuals remain <5 m from water during dry periods and within 130 m of water during wetter periods (Bulger et al. 2003). However, during migrations individual frogs have been observed moving between sites separated by up to 2.8 km (Bulger et al. 2003). Migratory individuals were often leaving ponds that dry in late summer, making it essential that they find another suitable habitat for the non-breeding season.

Observed dispersal distances underestimate a species potential for longer-distance movements. Smith and Green (2005) reviewed the literature on amphibian dispersal and concluded that in continuous suitable upland habitat individuals will commonly disperse over distances of 8-13 km. Clearly some species will be more mobile than others, but this analysis emphasizes that both frogs and salamanders do commonly disperse over more substantial distances than we might suspect.

Corridor Design

There is no information currently available indicating how or if California tiger salamanders actively select or avoid certain habitat types during migration and dispersal. The available data suggest that they do not move along streams or riparian habitat but rather wander over hills as an upland creature (Trenham 2001). In rapidly developing areas in Sonoma County, biologists commonly find California tiger salamanders both dead and alive on streets in subdivisions, indicating that roads are not a behavioral barrier to dispersal, but also that salamanders do not recognize the threat that these roads represent (David Cook unpublished data). To accommodate this species' potential random wandering, corridors would need to be sufficiently wide. Narrow corridors would likely result in high levels of mortality as salamanders wander into unsuitable habitats such as residential areas. Red-legged frogs are more likely to favor stream corridors and areas of riparian habitat for migration and dispersal than are tiger salamanders. However, some individuals make long-distance movements, usually from one aquatic habitat to another, independent of any detectable aquatic or favored upland habitats (Bulger et al. 2003). In general, wide corridors would reduce the mortality of this species due to straying into unsuitable habitats.

Because even roads with moderate traffic levels kill most or all amphibians that attempt to cross, overpasses or underpasses would be needed to allow safe road passage for both of these species (Hels and Buchwald 2001). There are no data available to evaluate whether tiger salamanders or red-legged frogs actively seek overpasses or underpasses to cross roads. However, there is some anecdotal evidence that both tiger salamanders and red-legged frogs at times use culverts to cross beneath roads. Agricultural land, while not being suitable permanent habitat for long term occupancy by either species, is probably suitable dispersal and migratory habitat. Inclusion of a network of both temporary and permanent ponds distributed along the corridor would promote use of this habitat by these species and thus their successful dispersal over time. Design considerations would include spacing ponds close enough to facilitate dispersal across a region. Ideally, the more extensive habitat areas on each end of the corridor would support viable populations of both species, but maintaining habitat connectivity will allow for gene flow, which helps maintain genetic diversity over the long-term (Trenham, pers. comm.).

Tule Elk (Cervus elaphus nannodes)

Species Status and Ecological Considerations for Migration

Tule elk, endemic to California, is the smallest subspecies of North American Elk (McCullough 1969). Tule elk were once abundant throughout most of Central California but by the 1870's, it was thought that tule elk were extinct. A small group of less than 20 elk were discovered and through careful management were gradually reintroduced statewide. Tule elk were never specifically listed under either the state or federal Endangered Species Act but have had a long history of protection by the legislature and the California Department of Fish and Game (Rigney 2002). As of 2004, the statewide population had increased to approximately 3,700 tule elk in 22 different herds (California Department of Fish and Game).

The Mt. Hamilton region of the Diablo Range is historically part of the tule elk range. Evermann (1916) referred to "convincing evidence of elk range over the entire San Joaquin Valley and adjacent foothills and through the Livermore and Sunol Valleys across to Santa Clara Valley and even to Monterey." The State Legislature enacted the Behr Bill (1971) and in 1976 the United States Congress passed a resolution resulting in the formation of an Interagency Task Force to evaluate and select appropriate relocation sites for tule elk which included the Diablo Range (Santa Clara County) south into the Temblor Range in San Luis Obispo County (Phillips, 1988). The primary management policy of government agencies has been to develop management plans for each herd as part of a state management plan.

The initial reintroduction of tule elk into the Mt. Hamilton region between 1978 and 1981 resulted in a scattering of the elk and eventual establishment of herds in Isabel Valley, San Antonio, Livermore area, Coyote Ridge and surrounding areas. The total study area with the Mt Hamilton region included an area of 1875 km^2 (Phillips 1985). At this point, the tule elk has been successfully reintroduced into this area, with Santa Clara County and surrounding areas designated as suitable elk habitat by the Interagency Task Force with the California Department of Fish and Game as the lead agency.

Tule elk are a potential grassland keystone species and are considered an indicator of grassland connectivity (Rigney 2002). Large species such as the tule elk could help disperse grassland plant species that could be aided by hoof and dung dispersal more than wind (Kiviniemi and Eriksson 1999). In a relocation effort in Brushy Mountain, Mendocino County, tule elk were noted traveling as much as 28 km from the release site (Livezey 1994). Tule elk in the Mt. Hamilton region showed the greatest utilization of grassland during all seasons indicating their possible role in native grassland restoration work (Phillips 1985). Fluctuating herd sizes and locations may be an indication of changes in forage quality and quantity, a response to different habitats and an anti-predator strategy (McCullough 1969, Franklin et al. 1975, Hanley 1982, Thomas and Toweill eds. 1982). The continuing long-term dispersal of this large vertebrate species will include movement across Coyote Valley and surrounding areas (Phillips pers. comm., Coletto pers. comm.).

Corridor Design

Tule elk have been observed utilizing riparian corridors, including one female elk utilizing a riparian corridor adjacent to Interstate 5 and east of the Temblor Range in SLO County (Phillips 1988). In addition, tule elk have been observed moving across roads and highways as they shift to different areas of their home range during calving and breeding seasons (Phillips 1988). This indicates their ability to disperse across developed areas.

Crossing structures (including underpasses and overpasses) were constructed along the TransCanada corridor in Banff National Park in an effort to link habitat and provide safe routes for wildlife across the highway. Two years after the structures and fencing were installed, ungulate road mortality was reduced by 96% (Clevenger 1997).

Santa Clara Valley HCP/NCCP

The Santa Clara Valley habitat conservation plan and natural community conservation plan (HCP/NCCP) is currently in its early stages and is in a unique position to incorporate scientific data on wildlife connectivity into its plans. The California NCCP Act requires that NCCPs address connectivity among reserves and consider landscape-level processes such as wildlife linkage needs. The HCP/NCCP study area includes 520,000 acres, or about 62% of Santa Clara County. This includes all of the Coyote Creek watershed and the Uvas/Llagas/Pajaro watershed. Jones & Stokes, working on the HCP/NCCP, has developed several new data sets that can be used to evaluate potential for wildlife connectivity through the region and in Coyote Valley in particular. The first data set, existing open space, is the best compilation of protected lands in the region, and goes further than other open space data sets by including development set-asides as well as other types of protected land. The data set also identifies open space with different levels of protection and management focus. The second data set of importance is a land cover classification and detailed map for the entire study area. Jones & Stokes mapped 38 land cover types from orthorectified color air photos, soil and geology maps, and other sources. While the data set does have some limitations (e.g. a minimum mapping unit of 10 acres for most land types and the inability to map the full diversity of natural communities), it can be used to assess gaps in protected areas, identify most likely movement zones across major barriers, and to run Least Cost Path analysis for selected species (Zippin pers. comm.).

The HCP/NCCP will be covering 28 species. Some of these species, including Bay checkerspot butterfly, California tiger salamander, San Joaquin kit fox, steelhead trout, Chinook salmon, and California red-legged frog, have connectivity needs. Jones & Stokes has developed habitat distribution models, based on their land cover maps, topography, dispersal distances, and other criteria, for these species. These models predict where a species will occur in their study area and can be used to illustrate linkage needs. For instance, the habitat distribution model for California tiger salamander includes over 600 ponds with tiger salamander in the study area. The habitat is fairly extensive and connected in the region except for across Coyote Valley (Zippin pers. comm.). The habitat models also indicate that the connection between Metcalf Canyon and Tulare Hill is important for a number of species, including Bay checkerspot butterfly. The project is currently developing biological goals and objectives that will form the foundation of the conservation strategy. These goals and objectives will include conservation targets to maintain and, where feasible, improve wildlife connections in the study area. The project maintains a web site (www.scv-habitatplan.org) where extensive information on the plan is posted.

Coyote Valley as a Connection Point

At the current level of development in Coyote Valley, the evidence indicates that some important wildlife species are dispersing across the valley. Substantial resources have already gone into preserving corridors in the area. For instance, the Basking Ridge development on the east side of Highway 101 set aside 250 acres as a dispersal corridor for Bay checkerspot butterfly. The recolonization of Bay cherckerspot butterflies at Tulare Hill in 1995 suggests that butterflies were able to travel there from the core population on Coyote Ridge. A group of Tule Elk live on Coyote Ridge and have been spotted on the west side of Highway 101, suggesting that they can cross the valley (Coletto pers. comm.). Highway 101 is currently the largest barrier to connectivity and dispersal in the valley. However, there are 25 culverts passing under Highway 101 in Coyote Valley that could potentially be used by small to medium sized animals to facilitate movement between the Diablo and Santa Cruz Mountains. Of these, three to five could be used by large mammals as well (Johnston pers. comm.).

In addition to existing culverts, the Santa Clara Valley Water District's canals run throughout Coyote Valley and include narrow easements; these canals could provide possible connectivity within the valley. For instance, Coyote Canal runs under 101, and this and other canals that remain perennially wet support red-legged frog populations (Hillman pers. comm.). Many of these canals are currently unused. It was suggested at the workshop that these unused canals, such as the Coyote-Alamitos Canal, could be converted to amphibian movement corridors, though they might also have the dual effect of being routes for invasive species like bullfrogs.

Although some participants of the workshop suggested the potential for designing multiple corridors through Coyote Valley, it was most evident that there are two most feasible, larger potential wildlife corridors: Metcalf Canyon to Tulare Hill in northern Coyote Valley, and a corridor using the 101/Coyote Creek bridge and then commencing westward through the proposed Greenbelt Area in southern Coyote Valley. The Tulare Hill – Metcalf Canyon area is currently the shortest point between the two foothills in the Valley. The land is mostly owned by public entities and there are few property owners, so land acquisition could be easier here. However, this potential corridor borders the southern end of San Jose, a highly developed urban area. There is risk that species using this northern connection point could wander into highly developed areas, causing increased mortality rates. One possible solution to this threat is to convert the canal on the north side of Tulare Hill into a "moat" to create a barrier between urban areas and wildlife. While not a complete barrier, a moat may discourage wildlife from wandering into unsuitable habitat.

At the southern end of Coyote Valley, there is a wide underpass under Highway 101 along Coyote Creek. This potential connection point includes a wide area of open habitat with an abundance of agricultural land. Although this area may not currently represent a functional biotic connection, the opportunity exists here to create and restore ponds and vernal pools to facilitate amphibian dispersal. However, logical connectivity to the Sierra Azul is already interrupted by development, and numerous small, privately owned parcels that may conflict with many corridor design elements.

Two large corridors at either end of the valley could serve different functions for different species. Bay checkerspot butterflies are more likely to use a northern connection point because of the short flight distance between serpentine grasslands. However, conference participants noted that current land uses in the valley are not likely to preclude the butterfly's ability to move across the valley. On the other hand, based on an initial visual inspection of the landscape and the location of known populations, it appears that the southern connection point would be better suited for promoting tiger salamander dispersal because of the opportunity for creating and restoring ponds and vernal pools. These ponds and vernal pools could function as stepping stones for amphibians to move across the valley, even if it took several generations. In addition, mountain lions and other predators are likely to pass under the existing 101/Coyote Creek bridge because of the wide riparian corridor and vegetative cover in that area. Yet the higher probability of using one connection point over the other does not negate the use of a lesser connection point for any given species.

Both potential corridors raise issues of the benefits of overpasses versus underpasses in the Highway 101 pinch point. The northern connection point provides a feasible overpass at Metcalf Road. Metcalf Road is a low use road over Highway 101, which could be converted to a wildlife overpass. This would require re-routing local traffic to the frontage road and the Bailey Avenue interchange. The overpass would also have to be extended across Monterey Road and the railroad tracks to allow wildlife to access Tulare Hill. Large species such as Tule Elk would be more likely to use an overpass than an underpass (Phillips pers. comm.). Converting this site to a wildlife overpass makes biological sense, but there would be significant logistical and engineering constraints to overcome. However, the southern connection point provides a good underpass along Coyote Creek, for species that are more likely to use underpasses than overpasses.

Sierra Azul Corridors

Coyote Valley does not exist alone in the Sierra Azul region as the only possible area of biotic connectivity. The area along Highway 129 near the Chittenden Gap provides another likely corridor between the Santa Cruz Mountains, the Southern Diablo Range, and the Gabilan Range. The additive or differential importance of the Coyote Valley vs. the Chittenden Gap corridors has yet to be analyzed. Relative impact of the loss of each is an important factor in such an analysis, as well. There is at least one research project pending that could analyze this for mountain lions and smaller predator and prey species (Korpos pers. comm.).

Participants in the workshop suggested that mountain lion movement would be benefited by the Chittenden Gap corridor because it is currently far less developed. Participants suggested that Coyote Valley does have some conservation value, but the Chittenden Gap corridor should be given higher priority for mountain lions. However, this was based on anecdotal not empirical or modeling data (Hopkins pers. comm.).

Other workshop participants made the case for preserving habitat corridors in both areas. They pointed out that the Precautionary Principle would suggest the need for both connection points in case something disastrous happens in one or the other corridor: multiple connections are important to increase connectivity and build redundancy into the system. The two corridor areas may each be important by serving different functions for different species. While Chittenden Gap may be more important for mountain lions, Coyote Valley is certainly more important for Bay checkerspot butterfly because of the large core population on Coyote Ridge. Also, current data suggest larger populations of red-legged frog and tiger salamander near Coyote Valley than Chittenden Gap, so Coyote Valley could prove a more important corridor for those species.

Much remains uncertain about the viability of many populations of species should either or both connectivity areas be lost or further degraded. Different species can persist at different population numbers in different amounts of core habitat. Whereas the Santa Cruz Mountains may be too small to preserve a long term mountain lion population without the benefits of immigration, the range might support long-term viable populations of other species, such as California tiger salamander. If both corridors lose viability and biotic connectivity between the Santa Cruz Mountains and other areas altogether ceases, genetically isolated populations may become eligible for legal protection under the endangered species act in the future. This would create additional burdens on agencies and private land owners alike and so it would behoove all to plan for and preserve effective biotic connectivity in the Sierra Azul region.

Further Research

Many opportunities for future research exist. Jones and Stokes mapped 38 land cover types for the current Santa Clara Valley HCP/NCCP, but comparable data do not exist for the Chittenden Gap corridor area at this time (Zippin pers. comm.). In addition, there is a general lack of good corridor modeling data for any species other than American badgers in the region; such data could help in prioritizing areas of biotic connectivity. It should be noted that the workshop did not consider many important species in the area that have various needs for connectivity, such as avian species and plant species. While some of these species should be considered, it is also important to prioritize some species as indicator species for wildlife movement because it is not possible to consider all when designing a corridor. Most importantly, we need to demonstrate the consequences of losing connectivity in order to justify preserving it. We encourage further research and analysis of habitat connectivity to improve conservation acquisition, design, and management of biotic corridors in the Sierra Azul Region.

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Appendix A

Workshop Participants

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Patrick Congdon, General Manager, Santa Clara Open Space Authority
Tanya Diamond, graduate student, San Jose State University
Craige Edgerton, Executive Director, Silicon Valley Land Conservancy
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Janell Hillman, botanist, Santa Clara Valley Water District
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Brenda Johnson, Conservation Planning Ecologist, CA Department of Fish and Game
David Johnston, Environmental Scientist, California Department of Fish and Game
Michele Korpos, Wildlife Ecologist, Live Oak Associates
Bill Lidicker, Professor of Integrative Biology, UC Berkeley
Grant Lyon, Assistant Coastal Training Program Coordinator, ESNERR
Daniel Olstein, Project Manager, The Nature Conservancy
Julie Phillips, Professor, De Anza College
Jessie Quinn, Graduate Student, UC Davis
Paul Rich, Creekside Center for Earth Observations
Pete Trenham, US Fish & Wildlife Service
Stuart Weiss, Consulting Ecologist, Creekside Center for Earth Observations
Nina Wohlers, Research Assistant working with Tanya Diamond
David Zippin, Associate Principal, Jones & Stokes

Appendix B

Workshop Presentations

Bill Lidicker, Museum of Vertebrate Zoology, UC Berkeley
Corridor Ecology: A Snapshot

David Zippin, Jones & Stokes
Wildlife Connectivity and the Santa Clara Valley Habitat Conservation Plan and Natural Community Conservation Plan

Verna Jigour, Verna Jigour Associates
Conservation in a Regional Context: The Central Coast Wildlands Project

Henry Coletto, Santa Clara County Game Warden (retired)
History of Wildlife Along the Coyote creek and 101 Corridor

Tanya Diamond, Graduate Student, San Jose State University
Using GIS to Identify Potential Corridors Utilized by North American Badgers in the San Francisco Bay Area and Monterey County

Jessie Quinn, Graduate Student, UC Davis
Understanding Badger Conservation Status and Movement Behavior in California

Rick Hopkins, Live Oak Associates
Modeling Reality in an Uncertain Universe: The Cougar in Southern California as a Case Study

Michele Korpos, Live Oak Associates
Cougar Corridors and Bay Area Regional Planning

Stuart Weiss, Creekside Center for Earth Observations
Dispersal of Checkerspot Butterflies Across Coyote Valley

Pete Trenham, U.S. Fish and Wildlife Service
Biological criteria for promoting habitat connectivity for California tiger salamanders and California red-legged frogs