SPONSORS

The *Missing Linkages* conference was cosponsored by the California Wilderness Coalition, The Nature Conservancy, the Biological Resource Division of the United States Geological Survey, the Center for Reproduction of Endangered Species, and California State Parks. Together these organizations represent a wealth of expertise in conservation issues, including biological assessments, reserve design, land acquisition and preservation, active land management, and reintroduction programs for endangered species.

Missing Linkages is overseen by a steering committee and staff including Paul Spitler, Executive Director, California Wilderness Coalition; Dr. Kevin Crooks, Department of Wildlife Ecology, University of Wisconsin, Madison; Dr. M.A. Sanjayan, Director of Conservation Science, The Nature Conservancy; Rich Hunter, GIS Conservation Planner, Talon Associates; and Kristeen Penrod, Executive Director, South Coast Wildlands Project.

The California Wilderness Coalition (CWC) is a statewide organization whose mission is to protect California's remaining wilderness. CWC has initiated and led numerous statewide and regional wilderness campaigns to gather support for the preservation of California's wildlands. Website address: http://www.calwild.org

The Nature Conservancy (TNC) is a national organization whose mission is to preserve the plants, animals and natural communities that represent the diversity of life on earth by protecting the land and water they need to survive. TNC has a keen interest in connectivity and relies on protecting entire functional landscapes as a strategy for conserving biodiversity. Website address: http://www.tnc.org

The Biological Resources Division (BRD) is the research arm of the United States Geological Survey. BRD conducts studies and inventories of wildlife habitat throughout the United States. BRD enters into partnerships with scientific collaborators to produce high-quality scientific information and ensures the information's application to real problems. Website address: http://www.usgs.gov

The Center for Reproduction of Endangered Species (CRES) is the research department of the Zoological Society of San Diego. Since its founding in 1975, CRES scientists have worked to acquire knowledge vital for the conservation of the world's plant and animal communities, both locally and abroad. The Ecology and Applied Conservation Division of CRES is devoted specifically to the conservation of

endangered species in their native habitats. Website address: http://www.sandiegozoo.org/conservation

California State Parks manages and conducts research on over one hundred publicly owned parks and preserves in the state. Many plant and wildlife species rely on these parklands for all or a portion of their life cycle. Active grant programs that may aid in the protection of linkages identified at the conference include the Land and Water Conservation Fund, Habitat Conservation Fund, and 2000 Park Bonds Act. Website address: http://www.cal-parks.ca.gov

1.0 INTRODUCTION

Nature needs room to move. For many species to persist and for communities to withstand environmental disturbances such as fire or climate change, isolated nature preserves simply will not suffice. Habitat fragmentation reduces, often irreversibly, the permeability of the landscape to its native flora and fauna. In California, urban sprawl, roads, and other anthropogenic forces are carving up habitat into ever-smaller fragments. Maintaining connectivity between the remaining natural areas and minimizing further fragmentation is crucial to the long-term viability of California's natural heritage. If selected carefully and managed properly, habitat linkages and wildlife corridors – which can range from a large intact ranch bridging two protected areas to narrow riparian corridors or highway underpasses – can significantly contribute to both the viability of individual species but also to the integrity of the natural community.

Until recently there has been little coordinated statewide effort in California to systematically identify, study, and protect wildlife corridors. In some cases, local or regional reviews have been completed and the results documented. In other cases, the location of critical corridors remains hidden in the archives of "local knowledge" and therefore does not influence public policy and private land conservation initiatives. Access to the best information is crucial and despite advances in conservation planning, there is still no forum for interested parties to share information about wildlife corridors. Thus, many linkages are being severed simply because their existence is unknown.

To address this problem we began working with several partners (California State Parks, United States Geological Survey, San Diego Zoo) to convene a conference to bring together experts who had on-the-ground familiarity with habitat corridors. The conference was held in November 2000 at the San Diego Zoo, and its success was entirely attributable to the diverse mix of agency staff, conservationists, and university scientists who attended and worked together to delineate the State's most important linkages, along with pertinent annotations for each linkage.

The results of this gathering, presented here, not only provides scientific credibility to all our collective efforts to maintain a network of interconnected public and private conservation areas throughout the state but also guidance on where future conservation might be directed. While we caution that these results are at a coarse scale and should not supplant fine resolution planning necessary to determine the exact location and design of individual corridors, we nevertheless assert that the information provided here is unprecedented in its scope and detail.

It is likely that in the coming few decades, the establishment of major new protected areas in California will become increasingly rare. Thus, keeping existing wild places connected is the only rational means of maintaining enough accessible habitat for many species that call California home. Further, with regional climate change looming, community expansion or range shifts can only occur if some measure of landscape permeability is maintained. We hope that our collective efforts presented here provide a necessary first step for maintaining connectivity to an increasingly fragmented California landscape.

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Paul Spitler
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1.1 MISSION AND GOALS

The primary goal of the *Missing Linkages: Restoring Connectivity to the California Landscape* conference was to bring together land managers and planners, conservationists, and top scientists from each ecoregion in the state to identify the location of, and threats to the most important movement corridors for California's wildlife. The mission of *Missing Linkages* was to raise the awareness level of the need for protecting and restoring connectivity; this can be accomplished through advocacy, education, planning, and bringing together key stakeholders to work towards implementation. The conference was held on November 2, 2000 at the San Diego Zoo, San Diego,

California (Appendix A, *Conference Agenda*). *Missing Linkages* was a tremendous success with one hundred and sixty scientists, conservationists, land managers, and planners in attendance. Participants delineated over three hundred linkages throughout the state.

1.2 CONFERENCE STRUCTURE

Missing Linkages was a one-day event that was divided into two sessions. The first session was a series of presentations about the importance of corridors by renowned conservationists. This information-sharing session informed conference participants about the importance of, and the latest research in corridor protection, and set the stage for the following section. The second section was a hands-on working session. The state was divided into eight ecoregions: North Coast, Bay Area, Central Coast, South Coast, Central Valley, Modoc Plateau & Cascades, Sierra Nevada, and Mojave & Sonoran Deserts (Figure 1-1, *California Regions and Topography*). Each ecoregional team was provided with a series of base maps detailing landownership, road density, land cover, and log sheets. Conference participants shared their knowledge in their ecoregion of expertise by marking the locations of important movement corridors and providing detailed information on each linkage identified. Participants also worked with adjacent ecoregions to ensure habitat connectivity throughout the state. The proceedings have been organized in a similar structure to the conference, arranged by ecoregion, with a statewide overview of California's *Missing Linkages.*

1.3 KEYNOTE ADDRESSES

THE ROLE OF ZOOLOGICAL INSTITUTIONS IN CONSERVATION

ALAN DIXSON
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Abstract: The Zoological Society of San Diego has developed a superlative collection of animals and plants; many of them are extremely rare, and all of us are privileged to work in this unique environment. Beyond our gates, however, the plight of these animals and plants is steadily worsening as the human population increases and exploits the earth's resources. There are now six billion people in the world, and every minute a further 260 babies are born. Within the lifetime of these children, the human population is going to double. This is a terrifying prospect. All of us who are concerned with conservation, maintenance of biodiversity, sustainable use of resources, and the quality of life cannot ignore the problems created by uncontrolled human reproduction.

As habitats are destroyed and species are lost, those of us who work in zoological institutions have several important responsibilities. We must continue to do everything possible to maintain self-sustaining populations of endangered species in captivity; we must also study their biology and bank genetic material, particularly from the most endangered forms. Our zoological collections also represent a powerful educational tool; for children, in particular, there is no substitute for seeing animals and plants in the living state. Then there is the responsibility to study endangered species in the wild and to help conserve their natural habitats. In this latter regard, I am delighted that the Zoological Society's Board of Trustees has approved the creation of a postdoctoral fellowship program, specifically for field research on endangered species and ecosystems. These posts will provide gifted young scientists from the United States and abroad with opportunities to carry out field projects in collaboration with workers at CRES and in our Curatorial, Veterinary, and Education Departments. In this way we shall increase our efforts to prevent the extinction of endangered species, and we shall help to train the next generation of biologists who will act as ambassadors for the Society in the broader world of conservation science. As testament to the urgency of wildlife conservation here at home, we currently have postdoctoral fellows carrying out research programs on bighorn sheep, California condors, and southern California reptiles.

In light of increasing habitat fragmentation both here and abroad, planning for conservation must take into account wildlife movement between and among metapopulations through corridor protection and restoration. We are pleased that this effort is being undertaken to identify key habitat linkages here in California. The work of the Missing Linkages Conference will take a major

step toward delineating statewide corridors crucial to sustaining California's unique and increasingly threatened natural areas. Together with our conservation partners, we look forward to the day when the importance of habitat linkages is better understood and appreciated as a critical component of the planning and maintenance of wildlife reserves throughout our state.

IS CONNECTIVITY NECESSARY?

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Abstract: The fate of isolated habitat remnants has been one of the most active research areas in conservation biology. Based on hundreds of such studies, the evidence is clear: isolated remnants suffer predictable, cumulative losses of species; this is one of the strongest generalizations in the field of ecology. Therefore, it is self-evident that isolation is harmful. It follows that connectivity should be maintained or restored wherever possible. The detailed architecture of landscape linkages is not as important as we might imagine. Mammals, at least, are smarter than we think, and they learn over time where the safe areas of connectivity exist, and this knowledge spreads in species in a fashion similar to cultural transmission.

In other words, "wildlands integrity" or "wildlands intimacy" should be our goal. This requires large, undisturbed core areas, the maintenance of keystone interactors, including large carnivores (ecological governors), and connectivity to maintain ecologically effective populations of these key species. In the absence of large carnivores and other keystone (or foundation) species, species diversity declines.

Connectivity also includes the concept of stepping stone reserves for pollinators, seed dispersers, and other flying species such as birds, bats, and insects.

Regarding the design of protected area networks, history dictates that we plan for the worst possible scenario (e.g., regarding build-out and changes in technology). We must also plan for species, such as wolves and grizzly bears, that have been extirpated and that should be allowed to return. If it scares us to think in these terms, it is probably a good idea.

DOCUMENTING THE CONSERVATION VALUE OF CORRIDORS

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Abstract: Skeptics have questioned the empirical evidence that corridors provide landscape connectivity. We reviewed published studies that empirically addressed whether corridors enhance population viability of species in habitat patches connected by corridors. The most meritorious studies followed one of two approaches.

Mansergh and Scotts (1989) provided the best example of the experimental approach. They studied two subpopulations of a rare species, the mountain pygmy-possum (*Burramys parvus*), restricted to alpine rocky screes in Australia. One subpopulation enjoyed an intact landscape, whereas the formerly contiguous habitat of the second subpopulation had been fragmented by a ski development and an associated road. The fragmented area exhibited skewed sex ratios and lower survival rates than the intact area. After construction of a corridor, however, the population structure and survival rates in the ski resort changed to those observed in the undisturbed area. The study was not replicated, consisting of a single treated; and a single control landscape. Nonetheless, by collecting data on both treatment and control areas before and after manipulation, they made strong inferences regarding the effects of this particular corridor, though they cannot make inferences about the utility of corridors in general. The experimental approach is superior to observing the demographic conditions in various landscapes because of the tendency (in most

landscapes) for corridor presence to be correlated with other variables, such as patch size, that can confound the analysis.

Because there is general agreement that landscape connectivity enhances population viability, the second approach is to observe whether individual animals in fragmented landscapes use corridors to move from patch to patch, and that in a landscape without corridors such movements would occur too rarely to influence the population. Of 17 studies of animal movements, Suckling (1984) and Beier (1995) provided strongest inferences because they focused on dispersing juveniles, reported the fraction of dispersers using corridors, and explicitly documented a lack of movement through the matrix. Beier, working on *Puma concolor* in southern California, found that five of nine dispersers found and successfully used corridors, that all three potential corridors were found and traversed by at least one disperser, and that no inter-patch movements occurred via the urban matrix.

Studies of animal use of corridors should focus on fragmentation-sensitive species that need corridors (rather than easily-studied species of no management concern), on dispersing juveniles, and on the real landscapes that are the subject of decisions on corridor preservation. We found limited value in studies that merely documented animal presence in corridors, rather than movement through corridors, and in those that failed to compare movement rates through corridors to movement rates through the matrix.

We found no empirical evidence for the hypothesized negative impacts of conservation corridors. Despite the shortcomings of many studies, the preponderance of evidence is that corridors facilitate travel by a great many species.

GOALS OF THE MISSING LINKAGES CONFERENCE

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Abstract: The purpose of the *Missing Linkages* conference is to convene scientists, lands managers, and conservationists from throughout California to plan for regional habitat connectivity issues. The conference will consist of ecoregional break-out sessions, allowing participants to share local knowledge and expertise in order to identify the primary landscape linkages and connectivity choke-points within each ecoregion in the state; ecoregional chairs have been chosen to help facilitate this process. Each ecoregional team will have base maps (topographic maps, road density models, land cover depictions) to help participants identify key linkages; each linkage identified will be labeled directly on the maps. Additionally, for each linkage, a Linkage Description Form will be completed to record the linkage identification (ID) number, linkage name, linkage type, key species or ecological processes considered, immediacy of threat to connectivity, feasibility of conservation opportunity, and other supporting information, materials, and citations. The resulting maps and description logs from all ecoregions will be compiled to assess and prioritize the key linkages throughout the state. We hope that this forum will help facilitate communication, coordination, and concentration on regional connectivity issues in California.

1.4 EVALUATING THE DATA

Ecoregional team members labeled the linkages directly onto 1:250,000 scale base maps. This information was digitized, imported into ArcView GIS and linked to ecoregional databases created from the data gathered at the conference. The ecoregional maps produced were then joined to generate a statewide map of California's *Missing Linkages*. Map identification numbers (Map ID#s) referenced in the text correspond with the *Missing Linkages* map for that ecoregion.

Conference participants provided information on specific linkages by completing linkage description log sheets for each linkage identified (Appendix B, *Identifying the Linkages*). The log sheets completed, were sorted by ecoregion and have been provided on a CD, located in the front cover, *Linkage Description Log Sheets*. Information gathered from the log sheets has been analyzed separately by ecoregion, and collectively for the state.

Participants specified the type of linkage (e.g. Landscape Linkage, Connectivity Choke-Point, Missing Link); this information was evaluated to determine the relative number of linkages

identified for each linkage type. Linkage types were defined on the linkage description log sheet as:

- Landscape Linkage = Large, regional connections between habitat blocks ("core areas") meant to facilitate animal movements and other essential flows between different sections of the landscape (taken from Soulé and Terborgh 1999). These linkages are not necessarily constricted (yet), but are essential to maintain connectivity function in the ecoregion. These may include habitat linkages, riparian corridors, etc.
- Connectivity Choke-Point = A narrow, impacted, or otherwise tenuous habitat linkage connecting two or more habitat blocks ("core areas"). Choke-points are essential to maintain landscape-level connectivity, but are particularly in danger of losing connectivity function. An example of a connectivity choke-point is a narrow peninsula of habitat, surrounded by a human-dominated matrix, that connects larger habitat blocks. Another example would be an underpass under a major roadway that is critical to allow animal movement between habitat blocks.
- Missing Link = A highly impacted area currently providing limited to no connectivity function (due to intervening development, roadway, etc.), but based on location one that is critical to restore connectivity function. For example, a missing link might be a critical section of a major highway that bisects two larger habitat blocks but that is currently impermeable to animal movement.

Participants listed the key species and/or ecological processes used to identify each linkage. Key species and/or ecological processes have been listed for each ecoregion and compiled for the state. In addition, the percent of linkages identified by each taxonomic group was calculated.

Conference participants provided information on land cover and habitat types for each linkage; a brief description of the primary habitat types identified has been provided in the ecoregional summaries. In addition, significant blocks of publicly owned habitat (state parks, national forest, etc.) and military lands have been listed for each ecoregion.

Ecoregional team members documented the most significant barriers to animal movement (e.g. roads, dams) and the primary features that facilitate wildlife passage in each linkage. Conference participants recorded if the linkage required restoration to reestablish connectivity function; they listed the primary restoration needs (e.g. exotic species eradication, habitat restoration, underpass enhancement) and identified the habitat types in need of restoration (e.g. riparian, coastal sage scrub, forest). This information was evaluated to determine the primary barriers, linkage features, and restoration needs.

Participants ranked the overall threat to connectivity function for each linkage from one to five, with one being no threat/secure, and five being severe threat/loss imminent. This information was evaluated to determine the number of linkages ranked for each category. Participants also identified and ranked specific threats to each linkage on the linkage description log sheets. This information was analyzed to determine the percent of linkages affected by each threat. The weighted average (average rank score number of linkages affected) was also calculated to find out the severity of each threat.

Ecoregional team members scored the overall feasibility of conserving each linkage from one to five, with one being not feasible, and five being a good opportunity. This information was also evaluated to determine how many of the linkages were ranked for each category. Scores for the overall degree of threat and the feasibility of conserving the linkage were compared to identify the top-ranked linkages in each ecoregion. A brief description has been provided for the top-ranked linkages.

Participants identified whether there were willing sellers, local support, and/or the potential for agency acquisition. They also recorded if the habitat linkage was part of a formal conservation plan. The information on willing sellers and agency acquisition was evaluated to determine the percent of linkages with either classification; they were then compared to identify those linkages with both willing sellers and opportunities for agency acquisition. Other opportunities listed to restore habitat connectivity (e.g. conservation easements, formal conservation plans) were summarized.

Documentation referencing specific linkages is listed in the ecoregional summaries and, when possible, included in Appendix C, *Connectivity References*. Conference participants also provided some site-specific maps that highlight one or more linkages; these are provided in the ecoregional summaries and are cross-referenced with Map ID#s depicted on the *Missing Linkages* ecoregional maps.

Decision rules were developed for prioritizing the linkages statewide. This involved calculating information on (1) Conservation opportunity, (2) Presence of target species, (3) Overall threat, and (4) Existence of documentation. Data for Conservation opportunity, Presence of target species, and Overall threat were each normalized with quantile breaks to create three different classification fields. If there was existing documentation for the linkage, it received three additional points. Scores for each were then added and the linkages classified into three broad categories: high (score 10-12), medium (score 7-9), and low priority (score = 6). A statewide map has been generated to graphically display the results of this analysis. The results were then summarized in tabular format. For more detailed information on the methodology for this analysis please refer to Appendix D, *Statewide Analysis*.

We draw attention to some limitations in the data gathering process to aid in the interpretation of the results:

- Not all studies documenting the importance of habitat connectivity in the state were referenced on the log sheets.
- Some linkages have multiple arrows on the ecoregional and statewide maps with one corresponding data sheet and linkage ID#, whereas a few linkages were drawn as a single arrow but represent multiple choke-points.
- There were variances in the representation of the arrows. Some were drawn from the boundaries of one protected area to another, while others were drawn without regard for political boundaries.
- There were differences in criteria between and among ecoregions; participants had different perceptions of what constitutes a severe threat (e.g. expanding vs. existing urbanization).
- There were differences in how participants interpreted the type of linkage: Missing Link, Choke-Point or Landscape Linkage.
- There was a disparity across individual linkages in terms of available information (e.g. willing sellers, restoration needs, scientific documentation). In addition, for some linkages, participants completing the log sheets might not have been aware of all existing information.

1.5 A NOTE FROM THE SPONSORS

We acknowledge that this is the first step in a long process of restoring and/or protecting habitat connectivity across the California landscape. Because the conference was limited to 160 participants, not all the key players and stakeholders in the state were present. Therefore, not every habitat linkage in the state is represented herein. Future iterations of the maps generated will be required and additional data will need to be gathered. We do not yet understand all there is to know about habitat connectivity in California and recognize that it is impossible to lay the biological foundation for statewide connectivity in a day. However, we feel that *Missing Linkages* was a tremendously productive first step. Recommendations for future steps include:

- Follow-up workshops in each ecoregion to further refine linkage identifications and descriptions
- Connectivity planning workshops for specific high priority linkages
- Meetings with key decision-makers to discuss implementation strategies
- Producing and publishing articles in mainstream media to educate the public on the role of corridors in conservation and the need for corridor protection
- Conducting follow-up research to gather supporting documentation and the additional data (e.g., radio-telemetry studies, corridor studies, road-kill data) necessary to substantiate the need for full protection of the linkages identified
- Further research on connectivity for under-represented taxonomic groups
- Seeking scientific peer review of proceedings and other products
- Working to protect and restore habitat linkages to ensure the persistence of California's native flora and fauna

Missing Linkages was an opportunity for a number of stakeholders to work cooperatively on habitat connectivity issues throughout the state; it proved to be an extremely productive event. We would like to thank the ecoregional chairs and conference participants for their enthusiasm and dedication to the task of identifying California's *Missing Linkages* (Appendix E, *Ecoregional Chairs & Conference Participants*). The proceedings will be used for an ambitious campaign designed to heighten the awareness of wildlife movement and habitat connectivity issues, and to gain protection for important corridors. The proceedings will be broadly distributed to land managers and planners, regional and statewide decision-makers, policy-makers, scientists, conservation advocates and the media.