Connectivity Strategic Plan for Western San Diego County
Science Session – July 1, 2014

Connectivity Project Summaries

These project summaries document expert findings regarding connectivity on at-risk resources.

**prepared by SDMMP, please excuse errors in interpretation of reports*

Connectivity Project Summary of At Risk Resource – Mountain Lion

Assessor: Winston Vickers

Agency/Institution: UC Davis Wildlife Health Center

Resource being assessed: Mountain lion (puma (*Puma concolor*)) connectivity

Sampling technique: Trail cameras, puma capture and GPS-collaring

General location: Western San Diego County west of the Cuyamaca Mountains, and extending from the US-Mexico border in the south to the area just north of Ramona.

Specific preserves (if applicable):

Time series: May 2012 – June 2014

Finding regarding connectivity and resource: Connectivity for pumas between certain San Diego County conserved lands is very limited, and mortality rates from roads are high, though other risks to pumas such as being killed after issuance of a depredation permit (4 pumas in the last year), are also quite significant. Highways and associated development, even rural development, appear to be the primary limiters of connectivity between conserved lands.

Highways in the study area that are implicated as partial barriers to movement or containing sections that are higher risk for pumas include Interstate 15, Valley Center Rd (S6), SR 67, SR 78, Wildcat Canyon / Barona Road, Interstate 8, Interstate 15, and SR 94. In many sections noted as having limited puma crossings or collisions with vehicles, conserved lands existed adjacent to or near both sides of the highway. No puma use was documented on conserved lands west of I-15, and very minimal use of conserved lands was noted west of SR 67 south of Ramona. The one crossing of a GPS-collared puma onto conserved lands west of SR 67 was a one-time brief crossing from east to west followed by the puma involved (M107) being killed by a vehicle collision when trying to cross back to the east. Crossing of Wildcat Canyon / Barona Road was limited almost entirely to one short section north of the Barona Casino, despite the presence of conserved lands on both sides of the road over a much more substantial distance.

It is apparent that in order for pumas to occupy normally sized territories (over 100 square miles in some cases) in this landscape, regular crossings of busy highways are required of essentially all individuals, and this fact should be taken into account in highway / development and conservation planning. In order for highway crossings by pumas to safely occur consistently, adequately sized crossing structures as well as fencing that is adequate to funnel animals to safe crossings is often required. It appears that numerous sections of the named highways and other roads and development in the study area likely pose a hazard for pumas, and are at least partial barriers to connectivity between blocks of conserved habitat.

The UCD team believes that data to date suggests that conservation prioritization should be given to protection and expansion of the natural travel corridors between conserved lands that have been shown to be utilized or potentially utilized by pumas in this study and our previous work.

Additional preservation of corridors is especially critical between the conserved lands in the Ramona area and those to the north and northwest (Palomar and Santa Ana Mountain ranges) due to recent findings of severe genetic restriction of pumas in the Santa Ana range (inclusive of the San Diego County portion of the range), and clear genetic separation between those pumas and the populations east of I-15.

We urge conservation of additional lands near roads where puma approaches to road crossings have been documented, and expansion of the size of currently conserved lands wherever possible. We urge joint effort between San Diego, Riverside, and Orange Counties to improve connectivity for mt lions specifically across I-15 between Temecula and Escondido. The few remaining locations where viable crossings could be created or improved exist in that section of I-15, and are rapidly being degraded further.

We feel that it is also important to assure not only that adequate numbers of safe crossing structures are present in all of the travel corridors that we have documented, but also appropriate fencing (for this species) should be utilized to funnel animals to safe structures and prevent vehicle-related mortalities. It is important to note that the remaining connections between conserved lands in this study area are currently often fragmented, and present elevated risks to pumas from other human interactions that are independent of risks posed by the highway crossings.

Hypothesized mechanism for impacts: Fragmentation of habitat by roads and human development (barrier effects, mortality from vehicles, higher risks overall in areas adjacent to human activity), and relatively small size of conserved habitat patches and corridors (relative to mt lion home range sizes), are both responsible for negative impacts on puma use of conserved lands. These factors are exerting especially negative effects on puma population stability and genetics in the northwest portion of the county west of I-15, and the contiguous counties to the north.

These negative mechanisms can be expected to further erode connectivity and possibly impact puma population demographic and genetic stability elsewhere in western San Diego County if the amount of conserved lands and the connections between them are not improved.

Information needs for future adaptive management:
Additional camera monitoring, acquisition of additional puma movement and genetic data, updated modeling of habitat and potential movement corridors (based on both habitat use data and genetic data) in the northern portion of the county.

Current and future information developed by study of puma can provide important guidance for prioritization of conservation purchases in the future, especially in the central- and north-western portions of the county.

References:

See attached sheet

Connectivity Project Summary of At Risk Resource - Bobcat

Assessor: Megan Jennings and Rebecca Lewison with Erin Boydston and Lisa Lyren

Agency/Institution: Institute for Ecological Monitoring and Management at SDSU and USGS

Resource being assessed: Connectivity for large animals using bobcats as a model species

Sampling technique: Remote cameras, GPS telemetry, road kill collection, genetic analysis, habitat/connectivity modeling, occupancy modeling

General location: San Diego MSCP Area

Specific preserves (if applicable): Los Penasquitos Canyon, Black Mountain, Boden Canyon, San Dieguito River lands, Ramona Grasslands, Boulder Oaks, Iron Mountain, Sycamore Canyon/Goodan Ranch, Rattlesnake Canyon, Mt. Woodson, Cleveland National Forest

Time series: 2009-2012

Finding regarding connectivity and resource (see attached map):

- Overall, there is evidence of connectivity in the inland and coastal areas of the MSCP network that we sampled.
- Genetic analysis showed some degree of genetic differentiation between coastal bobcats west of I-15 and inland animals to the east, but did not indicate subpopulation differentiation has occurred. This supports the assertion that the coastal and inland areas have some level of connectivity.
- Movement analyses (camera and telemetry) showed direct use of five of seven linkages that were monitored. Detected movement was highest in Linkage 6-7, Linkage 8-10, and Linkage 5-6.
- For linkages not directly monitored, results from landscape models suggest that at least five other areas identified as putative linkages may have limited to no current connectivity, and another nine may only function partially. These limitations will likely increase under future, projected land use.
- Our analyses suggest that connectivity of large animals is more likely to be affected by project changes in land use patterns than projected changes in habitat related to climate change.

Hypothesized mechanism for impacts:

- Habitat alteration and recreation, in addition to other ecological variables, are currently affecting wildlife occupancy. These effects may increase under projected land use shifts.
- Heavily traveled secondary roads with traffic moving at high rates of speed may pose the largest threat to medium-wide ranging wildlife species attempting to move between core conserved areas, especially from coastal to inland areas. Roadkill mortality appears to increase with seasonal increases in animal movement.

- For species sensitive to habitat fragmentation, increasing fire frequency may be leading to impaired landscape connectivity. Failure to account for fire return interval departures can result in overestimation of landscape connectivity.
- Projected habitat shifts resulting from climate change did not lead to substantial changes in habitat suitability or effective distance between preserves. However, future land use plans that lead to increased areas of altered use categories are likely to reduce habitat suitability in and around inland preserves.

Information needs for future adaptive management:

For large animals (not to be interpreted as a prioritized list):

- Additional genetic data and analyses
- Region-wide analysis of genetic data (Los Angeles, Orange County, and San Diego County)
- Further occupancy analysis of remote camera data, including an analysis of the patterns of species co-occurrence in conserved cores, at pinch points, and in linkages
- Comparison of CBI connectivity assessment remote camera data from early 2000s to present day
- Additional roadkill collection and data mining to conduct hotspot analysis
- Ensemble analysis of connectivity using species distribution modeling and connectivity assessment programs such as Circuitscape, MaxEnt, Linkage Mapper, and ModEco
- Continue to map actual movement corridors between conserved cores using above data to improve monitoring and management
- Testing and refinement of individual-based models developed from Orange County bobcat data (Tracey et al.) with San Diego bobcat data

For all currently monitored indicator species:

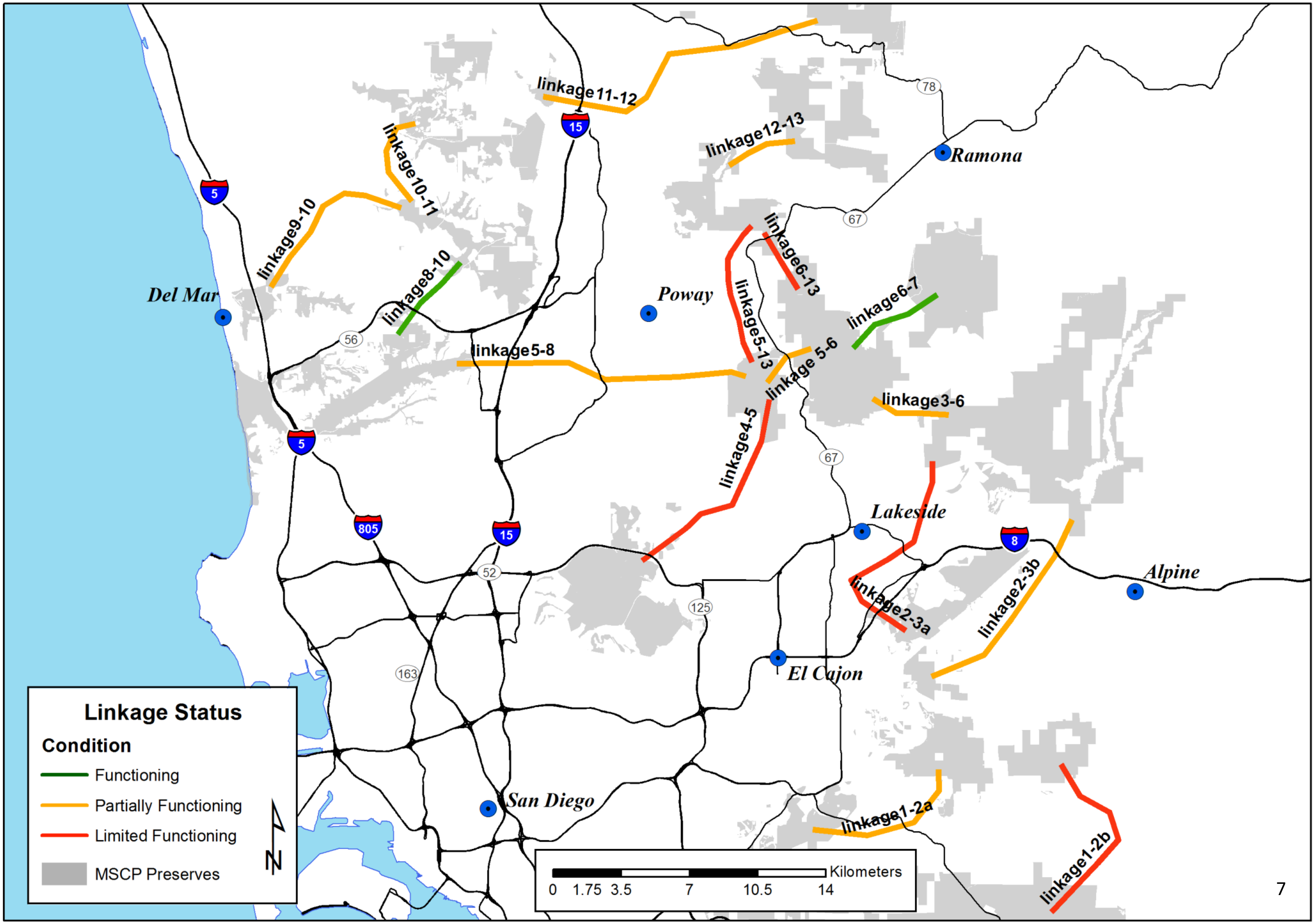
- Synoptic assessment of connectivity data from all focal species across projects conducted in the County, including analysis of connectivity under climate change and shifting land use patterns. This comprehensive assessment can also take an ensemble analysis approach. This approach is needed to ensure return on investment for all the individual connectivity that have been funded and to ensure that the results from these different studies can be integrated into a common connectivity assessment for the MSCP.

References:

Conservation Biology Institute. 2002. Wildlife corridor monitoring study for the MSCP. Prepared for City of Poway, City of San Diego, and CA Dept of Fish and Game.

Conservation Biology Institute. 2003 a. Review of regional habitat linkage monitoring locations, MSCP. Prepared for the CA Dept of Fish and Game. NCCP Local Assistance Grant #P0050009, Task A.

Jennings, M & R Lewison. 2013. Planning for connectivity under climate change: Using bobcat movement to assess landscape connectivity across San Diego County's open spaces. *Technical Report*.


linkage11-12
linkage12-13
linkage10-11
linkage9-10
linkage8-10
linkage6-13
linkage5-13
linkage6-7
linkage5-8
linkage 5-6
linkage3-6
linkage4-5
linkage2-3a
linkage2-3b
linkage1-2a
linkage1-2b
Ramona
Del Mar
Poway
Lakeside
Alpine
El Cajon
San Diego
5
15
805
8
78
67
56
52
125
163
Linkage Status
Condition
Functioning
Partially Functioning
Limited Functioning
MSCP Preserves
N
Kilometers
0 1.75 3.5 7 10.5 14

Connectivity Project Summary of At Risk Resource – American Badger

Assessor: Cheryl Brehme

Agency/Institution: USGS

Resource being assessed: American Badger

Sampling technique: Sign surveys, canine scent detection of scat, genetic testing of scat, hair snags and cameras.

General location: Western San Diego County (on or near Conserved Lands in MSPA)

Specific preserves (if applicable): NA- see below

Time series: 2011, 2014

Finding regarding connectivity and resource: Badgers are present but likely in low densities in areas of western San Diego County. Activity was confirmed in 2011 in Marine Corps Base Camp Pendleton, Fallbrook Naval Weapons Station, Daley Ranch in Escondido, Ramona Grasslands, Warner Springs Ranch, Whelan Lake, Crestridge Ecological Reserve, Santa Ysabel Ecological Reserve, Hollenbeck Canyon Wildlife Area (HCWA), and Marron Valley. In 2014, we could not confirm recent badger activity in the MSPA and adjacent focal areas of Ramona Grasslands, HCWA, Marron Valley, or Santa Ysabel ER, but have confirmed recent badger activity at Volcan Mountain ER, upper San Diego River, and Barnett Ranch. Study is ongoing with results and conclusions still pending.

Hypothesized mechanism for impacts: Badgers have large home ranges and are thus vulnerable to effects of habitat fragmentation. Road kill has been shown to be a primary cause of mortality in other parts of their range. Historic and current sighting records in San Diego are primarily from road kill records. Rodenticide exposure is a major concern due to their widespread use in suburban and rural areas and because the badgers' primary prey items (squirrels and other small mammals) are often considered rodent pests. Take of badgers for depredation, predator control, and fur-trapping are legal and could also be a significant contributor to their decline.

Information needs for future adaptive management: Identify areas within San Diego County with stable badger populations or recurring annual activity, characterize home range patterns within occupied habitat and document dispersal into adjacent conserved lands in the MSPA. Use these data to identify important movement corridors, foraging areas, primary threats, and causes of mortality.

Key References:

Adams, I.T. and T.A. Kinley. 2004. Badger (Taxidea taxus jeffersonii). Accounts and Measures for Managing Identified Wildlife; Coast Forest Region. British Columbia Ministry of Water, Land and Air Protection.

Brehme, C.S., C. Rochester, S.A. Hathaway, B.H. Smith, and R.N. Fisher 2012. Rapid Assessment of the Distribution of American Badgers within Western San Diego County. Data Summary prepared for California Department of Fish and Game. 42pp.

California Department of Fish & Game Trapping License Examination Reference Guide http://dfg.ca.gov/wildlife/hunting/uplandgame/docs/CADFGTrappingGuideJan2009.pdf

Quinn, J. 2008. The ecology of the American badger (Taxidea taxus) in California: assessing conservation status on multiple scales. Ph.D. Dissertation. The University of California Davis, Davis, CA. 200pp.

Other references available upon request

Connectivity Project Summary of At Risk Resource – Small Vertebrates

Assessor: Jeff A Tracey, Cheryl S. Brehme, Carlton Rochester, Denise Clark, and Robert N. Fisher

Agency/Institution: USGS

Resource being assessed: Small Vertebrate Use of Wildlife Underpasses

Sampling technique: Specialized infrared motion detection cameras in underpasses, BACI design to investigate the effectiveness of adding structures to underpasses to enhance small vertebrate use.

General location: Large underpasses in coastal San Diego County that had no roads or water courses passing through them

Specific preserves (if applicable): Valley Center, Carmel County, Sorrento Valley Road, Scripps Poway Pkwy, Highway 52

Time series: 2012 - 2014

Finding regarding connectivity and resource:
This is the first study, to our knowledge, to show the use of underpasses by a community of small vertebrates. Previous studies have lacked the sensitivity to document mice, lizards and snakes. We have shown that these members of the community can be studied successfully using these passive methods.

The results of modeling gave evidence to support the short-term effectiveness of the added structure treatments on small vertebrate use and suggested that these rates changed on the specific side the treatment was applied rather than the entire underpass. There were also larger numbers of images per day containing of small mammals on ledges, where they exist, compared to ground level interior and exterior cameras. Many pictures of rodent species using the ledges appeared to show that they were using the ledges as a vantage point to prey upon invertebrate species below.

The community composition appeared to differ within the underpasses in comparison to outside the underpasses. In particular, initial results indicate that small mammals, rabbits, bobcats, and roadrunners may tend to use underpasses less than the surrounding habitat, while reptiles (snakes and lizards), squirrels, medium sized mammals and deer use underpasses more than the surrounding habitat. Future modeling of these data will help us to better discern these effects.

Our initial correlation analysis does not suggest a strong association between mean daily small vertebrate use and use by bobcats, foxes and coyotes, deer, or roadrunners. These species are often used in the region as indicators of functional landscape connectivity or “umbrella species”. However, if there is no evidence to support the association between use or connectivity for these species and small vertebrates, then small vertebrates must be studied and monitored separately.

Hypothesized mechanism for impacts:
Roads of different sizes, substrates, and traffic volumes have been shown to inhibit the movement of large mammals, small mammals and herpetofauna. If a road creates an impermeable barrier to animal movement, populations can become isolated or fragmented. Fragmented populations are more vulnerable to local extinctions and other negative effects from demographic and environmental stochasticity, as well as from increased inbreeding and genetic drift (see reviews by Trombulak and Frissel 2000, Foreman et al. 2003, Fahrig and Rytwinski 2009, Taylor and Goldingay. 2010).

Information needs for future adaptive management:
Our recommendations include additional monitoring in 2017, five years after addition of structure, to reassess the effect of structure on the use of underpasses by small and large vertebrates. This will allow sufficient time for most species to have acclimated to the structures and for us to adequately make a conclusion on their long term effectiveness. Because of the very large data set, many potential research questions, and many underpass covariates for the analyses, we recommend further analyses that will be valuable for evaluating the effectiveness of wildlife structures and differential responses of species and species groups based upon life history characteristics.

Finally, additional field experiments, such as addition of ledges to underpasses and relocation experiments will provide further information to allow for informed and successful decision making for maximizing wildlife connectivity under roadways that would otherwise be barriers for movement or mortality sinks.

References:

Tracey, J. A., C. S. Brehme, Rochester, C., Clark D., and R. N. Fisher. 2014. A Field Study of Small Vertebrate Use of Wildlife Underpasses in San Diego County, 2014. U.S. Geological DRAFT Data Summary prepared for California Department of Fish and Wildlife. 74 pp.

Connectivity Project Summary of At Risk Resource – Wildlife Linkages

Assessor: Carlton Rochester

Agency/Institution: U.S. Geological Survey – Western Research Center: San Diego Field Station

Resource being assessed: Wildlife linkages evaluation

Sampling technique: GIS, satellite imagery, land use data

General location: San Diego MSCP

Specific preserves (if applicable): core conserved areas within the MSCP as identified in the Connectivity Monitoring Strategic Plan for the San Diego Preserve System (CMSP)

Time series: 2011 through 2014

Finding regarding connectivity and resource: Of the 16 linkages identified in the CMSP, eight are estimated to be functional, having a high likelihood to provide suitable habitat and movement routes to allow wildlife to effectively move back and forth between the conserved areas. These linkages typically have low levels of development between the core conserved areas and infrastructure to allow wildlife movement past potential barriers. Eight linkages were estimated as non-functional, having significant barriers to wildlife movement, so much so that it seems very unlikely that none but the most disturbance tolerant species will be able to move from one area to the next.

Functional:

1. CA-1 to CA-2B: Otay Mountain/RJER to SDNWR/Crestridge (Eastern linkage through Rancho Jamul/Hollenbeck Canyon)
2. CA-3 to CA-6: El Capitan Reservoir to Iron Mountain/San Vicente Reservoir
3. CA-4 to CA-5: Mission Trails Regional Park to Gooden Ranch/Sycamore Canyon
4. CA-6 to CA-7: Iron Mountain/San Vicente Reservoir to Barnett Ranch/Monte Vista Ranch
5. CA-8 to CA-10: Los Peñasquitos Canyon to Black Mountain
6. CA-10 to CA-11: Black Mountain to Lake Hodges/Del Dios
7. CA-11 to CA-12: Lake Hodges/Del Dios to Ramona Grasslands/Boden Canyon (during low water level)
8. CA-12 to CA-13: Ramona Grasslands/Boden Canyon to Mt. Woodson/Blue Sky ER

Non-functional:

1. CA-1 to CA-2A: Otay Mountain/RJER to SDNWR/Crestridge (north of SR-94 at Las Montañas)
2. CA-2 to CA-3A: McGinty Mountain/Crestridge to Harbison Canyon/El Capitan Reservoir (Lakeside Archipelago)

3. CA-2 to CA-3B: McGinty Mountain/Crestridge to Harbison Canyon/El Capitan Reservoir (Peutz Valley Road and I-8)
4. CA-5 to CA-6: Goodan Ranch/Sycamore Canyon to Iron Mountain/San Vicente Reservoir
5. CA-5 to CA-8: Sycamore Canyon/Goodan Ranch to Torrey Pines/Del Mar Mesa/Los Peñasquitos Canyon
6. CA-5 to CA-13: Sycamore Canyon/Goodan Ranch to Mt. Woodson
7. CA-6 to CA-13: Iron Mountain/San Vicente Reservoir to Mt. Woodson/Blue Sky ER
8. CA-9 to CA-10: Del Mar Lagoon to Black Mountain

Hypothesized mechanism for impacts: habitat fragmentation associated with housing and other development, lack of suitable structures supporting wildlife movement

Information needs for future adaptive management: For all linkages, whether estimated to be functional or non-functional, monitoring critical points along the linkage should continue to help confirm or refute the linkage rating. Additional monitoring and wildlife use data will better inform species models and future management decisions.

References:

San Diego Management and Monitoring Program. 2011. Connectivity monitoring strategic plan for the San Diego Preserve System. Prepared for the San Diego Environmental Mitigation Program Working Group.

Connectivity Project Summary of At Risk Resource – Mule Deer

This project summary is to document expert findings regarding connectivity on at-risk resources

Assessor: Andrew Bohonak[1] and Anna Mitelberg[2]

Agency/Institution: San Diego State University[1] and San Diego Zoo Institute for Conservation Research[2]

Resource being assessed: Southern mule deer shrimp *Odocoileus hemionus fuliginatus* (MSCP focal species)

Sampling technique: Genetic analysis of scat samples

General location: Coastal San Diego County, particularly in the suburbs north of Miramar, and with particular attention to open spaces and wildlife corridors.

Specific preserves (if applicable): Torrey Pines State Reserve, Sorrento Valley, Penasquitos Canyon, Penasquitos Creek, Carrol Canyon, Miramar, Mission Trails Regional Park, Tierrasanta, Beeler Canyon, Sycamore Canyon, Calavera Preserve, Rancho La Costa HCA, Wild Animal Park, Cuyamaca Reserve, Cleveland National Forest, Julian, Lake Jennings, Hollenbeck Canyon, Rancho Jamul ER, San Miguel Mountain Open Space, South Crest, Sycuan Peak

Time series: Field collections from 2006-2007, and 2012-2013

Finding regarding connectivity and resource:

1. Southern mule deer have less overall genetic diversity than subspecies elsewhere in the state.
2. There is statistical justification for dividing coastal San Diego County into numerous management units. In the western part of our study area where sampling was the most dense (Torrey Pines east to Sycamore Canyon), populations generally correspond to existing reserves and canyons.
3. As in prior studies, the isolating effects of I-5 north of the I-5/805 merge are apparent, as well as the isolating effects of I-805 south of the merge.

Hypothesized mechanism for impacts:

4. Southern mule deer are relatively sedentary/territorial over many years. Offspring are often found very close to one or both parents. Females in close proximity tend to be more closely related than males in close proximity.

5. Low genetic diversity is consistent with an effective population size that is less than 200 individuals for the region we studied (up to 500 km^2), and perhaps less than 100. It is unclear how extreme and recent any past population bottleneck may have been. For example, it is possible that this subspecies has always had relatively small population sizes -- even prior to modern urbanization.
6. Major freeways correlate with population boundaries, at least in some areas.

Information needs for future adaptive management:

7. Prevent regional declines in genetic diversity
   a. We recommend that further urban encroachment be minimized, and that connectivity and local population sizes be maintained at least at their current levels, or increased where feasible.
8. Define multiple management units for southern mule deer
   a. We recommend that southern mule deer in an area that includes Torrey Pines, Sorrento Valley, Penasquitos Canyon, Penasquitos Creek, Carrol Canyon, MCAS Miramar and Mission Trails be considered as a separate management unit from those elsewhere in the subspecies range. This corresponds to the "Western gene pool" from this study.
   b. We recommend that management units more spatially restricted than these two gene pools also be considered.
   c. We recommend that genetic analyses be conducted in other areas of the species range under threat of habitat conversion, comparable in spatial and temporal coverage to this study.
   d. We recommend that the existing literature be combined with new demographic studies to provide accurate estimates of population size (both Ne and census size), and generation time. These estimates will improve interpretations of current and future genetic data.
9. Maintain high levels of connectivity
   a. We recommend that existing levels of habitat connectivity in western San Diego County be maintained, in light of limited lifetime movement that appears to be typical of southern mule deer.
   b. We recommend that additional non-genetic studies be conducted to quantify mule deer movement between SV and CC.
   c. We recommend that additional genetic studies of mule deer be conducted on MCAS Miramar, to clarify its role in regional conservation of this species.
10. Future studies

a. DNA of sufficient quality for reliable, high resolution genetic analyses can be obtained from mule deer scat for future studies. The microsatellites we have optimized provide a very accurate individual DNA fingerprint. Even for full siblings (same mother and same father), the probability of an identical fingerprint is only 5×10^{-5}. Gender, parent-offspring relationships, within-generation movement and cross-generation movement can be inferred.
b. Fine-scale inferences about movement patterns could be made elsewhere in the species range with new field samples that have spatial and temporal coverage comparable to our completed study. The goals for future genetic studies must be defined before sampling, and should link to specific parameters that inform management directly.
c. Low-cost (or volunteer) field assistants could annually archive scat or tissue samples in a permanent genetic resource bank, even if funds for another genetic study are not immediately available. The supply costs to extract, preserve and archive DNA for future studies would be relatively low.

References:

Bohonak, A. J., and A. Mitelberg. 2014. Social structure and genetic connectivity in the southern mule deer: Implications for management. Final Report. San Diego State University. Contract from California Department of Fish and Wildlife. April 16, 2014.

Mitelberg, A. 2010. Social structure and genetic connectivity in the San Diego southern mule deer. Master's thesis, Department of Biology, San Diego State University. San Diego, California.

Connectivity Project Summary of At Risk Resource – S. W. Pond Turtle

Assessor: Chris Brown, Robert Fisher

Agency/Institution: U.S. Geological Survey, Western Ecological Research Center

Resource being assessed: Southern western pond turtle

Sampling technique: Single nucleotide polymorphism/Visual encounter & trapping surveys

General location: Coastal San Diego, Orange, Los Angeles and Riverside counties

Time series: 2002-2013

Finding regarding connectivity and resource: The SNP loci data had enough resolution to identify "natural" breaks in the species (where populations became genetically distinct from adjacent populations), so that management units for conservation could be developed. In assessing genetic bottlenecks, we determined that only the most remote and undisturbed sites appear to genetically retain high diversity and a full complement of haplotypes. In our sampling for tissue collection we found similar numbers of native and nonnative turtles in the wild. We also detected evidence of pond turtles being moved into the area from the north, as released or escaped pets, human mediated movement of pond turtles being more of a problem than we knew.

Hypothesized mechanism for impacts: Interactions between altered hydrologic regimes (water diversion/impoundment), nonnative aquatic species (crayfish, bullfrogs, and predatory fish), and public access impact the species. Nonnative aquatic species effect recruitment through both predation and competition. Distance to road, nearest public access and type of public access increase the potential for individual turtles to be removed from the site (either picked up as pets or through road mortality) and increase the potential for nonnatives to be released at the site.

Information needs for future adaptive management: There are watersheds where we know little about turtle populations and/or their genetics which are regional gaps in knowledge that could help in making decisions for management and recovery of the species.

References:

Fisher, R.N., Wood, D.A., Brown, C.W., Spinks, P.Q., and A.G. Vandergast. 2014. Phylogenetic and population genetic analyses of the western pond turtle (*Emys marmorata*), in southern California. Prepared for the California Department of Fish and Wildlife, January 2014. U.S. Geological Survey, San Diego, CA, 59 pp.

Harmsworth Associates and B. Goodman. 2006. Shady Canyon turtle pond mitigation monitoring annual report for July 2005 through June 2006. 41pp.

Madden-Smith, M.C., E.L. Ervin, K.P. Meyer, S.A. Hathaway, and R.N. Fisher. 2005. Distribution and status of the arroyo toad (*Bufo californicus*) and western pond turtle (*Emys marmorata*) in the San Diego MSCP and surrounding areas. Report to County of San Diego and CDFW, San Diego, California. 190 pp.

Spinks, P.Q., R.C. Thomson, and H. B. Shaffer. The advantages of going large: genome-wide SNPs clarify the complex population history and systematics of the threatened western pond turtle. Molecular Ecology. 23(9): 2228-2241.

Connectivity Project Summary of At Risk Resource – Native Bees

Assessors: Keng-Lou James Hung and Dr. David A. Holway

Agency/Institution: University of California, San Diego

Resource being assessed: Native bees (Hymenoptera: Anthophila)

Sampling technique: Aerial netting, fluorescently painted bowl traps, visual plant surveys

General location: Greater San Diego Region

Specific preserves (if applicable): Mission Trails RP, Scripps Coastal Reserve (UCNRS), Elliott Chaparral Reserve (UCNRS), Otay-Sweetwater Unit (SDNWR), Tijuana River National Estuarine Research Reserve (SDNWR), Chollas Creek Park, Pasatiempo Open Space, Juniper Canyon.

Time series: 2011-2012

Finding regarding connectivity and resource: In fragments of scrub habitat <40 ha in size (e.g. open space parks embedded in urban matrix), native bee species richness and genus richness were roughly 35% lower than those in large, intact patches of scrub habitat >400 ha in size (e.g. Mission Trails Regional Park), despite similar richness and density of blooming native plant species in the two types of habitats. Bee assemblages in fragments also included a higher proportion of floral generalist species. Certain bee taxa that occur in large numbers in intact habitats but are mostly absent from fragment (e.g. *Eucera* spp.) may serve as indicators of habitat connectivity / quality.

Hypothesized mechanism for impacts: Certain specialist bee species (and genera) may disappear from fragments when their host plants fail to occur at high enough densities (or are extirpated altogether). Certain bee species may also require special nesting substrates that are absent from fragments. Also, given their isolation fragments may also lose species when they fail to receive recolonization following natural processes of local metapopulation extinctions. Generalists are more abundant in fragments likely because of their ability to thrive on invasive flowering plants, which tend to be more abundant in fragments.

Information needs for future adaptive management: What is the rate of bee species recolonization to isolated fragments? How do different bee species move among discrete patches of urban habitat through non-green urban matrices? What constitutes a “corridor” from the point of view of native insect pollinators? What are the levels of pollinator diversity required for indefinite persistence of our native insect-pollinated flora?

References:

Bommarco, R., J.C. Biesmeijer, B. Meyer et al. 2010. Dispersal capacity and diet breadth modify the response of wild bees to habitat loss. *Proc. R. Soc. Lond. B Biol. Sci*., 277, 2075–2082.

Brosi, B.J. and H.M. Briggs. 2013. Single pollinator species losses reduce floral fidelity and plant reproductive function. *PNAS* 110:13044-13048.

Cane, J.H., R.L. Minckley, L.J. Kervin, T.H. Roulston and N.M. Williams. 2006. Complex responses within a desert bee guild (Hymenoptera: Apiformes) to urban habitat fragmentation. *Ecological Applications* 16: 632-644.

Winfree, R., R. Aguilar, D.P. Vázquez, et al. 2009. A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology* 90:2068–2076.

Connectivity Project Summary of At Risk Resource – S.D. Fairy Shrimp

Assessor: Andrew Bohonak[1] and Marie Simovich[2]

Agency/Institution: San Diego State University[1] and University of San Diego[2]

Resource being assessed: San Diego fairy shrimp Branchinecta sandiegonensis (federally endangered)

Sampling technique: Genetic analysis of samples from pools across the species range

General location: Coastal San Diego County.

Specific preserves (if applicable): Most populations are on property owned by MCAS Miramar, MCB Camp Pendleton, or the City of San Diego. Some are found in other protected lands.

Time series: Field collections primarily from 2002-2005; time series not explicitly analyzed

Finding regarding connectivity and resource:

Genetic divergence among vernal pools and pool complexes

11. Genetic differentiation among vernal pools is statistically significant and relatively strong, even over relatively small distances. These patterns hold for two types of genetic markers (mtDNA sequences and microsatellites). Genetic differentiation generally increases as geographic distance increases. Pool connectivity is greater within complexes than between complexes. This implies limited connectivity among pool complexes, and throughout San Diego County.
12. Previous research identified two highly divergent mtDNA lineages within the species that have specific geographic distributions. With the newer data, these mtDNA lineages are more divergent for microsatellite markers *on average* than one would expect. However, the degree of microsatellite divergence between these lineages is far less than for the mtDNA.
13. Preliminary sampling of MCAS Miramar shows that the A4 complex is unusually divergent in terms of microsatellite markers, but not mtDNA. We interpret this to mean that the biological isolation of this area is relatively recent (compared to evolutionary time scales). Additional sampling form Miramar is needed.
14. In the microsatellite data set, Mira Mesa and Del Mar Mesa pools show somewhat higher divergence than one would expect. The southern border of this group is largely coincident with a small portion of the Rose Canyon fault zone, with the exception of

Nobel Drive pools just north of the canyon, and Sander pools just south. Fine scale genetic patterns in this area would benefit from additional sampling.

Hybridization

15. Versatile fairy shrimp (B. lindahli) are found in disturbed pools within the costal range of B. sandiegonensis. Hybridization between these species is recognized as a threat to the San Diego fairy shrimp. These two species can hybridize in the lab, consultants have previously speculated about hybrids in field populations, and we have published a paper demonstrating that hybrids are present in several disturbed pools in coastal San Diego County.

Hypothesized mechanism for impacts:

Genetic divergence among vernal pools and pool complexes

16. Significant loss of vernal pool habitat has already occurred. The integrity of remaining pool complexes should be maintained at the broadest possible spatial scale (pool complex, preferably the micro-watershed for the complex).
17. Our overall assessment is significant biotic connectivity is normally restricted to pools within complexes, and pools within 5 km of one another. These patterns are assumed to correlate with local adaptation in traits that matter for individual fitness.
18. After several studies study, we can still find no single environmental factor such as soil type, latitude or elevation that is an obvious causal factor for overall genetic divergence within San Diego fairy shrimp
19. Human activities often homogenize these naturally distinct populations, rather than isolate them.

Hybridization

20. Preliminary data suggest that hybrids are primarily found in severely disturbed pools. Although their "background" presence in undisturbed landscapes has not yet been documented, they are clearly more prevalent in road ruts and other highly disturbed basins than in undisturbed pools.

Information needs for future adaptive management:

21. Movement of cysts among pools should be minimized, and especially outside of pool complexes. The genetic data suggest that biotic connectivity is very localized. (A common assumption in conservation genetics is that restricted gene flow for microsatellites correlates with local adaptation for traits that affect survival and

reproduction. However, we acknowledge that this assumption must be validated with actual studies of individual fitness.)

22. It follows that newly created pools should be stocked from a single pool complex as close as possible. Stocking single new pools from a single source pool (rather than a multi-pool mixture) is recommended unless logistical or endangered species impacts preclude this.
23. Beyond low levels of connectivity among pool complexes, there may be an even more significant amount of divergence between the pools of {Mira Mesa, Del Mar Mesa} and the remainder of the species range. Additional care should be taken to minimize homogenization of these sites with Miramar and populations south, with Ramona to the east, and with Pendleton to the distant north.
24. We have published a method for identifying hybrids from mature fairy shrimp females. We are attempting to develop a genetic hybrid index at this time.
25. Quantifying the extent of hybridization and its correlates is our current goal.

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Connectivity Project Summary of At Risk Resource - Lizards

Assessor: Tara Luckau

Agency/Institution: San Diego State University

Resource being assessed: population genetics of lizards (*Aspidoscelis hyperythra* [a CA species of special concern] and *Sceloporus occidentalis*)

Sampling technique: tissue taken from animals in USGS pitfall trap arrays; microsatellite genetic analysis

General location: San Diego County

Specific preserves: Rancho Jamul Ecological Reserve, Hollenbeck Canyon Wildlife Area, Torrey Pines State Park, Cabrillo National Monument, Santa Ysabel Preserve, Marine Corps Base Camp Pendleton

Time series: 2010-2013

Finding regarding connectivity and resource:
On a county-wide scale, there is evidence to support population structure (genetic differentiation) for both species of lizards, based on F-statistics as well as Bayesian clustering. However, since sampling sites were widely separated by urbanization, much greater than the lizard species' dispersal distances, this result is expected.

On the other hand, analysis conducted at the scale of each sampling site shows little population structure, based on Bayesian clustering. Further fine-scale landscape analysis indicates some influence of landscape features on genetic patterns, but this pattern largely varies with sampling site rather than lizard species or particular landscape features. At nearly all sampling sites, the presence of roads does not correlate with genetic patterns for either species of lizard, indicating these linear anthropogenic structures do not present a barrier to dispersal for these lizards. For those sampling sites that did have landscape features that correlated with genetic patterns, vegetation and slope correlated most consistently, though not at all sites for either species of lizard. Soil type does not correlate with genetic patterns at nearly all sampling sites. Interestingly, the Torrey Pines sampling site showed no significant correlations between landscape features and genetic patterns.

Hypothesized mechanism for impacts:
Though population differentiation exists on a county-wide scale, lizards seem to be robust to fine-scale features of the landscape. Anthropogenic structures seem to impact these lizards

only at a large scale; there is no genetic evidence to suggest that roads bisecting lizard habitat impede sufficient gene flow to maintain population connectivity. Estimations of population size have not yet been conducted using this genetic dataset, but the populations of these lizards may be large enough to resist population differentiation at the scales and sites included in this assessment.

Information needs for future adaptive management:
Future monitoring of habitat connectivity may be the only concern for *Aspidoscelis hyperythra* and *Sceloporus occidentalis*. Vegetation and slope were the habitat features that correlated strongest and most frequently for this dataset, so maintenance of native habitats like coastal sage scrub and chaparral should be considered. A more uniform sampling design, where lizard tissues are collected across the landscape, rather than at particular trap sites, may be able to better capture potential gene flow barriers not considered in this assessment.

References: