Applying Hot Spot Analysis to Carnivore GPS-telemetry Data and Camera Images to Examine Wildlife Connectivity across Highways in Southern California

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INTRODUCTION

Underpasses can offer a way to ameliorate the negative effects of roads on animals. A highway-widening project in southern California at the intersection of CA-71 and CA-91 in 2005 included underpass modifications and added roadside fencing. To study functional connectivity for wildlife in this area, we tracked bobcats and coyotes in 2008-2010 and monitored underpasses with remotely-triggered cameras to determine where and how often animals crossed after highway alterations. We applied the **Hot Spot Analysis (Getis-Ord Gi*) Tool in ArcGIS** to our field data to identify underpasses of high use and "cold spots" where bobcats and coyotes rarely crossed, and to estimate if animals sometimes crossed over instead of under highways. We also recorded locations of dead carnivores for comparison to roadkill data from 1997-2000 before highway alterations to evaluate success of fencing in reducing wildlife mortalities. Finally, we used ArcGIS to examine hot and cold spots of crossing activity relative to fencing, other highway and habitat features, and relative to burned areas from a 2008 wildfire (**Fig. 1a, 1b**).

Fig. 1a. The study area included 65 underpasses on highways CA-71 and CA-91 in southern California. Light red shading indicates a wildfire that burned 90% of Chino Hills State Park and across 14 underpasses in November 2008.

Fig. 1b. Photo of the study area at the intersection of Orange, Riverside, and San Bernardino Counties.

Camera trap at an underpass.

METHODS

Carnivore data

- **Remotely-triggered cameras placed at 52 of 65 underpasses, August 2008 – November 2009**
  - Each underpass was monitored with a pair of cameras, one camera on either side of the highway.
  - Images from each camera pair were examined to determine the number of crossings at an underpass.
  - Individual animals identified by natural markings, collars, and tags.
  - Numbers of camera-documented crossings and numbers of individuals summed per underpass.
- **Individual bobcats and coyotes tracked with GPS-telemetry collars, December 2008 – July 2009**
  - 15 bobcats and 11 coyotes tracked approximately 4 months each.
  - Collars collected GPS coordinates at 15 minute intervals every 2nd or 3rd day.
  - GPS point data converted to polylines (**Fig. 2a**).
  - Intersections of polylines with highways called "GPS crossings" and mapped as points (**Fig. 2b**).
- **Roads surveyed for carnivore mortalities, 1997 - 2000 and 2008 - 2010**

GPS-collared female bobcat and kitten entering an underpass.

Fig. 2a. A movement path for a GPS-collared male bobcat that crossed CA-71 three times during a 24-hr period. Yellow icons are daytime GPS locations; blue are night. Paired white or red symbols on highway indicate cameras at different types of underpasses.

Fig. 2b. GPS movement paths for a male bobcat along CA-71. Green dots indicate where paths crossed the highway. These "GPS crossings" were assigned to the closest underpass using the **Near Tool**. The path highlighted in cyan is depicted in the previous map.

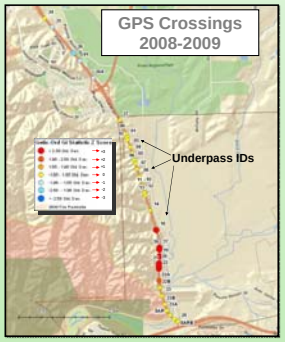

Fig. 2c. Getis-Ord Hot Spot results based on GPS-crossings of CA-71 by bobcats. Underpasses 16-22B showed hot spots (red) while 25-26A appeared cold (blue).

Getis-Ord Analyses

- **Step 1 - Determined distance band for use in Getis-Ord analyses by two approaches**
  - We calculated the mean distance between locations where each collared animal crossed roads (800 m).
  - We aggregated locations of GPS crossings to the nearest underpass with the **Near Tool** and used the **Global Moran's I Spatial Autocorrelation Tool** to determine if use of these undercrossings were clustered at the same distance and multiple distances (**Fig. 3**).
- **Step 2 - Getis-Ord Hot Spot Analysis of crossing zones and intensity of use**
  - We selected the 800 m distance band and Zone of Indifference to conceptualize the spatial relationship among underpasses and animal movement.
  - Tool applied to 1) 2 species, bobcats and coyotes; 2) two monitoring methods: camera traps and GPS collars; 3) two metrics: # of individuals and # of crossings; 4) two scales: landscape (all underpasses from both highways) and local (each highway analyzed separately).
  - Z-scores within 1 standard deviation of the mean (not significant) were assigned a value of zero. Significant Z-scores were assigned a value of 1 to 3 for hot spots and -1 to -3 for cold spots to represent the number significant units of standard deviations away from the mean (**Fig. 2c**).
  - A crossing intensity was calculated as a relative index of underpass usage by adding significant Crossings and Individuals intensities together for an overall intensity ranging from 6 (highest) to avoidance (-6).

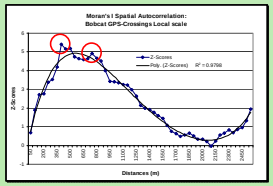

Fig. 3. Results of Global Moran's I tool showing Z-score peaks at 400 & 800 meters.

RESULTS

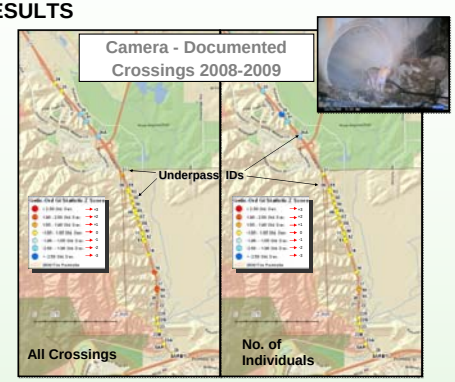

Fig. 4. Results of Getis-Ord Hot Spot analysis for Camera-documented bobcat crossings of CA-71, based on all camera crossings (left) and numbers of individuals using underpasses (right).

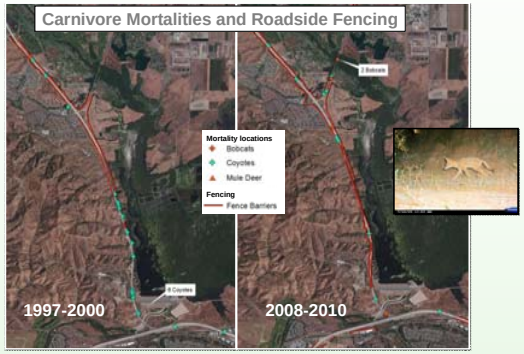

Fig. 5. From 1997-2000 to 2008-2010, coyote road kill decreased 58% (18 to 7) on CA-71, most notably where fencing was extended to the south.

Bobcat Getis-Ord Results, 2008-2009

- Landscape-level analyses indicated a long hot spot of movements across 25 consecutive underpasses on CA-71, and identified several cold spots on CA-91 corresponding with available habitat and the fire boundary (**Fig. 6a**).
- In local scale analyses for CA-71 (**Fig. 6b**), 9 of 25 underpasses appeared "hot" and thus important to connectivity for bobcat populations. We had assumed that four of these often-used underpasses, which were capped culverts, were inaccessible to bobcats.
- Local scale analyses of CA-91 (**Fig. 6c**) suggested that despite less bobcat movement across CA-91 than CA-71 (shown in Landscape scale), appearance of hot spots here indicated when bobcats moved, they preferred certain underpasses clustered at two locations along the road.

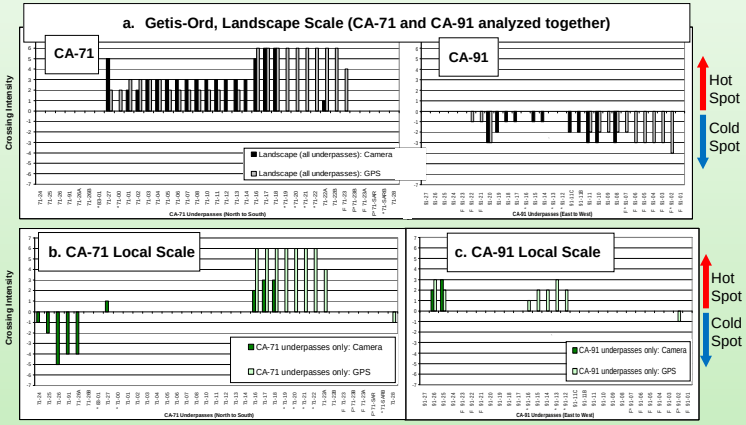

Fig. 6. Getis-Ord results for 2008-2009 bobcat crossings based on camera and GPS data at two spatial scales: **(a) Landscape scale:** all underpasses on CA-71 and CA-91 evaluated simultaneously **(b) Local scale:** CA-71 underpasses evaluated independently of CA-91 **(c) Local scale:** CA-91 underpasses evaluated independently of CA-71. * indicates underpass was not monitored by a camera. F indicates fire burned across the underpass.

Capped culverts.

CONCLUSIONS

- Getis-Ord Hot Spot analysis allowed comparison of methods, scales, and species. This analysis performed well in identifying relative intensity of crossings by wildlife.
- Getis-Ord results based on GPS-telemetry data and remotely-triggered camera data were similar. Most differences could be attributed to a longer sampling period for camera traps.
- Cameras offered the advantage of monitoring undercrossings, regardless of use by GPS-collared animals. GPS-telemetry showed where animals moved regardless of whether cameras were present, including unexpected crossing locations. For example, GPS-telemetry data strongly suggested bobcat use of capped culverts that we assumed were not usable by wildlife.
- Most mortality of coyotes on roads occurred where roadside fencing was absent or incomplete. Improvements in fencing and widening of undercrossings appeared to have reduced wildlife road kill while allowing for wildlife movement across the highway. The Getis-Ord Hot Spot analysis indicated a hot spot of bobcat movement where fencing was extended to the south.

Adult coyote exiting underpass.

Female bobcat with kitten entering underpass.

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