FINAL REPORT: Continued Monitoring of Harbor Boulevard Wildlife Underpass

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BACKGROUND

In May 2006, a wildlife underpass was completed beneath Harbor Boulevard in La Habra Heights, Los Angeles County, with the aim of reducing wildlife-vehicle collisions and protecting functional habitat connectivity for wildlife in the Puente-Chino Hills Wildlife Corridor (Gullo 2007). We were awarded a contract from the Puente Hills Landfill Native Habitat Preservation Authority (PHLNHPA; hereafter Habitat Authority) to study the effectiveness of the underpass, which included monitoring its use by wildlife via remote cameras; determining carnivore activity in the Wildlife Corridor; and assessing the frequency of roadkills on Harbor Blvd. and nearby roads before, during and for 1 year after underpass construction. Field work on this project was completed in June 2007 by David Elliott, my M.S. graduate student at Cal-State Fullerton, and we submitted the last draft of the Final Report to the Habitat Authority in February 2008. We found that, although wildlife such as mule deer (*Odocoileus hemionus*) and coyotes (*Canis latrans*) began using the underpass almost immediately, the number of road-killed animals, especially coyotes, had not decreased significantly by 1 year after construction. In June 2008, our contract with the Habitat Authority was extended to allow us to continue to monitor use of the underpass and carnivore activity in the area of Harbor Blvd., and to count roadkills on Harbor Blvd. and Colima Rd. for an additional year (July 2008-June 2009). Specifically, the goals of the current project were to:

1) determine the extent to which wildlife continue to use the new underpass;

2) identify possible areas on Harbor Blvd. where animals, particularly coyotes, cross at the surface and therefore, risk being struck;

3) determine if the frequency of roadkills on Harbor Blvd. has decreased since our previous monitoring ended, using roadkills along a comparable stretch of Colima Rd. as a reference to control for differences in the background rate of roadkills in the region since 2006.

We hypothesized that, by the 3rd year after completion of the underpass, wildlife would continue to use the underpass regularly, and that the frequency of roadkills, especially of coyotes, would now be lower than the period prior to and after construction. In addition, we expected that wildlife activity along Harbor Blvd. would be high in the vicinity of the underpass and lower in areas where earlier monitoring suggested surface crossings were still being attempted. Such information would be needed to evaluate whether other approaches such as fencing would be needed to reduce roadkills, and if so, to determine

where such measures might be most effective. All field work on the current project was conducted by Stephanie Cashin, a M.S. student in Environmental Studies at Cal-State Fullerton. **The current report is intended to be a <u>supplement</u> to the findings from our previous one (Stapp and Elliott 2008), which includes information on the project rationale, study area, and basic methods that are not replicated here.**

METHODS

Roadkill Surveys

Beginning 1 July 2008, both lanes of Harbor Blvd. (4.02 km; between Whittier Blvd. and Old Fullerton Rd.), and both lanes of Colima Rd. (3.86 km; between Mar Vista St. and Hacienda Blvd.) were driven once on an approximately weekly basis to record all roadkills seen. The 2 roads were driven on the same day and at roughly the same time. Locations of roadkills were recorded using a Garmin global positioning system (GPS) unit. Roadkills seen on the roads during periods outside of the regular weekly surveys were not included unless they were known to have been intentionally removed.

Track Station Surveys

A series of 16 track stations were established on the shoulder of Harbor Blvd. (Fig. 1). Nine stations were located on the eastern shoulder of the road, and 7 stations were located on the western shoulder. Stations were approximately 100 m apart and when possible, were placed in locations near obvious wildlife trails. In addition, stations were placed at both ends of the tunnel and run concurrently with those along the shoulder. Each track station consisted of a 1-m^2 cleared area of ground spread with gypsum powder to record tracks. Liquid scent lure (Carman's Pro's Choice) was placed on a stake or rock at the center of each station. Stations were checked for tracks and smoothed each morning for 3 consecutive nights in a tracking session[1]. At each station, we attempted to discern based on the orientation of the tracks whether the animals were moving parallel to the road or attempting to cross. Track sessions were conducted approximately bi-monthly. Three-night tracking sessions were conducted in July, September and December 2008, and January, March and May 2009.

Remote Camera Surveys

On 1 July 2008, 3 remotely triggered, infrared-flash digital cameras (Leaf River iR-3BU) were installed in the underpass, at the same locations as in our previous study. The cameras ran continuously and images were downloaded approximately weekly. In an attempt to obtain better color photos of nocturnal species using the underpass, in February 2009 we replaced the center camera with a Cuddeback digital camera (Expert Model#C3300, with white-light flash). Using the number of images seen in all 3 cameras, we estimated the number of individuals of each species that were seen per month in the underpass. Images were considered to be from different individuals if they were taken >15 min apart, when it was possible to recognize distinctive traits (size, coat markings), or when multiple individuals were seen in the same image.

[1] In our previous study (Stapp and Elliott 2008), we compared activity based on 3 nights vs. 5 nights of tracking and found that 3 nights was sufficient for tracking common species such as coyotes.

RESULTS

Roadkill Surveys

Excluding domestic animals, rodents and birds, a total of 11 roadkills were observed on Harbor Blvd. and 8 roadkills were observed on Colima Rd. during 53 surveys between July 2008 and June 2009 (Tables 1, 2). Most roadkills were Virginia opossums (*Didelphis virginiana*, 6), followed by striped skunks (*Mephitis mephitis*, 5). Two coyotes were killed on Harbor Blvd., near or south of the south Fullerton Rd. intersection (Fig. 2a). No coyotes were killed on Colima Rd., but one bobcat (*Lynx rufus*) was reported dead by a Habitat Authority ranger on 14 January (Fig. 2b). More rodents, especially tree squirrels (*Sciurus* sp.) and ground squirrels (*Spermophilus beecheyi*), and desert cottontails (*Sylvilagus audubonii*) were found dead along Harbor Blvd. (13) than on Colima Rd. (7). Similar numbers of small carnivores (skunks, opossums) were killed on Harbor Blvd. (6) and Colima Rd. (5). As in our previous monitoring, on both roads most small carnivores continued to be killed in areas near human housing developments (Fig. 2). We did not detect any road-killed mule deer on Harbor Blvd., which is surprising given the traffic speed and volume, and the number of deer recorded using the underpass. Unlike our previous study, there was no clear difference in the number of roadkills between the southbound and northbound traffic lanes (Table 2).

Expressing vehicle mortalities using a roadkill index [individuals killed per km of road per 5 surveys; this is the same index that we used in our previous monitoring (Stapp and Elliott 2008)], the incidence of roadkills of all species combined (excluding rodents, birds and pets) on Harbor Blvd. was similar to that on Colima Rd., and similar to that during our previous study of roadkills before, during and after underpass construction (Table 1; Fig. 3). Although the frequency of coyote mortalities continued to be higher on Harbor Blvd. than on Colima Rd., the roadkill index during the current study (0.04 roadkills/km/5 surveys; 2008-09) was less than one-third of that during the 1-year post-construction period in 2006-07 (0.15). Because the durations of the pre-, 1-year post and 3-year post-construction sampling periods were equivalent (53 weeks), we could compare the frequencies of roadkills on Harbor Blvd. between these periods. There was no significant ($P \leq 0.05$) difference in the total number of roadkills between the 3 periods (chi-square test; $X^2 = 0.67$, d.f. = 2, P = 0.72), but the number of dead coyotes was significantly lower in the 3rd-year post-construction period than in the previous 2 sampling periods ($X^2 = 8.67$, d.f. = 2, P = 0.01; Fig. 3)[2].

Track Station Surveys

Coyote tracks were recorded at track stations placed at the ends of the underpass during all 6 tracking sessions; coyotes left tracks at the eastern end on all 18 nights of

[2] A chi-square test is a statistical test used to compare the frequency of occurrence of discrete events, here roadkills, between 2 or more categories (study periods). The null hypothesis tested here is that the number of roadkills were equally divided among the 3 sampling periods. A test statistic (chi-square X^2) is calculated using observed and expected frequencies and is evaluated based on the degrees of freedom (d.f.), which is based on the number of categories. A P-value reflects the likelihood (probability) that the null hypothesis is true, i.e. no difference among sampling periods in roadkills, based on the roadkill patterns we observed. A low P-value (by convention <0.05) indicates that it is very unlikely that the differences we observed occurred by chance, leading one to reject the null hypothesis and providing evidence of a significant difference among categories.

tracking (6 sessions of 3 nights each) and at the western end on 16 of the 18 nights. Tracks of striped skunks and raccoons (*Procyon lotor*) were also observed in the underpass, but were rarely recorded along the road (tracks were found at only 1-3 of the 16 stations during a single session). Bobcat tracks were detected at stations in the eastern side of the underpass in May 2009, but we also occasionally spotted them in mud on the underpass floor at other times.

Compared to 100% visitation of at least one track station in the underpass itself, on the surface 4 of the 16 track stations were visited by coyotes during at least 5 of the 6 of the tracking sessions and on 50% or more of the nights (Fig. 1). Conversely, 2 stations were never visited and another 3 were visited only once (6% visitation). Except for the last sampling session, stations on the western shoulder of Harbor Blvd. were consistently visited more frequently than those on the eastern shoulder (Fig. 4). However, coyotes appeared to cross Harbor Blvd. more often at stations on the eastern shoulder, whereas they paralleled the street more often on the western side (Fig. 4). Consistent evidence of crossing (vs. paralleling the road) was recorded at 3 stations on the eastern shoulder of Harbor Blvd. and 3 stations on the western shoulder, including stations well north and south of the underpass (Fig. 1). Heavily used stations on the eastern shoulder were usually associated with wildlife trails and with constriction points caused by existing barriers, e.g. fencing or dense vegetation. Regular crossings of Fullerton Rd. were also recorded at the most southwesterly track station (Fig. 1).

Remote Camera Surveys

Cameras captured a total of 953 images representing different individuals using the underpass; 78% were coyotes and 19% were mule deer. An average of 2.7 species were detected each month (range 2-4; Fig. 5), with bobcats, raccoons, striped skunks and desert cottontails also recorded using the underpass. Based on camera images, bobcats used the underpass during 4 of the last 5 months of monitoring. The highest numbers of images (all species combined) were taken in May 2009, October 2008 and March 2009, when more than 100 individual crossing events were recorded (Fig. 6). Use of the underpass by deer was highest in winter 2008-09, whereas coyotes were recorded during all months (mean images per month = 62.3), with peaks in October 2008 and May 2009 (Fig. 6). The decrease in the number of images in January 2009 was likely the result of problems with the operation of the cameras, and probably does not reflect an actual decrease in activity.

Comparing results from the current study with those from our previous monitoring efforts (2006-07), the activity of coyotes in the underpass has remained very high (Fig. 6). Deer also continued to use the underpass often, although sporadically and with no consistent seasonal pattern. Based on the amount of track activity in the underpass, small carnivores seemed to use the underpass fairly regularly but were not consistently recorded with our cameras. However, we more consistently recorded small carnivores using remote cameras than in our previous monitoring (Fig. 6).

DISCUSSION

Based on visitation at track stations in the tunnel and images captured by the remote cameras, wildlife continued to use the underpass beneath Harbor Blvd. regularly. Track-stations recorded the presence of coyotes in the underpass every night during the 6

tracking sessions, and our camera results suggest that coyote activity in the tunnel has remained high or even increased since the underpass was completed in 2006. Other species, e.g. deer, bobcats, skunks, and raccoons, were also seen or recorded consistently in the underpass. In this regard, the underpass is an unmitigated success.

Despite the regular and heavy use of the underpass by wildlife, the frequency of roadkills of all species combined has not declined since our previous monitoring ended in 2007. However, 3 years after the completion of the underpass, the number of coyotes killed on Harbor Blvd. was significantly lower than during the same number of surveys conducted during pre- (2004-06) and 1-year post-construction (2006-07) sampling periods. The 2 coyotes killed during 2008-09 were killed at or well south of the intersection with south Fullerton Rd., including at or near locations where coyotes were killed during our previous study, which suggests that barriers along those stretches of Harbor Blvd., e.g. old fencing, landscaping, may force animals to stay on the road longer. We note that, although similar numbers of roadkills of all species were detected on Colima Rd., more coyotes continued to be killed on Harbor Blvd., suggesting either higher levels of coyote activity in the Harbor Blvd. area or that the more restricted natural vegetation or more gentle topography increases opportunities for coyotes to be hit on the road.

Although coyotes clearly used the underpass regularly, they continued to cross at the surface on Harbor Blvd. (Fig. 1). Coyotes were the only species that were recorded consistently at track stations and seemed to cross the road at several different points, with the greatest frequency of crossing apparently along the eastern side of the road. Track stations that were near heavily used wildlife trails along the narrow eastern shoulder often showed evidence of crossing, suggesting that animals enter the road immediately after traveling on these trails, or leave the road immediately after crossing. Surprisingly, coyotes crossed at points above and below the underpass, which, combined with the heavy use of the underpass itself, underscores the large amount of movement that continues across Harbor Blvd. Haas and Crooks (1999) also reported high coyote activity at a single track station just north of Fullerton Rd. It is interesting that, despite the number of crossings near the underpass, in our study no coyotes were found dead in the immediate area, suggesting that those that travel across Harbor Blvd. here seem to do so safely, either at the surface or through the underpass. Surprisingly, stations on the shoulder of Harbor Blvd. at the Fullerton Rd. intersection were rarely visited, in spite of the high number of road-killed coyotes found in this area (Stapp and Elliott 2008), which suggests that animals crossed north or south of the intersection itself and did not linger to leave tracks at our scent stations.

CONCLUSIONS AND RECOMMENDATIONS

As expected, the Harbor Blvd wildlife underpass continues to be used regularly by the diversity of common wildlife species known to occur in the area, especially coyotes and mule deer. Other studies of purpose-built underpasses have found similarly high usage by common wildlife species; however, as we noted in our previous report, deer began to use the underpass much more quickly than we expected based on studies of other wildlife underpasses. The use of the underpass by deer is also noteworthy because neither we nor Haas (2000) observed any road-killed deer on surveyed areas of Harbor Blvd. Contrary to our expectation, however, coyotes still appear to be crossing at the surface both north and south of the underpass, where many animals were killed previously.

Evidence of crossing was greater on the eastern shoulder, where the right-of-way is narrow and steep. Heavily-used crossing points were associated with well-traveled trails on the slope and were near to existing fencing and dense vegetation, suggesting that these may represent obstacles to movement. These points included the most southwestern station, along Fullerton Rd. west of Harbor Blvd. Clearly, any additional efforts to reduce roadkills on Harbor Blvd. must take into account the heavy activity that seems to occur on and near Fullerton Rd.

Collectively, coyotes, small carnivores and rabbits continued to be killed on Harbor Blvd., at the rate of approximately 1 per month, although our current study indicates that significantly fewer coyotes (2) were killed in 2008-09 than during the pre-construction period (5) or the first year after the underpass was completed (6). We speculated that the high numbers of coyote roadkills during the first year after underpass completion represented individuals which had not yet learned to use the underpass, and predicted that the number of roadkills would decline over time as these individuals were replaced in the population (Stapp and Elliott 2008). Assuming that our results from 2008-09 are applicable to the future, we conclude that the underpass has met a key goal of reducing the high numbers of vehicle-related coyote deaths on Harbor Blvd., although it did not reduce the frequency of roadkills of smaller mammals that are commonly associated with suburban development in southern California.

Lastly, in our previous report (Stapp and Elliott 2008), we discussed possible strategies for reducing roadkills on Harbor Blvd. These included measures to slow traffic on Harbor Blvd., and to keep vegetation near the road low to maintain high visibility for both drivers and wildlife and to avoid attracting wildlife to the road margins. We continue to advocate these measures, and also recommend, as resources permit, continued monitoring of roadkills along Harbor Blvd., as well as wildlife use of the underpass using track stations, remote cameras or both. We also suggest removing the dilapidated fence immediately across from Fullerton Rd., which may represent an incomplete barrier to crossing attempts.

One of the aims of the current study was to identify areas of the road where animals continue to cross, so that these might be targeted for other mitigation measures. In particular, the original design for the underpass called for fencing to funnel individuals into the underpass and prevent them from entering the road (Gullo 2007). We emphasize that our studies were not designed to evaluate specifically the efficacy of fencing in conjunction with the Harbor Blvd. underpass. However, to assist the Habitat Authority with their evaluation of the need for additional fencing along Harbor Blvd., below we assess the potential benefits and costs associated with fencing, specifically as they might apply to the Puente Hills Wildlife Corridor.

Benefits of fencing:

a. Assuming that an effective fence with escape structures could be constructed and maintained, fencing would likely reduce roadkills in the area of the underpass. There is a growing consensus that fencing is effective in reducing wildlife-vehicle collisions, especially in conjunction with crossing structures (e.g., Ward 1982, Clevenger et al. 2001, Hedlund et al. 2004, Dodd et al. 2007, Olsson and Widen 2008, Glista et al. 2009; see review by Huijser et al. 2008).

b. Assuming continued pressure for development in native habitat in the Puente-Chino Hills, traffic volume on Harbor Blvd. and neighboring roads will likely increase, which may lead to a return to high numbers of roadkills. It therefore could be an advantage to have a fence in place to mitigate these future effects as native habitat in the area continues to be lost and fragmented.

Concerns associated with fencing:

a. Because coyotes cross at multiple points along Harbor Blvd., fencing would likely have to extend south to Bella Vista Dr. and north to at least Wellington Ln. or Vantage Point Rd. In addition, given the propensity of coyotes to travel on Fullerton Rd., fencing would have to extend some distance up this and possibly other feeder roads, with structures at the ends to minimize concentration of roadkills where the fence ends (Clevenger et al. 2001). In addition, fencing along Harbor Blvd. would require multiple escape structures to allow those animals who enter the road via other surface roads to escape traffic, especially along the narrow, eastern right-of-way (see Huijser et al. 2008 for a review of the types and efficacy of these structures).

b. Restricting access to Harbor Blvd. at one of the narrowest remaining points of natural open space would likely push animals into the adjacent neighborhoods and developed areas, where they might try to cross roads at riskier locations and increase opportunities for other human-wildlife conflicts.

c. The vast majority of published studies showing the benefits of fencing involve populations of ungulates or large carnivores living along long stretches of multi-lane highways and freeways through rural or wilderness habitat. There is little direct evidence that fencing affects crossing behavior or effectively reduces vehicle-related mortality for small and medium-sized carnivores. In Alberta, the addition of fencing did not significantly reduce the frequency of coyote roadkills and only marginally reduced the number of vehicle-related deaths of other carnivores (Clevenger et al. 2001). In the Chino Hills east of our study area, Haas (2000) found no significant difference in the use of fenced vs. unfenced underpasses by coyotes. Working in the same area, Lyren (2001) reported significantly higher numbers of road-killed coyotes on stretches of highway without fences than in those with fences; however, this trend was confounded by differences between fenced and unfenced roads in the amount of available natural habitat, the length of survey route, and by the fact that fenced areas contained approximately 4 times higher density of crossing structures than unfenced areas. In Texas, fencing did not increase use of culverts by bobcats (Cain et al. 2003). Coyotes are also known to dig under fences (Clevenger et al. 2001, Lyren 2001), which therefore must be maintained regularly.

d. Even if an effective fence could be constructed, the benefits of reducing roadkills even further could be offset by ecological costs of further restricting movement, dispersal and ultimately gene flow across a heavily used wildlife corridor. For example, Olsson and Widen (2008) found that, even with crossing structures, the establishment of an exclusion fence reduced movements of moose (*Alces alces*), creating a barrier that may reduce access to resources and population connectivity. If fencing was added to Harbor Blvd., in

theory all crossings in the immediate area would be restricted to, and therefore dependent upon proper functioning of, the underpass. Citing the possible consequences of fences as barriers to movement, Jaeger and Fahrig (2004) suggested that fences should only be used for populations of species of concern that are known to be declining and for which high vehicle mortality is known to be a threat to persistence. With the possible exception of bobcats, which are particularly sensitive to fragmentation (Riley et al. 2003), none of the other species we detected are known to be declining regionally. We also do not know whether vehicle collisions are a major source of mortality for any of these populations; 9% of bobcats and 15% of coyotes radio-tracked by Tigas et al. (2002) in northwestern Los Angeles were killed by vehicles over a 17-month period. However, our results suggest that roadkills of bobcats and deer are uncommon on Harbor Blvd. and that vehicle-related mortality of coyotes is now lower than before the establishment of the underpass. By reducing all crossings to a single location (or forcing animals to use and cross in unfenced residential areas), fencing could be more detrimental to population connectivity and persistence than roadkills currently are.

e. Design, construction and continued maintenance (e.g. Feldhammer et al. 1986) of the fence would likely be costly (see Huijser et al. 2008), and require agreements from the multiple landholders in the area.

Based on this assessment, and our results showing 1) high activity, and presumably population densities, of coyotes and other wildlife in the area; 2) consistent and high use of the underpass by multiple species; 3) evidence of continued regular surface crossings by coyotes, suggesting the area is an important movement corridor; and 4) an apparent decline in the number of coyote roadkills since our previous monitoring, at this time we do not recommend the erection of a fence on either side of Harbor Blvd. Evidence of increased incidence of roadkills on Harbor Blvd. in the future, especially following any changes in land-use in the area, may require a re-assessment of the need for fencing.

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Table 1. Mean and standard error (SE) of the roadkill index (individuals killed per km per 5 weekly surveys), calculated for all species combined and for coyotes separately, on ~4-km stretches of Harbor Blvd. and Colima Rd., Los Angeles County, California. N is the number of animals killed. Period refers to the sampling period relative to construction of the wildlife underpass on Harbor Blvd., which was completed in May 2006. Other wildlife killed on roads during the post-3 year sampling period included Virginia opossums (*Didelphis virginiana*; 4 on Harbor Blvd., 2 on Colima Rd.), striped skunks (*Mephitis mephitis*; 2, 3), desert cottontails (*Sylvilagus audubonii*; 3, 2) and bobcats (*Lynx rufus*; 0, 1). Roadkills of domestic animals (4, 8), rodents (10, 5) and birds (2, 0) were not included in totals for all species.

		All species combined						Coyotes					
		Harbor Blvd.			Colima Rd.			Harbor Blvd.			Colima Rd.		
Period	Surveys	Index	SE	N	Index	SE	N	Index	SE	N	Index	SE	N
Post 3 years (7/08 - 6/09)	**53**	**0.25**	**0.07**	**11**	**0.19**	**0.05**	**8**	**0.04**	**0.03**	**2**	**0**	**0**	**0**
Post 1 year (6/06 - 7/07)	53	0.26	0.08	11	0.25	0.08	10	0.15	0.05	6	0.02	0.02	1
During construction (10/05 - 5/06)	34	0.34	0.10	9	0.33	0.04	9	0.07	0.05	2	0.18	0.05	5
Pre-construction (7/04 - 9/05)	53	0.30	0.09	12	0.26	0.07	11	0.11	0.05	5	0.02	0.02	1

Table 2. Locations of roadkills of small and medium-sized carnivores found along ~4-km stretches of Harbor Blvd. and Colima Rd. during weekly surveys between 1 Jul 2008 and 2 Jul 2009. Location is given in UTM coordinates (datum WGS84). The bobcat was reported by a Habitat Authority Ranger before it was removed by him on the day of our survey. Except for the opossums found on 25 Nov on Colima Rd. and on Harbor Blvd. on 18 Apr, which were found in the inner traffic lane, all of the roadkills listed here were found in the outermost lane.

					Location		
Road	Day	Month	Year	Species	Easting	Northing	Lane direction
Harbor Blvd.							
	23	Jul	2008	coyote	0414409	3757233	S
	28	Sep	2008	opossum	0413971	3756715	N
	07	Jan	2009	coyote	0414566	3757432	N
	14	Jan	2009	striped skunk	0414896	3757853	N
	25	Jan	2009	striped skunk	0415504	3758367	S
	11	Apr	2009	opossum	0414379	3757184	S
	18	Apr	2009	opossum	0415488	3758545	S
	8	May	2009	opossum	0414063	3756870	N
Colima Rd.							
	01	Jul	2008	striped skunk	0407568	3758787	N
	23	Jul	2008	opossum	0407560	3758784	N
	09	Oct	2008	striped skunk	0407390	3758431	S
	06	Nov	2008	striped skunk	0410149	3760513	S
	25	Nov	2008	opossum	0407406	3758595	N
	14	Jan	2009	bobcat	0408416	3759337	S

Fig. 1. Locations of track stations along the western and eastern shoulders of Harbor Blvd., La Habra Heights, California. The size and color of the filled circles corresponds with the level of coyote activity at each track station during six 3-night tracking sessions conducted between July 2008 and May 2009, here expressed as the percentage of the 18 station-nights that each station was visited. Yellow arrows denote stations that consistently showed evidence of surface crossing by coyotes (tracks indicated crossing during at least 4 of the 6 tracking sessions and 5 of the 18 station-nights). The location of the underpass is indicated with a dark blue rectangle. By comparison, coyotes left tracks in at least one of the underpass stations on all 18 nights of track surveys (track-use intensity = 100%).

a)

b)

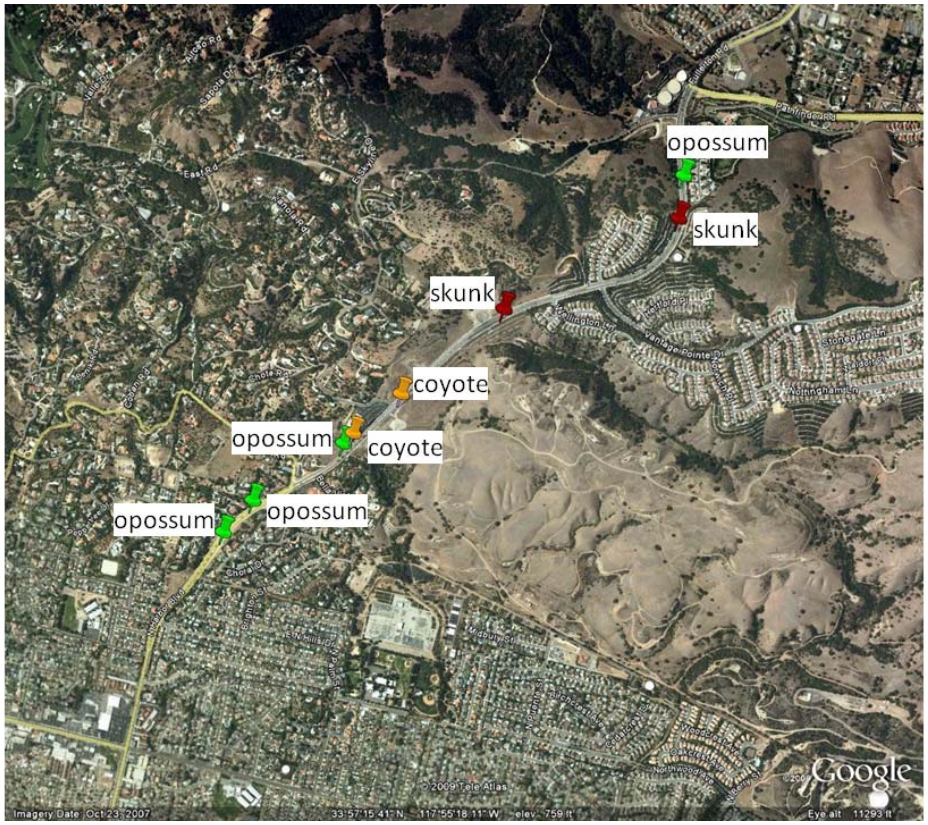

Fig. 2. Locations of roadkills of carnivores between July 2008 and June 2009 on a) Harbor Blvd. and b) Colima Rd. Locations plotted using Google Earth Pro. The Harbor Blvd. underpass is visible in the center of panel a) immediately west of the westernmost location of a road-killed striped skunk.

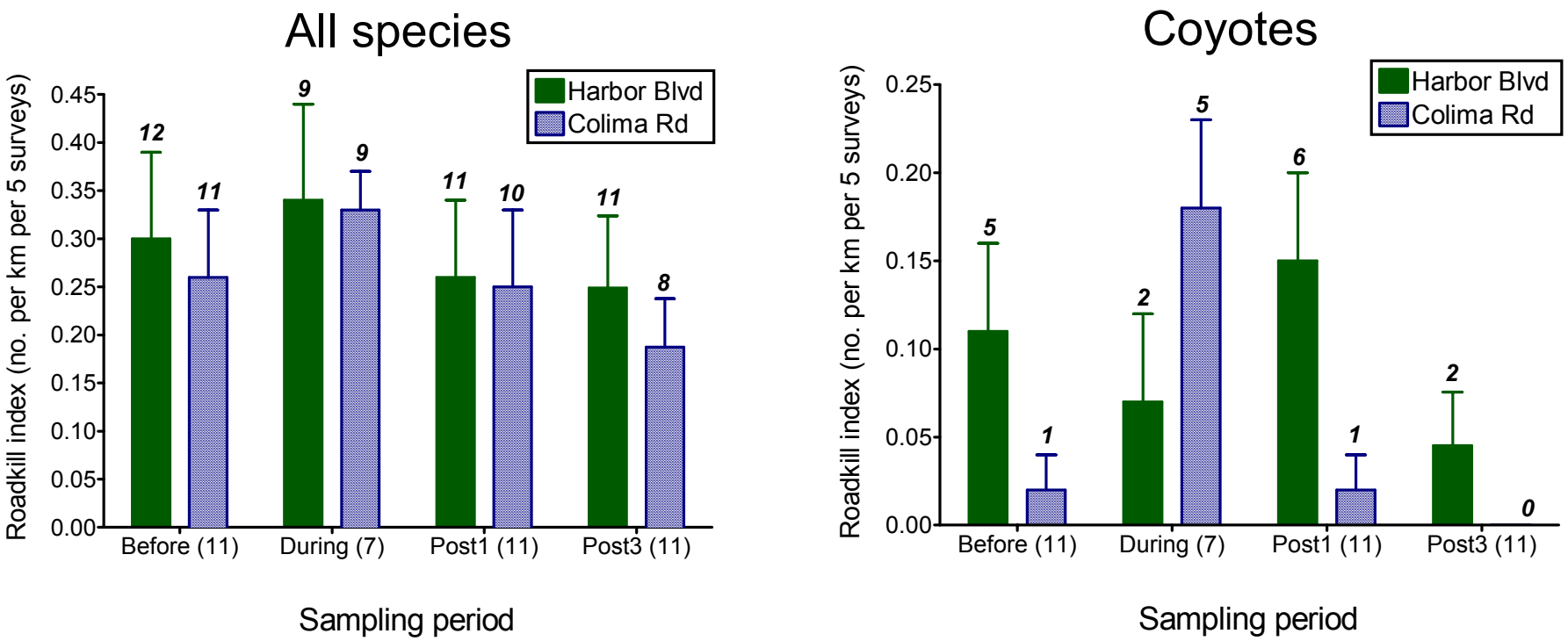

Fig. 3. Mean and standard error (SE) of the roadkill index (individuals killed per km per 5 weekly surveys), calculated for all species combined (left panel) and for coyotes (*Canis latrans*) separately (right), on ~4-km stretches of Harbor Blvd. and Colima Rd., La Habra Heights, California. Values in parentheses (x-axis) are the number of 5-week surveys in each sampling session. Values above bars are the numbers of roadkills during that period. Note difference in the scale of the y-axes for the 2 graphs.

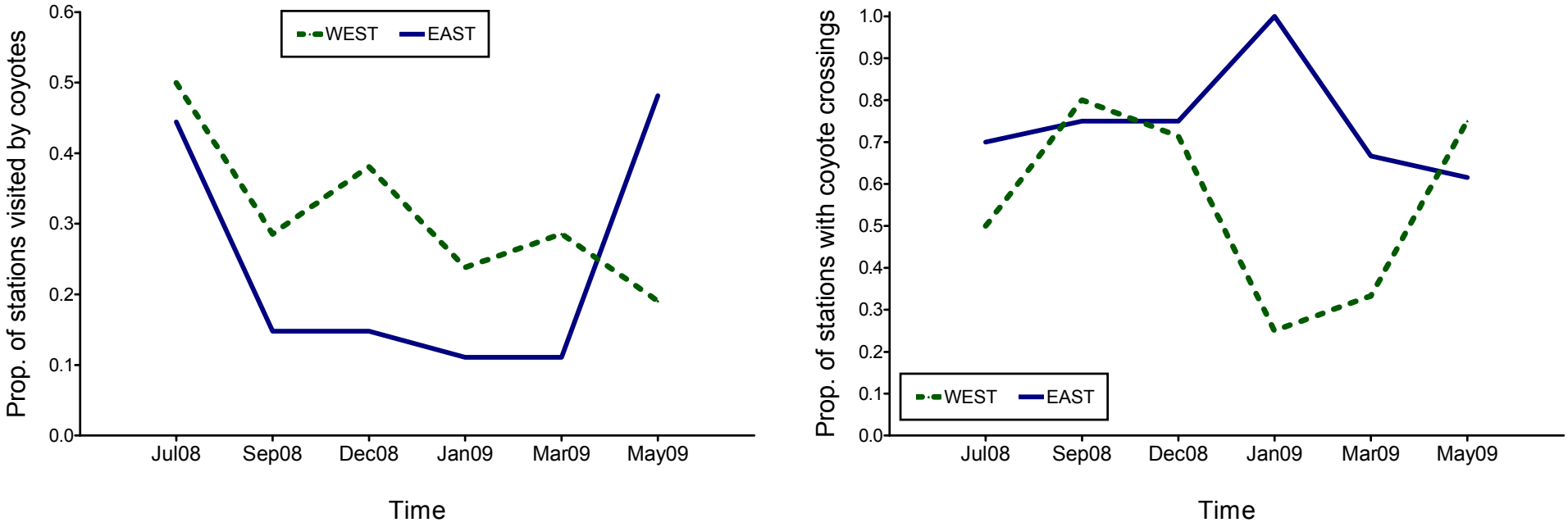

Fig. 4. Proportion of scent-baited gypsum track stations along the western and eastern shoulders of Harbor Blvd. that were visited by coyotes (left) and the proportion of stations where tracks indicated that coyotes crossed Harbor Blvd. (right). During each of the six 3-night tracking sessions, 9 stations were set on the western shoulder and 7 stations were set on the eastern shoulder (see Fig. 3 for locations), with stations checked for tracks each morning and cleared. Values are expressed as a proportion of the number of station-nights in each session (27 west, 21 east).

Fig. 5. Sample images of wildlife [top, from left: coyote; mule deer, striped skunk; middle: coyote, bobcat, desert cottontail; bottom: coyotes, bobcat, raccoon] taken by digital cameras in the Harbor Blvd. underpass from July 2008 and June 2009.

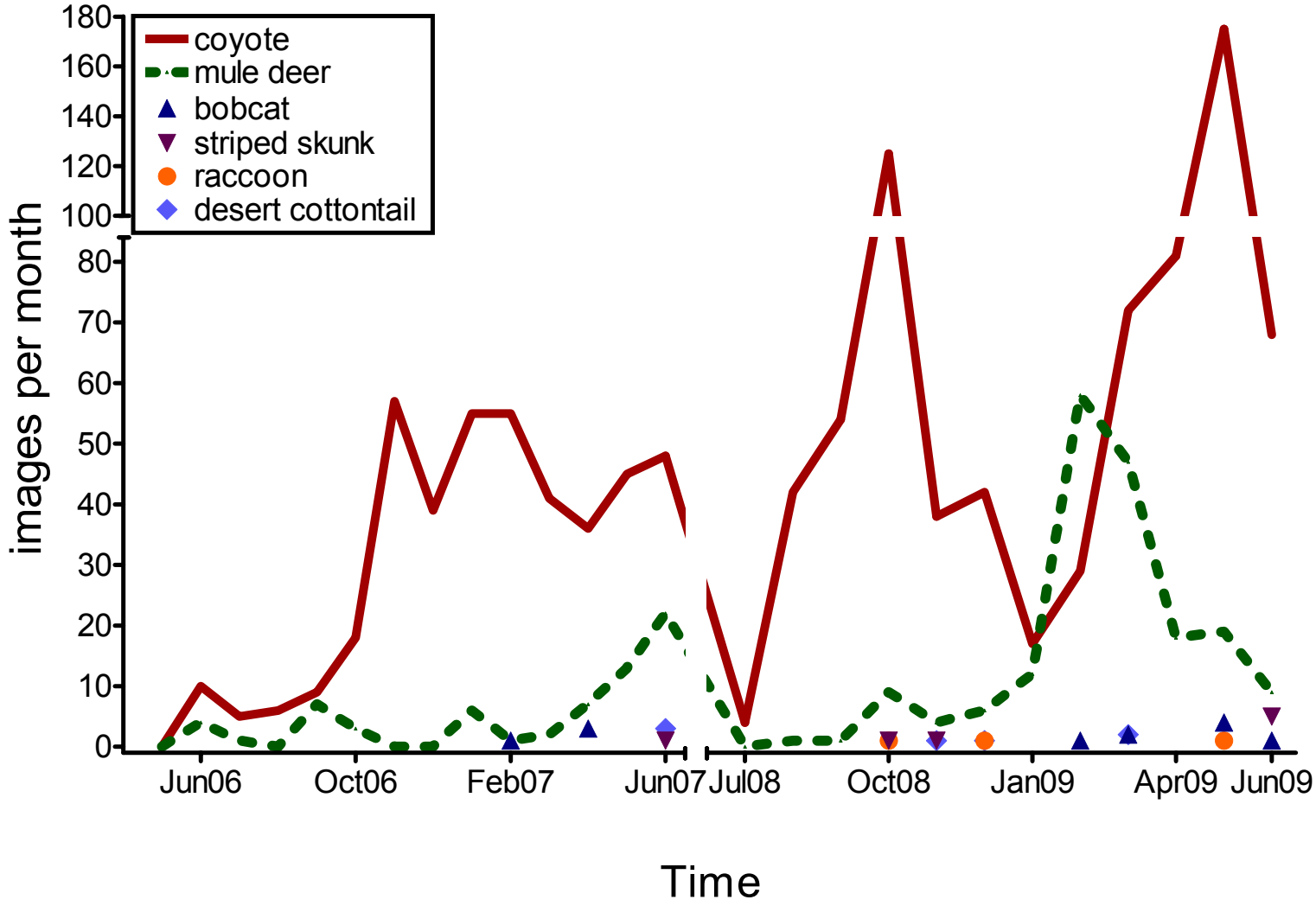

Fig. 6. Numbers of images of wildlife species detected in the Harbor Blvd. wildlife underpass using three remote digital cameras, through June 2009. Construction of the underpass was completed in May 2006, and cameras were monitored through June 2007. Monitoring for the current study began in July 2008. Coyotes and mule deer were the most common species seen during the current study, although bobcats, raccoons, striped skunks and desert cottontails were also photographed in the underpass in 2009.