A Field Study of Small Vertebrate Use of Wildlife Underpasses in San Diego County, 2014

Prepared for:

California Department of Fish and Wildlife

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U.S. GEOLOGICAL SURVEY

WESTERN ECOLOGICAL RESEARCH CENTER

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Table of Contents

Tables

Figures

Abstract

In 2012, the U.S. Geological Survey (USGS) started a small animal connectivity study as part of Connectivity Monitoring Strategic Plan (CMSP) developed by the San Diego Monitoring and Management Program (SDMMP). The plan focused on small animals and their use of 8 underpasses throughout San Diego County. Specialized infrared motion detection cameras were set up at each of the underpasses and monitored from May 15 to October 1, 2102 and from March 19 to September 23, 2012. After the first year, concrete structures were set up along the interior wall at 4 of the underpasses to determine if the addition of structure would enhance the use of wildlife undercrossings by small vertebrates.

Over the two year period we collected over 3 million of pictures, developed specialized software and methods for processing images, and documented the following species; Pocket Mouse (*Chaetodipus spp*.), Kangaroo Rat (*Dipodomys spp.),* California Vole (*Microtus californicus*), Woodrats (*Neotoma spp.),* Grey Shrew (*Notiosorex crawfordi*), Brush Mouse (*Peromyscus boylii*), California Mouse (*Peromyscus californicus*), Deer Mouse (*Peromyscus maniculatus*), White footed Mouse (*Peromyscus spp*.), Domestic Rat (*Rattus rattus),* Orange Throated Lizard (*Cnemidophorus hyperythrus*), Western Whiptail (*Cnemidophorus tigris*), Western Fence Lizard (*Sceloporus occidentalis*), Granite Spiny Lizard (*Sceloporus orcutti*), Side Blotched, Lizard (*Uta stansburia*), Red Diamond Rattlesnake (*Crotalus ruber*)- outside only, Western Rattlesnake (*Crotalus viridis*), Bobcat (*Lynx rufus*), Coyote (*Canis latrans*), Grey Fox (*Urocyon cinereoargenteus*), Mule Deer (*Odocoileus hemionus*), Greater Roadrunner (*Geococcyx californianus*), Opossum (*Didelphis marsupialis*), Striped Skunk (*Mephitis mephitis*), Raccoon (*Procyon lotor*), Spotted Skunk (*Spilogale putorius*), Jackrabbit (*Lepus californicus*), Rabbit species (*Sylvilagus spp*.), California Ground Squirrel (*Spermophilus beecheyi*), Chipmunk Species (*Neotamias merriami*).

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 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 little evidence to support the association between use or connectivity for these species and small vertebrates, then small vertebrates must be studied and monitored separately.

Finally, we made substantial process in development of this methodology for studying and monitoring underpass use by both small vertebrates and other taxa. These developments include configuration and installation of the cameras, software and methods for processing images, study design, and statistical analysis.

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.

INTRODUCTION

Wildlife underpasses are intended to facilitate safe wildlife movement between natural areas transected by major roads. To date, most studies have focused on large animal movement through road underpasses. We know very little about how small vertebrates respond to these structures or if current underpasses facilitate their connectivity across roads. The Department of Transportation (DOT) currently recommends that structure be added to underpasses and overpasses to increase wildlife use and movement (DOT 2011).

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).

Locally, the San Diego Monitoring and Management Program (SDMMP) has developed a draft Connectivity Monitoring Strategic Plan (CMSP). The plan identified the importance of determining existing connectivity for a suite of small animal species sensitive to fragmentation as well as to identify and inform adaptive management actions needed to maintain, restore, or improve connectivity between conserved NCCP core areas in San Diego County. Our study was conducted to assess both existing connectivity and effects of adaptive management for movement of small terrestrial vertebrates through underpasses that connect habitats transected by roads (although data on larger wildlife was also collected and analyzed). The underpasses in our study are large, open structures that connect upland habitats.

We had three main objectives in this study. First, to determine which groups of small vertebrates are currently using or avoiding these wildlife underpasses and understand how these behaviors may be predicted by life history characteristics. Secondly, to investigate the effectiveness of adding cover structures to underpasses as a way to enhance small vertebrate use of underpasses. Third, to evaluate the extent to which larger vertebrates often used as focus species in connectivity studies in the region act as indicators of use by small vertebrate species.

METHODS

Study Sites

We considered only large underpasses in coastal San Diego County that had no roads or water courses passing through them for the study. We visited potential study sites on February 29, 2012. We identified eight underpasses connecting natural upland habitats that satisfied these criteria and included all eight in the study (Figure 1, Table 1). A three-letter Site ID identifies each sample unit (Figure 1, Table 1). The underpasses at Valley Center Road are constructed completely of concrete. During our initial reconnaissance, we observed evidence of small mammals, bats, and granite spiny lizards in the seams between the concrete sections and in the drainage pipes in the concrete. The Valley center underpasses also have concrete ledges on each side. In addition, VCS and VCM have a shallow concrete drainage ditch running along the east side of the underpass interior. The underpasses at Carmel County Road (CCS and CCN) are right next to each other and are constructed entirely of corrugated metal. CCS has a recreation path through the underpass whereas CCN does not. The Sorrento Valley Road (SVR) underpass was also constructed entirely of corrugated metal. The two southern-most underpasses, Scripps Poway Parkway (SSP) and Highway 52 (HFT) were also the longest. SSP is constructed of corrugated metal covered with spraycrete. It has light tubes for illumination and wooden structures mounted to the ceiling in which birds can nest as well as bat boxes attached to the wooden structures. HFT was constructed of concrete side walls and a corrugated metal upper section. The concrete side walls provided ledges on which small animals could move. HFT also had openings to add illumination.

The eight study sites are associated with three complexes of conserved lands. The three Valley Center Road sites are associated with Daley Ranch Open Space Preserve/ City of Escondido Open Space. The two Carmel County Road underpasses and the Sorrento Valley Road underpass are associated with Los Pensquitos Canyon and surrounding conserved lands. Finally, the Scripps Poway Parkway and Highway 52 sites are associated with a relatively large area of open space that includes Mission Trails Regional Park, Marine Corps Air Station Miramar, and Sycamore Canyon.

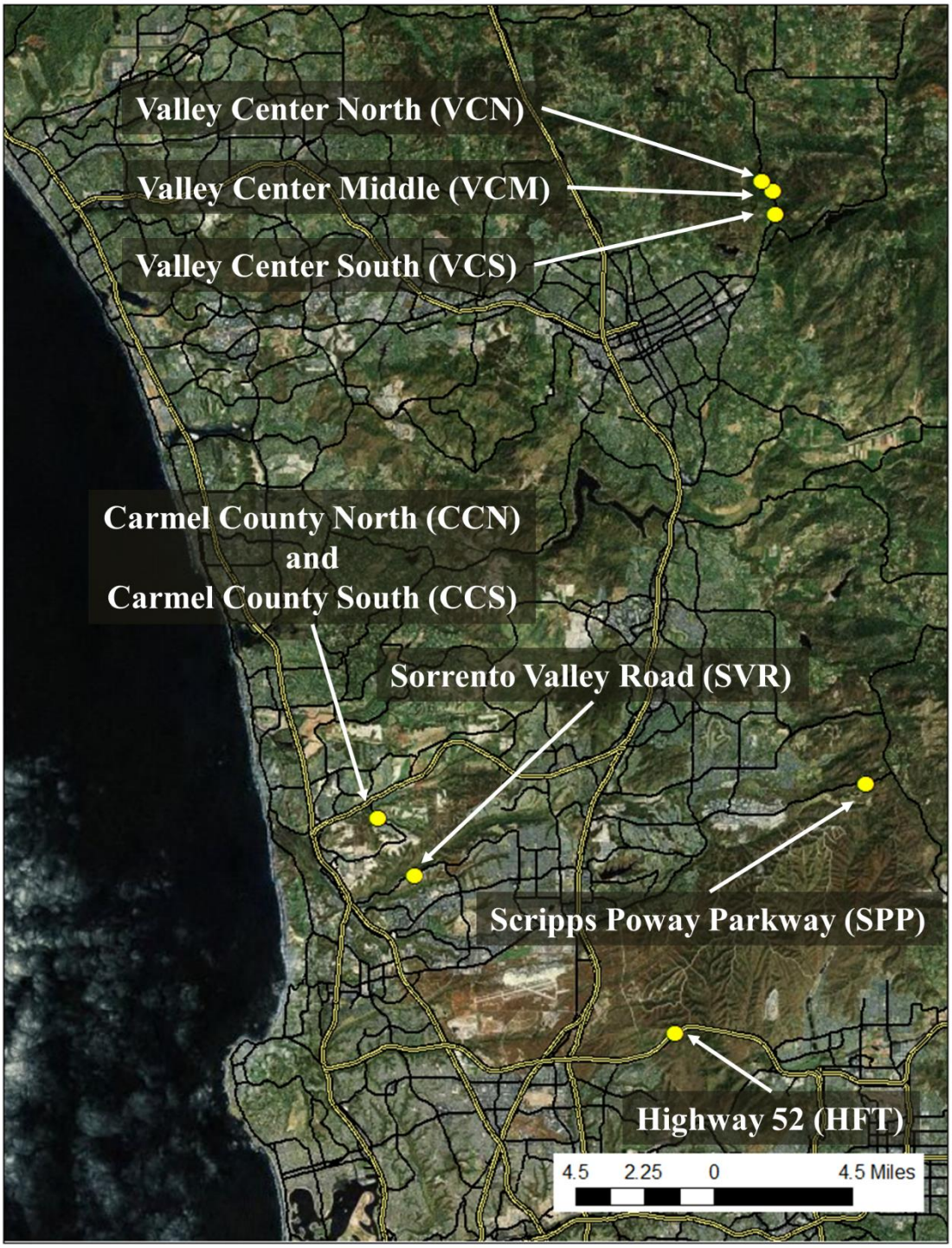

Figure 1: Locations of the eight underpasses in coastal San Diego County selected for study.

In addition to our study, the San Diego Tracking Team (SDTT) surveys six of the eight underpasses (VCN, VCM, VCS, SVR, SPP, and HFT) every quarter. In addition, Megan Jennings (SDSU) sampled two sites (CCS and SPP) for bobcats using motion-triggered cameras.

Table 1: Underpasses and their attributes. Each of the eight study sites is assigned a three-letter Site ID. The number of cameras at each site is given under # Cam and the number of treatment structures placed in the underpass in January 2013 is given under # Struct.

Site (Site ID)	Longitude (deg)	Latitude (deg)	Length (m)	Width (m)	Azimuth (deg)	Group	# Cam	# Struct
Valley Center North (VCN)	-117.0303	33.1871	34	4.5	34	Control	4	NA
Valley Center Middle (VCM)	-117.0249	33.1833	45	4.5	31	Treat	4	12
Valley Center South (VCS)	-117.02401	33.1743	37	4.5	255	Control	4	NA
Carmel Country Road North (CCN)	-117.21028	32.9368	51	9	256	Treat	3	13
Carmel Country Road South (CCS)	-117.21028	32.9368	51	9	256	Control	2	NA
Sorrento Valley Road (SVR)	-117.19281	32.9143	46	6	330	Treat	3	12
Scripps Poway Parkway (SPP)	-116.9814	32.9501	62	9	11	Control	3	NA
Highway 52 (HFT)	-117.07096	32.8517	87	5	315	Treat	4	18

Study Design and Data Collection

We selected a Before-After Control-Impact (BACI) design (McDonald et al. 2000) to investigate the effectiveness of adding structures to underpasses to enhance small vertebrate use. A pre-treatment sampling period was conducted so that we can acquire data to establish baseline conditions. Next, the treatment was applied to some of the sample units and then a second sampling period was conducted. During each sampling period, small vertebrate (small mammal and reptile) use within the underpasses was observed using motion detection cameras specially configured to detect small animals. We set cameras to take time-lapse images at five-minute intervals to aid in the detection of small animals that did not set off the motion sensor. We also sampled adjacent habitat outside the underpass for small vertebrates during small animal activity periods in 2012 and 2013.

Camera Placement

To sample small vertebrate use inside the underpasses, we placed two interior cameras at ground level in each underpass (Figure 2A, locations ① and ② and Figure 2C). Because we considered data collection at ground level to be most important for the study objectives, we used two cameras to act as "double observers." Cameras were placed on each wall at opposite ends of the underpass, 7.5 meters

from the underpass opening (Figure 2A). Cameras were mounted approximately 4 cm above ground level at a 10-degree angle from the wall toward the central axis of the underpass (Figure 3C). We mounted the interior ground level and ledge cameras to the underpass wall using a wooden bracket to control the orientation of the camera and toggle bolts or drop-in anchors and carriage bolts, depending on the underpass construction (Figure 3C,D and Appendix A).

If the underpass had concrete ledges (Figure 2B), we also added a ledge camera to one of the ledges (Figure 2A, location ③and Figure 3D). We placed a ledge camera on one ledge at the midpoint of the underpass, aimed directly down the ledge. We mounted the ledge cameras approximately 10 cm above the ledge so that small vertebrates could pass under it without obstructing their movement.

We added exterior cameras (as funding permitted) near one opening of the each underpass (Figure 2A, location ④and Figure 3E) to observe species using areas outside the underpass. We placed exterior cameras about 4 cm above ground level perpendicular to a trail or wing fence. We mounted exterior cameras to a metal post driven at least 0.5 meters into the ground with carriage bolts or existing wing fencing posts with U bolts (Figure 3E, Appendix A).

We assigned each camera a Camera ID, which was the Site ID with two numerals appended to it. For example, at the Scripps Poway Parkway underpass, which has a Site ID SPP, we installed two interior cameras SPP01 and SPP02 and an exterior camera SPP03. In general, the interior ground level cameras always had the numerals "01" and "02" appended to the Site ID, while "03" and "04" designated ledge or exterior cameras (in no particular order).

Motion Detection Cameras

Because we wanted to sample small vertebrate use, we required cameras with excellent motion detection mechanisms by manufacturers that were able to make custom modifications. After investigating and testing several models, we selected Reconyx PC800 HyperFire™ Professional cameras (Figure 3A). These cameras feature semi-covert infrared flashes that make no noise. Reconyx cameras store more complete Exif image metadata than most manufacturers (in the MakerLabel field), operate in both motion detection and time lapse mode, and allow users to set a camera ID that is stored with all images taken by the camera. Reconyx increased the sensitivity of the cameras per our request, and focused the cameras at a distance of 5 feet, although the cameras had considerable depth of field so a large portion of the image was typically in focus.

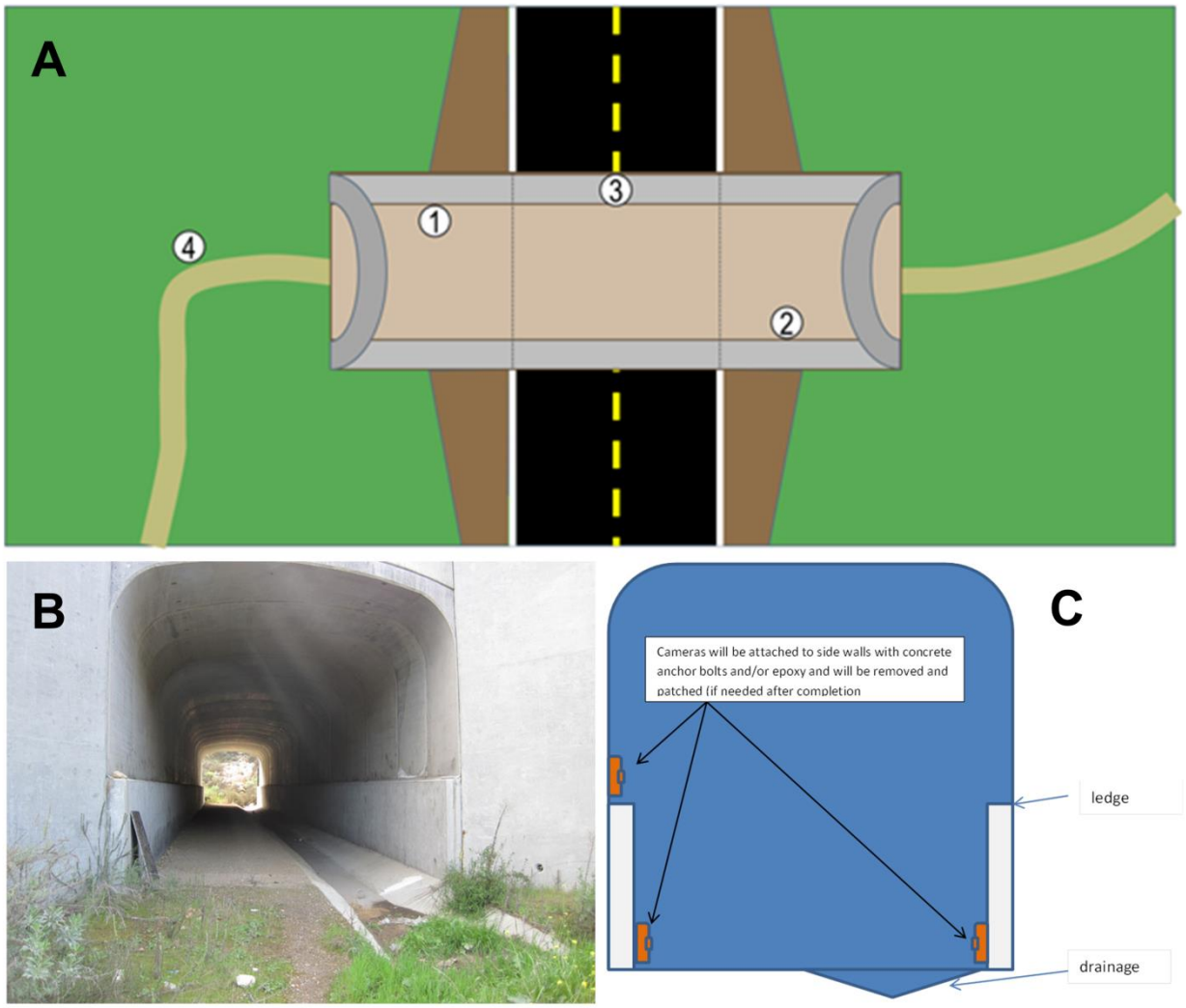

Figure 2: Placement of cameras at study sites. A general layout of cameras in the underpasses is shown in A. Camera positions are shown as circles with numbers, but not all underpasses had concrete ledges. Valley Center Middle, shown in B, is an example of an underpass with concrete ledges. A cross-section of camera placement in the underpasses is shown in C.

For security, a numerical code can be set that must be entered whenever the camera is turned on or when the user changes settings. In addition, Reconyx makes custom fit security enclosures for HyperFire Series cameras (Figure 3B). The 17.8h × 14.0w × 8.9d cm enclosures are made of 16-gauge steel with weather resistant powder coat finish. The security enclosure provided a way to mount the cameras, remove them when not in use, and replace them in the same position and orientation at a later time.

In addition to security boxes, padlocks, and mounting hardware, each camera requires batteries and memory cards on which to store images. The cameras are powered by 12 AA batteries. To minimize cost and waste, we used rechargeable NiMH batteries (AccuPower NiMH-AKKU) for the interior cameras. The rechargeable batteries drained quickly in the exterior cameras (presumably due to the higher temperatures), so we used high-quality lithium batteries (Energizer Ultimate Lithium) in the external cameras. The cameras store images on SDHC cards, so we used two SanDisk 8GB or 16GB SDHC cards per camera.

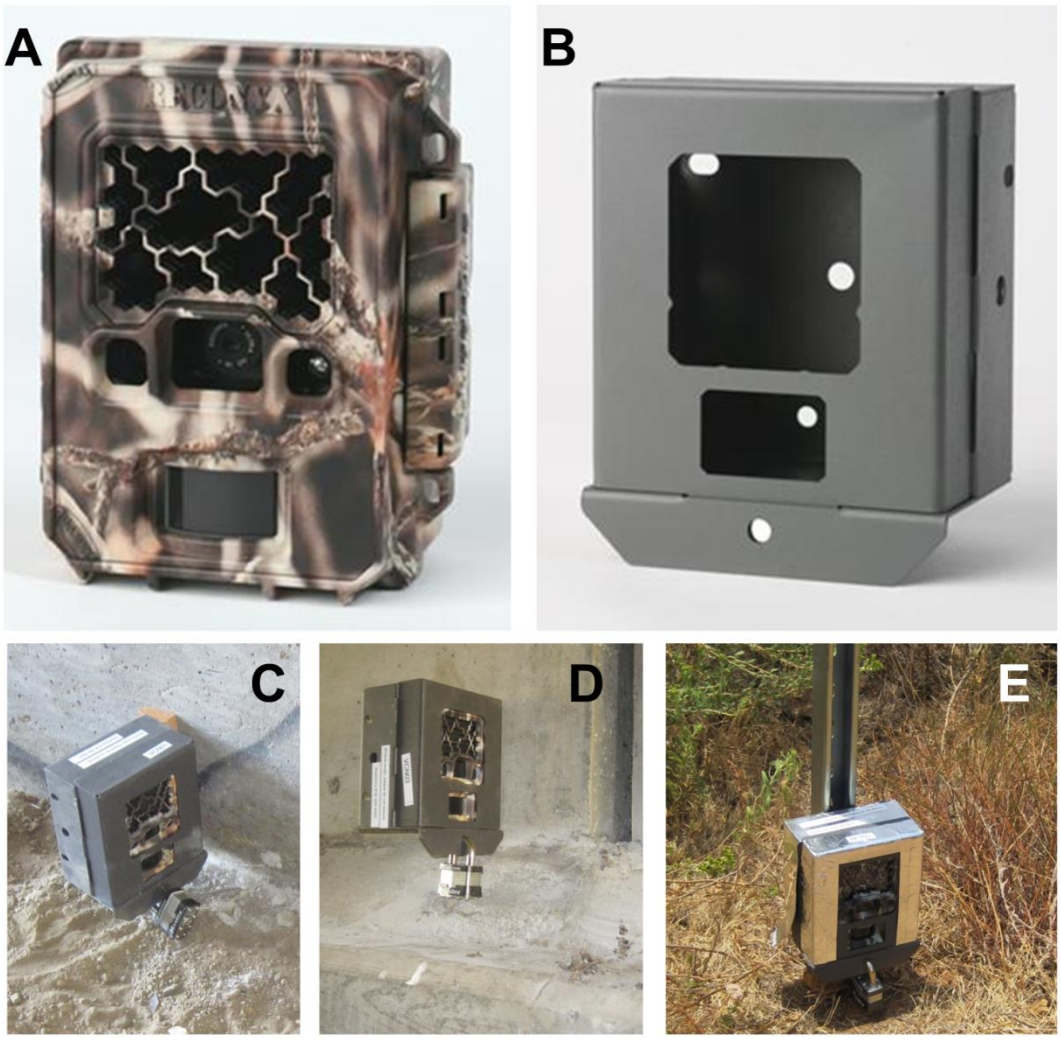

Figure 3: Cameras and installation. The camera model we used, the Reconyx HyperFire PC800, is shown in A, The camera security box is shown in B. We placed cameras in the underpass interior at ground level (C), on concrete ledges inside the underpass (D), and at exterior locations at ground level (E).

Data Collection

In 2012 and 2013, we operated the cameras continuously during summer months when small mammals and reptiles were most active. We set the cameras to take both motion-detection and time-lapse images at five-minute intervals. Time-lapse images provide an alternative way to observe species independent of the motion detection mechanism. We checked the cameras every two weeks. During camera checks, we replaced the batteries, exchanged the memory cards, cleaned the camera lenses, and corrected any other problems that arose. When we removed the cameras at the end of the 2012 season, we left the security boxes in place so that we could reinstall the same camera at the same position with the same height and orientation. When we removed the cameras at the end of the 2013 season, we again left the security boxes in place in case there is an opportunity to conduct additional data collection in the future.

Treatment

We randomly assigned four underpasses to the treatment group and four underpasses to the control group (Table 1). In January of 2013, we added small structures to the treatment underpasses. Each structure consisted of concrete blocks stacked on top of two half-meter sections of black PVC pipe (Figure 4A). The structures were placed at five-meter intervals along the entire length of one side (the "cover side") of the treatment underpasses (Figure 4B), and were intended to allow small vertebrates to move from one structure to the next, thereby facilitating movement through the underpass. We did not place structures on the wall opposite the cover side of the treatment underpasses (the "open side"). The purpose of this design was to facilitate movement of species with both open and closed microhabitat preferences. Furthermore, the structures were very small compared to the lengths and widths of the underpasses, so they would not impede the movement of humans or any other animals. Since there were two interior cameras at ground level on each wall of each underpass, one of the ground-level interior cameras was on the cover side and the other was on the open side of the treatment underpasses. We allowed over two months for animals to habituate to the treatment before subsequent post-treatment monitoring (late March to late September 2013).

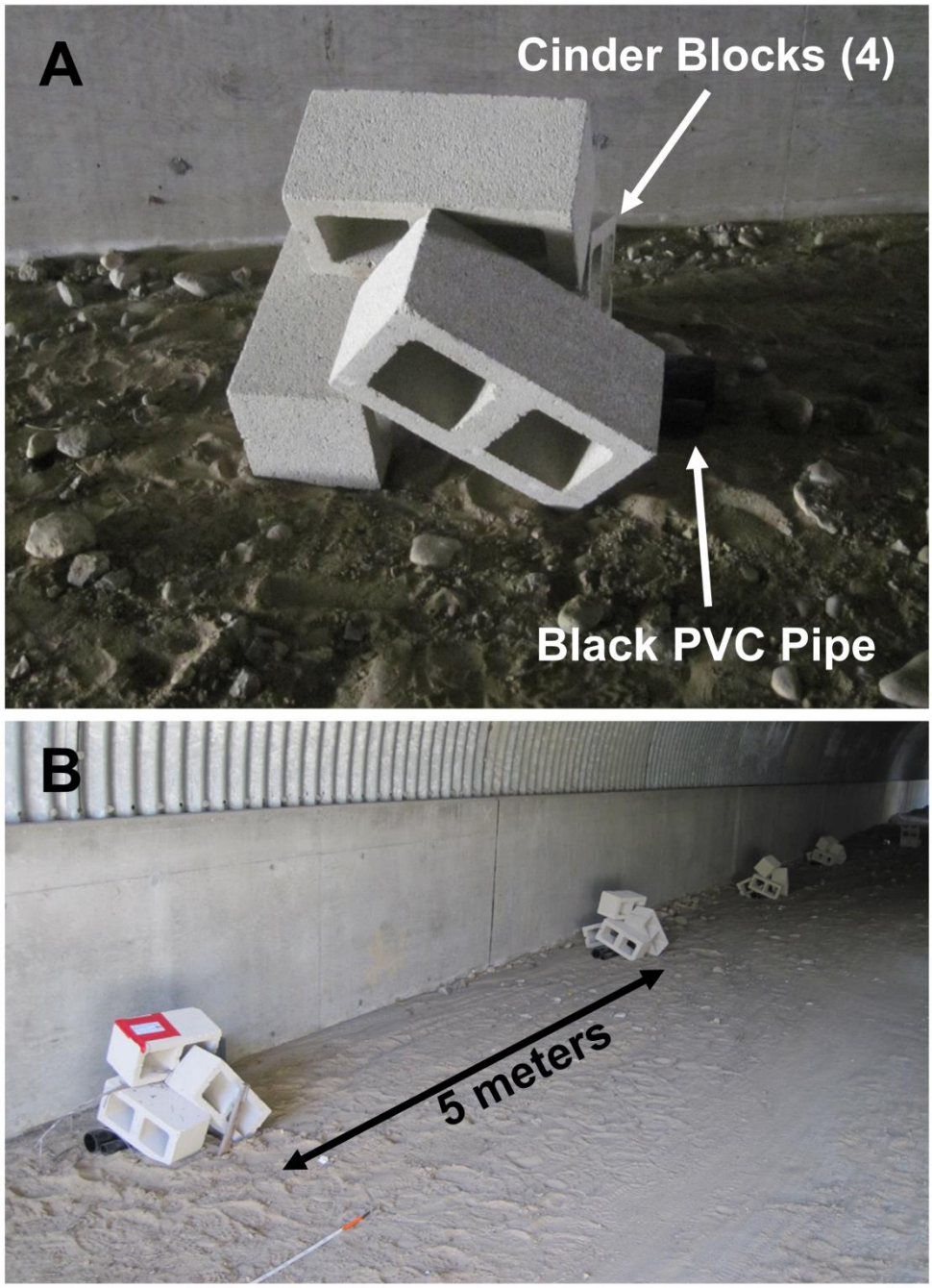

Figure 4: Treatment applied to randomly selected underpasses. Each structure consisted of four cinder blocks, one 0.5-meter length of 1-inch black PVC pipe, and one 0.5-meter length of 1-inch black PVC pipe (A). Structures were placed at 5 meters intervals along one wall of the treatment underpasses for the entire length of the underpass (B). Thus, the number of structures placed in the control underpasses varies based on the length of the underpass (**Table 1**).

Data Analysis

Image Processing

Digital motion-triggered cameras have allowed ecologists to collect large numbers of images with a reasonable investment in equipment and field effort. However, the time and expense required to process images from camera studies is commonly underestimated and often becomes a bottleneck in transforming the images collected into data useful for statistical analysis and far outweighs the number of hours spend in the field installing and maintaining the cameras. In this study, the effort required to process the over three million images collected is substantial (Table 2). Of equal importance is that the images with animals are correctly identified, the species in these images are correctly classified, and attribute data is associated with each image for analysis. We addressed this problem in three ways: (1) by developing software tools to facilitate accurate and rapid processing of imagery, (2) dedicating several USGS staff and enlisting the aid of volunteers from the San Diego Tracking Team to use the software to process images, and (3) prioritizing images into groups for processing.

A cross-platform Java program, written by Jeff A. Tracey (USGS, San Diego Field Station), allowed personnel to rapidly review images and assign data to them (**Figure 5**). USGS staff used the first version of the program in 2012 to process images. The program was further tested and improved in late 2013. Because the cameras create image files with the same sequence of file names (IMG_0001, IMG_0002, …), there is a risk of over-writing image files and losing the data they contain. Thus, the program we created automatically copies images to a new file with a unique name. During this process, the program also automatically extracts and stores Exif metadata (date, time, camera name, temperature, moon phase, trigger mode, and image sequence) by making a system call to the ExifTool utility (http://www.sno.phy.queensu.ca/~phil/exiftool/). A reviewer can then view the images by stepping through them one image at a time, or animating them, in either a forward or backward direction. A reviewer can also group similar images together and assign species data from a pull-down menu, indicate the number of individuals in the image, and the direction that the animals were traveling. This interface allowed the data assigned to an image to be checked, and because qualitative data was added from menu selections, these attributes were recorded in a consistent manner. Image processing projects can be saved to XML files and re-opened, and the data generated by a reviewer using the program can be exported to CSV (comma-separated values) files (Figure 6). Additional details about the image processing methodology can be found in the user guide for the image processing program (Appendix B).

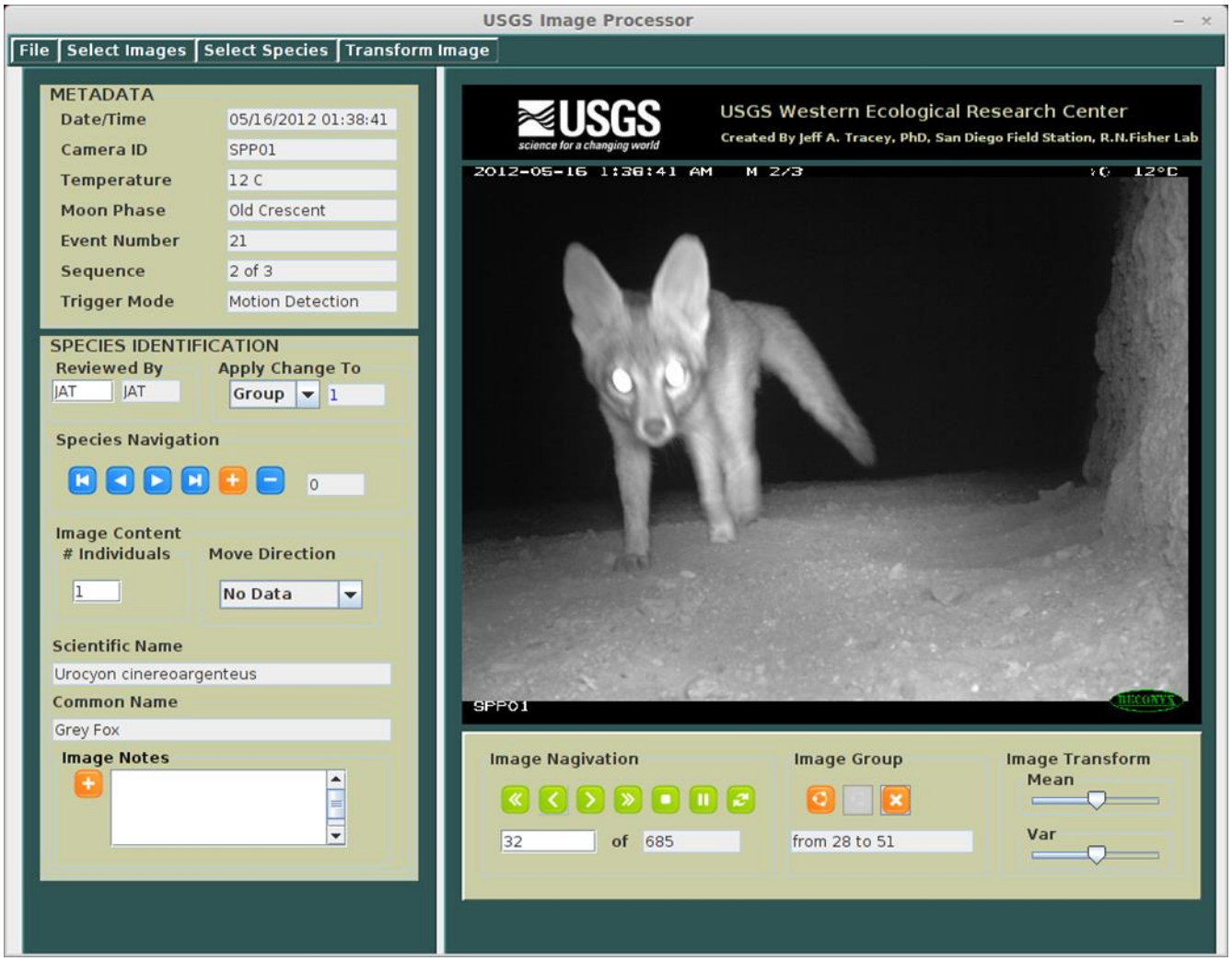

Figure 5: User interface for an image-processing program developed at the USGS San Diego Field Station.

Once the initial review is completed and data has been exported to CSV files, it can be used as input for statistical analysis or imported into spreadsheet or database applications. In order to facilitate review of the image data, Carlton Rochester (USGS San Diego Field Station) created a Microsoft Access™ tool (**Figure 7**). This tool allows the user to query data, compare data against the original imagery, and correct errors in species identification and data assignments (**Figure 7**).

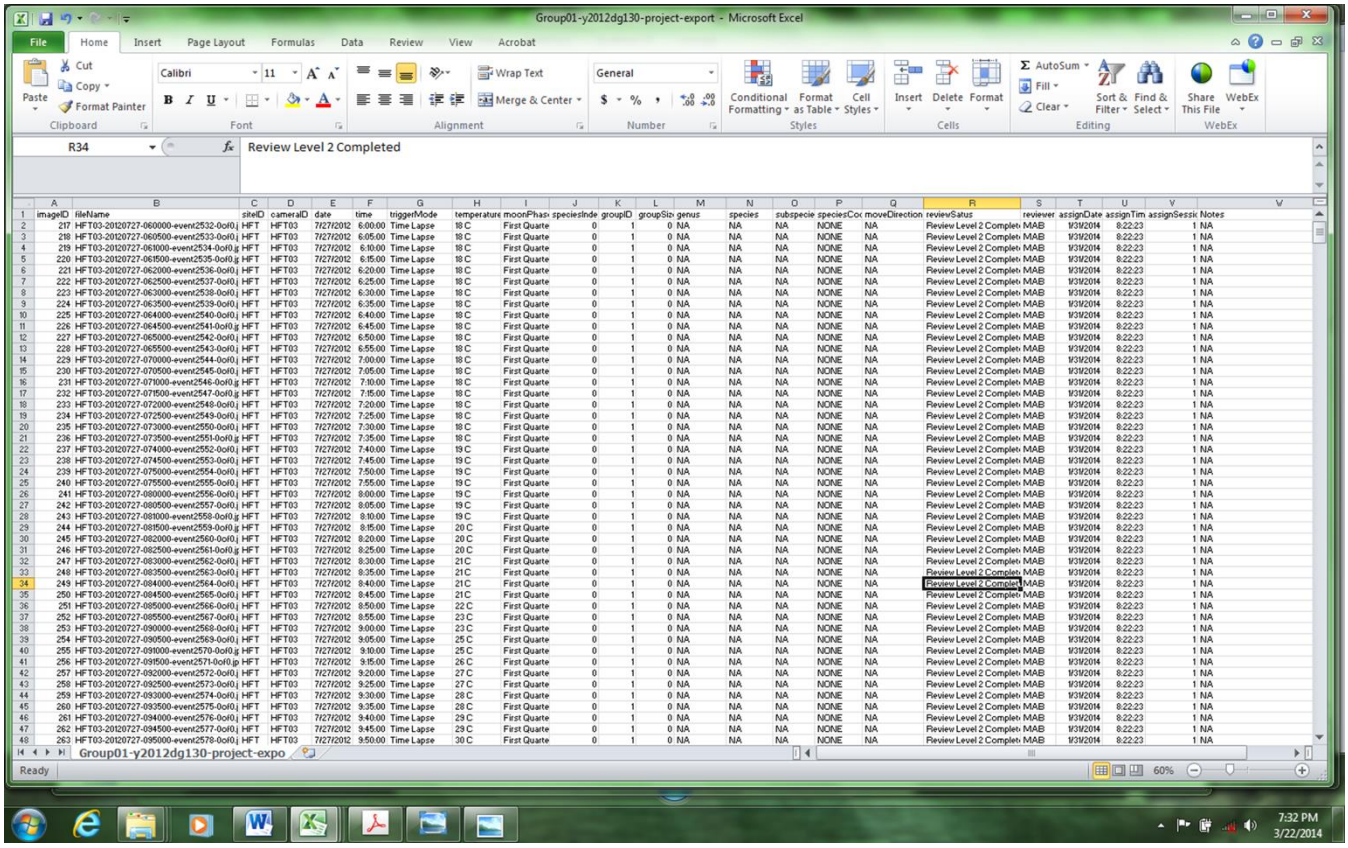

Figure 6: Data exported to CSV format from the Java image processing program.

While these software tools are not ready for general use, they greatly reduced the time required to process images and improved the quality of the data generated from the images. We prioritized images into three groups, where the first group contained 208,573 images (92 GB) necessary to address the main objectives of the study. In 2012, five USGS staff members dedicated a month or more of part-time effort to review images. In 2014, six USGS staff and five San Diego Tracking Team (SDTT) volunteers worked part-time for several weeks or more reviewing images from the first group. Three other USGS staff reviewed the image data and made species-level identifications of small mammals and reptiles.

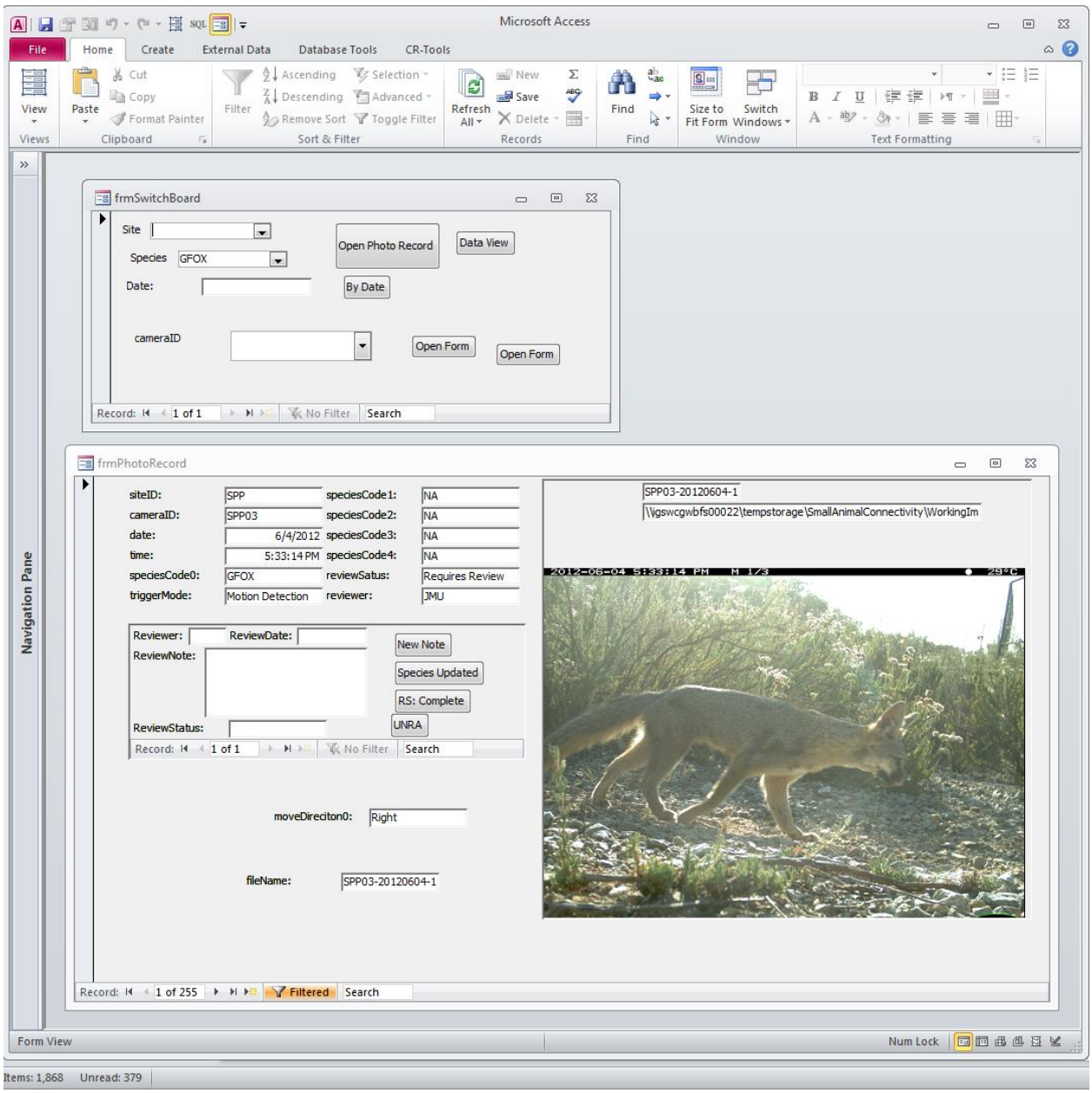

Figure 7: Screenshot of a Microsoft Access tool to QAQC data associated with images.

Data Collection

In 2012, USGS staff installed interior cameras between 5/15/2012 and 6/19/2012 and continued to install ledge and exterior cameras through 8/15/2012. Data collection continued from the date of camera installation until we removed the cameras on 10/3/2012. One camera (HFT04, a ledge camera in the Highway 52 underpass) was stolen on 10/1/2012. The other cameras (HFT01 and HFT02) photographed the perpetrator, but he remains unidentified. The increased sensitivity of the cameras required to detect small vertebrates exacerbated issues related to continual triggering of the motion detector by wind-driven plant motion in some exterior cameras. At some locations, 8GB or 16GB memory cards were completely filled with images in 2 to 4 days, halting any further image collection until the camera was checked. As a result, we switched some exterior cameras to time lapse mode only.

In January 2013, USGS staff installed the treatments in the HFT, SVR, CCN, and VCM underpasses. The cameras were reactivated on 3/19/2013 – 3/20/2013, and data collection continued until 9/25/2013. Prior to the start of data collection in 2013, a local avocado farmer constructed a dirt road through the VCS underpass to connect groves on either side of Valley Center Road. During, 2013, we detected increased off-highway vehicle use through this underpass. Also during the second field season, construction crews made improvements to Valley Center Road in the vicinity of study sites VCS, VCM, and VCN. When we removed the cameras in 2013, we left the security boxes in place in case there is an opportunity to conduct follow-up studies in the future. The same perpetrator that stole camera HFT04 in 2012 stole the replacement HFT04 camera again on 6/4/2013 and we did not replace it. After receiving additional funding, we added an exterior camera at VCN (Camera ID VCN04). However, although this camera continued to collect images, it appears that the images were corrupted and unusable.

Table 2: Summary of data collection effort by camera.

			Treatment		2012				2013			
Camera	**Site**	**placement**	**Site**	**Side**	**Start**	**End**	**Motion**	**Time**	**Start**	**End**	**Motion**	**Time**
CCN01	CCN	interior	Yes	Yes	6/8	10/3	1,180	35,628	3/20	9/25	1,961	54,442
CCN02	CCN	interior	Yes	No	6/8	10/3	2,007	39,646	3/20	9/25	2,101	54,445
CCN03	CCN	exterior	Yes	No	6/27	10/3	52,895	25,891	3/20	9/21	91,193	49,753
CCS01	CCS	interior	No	No	6/8	10/3	23,171	33,639	3/20	9/25	44,430	54,446
CCS02	CCS	interior	No	No	6/8	10/3	14,438	37,658	3/20	9/25	25,659	54,446
CCS03	CCS	exterior	No	No	6/8	6/22	27,831	843	*	*	0	0
HFT01	HFT	interior	Yes	Yes	6/19	10/3	2,367	30,454	3/19	9/25	5,849	54,693
HFT02	HFT	interior	Yes	No	6/19	10/3	4,889	30,456	3/19	9/25	5,928	50,370
HFT03	HFT	exterior	Yes	No	7/3	10/3	25,093	25,009	3/19	9/25	100,602	48,724
HFT04	HFT	ledge	Yes	Yes	7/3	9/26	2,855	24,354	‡	‡	0	0
SPP01	SPP	interior	No	No	5/15	10/3	5,702	37,661	3/19	9/25	5,462	54,693
SPP02	SPP	interior	No	No	5/16	10/3	1,278	37,654	3/19	9/25	3,599	54,690
SPP03	SPP	exterior	No	No	5/16	10/3	6,268	35,337	3/19	9/25	46,023	54,701
SVR01	SVR	interior	Yes	Yes	6/14	10/3	2,580	29,474	3/20	9/25	4,186	54,441
SVR02	SVR	interior	Yes	No	6/14	10/3	2,511	27,692	3/20	9/25	4,338	54,443
SVR03	SVR	exterior	Yes	No	7/3	10/3	61,856	18,543	3/20	9/25	184,168	49,912
VCM01	VCM	interior	Yes	Yes	5/25	10/3	2,739	41,709	3/19	9/25	3,879	54,679
VCM02	VCM	interior	Yes	No	5/25	10/3	7,092	37,691	3/19	9/25	7,757	54,685
VCM03	VCM	ledge	Yes	Yes	5/25	10/3	6,265	37,692	3/19	9/25	7,573	54,681
VCM04	VCM	exterior	Yes	No	8/15	10/3	1,017	14,056	3/19	9/25	15,079	52,676
VCN01	VCN	interior	No	No	5/31	10/3	4,554	31,924	3/19	9/25	4,564	54,683
VCN02	VCN	interior	No	No	5/31	10/3	5,335	35,938	3/19	9/25	4,720	54,681
VCN03	VCN	ledge	No	No	5/31	10/3	7,767	31,913	3/19	9/25	2,362	54,683
VCN04	VCN	exterior	No	No	-	-	0	0	-	-	0	0
VCS01	VCS	interior	No	No	5/24	10/3	18,392	46,094	3/19	9/25	18,373	54,689
VCS02	VCS	interior	No	No	5/24	10/3	9,391	48,111	3/19	9/25	11,233	54,683
VCS03	VCS	ledge	No	No	5/24	10/3	5,333	47,922	3/19	9/25	8,094	54,687
VCS04	VCS	exterior	No	No	8/15	10/3	32,471	9,260	3/19	9/25	29,381	48,386
Total Images By Trigger Mode and Year							337,277	852,249			638,514	1,337,412
Total Images By Year							1,189,526				1,975,926	
Total Images											3,165,452	

* camera was moved to position CCN03 in June 2012.

‡ camera was stolen just over two months into the 2013 field season and not replaced.

- camera was installed in 2013, however it only yielded corrupted images.

Table 3: Taxonomic groups used for some data analysis

Taxonomic Group	Species Included
Small Mammal	Pocket Mouse (*Chaetodipus* spp.), Kangaroo Rat (*Dipodomys* spp.), California Vole (*Microtus californicus*), Woodrat (*Neotoma* spp.), Grey Shrew (*Notiosorex crawfordi*), Brush Mouse (*Peromyscus boylii*), California Mouse (*Peromyscus californicus*), Deer Mouse (*Peromyscus maniculatus*), White footed Mouse (*Peromyscus* spp.), Domestic Rat (*Rattus* spp.), Unknown mouse (Unknown mouse), Small Mammal Species (Unknown spp.)
Lizard	Orange Throated Lizard (*Cnemidophorus hyperythrus*), Western Whiptail (*Cnemidophorus tigris*), Western Fence Lizard (*Sceloporus occidentalis*), Granite Spiny Lizard (*Sceloporus orcutti*), Sceloporus Species (*Sceloporus* spp.), Lizard Species (Unknown spp.), Side Blotched, Lizard (*Uta stansburia*)
Snake	Red Diamond Rattlesnake (*Crotalus ruber*), Western Rattlesnake (*Crotalus viridis*), Snake Species (Unknown spp.)
Bobcat	Bobcat (*Lynx rufus*)
Canine	Coyote (*Canis latrans*), Canine Species (Unknown spp.), Grey Fox (*Urocyon cinereoargenteus*)
Deer	Mule Deer (*Odocoileus hemionus*)
Roadrunner	Greater Roadrunner (*Geococcyx californianus*)
Medium Mammal	Opossum (*Didelphis marsupialis*), Striped Skunk (*Mephitis mephitis*), Raccoon (*Procyon lotor*), Spotted Skunk (*Spilogale putorius*)
Rabbit	Jackrabbit (*Lepus californicus*), Brush Rabbit (*Sylvilagus bachmani*), Sylvilagus Species (*Sylvilagus* spp.), Rabbit Species (Unknown spp.)
Squirrel	Western Gray Squirrel (*Sciurus griseus*), California Ground Squirrel (*Spermophilus beecheyi*), Squirrel Species (Unknown spp.), Chipmunk Species (Unknown spp.)

Statistical Analysis

For analysis, we grouped species into small mammal, lizard, snake, bobcat, canine, deer, roadrunner, medium mammal, rabbit, and squirrel taxonomic groups (Table 3).

We created bar plots that summarized the number of images per sample day by taxonomic groups, camera, and year. These figures provided a visual overview of the data and aided in interpretation of the modeling results.

An important objective of this study was to determine whether our treatment had a beneficial effect on small vertebrates. We based our analysis on usage for each taxonomic group. We interpret the number of images per day for each taxonomic group as detected usage. In motion detection mode, a camera can take one photograph per second. There are 86,400 seconds in a day; hence, the number of images per day in which a taxonomic group is captured divided by 86,400 seconds can be used to estimate the proportion of time a site is used. For time-lapse images, one photograph was taken every five minutes, thereby sampling 288 seconds per day. The number of time lapse images per day in which a taxonomic group is captured divided by 288 is an estimate of the proportion of time used based on time-lapse imagery. We analyzed data for up to 30 sample days per year; therefore, we have multiple image counts per taxonomic group per camera. However, we cannot assume perfect detection using the

cameras, so we must account and model for imperfect detection probability in the analysis. We applied an open-population generalized N-mixture model (Dail and Madsen 2010) to these data. We interpret initial usage as a Poisson random variable for the number of seconds used per day; that is, $N_{i,g,2012} \sim Pois(\lambda_{i,g})$, where the Camera ID is index by *i* and the taxonomic group is index by *g*. Although we could model usage using a binomial distribution (since our number of trials is the number of seconds sampled per day, a known quantity), we are theoretically justified in using the Poisson distribution because we have a large number of trials and a low probability of success. We modeled our observed count as the binomial random variable $C_{i,g,2012} \sim Binom(N_{i,g,2012}, p_{i,g})$, where detection probability $p_{i,g}$ may be dependent on taxonomic group *g* and may also depend on camera *i*. Because we used the same cameras placed in the same positions each year, we assumed that detection probability did not depend on year. The usage in 2013 depends on the usage that carried over (survived) from the previous year and new usage gained (arrived) in 2013. We modeled the carry over in usage as the binomial random variable $S_{i,g} \sim Binom(N_{i,g,2012}, \omega_j)$ and the new usage as the Poisson random variable $G_{i,g} \sim Pois(\gamma_j)$, and consider models where the rates ω_j and γ_j are constant or depended on the treatment applied to the underpasses. Hence, $N_{i,g,2013} = S_{i,g} + G_{i,g}$ and $C_{i,g,2013} \sim Binom(N_{i,g,2013}, p_{i,g})$. We used the *pcountOpen* function from the R package *unmarked* to estimate the model parameters and their standard errors. Recently, occupancy models have been used in a Before-After Control-Impact study design (Popescu et al. 2012). Here, we extend this concept using count-based models with uncertain detection.

We fit 54 alternative versions of these models to data for each taxonomic group. We considered constant and camera-dependent detection probability. Initial year animal usage ($\lambda_{i,2012}$) was modeled as a constant or as a function of study site. We considered two forms of the study site predictor. *Site 1* was a separate ID for each study site. *Site 2* grouped all of the Valley Center Road sites together and all of the Carmel County Road sites together based on their spatial proximity. The two parameters representing change in animal use between years, use carry-over (i.e. apparent survival, ω_j) and new usage (i.e. arrivals γ_j), were modeled as a constant, as a function of Treatment 1, or as a function of Treatment 2. We represented the treatment in two ways in the models. The binary covariate *Treatment 1* was true (1) if a camera was located in an underpass to which the treatment was applied and false (0) for control sites. The binary covariate *Treatment 2* was true (1) if a camera was located in an underpass

to which the treatment was applied *and* on the cover side of the underpass, and false (0) otherwise. Evidence to support the alternative models was assessed using AIC (Akaike's Information Criterion; Burnham and Anderson 2002). AIC, calculated as $AIC = -2\ell(\boldsymbol{\theta} \mid \mathbf{x}, m) + 2k$, where $\ell(\boldsymbol{\theta} \mid \mathbf{x}, m)$ is the log-likelihood function for model *m* with parameters $\boldsymbol{\theta}$ and data $\mathbf{x}$, is an information-theoretic measure of the relative distance between a postulated model and the true unknown model conditional on data (Burnham and Anderson 2002). Models with smaller AIC values are considered to have more empirical support than those with larger AIC values.

Using the parameter estimates and standard errors, we conducted a parametric bootstrap simulation for selected taxonomic groups to assess the change in usage in 2012 and 2013. In the simulations, we conducted 2000 trials for each combination of taxonomic group and camera. In each trial, we randomly selected each parameter from a normal distribution using the parameters estimated for the model with the lowest AIC, back-transformed the parameters (because they are fit on a log or logit scale), and randomly selected the state variables according to the models described above. We also computed $N_{i,2013} - N_{i,2013}$ to help assess the change in usage.

We also performed several descriptive analyses. We generated a table simply indicating which small mammal, lizard, and snake species were detected by exterior and interior cameras across four sites (CCN, HFT, SPP, and SVR). We augment this table by calculating the proportion of images at each camera that could be attributed to each species, and then compare these proportions for exterior and interior cameras. This descriptive analysis may suggest which species avoid underpasses. We also compared mean images per day containing small mammals captured by exterior, interior, and ledge cameras. Finally, we computed Pearson's correlation coefficient for mean images per day for lizards, snakes, rabbits, small mammals, and squirrels compared to bobcats, grey fox and coyote (canine), deer, and roadrunners. The last four taxa are often used as indicator or focal species for connectivity in southern California. We would like to determine how well usage by these species indicated usage by smaller vertebrates.

RESULTS

We documented the following species; Pocket Mouse (*Chaetodipus spp*.), Kangaroo Rat (*Dipodomys spp.),* California Vole (*Microtus californicus*), Woodrats (*Neotoma spp.),* Grey Shrew (*Notiosorex crawfordi*), Brush Mouse (*Peromyscus boylii*), California Mouse (*Peromyscus californicus*), Deer Mouse (*Peromyscus maniculatus*), White footed Mouse (*Peromyscus spp*.), Domestic Rat (*Rattus rattus),* Orange Throated Lizard (*Cnemidophorus hyperythrus*), Western Whiptail (*Cnemidophorus tigris*), Western Fence Lizard (*Sceloporus occidentalis*), Granite Spiny Lizard (*Sceloporus orcutti*), Side Blotched, Lizard (*Uta stansburia*), Red Diamond Rattlesnake (*Crotalus ruber*)- outside only, Western Rattlesnake (*Crotalus viridis*), Bobcat (*Lynx rufus*), Coyote (*Canis latrans*), Grey Fox (*Urocyon cinereoargenteus*), Mule Deer (*Odocoileus hemionus*), Greater Roadrunner (*Geococcyx californianus*), Opossum (*Didelphis marsupialis*), Striped Skunk (*Mephitis mephitis*), Raccoon (*Procyon lotor*), Spotted Skunk (*Spilogale putorius*), Jackrabbit (*Lepus californicus*), Rabbit species (*Sylvilagus spp*.), California Ground Squirrel (*Spermophilus beecheyi*), Chipmunk Species (*Neotamias merriami*).

Overview of Images per Sample Day by Taxonomic Groups

Here, we summarize the subsampled data for small vertebrates (small mammals - Figure 8, lizards - Figure 9, and snakes - Figure 10), species frequently used as indicators of connectivity in the region (bobcats - Figure 11, coyotes and foxes - Figure 12, deer - Figure 13, and roadrunners - Figure 14), and medium-sized mammals (spotted and striped skunks, opossums, and raccoons - Figure 15, rabbit species - Figure 16, and squirrels - Figure 17). Species in each taxonomic group are listed in Table 3.

Small mammal usage occurred in every site, but more small mammal image captures occurred in the Valley Center Road sites than anywhere else and were rarely detected at Scripps Poway Parkway (Figure 8). However, there was a decline in the number of small mammal images captured at many sites in 2013 compared to 2012. Lizard species were also captured in imagery more often in the Valley Center Road sites than elsewhere, were undetected in one of the years at CCN02, SVR01, and HFT01 and were not detected at CCN01, CCS01, CCS02, SVR01, and HFT02 (Figure 9). Snake species usage were undetected at most sites, with the exceptions of HFT and VCN (Figure 10). Bobcat usage was detected at every camera except for HFT01, HFT02, and VCM01 (Figure 11). At the VCM site, bobcats were detected more often on the side of the underpass with the concrete drainage ditch in both the pre-treatment and post-treatment years. Grey fox and coyote (canine) usage was common in most

study sites, with the exception of HFT (Figure 12). They were detected by camera HFT02 in 2012, but not in 2013. Like bobcats, they were not detected either year by camera VCM01, but were detected on the side of the underpass with the drainage ditch and camera VCM02. Deer were also common, but were not detected by cameras CCN01 and VCM01 (Figure 13). Again, like bobcats and canine species, they were detected more often on the side of the underpass with the drainage ditch. At HFT, they were only detected on the cover side of the underpass by camera HFT01 during the pre-treatment year, but the number of detections were small and they were detected more often on the open side of the underpass by camera HFT02 during both years. Roadrunners were uncommonly detected at HFT02 (both years),VCN01 (both years), and VCN02 (2012 only; Figure 14). However, they were most often detected by camera VCS01 and less frequently by CVS02 during both years. Medium-sized mammal usage was detected at all sites, but most often at the Valley Center Road and Scripps Poway Parkway sites (Figure 11). At HFT, they were only detected in 2013 on one side of the underpass by camera HFT02. Rabbit species usage was detected most often at the VCN and HFT sites, less commonly at VCM, VCS, CCN, and SVR sites, and not at all at the CCS site (which is the site most heavily used by humans; Figure 16). At SVR, they were only detected post-treatment on the cover side of the underpass. Squirrel (ground squirrels) usage was detected very often at VCS and less commonly at the other sites, except for HFT where they were not detected (Figure 17).

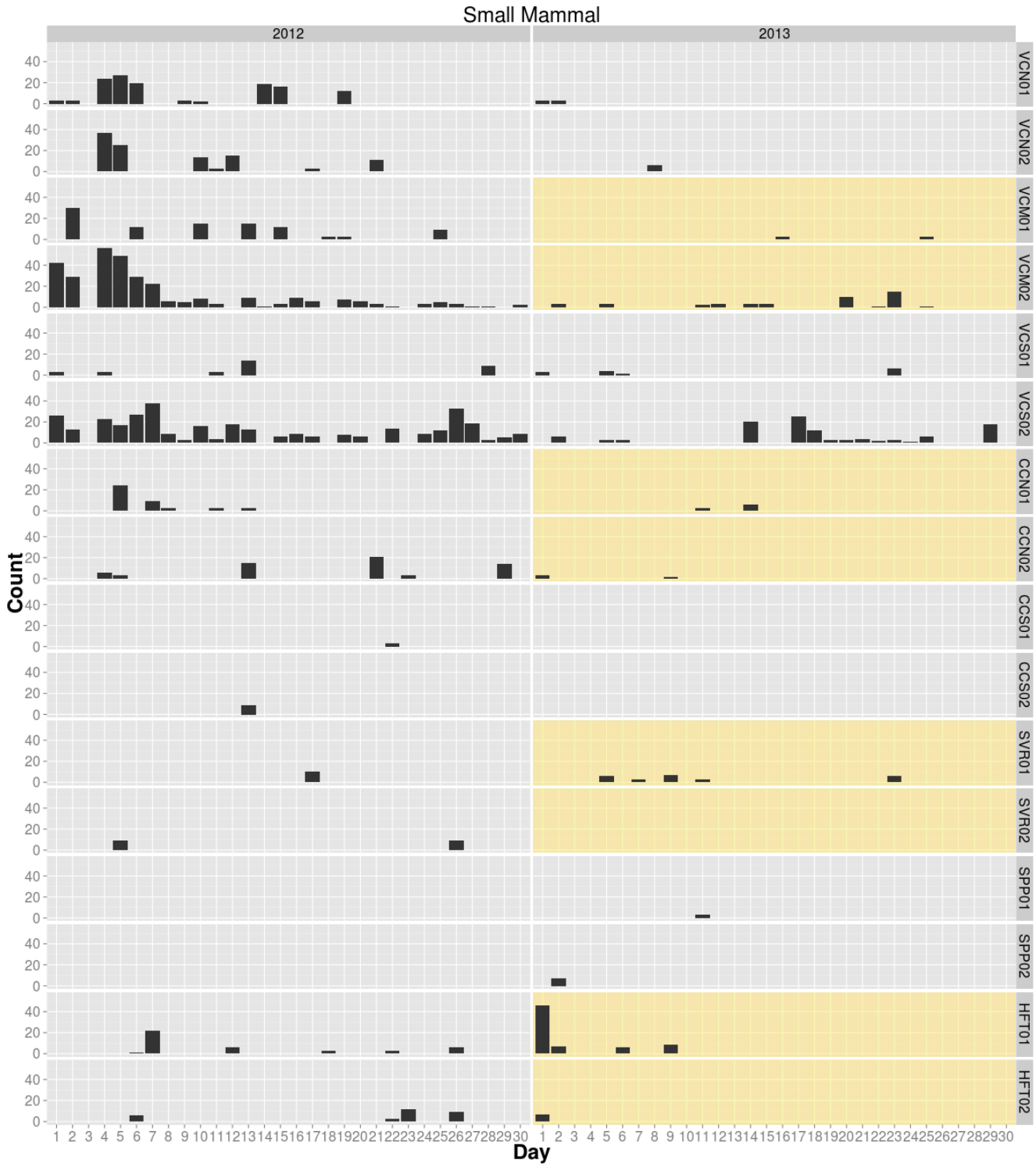

Figure 8: Numbers of images with small mammals per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

Figure 9: Numbers of images with lizard species per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

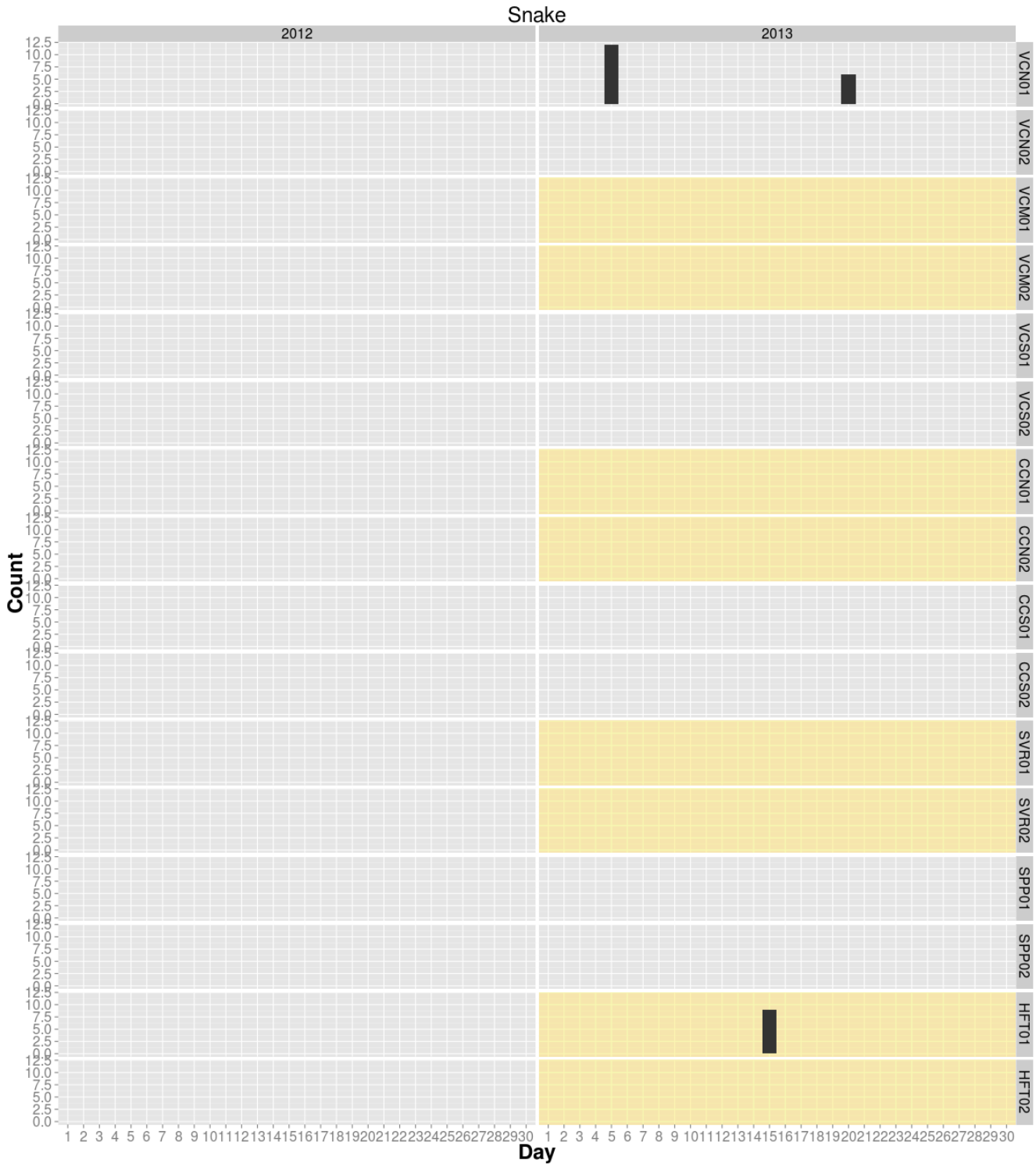

Figure 10: Numbers of images with snake species per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

Figure 11: Numbers of images with bobcats per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

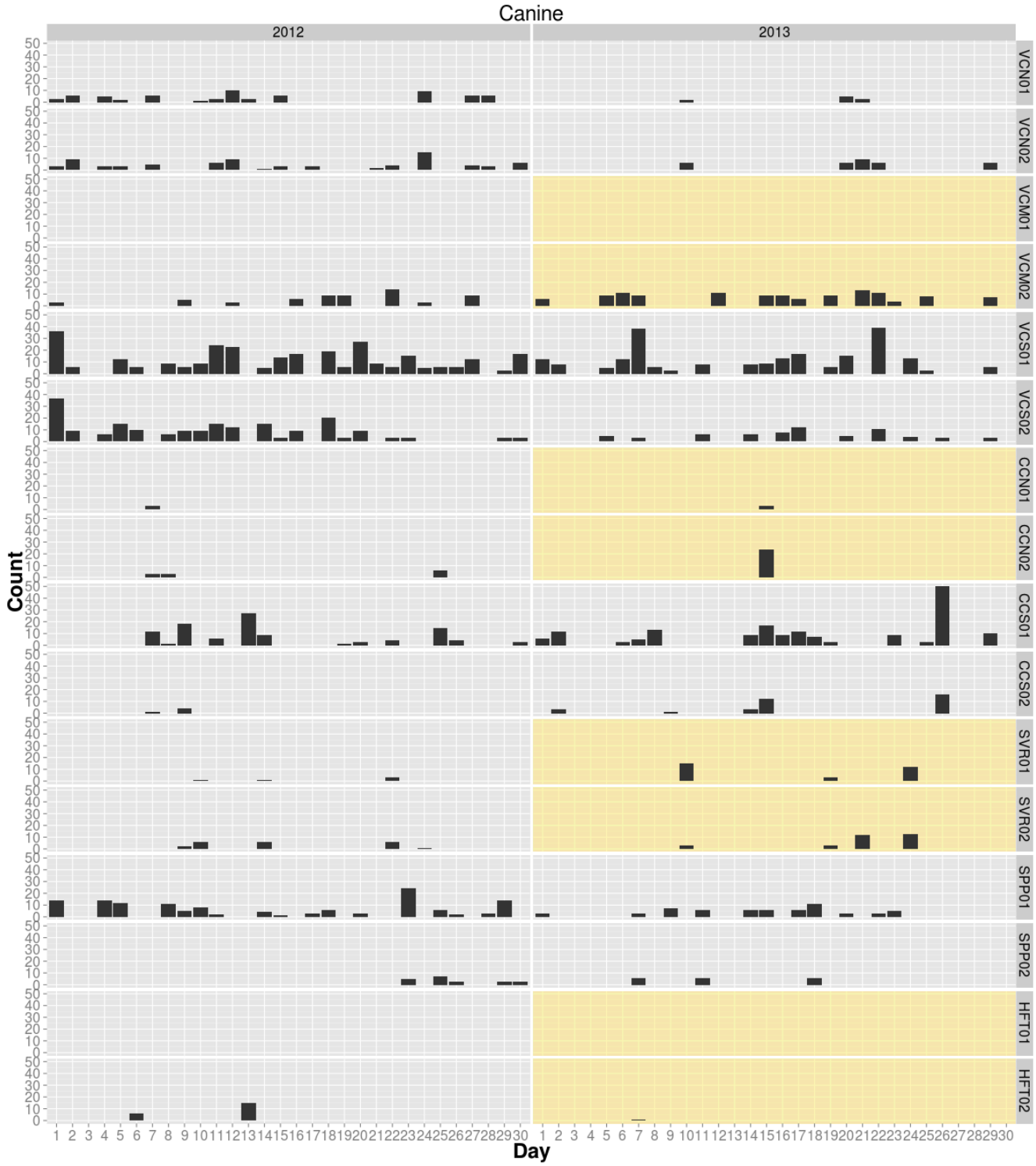

Figure 12: Numbers of images with coyotes or foxes per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

Figure 13: Numbers of images with deer per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

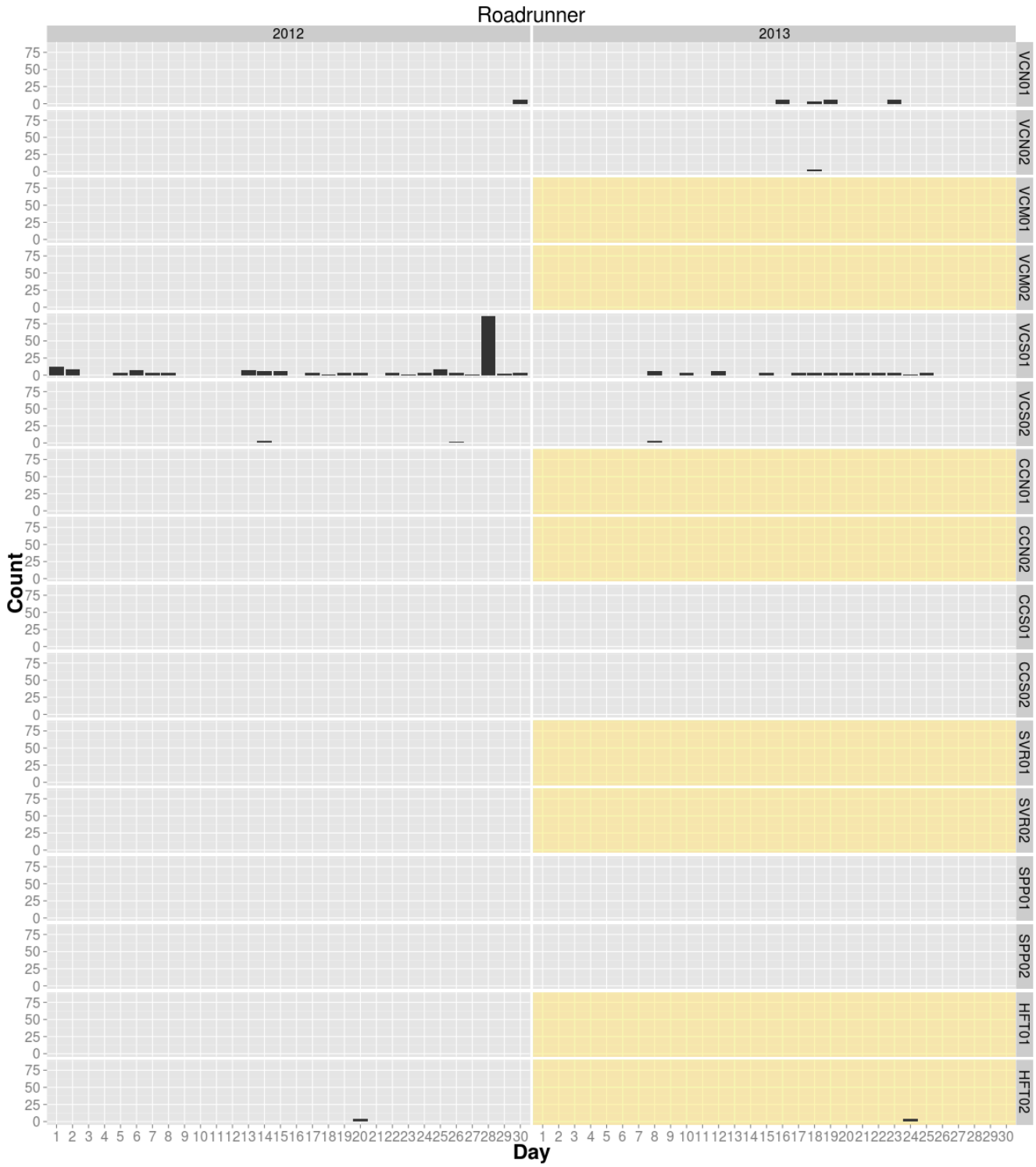

Figure 14: Numbers of images with roadrunners per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

Figure 15: Numbers of images with medium-sized mammals per sample day. Stripped and spotted skunks, opossums, and raccoons. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

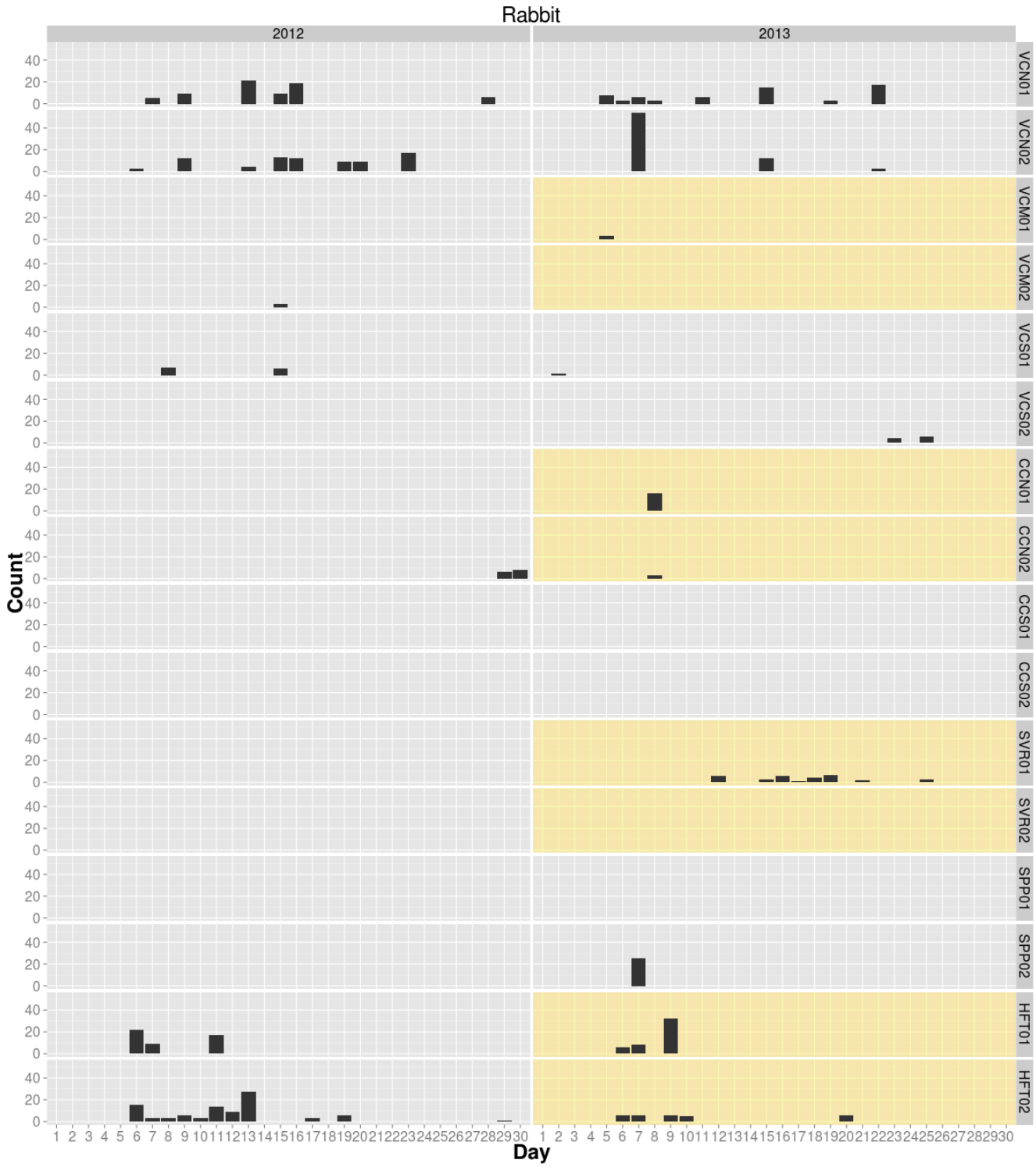

Figure 16: Numbers of images with rabbit species per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

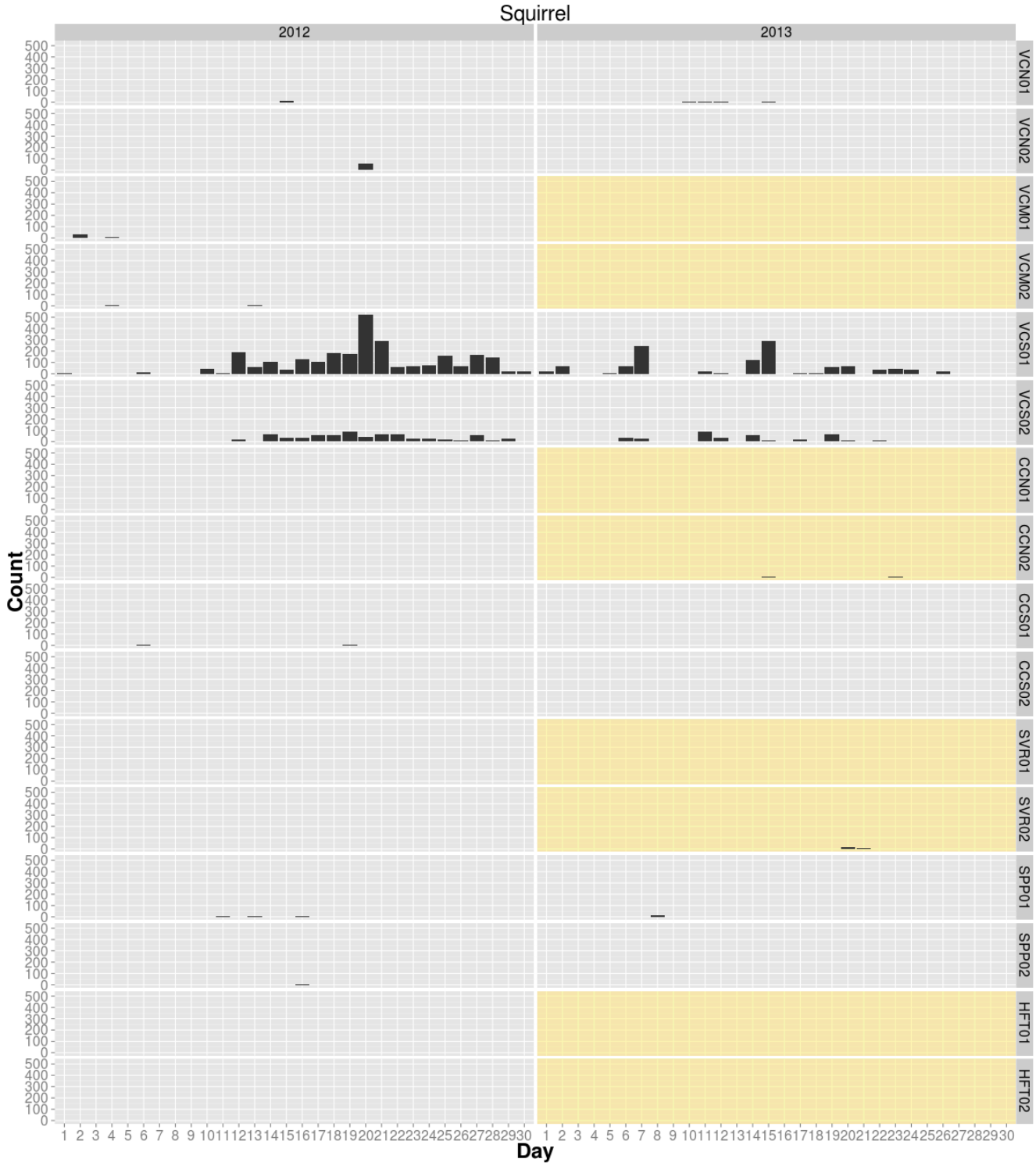

Figure 17: Numbers of images with squirrels or chipmunks per sample day. Separate bar plots are shown for each camera and year. Plots shaded in yellow indicate underpasses where the treatment was applied. The sample day is given on the x-axis and the number of images per day that captured species in this group is given on the y-axis.

Underpass Enhancement Experiment

We present the models with the greatest empirical support ($\Delta AIC \leq 5$) for each taxonomic group in Table 4. We were unable to fit a model to the squirrel data due to technical (numerical) issues associated with the high counts on some sample days. Every model, except for the 5th ranked bobcat model, used Site 1 as the covariate for mean initial usage ($\lambda_{i,2012}$). All models also included a constant detection probability for each taxonomic group across all cameras. Most of the models, including the top-ranked model for all species except snakes, included one of the treatment covariates in the model for the change in usage parameters from 2012 to 2013 (γ, ω). Model fitting was generally not very successful for snakes due to the low number of snake species detections. We list the parameter estimates for the model with the lowest AIC for each taxonomic group in Table 5. For some sites and species, the standard errors for $\lambda_{i,2012}$ were very large. However, these estimates corresponded to sites where species from the taxonomic group were rarely or never detected in the subsampled images.

Using the parameters in Table 5, we simulated distributions of usage each year for small mammals, lizards, and rabbit species (Figure 18, Table 6). We omitted the aforementioned sites where a given taxonomic group did not occur or occurred too rarely. Simulations were not conducted for snakes because they were rarely detected and the data was insufficient to obtain standard errors for the parameter estimates (Table 5).

Table 4: Summary of models with ΔAIC ≤ 5 for each taxon (except squirrels). Under model structure. Tx1 indicates Treatment 1 (treatment underpass) and Tx 2 indicates Treatment 2 (cover side of treatment underpasses). $-\ell(\boldsymbol{\theta} \mid \mathbf{x})$ is the negative log-likelihood for the model, k is the number of model parameters, AIC is Akaike's Information Criterion for the model, ΔAIC is the model AIC minus the lowest AIC, AICwt is ½ the -ΔAIC passed through a softmax function for all models considered, and rank is the relative rank of the model.

Taxon	Model Structure	$-\ell(\boldsymbol{\theta} \mid \mathbf{x})$	k	AIC	ΔAIC	AICwt	Rank
Bobcat	λ(Site 1)γ(Tx 1)ω(Tx 2)p(.)	1272.349	13	2570.697	0.000	0.385	1
	λ (Site 1)γ(Tx 2)ω(Tx 1)p(.)	1272.997	13	2571.994	1.297	0.201	2
	λ (Site 2)γ(Tx 2)ω(Tx 1)p(.)	1276.695	10	2573.390	2.693	0.100	3
	λ (Site 1)γ(Tx 2)ω(.)p(.)	1274.697	12	2573.394	2.697	0.100	4
	λ (Site 1)γ(Tx 2)ω(Tx 2)p(.)	1274.007	13	2574.014	3.317	0.073	5
	λ (Site 2)γ(Tx 2)ω(.)p(.)	1278.071	9	2574.142	3.445	0.069	6
	λ (Site 2)γ(Tx 2)ω(Tx 2)p(.)	1277.465	10	2574.930	4.233	0.046	7
Canine	λ (Site 1)γ(Tx 2)ω(Tx 2)p(.)	2795.599	13	5617.198	0.000	0.500	1
	λ (Site 1)γ(Tx 2)ω(.)p(.)	2796.600	12	5617.200	0.001	0.500	2
Deer	λ (Site 1)γ(Tx 2)ω(Tx 2)p(.)	2554.359	13	5134.719	0.000	0.790	1
	λ (Site 1)γ(Tx 2)ω(.)p(.)	2557.692	12	5139.384	4.665	0.077	2
	λ (Site 1)γ(Tx 2)ω(Tx 1)p(.)	2556.842	13	5139.684	4.965	0.066	3
Lizard	λ (Site 1)γ(Tx 2)ω(Tx 2)p(.)	1274.066	13	2574.131	0.000	0.967	1
Medium Mammal	λ (Site 1)γ(Tx 2)ω(Tx 1)p(.)	1811.359	13	3648.718	0.000	0.822	1
	λ (Site 1)γ(.)ω(Tx 1)p(.)	1814.129	12	3652.258	3.541	0.140	2
Rabbit	λ (Site 1)γ(Tx 1)ω(Tx 1)p(.)	1564.665	13	3155.329	0.000	0.709	1
	λ (Site 1)γ(.)ω(Tx 2)p(.)	1567.165	12	3158.330	3.001	0.158	2
	λ (Site 1)γ(.)ω(.)p(.)	1568.349	11	3158.697	3.368	0.132	3
Roadrunner	λ (Site 1)γ(Tx 1)ω(Tx 1)p(.)	606.530	13	1239.059	0.000	0.553	1
	λ (Site 1)γ(Tx 1)ω(.)p(.)	608.969	12	1241.938	2.879	0.131	2
	λ (Site 1)γ(.)ω(Tx 1)p(.)	609.519	12	1243.038	3.979	0.076	3
	λ (Site 1)γ(Tx 1)ω(Tx 2)p(.)	608.721	13	1243.443	4.384	0.062	4
	λ (Site 1)γ(Tx 2)ω(Tx 1)p(.)	608.882	13	1243.764	4.705	0.053	5
	λ (Site 1)γ(Tx 2)ω(.)p(.)	609.952	12	1243.904	4.845	0.049	6
Small Mammal	λ (Site 1)γ(Tx 2)ω(Tx 2)p(.)	2946.148	13	5918.296	0.000	0.943	1
Snake	λ (Site 1)γ(.)ω(.)p(.)	122.998	11	267.996	0.000	0.337	1
	λ (Site 1)γ(.)ω(Tx 2)p(.)	122.998	12	269.996	2.000	0.124	2
	λ (Site 1)γ(.)ω(Tx 1)p(.)	122.998	12	269.996	2.000	0.124	3
	λ (Site 1)γ(Tx 1) ω (.)p(.)	122.998	12	269.996	2.000	0.124	4
	λ (Site 1)γ(Tx 2) ω (.)p(.)	123.082	12	270.163	2.167	0.114	5
	λ (Site 1)γ(Tx 1) ω (Tx 2)p(.)	122.998	13	271.996	4.000	0.046	6
	λ (Site 1)γ(Tx 1) ω (Tx 1)p(.)	122.998	13	271.996	4.000	0.046	7
	λ (Site 1)γ(Tx 2) ω (Tx 2)p(.)	123.081	13	272.162	4.166	0.042	8
	λ (Site 1)γ(Tx 2) ω (Tx 1)p(.)	123.082	13	272.165	4.169	0.042	9

Table 5: Untransformed parameter estimates and standard errors for the lowest-AIC model for each taxonomic group. A dash ("-") indicates that the parameter was not relevant to the model and an asterisk ("*") indicates that a standard error could not be obtained due to lack of data. The logit function is log(x/(1-x)) and is used as a link function for parameters from 0 to 1 such as probabilities, while the log function is used as a link function for non-negative parameters.

			Bobcat	**Canine**	**Deer**	**Lizard**	**Medium Mammal**	**Rabbit**	**Road-runner**	**Small Mammal**	**Snake**
		$\hat{\lambda}$	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1
		$\hat{\omega}$	Tx 2	Tx 2	Tx 2	Tx 2	Tx 1	Tx 1	Tx 1	Tx 2	Const
		$\hat{\gamma}$	Tx 1	Tx 2	Tx 2	Tx 2	Tx 2	Tx 1	Tx 1	Tx 2	Const
		p	Const	Const	Const	Const	Const	Const	Const	Const	Const
	Cov										
$\log(\hat{\lambda})$	CCN	est	3.123	1.615	2.686	-7.853	2.792	2.078	-10.814	3.405	-43.214
		se	0.194	0.332	0.220	44.385	0.238	0.334	161.141	0.143	*
	CCS	est	2.655	3.208	3.554	-8.020	1.483	-12.119	-10.440	1.858	-43.214
		se	0.244	0.162	0.136	46.935	0.410	329.536	142.160	0.289	*
	HFT	est	-8.969	2.065	3.261	-7.093	-5.898	4.064	0.828	3.130	3.280
		se	71.090	0.258	0.194	37.358	18.601	0.096	0.496	0.165	*
	SPP	est	2.433	3.341	-7.088	1.799	4.148	-9.215	-10.477	-10.650	-44.732
		se	0.276	0.151	45.753	0.390	0.128	105.453	143.400	151.349	*
	SVR	est	4.066	2.066	3.830	1.776	0.933	-10.897	-10.818	2.439	-42.450
		se	0.096	0.306	0.140	0.334	0.717	212.934	161.799	0.223	*
	VCM	est	2.656	2.433	3.392	4.050	4.068	0.680	-10.805	3.991	-44.732
		se	0.239	0.233	0.173	0.097	0.113	0.578	160.081	0.102	*
	VCN	est	1.259	3.276	4.073	3.552	3.730	4.066	1.478	3.982	3.763
		se	0.447	0.157	0.094	0.142	0.151	0.096	0.416	0.108	*
	VCS	est	1.781	4.087	1.921	3.042	4.368	1.730	3.941	3.704	-44.732
		se	0.363	0.092	0.333	0.232	0.081	0.362	0.103	0.115	*
$\text{logit}(\hat{\omega})$	Inter	est	0.543	-0.624	0.004	-0.629	0.801	1.562	-0.583	-1.340	65.962
		se	0.329	0.298	0.281	0.392	0.358	0.489	0.323	0.212	*
	Tx 1	est	-	-	-	-	-1.462	-1.528	13.109	-	-
		se	-	-	-	-	0.497	0.615	399.011	-	-
	Tx 2	est	-1.422	3.320	-1.314	8.758	-	-	-	-8.392	-
		se	0.469	5.770	0.505	16.042	-	-	-	37.669	-
$\log(\hat{\gamma})$	Inter	est	2.240	2.815	1.919	2.177	2.328	2.121	0.310	1.036	-12.782
		se	0.180	0.127	0.290	0.184	0.230	0.186	0.498	0.289	*
	Tx 1	est	-6.893	-	-	-	-	0.116	-14.046	-	-
		se	10.668	-	-	-	-	0.265	401.748	-	-
	Tx 2	est	-	-1.755	-9.298	-1.501	-1.205	-	-	1.904	-
		se	-	0.472	31.403	0.593	0.661	-	-	0.313	-
$\text{logit}(\hat{p})$	Inter	est	-3.100	-2.236	-3.223	-3.351	-3.637	-3.228	-2.836	-2.318	-5.654
		se	0.071	0.034	0.060	0.067	0.055	0.051	0.079	0.035	*

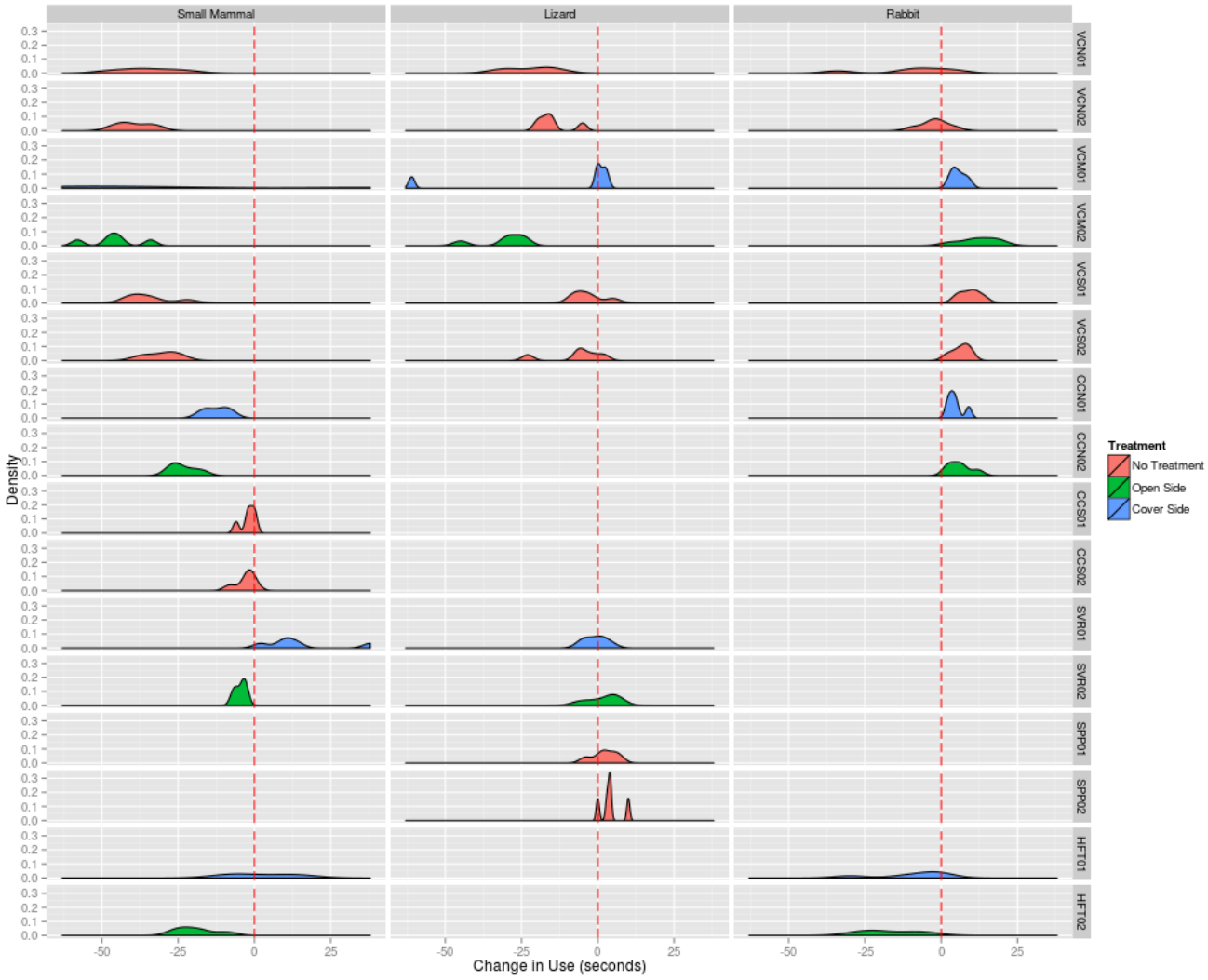

Figure 18: Results from a parametric bootstrap of change in usage based on the models with the lowest AIC for small mammal, lizard, and rabbit species at each camera. The change in usage from 2012 to 2013 is shown on the x-axis and the density of the simulated values is shown on the y-axis. The red, vertical, dashed line at 0 indicates no change in usage. Subplots with no density correspond to sites where the initial usage in 2012 had a high standard error due to little or no detected usage at the site.

Table 6: Summary of state variables by camera generated by parametric bootstrap using the lowest-AIC models for small mammals, lizards, and rabbits. The mean is given with the standard deviation in parenthesis. Use represents the actual usage in each year ($N_{i,2012}$ and $N_{i,2013}$), change in use is ($N_{i,2013} - N_{i,2012}$) by camera, and counts ($C_{i,2012}$ and $C_{i,2013}$) are drawn from usage based on detection probability.

Taxon	Camera ID	Treatment	Use (2012)	Use (2013)	Change In Use	Count (2012)	Count (2013)
Small Mammal	CCN01	Cover Side	26.2 (5.63)	13.8 (4.438)	-12.4 (4.037)	2.6 (1.673)	2.2 (1.304)
	CCN02	Open Side	31.6 (3.912)	8.2 (0.837)	-23.4 (4.393)	1.6 (0.894)	0.6 (0.548)
	CCS01	No Treatment	6.6 (2.51)	4.6 (1.817)	-2 (2.449)	1 (1)	0.4 (0.548)
	CCS02	No Treatment	7.2 (2.95)	4.4 (1.14)	-2.8 (3.033)	0.4 (0.894)	0 (0)
	HFT01	Cover Side	25.6 (3.507)	28 (10.198)	2.4 (10.831)	3.4 (1.14)	5.4 (2.408)
	HFT02	Open Side	27 (8.155)	7.8 (3.033)	-19.2 (6.686)	2.6 (1.342)	1 (0.707)
	SVR01	Cover Side	10.2 (4.712)	25 (10.654)	14.8 (13.7)	0.6 (0.894)	2.6 (3.13)
	SVR02	Open Side	8.4 (3.435)	3.8 (2.683)	-4.6 (1.817)	1.4 (1.14)	0 (0)
	VCM01	Cover Side	65 (11.79)	34 (30.733)	-31 (39.579)	7 (1.871)	2.6 (2.302)
	VCM02	Open Side	60.2 (5.933)	14.2 (3.493)	-46 (8.602)	4 (1.871)	0.8 (0.447)
	VCN01	No Treatment	50 (10.677)	15 (8.396)	-35 (10)	6.2 (1.924)	2 (1.414)
	VCN02	No Treatment	53 (7.176)	13.6 (6.066)	-39.4 (5.639)	3.6 (2.966)	1.2 (1.304)
	VCS01	No Treatment	46 (7.969)	11.6 (4.722)	-34.4 (7.635)	4.6 (2.191)	1.8 (1.483)
	VCS02	No Treatment	41.4 (4.506)	11 (2.55)	-30.4 (5.595)	4.2 (0.837)	1.4 (1.342)
Lizard	SPP01	No Treatment	7 (6.364)	9.2 (2.588)	2.2 (4.207)	0.2 (0.447)	0.6 (0.894)
	SPP02	No Treatment	4.4 (3.647)	8.6 (1.517)	4.2 (3.633)	0 (0)	0.2 (0.447)
	SVR01	Cover Side	8.8 (4.817)	8 (7)	-0.8 (3.701)	0.2 (0.447)	0.4 (0.548)
	SVR02	Open Side	8.6 (4.219)	10.4 (3.362)	1.8 (5.263)	0.6 (0.548)	0.4 (0.548)
	VCM01	Cover Side	54.6 (6.804)	43.4 (22.81)	-11.2 (27.869)	1.8 (1.924)	2 (1.414)
	VCM02	Open Side	59.6 (6.731)	29 (7.746)	-30.6 (8.444)	2.2 (1.643)	1.2 (0.837)
	VCN01	No Treatment	43.8 (6.76)	21.6 (8.562)	-22.2 (7.855)	0.6 (0.894)	0.2 (0.447)
	VCN02	No Treatment	35.8 (5.167)	21 (5.477)	-14.8 (5.805)	0.8 (0.837)	0.4 (0.548)
	VCS01	No Treatment	21.2 (6.907)	18 (4.472)	-3.2 (5.167)	0.6 (0.894)	0.4 (0.548)
	VCS02	No Treatment	21.8 (9.391)	14.8 (4.97)	-7 (9.539)	1 (1.732)	0.4 (0.548)
Rabbit	CCN01	Cover Side	9.4 (3.507)	14 (5.339)	4.6 (2.702)	0.4 (0.548)	0.2 (0.447)
	CCN02	Open Side	6.2 (1.483)	12.2 (4.764)	6 (3.937)	0 (0)	0.4 (0.548)
	HFT01	Cover Side	59 (9.301)	49.4 (11.546)	-9.6 (12.341)	2.6 (1.949)	1.6 (1.517)
	HFT02	Open Side	55.4 (11.524)	38.6 (8.503)	-16.8 (9.311)	4.6 (1.14)	1 (1)
	VCM01	Cover Side	2.8 (2.28)	8.4 (2.881)	5.6 (2.408)	0.2 (0.447)	0 (0)
	VCM02	Open Side	1.8 (0.837)	14 (6.708)	12.2 (6.301)	0 (0)	0.4 (0.894)
	VCN01	No Treatment	57.2 (11.841)	47.6 (7.829)	-9.6 (14.926)	1.4 (1.517)	2.2 (0.837)
	VCN02	No Treatment	59.8 (7.396)	57.6 (9.737)	-2.2 (4.604)	3.4 (1.949)	2.8 (2.168)
	VCS01	No Treatment	5.4 (2.881)	14.8 (3.114)	9.4 (3.507)	0.2 (0.447)	0.2 (0.447)
	VCS02	No Treatment	7.2 (3.033)	13.6 (3.286)	6.4 (2.966)	0.4 (0.548)	0.6 (0.548)

Small Vertebrate Species Detected in Underpasses

Here, we provide a table of small vertebrate species detected by interior ground level cameras and exterior cameras across all sites.

Table 7: Species detected by interior and exterior cameras with motion detection mode.

		CCN		HFT		SPP		SVR	
Code	**Species**	**Ext**	**Int**	**Ext**	**Int**	**Ext**	**Int**	**Ext**	**Int**
CHSP	Chaetodipus spp.	No	No	**Yes**	No	No	No	**Yes**	No
CNHY	Cnemidophorus hyperythrus	No	No	No	No	**Yes**	No	No	No
CRVI	Crotalus viridis	No	No	No	**Yes**	No	No	No	No
JACK	Lepus californicus	No	No	**Yes**	**Yes**	**Yes**	No	No	No
MICA	Microtus californicus	**Yes**	No	No	No	No	No	No	No
NESP	Neotoma spp.	No	No	**Yes**	**Yes**	No	No	No	No
PECA	Peromyscus californicus	No	No	No	No	No	No	No	No
PEMA	Peromyscus maniculatus	No	No	No	No	No	No	No	No
PESP	Peromyscus spp.	No	**Yes**	**Yes**	No	No	**Yes**	No	**Yes**
RASP	Rattus spp.	No	No	No	No	No	No	No	No
SCOC	Sceloporus occidentalis	No	**Yes**	No	**Yes**	**Yes**	**Yes**	No	No
SCOR	Sceloporus orcutti	No	No	No	No	No	**Yes**	No	No
SPBE	Spermophilus beecheyi	No	**Yes**	No	No	**Yes**	**Yes**	No	**Yes**
SYAU	Sylvilagus spp.	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
UTST	Uta stansburiana	No	No	No	No	No	**Yes**	No	No

Interior and Exterior Species Detections

The frequency of detections for each species or species group documented with the interior cameras in comparison to the exterior cameras was used to get an initial idea of species or group specific avoidance or preferential use of underpasses (without modeling detection probability; Table 7: Species detected by interior and exterior cameras with motion detection mode.). These 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. Interpretation of relative use patterns may change with future modeling that includes probability of detection

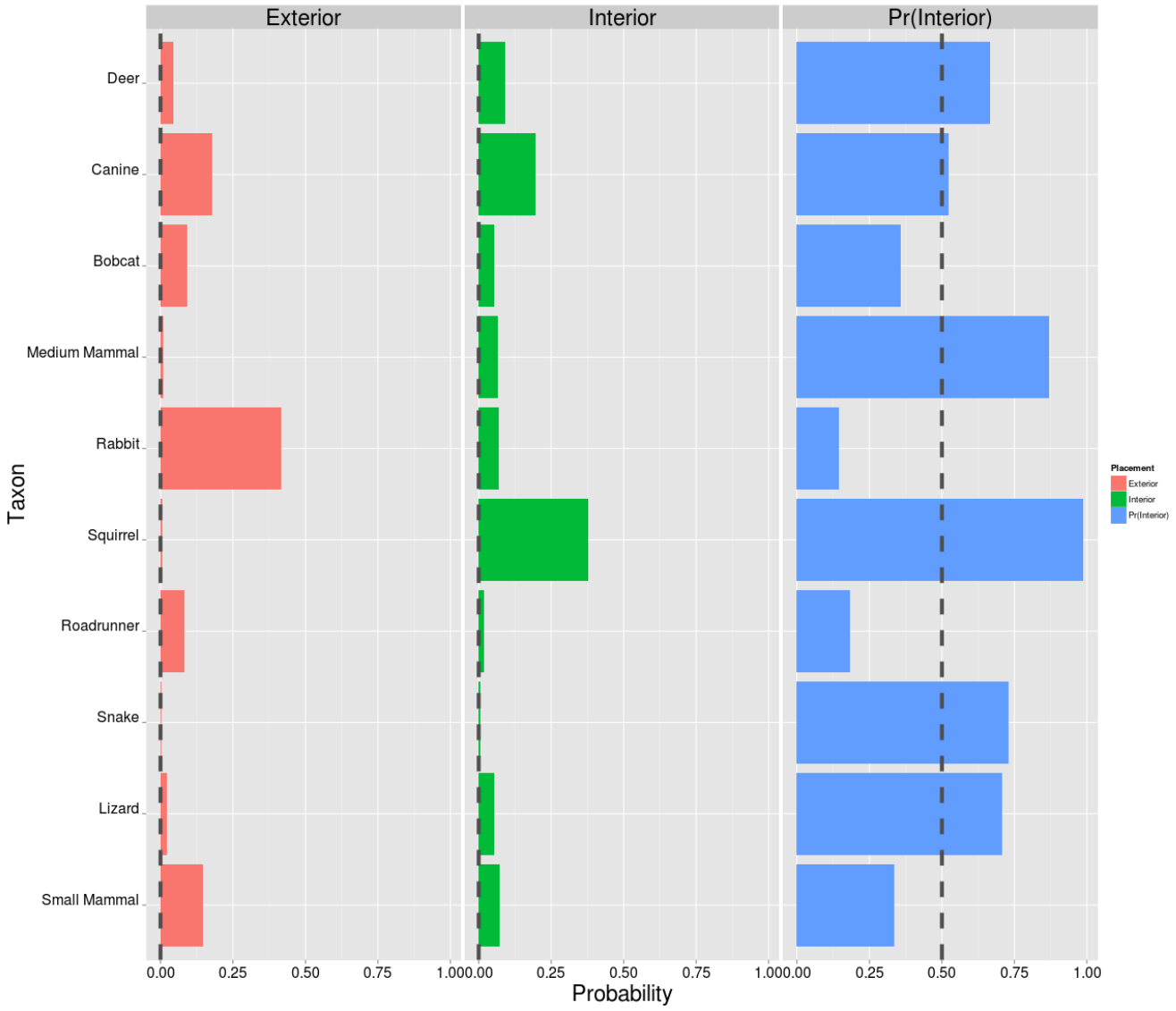

Figure 19: Relative Use of Underpasses by species or group. The first two columns represent the probability an animal species or group was observed within the underpass and outside of the underpass. The last column represents the relative probability an animal or group is within the underpass. Values less than 0.5 indicate avoidance of underpass while probabilities greater than 0.5 indicate preferential use of underpass (but see discussion).

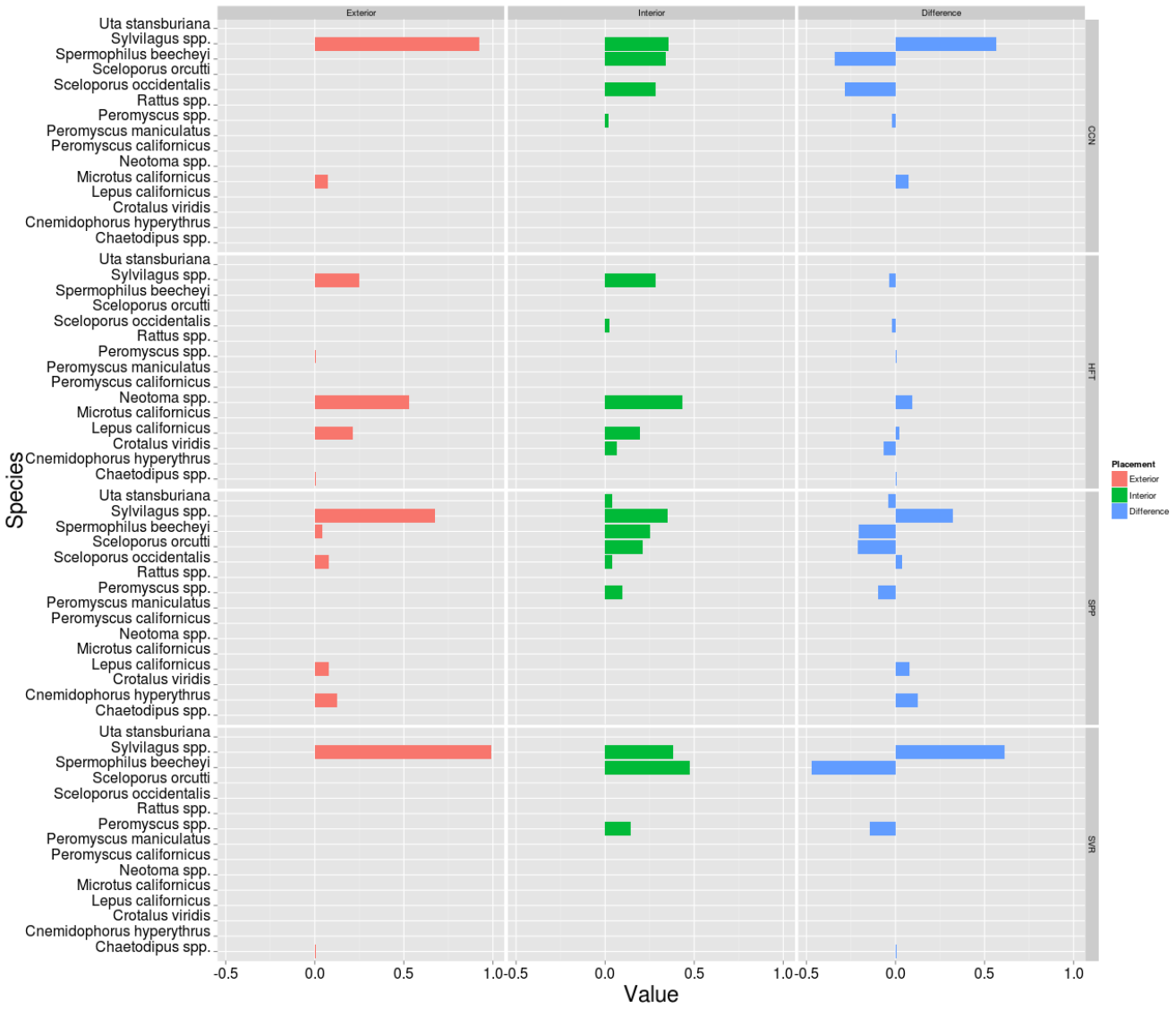

Figure 20: Comparison of normalized proportion of images by species. Here we focus on lizard, snake, small mammal, rabbit, and squirrel species at sites where motion detection images were available for both internal and external cameras.

Ledge versus Interior Camera Species Detections

We compared the mean number of images per day each year for small mammals at sites that had exterior, ground level interior, and ledge cameras. In most cases, the ledge cameras had a higher mean number of images per day compared to other camera placements. This may be due to greater use of ledges by small mammals, higher detection probabilities of ledge cameras due to the constriction of movement to an area in front of the camera, or likely both.

Table 8: Summary of small mammal images captured by exterior, interior, and ledge cameras at sites with underpasses that had ledges. The mean number of images per day with small mammals is given with the number of days sampled in parentheses.

	Mean Images per Day - 2012			Mean Images per Day - 2013		
Site	**Exterior**	**Interior**	**Ledge**	**Exterior**	**Interior**	**Ledge**
VCN	-	4.086 (n = 58)	55.069 (n = 29)	-	0.214 (n = 56)	0.000 (n = 28)
VCM	1.091 (n = 11)	7.034 (n = 58)	28.862 (n = 29)	0.000 (n = 28)	0.893 (n = 56)	11.607 (n = 28)
VCS	0.000 (n = 11)	6.517 (n = 58)	24.931 (n = 29)	0.000 (n = 28)	2.196 (n = 56)	2.143 (n = 28)
HFT	7.636 (n = 22)	1.420 (n = 50)	17.227 (n = 22)	4.143 (n = 28)	1.339 (n = 56)	-

Small Vertebrate versus Large Vertebrate

Here we compare the mean number of images per day for several small vertebrate taxa to larger species commonly used as indicators of landscape connectivity in San Diego County. Pearson's correlation coefficients and associated p-values are given in Table 9. The data used to calculate these coefficients are illustrated in Figure 21. These descriptive results do not suggest that bobcats, coyotes, foxes, deer, or roadrunners are strong indicators of use by the small vertebrate taxonomic groups. In cases where small p-values were obtained, the result depended on a small number of extreme events.

Table 9: Pearson's correlation coefficients (and p-values) for mean images per day for large vertebrates compared to small vertebrates. (7 exterior 2012, 6 exterior 2013, 8 interior (mean across both cameras) in both 2012 and 2013).

	Lizard	**Snake**	**Rabbit**	**Small Mammal**	**Squirrel**
Bobcat	-0.0985 (p=0.611)	-0.1343 (p=0.487)	-0.1862 (p=0.334)	-0.2333 (p=0.223)	-0.1041 (p=0.591)
Canine	**0.2954 (p=0.120)**	-0.109 (p=0.573)	-0.1573 (p=0.415)	**0.3113 (p=0.100)**	**0.832 (p=2.230e-08)**
Deer	0.2381 (p=0.213)	0.0991 (p=0.609)	-0.0811 (p=0.676)	0.1139 (p=0.556)	-0.1567 (p=0.417)
Roadrunner	0.0292 (p=0.880)	-0.0551 (p=0.777)	**0.6376 (p=0.0002)**	**0.5507 (p=0.002)**	-0.0237 (p=0.903)

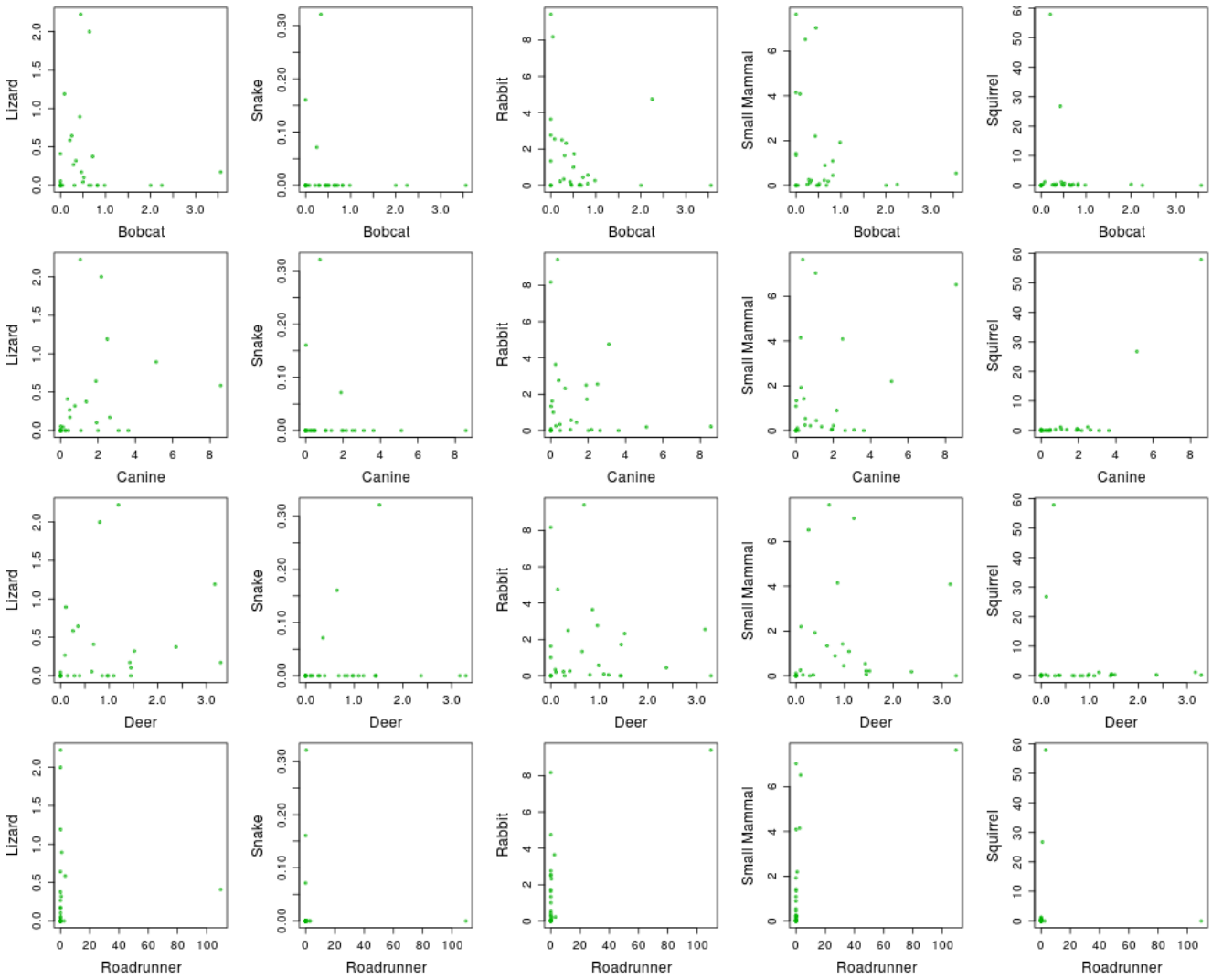

Figure 21: Scatterplots showing mean pictures per day for species often used as indicators of connectivity versus small vertebrates.

DISCUSSION

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.

There is evidence to support the short-term effectiveness of the added structure treatments on small vertebrate use. First, nearly all of the top models include treatment as a positive predictor of change in use from 2012 to 2013 (i.e. carry over (survival) and addition (arrival) in 2013). The models suggested that these rates changed on the specific side the treatment was applied rather than the entire underpass. Even though there was a decline in small mammal use in many underpasses from 2012 to 2013 (see impacts described below), the decrease was often less in the cover side of the treatment underpasses for small mammals and lizards. The parameter estimates of the models with the lowest AIC suggest that some larger vertebrates (particularly bobcats and deer) might avoid the treatment side of the underpasses. It is important to understand that it can take several years of acclimation for animals to change their movement behavior in response to changes in their environment. This has been commonly shown for specific species responses to the construction of wildlife underpasses.

There were larger numbers of images per day of small mammals on ledges, where they exist, compared to ground level interior and exterior cameras. This may be due to greater use of the ledges by small mammals, higher detectability of cameras placed on ledges because the animal's movements are restricted to an area directly in front of the camera, or both. Future modeling of these data will help us to better discern these effects. However, 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. There were many pictures of them peering over the edge and a few showing them jumping from the ledge (see Appendix). These results support that the incorporation or addition of ledges may be used to enhance use and connectivity for small mammals (and medium sized mammals depending upon size of ledge; DOT 2011).

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. As with the ledges, in addition to indicating avoidance or preference in the use of underpasses, results may be influenced by differences in detectability of cameras placed within the underpasses because the animal's movements are restricted to an area directly in front of the camera. 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.

We made substantial progress in development of this methodology for studying and monitoring underpass use by both small vertebrates and other taxa. These developments include configuration and installation of the cameras, software and methods for processing images, study design, and statistical analysis. Although we can acquire hundreds of thousands, or millions, of images at a relatively low cost, processing the images requires a tremendous investment of human resources. Software tools are required to more quickly process images, assign species and other data to images, and QAQC data. After investigating existing tools, we judged them insufficient for our needs and we developed two software tools and a protocol for reviewing images. The first software tool is a standalone, cross-platform Java application for processing images, extracting metadata, viewing images, and assigning data to images. The second software tool is a Visual Basic (Windows only) tool that allows users to QAQC data after it has been loaded into Microsoft Access. The protocol involves conducting a "level 1" review during which images are initialize reviewed by personnel with basic biological and natural history knowledge, and many species are assigned to broad taxonomic groups such as "small mammal," "snake," or "lizard." Next, a "level 2" review is conducted by personnel with expertise in specific taxonomic groups during which species-level identifications are made, if possible. Thus, the image processing applications and protocol we developed addresses an important need in wildlife camera studies. With additional resources, we can continue to develop these tools and eventually make them available for use by other researchers, extending the results of this work to countless other studies.

RECOMMENDATIONS

We highly recommend that monitoring be conducted again 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, there are still more 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. Review of the full set of time-lapse photos and remaining motion detection

photos will help increase the power to detect smaller changes. We recommend the specific analyses for ledge use and underpass avoidance/preference mentioned above as well incorporation of time-lapse photos and comparison of the detection probabilities of species using timed lapse vs. motion detection. 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.

While the results seem promising, they do suggest a more complex story that we anticipated. It is premature to make recommendations to managers that may be costly and ineffective, or worse, lead to unintended results. More study and analysis is needed. However, managers could contribute to an improved understanding of small vertebrate use of underpasses and effective enhancement of underpasses by coordinating with USGS to conduct treatments within an adaptive management framework and then providing pre- and post-treatment monitoring data to USGS for analysis. This can increase our sample size and obtain observations under more types of treatments and a broader range of habitat and environmental conditions.

Acknowledgements

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References Cited

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference. Springer-Verlag, New York. 484 pp.

Department of Transportation. 2011. Wildlife Crossing Structure Handbook. Design and Evaluation in North America. Publication No. FHWA-CFL/TD-11-003. *http://www.cflhd.gov/programs/techDevelopment/wildlife/*

Dail, D. and L. Madsen. 2011. Models for estimating abundance from repeated counts of an open metapopulation. Biometrics 67(2): 577 – 578.

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: an empirical review and synthesis. Ecology and Society 14(1):21. [online]. *URL:http://www.ecologyandsociety.org/vol14/iss1/art21/*

Forman, R. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road Ecology: Science and Solutions. Washington: Island Press.

Popescu, V. D., P. de Valpine, D. Tempel, and M. Z. Peery. 2012. Estimating population impacts via dynamic occupancy analysis of Before-After Control-Impact studies. Ecological Applications 22(4): 1389 – 1404.

Trombulak, S. C. and C. S. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

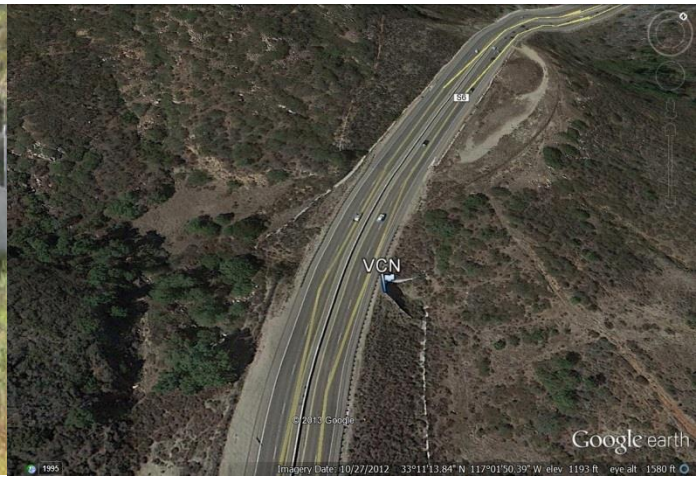
Taylor, B. D., and, R. L. Goldingay. 2010. Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia. Wildlife Research 37:320–331.

Appendices

Appendix A: Additional Information on Study Sites and Cameras

Valley Center Road

A. Valley Center North (VCN)



B. Valley Center Middle (VCM)

C. Valley Center South (VCS)

Underpass	Site ID	Group	# Cameras	Camera Positions
Valley Center North	VCN	Control	3	2 interior, 1 ledge
Valley Center Middle	VCM	Treatment	4	2 interior, 1 ledge, 1 exterior
Valley Center South	VCS	Control	4	2 interior, 1 ledge, 1 exterior

Notes: All underpasses have concrete ledges along both sides. Four-lane highway above each underpass with concrete barrier dividing the highway. Tall chain link fence borders the highway. Dirt road connecting avocado groves on either size of Valley Center Road was built between 2012 and 2013 sample periods. Road construction was done on Valley Center Road during the 2013 sample season.

Cameras:

VCN01

VCN02

VCN03

VCM01

VCM02

VCM03

VCS01

VCS02

VCS03

Sample of Camera Photos:

Crotalus helleri (Western Rattlesnake)

Rattus species(Rat species)

Peromyscus californicus (CA Mouse)

Pipilo crissalis (CA Towhee) and *Sceloporus occidentalis* (Western Fence Lizard)

Canis latrans (Coyote)

Rattus *species* (Rat species)

Unknown mouse jumping of ledge

Chaetodipus species (Pocket Mouse)

Sceloporus orcutti (Granite Spiny Lizard)

Spermophilus beecheyi (CA Ground Squirrel)

Peromyscus maniculatus (Deer Mouse)

Disturbances: Road built through VCS




Scripps Poway Parkway (SPP)


Underpass	Site ID	Group	# Cameras	Camera Positions
Scripps Poway Parkway	SPP	Control	3	2 interior, 1 exterior

Notes: Four-lane highway above underpass with concrete barrier dividing the highway. Tall chain link fence partially borders the highway.

Cameras:

SPP01

SPP02

SPP03

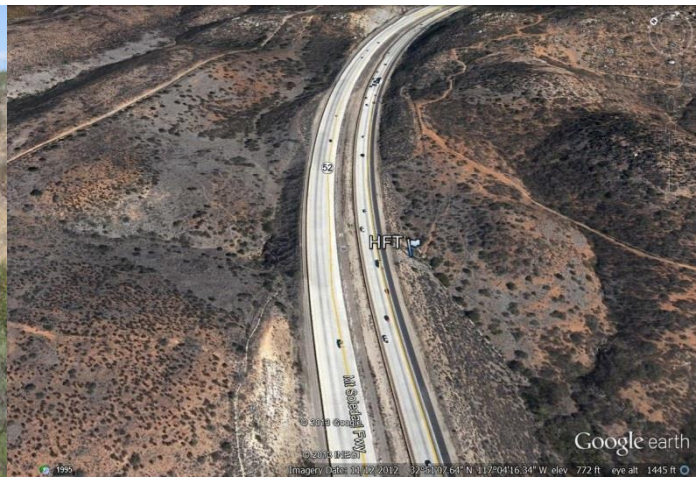
Sample of Camera Photos:

Cnemidophorus tigris (Western Whiptail)

Sceloporus orcutti (Granite Spiny Lizard)

Cnemidophorus hyperythrus (Orange Throated Whiptail)

Highway 52 (HFT)



Underpass	Site ID	Group	# Cameras	Camera Positions
Highway 52	HFT	Treatment	4	2 interior, 1 ledge, 1 exterior

Notes: Four-lane highway above underpass. No fencing borders the highway. Camera at position HFT04 (ledge) was stolen twice. Rocks were piled up in front of cameras HFT02 during one sample interval.

Cameras:

HFT01

HFT02

HFT03

HFT04

Sample of Camera Photos:

Snake species

Microtus califonicus (CA Vole)

Dipodomys species (Kangaroo Rat) *Notiosorex crawfordi* (Grey Shrew)

and *Neotoma species* (Woodrat)

Carmel Country Road (CCN, CCS)

Underpass	Site ID	Group	# Cameras	Camera Positions
Carmel Country North	CCN	Treatment	3	2 interior, 1 exterior
Carmel County South	CCS	Control	2	2 interior, 1 exterior

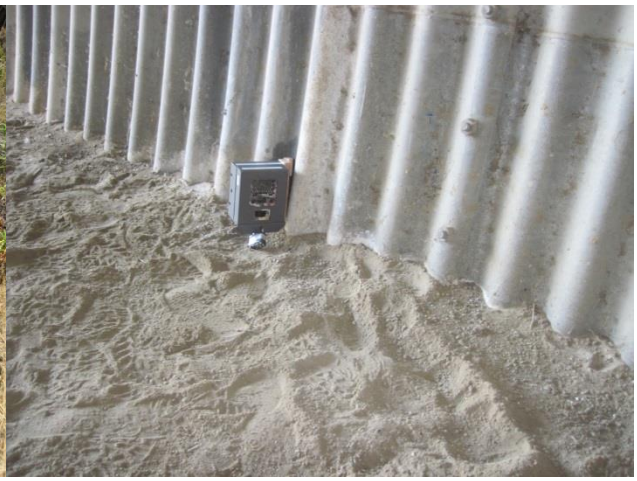
Notes: Both underpasses have a three-lane road above it. Underpasses are adjacent to each other. CCS has a recreation trail through it.

Cameras:

CCN01

CCN02

CCN03



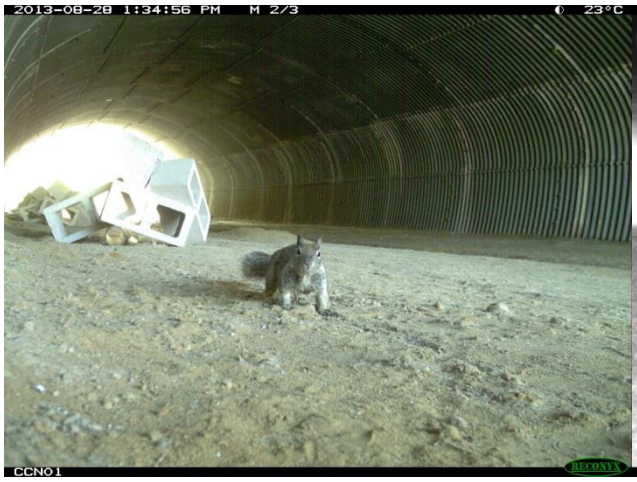
CCS01

CCS02

CCS03

Note: In the photo of CCN03, we initially placed the camera at a greater height and angled toward the ground in a attempt to reduce the number of motion detection images due to plants moving in the background. However, this proved to be ineffective, so the camera was moved to ground level.

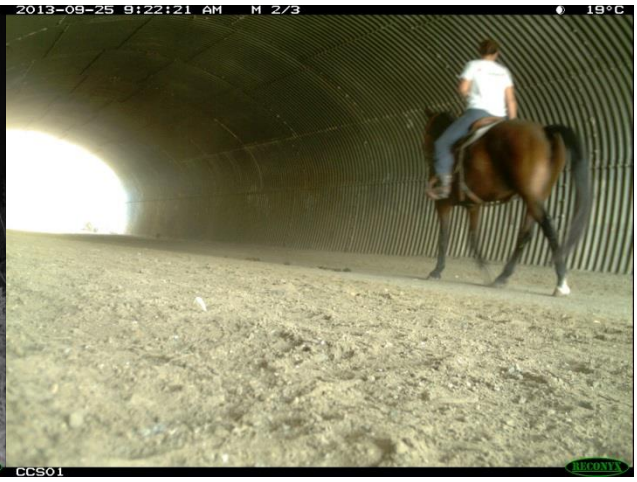
Sample of Camera Photos:



Spermophilus beecheyi (CA Ground Squirrel)

Troglodytidae species (Wren species)

Microtus californicus (CA Vole)



Homo sapiens (Human on Horse)

Homo sapiens (Human on Bike) *Lynx rufus* (Bobcat)

Sorrento Valley Road (SVR)

Notes: Underpass has two lane road above it. Part of road has a fence along it. Houses are nearby. Treatment structure was messed with.

Underpass	**Site ID**	**Group**	**# Cameras**	**Camera Positions**
Sorrento Valley Road	SVR	Treatment	3	2 interior, 1 exterior

Notes: A small amount of vandalism occurred to a few of the treatment structures on the north end of the underpass.

Cameras:

SVR01

SVR02

SVR03

Sample of Camera Photos:

Rattus *species* (Rat species)

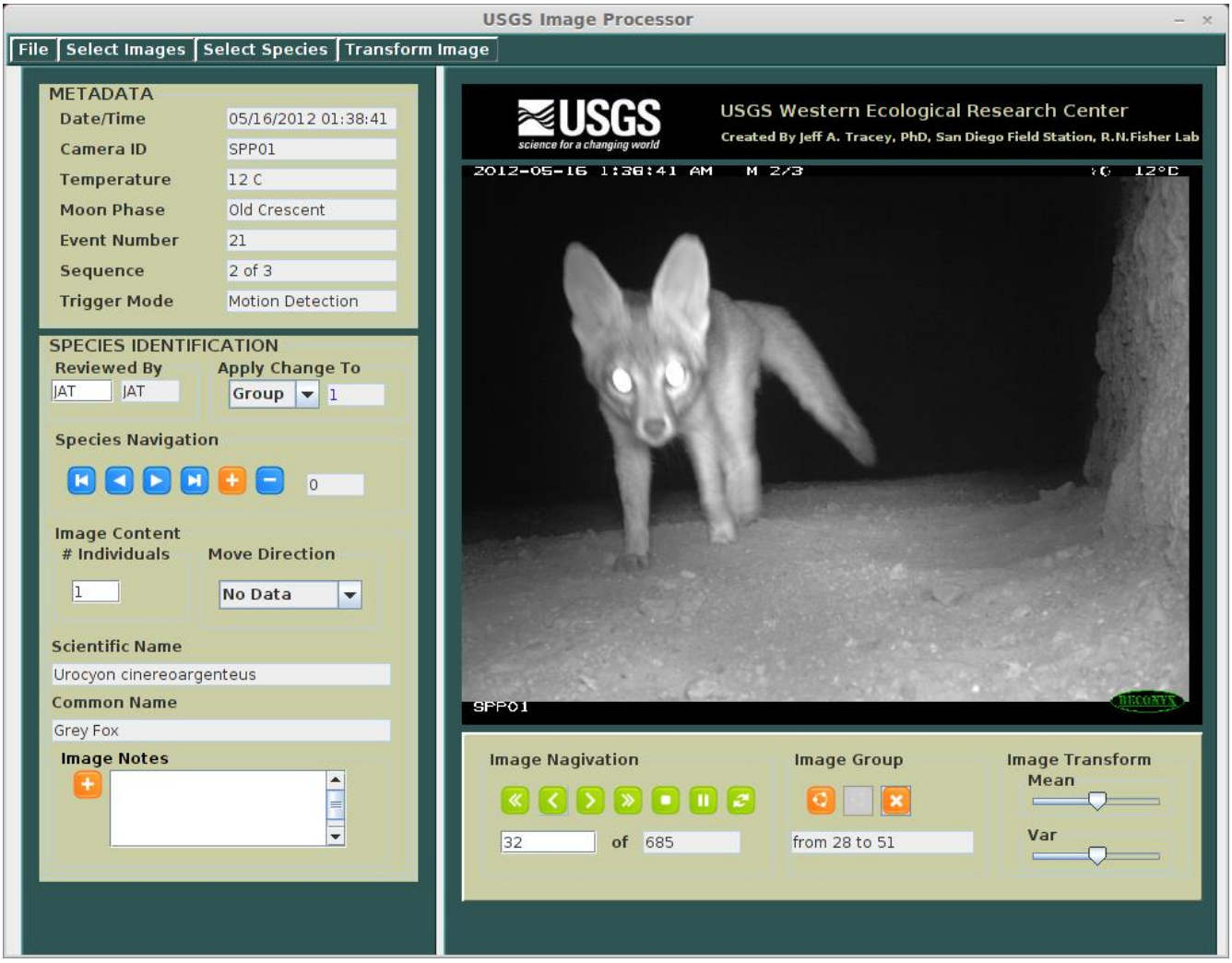
Pipilo crissalis (CA Towhee)

Sylvilagus species (Cottontail species)

Appendix 2: User Guide for Image Processing Program

USGS Image Processor

Quick Start Guide



San Diego Field Station

U.S. Geological Survey, Western Ecological Research Center

January, 2014

Background:

Because our goal is to extract scientific data from these images, it is extremely important that the images are processed in a careful, consistent manner and that species assignments to the images are made correctly.

Setting Up Your Computer and Files:

System Requirements:

- You need an up-to-date version of the Java Runtime Environment (JRE)
- Screen size (≥ 800 pixels vertically)
- You should have a mouse with a wheel
- The program works on Linux, Windows, and Mac.

Project Folder:

- We provide a project folder (called something like ProjectFolderTemplate) that contains all of the files you need to process images, except the images themselves. An example of this folder is shown in *Figure 22*. All of the files related to image processing must be inside your copy of this folder.
- You copy the folders containing a batch of images (see below) *into* this folder. NOTE: There should be no spaces (e.g. "C:\My Folder\") in the path to the directory containing the project files.
- When you create a new project, all of the project files will be created inside of this folder.

Image Batch Folders:

- Each folder that contains all of the images in a batch will have a name like **Group0X-y201XbgXXX** (where the Xs are numerals specific to each group, year, and batch). This folder is referred to as the "Working Image Directory."
- These contains 2 sub-folders: **MotionDetection** images & **TimeLapseImages** (you do not have to worry about these, the program knows that these subfolders are in the batch folder)

Project Files and Directories (*Figure 22*):

- Executable program (ImageOrganizer.jar).
- Supporting libraries (lib directory)

- Supporting tools and files (tools directory)
- Project files (an XML file and a directory containing other files; if a project has been created)
- Working image directories
- Program log file (called “ImageProcessorLog.txt,” created by the program)

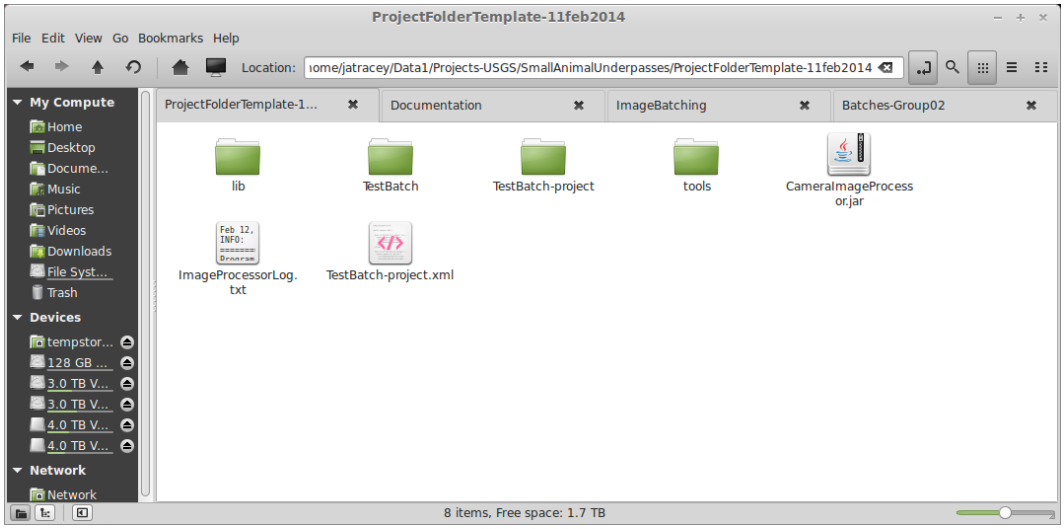


Figure 22: Layout of a project directory

Double-click on CameraImageProcessor.jar to start program

Creating A New Project: (each new batch)

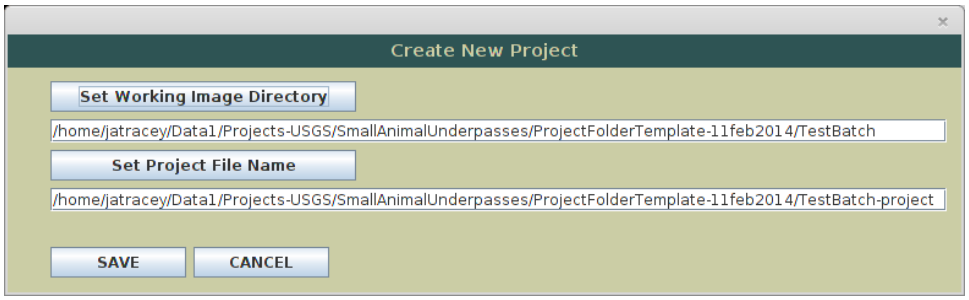


Figure 23: The New Project dialogue box.

A few things have changed with the new version of the program. There is a folder called "tools" that sits next to the program. This folder contains the species list and the different version of the ExifTool

that extracts the image metadata. The program finds these automatically as long as that folder stays in the right place. To create a new project, all you need to do now is:

- Open the program (by double-clicking on icon for the CameraImageProcessor.jar file).
- Select "New Project" from the File menu. You should see a dialogue box like the one shown in *Figure 23*.
- Hit the “Set Working Image Directory” button. In the file chooser, select the working image directory (the folder containing the batch of images, e.g. Group01-y2012bg074) and then press “Open”. Notice that when you select the working image directory, the project file name is automatically set to that folder name with "-project" appended to it. You do not need to change this automatically assigned project name.
- Hit the “SAVE” button.
- Hit the close button [X] at the top of the window to close the Create New Project dialogue box.

Next, preprocess the files:

- In the File menu, select “Preprocess Files.” After a few minutes (it may take a little while) a progress bar (*Figure 24*) should appear indicating the progress of the image import process. If you do not see this progress bar after a while (I would start worrying after 5 or 10 minutes, depending on how many images are in the batch), something probably has gone wrong. A common problem is that there is one or more spaces in the folder names on the path to the directory containing your image project.
- If the process completes, you should see an image in the viewer. At this point, select “Save Project” in the File menu. You do not have to preprocess the images again if they have already been successfully imported and you have saved the project.

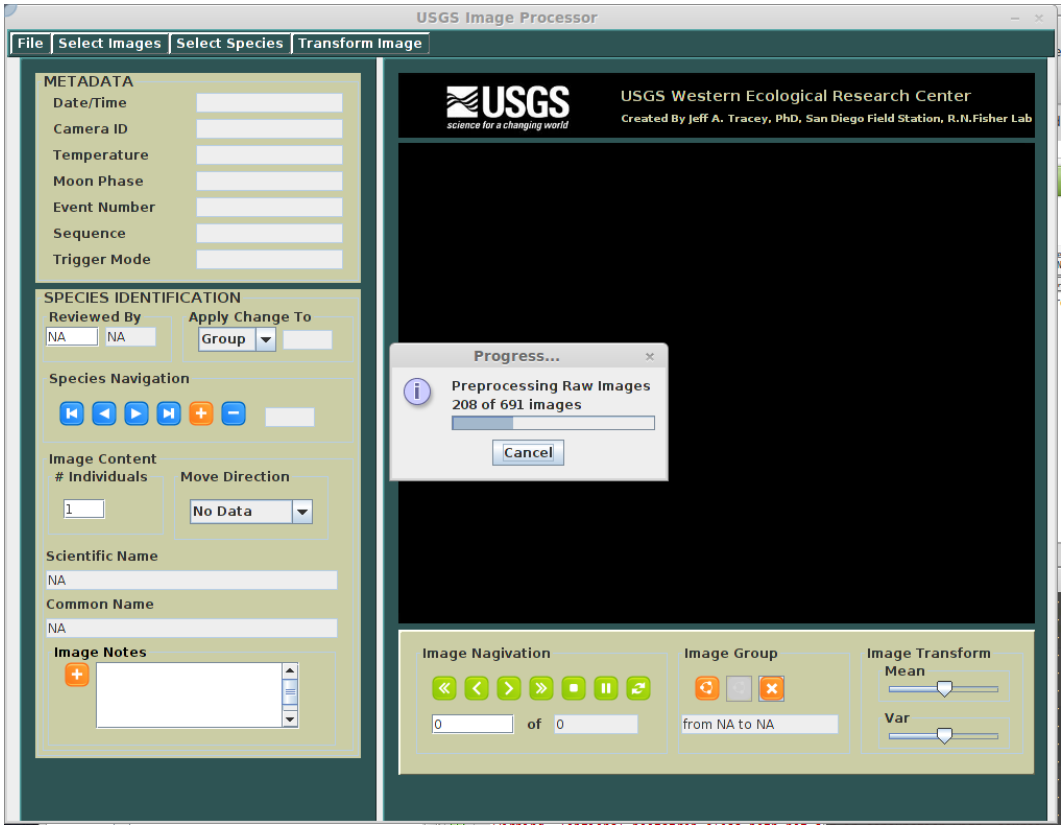


Figure 24: Preprocessing the images in the working image directory. Notice that there should be a progress bar showing how many images have been loaded. It may take a few minutes for the progress bar to appear, depending on the number of images in the working image directory.

Opening an Existing Project:

- Select "Open Project" from the File menu.
- Select the project XML file (named <project_name>.xml); for example, "Group01-y2012bg074-project.xml."
- Don't open the folder with the same name that contains the data!!!! This folder contains files with names like <project_name>.-data.xml and <project_name>.-export.csv. These are NOT the files you select when opening a project. Back out of that folder.

If you have already processed some images, you can select "Review Status → Not Reviewed" from the "Select Images" menu to reduce the list to the images that still need to be processed.

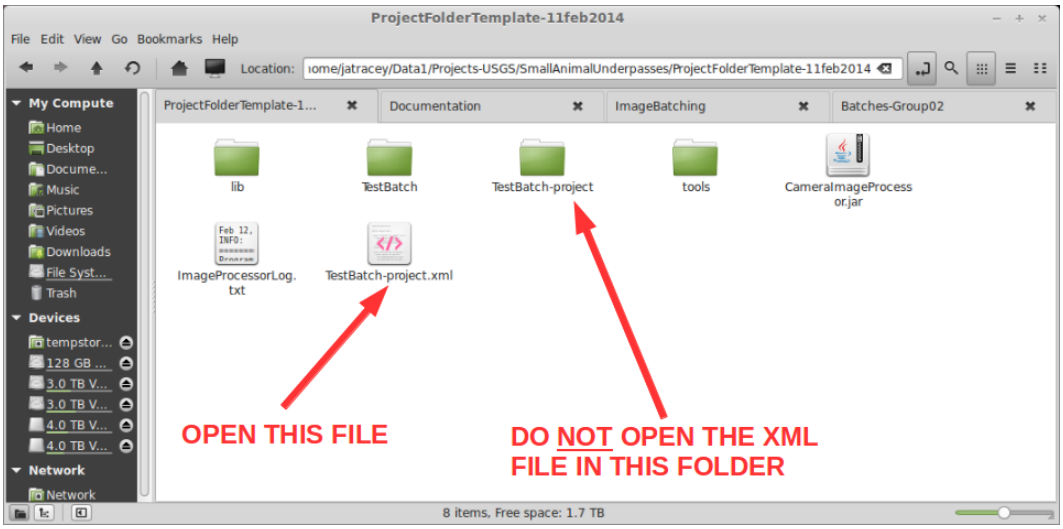


Figure 25: Opening a existing project. Notice that there is a folder called "TestBatch." In this example, this is our working image directory. After the project has been saved for the first time, there will be a new folder with the same name but with "-project" appended to it. This folder contains the project data. The file that you open is the XML file with the same name as the working image directory but with "-project.xml" appended to it.

Processing photos:

The one-page user guide will help you locate the controls on the program's graphical user interface (GUI).

The first thing you should do when opening a project is to enter your Reviewer ID in the left text box under "Reviewed By" and then hit the enter key. DO NOT FORGET TO DO THIS EACH TIME YOU OPEN THE PROGRAM!

"Apply Change To" List:

In the viewer, you have access to a list of images (which can be modified using the "Select Images" menu) and species data assigned to images. The group option is the one that is used most, if not always, so it is the default.

Image and Species Navigation:

Each species datum corresponds to a group of images that was specified by the user when it was added to the images. If Group is selected under "Apply Change To," and a change is made to a species datum

for an image, this change will be made for all images in that original user-defined group. Here, I briefly describe the controls for navigating through images and species:

- Image Navigation: The green arrows ("VCR controls") under "Image Navigation" at the bottom allow you to step through or animate images forward and backward. You can also type a number in the left text field below these buttons (from 1 to the number displayed in the right text field) to go directly to an image.
- Species Navigation: The blue arrows under "Species Navigation" on the left side allow you to step through species assigned to each image. There is always a "No Data" species at the end of this list. You can go directly to the No Data species by pressing the () button. If you only want to add more species to a group of images when you press the () button, you want to be on the No Data species when you start setting the species data. Otherwise, when you press the () button, you will modify (remove or replace) the species data that was displayed (not just for the image shown, but for all of the images that were grouped together when this species was originally assigned).

Grouping Images:

Changes can be applied to a single image, the images in an event, or a group of images that you specify. This can be controlled by the "Apply Change To" pull-down list. This list defaults to "Group," because most of the time this is what we will do. A group should be assigned to images that have some number of individuals of the same species moving together. You can create a group of only 1 image. If there are two or more species in the same images, create a different group for each species. To create a group:

- Use the controls to find the beginning and end of the group, how many individuals of that species are present, and their general direction of travel.
- Go to the first image in the group and press the () button to start the group. This should mark the first image in which the species appears.
- Then go to the last image in the group and press the () to end the group. This should mark the last image in which the species appears.
- You can unset a group but pressing the () button.

- The range of numbers (indexes in the image list) will be shown in the text field below these buttons (i.e., “from X to Y”).

Setting Species Data:

- Select the appropriate species from the “Select Species” menu.
- In the text box under “# Individuals,” type a non-negative integer in the box to indicate the number of individuals of that species, and then hit the enter key.
- Select the best choice describing the movement under the “Move Direction” pull-down list.

Adding and Removing Species Data:

Assuming “Apply Change To” is set to “Group,” if you want to:

1. Remove existing species data from an image:
    a. Navigate to one of the images with the species data you want to remove.
    b. Navigate to the species you want to remove.
    c. Press the () button.
    d. This will remove the species data from all of the images in the group created when the species was originally added.
2. Add new species data to an image:
    a. Create the group of images to which you want to add the species data.
    b. Go to the No Data species by pressing the () button.
    c. Set the species data.
    d. Press the () button.
    e. This will add new data to the group of images you defined.
3. Replace existing species data with new species data:
    a. If you want to add the species to a different set of images than the group created when the species data you want to remove was added, create your image group. Otherwise, clear the image group by pressing the () button.
    b. Navigate to one of the images with the species data you want to remove.
    c. Navigate to the species you want to remove.
    d. Set the species data that you want to add.

e. Press the () button.
f. One of the following will happen:
    i. If you created your own group, the old species data will be removed from all images in the group created when that data was originally added and then the new species data will be added to the group of images you defined (i.e. remove the species from the old group and add new species to a newly defined group).
    ii. Otherwise, the old species data will be removed from all images in the group created when that data was originally added and then the new data will be added to those same images (i.e. replacement).

Each image has a "No Data" species, it can't be removed. If an image has no animals in it, then you select the species "None."

NOTE: If you set an image to the "None" species, you must remove it before you add any other species data. If you want to set the species data to "None," you must remove all other species data from an image, except for the "No Data" species.

Repeat this process until you have added species data to all of the images in the working image directory.

Each time you close the program (by pressing the [X] button at the top of the window) you should save your work. A dialogue box will appear asking you if you want to save the project.

A few additional notes:

- Be careful not to group images that were taken by different cameras or that are separated by a long period of time (it is possible to have a coyote go past the camera and then have another one go by a few hours later, but it is not the same encounter of a coyote!).
- *You can look at export file under project folder to see how it assigned values for everything*. However, do not edit the XML files or the output CSV file. Doing so can destroy all of your work!
- If the program freezes, try closing it (save if possible), restarting, and opening your project.

- Remember to do your work carefully and accurately. We are building a data set for statistical analysis. It takes us much longer to track down and correct data entry errors than it does to enter the data in correctly in the first place.
- Identify species only to the level of your *certainty*. If you have no idea what is in an image, "Unknown" is a better answer than picking something that is not correct.
- If you encounter an unusual situation and are not sure what to do, stop working and contact me. We will decide on an appropriate way to handle that case and then let everyone know so that everyone does there work in a consistent manner.
- Remember that these images and the data generated from them are government property. You are not allowed to make copies of them, put them on the internet (e.g. FaceBook!), or distribute them without written permission.
- *In general, always press enter after entering text in a text field.*

Turning in a project:

Make sure that you have reviewed everything before you turn in your project. Every image should have a "species" assigned to it, even it that species is "None."

We need project folder and xml file that is associated with that folder. For example:

- Group01-y2012bg074-project.xml
- Folder: Group01-y2012bg074-project

If the images are given to you on a USB drive, you can just leave them on the USB drive when you turn it in. If you got the batch of images over the network, copy the project files to the designated network-accessible directory.

Reporting Bugs:

Unfortunately, there is no way to prove that a program, other than very simple ones, are devoid of any bugs. Software development companies often spend ten times more resources testing software than they do in its original design and implementation. They are also able to invest much more money, time, resources in development than we are. As a result, we rely on users to report bugs that the encounter during the use of this software.

In order for us to debug the program based on a bug reported by a user, we have to be able to reproduce the conditions that resulted in the error. This means we need:

- To know which batch of images you were working on.
- To know what you did prior to the problem's occurrence and the nature of the problem.
- A copy of the project XML file and project folder.
- A copy of the ImageProcessorLog.txt file and your project files.