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American Badger Research in Western San Diego County, 2015

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San Diego Association of Governments

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Western Ecological Research Center

Research Results for American Badgers in Western San Diego County, 2015

By C.S. Brehme, M.A. Burlaza, and R.N. Fisher

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Cover photo: Fresh badger burrow with IR camera at San Diego River, El Capitan Grande. Inset is subsequent badger photo from IR camera at this site (C. Brehme, M. Burlaza, D. Adsit-Moris 2015)

Table of Contents

Abstract 1

Introduction 3
American Badger 4

Methods 6
Badger Sign Surveys 8
Infrared Cameras 8
Hair Snags 8
Outreach Efforts 9

Results 11
Field Surveys 11
Outreach Efforts 17

Other animals detected: 19

Discussion 20

Conclusions 23

Acknowledgements 24

References Cited 25

Tables

Table 1. Badger Survey Dates 2015 6

Table 2. Badger Survey Results 2015 11

Figures

Figure 1. Focal sites monitored for American badger seasonal activity, 2015 7

Figure 2. (A) Hair snag in burrow in Volcan Mountain, (B) Close-up of snag with hair 9

Figure 3. Badger information outreach poster with hotline information 10

Figure 4. Badger burrows at Rancho Guejito (A), showing claw marks (B), badger burrow at San Diego River (C), another with camera set-up (D), possible badger dig at Ramona Grasslands (E), and biologists Melanie Burlaza and Devin Adsit-Morris recording information at badger burrow (F). 12

Figure 5. Badger IR Camera photos captured at 4 locations within Rancho Guejito (A-E). 13

Figure 6. Badger IR Camera photos at San Diego River/ El Capitan Grande Reservation from (A) June and (B) August, 2015 16

Figure 7. American badger localities in San Diego County with 2015 detections at focal sites (red triangles) and confirmed hotline reports (red circles). 18

Figure 8. Three mountain lions on Volcan Mountain on March 8, 2015 19

Abstract

Badgers (*Taxidea taxus*) are wide-ranging mid-sized predators associated with grassland and upland habitats. Their large home ranges, low densities, and low fecundity make them particularly vulnerable to habitat fragmentation and road mortality. The American badger is a covered species under the San Diego Multiple Species Conservation Plan (MSCP) and has been identified by the San Diego Monitoring and Management Program (SDMMP) Connectivity Monitoring Strategic Plan as a target species for monitoring regional-scale functional connectivity of upland and grassland habitats and is considered to be at risk of loss from the SDMMP Management Strategic Plan Area (MSPA).

In 2015, we continued studies of the spatial and temporal use of habitats by the American badger by conducting monthly field sign and infrared (IR) camera surveys across seven focal sites in the County where we previously documented substantial and/or repeated badger activity; Volcan Mountain Ecological Reserve (ER), Santa Ysabel ER, Ramona Grasslands Preserve, Barnett Ranch Preserve, Marron Valley Cornerstone Lands, Rancho Guejito (privately owned), and the upper San Diego River and El Capitan Grande Reservation. Our objective was to determine if badgers use these areas annually and if so, to better document the duration and season(s) of activity

American badgers were active at two of the seven focal sites in 2015, the upper San Diego River at El Capitan Grande Reservation and Rancho Guejito. Activity was documented by the presence of fresh burrows and digs and with IR camera photos and video. Although we were unable to begin monitoring these two sites until April and May to obtain access permissions, we documented badger activity intermittently through the remainder year. This included June, August and September at both sites as well as November in Rancho Guejito. Our data indicate these sites are likely core-use areas for badgers in the western San Diego County as badgers used them for two consecutive years and for multiple months throughout the year. Future monitoring will be needed to determine whether this remains true over the longer term. Other previously identified badger use areas may be used on a less frequent basis based upon such things as population density and prey availability.

Several studies of American badgers elsewhere have shown a strong correlation between badger occupancy and primary prey densities, particularly preferred squirrel species. Five of the seven focal sites in our study had squirrel burrow densities greater than 11 burrow entrances per hectare in 2015, including the two sites that were occupied by badgers. However, our highest ground squirrel burrow density estimates (~25/ha) were 4 times lower than a California ground squirrel research area in San

Joaquin Valley and 20 times lower than badger hunting grounds in Saskatchewan Canada. In southern California, 2015 marked the 4th year of a prolonged drought. Although drought studies are lacking for California ground squirrels, the effect of drought on the grassland associated Piute ground squirrel in southwestern Idaho is well documented. During drought years, squirrel densities crashed due to sharply decreased survivorship and reproduction and their habitat preference changed from grasslands to shrublands. California ground squirrels may respond similarly to drought. If so, we would expect squirrels to be at historically low densities overall with concomitant reduced use of grasslands habitats. Thus, the limited activity documented for badgers in these successive drought years may underrepresent the extent of their spatial and temporal habitat use of western San Diego County over the longer term.

We continued outreach efforts that included a poster and badger reporting hotline and email. Out of 30 reports in 2015, nineteen were high confidence or confirmed as American badger and three were road-killed animals. Because of the wide ranging nature of the species, road mortality is a primary concern for their continued persistence within the county and has been identified as the largest cause of badger mortality in other parts of their range. In concert with regional management goals, we continue to collect information and identify roads of concern where there is potential to enhance connectivity and reduce badger mortality through barrier fencing and crossing structures.

From 2011 to present, we have established that the American badger currently occupies or uses conserved lands within MSCP and MHCP and many other portions of the county. The American badger is a unique and iconic mammal that may act as an umbrella species for a large suite of animal species that occupy conserved upland habitats in western San Diego County. Their very large home ranges make them uniquely suitable for use in assessing connectivity of grasslands and uplands.

We are currently assessing possibilities for future badger monitoring and research in San Diego County. This includes evaluating the costs and benefits of active monitoring by radiotelemetry and passive monitoring using burrow surveys, canine scent surveys, and camera traps. We are also exploring methods such as facial recognition and further development of genetic tools to identify and count individuals. We continue to recommend and explore further outreach efforts and citizen involvement in reporting badger sightings.

Introduction

Badgers (*Taxidea taxus*) are wide-ranging mid-sized predators that are known to inhabit San Diego County. Similar to the mountain lion, they are known to range over wide areas, often making movements of 10km or more per day. Therefore, they are a suitable focus species for monitoring regional-scale connectivity. Unlike mountain lions that prefer to move within riparian areas (Dickson et al. 2005), badgers prefer open or grassy areas and thus are likely better indicators for upland connectivity and represent a different suite of species. Badgers are a covered species under the San Diego Multiple Species Conservation Plan (MSCP) and have been identified by the San Diego Monitoring and Management Program (SDMMP) Connectivity Monitoring Strategic Plan as a target species for monitoring regional-scale functional connectivity of upland and grassland habitats as well as a species considered to be at risk of loss from the SDMMP Management Strategic Plan Area (MSPA) (SDMMP 2013).

In fiscal year 2011-2012, the NCCP LAG program funded an initial study to determine if badgers persisted in the western portion of San Diego County (Brehme et al. 2012). Canine scent surveys were performed across the County in suitable grasslands within MSCP/Multiple Habitat Conservation Program (MHCP) boundaries and nearby areas. Badger sign (scat and/or burrows) was confirmed in Camp Pendleton, Fallbrook Naval Weapons Station, Daley Ranch (northern Escondido), Ramona Grasslands, Crestridge Ecological Reserve, Santa Ysabel Ecological Reserve, Hollenbeck Canyon Wildlife Area, and Marron Valley. Because badgers do persist within the western portion of the county, they are believed to be a suitable species for assessing upland connectivity.

In 2013-2014, the NCCP LAG program and SANDAG funded 2014 field studies to identify target areas with potentially higher densities of badgers and to better assess the level of connectivity between known occupied areas. We found that many sites where badger activity was confirmed in 2011-12 had no recent sign of badger activity. In areas where we found fresh sign in the spring, activity quickly ceased and no further activity was documented through the summer and fall. Although stable populations with smaller home ranges have been documented in some parts of their range, badger home ranges of 35 to 300 km^2 are common in other areas, with size largely determined by availability of dispersed prey, burrowing sites and mates. The 2014 results suggested that badgers in San Diego County also operate on a larger spatial scale. Thus, rather than stable population locations of badgers, areas may be used frequently or infrequently. In 2014, we also established an outreach effort that included

a poster and badger reporting hotline and email. This has been successful in identification of other badger use areas within the County. Finally, although we are presently able to genetically identify badgers at the species level from scat, there have been challenges to the identification of individuals except from hair or tissue samples (Wood et al. 2016).

In 2015, we focused on areas that were previously found to have high or repeated badger use. Our goal was to determine if American badgers use these areas annually and if so, to better document the duration and season(s) of activity. This would help us to better understand the spatial and temporal dynamics of badgers within core-use areas and to inform locations and timing of any future trapping efforts for radiotelemetry. We focused our surveys in seven areas where we documented substantial badger use in previous years; Barnett Ranch, Ramona Grasslands, Santa Ysabel Ecological Reserve, Volcan Mountain, and Marron Valley, Guejito Ranch, and Capitan Grande Reservation (upper San Diego River: Brehme et al. 2012, 2015). Surveys included monthly on the ground searches for badger burrows and other sign, as well as monitoring by use of infrared cameras.

We also continued public outreach to further our collection of badger records throughout the County. This included continued distribution of posters at open space kiosks and monitoring of the dedicated USGS badger hotline and email.

American Badger

The American badger (*Taxidea taxus*) is a nocturnal medium-sized fossorial carnivore of the Mustelid family that includes weasels and wolverines. Badgers are stocky with very powerful forearms and claws for digging. Their primary prey are small mammals such as ground squirrels, gophers, ground hogs, prairie dogs, voles, mice, woodrats, and kangaroo rats, but they also eat birds, herpetofauna, invertebrates, and plants (Grinnell 1937, Long 1972, Messick 1987, Quinn 2008). Their home ranges and densities have been associated to density of prey, particularly ground squirrels (i.e. Owing and Borchert 1975, Lay 2008, Prioulx 2016). Badger densities are typically low, ranging from 0.2 to 5 individuals per km^2, while their home ranges are large, ranging from 2 to 50 km^2 and sometimes up to 450 km^2 (Messick and Hornocker 1981; Hoodicoff 2003, Minta 1993, Quinn 2008). Except for mothers with their young, adults are largely solitary moving an average of 0.5 km per night in search of prey (Lindzey 1978, Hoodicoff 2003). Badgers mate July through September and with delayed implantation, females give birth the following spring to an average litter size of 2 to 3 young. Their lifespan is 9 to 10 years in the wild (Long 1972).

Badgers range across much of North America, from southern Mexico to central Canada and from the west coast of California to the Great Lakes region. Within the range of the species, they are known to prefer sandy loam soils and open grasslands, although they are found in open scrublands, open woodlands, and open chaparral (Grinnell 1937, Long 1972, Messick and Hornocker 1981, Hoodicoff 2003, Quinn 2008). In Quinn's (2008) study of badger habitat and movement in Monterey County, California, she found they spent 91% of their time in grassland habitats.

Because of their large home ranges, habitat preferences, and low fecundity, badgers are especially vulnerable to the negative effects of habitat loss, habitat fragmentation, and road mortality (e.g. Crooks 2002, Lay 2008, Klafki 2014). Significant declines of badger populations and distribution have been documented in California and British Columbia (Williams 1986, Adams and Kinley 2004). In a habitat fragmentation study of southern California, badgers were only found in very large unfragmented sites (Crooks 2002). Even in less developed areas, badgers large home ranges often require them to cross roads resulting in high rates of road mortality (e.g. Messick et al. 1981, Klafki 2014). Finally, because rodents make up their primary prey base, rodenticide use is associated with lower badger densities (Proulx, G. and N. MacKenzie 2012).

Badgers were extensively hunted for their pelts in 1930's and 1970's, and are still reportedly being trapped in high numbers (Williams 1986, Quinn 2008). Currently, a California DFW Trapping License is required for any for-profit trapping or hunting of badgers with no limits to the number of individuals. Depredation and predator control that is not for-profit does not require a permit or reporting. This species has long been considered a pest species for agriculture. It is hypothesized that there are many more badgers killed for depredation and it is unknown how much this has contributed to their decline (Williams 1986, Quinn 2008). To date there is little known about the ecology of the badger in coastal southern California.

In 1986, the American badger was listed as a California Department of Fish and Wildlife (DFW) Species of Special Concern due to a substantial reduction of their distribution and abundance.

Primary stressors to the American badger in southern California include:

1. Road mortality
2. Habitat loss
3. Habitat fragmentation: Lack of open habitat and/or corridors for movement and dispersal.
4. Hunting and trapping: Predator control/ sport shooting/ fur trapping
5. Reduced prey base from use of rodenticides.
6. Consumption of rodenticides from small mammal prey

Methods

From January 13 to December 18, 2015, we surveyed for badger sign every 3 to 5 weeks across seven focal sites in the County that were previously documented to have substantial and/or repeated badger activity; Volcan Mountain Ecological Reserve (ER), Santa Ysabel ER, Ramona Grasslands Preserve, Barnett Ranch Preserve, Marron Valley Cornerstone Lands, Rancho Guejito (privately owned), and the upper San Diego River and El Capitan Grande Reservation (Table 1, Figure 1; Brehme et al. 2012, 2015). Sites were surveyed on foot for fresh badger sign (i.e. badger burrows and digs) and several infrared cameras were set in key locations at each site. Cameras and snags were also set at any fresh burrow sites. The onset of surveys ranged from January to June depending upon the time it took to receive permissions from the land owners/ managers.

Table 1. Badger Survey Dates 2015

	Site						
Month	Volcan Mountain Ecological Reserve	Santa Ysabel Ecological Reserve	Ramona Grasslands Preserve	Barnett Ranch Preserve	Marron Valley Cornerstone Lands	Rancho Guejito	Upper San Diego River; Capitan Grande Reservation/ El Capitan Reservoir
January	1/13/2015*	1/13/2015*					
February	2/26/2015	2/26/2015	3/5/2015*	3/5/2015*			
March	3/19/2015	3/19/2015	3/19/2015	3/19/2015	3/5/2015*		
April	4/15/2015	4/15/2015	4/9/2015	4/9/2015	4/2/2015	4/3/2015*	
May	5/13/2015	5/13/2015	5/14/2015	5/14/2015	5/7/2015	4/30/2015 5/1/2015*	
June	6/18/2015	6/18/2015	6/18/2015	6/18/2015	6/12/2015	5/29/2015 6/5/2015	6/4/2015* 6/24/2015
July	7/23/2015	7/23/2015	7/9/2015	7/9/2015	7/15/2015	7/10/2015	7/29/2015
August	8/13/2015	8/13/2015	8/5/2015	8/5/2015	8/12/2015	8/6/2015 8/25/2015	8/4/2015 8/26/2015
September	9/10/2015	9/10/2015	9/11/2015	9/11/2015	9/23/2015	9/24/2015	9/17/2015
October	10/9/2015	10/9/2015	10/7/2015	10/7/2015	10/13/2015	10/15/2015	10/14/2015
November	11/19/2015	11/19/2015	10/29/2015	10/29/2015	11/20/2015	11/6/2015	11/12/2015
December	12/18/2015	12/18/2015	12/14/2015	12/14/2015	-	12/15/2015	12/17/2015

* IR Cameras initially set

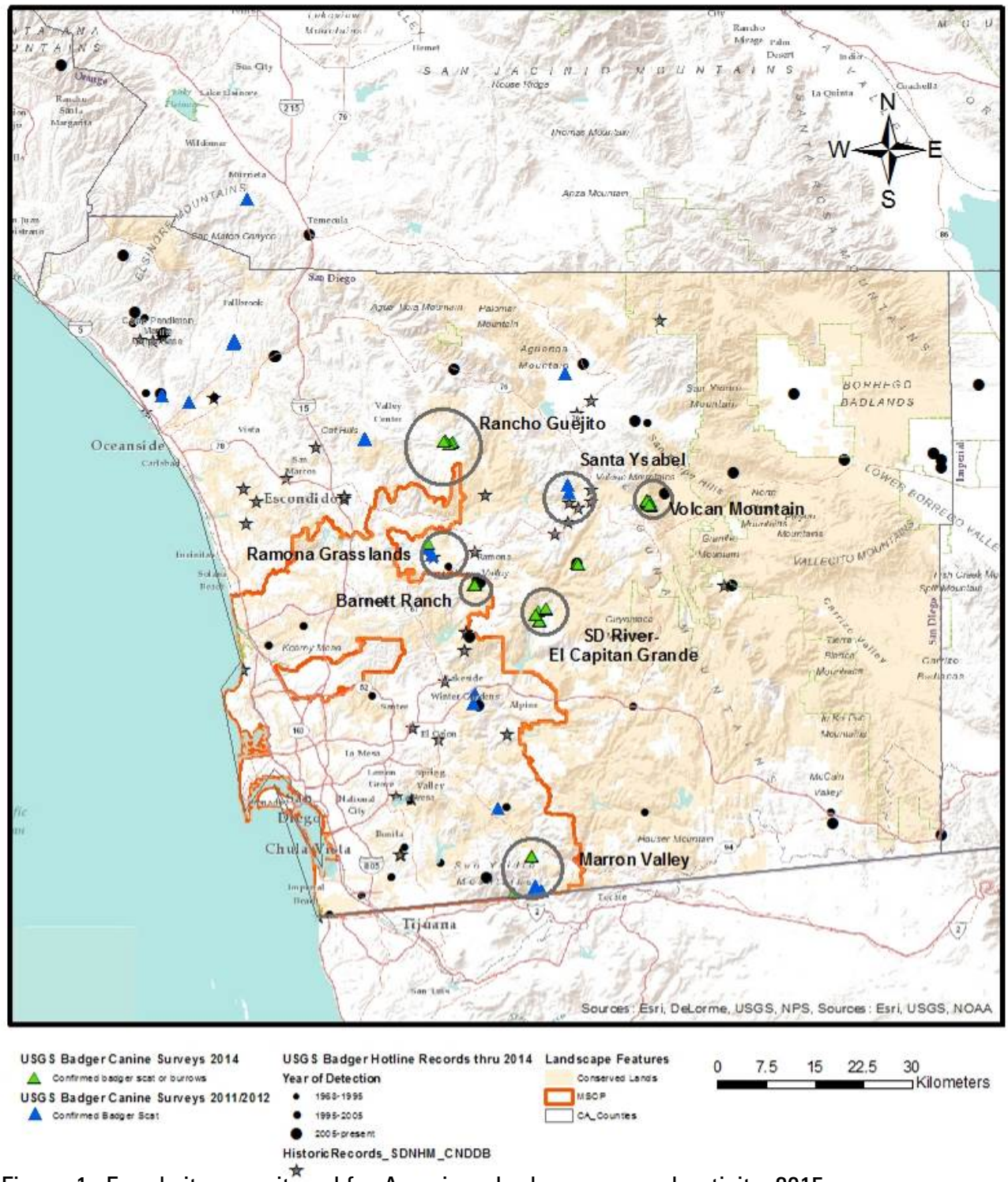

Figure 1. Focal sites monitored for American badger seasonal activity, 2015

Badger Sign Surveys

Badger sign surveys involved surveying the landscape for potential badger sign (burrows, digs, and tracks). The surveyor would walk around the site while scanning for mounds and burrows. Burrows were confirmed as badger if they were the correct size and shape (approximately 8-12 inches wide and 6-10 inches in height) and contained characteristic horizontal claw marks within the burrow (approximately one inch spacing between claws). Freshness was determined by evidence of loose soil at the entrance indicative of recent digging. Other evidence included body 'drags' and/or tracks observed at the burrow entrance. Older burrows were identified as such if they had new or substantial growth of grasses or forbs at the entrance, there was no evidence of recent digging, or contained evidence of recent squirrel use.

We also recorded an index of prey density for squirrels and gophers at the survey sites. The index was based upon a visual estimate of burrow density with categorical estimates of 0, 1-5, 6-10, 11-20, 20-50, and >50 burrows/hectare.

Infrared Cameras

Infrared cameras (Reconyx and Bushnell) were set facing landscapes with previous or recent badger activity, on nearby upland animal trails, facing suitable grassland habitat, and directly on any fresh and potentially occupied burrows using both motion detection and time-lapse settings. Reconyx PC800 HyperFire Professional Semi-Covert IR cameras were set to medium sensitivity for motion detection and automatic time-lapse photo captures every 1 minute. Bushnell Trophy HD Cameras were set with three different detection types, depending on the type of sign present: normal sensitivity motion detection (for burrows), low sensitivity motion detection with automatic 1-minute interval time-lapse capture (for landscapes and trails) and normal sensitivity motion detection with video (for high confidence burrows).

Hair Snags

When fresh badger burrows were identified at sites where repeat visits were possible, hair snags were placed within the burrow entrances. Hair snags were constructed according to protocol provided by American badger researcher, Richard Klafki (British Columbia), who travelled to San Diego and shared his expertise and methods with the USGS from May 1 to May 6, 2014.

Snags were made from 30 cm (12”) of 2-cm (3/4”) wide metal strapping formed into a ‘D’ (Figure 2). Two 3-inch nails were inserted through holes drilled at the base of the ‘D’ and were used to secure the snag inside the burrow. Three rivets were placed at each edge and middle to secure the strapping in its shape. Two squares (approximately 3-4 cm by 2 cm) of pinned-knaplock (used to anchor carpet in doorways) were riveted to the curved edge of the metal strapping. The teeth of the knaplock were slightly bent down to better force hair into the snag and prevent injury to an animal.

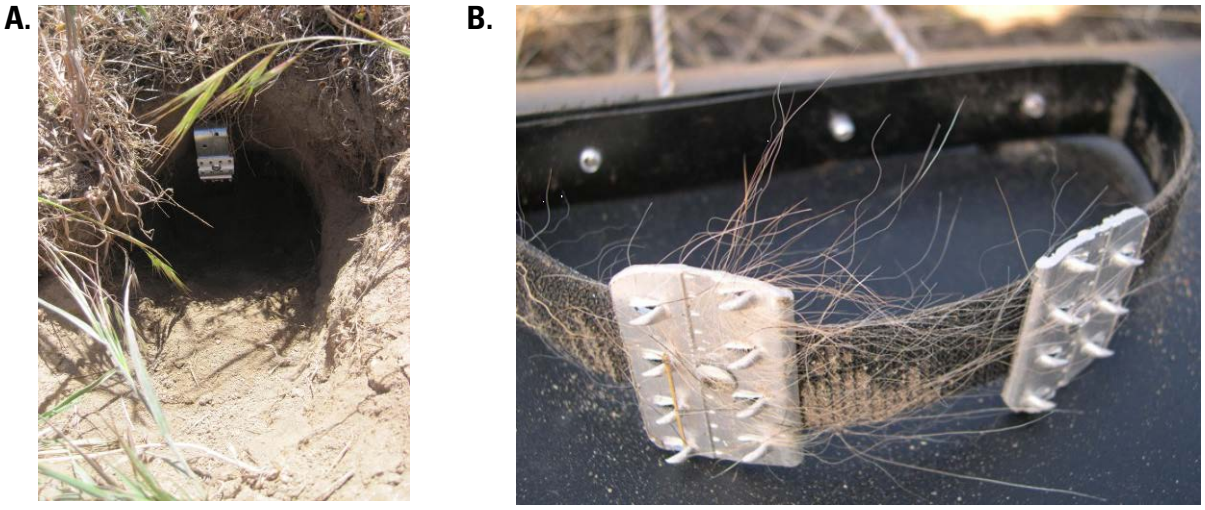

Figure 2. (A) Hair snag in burrow in Volcan Mountain, (B) Close-up of snag with hair provided by Richard Klafki.

Outreach Efforts

Outreach efforts to the public and other wildlife professionals are commonly used in order to gain information on badger localities and their spatial and temporal use of habitat (Ministry of Environment Ecosystems 2007). We created and distributed a poster for public and professional outreach for this information in July 2014 (modified from R. Klafki, Figure 3). In 2015, we continued to distribute the outreach poster to wildlife professionals, land managers, and others to include the San Diego Habitat Conservancy, San Diego Audubon Society, US Forest Service, SD County Otay Ranch Preserve, Caltrans Department of Transportation, Cuyamaca State Park, Escondido Creek Conservancy, Fallbrook Land Conservancy, Friends of Daley Ranch, and Friends of San Diego River Valley. The poster was also posted to the Western Ecological Research Center and San Diego Monitoring and Management Program websites. We continued monitoring the “San Diego Badger Hotline” dedicated phone and email established in 2014. Updated pictures and videos were posted to the USGS project

website “American Badgers in San Diego County” at web address http://www.werc.usgs.gov/project.aspx?projectid=257.

Figure 3. Badger information outreach poster with hotline information (adapted from version provided by Richard Klafki). Example of poster in kiosk at Barnett Ranch Preserve.

Results

Field Surveys

We confirmed American badger activity in 2015 at only two of the seven previously occupied focal sites (Rancho Guejito and El Capitan Reservoir; Table 2). Badger activity was documented in June, August, and September at both sites and in November at Rancho Guejito. We used facial recognition to identify at least two individual badgers at El Capitan Reservoir. We documented badgers with IR cameras at four locations within Rancho Guejito; however, facial patterns were only apparent for one individual at a single location. Badger sign and IR camera photos are presented in Figures 4-6. No hairs were obtained from burrow snags in 2015. Squirrel activity was low at Volcan Mountain and Marron Valley (squirrel activity is color coded on Results Table 2).

Table 2. Badger Survey Results 2015

Month	Volcan Mountain Ecological Reserve	Santa Ysabel Ecological Reserve	Ramona Grasslands Preserve	Barnett Ranch Preserve	Marron Valley Cornerstone Lands	Rancho Guejito	Upper San Diego River; Capitan Grande Reservation/ El Capitan Reservoir
January	ND	ND					
February	ND	ND	ND	ND			
March	ND	ND	ND	ND	ND		
April	ND	ND	ND	ND	ND	ND	
May	ND	ND	ND	ND	ND	ND	
June	ND	ND	ND	ND	ND	BADGER (C)	BADGER (B,C)
July	ND	ND	ND	ND	ND	ND	ND
August	ND	ND	ND	ND	ND	BADGER (B,C)	BADGER (B)
September	ND	ND	ND	ND	ND	BADGER (B,C)	BADGER (B,C)
October	ND	ND	ND	ND	ND	ND	ND*
November	ND	ND	ND	ND	ND	BADGER (C)	ND
December	ND	ND	ND	ND	-	ND	ND

Color Legend: Squirrel burrows/ha	0	1-5	6-10	11-20	20-50	>50
B= Fresh Burrows, C= Camera detection, * Cameras stolen						

A.

B.

C.

D.

E.

F.

Figure 4. Badger burrows at Rancho Guejito (A), showing claw marks (B), badger burrow at San Diego River (C), another with camera set-up (D), possible badger dig at Ramona Grasslands (E), and biologists Melanie Burlaza and Devin Adsit-Morris recording information at badger burrow (F).

Figure 5. Badger IR Camera photos captured at 4 locations within Rancho Guejito (A-E). Video footage also captured along with August and November photos. Facial markings were not apparent in most pictures, so the number of individual badgers detected at this site is unknown.


Bushnell
RG05S 57°F13°C
Corrected Date: Aug 14, 2014 10:27:51


Bushnell
RG07S 60°F15°C
09-26-2015 01:55:32


With video
Bushnell
2015-11-07 19:54:22

Figure 6. Badger IR Camera photos at San Diego River/ El Capitan Grande Reservation from (A) June and (B) August, 2015. June photo was taken from video capture. These are two different animals based on differences in facial markings.

Outreach Efforts

We continued our outreach in 2015 with the additional distribution of posters to San Diego Habitat Conservancy, SD Audubon Society, US Forest Service, Otay Ranch Preserve, Caltrans, Cuyamaca State Park, Escondido Creek Conservancy, Fallbrook Land Conservancy, Friends of Daley Ranch, Friends of SD River Valley, and various common places in Julian, Escondido, Ramona, and Fallbrook. In 2015, we received 30 reports of which 19 were high confidence and/or confirmed as American badger. Several reports contained photographs. All reports were followed up by phone or email interviews, survey visits or collection of tissue (if a mortality). Three of the reports in 2015 were road killed animals found on S22 in Anza Borrego (Joni Bye, CA State Parks), Basilone Road in Camp Pendleton (Lee Hamm, MCBCP) and Buckman Springs Road in Campo (Ryan McCreary, USDA). The carcasses were kept by the agencies or transferred to the SD Natural History Museum with tissues collected. Other reports were verified in Julian, Harbison Canyon, Thing Valley (near Pine Valley), Borrego Springs, Barrett Lake, Camp Pendleton, several in and around Boulevard, and several in Western Riverside.

Outreach has been an integral part of our program to better understand the spatial distribution and movement corridors for the American badger in San Diego and adjacent counties. We continue to maintain a database of badger records that is much more comprehensive than what was known prior to the onset of our badger research program. Since distribution of the poster and establishment of the hotline in July 2014, we have received over 42 reports (28 high confidence) from biologists and citizens in San Diego and adjacent Counties. Prior to the hotline, we also obtained 39 high confidence reports from biologists and agency personnel across the County, resulting in a total of 67 unique locations of American badger across the region that may have otherwise gone undocumented.

All American badger documented localities within the County including USGS survey detections and high confidence hotline reports from 2015 are shown in Figure 7.

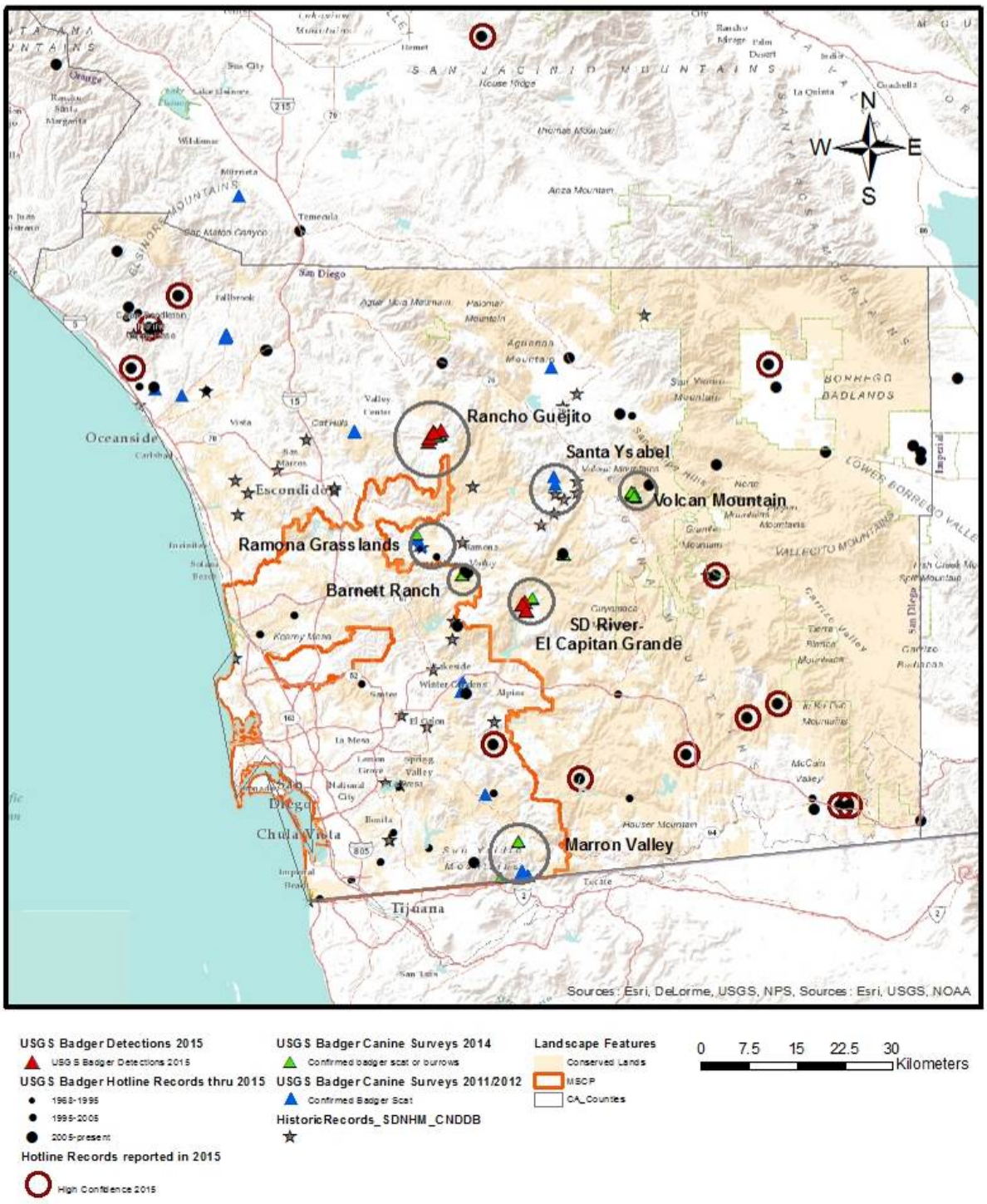

Figure 7. American badger localities in San Diego County with 2015 detections at focal sites (red triangles) and confirmed hotline reports (red circles).

Other animals detected:

Although our surveys were targeting badgers within the study areas, we also detected many other wildlife species on our cameras. Of note, mountain lions (*Puma concolor*) were detected at Volcan Mountain on 5 occasions between March 8 and May 25 and on 3 occasions from August 10-24, 2015. The March 8, 2015 siting was of three lions together, perhaps a family group (Figure 8). Mountain lions were also detected on cameras in Rancho Guejito on 5 occasions between June 22 and August 15, 2015. Bobcats (*Lynx rufus*), Coyote (*Canis latrans*), and mule deer (*Odocoileus hemionus*) were detected at all seven sites, while gray fox (*Urocyon cinereoargenteus*) were detected at Rancho Guejito, Santa Ysabel, and San Diego River.

Figure 8. Three mountain lions on Volcan Mountain on March 8, 2015.

Discussion

American badgers were active at two of the seven focal sites in 2015, the upper San Diego River at El Capitan Grande Reservation and Rancho Guejito. Although we were unable to begin monitoring these sites until April and May due to access permissions, we documented regular activity at both sites intermittently through the year. This included June, August and September at both sites as well as November in Rancho Guejito. Because females typically give birth in March, we do not know if these were used as reproductive den sites.

We have previously theorized that badgers in San Diego County are operating on a large spatial scale and do not appear to have stable populations occupying specific reserve areas. Stable higher density populations containing individuals with smaller home ranges have been documented in other parts of their range, but larger badger home ranges of 35 to 300 km^2 are common in many areas, with size largely determined by availability of dispersed prey, burrowing sites and mates (i.e. Lindzey 1978, Minta 1993, Hoodicoff 2003, Klafki 2014). Although specific sites may not be occupied year around, some areas may be more frequently visited than others (i.e. core-use areas). Our data from 2015 indicate that the upper San Diego River (El Capitan Grande Reservation) and Rancho Guejito are core-use areas for badgers in the western San Diego County as they were used by badgers for two consecutive years and for multiple months throughout the year. Other previously identified badger use areas may be important but used on a less frequent basis based upon such things as population densities and prey availability. Future monitoring will be needed to determine whether this remains true over the longer term.

Several studies of American badgers elsewhere have shown a strong correlation between badger occupancy and primary prey densities, particularly preferred squirrel species (Owing and Borchert 1975, Van Horne et al. 1997, Lay 2008, Prioux 2016). These studies have confirmed the dependence of badgers' home ranges upon spatially and temporally variable prey resources (e.g. Hoodicoff 2003).

Five of the seven sites in our study had squirrel densities greater than 11 burrow entrances per hectare in 2015 (Santa Ysabel, Ramona Grasslands, Barnett Ranch, upper San Diego River, Rancho Guejito), two of which were intermittently occupied by badgers. The two sites that had low or no squirrel activity in 2015 (Volcan Mountain and Marron Valley) were not used by badgers in 2015. However, higher densities of ground squirrels were noted at Volcan Mountain and Marron Valley concomitant with badger activity in previous years. These results

suggest that badgers in this region may also be more likely to use areas with higher squirrel prey densities.

An example of this relationship was observed at Volcan Mountain. During our initial visits in 2014, when there was fresh badger activity, we noted abundant squirrel burrows and above ground activity. Although prey densities were not recorded on field forms that year, the author recollects squirrel densities of at least 40+ burrows/ha. When badger activity ceased by mid-May 2014, there was a marked and notable decrease in active squirrel burrows and sightings to almost nil. Squirrel densities remained low (< 5 burrows/ha) throughout 2015 along with no newly detected badger activity.

In southern California, 2015 marked the 4th year of a prolonged drought. Although drought studies are lacking for California ground squirrels (*Spermophilis beecheyi*), the effect of drought on Piute ground squirrels (*Urocitellus mollis*, formerly Townsends) has been well documented (Smith and Johnson 1985, Van Horne et al. 1997). During drought years, Piute squirrel numbers crashed due to sharply decreased survivorship and reproduction. Van Horne (1997) recorded squirrel persistence dropping 39%, 66% and 100% in adult males, adult females and juveniles, respectively in a single year. We expect that drought has also negatively impacted California ground squirrels resulting in low prey densities for badgers. Low California ground squirrel densities are thought to be negatively affecting other dependent species, such as the burrowing owl, which have prompted recent increased grassland habitat management and ground squirrel reintroduction/relocation efforts (McCullough et al. 2016). Further research is needed to better understand the natural fluctuations in ground squirrel and burrow densities in southern California. Fitch (1948) estimated an average density of 108 burrows/ha and 17 burrows per squirrel over a 198 ha CA ground squirrel research area in San Joaquin Valley. Also, our highest ground squirrel burrow density estimates (~25/ha) were at least 20 times less than those reported for badger hunting grounds in Saskatchewan Canada (Prioulx 2016). Therefore, limited distribution and activity of badgers documented in western San Diego County in recent years may underrepresent their spatial and temporal occupancy over the longer term.

In addition to affecting densities, drought has been shown affect habitat selection for Piute ground squirrels with grasslands preferred in normal years and sagebrush scrub preferred in drought years (Van Horne et al. 1997). This change in habitat selection has been attributed to higher moisture and more consistent food resources in shrublands during drought years (Van

Horne et al. 1998). This may be particularly true in grasslands dominated by non-native grasses as low germination rates of annual plants under drought conditions and their short period of succulence make them a poor food source (Van Horne et al. 1998). California ground squirrels may respond similarly to drought which could result in lower animal densities overall and a possible preference for coastal sage scrub and chaparral habitats. As selective predators of ground squirrels, American badgers are likely also at lower than normal densities and may potentially be using shrubland habitats more than would be expected in normal rainfall years.

In 2014, an effort was made to survey scrub and chaparral habitats adjacent to grasslands where badger sign was detected in 2011. This proved to be difficult except in open scrub habitats where we did find a small number of badger scats but no burrows (Marron Valley, Crestridge; Brehme et al. 2015). Visual surveys for badger sign are typically done at a landscape-level scale using a combination of moving across the landscape and scanning for soil mounds with binoculars in order to cover the area required to survey in a single day (Ministry of Environment Ecosystems 2007). This method is not possible in shrub habitats where movement is impeded and the field of view for badger sign under the shrub canopy is of very short range. The use of canine scent detection is superior but thick shrublands still significantly limit the movement of the dogs, trainers, and orienteers thus reducing the probability of detecting badgers in these landscapes. Due to this and the current hypothesized low densities of badgers in the region, changes in habitat preference of badgers in relation to drought and vegetation type would likely require longer term monitoring and radiotelemetry methods.

Prior to our surveys in 2011 and 2014, most badger records in this region were recorded from roadkill observations. Because of the wide-ranging nature of the species, road mortality is a primary concern for their continued persistence within the county. Roadkill has been identified as the largest cause of badger mortality in other parts of their range (i.e. Hoodicoff 2007, Klafki 2014). The regional management goals for the American badger include increasing connectivity (and reducing potential road mortality) between occupied and suitable habitat areas to allow expansion and movement of the occurrence and to ensure persistence in the MSPA over the long-term (SDMMP 2012). Preliminary roads of concern were identified in the previous report and include I78 and I79 near Santa Ysabel, I76, Wildcat Canyon Road, San Vicente Road, I8 at Peutz Valley Road, I94, Otay Lakes Road, Honey Springs Road, and Basilone Road (MCB, Camp Pendleton). Additional roadkill observations in 2015 confirm Basilone Road as a concern

and potentially Buckman Springs Road in Campo and S22 in Anza Borrego in eastern San Diego County.

Conclusions

We are beginning to get a clearer picture of badger space-use within the western portion of the county. However, there is much to be learned about badger ecology in this region. This includes continued investigation in the spatial and temporal use of grassland and other habitats for badgers, squirrel density as a predictor of badger use patterns, effects of prolonged drought on badger and prey populations, if there are predictable areas used for reproductive denning, and if the denning areas in western San Diego County are more likely to be located in grasslands or thicker scrub and chaparral habitats.

We are currently carefully assessing methods for future badger monitoring and research in San Diego County. We are evaluating costs and benefits of active monitoring through radiotelemetry and passive monitoring through burrow surveys, scat surveys, and camera traps. As discussed in our previous reports, radiotelemetry would help us to understand how badgers move through upland habitats, how they move among habitat patches and where they may frequently need to cross primary roadways. This information should better help to identify important upland movement corridors in the county and manage for upland connectivity. However, there are many challenges with this technique unique to badgers that need to be considered (e.g. Quinn et al. 2010, Proulx and MacKenzie 2013). Because density of burrows is not relatable to badger abundance (Ministry of Environment Ecosystems 2007), methods such as facial recognition and genetic tools can potentially be used to identify and count individuals. We and others have successfully identified individuals using facial recognition (e.g., USGS present study, Harrison 2016). Badgers individuals have also been successfully identified genetically from hair samples (Kierepka and Latch 2015, Wood et al. 2016), but these have been challenging to acquire. Further development of a microsatellite library from southern California badger tissues has been recommended to increase the potential of identifying individuals from more easily acquired but degraded sources such as scat (Wood et al. 2016).

From 2011 to present, we have established that the American badger currently occupies or uses conserved lands within MSCP and MHCP and many other portions of the county. The American badger is a unique and iconic mammal that may act as an umbrella species for a large suite of animal species that occupy conserved upland habitats in western San Diego County.

Their very large home ranges make them uniquely suitable for use in assessing connectivity of grasslands and uplands.

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