AMERICAN BADGER AND BURROWING OWL
HABITAT SUITABILITY ASSESSMENT REPORT 2019-2022

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Windy Hill badger burrows by Skyline Road.

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1.0 Executive Summary

In 2019 the study began with collecting a compilation of a comprehensive database of burrowing owl and American badger occurrence records from a variety of sources. To build the models, 142 badger and 1,426 burrowing owl occurrence records were collected from the San Mateo, Santa Cruz, Santa Clara, and San Benito counties via a regional email inquiry. After screening the records for duplicates and accuracy, 127 badger records and 424 burrowing owl records were used in analyses. A total of 127 badger locations were included in the database and 424 burrowing owl locations.

Species distribution models based on habitat characteristics at occurrence record locations were generated using Maxent for records of badgers in observed in burrows, badgers above ground (in transit), wintering burrowing owls (records from September 16th through April 9th) and breeding burrowing owls (April 10th through September 15th). Badger burrow presence was positively associated with grasslands, loam soils, and road density. Occurrence records of badgers in transit were associated with areas that are developed, closer to water, and higher than the surrounding terrain. Associations with road density and development may be related to locations where badgers are most visible, and where observers are most likely to be, rather than actual associations with habitat predictors. Burrowing owl models suggest that breeding owls are more likely to be present in lower elevations, which reflects what is observed on community science apps like eBird and iNaturalist. The model for wintering owls suggests that, in addition to low elevation sites, some mid elevation locations have higher probabilities of species presence than lower or high elevation areas. Owls were also associated with higher road densities, which again may indicate observational bias rather than actual biological associations. However, owls' preference for low elevation and flat areas may be associated with areas more likely to have roads.

To validate the species distribution models, we generated stratified across various levels of predicted badger presence from the Burrows model. Badger and burrowing owl surveys were then conducted for multiple seasons across three years from 2019-2021. Field work entailed transect surveys, camera work, and collecting genetic samples as described in Sections 3 and 4 Transect Methods and Data Collection. Field work and acquired sightings from other researchers resulted in another 248 records, resulting in a total of 375 records, which were used to validate the linkage model. A total of 13 additional burrowing owl sightings were collected by volunteers and field staff during the study period.

95.3% and 95.5% of the new burrows added to our badger records and observed during transect surveys, respectively, were in areas identified as medium to high likelihood of badger presence, thus validating our original Burrows model. However, we also found that many areas were not surveyed (e.g., between the Coast and the Southern Santa Cruz Mountains West of Highway 17) or did not show evidence of badger occupancy (e.g., Sierra Azul), suggesting some additional avenues for research.

New burrowing owl sightings were mostly observed in known locations of wintering owls collected during our 2019 preliminary database compilation. Notably, we also recorded the first sightings of owls in Sierra Azul and Tunitas Creek Open Space Preserves. Owls were seen using a variety of habitats, including sites with and without badgers, and also sites that didn't have any mammal-constructed burrows. We suggest that artificial burrows be added to sites our study identified as by wintering owls habitats in order to enhance the existing habitat and attract additional owls.

Badger surveys were then conducted for two years from 2019-2021. Field work entailed transect surveys, camera work, and collecting genetic samples as described in Section 4 Data Collection. Field work resulted in another 248 records, resulting in a total of 375 records, which were used to validate the linkage model.

To identify potential linkages connecting the study sites, a Linkage Pathway analyses was conducted. Midpeninsula Regional Open Space District (Midpen) Preserves and other protected lands that had badger records and highly suitable habitat, were considered core habitat areas. Habitat linkages between core areas were generated by using the Linkage Pathway tool, which is part of the Linkage Mapper Toolbox.

The linkage model was developed by creating a Cost Surface model for badgers to reflect the cost of movement through the study area for badgers. The habitat variables used for developing the model included vegetation, habitat types, soil, hydrology, land use, and roads from GIS layers. Each habitat variable was reclassified to reflect the suitability of a habitat feature for badger presence (denning) and movement using ArcMap 10.2. This resulted in a model which reflected a range of highly suitable habitat with low cost for movement for badgers to poor habitat with high movement costs for badgers within the study area.

The map resulting from the Cost Surface model (figure 1) showed a fragmented landscape for badgers on the Peninsula. Large swaths of habitat within the study area consist of highly unsuitable habitat, such as steep, forested ravines with dense vegetation understory. The ravines bisect a majority of the available highly suitable habitat for badgers, such as grasslands. Other areas of suitable habitat for badgers are bisected by high-use roads, which could restrict badger movement across the landscape due to mortality from vehicles, potentially isolating individuals or populations. The highly fragmented landscape highlights the importance of identifying connections between suitable habitats and increasing the permeability of the landscape for badgers to find resources and mates, and for juvenile dispersal from their natal areas.

The Linkage Pathway analyses resulted in several networks of linkage designs, including a central network of draft linkages between the MROSD preserves, a linkage running from north of San Mateo down the coast to Santa Cruz, and a linkage running from the central network down to Coyote Valley. The linkage models were validated by overlaying the 375 records collected from field work during the study period and the other compiled records from various sources.

A total of 114 badger records were collected from 21 transects that had badger presence, such as badger burrows or camera documentation of badgers. The sites with the highest percentage of badger burrows include Monte Bello OSP (30%), Russian Ridge OSP (19%), Long Ridge OSP (13%), Purisima Creek OSP (11%), and La Honda Creek OSP (8%).

The majority of badger records were found in six of the Midpen core preserves:

1. Monte Bello OSP
2. Russian Ridge OSP
3. Long Ridge OSP
4. Skyline OSP
5. Windy Hill OSP and
6. La Honda Creek OSP.

There is a clustering of records at these six preserves, with a total of 217 records combined out of the 375 total records.

It is critical to maintain the linkages between these core preserves by maintaining connected grassland habitats. It is also equally important to maintain quality habitat where the linkages run through the preserves. Within these preserves along the transects where the majority of badgers were recorded, grassland habitats were either being mowed or grazed. It seems that both moderate grazing and mowing is beneficial for badgers. Much like burrowing owls, this might make it easier for badgers to see, hunt, and travel through the landscape. The majority of badgers recorded traveling were not on recreational trails. This makes sense as badgers are sensitive to human disturbance (Crooks 2002).

Long Ridge OSP was the site with the southernmost records. Maintaining grassland connectivity from Russian Ridge OSP through Skyline OSP and Long Ridge OSP is important for keeping these preserves connected for badgers to have the ability to travel between them. These preserves also have highly unsuitable habitat such as densely forested ravines. The grassland habitats that connect the different preserves are critical for maintaining landscape connectivity for badgers.

There are also bottlenecks that would be helpful for opening and increasing the availability of grassland habitat for badger movement between the preserves. Improving the permeability between the six Midpen core preserves where the majority of badgers were found would help improve the ability for badgers to travel between them to find mates and for juvenile dispersal.

We found that some linkages were being used by badgers and some that were not. For example, the more northern Tunitas Creek OSP was heavily grazed and fragmented by unsuitable habitat. We also found no viable linkages through the Sierra Azul OSP to connect to Calero County Park and Coyote Valley, where there is a known badger population.

It seems there are major factors influencing badger presence or absence at sites. These factors include but are not limited to:

1. if the grassland habitat had some type of connection to other grassland habitats
2. grass height
3. management practices
4. variation in chaparral habitat

The high presence of badgers in the Midpen core preserves may be due to the preserves being relatively connected via grassland habitats. Within these preserves the vegetation was being managed by either mowing or grazing. The sites were not overgrazed. From our transect work, locations in which the grass was high (4 feet or higher) there were very few records of badger burrows. Grass height from 1 to 3 feet seemed to be optimum in which we observed many burrows along transects. Locations subject to heavy grazing where the grass was less than 1 foot, such as Tunitas Creek OSP, seemed to result in very few to no burrow records.

At the southern Fremont Older OSP, Tunitas Creek OSP, Coal Creek OSP, and Sierra Azul OSPs, there were relatively small patches of grassland habitats which were isolated by forested habitats. Variation in chaparral was also a major factor influencing badger presence. In locations where the chaparral was very thick, dense, and impassable, such as the Sierra Azul OSP no badger burrows or sign were found. Coastal scrub by comparison is much more permeable. Multiple badger burrows were recorded in coastal scrub habitat at Cloverdale.

The various sites make the case for managing linkages by creating more connected grassland habitats within the identified bottleneck areas by mowing and grazing, however not heavy grazing year-round. The study area is unique in that the grassland habitats are within a matrix of heavily forested habitats that fragmented landscape for badgers. Other neighboring mountain ranges such as the Gabilan Range and the Diablo range have much larger intact grasslands networks that intermingle with oak woodland savannahs, which badgers have been documented to travel through. These types are much less fragmented than the Santa Cruz Mountains and Peninsula.

The coastal linkage may be the only viable pathway for badgers to travel to/from the Midpen core preserve population. This linkage has much more highly suitable habitat available compared to the eastern Monte Bello-Sierra Azul linkage. The combined badger records of historical observations and data collected from this study indicate that badgers might be utilizing the coastal linkage. The predictive model also shows a higher probability of badgers occurring along the coast than through the Sierra Azul complex.

Another aspect that makes the coastal linkage more viable to allow dispersal for the core population is the high degree of connected protected lands running along the coast and within the coastal linkage. However, we would need to further investigate the following:

1. how La Honda OSP is connected to the coast
2. ground-truth the coastal linkage by replicating the transect and camera methods used in this study to build on this baseline data
3. collect more genetic samples to increase the genetic sample size to have a better understanding of the genetic structure of this population to determine if genetic drift or isolation is occurring.

We collected DNA samples from badgers through outreach and direct collection by the field team. The outreach effort, which started in May, 2019, focused on agency and independent biologists, and other personnel regularly in the field that might encounter badgers (including road-killed badgers) or their diggings. We provided sample collection instructions via email to respondents that expressed interest in collecting samples they encountered.

The field team actively collected hair samples between January 1, 2020, and August 31, 2021, by installing hair snares in active burrows identified during transect surveys or other field visits. We opportunistically collected shed hair and scat at badger mounds, and tissues from road killed badgers. We analyzed genetic data within and between three populations from where had collected or received samples:

- Peninsula (PN) – Includes the MROSD Preserves and extends from the eastern foothills of the Santa Cruz Mountains west to the Pacific Ocean in San Mateo, Santa Cruz, and northwestern Santa Clara Counties. Because the preserves are contiguous with other open space on the Peninsula, we considered samples from the preserves as part of the PN population.
- South Bay Area (SB) – Southeast of the PN population boundary, from Coyote Valley in Santa Clara County east into the Diablo Range; and
- North Bay Area (NB) – north of the PN population and San Francisco Bay, in Marin, Sonoma, and Napa Counties

We analyzed the samples at the Mammalian Ecology and Conservation Unit (MECU) of the Veterinary Genetics Laboratory at University of California, Davis to determine genetic relatedness within populations with MLRELATE software, generated F statistics including genetic diversity and structure and inbreeding indices within and between populations, and used STRUCTURE software to identify the mostly likely distinct populations.

We collected a total of 103 samples, including 11 samples from out outreach efforts, 9 samples Pathways for Wildlife had received or collected previously, and the remaining collected by the team. Of the 103 samples, 70 were collected on the MROSD Preserves. Overall, approximately 36% of the samples amplified successfully (produced DNA suitable for analysis). 30% of MROSD samples amplified.

The lab analysis identified 25 individual badgers from the 38 samples that amplified successfully. Eleven of those, 3 females and 8 males, were collected within the MRSOD Preserves. Further analysis produced the following key results:

1. The Peninsula population of badgers had the highest number of related individuals, including closely-related individuals (parent-offspring, siblings). The South Bay population had no related individuals and the North Bay had two pairs of related badgers.
2. Samples for several closely-related badgers were found within close proximity to each other at the La Honda Creek OSP, potentially indicating a current or recent natal den in that area.
3. Samples for one male badger were collected from the Stanford Lands and La Honda Creek OSP six months apart, indicating at least one badger traveled almost six miles navigating through or around steep, forested terrain, residential development, and roads.
4. Peninsula badgers are less genetically diverse than the other two populations, and had the fewest alleles (i.e., gene variants) in the animals we sampled. The F_{IS} value of 0.003 for the Peninsula population indicates a small, likely inbreeding population.
5. STRUCTURE analyses indicated that there were most likely three distinct populations across the individuals we sampled. The analysis showed some gene flow between the North Bay and South Bay populations, but none between those two populations and the Peninsula population.
6. We lacked enough successfully amplifying samples to estimate the effective population size (Ne) of the Peninsula badger population, which would help understand how the population is affected by inbreeding.

While the MROSD badgers, and those on the rest of the Peninsula appear to be an isolated population with some degree of inbreeding, it is important to understand both the trajectory of the inbreeding by tracking relevant indices over time to understand any trends, and also to determine the potential negative results of this inbreeding by monitoring reproductive rates in the MROSD preserves in the future. Collecting more genetic data in a focused, intensive effort could provide more information on population size and effective population size that may affect inbreeding. In the meanwhile, efforts should be made to identify usable movement corridors for badgers, potentially down the coast, where there may be opportunities for gene flow and an increase in genetic diversity, and to maintain linkages within the preserve network and adjacent areas to prevent further substructuring of the MROSD and wider Peninsula badger population.

2.0 Introduction

2.1 Study Purpose

The Midpeninsula Regional Open Space District (MROSD) Badger and Burrowing Owl Population Study (study) commissioned a study was initiated in January 2019 to evaluate and implement science-based management of American badgers (*Taxidea taxus*, badgers) and Western burrowing owl (*Athene cunicularia hypugaea*) throughout their Open Space Preserves (preserves). The three components of the study were

1) the development of habitat-based predictive species distribution models in the preserves using sightings data and validation with field surveys;
2) the development of GIS habitat linkage models within the preserve network and to adjacent areas and predicted corridor use documentation with remote cameras; and
3) genetic analysis to determine the characteristics and structure of badger populations in the preserves, the San Francisco Peninsula, and surrounding regions.

2.2 Report Structure

The report that follows is structured to describe each of the three study components separately and to integrate all the results to provide robust conclusions and management recommendations. Section 2 provides an overview of badger and burrowing owl ecology, as well as known and potential threats to their populations in California and elsewhere (as relevant). In Sections 3 through 5, we describe the purpose, methods, and results of each of the three study components. Section 6 contains a comprehensive discussion that provides ecological context and explanation of the overall study results. We also include in the discussion a review of the study design, field methods, and analysis used for each study component to highlight successes and opportunities to improve methodology. We summarize management recommendations based on the overall study results in Section 7.

2.3 Background

2.3.1 Badger ecology

The American badger (*Taxidea taxus,* Figure 2-1) is a medium-sized mustelid that occupies grasslands, shrublands, open stages of woodlands, and forests throughout California. The badger is a nocturnal to crepuscular, fossorial species, specialized for digging to pursue burrowing small mammal prey and to den during the day. Although badgers are relatively short-legged and not large (between 5 and 8 kg for females and up to 15 kilograms for males), they have few natural predators due to their aggressive defensive behavior, which enables them to confront and deter larger predators (Newman et al. 2005).

Figure 2-1. The only badger seen on a transect at La Honda Creek OSP. Photo credit: Dan Wenny

Badgers are polygamous and mate in late summer and early fall. Females give birth in a natal den late January through February after a delayed implantation (a process in which a fertilized egg does not implant in the uterine wall for a period of time – up to 6 months in badgers). Litter size ranges between 1 to 5 (average 2) kits born in March or April (Hamlett 1935, Messick & Hornocker 1981, Minta & Marsh 1988). Kits remain underground until they are about 6 to 8 weeks old, after which they will hunt with their mothers aboveground for another 1 to 3 months. Badgers become reproductively active in their second year, although some females will reproduce in their first year at the age of 4 months (Messick & Hornocker 1981, Minta & Marsh 1988).

Reproductive rates appear to be low in badgers. The few studies to observe reproduction in wild badgers suggest that females do not breed every year. Messick and Hornocker (1981) report that an average of 57% of females produce a litter in a given year; Minta (1990) reports 25% of females successfully raising litters to above-ground emergence. In British Columbia, out of 10 potential litter attempts in 2 years for 4 radio-marked female badgers, only one animal produced litters: one in her third year and another in her fifth (Newhouse & Kinley 2000). In a California study, of 3 adult females monitored through 2 breeding seasons, only one produced one litter of at least 1, and probably 2 kits. Messick and Hornocker (1981) found some evidence that female fecundity increased with age; thus, older females may be important to maintaining population growth rates. Breeding success may also increase with age for males (Minta 1993).

Badger home ranges vary widely, from approximately 2 km^2 to 21 km^2 in coastal California to over 650 km^2 at the northern extent of their range in British Columbia (Quinn 2008, Kinley and Newhouse 2008). Badger home range sizes and dispersal distances can in part be explained by resource distribution, wherein females' movements are dependent on the distribution of food resources and males' movements are dependent on the distribution of females (Minta 1993). Where these resources are patchy, a large home range can comprise several widely spaced areas of intense use (Hoodicoff et al., 2009). In California, home ranges of 21 km^2 have been recorded (Quinn 2008). Large home range sizes can correlate with long dispersal distances (Bowman et al. 2002); however, in badgers, even when a home range size was small (2 km^2), a dispersal distance of 110 km was recorded (Messick & Hornocker 1981). To exploit patchy resources, badgers have been observed moving distances of up to 14 km in a 4-hour period (Hoodicoff et al., 2009).

The American badger was listed as a species of special concern in California due to population declines historically statewide, and more recently, locally. Many of the threats to badgers are likely related to habitat loss and fragmentation, including road kills, and poisoning in agricultural and residential areas. Badgers persist in contiguous habitat (Quinn 2008).

2.3.2. Burrowing Owl Ecology

The Western Burrowing Owl (*Athene cunicularia hypugaea*) has experienced population declines in much of its range in western North America. Burrowing owls are listed as Endangered in Canada and as a Species with Special Protection in Mexico. In the US at the national level they are considered a Bird of Conservation Concern by the U.S. Fish and Wildlife Service. At the state level, burrowing owls are listed as Endangered in Minnesota, Threatened in Colorado, and as a Species of Concern in Arizona, California, Montana, Oklahoma, Oregon, Utah, Washington, and Wyoming (Poulin et al. 2020). Other subspecies (mostly non-migratory) of burrowing owls occur in Florida, the Caribbean, and Central and South America (mainly in temperate grasslands south of Amazonia).

Santa Clara County had about 500 owls at 250 locations in the 1980s. By 2020, fewer than 50 adult owls at 4 locations were present in the breeding season. Rapid development in the South Bay has eliminated most of the habitat previously occupied by breeding burrowing owls. However, recent surveys find that numerous wintering burrowing owls still visit the South Bay Area during the non-breeding season before departing to breed elsewhere (Trulio et al. 2018).

Burrowing owls in western North America generally do not dig their own burrows but rather use abandoned burrows dug by other animals. In the San Francisco Bay Area they most commonly use California ground squirrel (*Otospermophilus beecheyi*) burrows but will also use burrows or dens dug by badgers or other animals as well as artificial burrows. Signs of owl use at a burrow includes whitewash (the nitrogenous component of feces), regurgitated pellets, and feathers. During the breeding season (mainly March - July) bedding material, prey remains, and "decorations" can be found around active burrows. Decorations can include cow dung, fungi, and other items. Burrowing owls nest in short (< 15 cm) grassland areas with patchy bare areas. They will often perch on a mound or fence post near the burrow to scan for predators. They forage in habitat similar to that used for nesting although not much is known about burrowing owl foraging in our area. In other parts of their range the owls may forage up to a mile from their burrow. Burrowing owls are most active in the hours before and after dawn and dusk. Burrowing owls in the San Francisco Bay Area include nonmigratory breeding owls present all year and migratory owls from more northern breeding areas that are present here from October through March, and sometimes into April.

3.0 Species Distribution Model Validation Report

3.1 Introduction

In 2018, the Midpeninsula Regional Open Space District (MROSD) commissioned a study to examine how to improve habitat for American badgers (*Taxidea taxus*, badgers) and Burrowing Owls (*Athene cunicularia*, owls) on its lands. As part of our study, we obtained previous pre 2019 records of badgers and owls in Santa Clara and neighboring counties to create a species distribution model for the two species.

In order to validate our model and to provide MROSD with more targeted management recommendations, we continued to collect information on badgers and owls by adding to species' records between 2019-2021. In addition, we also surveyed transects to better understand how vegetation characteristics impacted badger and owl presence at a fine scale level.

In this report, we discuss the validity of our original species distribution model in light of new observations of the targeted species collected by our project as well as by other projects or researchers. We also present findings of habitat characteristics that are associated with badgers and owls based on our transect surveys. We use these results to guide our land management recommendations for MROSD.

3.2 Methods

3.2.2 Species Distribution Model

The habitat characteristics associated with known occurrences of badger and owls on the Peninsula, including San Mateo, Santa Clara, Santa Cruz, and San Benito Counties were used to develop species distribution models for both species (American Badger and Burrowing Owl Habitat Suitability Assessment Report 2019).

1. Model and transect development included the following steps:
2. Compilation of a comprehensive database of owl and badger occurrence records from a variety of sources
3. Use of occurrence records and GIS habitat data layers to create a MROSD-wide and beyond species distribution Burrows model and Transit model for badgers and Breeding and Wintering models for owls.

From the species distribution model and draft linkage design, generate transect locations for empirical testing of model results.

Species distribution models based on habitat characteristics at occurrence record locations were generated using Maxent for records of 53 badgers in observed in burrows, 57 badgers moving above ground (in transit), 346 wintering burrowing owls (records from September 16th through April 9th) and 78 breeding burrowing owls (April 10th through September 15th). Badger burrow presence was positively associated with grasslands, loam soils, and road density. Occurrence records of badgers in transit were associated with areas that are developed, closer to water, and in areas higher than the surrounding terrain, such as ridgelines and hilltops. Associations with road density and development may be related to locations where badgers are most visible, and where observers are most likely to be, rather than actual associations with habitat predictors. Burrowing owl models suggest that breeding owls are more likely to be present in lower elevations, which reflects what is observed on community science apps like eBird and iNaturalist. The model for wintering owls suggests that, in addition to low elevation sites, some mid elevation locations have higher probabilities of species presence than lower or high elevation areas. Owls were also associated with higher road densities, which again may indicate observational bias rather than actual biological associations. However, owls' preference for low elevation and flat areas may also be associated with areas more likely to have roads.

3.2.3 Species Distribution Model validation

We compiled new sightings of badgers between 2019-2021, although some of the information we received pre-dated 2019 (see Appendix C-1). We included burrow detections from our linkage camera and transect studies conducted for MROSD. In addition, we also received information from other studies and from researchers including, Pathways for Wildlife, The UC Santa Cruz Puma Project, Ken Hickman, and other incidental sightings.

We used ArcGIS 10.8 to extract model prediction values from our original Maxent species distribution badger Burrows model. The original model raw values were classified into 1) high (>33.3%), 2) medium (10.5%-33.3%), and 3) low (<10.5%) species presence likelihoods. The rankings were chosen based on the lowest Maxent model predicted threshold value at which a badger was observed (10.5%) and the threshold value which balanced the highest number of predicted presences and predicted absences (33.3%). We extracted the model-generated rankings for each new badger burrow observation to ascertain model performance.

3.2.4 Transect study

To validate the models, 1km-long transects were established at stratified randomly generated locations on MROSD properties. Transect length was selected to accommodate the smallest home ranges observed in badger telemetry studies in Monterey County (Quinn 2008), an area where the prey base of badgers is similar to the Peninsula in that it lacks California ground squirrels but supports an abundance of Botta's pocket gophers (*Thomomys bottae*) and voles (*Microtus californicus*). Transects cover a range of species presence probabilities categorized in three levels: 1) high (>33.3%), 2) medium (10.5%-33.3%), and 3) low (<10.5%). The rankings were chosen based on the lowest Maxent model predicted threshold value at which a badger was observed (10.5%) and the threshold value which balanced the highest number of predicted presences and predicted absences (33.3%).

While we originally selected transects to cover a range of model predicted low, medium and high rankings for badger burrow presence, field personnel adjusted transect locations significantly due to on the site conditions (e.g., to avoid steep slopes) or to only survey part of a transect (e.g., due to impenetrable vegetation). This reduced the amount of transect locations located in low and medium badger presence locations to 10.6% and 10.1%, respectively.

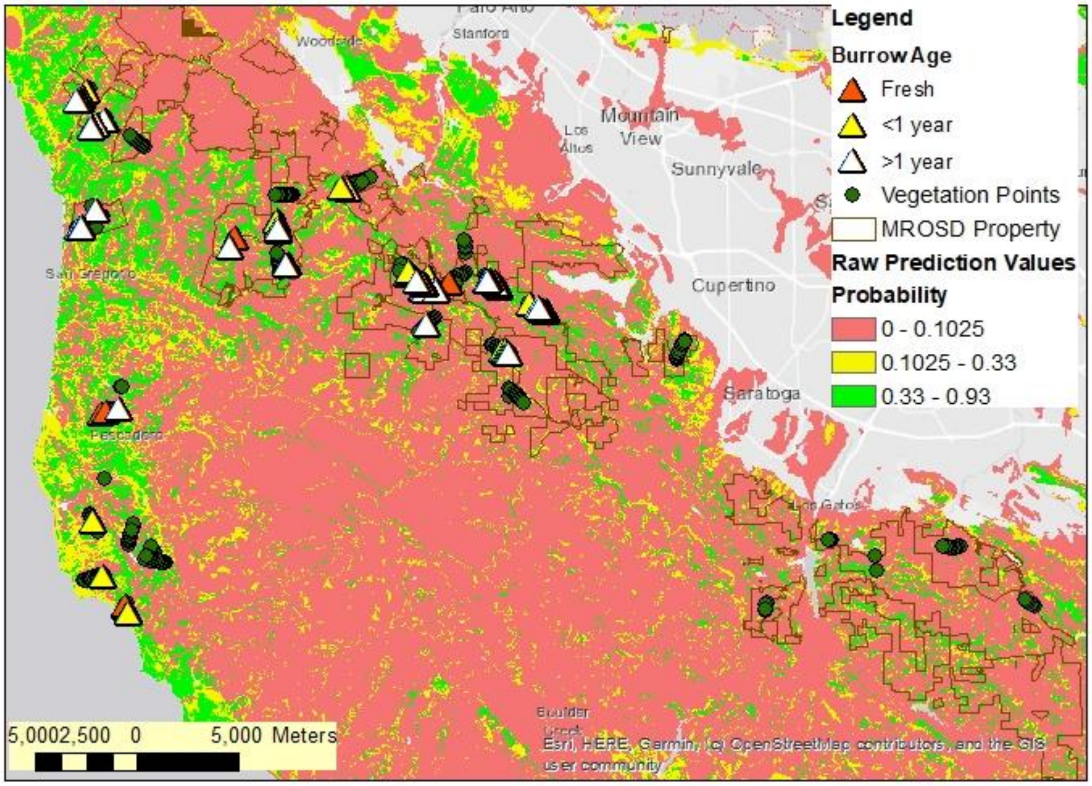


Figure 3-1. Map representation of vegetation points (where vegetation data was measured along the transects) and burrows observed during transects with MROSD lands outlined in brown and overlayed over original Maxent burrow model outputs (red to green represent low likelihood to high likelihood of badger presence).

We attempted 38 badger transects between 0 and 1000 meters in length from June 2019 through February 2021 (Section 4, Table 4-2). Zero meter transects occurred because field staff visited the site and subsequently decided they could not complete any of the transect. Some transects were surveyed two or three times if badgers were not observed during initial visits. Two to six observers walked each transect and surveyed 20-40 meters along either side of the transect for badger and burrowing owl sign or presence. Vegetation measurements were collected every 100 meters along the transect from the start to finish; thus if an entire transect was completed, there would be a total of 11 sets of vegetation measurements (Figure 3-1).

The vegetation measurements taken included using a Robel pole to measure visual obstruction (in decimeters), leaf litter depth (in cm), and max vegetation height (in dm). In addition, the observers recorded the coverage of shrubs and trees within 100 m radius as low (<10%), medium (10-50%), and high (>50%). If a burrow was observed, it was classified as fresh, < one year old, or > one year old. Burrow age was determined by the condition of tailings outside the burrow, the presence/absence of any vegetation growth, and signs of badger feces or hair. Generally, fresh burrows were 1-2 weeks old. Observers also recorded when they saw badger prey signs (e.g., gophers) and signs of cattle grazing in notes.

We completed 42 transect surveys (Table 3-1) for burrowing owls with two to six observers for each survey; some of these also simultaneously served as badger surveys. During the surveys, we took the same vegetation measurements as described in the previous paragraph. If an owl was observed, we noted whether it was near or in a badger burrow.

Table 3-1. Summary of Burrowing Owl transects

Date	Site	Transect #	Observers	# volunteers
Summer 2019				
6/24/2019	Russian Ridge OSP	11	2	1
	Skyline Ridge OSP	5	2	1
6/25/2019	Windy Hill OSP	4	2	1
	Monte Bello OSP	16	2	1
6/27/2019	Purisima Creek Redwoods OSP (October Farm)	1*	3	0
	Tunitas Creek Redwoods OSP (Toto Ranch)	23*	3	0
7/2/2019	La Honda Creek OSP	6*	2	0
	La Honda Creek OSP	8*	2	0
7/18/2019	Long Ridge OSP	21*	3	0
	Long Ridge OSP	20*	3	0
8/2/2019	Cloverdale Coastal Ranches	31*	2	0
	Cloverdale Coastal Ranches	30*	2	0
	Purisima Creek Redwoods OSP (Elkus Ranch)	2*	2	0
Winter 2019-2020				
1/17/2020	Russian Ridge	11	3	2
	Russian Ridge	12	2	1
1/18/20201	La Honda Creek OSP	8*	5	3
	La Honda Creek OSP	9*	5	3
1/20/2020	Monte Bello	16	6	4
	Monte Bello	17	6	4
1/25/2020	Tunitas Creek Redwoods OSP (Toto Ranch)	23*	5	3
	Tunitas Creek Redwoods OSP (Toto Ranch)	23a	5	3
2/1/2020	Purisima Creek Redwoods OSP (October Farm)	1*	6	4
	Purisima Creek Redwoods OSP (Elkus Ranch)	2*	6	4
2/5/2020	TomKat Ranch	27*	3	0
2/5/2020	Cloverdale Coastal Ranches	28	2	0
2/5/2020	Cloverdale Coastal Ranches	32	2	0
Summer 2020				
6/1/2020	La Honda Creek OSP	8	1	0
	La Honda Creek OSP	9	1	0
6/4/2020	Cloverdale Coastal Ranches	29	1	0
	Cloverdale Coastal Ranches	30	1	0
	Windy Hill OSP	4	1	0
10/16/2020	Los Trancos OSP	19*	1	0
	Long Ridge	21*	1	0
Winter 2020-2021				
12/22/2020	Russian Ridge OSP	41	2	1
	Russian Ridge OSP	12	2	1
12/30/2020	La Honda Creek OSP	9	2	1

Date	Site	Transect #	Observers	# volunteers
	La Honda Creek OSP	8	2	1
2/11/2021	Sierra Azul OSP (Cherry Springs)	48*	2	0
2/18/2021	Cloverdale Coastal Ranches	30*	2	0
	Cloverdale Coastal Ranches	29*	2	0
2/25/2021	Tunitas Creek Redwoods OSP (Toto Ranch)	23*	2	0
3/26/2021	Cloverdale Coastal Ranches	32	2	0

In addition to the transect surveys, we recruited volunteers to help look for owls and recent burrows in selected Midpen preserves. These volunteers surveyed an additional 27 miles of trails on MROSD property each month from October 2020 through March 2021 (See Appendix Table C-2). We added this volunteer effort for several reasons. First, based on the recent owl records we compiled, the number of owls on the transects was likely very low; more people searching for owls should improve our ability to find them. Second, during the first year of the study we had learned that badger burrows often do not remain usable for owls for very long. Badgers dig many burrows and move frequently so the best way to find recent burrows would be to visit an area repeatedly. Each volunteer selected a trail to hike monthly while searching for owls and badger burrows and reported any fresh burrows for us to investigate

3.2.5 Transect Study Statistics

We averaged vegetation measurements taken within 100 meters from any fresh badger burrows to create a set of habitat variables associated with each burrow (average leaf litter, average max vegetation height, average visual obstruction, and shrub and tree coverage; Figure 3-1). We also noted whether grazing and prey species were observed on each transect since those were not always recorded at each vegetation point. We then randomly selected five times as many points that were at least 200m apart from each other and >150m away from any burrows and calculated the same set of variables associated with each of these points.

We ran a logistic regression model to identify whether any vegetation and habitat measurements were correlated with burrow presence using the generalized linear model (glm) function in R. We started with single variable models, and then picked the best single variable model to add additional variables. We stopped adding variables when the Akaike Information Criterion value did not improve by 2 points, and we compared models using ANOVA. We also ran a glm comparing vegetation characteristics at fresh badger burrows compared with vegetation measurements captured on the same transect but >200m from burrows.

3.3 Results

3.3.1 Species Distribution Model validation

We obtained an additional 221 new badger location points, of which 190 were for badger burrows (Figure 3-2). 186 out of 190 (98.9%) badger burrow locations were located in areas classified as high presence possibility by the Maxent model (Table S1). We did not compare badger in transit (of which 7/31 were roadkill specimen) to our original transit model as we found at the time that the model was biased towards road kills and not necessarily representative of habitat selection by transiting badgers.

We collected 13 new observations of owls between 2019 and 2021 (Figure 2), but only one was observed during a transect survey (Table S2). All but one of the new records were of owls; the final record was of feathers suggesting predation.

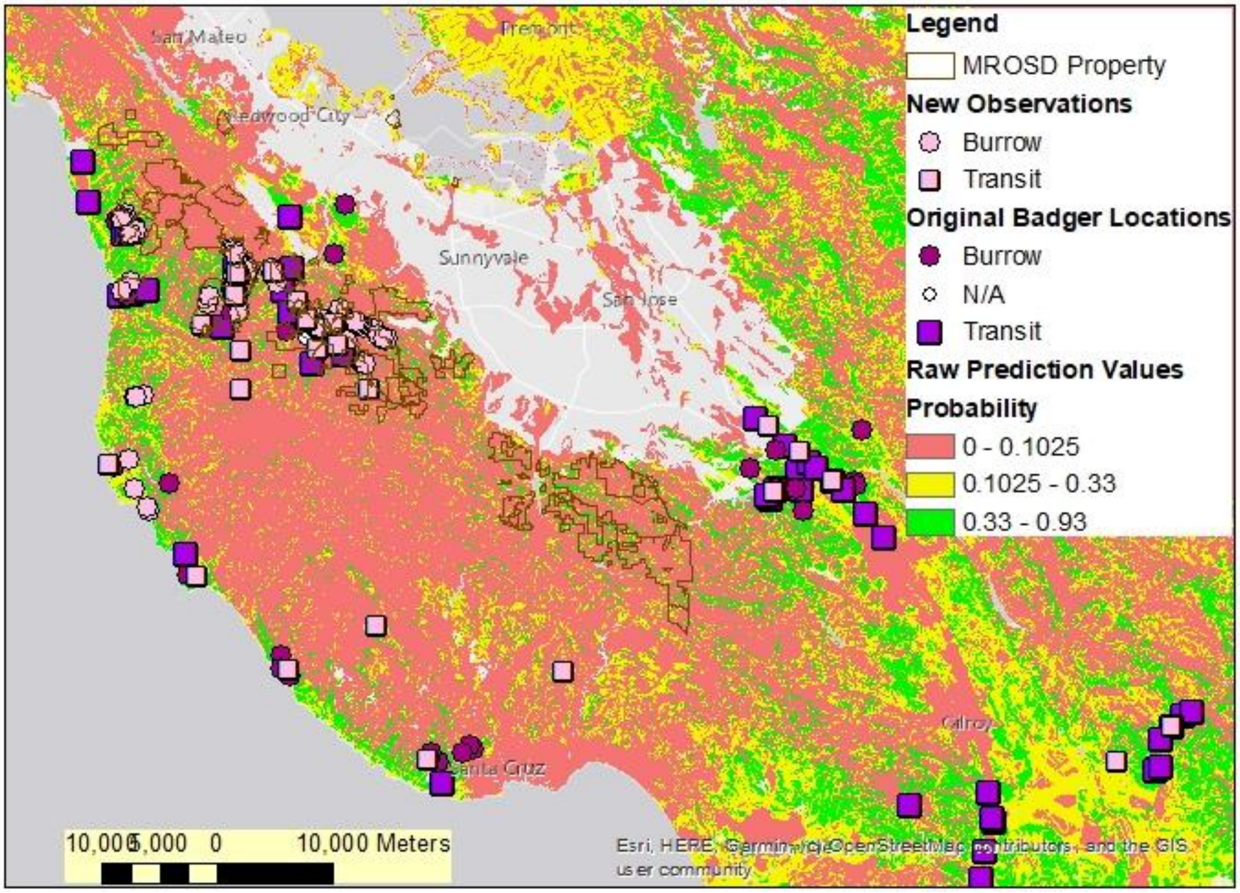


Figure 3-2. New and old badger observations collected during the first year of this project (2019) and for this report (2019-2021) with MROSD lands outlined in brown and overlayed over original Maxent burrow model outputs (red to green represent low likelihood to high likelihood of badger presence).

3.3.2 Transect Study

We documented 112 badger burrows or burrow complexes (e.g., several shallow digs of similar age and located within 10 meters of each other) during our transect surveys (Figure 3-1), of which 29 were fresh (e.g., there were fresh tailings). 107 or 95.5% of the burrows were found in areas classified by the original Burrows model as high or medium likelihood of badger presence. We extracted 20 fresh burrow locations that were associated with unique vegetation measurements (i.e., some burrows were close in proximity) and 98 randomly selected vegetation points.

Of the variables we tested, we found that the best model included the grazing (estimate= -1.974, SE = 0.778, p=0.0112) and the tree cover variable. Grazing was negatively associated with badger presence, and including the tree cover variable improved model fit significantly (deviance =8.14, p=0.017). Low tree cover in this case had a positive relationship with badger presence, in contrast to medium and high tree cover. In fact, all fresh badger burrows included in this model were associated with low-tree cover vegetation points. However, the overall deviance explained by the top model was only 15%, which means that the model variables only minimally contribute to explaining badger presence.

Because large portions of the study area (e.g., the transects) did not have badgers but were classified as suitable habitat by the original model, we decided to further examine a subset of our data to see if we could identify any vegetation differences in parts of the same transects that had badgers versus areas that did not. We used logistic regression to compare fresh badger burrow habitat characteristics with those found in the same transects but without badger presence and used a logistic regression to test whether any habitat characteristics were significantly predictive. We did not find that any of the vegetation measurements were significantly related to badger presence.

The only owl we observed during transects was seen at Russian Ridge Open Space Preserve (OSP) on 12/22/2020 on transect 41. The only owl observed by volunteers was likely the same one seen during the transect survey at Russian Ridge. The owl was observed using an old badger burrow, confirming that these burrows provide habitat and shelter for owls. Based on the records we collected, our study found the first recorded sighting of owls in Sierra Azul and Tunitas Creek OSPs. In addition, we found that owls continued to use La Honda, Russian Ridge and Windy Hill OSPs. Our survey results and compiled historical records confirmed that non-breeding owls have consistently used MROSD preserves at a low level. All owls were observed between September and March, which indicates that these were likely wintering owls and not breeding owls. None of the owls observed in the MROSD preserves were banded, which is further evidence that these are not birds from the local breeding population but migrants from more northern breeding populations. Several owls were also sighted using badger burrows of varying ages at different preserves.

We collected 13 new observations of owls between 2019 and 2021 (Figure 3-3), but only one was observed during a transect survey (Table 3-2). All but one of the new records were of owls; the final record was of feathers suggesting predation.

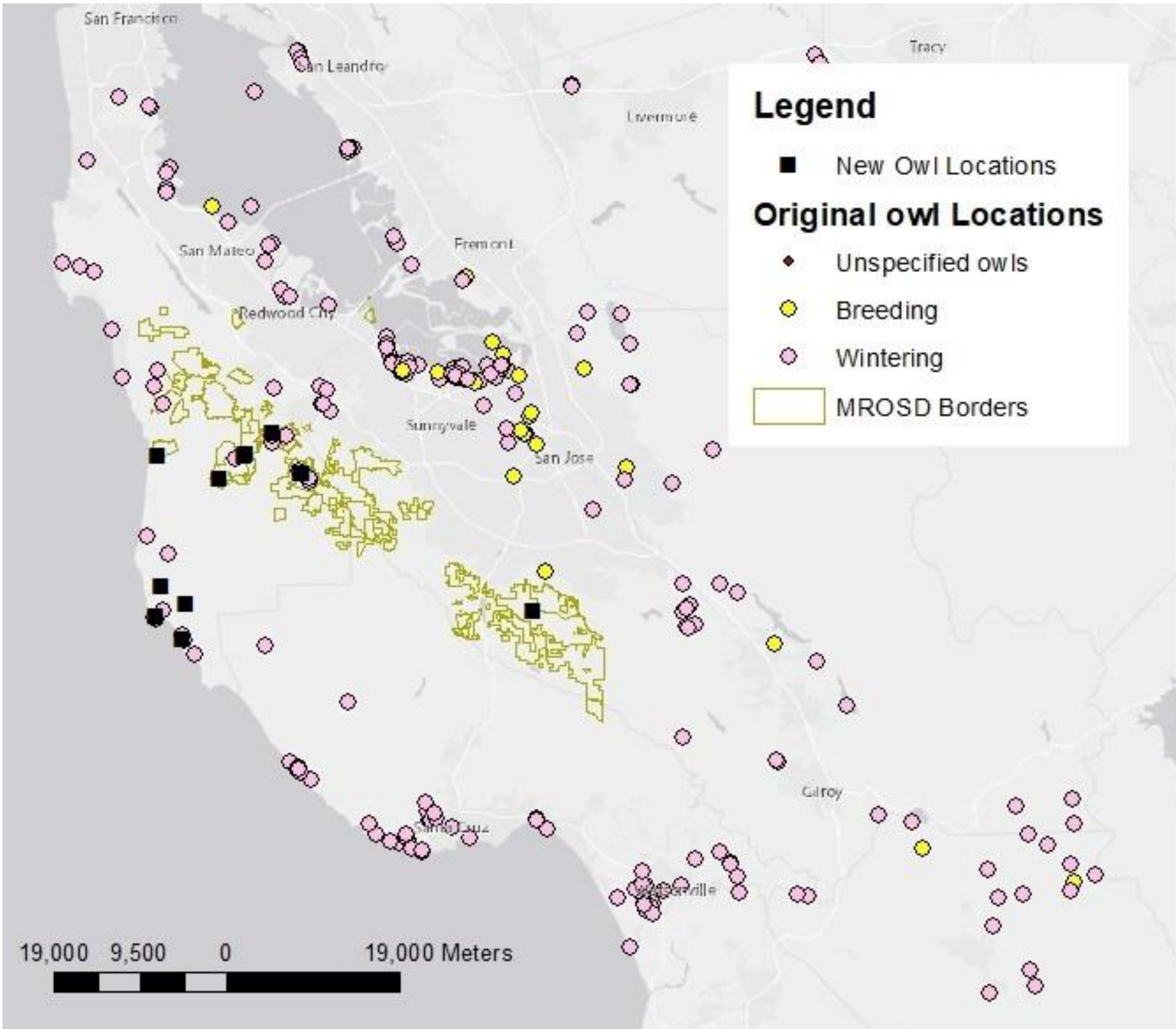


Figure 3-3. A map of new Burrowing Owl sightings (squares) and the original owl records (in yellow for breeding and pink for wintering birds) with MROSD boundaries in brown.

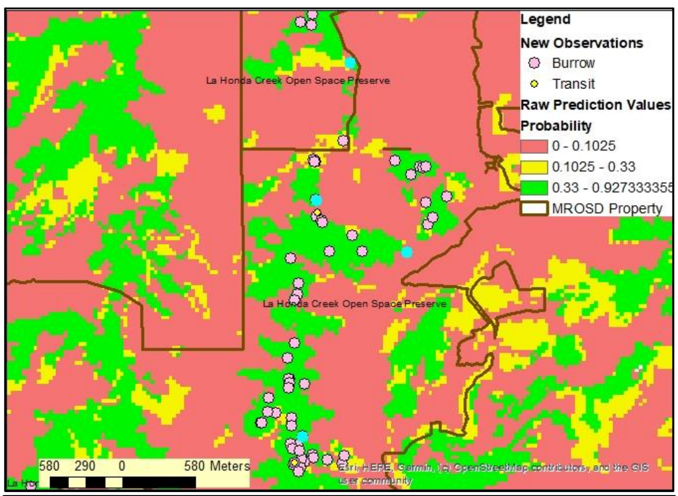
Table 3-2: Summary of all Burrowing Owl sightings

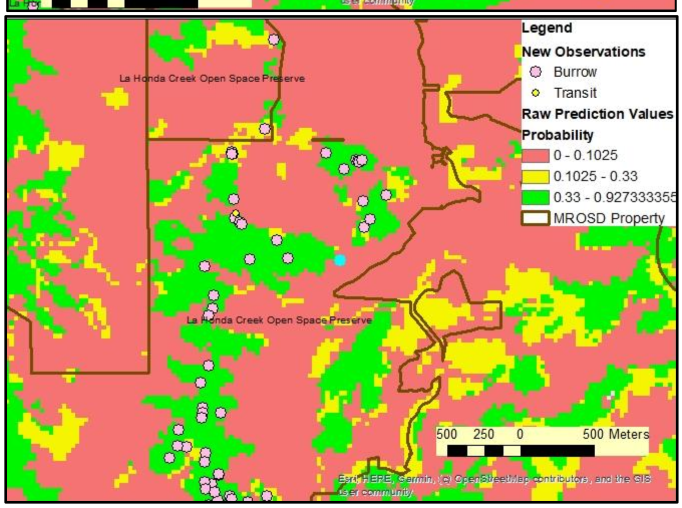
Date	Record ID	Location	Observation Type	Observers	East	North	Notes
12/16/2019	CCR01	Cloverdale Coastal Ranches	Camera trap	Ahiga Snyder & Tanya Diamond	557096.8	4117052	no burrows, but erosion gullies
10/17/2020	CCR02	Cloverdale Coastal Ranches	Direct observation and photo	Megan Derhammer (POST)	554432.1	4118902	foraging at night, burrow availability not known

Date	Record ID	Location	Observation Type	Observers	East	North	Notes
12/9/2020	LH01	La Honda Creek OSP	Camera trap (LAH3)	Ken Hickman	560764.8	4130783	Foraging at night, no burrows known in the area, not close to a transect
10/20/2020	RR01	Russian Ridge OSP	Direct observation (perched on camera)	Howard Higley (SFBBO volunteer) and PFW	569829	4131251	10/20/2020 and 11/16/2020; camera trap and direct observation; PFW; Howard Higley; was in old badger burrow on transect 41
11/10/2020	RR02	Russian Ridge OSP	BUOW feathers suggesting predation	Ahiga Snyder & Tanya Diamond	569775.9	4131240	possibly a second owl at Russian Ridge that was killed
12/22/2020	RR03	Russian Ridge OSP	transect survey	Dan Wenny	569945.9	4131259	at old badger burrow on transect 41; probably same individual as at RR01, 115 meters away
3/8/2021	LH02	La Honda Creek OSP	Direct observation and photo	Ken Hickman	563614.7	4133426	on transect 8; fairly fresh burrow but using multiple burrows
3/22/2021	LH03	La Honda Creek OSP	Direct observation	Ken Hickman	563578.2	4133332	probably same owl as earlier in month
12/24/2019	PP01	Pigeon Point	eBird records	Observed on 5 dates by 4 different parties	553749.9	4115688	12/24/2019-1/4/2020 approximate location; likely using old badger burrows
2/24/2020	WS01	Audubon Williams Sisters Ranch	iNaturalist	Garth Harwood	566520.4	4135722	approximate, probable badger burrow
12/3/2020	GC01	Gazos Creek	iNaturalist	Garth Harwood	556748.1	4113100	apparently foraging near the beach
9/21/2021	SA01	Sierra Azul	Camera trap	Ken Hickman	595333.9	4116206	clearing among chaparral
12/3/2021	TC01	Tunitas Creek Toto Ranch	Direct observation and photo	Unknown (ask Karine)	554045.3	4133250	approximate location

3.4 Discussion

Since almost all new badger burrow observations occurred in areas we identified as medium or high probability of badger presence based on our original Maxent Burrows distribution model, we found that the original model accurately identified badger habitat. We expect that the original factors identified as important, vegetation type, soil type, and road density within 500 meters, still are the best predictors of badger presence since many of the new badger locations were found in similar areas to the previously documented badger locations (Figure 3-2). Of the 190 new badger burrow locations identified, only 9 occurred in low badger probability areas predicted by the Burrows model. A closer examination of these areas show that they are all adjacent to high probability locations (Figure 3-4). Four of the burrows in Russian Ridge were located spatially close together and found on the same day, suggesting they might have been made by the same animal. Thus, badgers may go into more marginal habitats if they are located close to preferred habitats. Since the raster cells sizes in the predictive model are 30m by 30m, that scale is likely much smaller than the scale at which a badger would use to assess habitat quality. Instead, badgers may consider the overall quality of an area and not be deterred by small sections of marginal or poor habitat located adjacent to suitable habitat areas.





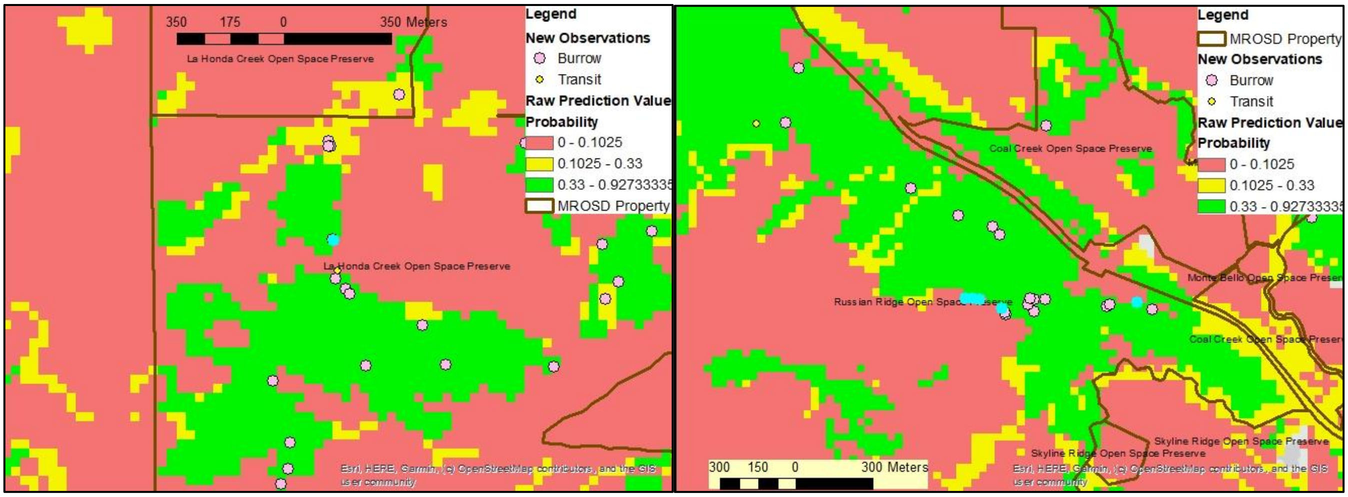


Figure 3-4. Close up depictions of 9 new badger burrow locations (light pink circles) located in raster cells that the original Maxent Burrows model did not predict as high or medium presence likelihood (yellow and green). The burrow locations of interest are highlighted in teal. Low likelihood of badger presence is represented by red and yellow, respectively.

While it is outside the scope of this current project, we suggest considering building a new Maxent distribution model in the future to further refine how additional habitat variables impact badger burrow presence. This would require identifying more specific habitat variables and GIS layers (e.g., soil moisture level, land use management) to incorporate into a new Maxent model. We could also generate a new Maxent model focused on linkage conditions that excludes roadkill locations so as to avoid biases towards roads. Currently, there are not enough data points (after excluding roadkill locations) to build a robust badger transit Maxent model. Since the data captured during this study period of transiting badgers were almost all obtained by linkage cameras, they would bias any habitat models because the cameras were placed in locations where badgers were predicted to experience fewer barriers to transit. Thus, to build a more robust transiting model, a future study should use more randomized placement of cameras to ensure that representative badger movement across different habitat variables are captured.

Although we tried to validate the model by designing transects which encompassed less optimal badger habitats, these areas also tended to have field conditions that made them difficult to survey safely. Many transects were adjusted by field staff before visiting the field to avoid steep slopes and some transects were shortened during the surveys to avoid dense shrub conditions or other difficult conditions (see transects as represented by vegetation measurement points on Figure 3-1). In the end, the vegetation points measured along transects were mostly in suitable badger habitat as predicted by the Burrows model (79.3%;), and that is possibly why we did not identify many significant vegetation factors (e.g., leaf litter depth, vegetation height, and vegetation structure) differentiating burrow versus non burrow sites. Thus, it appears we confirmed that we could find badgers in high habitat value places predicted by the original Burrows model. It also suggests that badgers are not too particular with vegetation conditions, vegetation height, and will dig burrows in areas with taller or denser vegetation or some shrub and tree cover.

It was surprising that we found a negative relationship between grazing and badgers, but that is likely a function of small sample sizes since only 10 transects featured fresh burrows and only two of those transects were recorded as grazed. Also, due to low data points and lack of detailed information, we did not assess differences in the degree of grazing (e.g., heavy versus light), which can also affect whether badgers will use the area. If grazing is removed as a variable, then average leaf litter, prey presence, and tree density were other variables that were significantly correlated with badger presence. Prey were relatively abundant across many transects. Most prey species were gophers, but California ground squirrels were found in Transects 6, 12, 16, 32, and 36 (La Honda, Russian Ridge, Montbello, CR and Windy Hill OSPs, respectively).

An area with limited badger presence was along the Pacific Coast. There are large, unsurveyed areas along the transition between the Santa Cruz Mountains and the ocean (e.g., between Tunitas Creek and Cloverdale Ranch along the coast, south of Cloverdale Ranch along the coast, and south of Long Ridge, Russian Ridge, and Skyline Ridge OSPs and between the coast and Highway 17, and it is possible that badgers or additional linkages could be found with more extensive surveys. For example, much of the Southern Santa Cruz Mountains was unsurveyed, but there's also a large amount of inhospitable terrain for badgers. Thus, a future study could examine whether badgers occur in the southern part of the Santa Cruz Mountains or if it's mostly impermeable to badgers and that badger movement south to Santa Cruz from the Skyline, Russian, and Long Ridge OSPs occurs primarily along the Pacific coast.

During the course of the study, we also received new records of badgers in transit (see Table S-). Since these are a combination of road kill data and data captured by cameras targeting linkages, they are more difficult to interpret as the methods for observation are very different. We do not expect that the road kill data will offer any refinement for our original badger transit models because of the inherent bias toward roads. However, the linkage camera data was used heavily to better understand movement between MROSD preserves. For specific recommendations on movement corridors for badgers based on these new records, see the Linkage Assessment section (section 4 of this report). For section 3 of the report, we will limit our recommendations to those pertaining to burrow sites.

Burrowing owls (9 of 13 observations in Table S1) continued to use MROSD preserves as wintering grounds (Figure 3-3). We found clear evidence that owls used badger burrows as well as locations without burrows (e.g., Cloverdale Coastal Ranches) or without badgers (e.g., Sierra Azul). Historically, there are records of wintering (e.g., Oct-March observations) owls in the Santa Cruz Mountains, so it's likely that this area has been supporting these populations for many decades. In the late 1980s, the Humane Society released one or two owls in Russian Ridge Open Space Preserve (email from MROSD staff). It is unlikely that this one-time release affected the winter owl population in the Santa Cruz Mountains (e.g., by attracting new owls) because of the earlier records from the area as well as records at similar elevations in the Diablo Range where no known releases occurred. Also, since the releases occurred 30-40 years prior, it's unlikely any impact they had persisted into the study period (2019-2021)

While breeding owls have precipitously declined in the South Bay Area, wintering owls continue to use the region. It is likely that the owls using MROSD areas in winter are long-distance migrants from populations to the north rather than dispersants from the bay-area breeding populations. Between May 2015 and August 2021, 425 owls in the Bay Area breeding areas have been banded by Lynne Trulio and colleagues. Although the banded owls do move among the breeding areas, none of the local banded owls have ever been observed in MROSD preserves or other non-breeding areas. Thus, our findings demonstrate that MROSD lands are important for supporting wintering owl populations but do not currently host any breeding owls.

The distinction that the owls in MROSD preserves are likely overwintering migrants raises an important difference in owl habitat use between breeding and nonbreeding seasons. While they use burrows in both seasons, the owls do not need a natal chamber in the nonbreeding season. A simple tunnel or similar cavity will suffice. In other areas, wintering burrowing owls have been recorded using rubble piles, pipes, and even dense vegetation instead of burrows (Poulin et al. 2020). This difference in habitat use explains why wintering owls can sometimes be found in areas without burrows. For example, two recent records of burrowing owls from Cloverdale Coastal Ranches (Table S1) are from areas where we did not find any badgers or suitable burrows but extensive erosion gullies were present and probably used by the owls.

Since many of these preserves are not occupied by badgers, MROSD managers may consider creating artificial holes and burrows to attract wintering owls if their aim is to serve more birds.

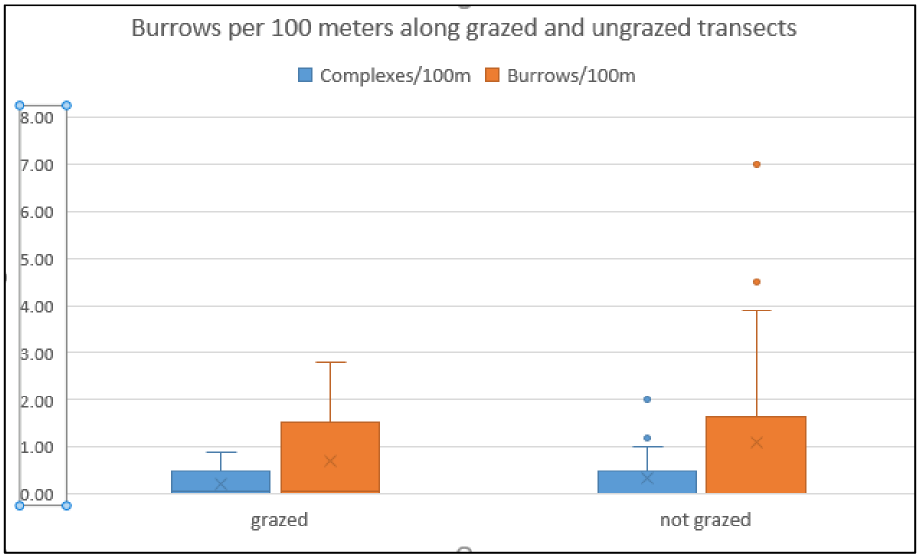


Figure 3-5. A box and whiskers plot of badger burrows and burrow complexes per 100m along transects that were grazed and ungrazed.

3.5 Acknowledgements

Thanks to these volunteers for help with the transect surveys: Amelia Black, Sean Chandler, Pete Dunten, Sidney Dunten, Wendy Gibbons, Cyrille Jeantet, Sebastian Jeantet, Elaine Lea-Chou, Brian Nissen, Ellie Resendiz, Susan Salkeld, Laura Sanborn, and Li Zhang. Thank you to these volunteers for conducting owl trail surveys: Howard Higley, Sirena Lao, Wendy Gibbons, Gabbie Burns, Angelo DiNardi, Laura Coatney, Susan Salkeld, Ronnie Eaton, Cathy Priest, Leigh Glerum, and Roel Funke. Thank you to Karine Tokatlian and other MROSD staff who helped us coordinate access for our surveys, advertise for volunteers, and review our reports.

3.6 References

American Badger and Burrowing Owl Habitat Suitability Report. 2019. Produced by Yiwei Wang of the San Francisco Bay Bird Observatory, Jessie Quinn, and Tanya Diamond of Pathways for Wildlife for the Midpeninsula Regional Open Space District.

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4.0 Introduction

Section 4.1 Background & Purpose

The Midpeninsula Regional Open Space District (MROSD) is seeking to improve the management of American badger (*Taxidea taxus*) and burrowing owls (*Athene cunicularia*, owls) throughout their Open Space Preserves (preserves). To evaluate and implement science-based management, the District needs to better understand where these species occur within the preserves, the habitat characteristics that best predict their occurrence, information about the existing populations of each species, and the relationship between the species based on their mutual association with grassland habitats and on owl dependence on badger burrows.

MROSD awarded a contract to Pathways for Wildlife and the San Francisco Bay Bird Observatory to construct a species distribution model to assess how habitat characteristics were associated with existing badger and burrowing owl location data throughout the San Francisco Bay Area. This model resulted in a predictive layer reflecting a range of predictive habitats for badgers and burrowing owls, ranked from high to low.

A cost surface model was also created that reclassified habitat characteristics in association with the cost of a badger to travel through the landscape. This model was developed by reclassifying habitat variables to reflect a range of highly suitable habitat and low cost for movement for badgers to poor habitat and high movement costs for badger within the study area. For example, highly suitable habitat for badgers consists of grasslands without roads or low use roads, while unsuitable habitat consists of dense redwood habitats with highways bisecting the habitat. Fair and moderate habitat suitability were also included in this range. This model was then used to develop a habitat linkage design connecting various preserves and other properties that consisted of highly suitable habitat for badgers.

To test the models, field-based surveys were conducted for badgers in areas of high, medium, and low probabilities of predicted species presence. Field surveys were also designed to identify other factors that may affect badger or burrowing owl presence in the preserves. Potential linkages identified in the linkage design were evaluated by overlaying the results of two years of badger surveys, camera data, roadkill data, and the cost surface and predictive model.

4.2 Cost Surface Development and Linkage Analysis

4.2.1 Methods Overview

The habitat characteristics associated with known occurrences of badgers on the Peninsula, including San Mateo, Santa Clara, and Santa Cruz Counties were used to develop a linkage model for badgers.

Model and transect development included the following steps:

1. Compilation of a comprehensive database of badger occurrence records from a variety of sources.
2. Use of occurrence records and GIS data layers to create a District-wide and beyond linkage model for badgers.
3. From the species distribution model and draft linkage design, generation of transect and camera locations for empirical testing of model results.

4.2.2 Baseline Database Compilation

To construct a database of badger occurrence records, a comprehensive email inquiry was conducted during January 2019, immediately after the project was set to proceed. The data inquiry included requests for information about badger sightings, roadkill data, photos, and burrow locations, along with the year of the occurrence, specific geographic coordinates (if possible), and any other accompanying information that contributors would be interested in sharing. The California Natural Diversity Database (CNDDB, CDFW 2019), eBird (eBird 2019), iNaturalist (iNaturalist 2019), and museum collection databases were also queried for online records of both species. MROSD and Pathways for Wildlife also provided records. Records obtained were entered into a database.

The compiled records from various studies before conducting the field work for this study resulted in **127 records** for the counties of Santa Clara, San Mateo, and Santa Cruz Counties (Appendix A). Out of the 127 badger occurrences, there were 53 burrow records, including photos of badgers at burrows, 27 roadkill locations, 26 live sightings, 15 camera records, and 6 records without a description of the occurrence type.

Badger surveys were then conducted for two years from 2019-2021. Field work entailed transect surveys, camera work, and collecting genetic samples.

Field work resulted in another **248 records**, resulting in a total of **375 records** which were used to validate the linkage model (Appendix B).

4.2.3 Cost Surface Development & Habitat Linkage Analysis

Habitat suitability and cost surface models were developed for badgers and included an analysis of habitat variables. These habitat variables were in GIS format and included vegetation, habitat types, soil, hydrology, land use, slope, and roads. Each habitat variable was reclassified to reflect the suitability of a habitat feature for badger presence and movement using ArcMap 10.2. This resulted in a model which reflected a range of habitats from highly suitable (low cost for movement) to poor habitat (high movement costs).

A cost surface layer is a raster grid in which the value in each cell is the cost of movement through the landscape for a given species. "Cost" in this sense is the effort required for an animal to travel through a landscape. Any path through space will accumulate these costs, and routes with high associated costs are less favorable than routes with a lower cost associated with it.

The cost for each cell is developed by the cell's characteristics, such as land cover or housing density, combined with species-specific landscape resistance models. For example, a cell that has high use roads or high-density housing will have a higher cost for movement for the animal to travel through that cell within the grid. A cell that contains highly suitable habitat and open space for a particular focal species will have a lower cost of movement for traveling through that cell. As animals move away from specific core areas, a cost-weighted distance analyses produces a map of total movement cost accumulated. Core areas are defined as habitat that is most preferred by a species and consists of habitat that provides resources such as food and water, breeding, and dispersal habitat for that particular species (Corridor Ecology 2012). Habitat layers include vegetation, a digital elevation model (DEM), soil, and hydrology (Table 1). The vegetation classes used were from the CA Wildlife Habitat Relationships (CWHR) data. The hydrology layer included creeks, rivers, and water bodies. Soil layers included soil type and texture, for example "gravelly loam" or "silty sand". The digital elevation model (DEM) was used to generate a slope layer.

Land use types included human development, roads, agricultural land use, protected lands, and lands with conservation easements (Table 1). Development within the land use layer included categories from low to high intensity development. Urban areas were used because badgers are highly sensitive to human development and have a low probability of occurrence in small, isolated habitat patches (Crooks 2002, Lay 2008).

Roads were classified by road type, for example, highways or rural roads. Roads were included because they can act as barriers to badger movement (Messick & Hornocker 1981) and are one of the leading causes of badger mortality (Williams 1986, Hoodicoff 2003).

A vegetation layer was used because badgers are considered grassland specialists (Lindzey 1982). Soil characteristics were included because badgers are fossorial animals and soil type may directly affect their distribution or distribution of their prey, which are also typically burrowing animals such as California ground squirrels (*Otospermophilus beecheyi*) and Botta's pocket gophers (*Thomomys bottae*) (Long 1983) and voles (*Microtus californicus*). A slope layer was also integrated into the model, as slope may influence burrowing locations (Apps et al. 2002).

Layers were clipped to the extent of the study area. Polyline layers, such as roads, were converted to raster layers to enable reclassification from the original raster value to a movement cost value. Hydrology layers for the separate counties were joined and converted to raster layers. Soil layers were joined based on soil properties.

GIS Layer	Source	Format	Raster cell/ minimum map unit size	Data Source
Digital Elevation Model (DEM)	USGS	Raster	10 meters	https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services
Vegetation fveg15_1_2014	CalFire	Raster	30 meters	http://frap.fire.ca.gov/data/frapgisdata-sw-fveg_download
National Land Cover Data 2016	MRLC Consortium	Raster	30 meters	https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects

GIS Layer	Source	Format	Raster cell/ minimum map unit size	Data Source
National Hydrography	USGS	Polyline	10 meters	https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset?qt-science_support_page_related_con=0#qt-science_support_page_related_con
Soil Survey Geographic (gSSURGO) Database	USDA - NRCS	Raster	10 meters	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053628
Roads: Tiger files	U.S. Census Bureau	Polyline	10 meters	https://www.census.gov/cgi-bin/geo/shapefiles/index.php
CA Protected Lands Database_2018a	GreenInfo Network	Polygon	Less than 1 acre	https://www.calands.org/
CA Conservation Easement Database_2018	GreenInfo Network	Polygon	Less than 1 acre	https://www.calands.org/

Table 1. GIS layers and attribute information used in mapping and analyses.

4.2.4 Draft Linkage Designs

i. Linkage width and design

Jessie Quinn, through her thesis work in radio tracking badgers at Fort Ord National Monument in Monterey County, found that the average home range size for badgers is 7.75km^2 (Quinn 2008). Linkage widths were truncated to half the average home range size of a badger, 4.0km^{2,} as badgers are considered corridor dwellers and need to have the ability to reside and dig burrows within the linkages (Majka, D. et al. 2007). However, these are cut-off widths, and the linkages greatly vary in width size due to bottleneck areas or constraints in suitable habitat. Since the landscape is fairly fragmented in terms of suitable habitat for badgers, many of the linkage widths are narrower than the average home range size. In locations where the linkages ran through more than enough highly suitable habitat, the resulting linkages had appropriately large widths.

The Linkage Pathway analyses resulted in a network design (Figure 1). MROSD Preserves and other protected lands that had badger records and highly suitable habitat were chosen as cores to run the analysis with. Core areas are defined as habitat that is most preferred by a species and consists of habitat that provides resources such as food and water, breeding, and dispersal habitat for that particular species (Corridor Ecology 2012). This resulted in several networks of linkage designs, including a central network of draft linkages between the MROSD preserves, a linkage running from north of San Mateo down the coast to Santa Cruz, and a linkage running from the central network east over to Coyote Valley.

The color coding within the draft linkage designs includes the linkage buffers being outlined in orange, while the core of the linkage is color coded as lime green within the buffers. Providing buffers are important because in locations where the linkages are constrained due to habitat fragmentation, buffers can provide the necessary space for facilitating badger movement through sensitive and /or impacted areas by human developments. Badger records are shown as black dots. The color scheme for the cost surface map (Figure 1) is as follows:

For Figure 1 and the rest of the cost surface maps in the report, the color coding is as follows:

Green = Highly suitable habitat and low movement costs.
Yellow = Fairly suitable habitat and moderate movement costs.
Blue = Poor habitat and higher costs for movement.
Red = Unsuitable habitat for movement and very high movement costs.

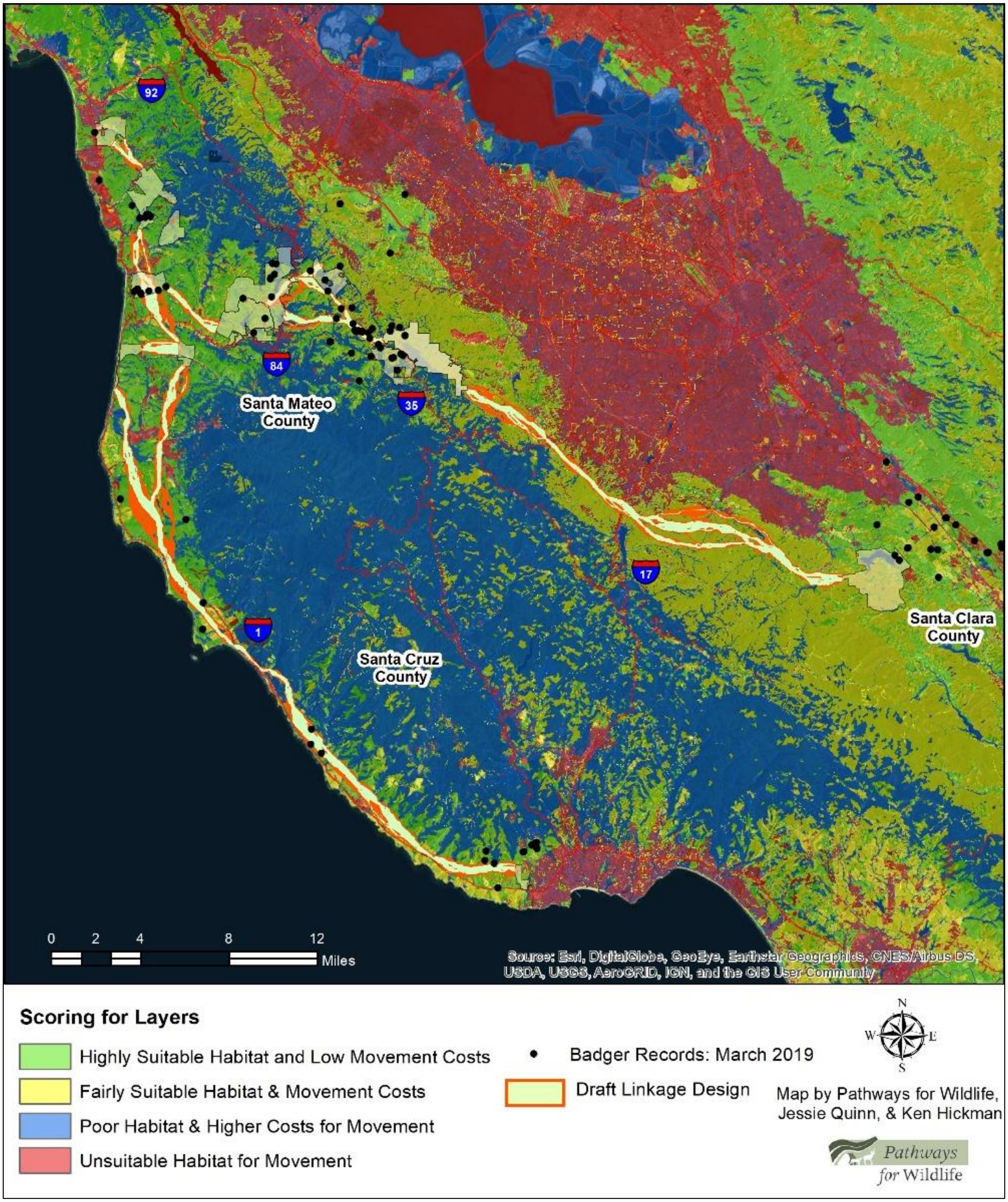


Figure 1. 2019 American badger: draft cost-surface layer and draft linkage design.

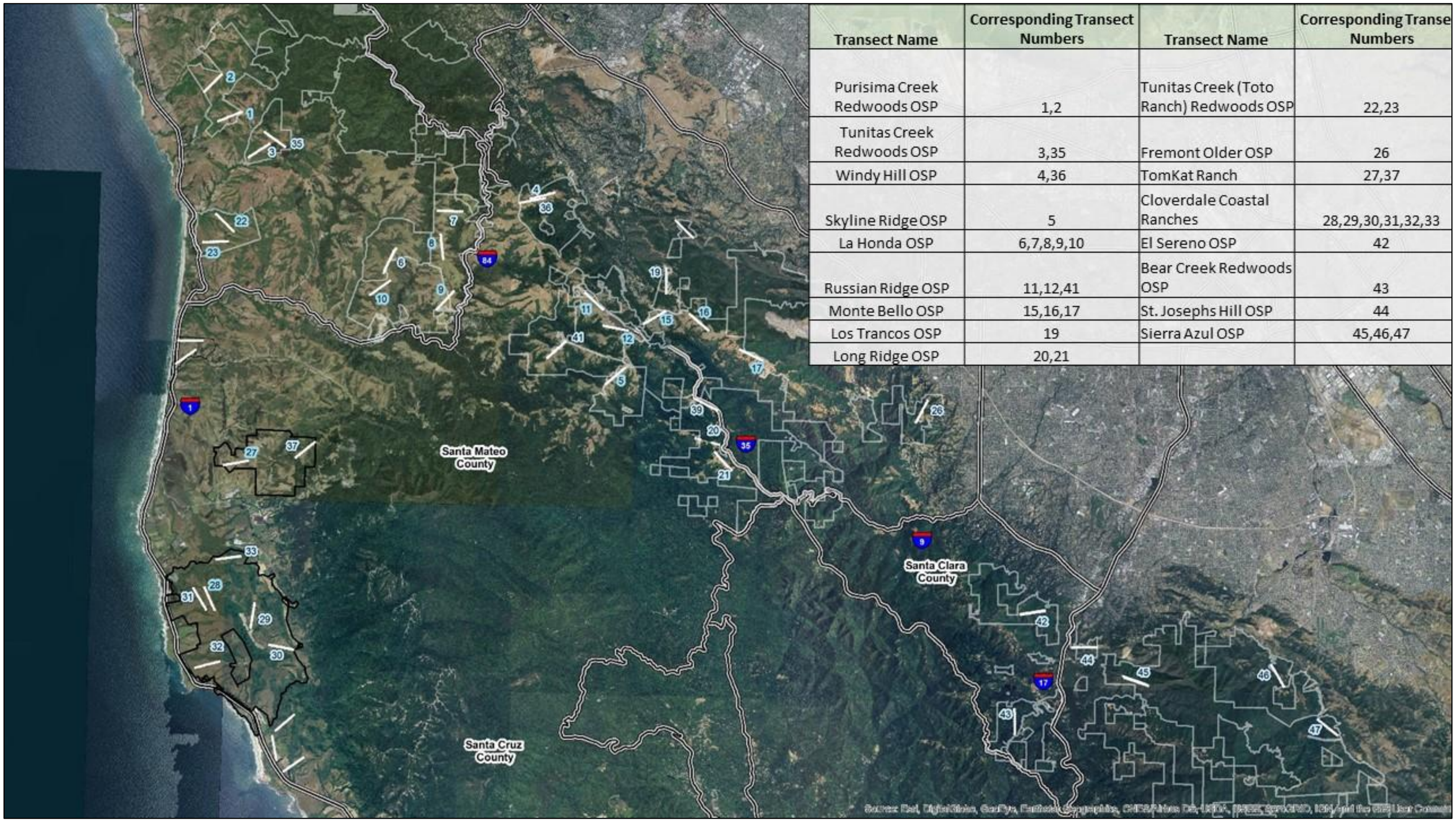
4.3 Data Collection: Transects and Linkage Cameras

4.3.1 Badger surveys: Transects

One kilometer transects were set up using the predictive model (Figure 2). Transects were set up within a range of high to low probability of badger occurrence in order to test the model across an array of habitat. Transect searches for badgers were conducted during the day in Spring/Summer (April-June), Fall (August-October) and Winter (November-January) beginning in August 2019 for six seasons. During badger transect surveys, two or more surveyors walked along transects and documented sign of badger activity, type (foraging digs vs. den burrows), and estimated age (how old the activity is) within approximately 10 meters on either side of the transect.

If a transect did not yield any sign of badger presence, it was repeated during the following season until: 1) badger sign was detected and recorded along the transect, or 2) it was surveyed for three different seasons to determine if seasonal variation was influencing badger activity and to conclude there was no badger presence at that study site. At each Year 2 site, there was relatively small grassland habitat patches that were not large enough to conduct the full 1km transects. In order to ensure as much data was being captured in these geographically limited areas, we set up cameras at the grassland patches.

A total of 38 transects were conducted of the transects mapped out (Figure 2). We concentrated on conducting surveys at the Midpen Open Space Preserves and two other properties, Cloverdale Ranch, and TomKat Ranch for developing management recommendations for badgers. These two non-District sites were chosen as Cloverdale Ranch is in the process of being transferred to Midpen and TomKat Ranch had historical records of both badgers and owl presence at the property. We also received an invitation to do surveys at the property that we wanted to take advantage of as one of the linkages also ran through the property.



Transect Name	Corresponding Transect Numbers	Transect Name	Corresponding Transe Numbers
Purisima Creek Redwoods OSP	1,2	Tunitas Creek (Toto Ranch) Redwoods OSP	22,23
Tunitas Creek Redwoods OSP	3,35	Fremont Older OSP	26
Windy Hill OSP	4,36	TomKat Ranch	27,37
Skyline Ridge OSP	5	Cloverdale Coastal Ranches	28,29,30,31,32,33
La Honda OSP	6,7,8,9,10	El Sereno OSP	42
Russian Ridge OSP	11,12,41	Bear Creek Redwoods OSP	43
Monte Bello OSP	15,16,17	St. Josephs Hill OSP	44
Los Trancos OSP	19	Sierra Azul OSP	45,46,47
Long Ridge OSP	20,21		

Figure 2. Transect map for conducting badger surveys. White lines are 1km transects and the numbers are the transect IDs.

Of the 38 total transects, 55% of them had documented badger presence while 45% did not (Table 2).

Study Site & Property Name	Transect ID	Badger Presence Yes	Badger Presence No
Cloverdale Coastal Ranches	28	Y	
Cloverdale Coastal Ranches	29		N
Cloverdale Coastal Ranches	30		N
Cloverdale Coastal Ranches	31	Y	
Cloverdale Coastal Ranches	32	Y	
Coal Creek	18		N
La Honda	6	Y	
La Honda	8	Y	
La Honda	9	Y	
La Honda	10		N
Long Ridge	20		N
Long Ridge	21		N
Long Ridge	39	Y	
Los Trancos	19	Y	
Monte Bello	15	Y	
Monte Bello	16	Y	
Monte Bello	17	Y	
Purisima Creek Redwoods	1	Y	
Purisima Creek Redwoods	2	Y	
Russian Ridge	11	Y	
Russian Ridge	12	Y	
Russian Ridge	41	Y	
Skyline Ridge	5	Y	
TomKat Ranch (Private)	37		N
TomKat Ranch (Private)	27	Y	
Tunitas Creek (Toto Ranch)	22	Y	
Tunitas Creek (Toto Ranch)	23	Y	
Tunitas Creek Redwoods	35		N
Windy Hill	4		N
Windy Hill	36	Y	
Fremont Older	26		N
El Sereno	42		N
Bea Creek Redwoods	43		N
St. Josephs Hill	44		N
Sierra Azul	45		N
Sierra Azul	46		N
Sierra Azul	47		N
Grand Totals		**21**	**16**

Table 2. List of total transects (38) indicating presence or absence of badger sign.

A total of 114 badger records were collected from the 21 transects that had badger presence (Table 3). Records include either documenting badger burrows or recording a badger on camera. If possible, hair and scat samples were collected from fresh badger burrows for the genetic analysis. The sites with the highest percentage of badger burrows include Monte Bello- OSP (30%), Russian Ridge OSP (19%), Long Ridge OSP (13%), Purisima Creek OSP (11%), and La Honda (8%) (Chart 1).

Number of Badger Records	Location	Transects
34	Monte Bello OSP	15,16,17
22	Russian Ridge OSP	11,12,41
15	Long Ridge OSP	39
13	Purisima Creek OSP	1,2
9	La Honda OSP	6,8,9
6	Cloverdale Ranch	28,31,32
5	Tom Kat Ranch	27
4	Tunitas Creek OSP	22,23
4	Windy Hill OSP	36
1	Los Trancos OSP	19
1	Skyline Ridge OSP	5
114	**Total Number of Transects with Badger Records**	**21**

Table 3. Number of badger records recorded per transect.

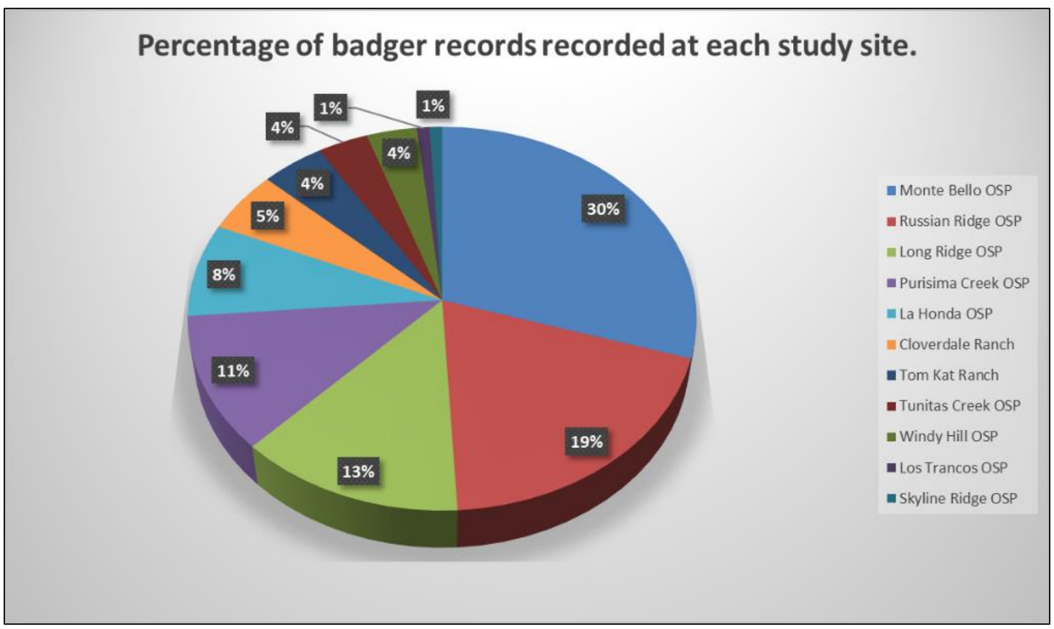


Chart 1. Percentage of badger records recorded at each study site.

4.3.2 Linkage cameras

The linkage design identified locations that connect the different study areas (Table 4 and Figure 3); 18 linkage cameras were set up at these locations. Our goal was to document if badgers were traveling within these modeled linkage pathways to identify important locations providing habitat connectivity for badgers to travel within the linkage design. Cameras were set up within the linkage design at locations that seemed to be key connections that connect grassland habitats between the various preserves that badgers might be traveling along. Please see Table 4 for a detailed account for each camera set up.

During the first year of the study (2019-2020), we set up several linkage cameras along roads to determine if badgers were traveling across roads that bisect the preserves, cameras within bottleneck areas or important pinch points within various linkages, and locations that might be important connections for badgers to travel between the preserves. We found badgers traveling through several of the linkages between the core preserves, please see Table 4 and Section 4.5 Camera Data Results for detailed data results and summaries from each linkage cameras. We did not find any badgers traveling from the core preserves through the Sierra Azul linkage, which is concerning as that might indicate the peninsula badgers are not connected to the Coyote Valley population.

During the second year of the study from (2020-2021), we found zero badger activity at year two study sites during the transect surveys at

1. Fremont Older
2. El Sereno
3. Bear Creek Redwoods
4. St. Joseph Hill and
5. Sierra Azul at Transects #45, 46, and 47.

At each of these sites except for Bear Creek Redwoods, there were small patches of grassland habitat along the transects. We set up cameras at the grassland patches with the objective to document if badgers were traveling within these small patches through the linkage design. The color coding within the draft linkage designs includes the linkage buffers being outlined in orange, while the core of the linkage is color coded as lime green within the buffers. Providing buffers are important because in locations where the linkages are constrained due to habitat fragmentation, buffers can provide the necessary space for facilitating badger movement through sensitive and /or impacted areas by human developments.

Camera ID	Camera Name	Year Camera was Set Up	Road/Trail	Badger Activity Recorded (Yes/No)	Structure
1	CloverdaleCam2	Year 1	Main dirt road Cloverdale Rd	No	Set up on main trail leading up to Cloverdale Road, connecting grassland habitat on either side. Multiple species tracks including two pumas, deer, and coyote along the dirt trail. See
2	SR-RR_AlpineRd	Year 1	Alpine Rd	No	Set up along a trail running between Skyline OSP and Russian Ridge OSP for the Russian
3	Montebelo_PM	Year 1	Page Mill Rd	No	Set up on Gate MB05 on a wooden post facing into the preserve by the Page Mill Rd for the Coal Creek-Monte Bello Linkage.
4	CC_Skyline	Year 1	Skyline Rd 35	No	Set up on a tree adjacent to Skyline Rd at Coal Creek for the Coal Creek and Monte Bello linkage across from Russian Ridge, in which trails from RR lead down to Skyline Rd.
5	CC2_SkyL35	Year 1	Skyline Rd 35	No	Set up on a tree adjacent to Skyline Rd on a wildlife trail that leads into a grassland area at Coal Creek for the Coal Creek and Monte Bello linkage across from Russian Ridge.
6	WH-SKL35	Year 1	Skyline Rd 35	Yes	Set up on the main trail leading from the Windy Hill preserve to the parking lot for the La
7	MB2_SKLN35	Year 1	Skyline Rd 35	No	Set up at a Monte Bello trail leading up to Skyline Rd, grassland connection from Skyline to
8	LH1_LHrd	Year 1	La Honda Road	No	Set up across from the La Honda Red Barn for the La Honda-Windy Hill linkage.
9	WindyHilCam2	Year 1	Skyline Rd 35	Yes	Set up off trail within the Windy Hill for the La Honda-Monte Bello linkage.
10	RR1_RapRd	Year 1	Rapely Ranch Rd	Yes	Set up at Russian Ridge, adjacent to Rapely Ranch Rd for the La Honda-Monte Bello
11	CloverdalCam3	Year 1	Main dirt road from Bean Creek Road	No	Set up on stakes in a grassland bottleneck area on a main dirt road from Bean Creek Road.
12	El Serno Transect 42	Year 2	Aquinas Trail	No	Set up by grassland patch at the beginning of the top of the ridgline.
13	St. Josephs Hill	Year 2	Novitate Trail	No	
14	Fremont Older	Year 2	Hayfield Trail	No	
15	Sierra Azul at Transect 45	Year 2	Priest Rock Trail	No	Priest Rock trail by grassland patch
16	Sierra Azul at Transect 46	Year 2	Rancho de Guadalupe	No	Rancho de Guadalupe: RdG1 - grassland past gate SA04
17	Sierra Azul at Transect 46	Year 2	Rancho de Guadalupe	No	Rancho de Guadalupe: RdG2 - grassland past gate SA30
18	Sierra Azul at Transect 47	Year 2	Mount Umunhum Trail	No	

Table 4. Linkage camera locations and findings.

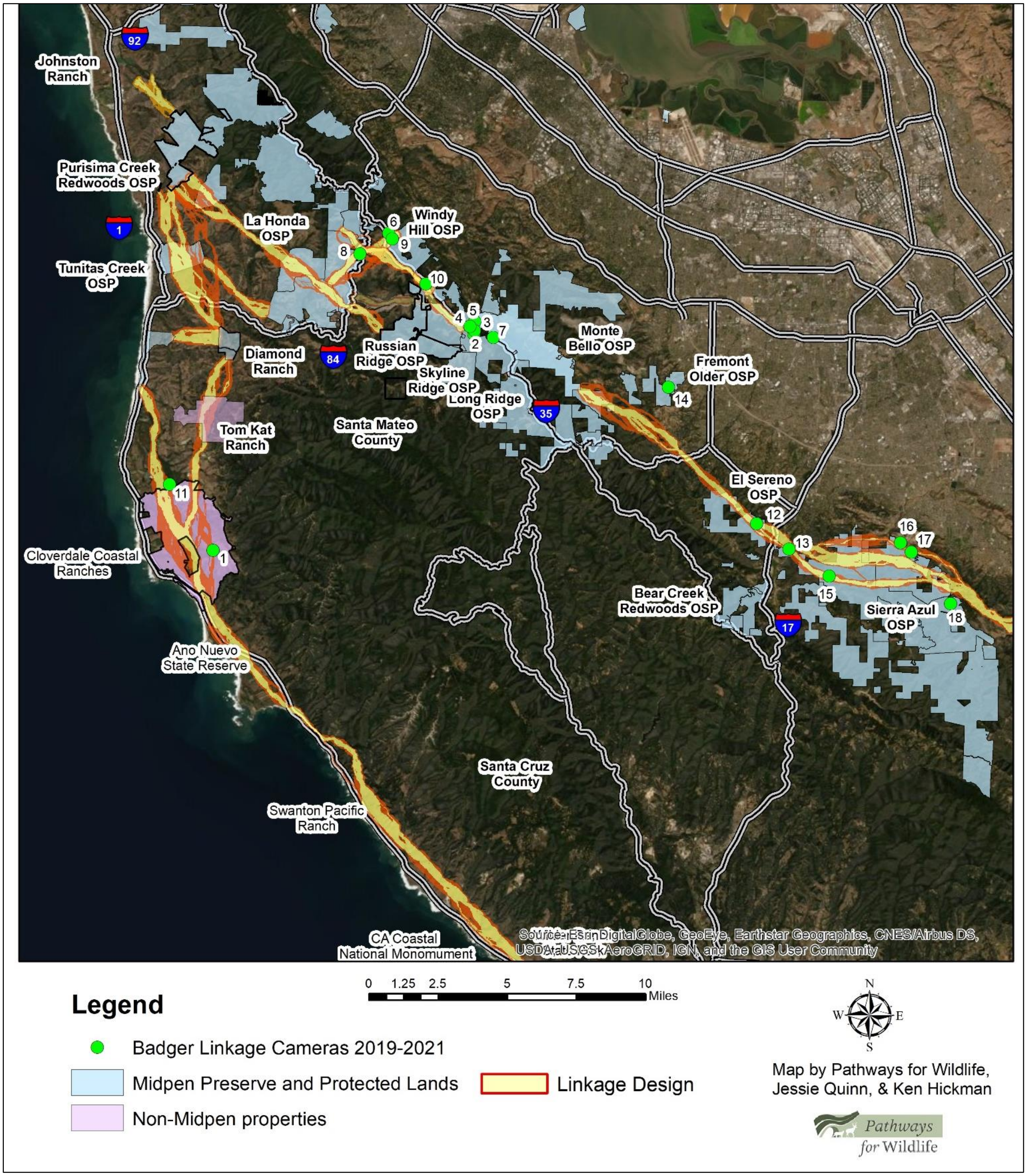


Figure 3. Linkage camera monitoring locations (2019-2021) and badger linkage design.
Cameras are noted by individual identification numbers. The Midpen preserves are color coded as blue and non-Midpen properties are color coded as purple.

4.4 Linkage Design: Field Validation

4.4.1 Ground-truthing linkage models with predictive and cost surface models overlays.

The linkage model was validated by overlaying the 375 records collected from field work during the study period and the other compiled records from various sources (Figure 4).

4.4.2 Entire Study Area

i. Predictive Model

Linkage buffers are outlined in white. This was changed from the linkage colors in Figures 1 and 3, so that the core of the linkage is unfilled making the predictive model visible underneath each linkage. Badger records are shown as black dots and open space preserves and protected lands used in the linkage analysis are outlined in black.

The color coding for the predictive model is a gradient from red to green corresponding from 0% (red) to 100% (green) of the probability of badger presence on the landscape. The model was overlaid with the linkages and badger records (Figure 4).

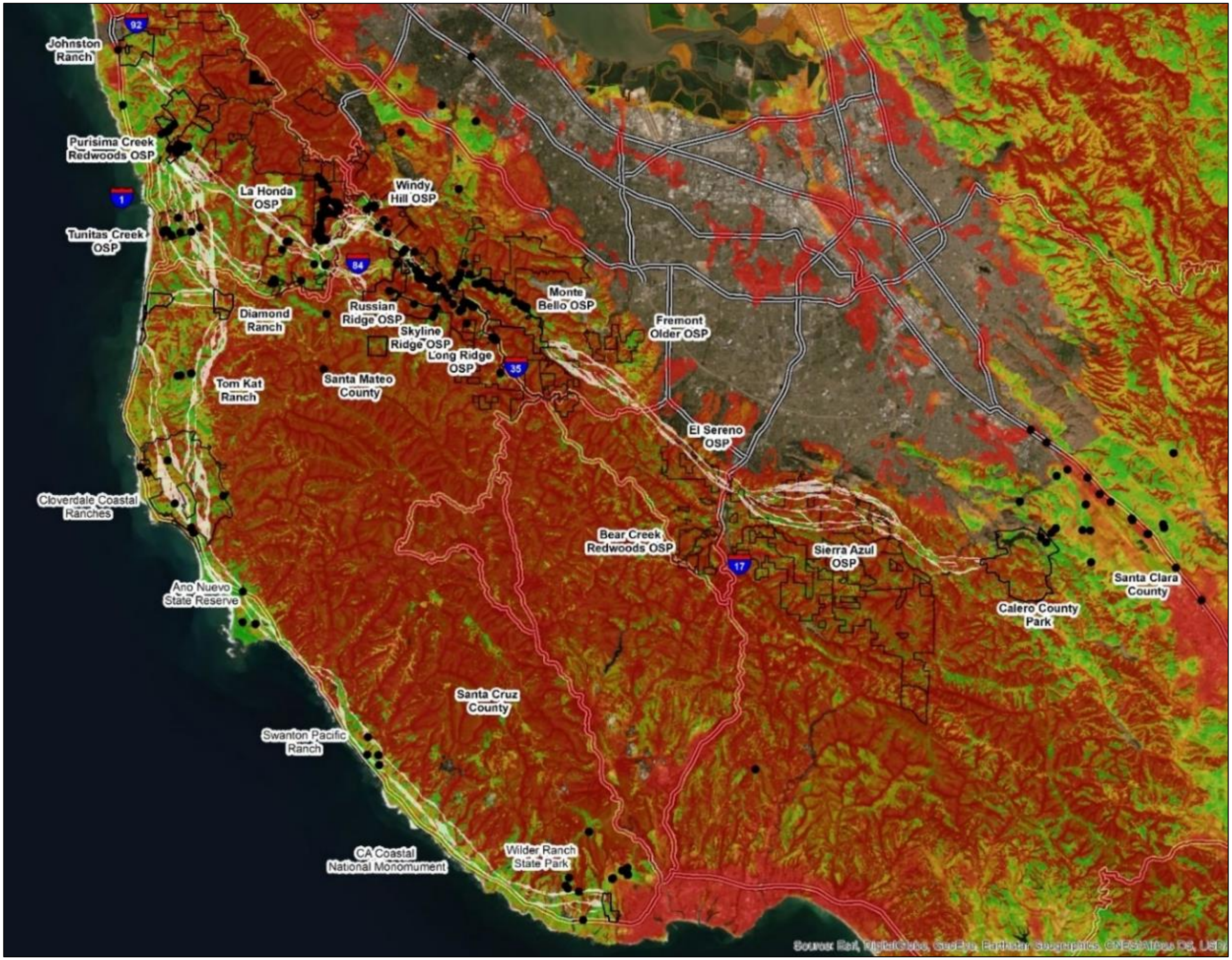


Figure 4. Linkage Design overlay with the predictive model and badger records. Color scheme: gradient from red to green corresponding from 0% (red) to 100% (green) of the probability of badger presence on the landscape.

The linkages run through the most suitable habitat and connect the various preserves and protected lands. As noted in the draft Linkage Designs, the landscape throughout the San Francisco Peninsula is highly fragmented for badgers. As a result, the north to south linkages have several bottlenecks in constrained areas that are lacking large tracts of grassland or oak woodland habitats for badgers to travel through. This makes it challenging for badgers, as grassland specialists, to travel to connected suitable habitats (Lindzey 1982).

ii. Cost surface model

Linkage buffers are outlined in white. The core of the linkage is unfilled so the predictive model is visible underneath. Badger records are shown as black dots and open space preserves and protected lands used in the linkage analysis are outlined in black. The color scheme for the cost surface map (Figure 5) is as follows:

Green = Highly suitable habitat and low movement costs.
Yellow = Fairly suitable habitat and moderate movement costs.
Blue = Poor habitat and higher costs for movement.
Red = Unsuitable habitat for movement and very high movement costs.

The cost model was overlaid with the linkages and badger records (Figure 5).

The linkages run through the most highly suitable habitat with low cost for badger movement and connect the various open space preserves and protected lands. Similar to the predictive model, the landscape is highly fragmented for badgers due to the majority of the peninsula consisting of heavily dense forested areas with steep ravines.

Of concern, there are no badger records in the linkage spanning from the Monte Bello OSP-Sierra Azul OSP-Calero County Park linkage (Figure 5). The peninsula badger population could very well be isolated from the Santa Clara population in the Coyote Valley area. A closer look and discussion are included in the southern extent section of the study area in this section of the report.

The only viable linkage for the badger population at the Midpen core preserves could be along the coast of the peninsula, as we collected both historical records at the beginning of the study and then records at properties along the coast at Cloverdale Ranch and Tom Kat Ranch during the badger surveys. An important future phase of the study could be to include conducting badger surveys within protected properties along the coast to ground-truth this linkage since this study focused mainly on the Midpen preserves.

The peninsula badger population could very well be isolated from the rest of Santa Clara and Santa Cruz counties. Preliminary genetic results also suggest that the peninsula badger population is more closely related to badgers in Sonoma than Santa Clara County (Chapter 5: Genetic Analysis).

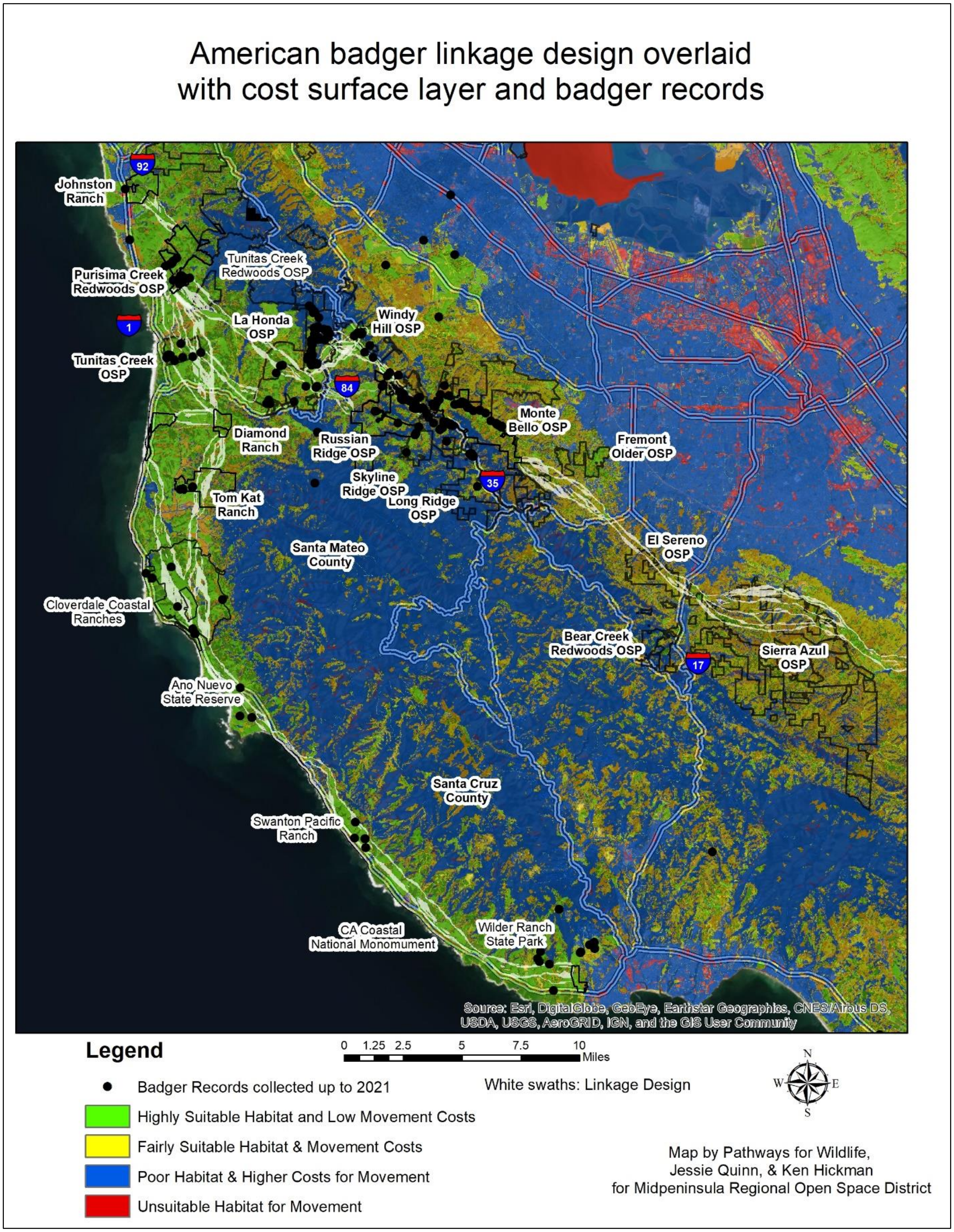


Figure 5. Final Linkage Design & Cost Surface Layer validated with all data. Shows the entire study area. Black dots are badger records, linkages outlined in white.

Linkage buffers are outlined in white. This was changed from the linkage colors in Figures 1 and 3, so that the core of the linkage is unfilled so that the cost surface is visible underneath each linkage. Badger records are shown as black dots and open space preserves and protected lands used in the linkage analysis are outlined in black.

4.4.3 South Section of the Study Area Results

We surveyed seven out of 38 total transects in the south section of the study area to survey for badger burrows and set up cameras at each site. These surveys were conducted at:

1. Fremont Older OSP
2. El Sereno OSP
3. Bear Creek Redwoods OSP
4. St. Joseph's Hill OSP
5. Three transects were surveyed within Sierra Azul OSP (Figure 6).

The transects were set up within locations that predicted high habitat quality for badgers and the lowest cost for movement (Figures 6 and 7). A camera station was also set up on routes within grassland patches to record if a badger was traveling through the linkage.

At each of the seven transect sites, no badger sign such as badger burrows were found. The cameras did record multiple bobcats (*Lynx rufus*), coyote (*Canis latrans*), black-tailed deer (*Odocoileus hemionus*), gray fox (*Urocyon cinereoargenteus*), mountain lions (*Puma concolor*), raccoons (*Procyon lotor*), and striped skunk (*Mephitis mephitis*) at many of these sites, indicating other species are traveling through this linkage on a consistent basis, however badgers were not recorded. These data indicate that the modeled linkage is not being used by badgers to travel through these OSP preserves at this time.

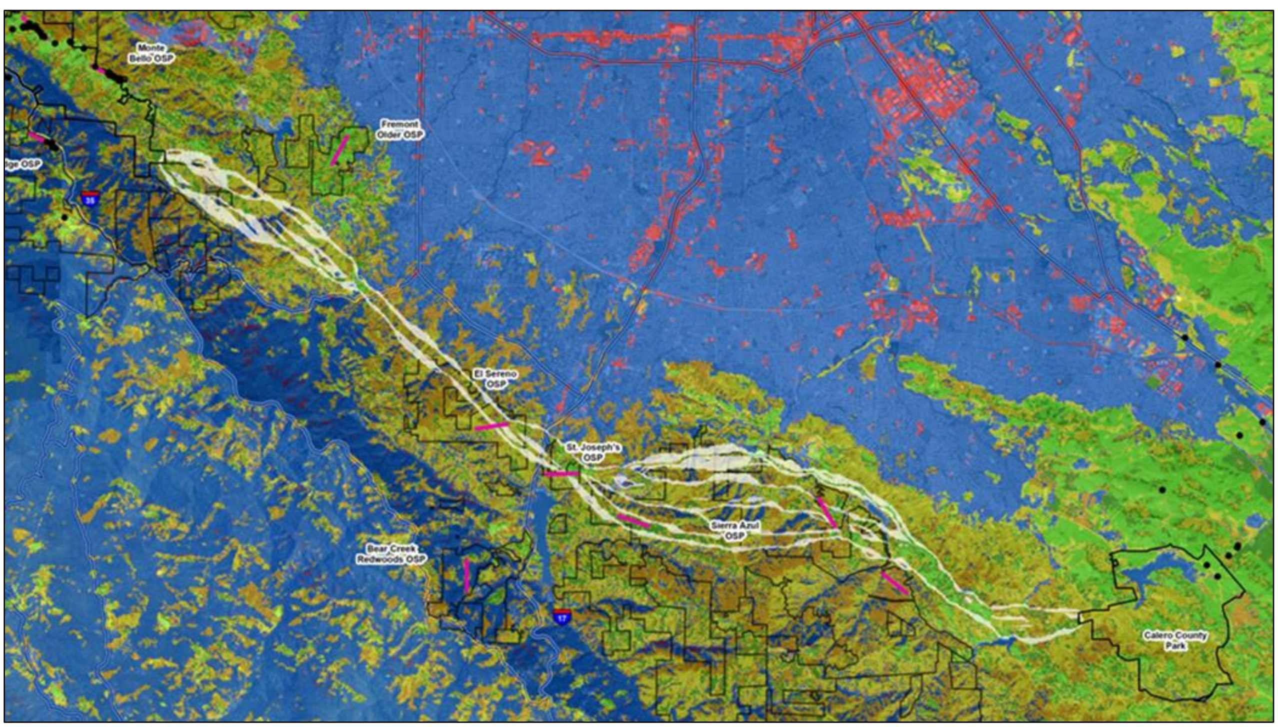


Figure 6. Southern Study Area Linkage Design and Cost Surface model validated with all data. Transects are shown as purple lines, the black dots are badger records, and linkages are outlined in white.

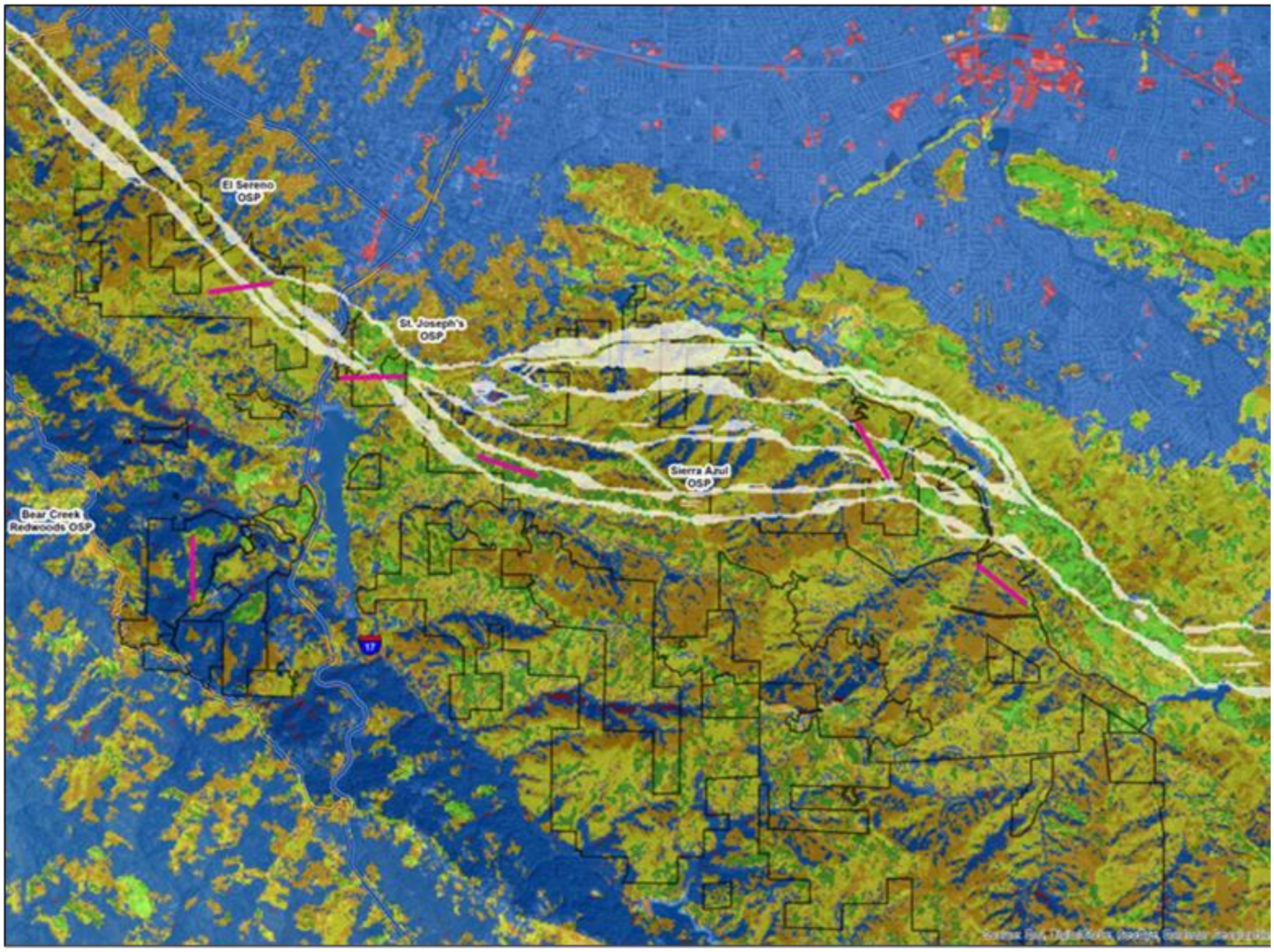


Figure 7. Map zoomed in to the Southern Study Area Linkage Design and Cost Surface model validated with all data. Transects are shown as purple lines, the black dots are badger records, and linkages are outlined in white.

4.4.4 Mid-section of the Study Area Results

The majority of badger records were found in six of the Midpen "core" preserves (Figures 8 and 9) along Skyline ridge:

1. Monte Bello OSP
2. Russian Ridge OSP
3. Long Ridge OSP
4. Skyline Ridge OSP
5. Windy Hill OSP and
6. La Honda Creek OSP

There is a clustering of records at these six preserves, with a total of 217 records combined out of the 375 total records (Figure 9). The Midpen core records account for 58% of the total records for all three counties (San Mateo, Santa Cruz, Santa Clara; Figure (Chart 2). Although the survey levels differ between counties, similar extensive badger surveys were conducted for these three counties for three different badger thesis work (Quinn, J. and Diamond, T 2008, Lay C. 2008, and Huck K. 2010).

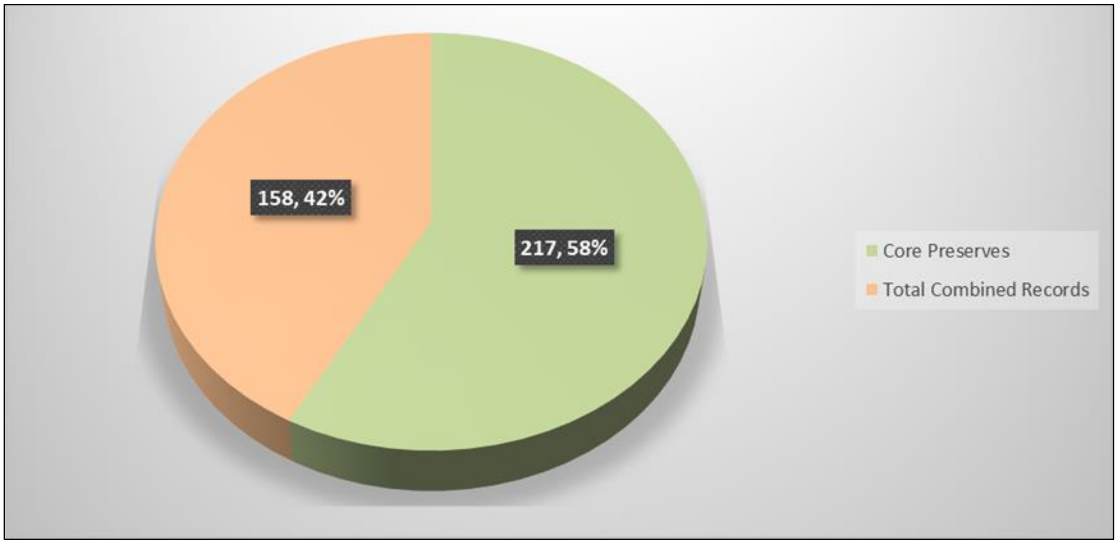


Chart 2. Percentage of badger records in Midpen cores
versus total combined records.

It is critical to maintain the linkages between these cores by maintaining connected grassland habitats (Figure 8). It is also equally important to maintain linkages within the preserves (Figure 9). Badgers were recorded within these preserves with grassland habitats that were managed by either being mowed or grazed.

Long Ridge OSP was the site with the southernmost records. Maintaining grassland connections from Russian Ridge OSP through Skyline Ridge OSP and Long Ridge OSP is important for maintaining badger connectivity through this important core area (Figure 10). These preserves also have highly unsuitable habitat such as densely forested ravines.

Our management recommendations will include a closer look at where to keep the grasslands connected between the preserves, and to identify important bottleneck areas. An example of a bottleneck location is noted in Figure 10. This area may benefit from increasing grassland habitat via mowing or other methods.

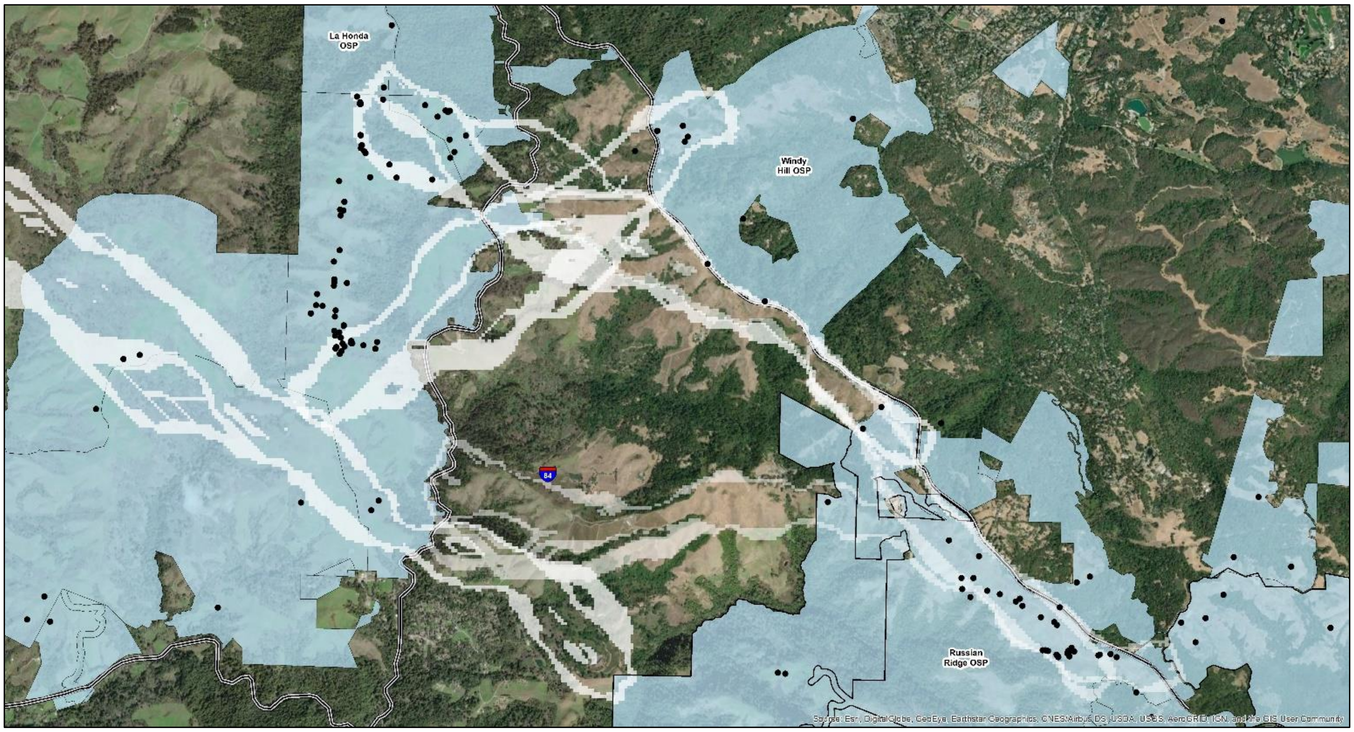


Figure 8. Midsection Study Area Linkage Design and badger records shown as black dots, linkages outlined in white.

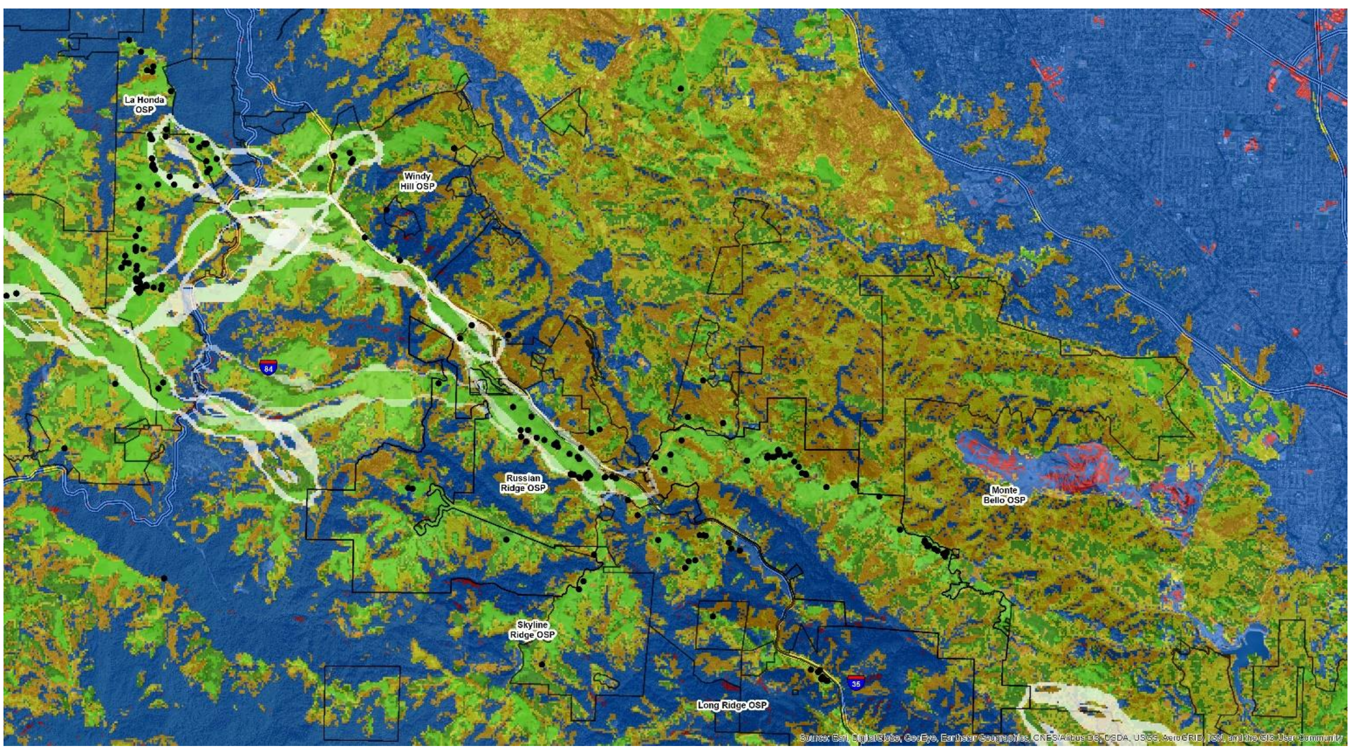


Figure 9. Midsection Study Area Linkage Design and Cost Surface Model validated with all data. Badger records shown as black dots, linkages outlined in white.

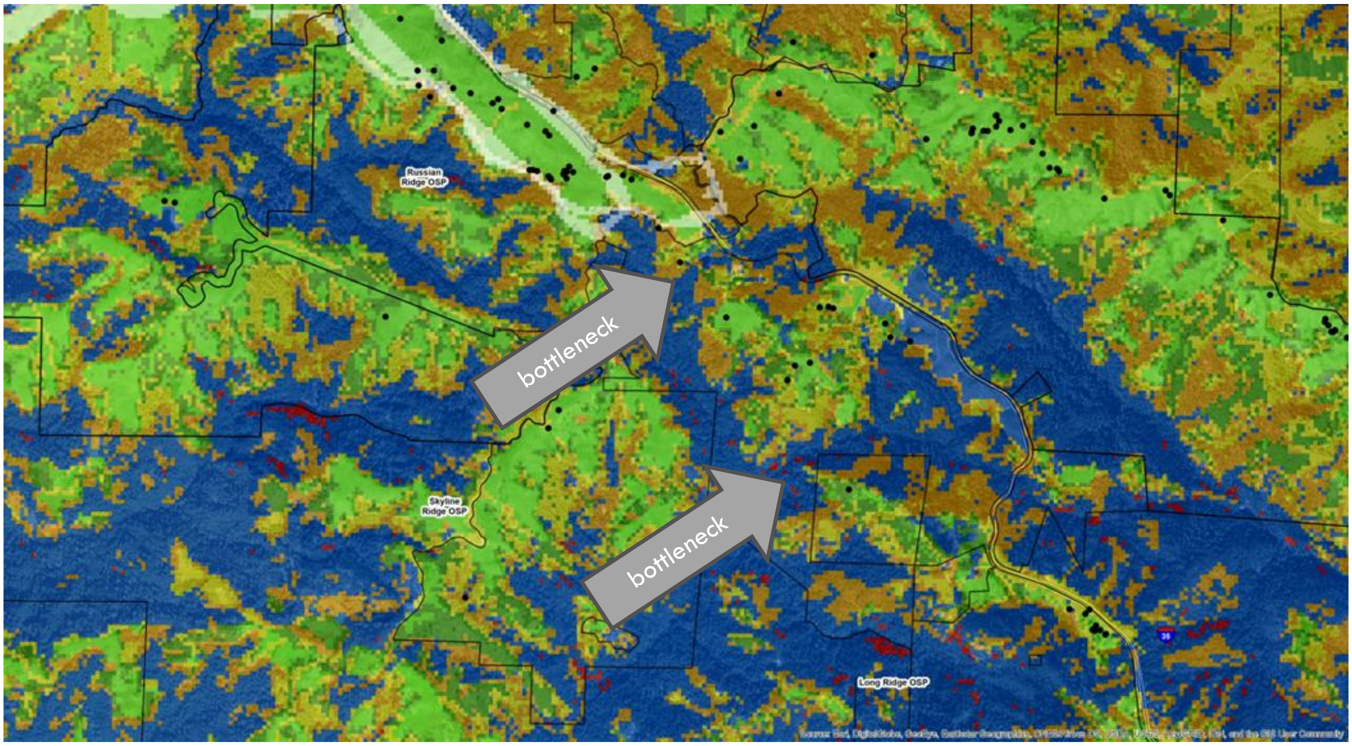


Figure 10. Zoomed into the bottleneck areas between Long Ridge OSP and Russian Ridge within the Midsection Study Area Linkage Design and Cost Surface Model validated with all data. Badger records shown as black dots, linkages outlined in white.

4.4.5 North section of the Study Area Results

There is a clustering of badger burrow locations within both Purisima Creek Redwoods OSP and Tunitas Creek OSP on the coast (Figure 11). However, there was no badger sign recorded during surveys within the linkage at northern Tunitas Creek OSP transects. We would need more data and ground-truthing to determine the most viable linkages that connect these two coastal sites, Purisima Creek Redwoods OSP and Tunitas Creek OSP, to the Midpen "core" preserves, where the majority of badgers have been found. For example, in Figure 12, the arrow notates a potentially important linkage that could be connecting the coastal northern preserves to La Honda, one of the main core preserves that has a high amount of badger records. Three different individual badgers were identified at the La Honda preserve, please see camera and genetic data results.

These linkages could be providing a critical connection for badgers to find viable mates and to maintain gene flow between these sub-populations. These linkages could also be important areas for land conservation and easements

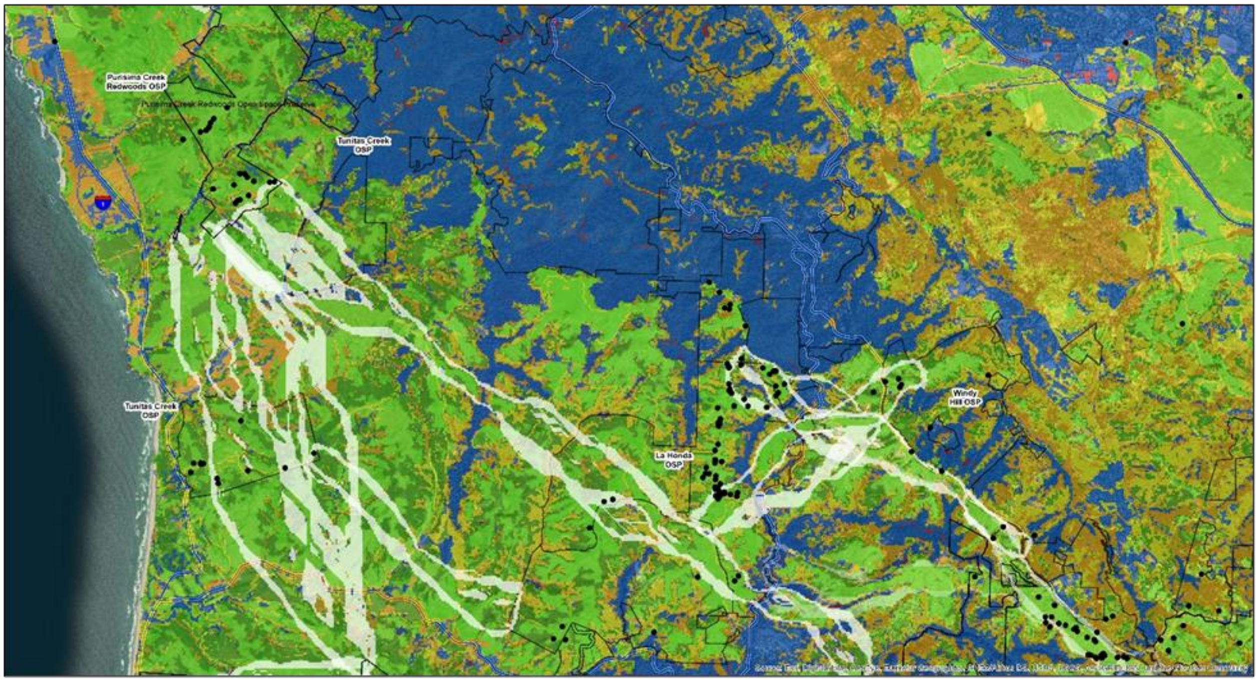


Figure 11. North Study Area: Linkage Design and Predictive Model validated with all data. Badger records shown as black dots, and linkages are outlined in white.

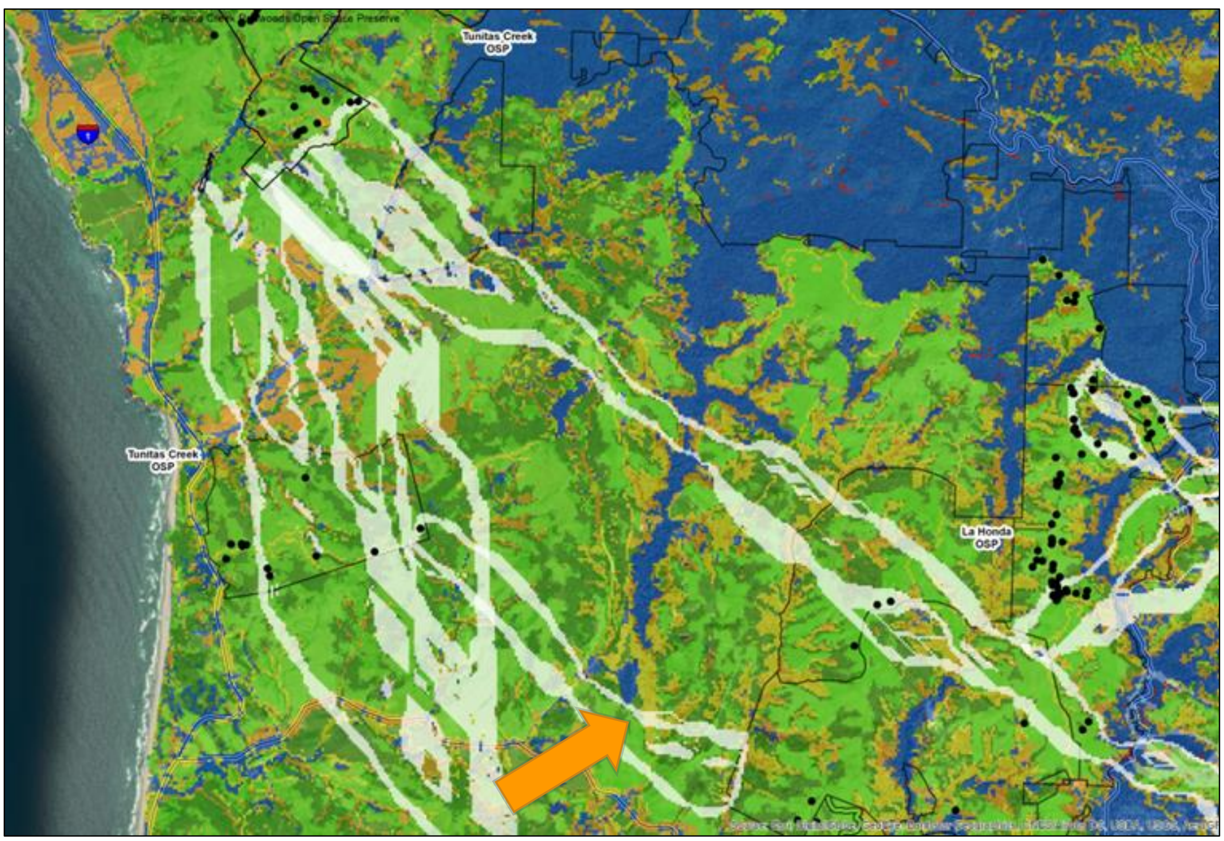


Figure 12. North Study Area: Linkage Design and Predictive Model validated with all data. Orange arrow: potentially important linkage. Badger records shown as black dots, and linkages are outlined in white.

4.4.6 Coastal section of the Study Area Results

A coastal linkage analysis was ran as the badger records collected at the beginning of the study spanned along the coast line from Johnston Ranch, the north section of the study, down to Wilder Ranch Sate Park by the UC Santa Cruz preserve (Figure 13). The majority of badger records fell in coastal grassland and coastal scrub habitats.

We conducted badger surveys at five of the northern coastal properties, Purisima Creek Redwoods OSP, Tunitas Creek Redwoods OSP, Tunitas Creek (Toto Ranch) Redwoods OSP, Tom Kat Ranch, and Cloverdale Coastal Ranches. Badger sign was recorded at all of the properties except for Tunitas Creek Redwoods OSP (Figure 14).

These surveys resulted in the first records of badgers at Tom Kat Ranch and additional badger records at new locations within Cloverdale Coastal Ranches, Tunitas Creek (Toto Ranch) Redwoods OSP, and Purisima Creek Redwoods OSP (Figures 13 and 14). The majority of badger records fall within or are close to the linkage design. This indicates this could be an important linkage for connecting badgers along the coast.

Also, important to note, that the majority of badger roadkill records within the study area were found along US-1. When the study first began, Portia Halbert from CA State Parks notified us that a badger was observed hit on US-1 on 6/4/2019 by Bean Hollow State Beach. We collected a genetic sample, which was analyzed for the study.

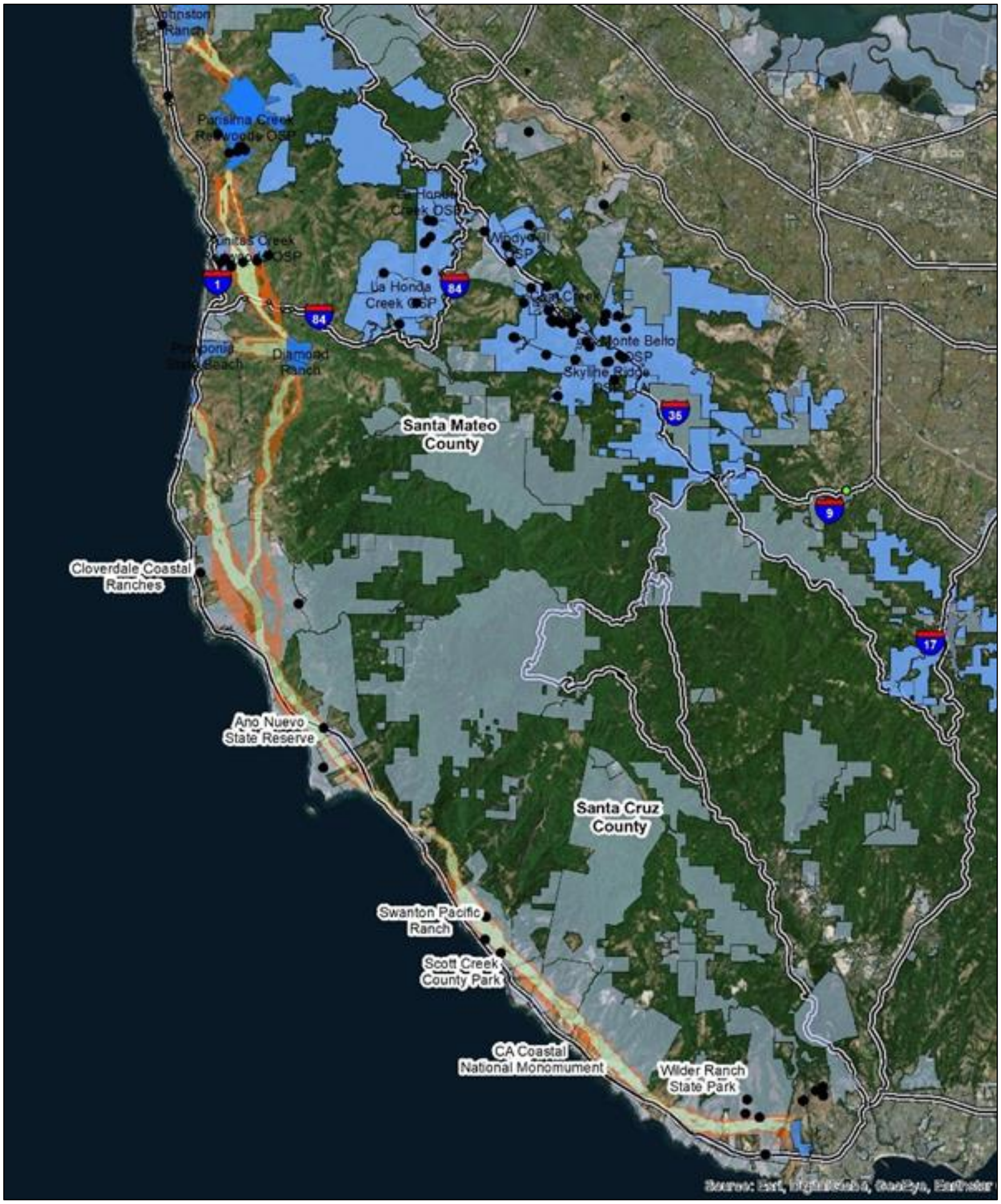


Figure 13. Coastal Section Area with draft Linkage Design.

The coastal linkage might be the only connection for the badgers residing within the Midpen core complex in the midsection of the study to another badger population in the peninsula. Transects have been set up within other protected properties spanning further south down the coast. However, it was beyond this scope of work to conduct badger surveys on those transects. We would recommend setting up a second phase of the study with this team to conduct those transect surveys as this might be the only linkage that connects into the midsection of the study area to where the majority of badgers have been recorded. It would be important to identify what properties are the critical connection between the coastal linkage and the core reserves (Figure 12). The coastal linkage has a much higher amount of highly suitable habitat and badger records compared to the Monte Bello OSP-Sierra Azul OSP linkage (Figure 14).

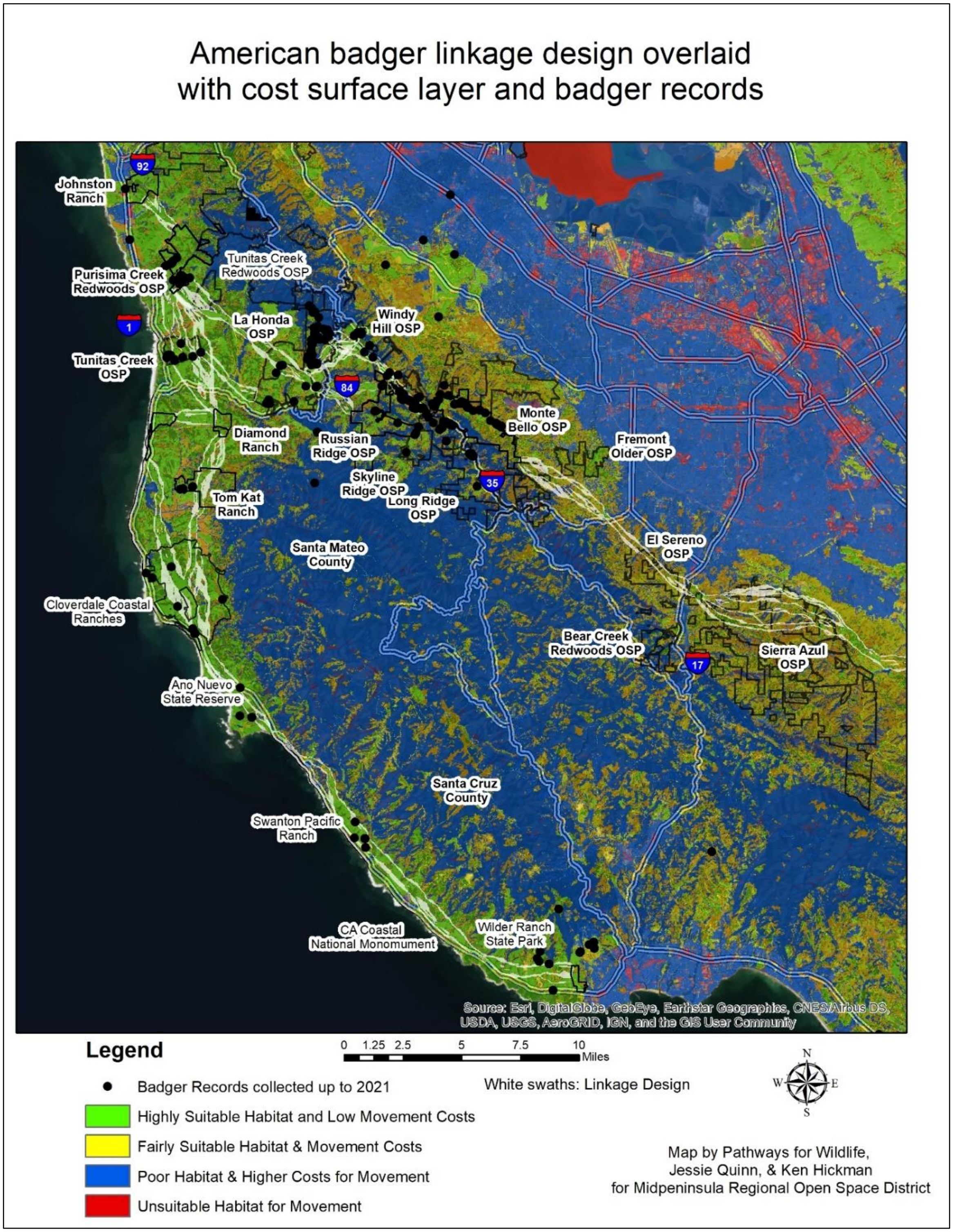


Figure 14. North Study Area Linkage Design and Cost Surface Model.

4.5 Camera data results and individual badger profiles

There were three different types of camera arrays set up. The first was the linkage cameras to detect badger movement between various MROSD preserves (Figure 3). The second set of cameras were set up to determine if burrowing owls were utilizing badger burrows. The third type of camera arrays were set up along newly dug badger burrows to determine if there were badgers present to inform us of which locations were best to collect genetic samples via hair snares or collecting hair samples at the burrow mounds. These cameras were set up during the last three months of the study when we finished the transects and were able to dedicate the rest of the available field time to collecting hair samples. Please supplemental materials, American badger records master database for detailed information on locations, date, time, ect in which badgers were recorded on camera.

We were very pleased to have recorded a burrowing owl utilizing a badger burrow at Russian Ridge, especially given the very low number of detections of burrowing owls, only three, during the study period. This burrowing owl was recorded using the badger burrow for over a month. Please see Section 4.6. Other Species Use of Badger Burrows for more information on the burrowing owl at Russian Ridge.

On each of these three types of camera arrays other species were recorded either traveling through the linkage or by the badger burrows. These species included bobcat, coyote, deer, gray fox, long tailed weasel (*Neogale frenata),* raccoon, skunk, and opossum (*Didelphis virginianus*). Please see the following sections for more information about the different species recorded at the various types of camera stations.

Figure 15. Badgers recorded at various preserves.

4.5.1 Russian Ridge-Rapley Road Linkage Camera #10

Rapley Road is a two-lane road which intersects with Skyline 35 and leads to a residential neighborhood. This linkage camera was set up to document whether badgers are traveling across Rapley Road to access Russian Ridge OSP (Figure 16).

On 10/5/2019 camera footage documented a badger traveling from Rapley Ranch Road, heading south into the Russian Ridge Preserve (Figure 17). We did not document a badger again or hit on the road during the study. However, we did document multiple species consistently traveling north and south throughout the year at this site. These species included mountain lion, deer, bobcat, coyote, and a gray fox pair (Figure 18). These results indicate this location is a major thoroughfare within the linkage and is a road wildlife are consistently crossing to access Russian Ridge OSP as it included monthly movement by multiple species, except for badgers and mountain lions. However, mountain lion and badgers overall had lower occurrences compared to other species for each camera station. This could be due to badgers having a lower population size and mountain lions having larger home ranges (Crooks 2002). The badger we recorded might have been a sub-adult dispersing into Russian Ridge.

Figure 16. Ahíga Sandoval and Ken Hickman setting up a linkage camera at Rapley Ranch Road at the Russian Ridge OSP.

Figure 17. Badger at Russian Ridge OSP by Rapley Ranch Road on 10-5-19.

Figure 18. Multiple species traveling both north and south at Russian Ridge OSP and Rapley Ranch Road on 10-5-19.

4.5.2 Windy Hill OSP Linkage Camera #9

This linkage camera was set up off trail within the Windy Hill OSP for the La Honda Creek - Monte Bello OSP linkage. The camera was set up on an animal trail that connects grassland habitats from the western border of the preserve to the midsection of it (Figure 19). We routinely recorded a badger along this trail for several months from October to December 2019 (Figure 20). The facial and stripe patterns suggest that this is the **same individual badger.** This method for identifying individual badgers has been used in other studies and is peer review (Gould & Harrison2018). The majority of burrows found during surveys were located in grassland habitats on the west side of the preserve (Figure 8). Of note, there were several large burrows across Skyline Blvd from the Windy Hill OSP on the Audubon property. The proximity of these observations suggests that this could be the same badger at the Windy Hill OSP crossing the road. Further genetic data collection and analysis could help answer these types of questions as the genetic results did for the La Honda OSP badgers (section #.#).

Similar to findings from the Russian Ridge Rapley Road linkage camera site (section 6.1), we documented multiple species consistently traveling along this trail throughout the year at this site. These species included mountain lion, deer, bobcat, coyote, gray fox, skunk, and a long-tailed weasel (Figure 16). This linkage in particular had the highest amount of badger records and records were recorded during both fall, winter, and spring seasons. These camera data results indicate this location is a major thoroughfare within this section of the linkage.

Of note, we recorded a female bobcat with a kitten (Figure 21). Please see supplemental video footage labeled: *Bobcat juvenile & mother playing at Windy Hill on 11-2-2020*.) Footage of the Windy Hill badger records is also included in the supplemental video footage labeled, *Badger Study Spring 2020 Update for Midpen by Pathways for Wildlife*.

Figure 19. Linkage camera #9 set up on a wildlife trail at Windy Hill OSP.

Figure 20. Multiple events that a badger was recorded at linkage camera #9 at Windy Hill OSP.

Figure 21. Multiple species recorded at linkage camera #9 at Windy Hill OSP.

4.5.3 Long Ridge OSP Camera Set up to locate active burrows to collect genetic hair samples

Along with the linkage camera arrays, cameras were set up at badger burrows to determine if they were active to set up hair snares at and collect genetic samples. Multiple badger burrows records are located in the southern extent of Long Ridge OSP. Interestingly, there was no badger sign detected at the north section of the preserve. We set up a camera on the west side of the preserve off Hickory Oak Trail after a volunteer notified us about observing fresh burrows at the location. We recorded a badger using a burrow over a several day period (Figure 22).

Figure 22. Badger recorded at Long Ridge OSP.

This footage was of interest as we recorded close up photos of the badger's stripe pattern and length. There are four American badger (*Taxidea taxus*) subspecies:

1. A) T*. t. jeffersonii* (California, reddish-chestnut fur)
2. B) *T. t. taxus* (paler, more hoary)
3. C) *T. t. jacksonii* (dark brown and blackish fur) and
4. D) *T. t. berlandieri* (smallest of the subspecies and long dorsal stripe).

These subspecies have either a stripe running just down to the base of the neck or all the way down to the tail (Figure 23).

The majority of badgers we have recorded during this study and throughout different studies the past ten years in San Mateo and Santa Clara have a stripe pattern running down to the mid-section of their backs. If the stripe morphology is a reflection of the badger's genetics and helps define the sub-species, the unusual mid-back stripe pattern documented in Long Ridge OSP could indicate a difference in the genetics of these sub-populations found in District preserves. We were hoping to have collected enough genetic data to answer this important question and if it is a result of genetic isolation, but we need to collect more samples to determine the genetic population structure of the peninsula badger population compared to the rest of the Bay Area. Please see the Chapter 5 Genetic Analysis for further information.

Figure 23. Badger stripe morphology.

4.5.4 La Honda Creek OSP Camera stations

The genetic results revealed there were several different individual badgers at La Honda Creek OSP, perhaps even a natal den site (please see Chapter 5 Genetic analysis). Multiple individual badgers were recorded on camera during the study period (Figures 24-27).

Figure 24. La Honda OSP on 1/20/2020 end of Transect #8.

4.5.5 Individual Identifications

In Figure 25, there are two different badgers recorded at the La Honda Creek OSP. The badgers in picture 1 and 2 were recorded in transit along a ranch road in the Lone Madrone area (Figure 25). The badger in picture 3 was also recorded at La Honda Creek OSP at the end of transect #8 at a burrow (Figure 25, photos by Ken Hickman).

Pictures 1 and 2. In a side-by-side comparison, the Team determined that these are two different badgers based on the stripe patterns and body size. The badger in picture 2 is smaller than the badger in picture 1. The badger's stripe in picture 2 is thinner and wavy mid-back, while the badger in picture 1 is thicker and larger, with the stripe running straight down it's back. The larger badger in picture 1 also has a boxy head versus the smaller badger has a sleeker head in picture 2.

Pictures 2 and 3. In a side-by-side comparison, the wavy center face stripe of the badger in picture 3 is similar to the stripe of the badger in picture 2. The badgers in picture 2 and 3, look like the same badger, the way the face stripe veers off to the right above the nose is distinctive (Figure 25 Picture 3 and Figure 26). This method for identifying individual badgers has been used in other studies and is peer review (Gould & Harrison 2018). It is similar to how researchers identify spot patterns in the coats of species such as tigers, ocelots, and bobcats.

Figure 25. Picture 1: Lone Madrone area. Picture 2: Lone Madrone area. Picture 3: 1/20/2020 end of Transect #8.

Figure 26. Picture 2: Lone Madrone area, zoomed into face stripe.

Figure 27. Picture 1: Lone Madrone area.

Picture 2: Badger rescued from downtown Palo Alto and released at Stanford in June 2019.

The genetic data results revealed that the badger rescued from downtown Palo Alto and released at Stanford in June 2019 was also at La Honda Creek OSP. The genetic sample collected of this badger matched with a genetic sample collected at La Honda. This was a surprising result as is the two locations are approximately 6 miles apart with stretches of fragmented habitat in-between. This existing habitat fragmentation between the two sites makes the particular journey surprising and noteworthy as badger are grassland specialists (Long & Killingley 1983). We considered that this individual may have been captured on linkage camera footage.

Figure 22 Picture 1 and 2. In a side-by-side comparison, a badger recorded on 5/4/2021 in transit at La Honda Creek OSP on a ranch road (Picture 1) had a very similar stripe pattern as the badger that was released at Stanford in June 2019 (Picture 2, Figure 27). The large boxy head size and facial markings are also very similar (Figure 27).

We will run a linkage design from Stanford to La Honda, to identify any potential routes that would facilitate movement between the two locations for badgers.

4.5.6 Monte Bello camera Station Set up to locate active burrow to collect genetic hair samples

We recorded a badger at an active burrow in Monte Bello OSP where we collected hair samples that were successfully run through the genetic analysis. We set the camera on video and got some terrific behavioral footage of a male badger grooming at its burrow entrance, (Figure 28, please see supplemental video footage labeled:*2021-09-08 Monte Bello male badger scratching video completion*). This type of grooming behavior might help explain why we were successful at finding hair samples at the throws (or soil mounds) at the entrance of the burrows.

Figure 28. Badger grooming at a burrow in Monte Bello OSP.

4.5.7 Cloverdale Linkage Camera #1 and #11

We did not document badgers on the linkage cameras at Cloverdale. However, we did record badger burrows on the coastal prairies at Cloverdale (Figure 4). The cameras recorded a high diversity of species movement throughout the property (Figure 29). Interestingly, a female mountain lion traveling with four subadults throughout the property was documented (Figures 30 -31), please see supplemental video footage labeled: *Cloverdale Puma Family Aug-Sept 2019 Update for Midpen by PFW* for footage recorded of the mountain lion family).

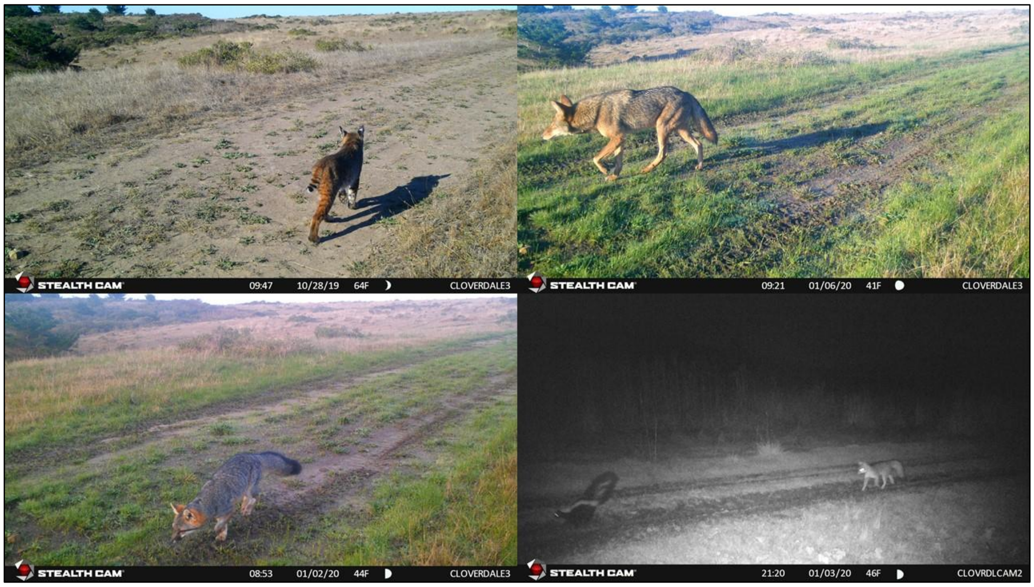


Figure 29. Multiple species movement at Cloverdale on 12/4/2019 at linkage camera #1 and #11.

Figure 30. Mountain lion family at Cloverdale on 10/1/2019 at linkage camera #1.

Figure 31. Mountain lion family at Cloverdale on 12/4/2019 at linkage camera #11.

4.5.8 Sierra Azul OSP Linkage Camera #18 at Transect 47

The Year 2 linkage camera sites included: 1. Fremont Older 2. El Sereno 3. St. Joseph Hill 4. Sierra Azul at Transects #45, 46, and 47. At each Year 2 site, there was relatively small grassland habitat patches that were not large enough to conduct the full 1km transects along. In order to ensure as much data was being captured in these geographically limited areas, we set up cameras at the grassland patches.

We recorded multiple species consistently traveling through these sites. The majority of species include mountain lion, deer, bobcat, gray fox, and skunk. Zero badgers were documented indicating these are potentially important linkages for other species but not for badgers.

Figures 32 and 33 are representative examples of the type of data that was collected in the Sierra Azul OSPs. This camera station was set up at the largest grassland habitat patch along the transects. We recorded a mountain lion consistently traveling through this site, along with deer, gray fox, and skunk (Figures 32 and 33). We recorded a western screech owl (*Megascops kennicottii*) several times at this camera station but no burrowing owls (Figure 32).

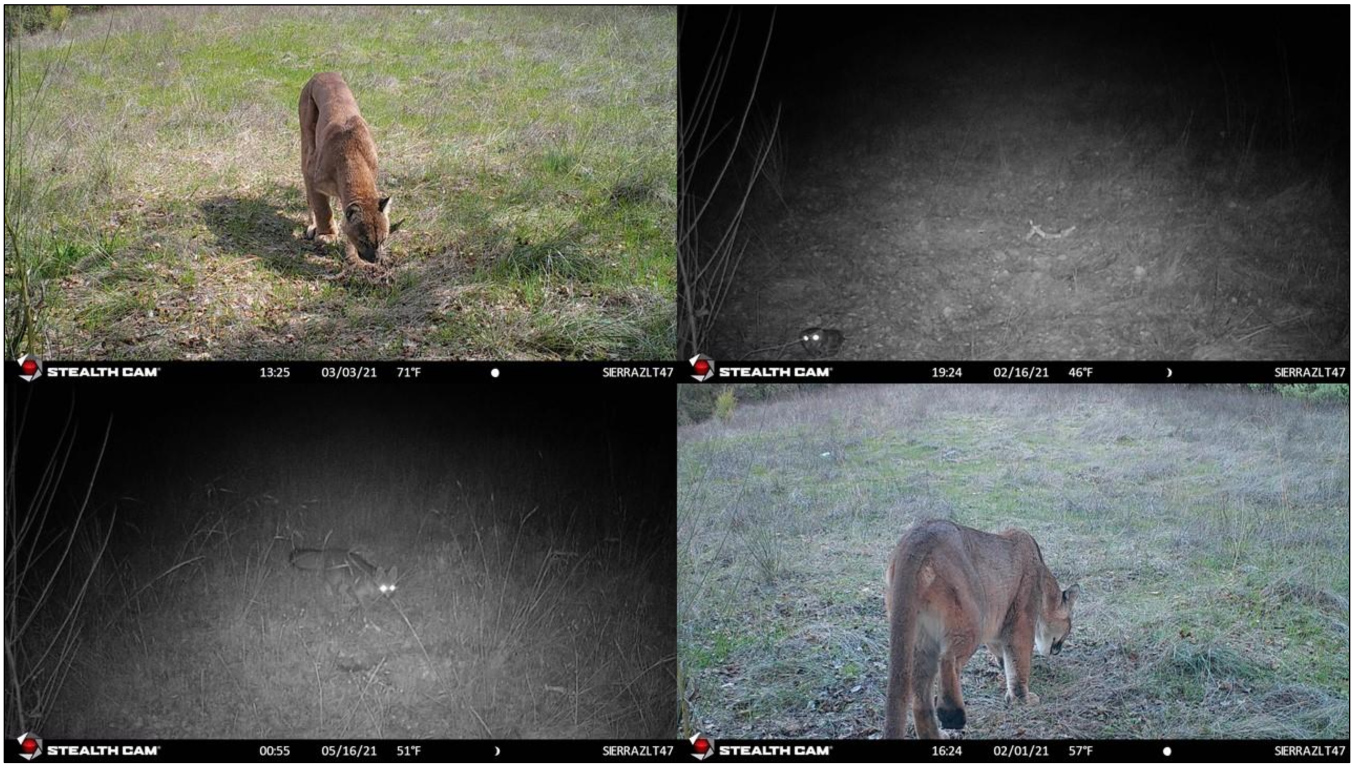


Figure 32. Multiple species recorded at Sierra Azul OSP transect 47, linkage camera #18.

Figure 33. Multiple species recorded at Sierra Azul OSP transect 47, linkage camera #18.

4.6 Other species use of badger burrows

One of the goals of the study was to document if burrowing owl were utilizing badger burrows. This was challenging as very few burrowing owls were recorded and documented throughout the study however other species were also documented.

We were very pleased to have recorded a burrowing owl utilizing a badger burrow in Russian Ridge OSP throughout the months of October to November in 2020 (Figure 34). This timeframe indicates it was a wintering owl. There have been several other historical records of burrowing owls at Russian Ridge in this vicinity. Please see the chapter on burrowing owls for more information and maps of this location. The burrowing owl was recorded standing outside of the burrow, calling, flying into the burrow with prey items, and even used the camera to perch upon (Figure 34). Please see supplemental video footage labeled: *Midpen Badger & BUOW study-Fall 2020 update by PFW* for video footage and a summary from this camera station.

Figure 34. Burrowing owl recorded at a badger burrow in the Russian Ridge OSP.

We were surprised to have recorded another Mustelid species utilizing a badger burrow at Monte Bello OSP. A long-tailed weasel was recorded utilizing a badger burrow for several days in January 2020. Up to this date there were only anecdotal sightings of long-tailed weasels, so this was a great opportunity to document another species that would benefit from badger burrows (Figure 35, Andersen J. pers. comm. 2/7/2020).

Figure 35. Long-tailed weasel recorded at a badger burrow in the Monte Bello OSP.

California newts were also recorded utilizing badger burrows at the Russian Ridge OSP (Figure 36). We found several newts at badger burrows during January 2020.

Figure 36. California newt recorded at a badger burrow in the Russian Ridge OSP.

4.7 Study Site Profiles in relation to badger presence or absence

Each study site had different characteristics that seemed to be influencing badger presence or absence (Table 5).

The major factors influencing badger presence or absence include but are not limited to:	1.Grassland connectivity between preserves
	2. Grass height
	3. Management practices (mowing and/or grazing)
	4. Variation in chaparral habitat

Table 5. Factors influencing badger presence and absence.

1. The high presence of badgers in the Midpen core preserves may be due to those preserves being relatively connected via grassland habitats. This allows badgers to be able to travel to find mates or for juveniles to disperse between the preserves (Figure 37). These were patterns we observed from mapping out all the records, not from a statistical analysis. The linkages overlaid with the total records shows there are higher numbers of badger records between preserves that have connected grassland habitats versus grassland preserves that are isolated.

The majority of badger records were found in six of the Midpen core preserve system at **1. Monte Bello OSP 2. Russian Ridge OSP 3. Long Ridge OSP 4. Skyline OSP 5. Windy Hill OSP and 6. La Honda OSP** (Chart 2 and Figure 5). These preserves are connected by large tracts of grasslands and have several bottlenecks that would benefit from active management (see Discussion section).

At the **Fremont Older OSP, Tunitas Creek OSP, Coal Creek OSP, and Sierra Azul OSP**, there were relatively small patches of grassland habitats which were isolated by forested habitats (Figure 37). There were no burrows located at these sites or badgers recorded on cameras.

2. Our transect work resulted in very few records of badger burrows in locations where the grass was high (4 feet or higher). Grass height from 1 to 3 feet seemed to be optimum in which we observed many burrows along transects. Locations in which there was heavy grazing, such as northern **Tunitas Creek OSP**, and the grass was less than 1 ft, seemed to result in very few to no burrow records. In making this deduction, we only took into account fresh/new badger burrows and not older badgers to be able to make the comparison as we wouldn't know the level of the grass when those were first dug.

3. These findings lead to management practices. Sites that were being routinely mowed, such as the **Russian Ridge OSP**, had a high amount of new badger burrows throughout the property. The locations that were mowed had a higher amount of new badger burrows compared to sites that were being grazed. At sites with records where grazing was occurring, sites in which grazing was being rotated had a higher amount of records than sites that were overgrazed. An example from two coastal properties include **Tunitas Creek OSP,** which was heavily grazed and had no badger records versus **Toto Ranch,** which was not overgrazed and had fresh badger burrows where cows were currently grazing.

4. Variation in chaparral was also a major factor influencing badger presence. We defined habitats and found results as follows:

Hard chapparal: dominant indicator species are chamise (Adenostoma fasciculatum), manzanita (Arctostaphylos manzanita), and buckbrush ceanothus (Ceanothus cuneatus). It occurred mostly in the driest areas on the eastern slopes, ridges, and south-facing slopes, and was quite dense and impassable. Locations where the chaparral was very thick, dense, and impassable, such as **all the Sierra Azul OSP sites**, resulted in **no badger burrows or sign found**.

Maritime chapparal (Arctostaphylos hispidula): a west slope version of hard chaparral, with generally much less abundant chamise, and with ceanothus, manzanita, and pine species; it is very similar to hard chaparral and often very dense. We found very few badger burrows in this habitat type.

Coastal scrub (Artemisia californica): dominant indicator species are coyote brush (Baccharis pilularis), toyon (Heteromeles arbutifolia) and coffeeberry (Frangula californica), and is often on west slope and in successional areas after clearing. This habitat was much more permeable; we found several badger burrows in coastal scrub habitat at **Cloverdale**.

See video compilation in supplemental materials: *Study Sites Profiles in Relation to Badger Presence or Absence* with photos and video documentation of each study site developed from the badger surveys.

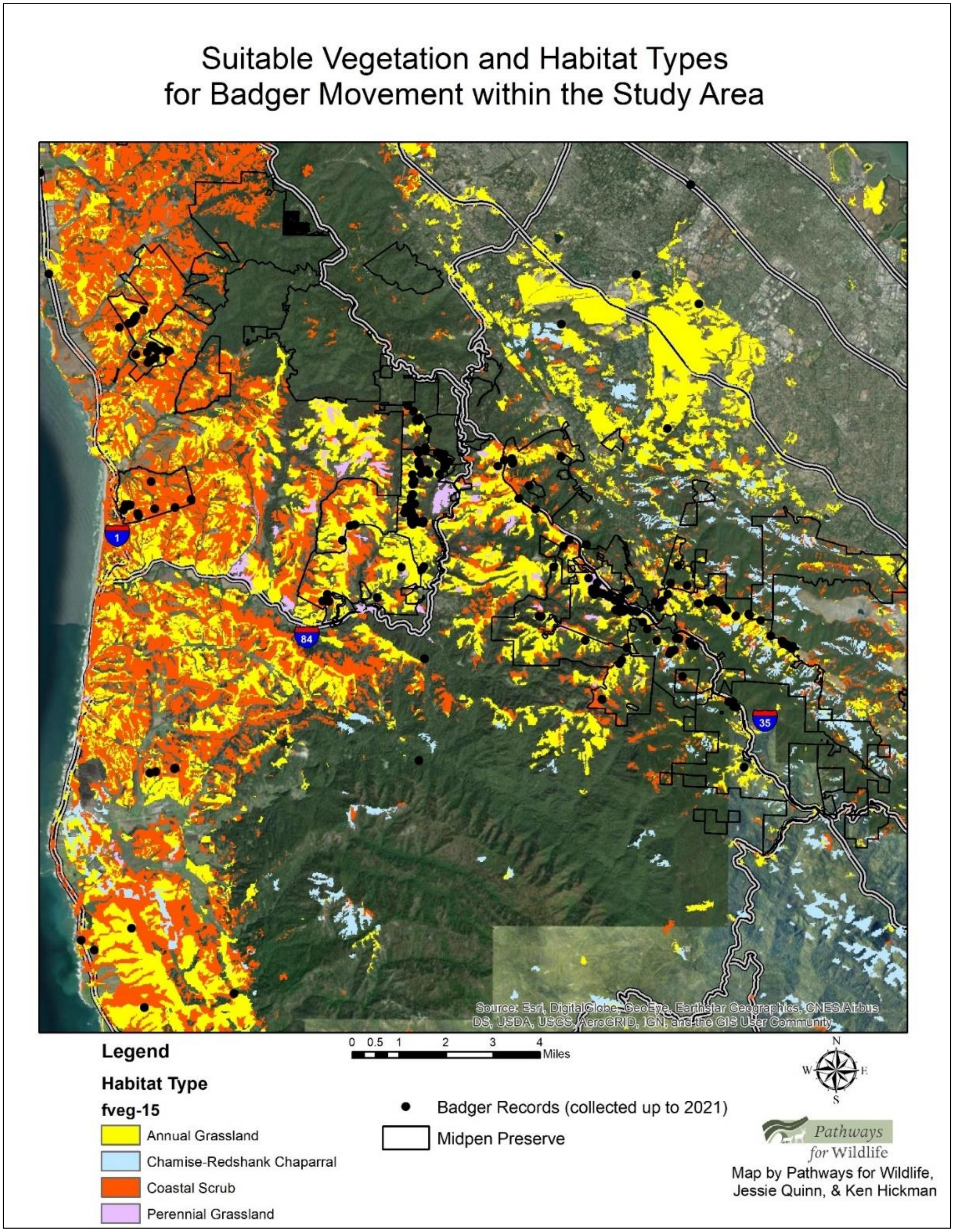


Figure 37. Suitable Vegetation and Habitat Types for Badger Movement within the Study Area.

4.8 Discussion and Next Steps

4.9 Management recommendations for enhancing the permeability for badger movement within linkages

The mid-section core preserves had the highest number of badgers records, and the genetic results revealed there were both female and male badgers at various preserves. Keeping the linkages in these areas connected is critical to maintain permeability between Skyline core Preserves for badgers to find mates and for juvenile dispersal. We detail and illustrate each linkage between these core preserves in the map sequence below.

The linkage connecting La Honda Creek OSP to Monte Bello OSP contains large tracts of grassland running through Russian Ridge OSP and the Audubon Ranch property. The District's management of Russian Ridge OSP as open space in perpetuity provides an opportunity for maintaining the permeability of this linkage (Figure 38).

It would be highly beneficial to convert or restore more grassland habitat in the Coal Creek OSP since it is another possible path along this linkage and may be a safer route for badger because of its increased distance from Hwy 35 (Figure 38, note orange arrow). We recorded multiple species at the Coal Creek linkage camera such as mountain lion, deer, bobcat, coyote, and gray fox; zero badgers were recorded.

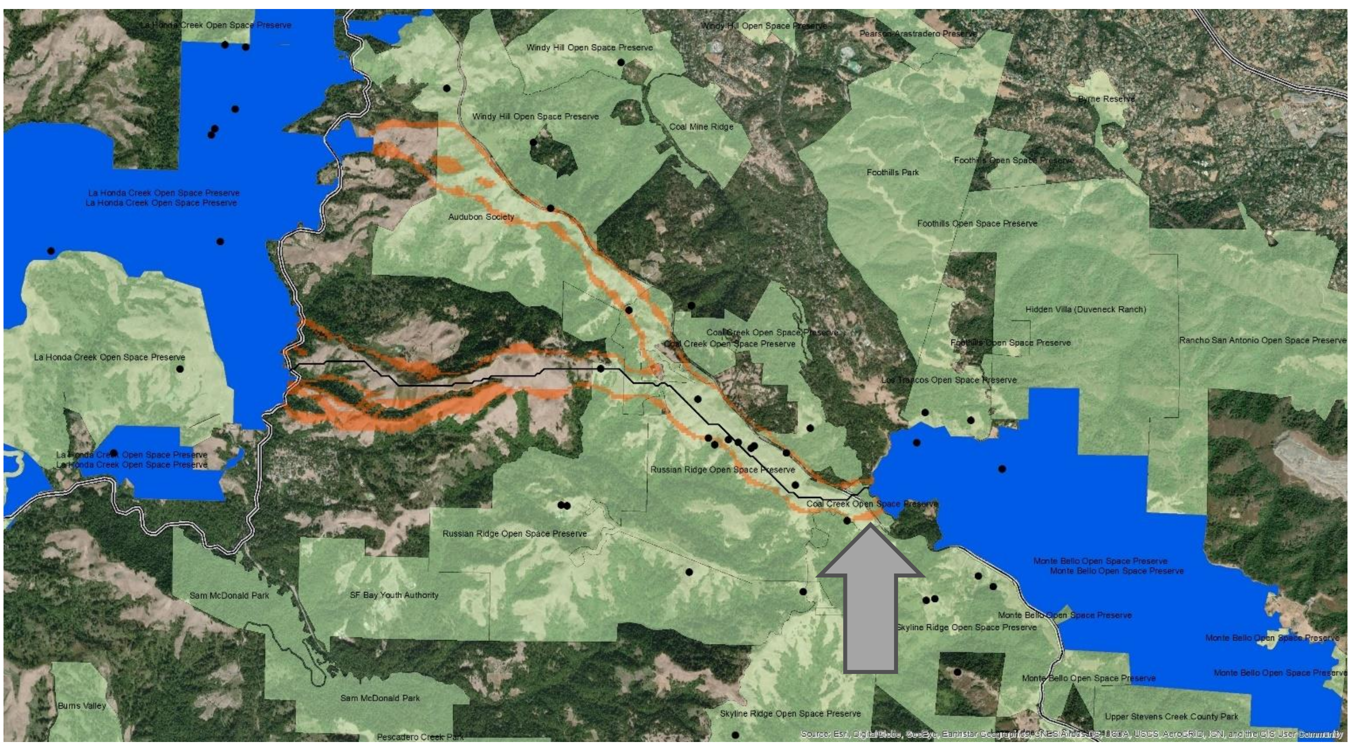


Figure 38. La Honda Creek OSP to Monte Bello OSP linkage.

Within the La Honda Creek OSP to Windy Hill OSP linkage there are large tracts running through both the La Honda Creek OSP and Windy Hill OSP, which is an opportunity for helping maintain the permeability of this linkage by either maintaining grassland habitats and/or creating new grassland habitats within the linkage design (Figure 39). Reaching out to neighboring landowners to encourage them to maintain grassland habitats and/or creating new networks of grassland habitats within the linkage would also be beneficial.

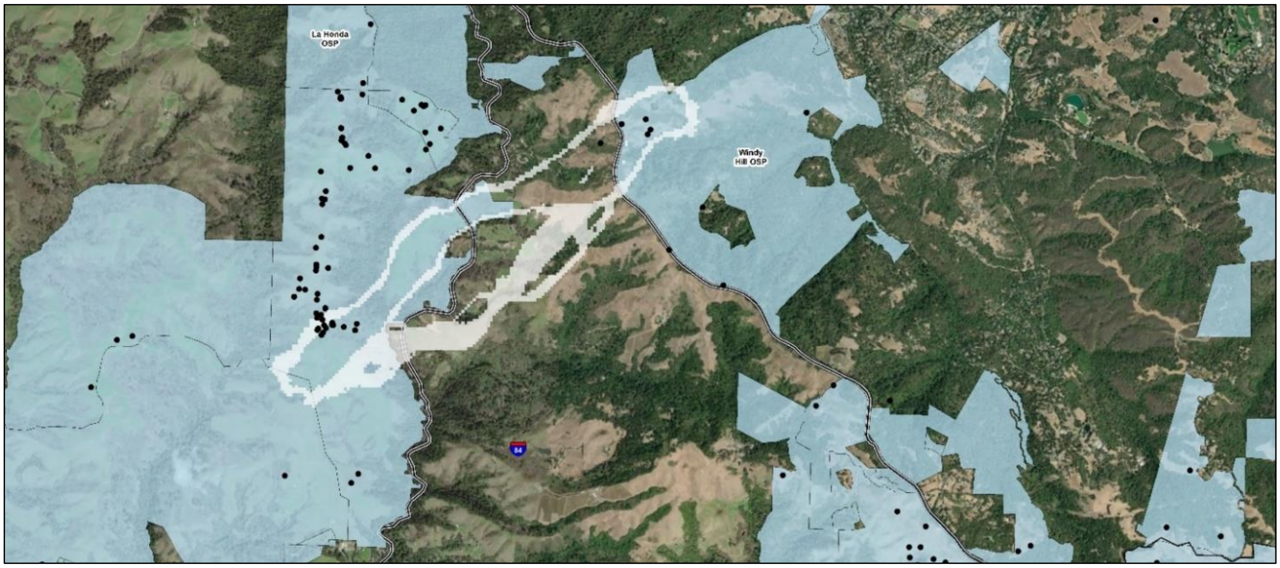


Figure 39. La Honda Creek OSP-Windy Hill OSP Linkage

I. Bottlecks

Bottlenecks are pinch points within a linkage where the linkage becomes constrained due to lack of available suitable badger habitat (Figures 40 and 41). Bottlenecks would be anything less than half of the badgers home range size, 4.0km^2 , as badgers are considered corridor dwellers and need to have the ability to reside and dig burrows within the linkages (Majka, D. et al. 2007). Our study identified many of these areas that would benefit from opening and increasing the availability of grassland habitat for badger movement between the core Midpen preserves. These bottlenecks are noted in Figures 40 and 41 below and circled in red.

Increasing the available grassland habitat in the outlined bottleneck areas would substantially increase the permeability for badger movement between the Long Ridge-Monte Bello-Russian Ridge OSP Complex and the Russian Ridge-Windy Hill-La Honda Creek OSP Complex. The badger population in the San Francisco peninsula seems to be isolated from the rest of Santa Clara County, therefore it is important to increase the permeability for badgers to be able to move between Midpen core preserves, which is where the majority of badger records were found during this study.

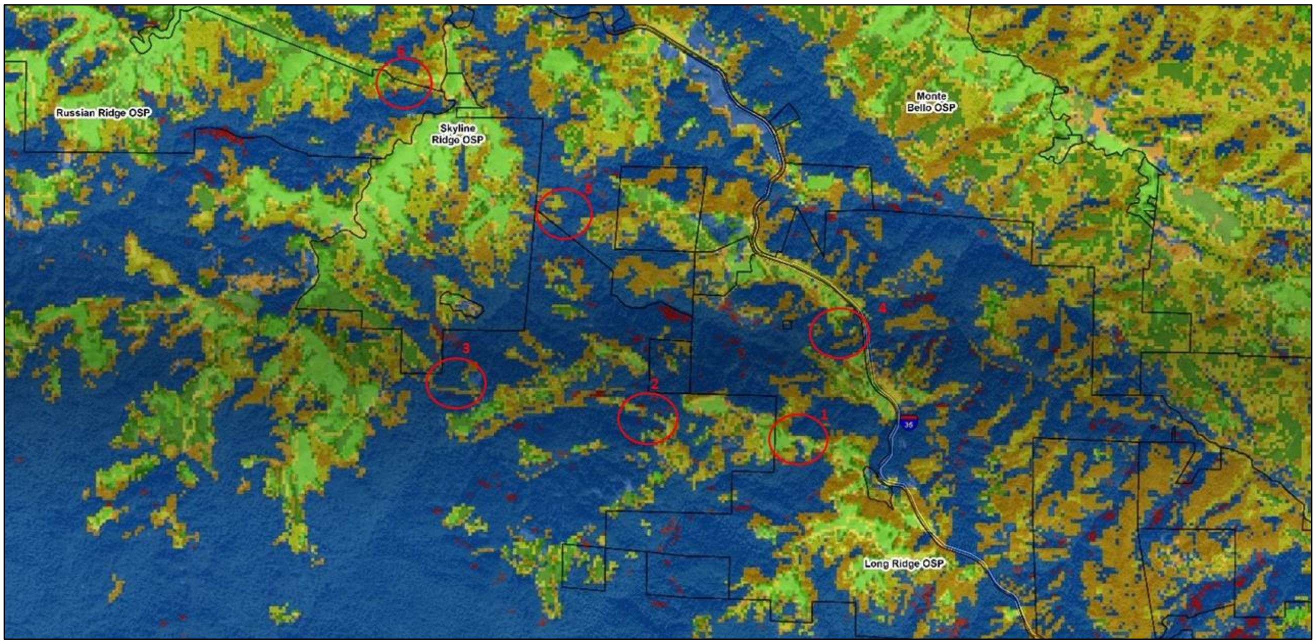


Figure 40: Long Ridge-Monte Bello-Russian Ridge OSP Complex: Bottlenecks 1-5.

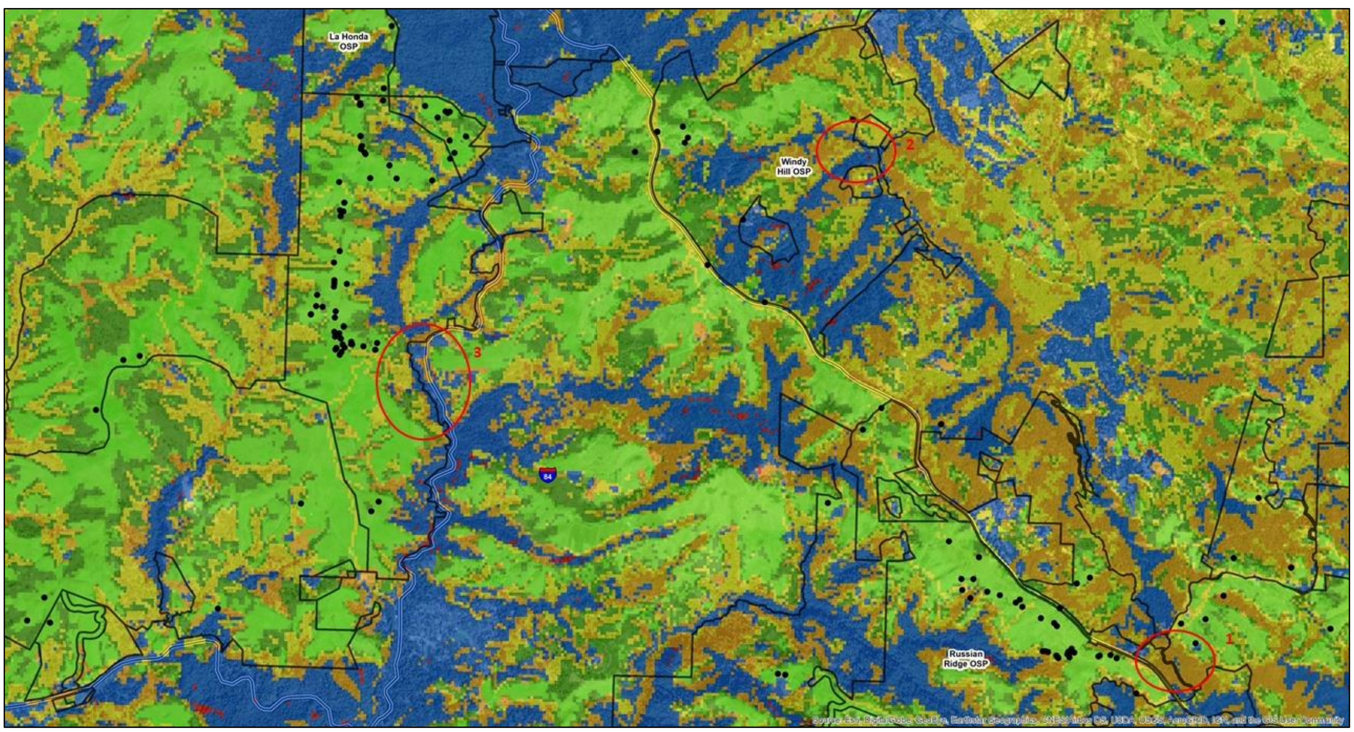


Figure 41. Russian Ridge-Windy Hill-La Honda Creek OSP Complex: Bottlenecks 1-3.

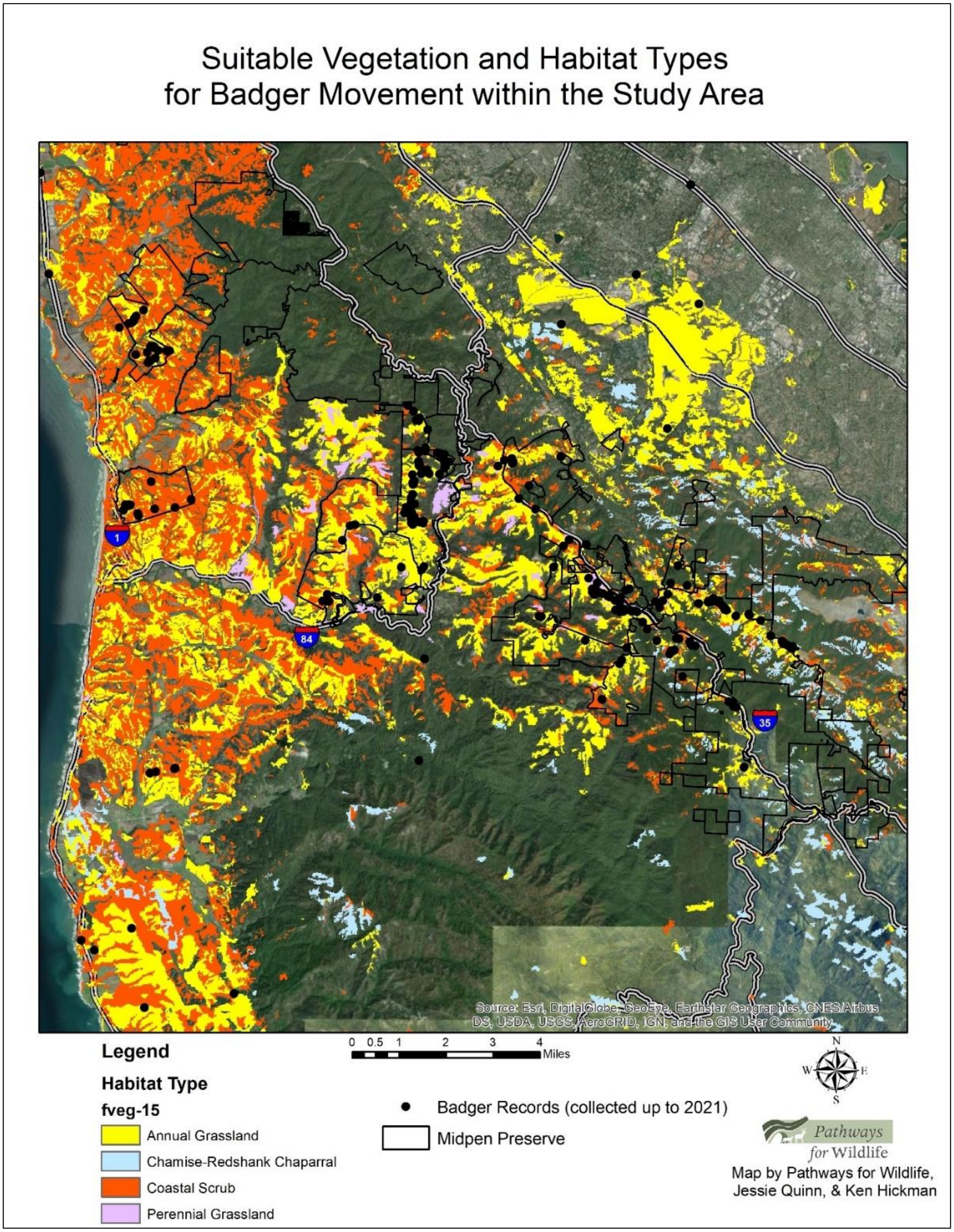

Suitable Vegetation and Habitat Types
for Badger Movement within the Study Area
1
84
35
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
0 0.5 1 2 3 4
Miles
N
W
E
S
Legend
Habitat Type
fveg-15
Annual Grassland
Chamise-Redshank Chaparral
Coastal Scrub
Perennial Grassland
Badger Records (collected up to 2021)
Midpen Preserve
Pathways for Wildlife
Map by Pathways for Wildlife,
Jessie Quinn, & Ken Hickman

Figure 42.

We learned that some linkages were being used by badgers and some were not. Tunitas Creek OSP was heavily grazed and fragmented by unsuitable habitat. We also found no viable linkages through Sierra Azul OSP to connect to Calero County Park and Coyote Valley, where there is a known badger population.

The various examples we discuss make the case for managing linkages by creating more connected grassland habitats within the identified bottleneck areas. This could be achieved by mowing or grazing, however not heavy grazing year-round. The study area is unique in that the grassland habitats are surrounded by a matrix of heavily forested habitats that fragment the landscape for badgers.

4.10 Road impacts to badger dispersal

Roadkill is the primary cause of badger mortality in the United States (Long 1973, Lindzey, F.G. 1982 Zeiner et al. 1990, Sullivan 1996). Badgers are highly susceptible to mortality from moving vehicles because they have poor vision, are unable to climb over road median barriers, which makes them particularly susceptible to collisions with vehicles (Minta 1993, Quinn, J. and Diamond T. 2008).

The road that poses the most threat to badgers at this time within the study area is US-1, as that was the road with the majority of badger wildlife-vehicle collision records. These records fell within where the highway bisected grassland habitats. Please see the Table X below for more detailed information on these locations. A genetic sample was collected from the badger that was hit on US-1 on 6/4/2019.

Date	Animal	# of Individuals	Roadkill Data	Road	Location
8/30/2018	American badger	1	Roadkill	US- 1	Badger was hit on Highway 1 at the Cascade Creek watershed.
9/2/2018	American badger	1	Roadkill	US- 1	Badger was hit on Highway 1 between an ag field and open space habitat (grassland or coastal chaparral). Stripe goes to the base of the neck.
9/13/2018	American badger	1	Roadkill	US- 1	Badger was hit on Highway 1 between POST properties Wavecrest Open Space & Johnston Ranch, just south of the City of Half Moon Bay.Cross road is Higgins Canyon Road.
9/13/2006	American badger	1	Roadkill	US- 1	Highway 1 by Wilder Ranch State Park by Wilder Creek in Peasley Gulch, culvert there?

4.10.1 Recommendations for improving connectivity

The locations in which badgers have been hit on I-I below would benefit from installing 3 foot round culverts as badgers have been recorded to travel through them (Figure 43). The installation of culverts and directional fencing where badgers have been recorded hit in Canada, Netherlands, and England has resulted in nearly doubling those populations (Neal 1986; Bekker & Canters 1995). Since badgers are burrowing animals, it is recommended that the directional fencing be dug at least 4 foot underground (Bekker & Canters 1995).

Figure 43. Two badgers traveling through a culvert in the Netherlands.

4.11 Potential future studies to build on this existing work.

The only viable linkage for badgers to travel from the Midpen core preserve population may be along the coastal linkage. This linkage has much more highly suitable habitat available compared to the Monte Bello OSP-Sierra Azul OSP linkage (Figure 5). The historical badger records indicate that badgers might be utilizing the coastal linkage as the majority of records fell within or in the vicinity of this linkage (Figure 5). The predictive model results indicate that there is a higher probability of badgers occurring along the coast than through the Sierra Azul OSP complex (Figure 44).

Another aspect that makes this linkage favorable is that there is a high degree of connected protected lands running along the coast within the coastal linkage (Figure 45). However, we would need to further investigate: 1) which linkage connects the La Honda OSP to the coastal linkage 2) ground-truth the coastal linkage by replicating the transect and camera methods used in this study to build on this baseline data and 3) further collection of genetic samples to increase the genetic sample size to have a better understanding of the genetic structure of this population to determine if the population is indeed isolated.

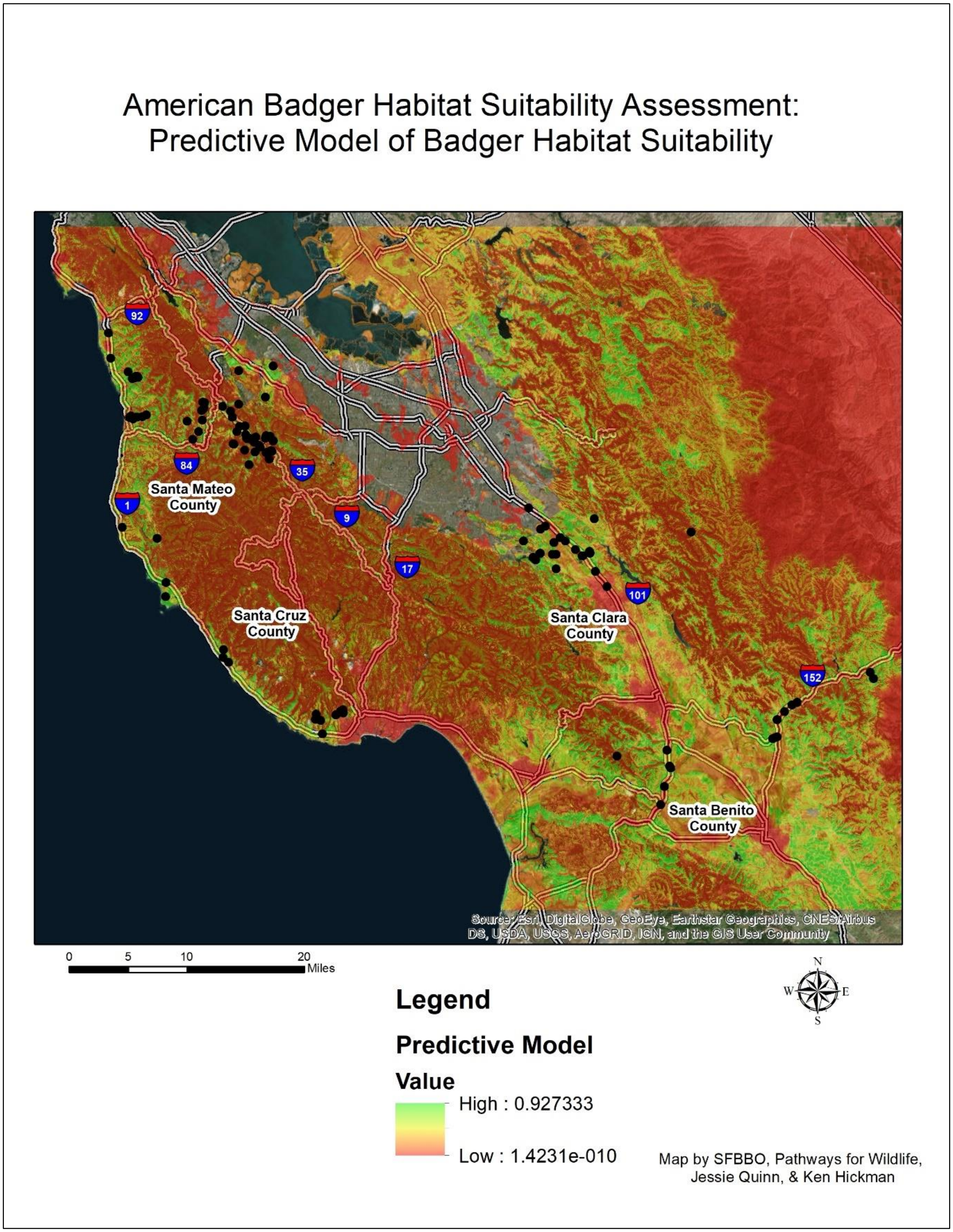


Figure 44. Predictive model of badger habitat suitability.

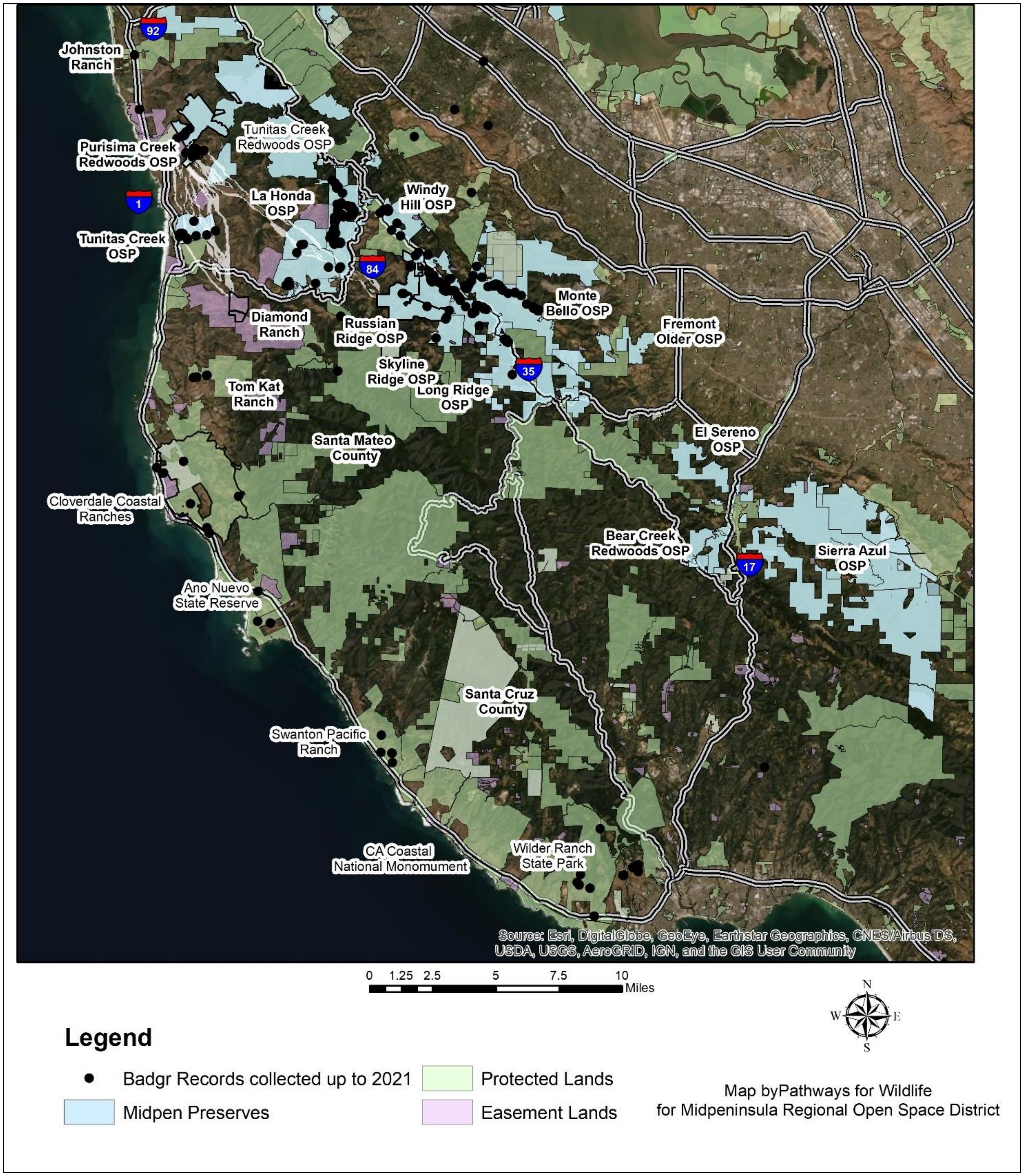


Figure 45. Badger records with protected and easement lands.

4.12 Acknowledgements

We would like to thank Midpeninsula Regional Open Space District (Midpen) for funding this study and working with this team to develop it. Our Midpen project manager Karine Tokatlian, Resource Management Specialist II, Julie Andersen, Midpen Senior Resource Management Specialist, and Kirk Lenington, Midpen Natural Resources Manager, were instrumental in launching this project and we are very thankful for their support.

We would also like to thank the California Department of Fish and Wildlife for their collaboration on the project. We thank Peninsula Open Space Trust (POST) for access to Cloverdale and staff at TomKat Ranch for conducting badger surveys.

Many thanks to the wonderful volunteer group who joined us in conducting badger surveys in 2019 and 2020. We very much appreciate your time and help on the project.

This study builds on the thesis work by T. Diamond and J. Quinn, CDFW Badger Status Report. We are very grateful to have the opportunity to build on that work and bring the recommendations from that 2008 status report to fruition through this study.

Badger recorded at Long Ridge.

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Badger Records collected from 2019-2021.

Please see supplemental materials: American badger Master Database (excel workbook) and GIS shapefile for the comprehensive database with detailed information.

5.0 Population Genetics of Badgers

5.1 Introduction

The purpose of the population study is to better understand the viability and potential trajectory of the badger population that inhabits the MROSD Preserves. While badgers have consistently occupied the San Francisco Peninsula (Peninsula) where the preserves are located, the population size and movement of individuals to adjacent areas is not well understood. Both of these factors can affect badger population persistence. Widespread, interbreeding populations can maintain higher levels of genetic diversity, be more able to adapt to environmental changes, and be less susceptible to extinction. Small populations that are geographically isolated can be subject to low levels of genetic diversity due to their small effective population size, inbreeding, and genetic drift (changes in allele frequency due to chance, when some individuals reproduce more than others). Burrowing owls were not included in this analysis due to their relatively low level of genetic structuring and few dispersal barriers across North America (Macías-Duarte et al. 2020).

The habitat on the Peninsula potentially limits both badger population size and movement. Grassland habitat and open areas in other habitat types that are preferred by badgers are separated by steep, forested ravines and dense chaparral throughout the Peninsula. Although badgers likely traverse these areas occasionally, and are capable of dispersing long distances, the Peninsula is further separated from habitat and other badger populations in the south and east Bay Area by urban development and highways, and from the north Bay Area by waters of the San Francisco Bay. These barriers potentially isolate badgers in patches of suitable habitat within the Peninsula.

This report presents the results of the genetic analysis of the badger population in the MROSD preserves. The objectives of the population study were to use genetic analysis to estimate the size and structure of the badger population within the preserves, and to determine whether it is a distinct, isolated badger population, or part of a widespread, interbreeding regional population across the Bay Area.

5.2 Methods

5.2.1 Sample Collection

The study area targeted for focused sample collection included the MROSD Preserves and nearby or adjacent lands owned by Peninsula Open Space Trust (POST), Stanford University, and TomKat Ranch. Surrounding counties were included for opportunistic sample collection, including Sonoma, Marin, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Benito, northern Monterey, Santa Cruz, San Mateo Counties. Sample types collected for analysis included badger hair, tissue, and scat samples from carcasses, live animals, or recent burrow digs and tailings (hair and scat).

We initially sought badger samples through an outreach effort starting in May 2019. We compiled a spreadsheet of agency and independent biologists and other personnel regularly in the field that might encounter badgers (including road-killed badgers) or their diggings. We either emailed or called contacts and provided a study description and request for badger samples or locations where badger samples could be collected. We sent sample collection instructions via email to respondents that expressed interest in collecting samples they encountered. In some cases, people that we contacted circulated the request and instructions to their own networks.

After receipt of a California Department of Fish and Wildlife Scientific Collection Permit #S-190250001-19025-001, application in December 2019, we actively collected samples between January 1, 2020, and August 31, 2021. To collect hair, we installed hair snares in active burrows identified during transect surveys or other field visits (Figure 5-1). The field team placed approximately 20 hair snares in locations across the preserves for periods of one to several weeks, rotating them through areas of recent activity. We also manually collected shed hair found in burrow tailings. Locating hair involved looking closely at the soil and sifting the top layer very lightly so as not to damage any hairs present. We collected potential badger scat and tissue samples from road-killed badgers when opportunistically encountered at the MROSD preserves or at other locations in the broader study area. We included additional hair and tissue samples collected by PFW between 2007 and 2017 within the study area in the genetic analysis. Sample collection protocols are in Appendix B.

For all samples, we recorded the date, location coordinates, sample type, and sample collector in a spreadsheet. If known, primarily for road killed badgers, we also recorded sex and estimated age.

Figure 5-1. Hair snare installed in a burrow.

Sample collection for this study followed standard protocols developed by the Mammalian Ecology and Conservation Unit (MECU) of the Veterinary Genetics Laboratory at University of California, Davis (Appendix B). Hair samples were typically stored in manilla coin envelopes or 50 too 100 cc vials of 95% ethanol (EtOH). Scat and tissue samples were also stored in EtOH or vials of desiccant. Some tissue samples were frozen prior to transfer to EtOH or desiccant. All samples were stored in a dark, dry location prior to transfer to the lab for analysis. Samples collected prior to the study and provided through the outreach effort had, in some cases, been stored in plastic bags, and scat stored in plastic or paper bags. Long term storage of these samples was not known in most cases.

5.2.2 Laboratory Analysis- Individual Identification

All laboratory procedures were conducted at the MECU. We used microsatellite DNA for genetic analysis to identify individual badgers. Microsatellites are segments of DNA characterized by repeating nucleotide sequences flanked by unordered sequences that are highly polymorphic, or have many variants, such that two individuals are extremely unlikely to share the same combination of alleles across multiple loci. This variation allows individuals to be distinguished from each other when the genotypes are identified.

We used Multiplex Manager 1.0 (Holleley and Geerts 2009) to select primers for 12 microsatellite loci developed in American badger (Davis and Strobeck 1998, Rico et al. 2014) and one developed in American marten (*Martes americana*; Ma1; Davis and Strobeck 1998) known to amplify in badgers. We used the microsatellite locus from American marten to increase the number of microsatellite loci in our analysis, and thus our ability to detect population structure. Primers can work across species because while the repeating sequences in microsatellites are different between individuals, the flanking regions can be similar for closely related species.

We used a primer-pair for a section of the male-specific SRY gene as a sex marker. Because the SRY gene is located on the Y chromosome, it only amplifies in males. A lack of amplification in a sample that is successfully genotyped for other loci indicates it is from a female. Because there was no badger- specific sex marker for badgers available, we used a primer pair developed for a related species, the Eurasian otter (*Lutra lutra*, Statham et al. 2007). Marker accuracy was evaluated post-hoc based on classification of individuals whose sex was known.

Samples of hair, scat, and tissue samples were extracted for genetic analysis at the Mammalian Ecology and Conservation Unit of the Veterinary Genetics Laboratory at U.C. Davis. Genetic material in hair that can be used for analysis is contained in the root bulbs, or follicles; this part of the hair was clipped from the rest of the hair shaft for analysis. Because scat samples contain not only the genetic material from the target animal, but also from its prey, the outer layer of scat samples, where the scat has the most contact with badger epithelial cells, was used for genetic analysis. Tissue analysis required small pieces of tissue.

DNA was extracted from samples using QIAGEN DNeasy 96 Blood & Tissue kit (cat no 69582) or QiaAmp stool kit following manufacturer's protocols with the appropriate digestion agents, buffers, and modified elution volumes for each sample type, then was prepared for amplification using QIAGEN Multiplex PCR kit (cat no 206145). DNA amplification was attempted by two or more independent polymerase chain reactions (PCR) to identify alleles, or gene presence, at each of the 13 microsatellite and SRY loci for all samples.

We mapped locations of all samples that identified individual badgers to review their locations on Google Earth.

5.2.3 Data Analysis

We mapped locations of all samples that identified individual badgers to review their locations Google Earth. To evaluate genetic relatedness between individuals and population structure, individual badgers were assigned to one of three hypothetical populations based on the location the sample was collected. We delineated the three populations in reference to the MROSD Preserves and assumed barriers to the north, and east/southeast (described in Section 5.1) as follows:

- Peninsula (PN) – Includes the MROSD Preserves and extends from the eastern foothills of the Santa Cruz Mountains west to the Pacific Ocean in San Mateo, Santa Cruz, and northwestern Santa Clara Counties. Because the preserves are contiguous with other open space on the Peninsula, we considered samples from the preserves as part of the PN population.
- South Bay Area (SB) – Southeast of the PN population boundary, from Coyote Valley in Santa Clara County east into the Diablo Range; and
- North Bay Area (NB) – north of the PN population and San Francisco Bay, in Marin, Sonoma, and Napa Counties.

The presence of only closely related badgers within a population could indicate limited movement and/or gene flow between other populations and inbreeding within populations. We used ML-RELATE (Kalinowski et al. 2006) to calculate maximum likelihood estimates (MLE) of relatedness between individuals. The MLE is the probability that two individuals are related on a scale of 0 (not related) to 1.0 (identical, same individual or twins) given a predicted distribution of kinship values.

We used thresholds of MLE >0.38 between pairs of individuals as likely first-order relatives (parent-offspring or siblings) and >0.12 and ≤ 0.38 as likely second-order relatives (grandparents, grandchildren, uncles, aunts, nephews, nieces, and half-siblings). Assuming that parents and offspring or siblings were once at the same place at the same time, we drew linear connections between these first-order badger pairs to illustrate the distance badgers traveled from each other and landscape types potentially traversed between locations. We also connected pairs of second-order relatives to show multigenerational movement distances traveled and landscapes crossed.

To evaluate genetic diversity and structure within and between the three populations, we evaluated unbiased heterozygosity (Hz), observed Hz, fixation indices F_{ST} and F_{IS}, and a subpopulation estimate (K).

We quantified two measures of heterozygosity (Hz), which are indications of overall genetic diversity in the population. Unbiased Hz indicates the estimated frequency of heterozygous loci (i.e., having two distinct alleles, rather than two copies of the same allele) assuming random interbreeding. Observed Hz estimates the same quantity by simply enumerating the proportion of loci that are heterozygous in genotypes of each individual and averaging across individuals. Generally, a high frequency (maximum 1.0) of heterozygosity in a population indicates high diversity, and low frequency (minimum 0) indicates low diversity. We used MS Toolkit (Park 2001) to calculate both measures of HZ.

F_{ST} is a measure of the amount of population differentiation due to genetic structure, calculated by comparing allele frequencies between populations as follows:

$$F_{ST} = \frac{H_T - H_S}{H_T}$$

where HT is the pooled proportion of heterozygotes in both populations and HS is the average proportion of heterozygotes for each of the individual populations. F_{ST} values range from 0 to 1, with higher values indicating higher degrees of differentiation. An F_{ST} of greater than 0.15 is considered to be significant differentiation for microsatellites (Frankham et al. 2002). We generated and compared F_{ST} between all pairs of populations using GENEPOP (Raymond and Rousset 1995, Rousset 2000).

The inbreeding coefficient F_{IS} shows whether there is a departure from theoretical expectations (i.e., assuming random mating) in the relationship between observed Hz and unbiased Hz. If the observed Hz of a population is substantially lower than unbiased Hz[1], F_{IS} is closer to 1. If the observed Hz of a population is equivalent to the unbiased Hz, F_{IS} is 0. High positive F_{IS} values indicate substructure, or genetically differentiated groups (subpopulations), within each population. We calculated F_{IS} values for all populations using the formula:

$$F_{IS} = 1 - \frac{\text{observed } H_Z}{\text{unbiased } H_Z}$$

We used the program STRUCTURE (Falush et al. 2003, Pritchard et al. 2000) to evaluate the number of populations (K) our data best defined. STRUCTURE analyses places samples into groups of individuals that share similar patterns of variation (i.e., reflect a single randomly interbreeding population, distinct from others). Close relatives based on MLE relatedness were removed from the PN population prior to analysis to reduce clustering bias. Although there were also relatives (second-order) in the SB population, they were retained for analysis to due to the population's small sample size. We used an admixture model with correlated allele frequencies to characterize population structure using 5,000 burn-in, 15,000 post-burn-in Markov Chain Monte Carlo (MCMC) cycles at hypothesized K values of 2, 3 and 4. The delta K (ΔK) model (Evanno et al. 2005) was used to select the optimal number of populations from the hypothesized values.

5.3 Results

5.3.1 Sample Collection

We sent 42 data requests directly to our list of contacts. Several individuals contacted forwarded the request to at least 50 additional contacts (based on emails where we were cc'd on the circulation). A total of 35 subsequent responses came from both direct contacts and additional contacts they referred; these are included in Table 5-1. Most contacts that responded agreed to contact the team if they saw a road killed badger or areas of recent badger activity where we could collect samples ("will contact" in Table 5-1).

A total of 11 samples were obtained from the solicitation. An additional two samples offered, including a taxidermied badger and bones of uncertain age, were unlikely to have viable DNA for analysis and were thus not collected from contacts. Table 5-1 includes a list of known direct and indirect contacts and results of the inquiry. Because we were not always given the information of those contacted second-hand, there were likely other individuals contacted that are not included in the Table 5-1.

[1] Unbiased Hz is calculated for a diploid population based on the Hardy-Weinberg Equilibrium principle, which states that a population's genotype frequencies are a function of random pairing of alleles as predicted from the frequencies of those alleles in the population; genotype frequencies will remain constant across generations if there are no outside influencing factors/disturbance (nonrandom mating, gene flow, mutation, natural selection, random genetic drift).

Table 5-1. Contacts solicited for badger genetic samples or collection opportunities. "Forwarded" = the solicitation was forwarded to a. "Will contact" = respondent would contact us if information or samples were found. "Activity info" = respondent shared locations of known badger activity.

County	Organization/Project Name	Contact Name	Direct or referred contact	Date Contacted	Response Date	Response Type
Caltrans District 4	Branch Chief-District 4	Robert Young	direct	5/13/19	--	none
Caltrans Districts 4 and 5	Wildlife Biologist	Morgan Robertson	direct	5/13/19	--	none
Caltrans Headquarters	Lead Wildlife Connectivity Specialist	Lindsay Vivian	direct	5/13/19	--	none
CDFW	Brian Acord, CDFW CNDDB Lead Zoologist	Brian Acord	direct	5/13/19	5/20/19	will contact
CDFW District 4	District 4 Wildlife Biologist	Terris Kasteen	direct	5/13/19	5/15/19	will contact
CDFW District 5	District 4 Wildlife Biologist	Cristen Langner	direct	5/13/19	5/17/19	activity info
CDFW/ CA	CDFW Wildlife Investigations Lab	Deanna Clifford	direct	5/12/19	--	none
CDFW/ Caltrans Headquarters	Mitigation Specialist & Caltrans Liaison	Andrew Amacher	direct	5/13/19	--	none
Bay Area	Biologist	Sue Townsend	direct	5/22/19	--	none
Alameda	UC Berkeley	Alan Shabel	referred	5/22/19	6/1/19	will contact
Contra Costa/Alameda	East Bay Regional Parks	Steve Bobzien	direct	5/13/19	5/14/19	will contact
Marin	National Park Service- Point Reyes Natl. Seashore	Dave Press	referred	5/21/19	5/22/19	will contact
Marin	UCNRS- Bodega Marine Lab	N/A	referred	5/21/19	--	none
Marin	Marin County Parks	Jim Chayka	direct	5/13/19	--	none
Marin	Marin County Parks	Mischon Martin	direct	5/28/19	5/28/19	will contact, forwarded
Marin	Marin County Parks	Lisa Michl	referred	5/28/19	5/28/19	will contact
Marin	Marin Open Space Trust	General line	direct	5/20/19	--	none
Marin	UCNRS- Point Reyes Field Station	Allison Kidder	referred	5/20/19	5/21/19	will contact, forwarded
Marin	National Park Service- Point Reyes Natl. Seashore	Dane Horowski	referred		--	provided samples in 2020, follow up samples in 2021
Monterey	UCNRS- Hastings Reserve	Jen Hunter	direct	5/13/19	5/15/19	sample, forwarded

County	Organization/Project Name	Contact Name	Direct or referred contact	Date Contacted	Response Date	Response Type
Monterey	UCNRS- Fort Ord Reserve	Joe Miller	referred	5/20/19	5/23/19	sample
Napa	Land Trust of Napa County	Lena Pollastro	referred	5/20/19	5/22/19	will contact, forwarded
Napa	Napa County Open Space District	General line	direct	5/20/19	5/20/19	will contact, forwarded
Napa	UCNRS- McLaughlin Reserve	Catherine Koehler	direct	5/22/19	5/22/19	invitation to survey
San Mateo	San Mateo County Parks	Hannah Ormshaw	direct	5/13/19	--	none
San Mateo	San Mateo County Parks	Ramona Arechiga	direct	5/13/19	5/14/19	will contact, forwarded
San Mateo	CA State Parks - Bay Area District	Portia Halbert	direct	5/13/19	5/14/19	non-viable sample offered in May 2019, follow up sample in June 2019
San Mateo, Santa Clara	Bay Area Tracking Club	Garth Hardwood	direct	5/13/19	5/21/19	will contact
Santa Clara	MROSD	Karine Tokatlian	direct	5/13/19	5/14/19	will contact
Santa Clara	Santa Clara Valley Transportation Authority	Ann Calnan	direct	5/13/19	5/14/19	activity info
Santa Clara	Santa Clara Valley Open Space Authority	Galli Basson	direct	5/13/19	5/14/19	will contact
Santa Clara	Santa Clara County Parks	Michael Rhoades	direct	5/13/19	--	none
Santa Clara	Santa Clara Valley Open Space Authority	Matt Freeman	direct	5/13/19	--	none
Santa Clara	Santa Clara County Parks	Jeremy Farr	direct	5/13/19	5/14/19	will contact
Santa Clara	UCNRS- Blue Oak Ranch Reserve	Zac Harlow	direct	5/20/19	--	none
Santa Clara	Santa Clara Valley Habitat Agency	Terah Donovan	direct	5/13/19	--	none
Santa Clara	Santa Clara Valley Habitat Agency	Ed Sullivan	direct	5/13/19	5/14/19	will contact
Santa Clara	Santa Clara Valley Water District	Shawn Lockwood	direct	5/13/19	5/14/19	will contact, forwarded
Santa Clara	Stanford Lands	Alan Launer	direct	5/13/19	5/14/19	will contact, forwarded
Santa Clara	Stanford Lands	Esther Cole	direct	5/13/19	--	none
Santa Clara	HT Harvey Biological Consulting Firm	Steve Rottenborn	direct	5/13/19	5/14/19	will contact
Santa Clara	Palo Alto Animal Control	Bill Warrior	direct	6/14/20	6/14/20	will contact

County	Organization/Project Name	Contact Name	Direct or referred contact	Date Contacted	Response Date	Response Type
Santa Clara, San Mateo, Santa Cruz	Peninsula Open Space Trust (POST)	Neal Sharma	direct	5/13/19	5/14/19	will contact
Santa Cruz	CA State Parks - Santa Cruz District	Tim Hyland	direct	5/13/19	--	none
Santa Cruz	Santa Cruz Museum of Natural History	Chris Lay	direct	5/13/19	--	none
Santa Cruz	UCSC WIlmers Lab	Chris Wilmers	direct	5/13/19	5/14/19	will contact
Santa Cruz	UCSC Campus Natural Reserve	Alex Jones	direct	5/13/19	5/14/19	will contact
Santa Cruz	TomKat Ranch	Wendy Millet	direct	5/24/19	5/24/19	invitation to survey
Santa Cruz	Cal Poly- Swanton Ranch	Grey Hayes	direct	5/24/19	5/24/19	will contact
Sonoma	Sonoma Land Trust	Tony Nelson	direct	5/20/19	5/21/19	forwarded
Sonoma	Sonoma Mountain Ranch	Jeff Wilcox	direct	5/22/19	5/23/19	sample, follow up sample
Sonoma	CDFW District 3	Stacy Martinelli	direct	5/22/19	5/29/19	2 samples
Stanislaus	The Nature Conservancy	Sasha Gennet	referred	5/22/19	5/22/19	non-viable sample
Yolo	UC Davis -ICE	Bob Meese	referred	5/22/19	5/23/19	will contact

Three snares placed in burrows successfully captured hairs. A total of 54 samples of between one and 14 hairs and 12 scat samples were collected from burrow tailings and burrow entrances. Nine hair samples included in the genetic analysis were from samples PFW and their contacts prior to the study. We collected 5 tissue samples: 2 from road-killed animal found during the study, and 3 provided by contacts from the data solicitation, including a sample from a road-killed badger and from a badger potentially killed by a mountain lion.

In total, we collected 103 samples, including 9 samples collected by PFW prior to this study. Of those, 74 were hair, 24 were scat, and 5 were tissues from 4 road-killed carcasses and one animal potentially killed by a mountain lion at Point Reyes National Seashore. All samples were used in PCR analysis. Results (DNA amplified successfully or not) are included in Table 5-2.

Table 5-2. Sample sources included in genetic analysis and PCR results. OSP – Open Space Preserve

Date Collected	Sample type	Latitude	Longitude	PCR success?	Age if known	Sex if known	Location	Collected by	County	Footnotes
2/1/07	hair	37.18718	-121.75731	No	--	--	Bailey Ave., San Jose	P. Congdon	Santa Clara	1, 2
7/1/07	hair	37.0367	-121.57418	Yes	--	--	Hwy 101, Gilroy	PFW	Santa Clara	2
7/11/07	hair	37.02476	-121.5684	Yes	--	--	Hwy 101 at Leavesley Rd.	PFW	Santa Clara	2
4/23/09	hair	--	--	No	--	male	Bailey Ave., San Jose	PFW	Santa Clara	2, 3
6/23/09	hair	--	--	No	--	--	Hwy 1	PFW	San Mateo	2
5/18/10	hair	37.40577	-122.05828	Yes	--	--	Hwy 101 at Bailey Ave.	PFW	Santa Clara	2
5/23/11	hair	37.04141	-121.63794	No	--	--	2600 Day Rd., Gilroy	C. Edgerton	Santa Clara	1, 2, 3
7/6/14	hair	--	--	No	juvenile	female	Windy Hill OSP	C. Roessler	San Mateo	1, 2, 4
12/16/17	hair	37.19606	-121.70029	Yes	--	--	Hwy 101	PFW	Santa Clara	2
5/29/19	hair	38.33452	-122.7383	Yes	--	female	Cotati	S. Martinelli	Sonoma	1
6/4/19	hair	37.21323	-122.40591	Yes	--	female	Hwy 1	P. Halbert, A. Sandoval	San Mateo	1
6/23/19	scat	36.68145	-121.77722	No	--	--	UC Santa Cruz Fort Ord Preserve	J. Miller	Monterey	1
6/23/19	hair	38.3306	-122.57801	Yes	--	--	Sonoma Mountain Ranch	J. Wilcox	Sonoma	1, 3
7/29/19	hair	36.97278	-121.42738	No	--	--	SR 152 eastbound	PFW	Santa Clara	
8/2/19	scat	37.40888	-122.39424	No	--	--	Purisima Creek Redwoods OSP	K. Hickman	San Mateo	4
8/6/19	hair	--	--	No	--	--	TomKat Ranch	D. Wenny	San Mateo	
1/11/20	hair	37.36391	-122.24355	No	--	--	Windy Hill OSP	J. Quinn	San Mateo	4
1/18/20	hair	37.34043	-122.28285	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
1/18/20	hair	37.34472	-122.28258	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
1/20/20	hair	37.3114	-122.14467	No	--	--	Monte Bello OSP	D. Wenny	Santa Clara	4
1/24/20	scat	--	--	No	--	--	Monte Bello OSP	PFW	Santa Clara	4
1/25/20	hair	37.34303	-122.38921	No	--	--	Toto Ranch/Tunitas Creek OSP	K. Hickman	San Mateo	4

Date Collected	Sample type	Latitude	Longitude	PCR success?	Age if known	Sex if known	Location	Collected by	County	Footnotes
1/25/20	hair	37.34818	-122.39302	Yes	--	--	Toto Ranch/Tunitas Creek OSP	K. Hickman	San Mateo	4
1/27/20	hair	37.31695	-122.14644	No	--	--	Monte Bello OSP	K. Hickman	Santa Clara	4
1/31/20	hair	37.41251	-122.21355	Yes	--	--	Stanford Collins Ranch	K. Hickman	San Mateo	
1/31/20	scat	37.41251	-122.21355	No	--	--	Stanford Collins Ranch	K. Hickman	San Mateo	
2/5/20	hair	37.26754	-122.37808	Yes	--	--	TomKat Ranch	K. Hickman	San Mateo	
2/5/20	scat	37.26754	-122.37808	No	--	--	TomKat Ranch	K. Hickman	San Mateo	
2/11/20	hair	37.3505	-122.28272	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
3/30/20	tissue	37.21893	-121.73236	Yes	--	--	Hwy 101	PFW	Santa Clara	
5/10/20	hair	38.0418	-122.87057	Yes	juvenile	male	Limnatour hostel/beach, Point Reyes Natl. Seashore	D. Horowitz	Marin	1
5/10/20	tissue	38.0418	-122.87057	Yes	juvenile	male	Limnatour hostel/beach, Point Reyes Natl. Seashore	D. Horowitz	Marin	1
5/24/20	scat	36.38736	-121.55172	No	--	--	UC Berkeley Hastings Preserve	J. Hunter	Monterey	1
6/2/20	scat	37.31054	-122.13792	No	--	--	Monte Bello OSP	PFW	Santa Clara	4
6/5/20	hair	37.35024	-122.28262	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
6/5/20	hair	37.35024	-122.28262	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
6/5/20	hair	37.35014	-122.28272	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
6/22/20	hair	37.3502	-122.28256	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
6/24/20	hair	36.99974	-121.37361	No	--	--	SR 152	PFW	Santa Clara	
6/25/20	hair	37.34841	-122.28257	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
6/25/20	hair	37.3502	-122.28256	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
9/21/20	hair	--	--	No	--	--	Windy Hill OSP	PFW	San Mateo	4
10/13/20	scat	--	--	No	--	--	Long Ridge OSP, Hickory Trail	PFW	San Mateo	4
10/19/20	scat	--	--	No	--	--	Long Ridge OSP	PFW	San Mateo	4
10/31/20	hair	38.45201	-123.11316	Yes	--	female	9069 Balboa Ave., Jenner	R. Gutierrez	Sonoma	1

Date Collected	Sample type	Latitude	Longitude	PCR success?	Age if known	Sex if known	Location	Collected by	County	Footnotes
10/31/20	scat	38.45201	-123.11316	Yes	--	female	9069 Balboa Ave., Jenner	R. Gutierrez	Sonoma	1
12/30/20	scat	37.34848	-122.28153	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
1/7/21	scat	37.3661	-122.28013	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
1/7/21	hair	37.3661	-122.28013	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
1/15/21	hair	37.2902	-122.15601	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.29023	-122.15555	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.29001	-122.15508	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.36365	-122.24259	No	--	--	Windy Hill OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.36435	-122.24271	No	--	--	Windy Hill OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.29108	-122.15686	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.29137	-122.1563	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
1/15/21	hair	37.29001	-122.15508	No	--	--	Long Ridge OSP	A. Sandoval, J. Quinn	San Mateo	4
2/8/21	scat	37.34815	-122.28459	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/8/21	scat	37.36573	-122.27068	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/8/21	hair	37.34914	-122.2846	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/8/21	scat	37.31751	-122.15593	No	--	--	Monte Bello OSP	T. Diamond	Santa Clara	4
2/19/21	hair	37.29152	-122.15672	No	--	--	Long Ridge OSP	PFW	San Mateo	4
2/22/21	scat	37.37597	-122.28045	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/22/21	hair	37.37597	-122.28045	Yes	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/23/21	scat	37.34684	-122.28144	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/23/21	scat	37.36215	-122.27007	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4
2/23/21	hair	37.34684	-122.28144	No	--	--	La Honda Creek OSP	K. Hickman	San Mateo	4

Date Collected	Sample type	Latitude	Longitude	PCR success?	Age if known	Sex if known	Location	Collected by	County	Footnotes
2/25/21	hair	37.29137	-122.1563	No	--	--	Long Ridge OSP	J. Quinn	San Mateo	4
4/2/21	hair	37.32125	-122.20501	Yes	--	--	Russian Ridge OSP	PFW	San Mateo	4
4/2/21	hair	37.32068	-122.20599	No	--	--	Russian Ridge OSP	PFW	San Mateo	4
4/2/21	hair	37.32028	-122.20344	No	--	--	Russian Ridge OSP	PFW	San Mateo	4
4/2/21	hair	37.3255	-122.21115	Yes	--	--	Russian Ridge OSP	PFW	San Mateo	4
4/7/21	tissue	37.23829	-121.76199	Yes	adult	male	US 101/Hwy 85	PFW	Santa Clara	
4/13/21	hair	37.30245	-122.20065	Yes	--	--	Skyline Ridge OSP – Big Dipper Ranch	A. Sandoval	San Mateo	4
4/16/21	hair	37.31926	-122.20031	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
4/16/21	hair	37.31954	-122.20467	Yes	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
4/16/21	scat	37.31954	-122.20407	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
4/28/21	hair	37.1904	-122.39365	Yes	--	--	Cloverdale Ranch	D. Wenny	San Mateo	4
5/14/21	hair	37.30041	-122.20206	No	--	--	Skyline - Dipper Ranch	A. Sandoval	San Mateo	4
5/19/21	tissue	38.23714	-122.51794	Yes	adult	female	Hwy 116	J. Wilcox	Sonoma	1
6/30/21	hair	38.1811	-122.94838	Yes	adult	male	Point Reyes Natl. Seashore	D. Horowitz	Marin	1
6/30/21	tissue	38.1811	-122.94838	No	adult	male	Point Reyes Natl. Seashore	D. Horowitz	Marin	1
7/2/21	hair	37.32008	-122.18556	No	--	--	Monte Bello OSP	K. Hickman	Santa Clara	4
7/15/21	hair	37.34477	-122.28141	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/15/21	hair	37.34575	-122.28225	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/15/21	hair	37.34573	-122.28226	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/15/21	hair	37.34751	-122.28402	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/15/21	hair	37.34765	-122.28559	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/15/21	hair	37.34785	-122.28145	Yes	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
7/19/21	hair	37.3222	-122.18451	Yes	--	--	Monte Bello OSP	A. Sandoval	Santa Clara	4
7/19/21	hair	37.32212	-122.18447	No	--	--	Monte Bello OSP	T. Diamond	Santa Clara	4

Date Collected	Sample type	Latitude	Longitude	PCR success?	Age if known	Sex if known	Location	Collected by	County	Footnotes
7/19/21	scat	37.32221	-122.18447	No	--	--	Monte Bello OSP	T. Diamond	Santa Clara	4
7/21/21	hair	37.31913	-122.19991	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/21/21	hair	37.31913	-122.19991	Yes	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/21/21	hair	37.31871	-122.19508	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/21/21	hair	37.31871	-122.19508	Yes	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/21/21	hair	37.31733	-122.19873	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/21/21	scat	37.31913	-122.19991	No	--	--	Russian Ridge OSP	D. Wenny	San Mateo	4
7/23/21	hair	33.1887	-122.3952	No	--	--	Pigeon Point Lighthouse State Park	D. Wenny	San Mateo	
7/23/21	scat	37.18885	-122.39529	No	--	--	Pigeon Point Lighthouse State Park	D. Wenny	San Mateo	
7/27/21	hair	38.19087	-122.95994	No	--	--	Point Reyes OSP, Tomales Elk Preserve Trail	J. Quinn	Marin	
8/18/21	hair	37.3457	-122.28128	No	--	--	La Honda Creek OSP	D. Wenny	San Mateo	4
--	scat	--	--	No	--	--	unlabeled	PFW	unknown	

"—": No data

PFW: Pathways for Wildlife

T. Diamond, K. Hickman, J. Quinn, A. Sandoval, D. Wenny: MROSD Study Team Biologists

[1] Collected/reported by contact

[2] Collected prior to study

[3] Coordinates estimated

[4] Collected on MROSD Preserve

Overall, 38 of the 105 samples amplified successfully, including 33 hair samples, 1 scat sample, and 4 tissue samples. Twenty-one (all hair samples) of the 70 samples collected within the MROSD Preserves amplified successfully (Table 5-3).

Table 5-3. Number of each sample type collected and success rate for study area and MROSD Preserves

Sample Type	Number of samples	Number successful	% success
Hair	76	33	43%
Scat	24	1	4%
Tissue	5	4	80%
Total	**105**	**38**	**36%**
Within MROSD Preserves			
Hair	49	21	43%
Scat	21	0	0%
Tissue	NA	NA	NA
Total	**70**	**21**	**30%**

5.3.2 Individual Badger Identification

The distinct genotypes identified in analysis are in Appendix A, which shows the alleles (one or two) at each of the microsatellite loci for each of the individual badgers identified. There were between 3 and 10 alleles at each locus identified among all individuals for the microsatellites in this study.

The PCR analysis identified 25 individual badgers from the 38 samples that amplified successfully. A total of 13 badgers were identified in the PN population (4 females, 9 males), six in the SB population (2 females, 4 males), and six in the NB population (4 females, 2 males). Thirteen of the samples were multiple samples from single individuals. In two cases, the duplicates resulted from two sample types (hair and tissue) from the same individual at the same location. The other samples represented multiple samples from the same individual collected at multiple locations. For one male and two females in the MROSD Preserves, 3, 5, and 6 samples, respectively, were collected at different locations (Table 5-4).

Samples for eleven badgers total, 3 females and 8 males, were collected within the MRSOD Preserves. Mapped locations of all individuals are in Figure 5-2; those in the MROSD Preserves are in Figure 5-3.

Table 5-4. Samples amplified for individual badgers. OSP – Open Space Preserve

Badger ID	Sex[2]	Number of Samples	Location[2]	Population[3]	Date(s) sample collected	Notes
F1	F	6	La Honda OSP	PN	1/18/2020; 1/7, 2/8, & 2/23, 7/15 2021	2 samples at 2 locations on 7/15/21
F14	F	1	Toto Ranch/Tunitas Creek OSP	PN	1/25/2020	--
F25	F	1	Hwy 1	PN	6/4/2019	--
F3	F	5	Russian Ridge OSP	PN	4/2/2021, 4/16/2021, 7/21/2021	--
M13	M	1	TomKat Ranch	PN	2/5/2020	--
M15	M	1	La Honda Creek OSP	PN	6/5/2020	--
M2	M	3	Stanford Collins Ranch, La Honda Creek OSP	PN	1/20/2020, 6/5/2020	--
M20	M	1	Cloverdale Ranch	PN	4/28/2021	--
M21	M	1	Monte Bello OSP	PN	7/19/2021	--
M22	M	1	Skyline Ridge OSP	PN	4/13/2021	--
M6	M	1	La Honda Creek OSP	PN	7/15/2021	--
M7	M	1	La Honda Creek OSP	PN	7/15/2021	--
M8	M	1	La Honda Creek OSP	PN	7/15/2021	--
F11	F	1	Gilroy	SB	7/1/2007	--
M10	M	1	Coyote Valley	SB	5/8/2010	--
M12	M	1	Gilroy	SB	7/11/2007	--
M9	M	1	Coyote Valley	SB	12/16/2017	--
F16	F	1	Coyote Valley	SB	3/30/2020	--
M17	M	1	San Jose	SB	4/7/2021	--
F18	F	1	Petaluma	NB	5/19/2021	--
F23	F	1	Cotati	NB	5/29/2019	--
F24	F	1	Sonoma Mountain Ranch	NB	6/23/2019	--
F5	F	2	Jenner	NB	10/31/2020	2 sample types, same location
M19	M	1	Point Reyes Natl. Seashore	NB	6/20/2021	--
M4	M	2	Point Reyes Natl. Seashore	NB	5/10/2020	2 sample types, same location

[1] M: male; F: female

[2] MROSD Preserve, other preserve/property, or nearest city (vicinity)

[3] PN: Peninsula Population; SB: South Bay Population; NB: North Bay Population

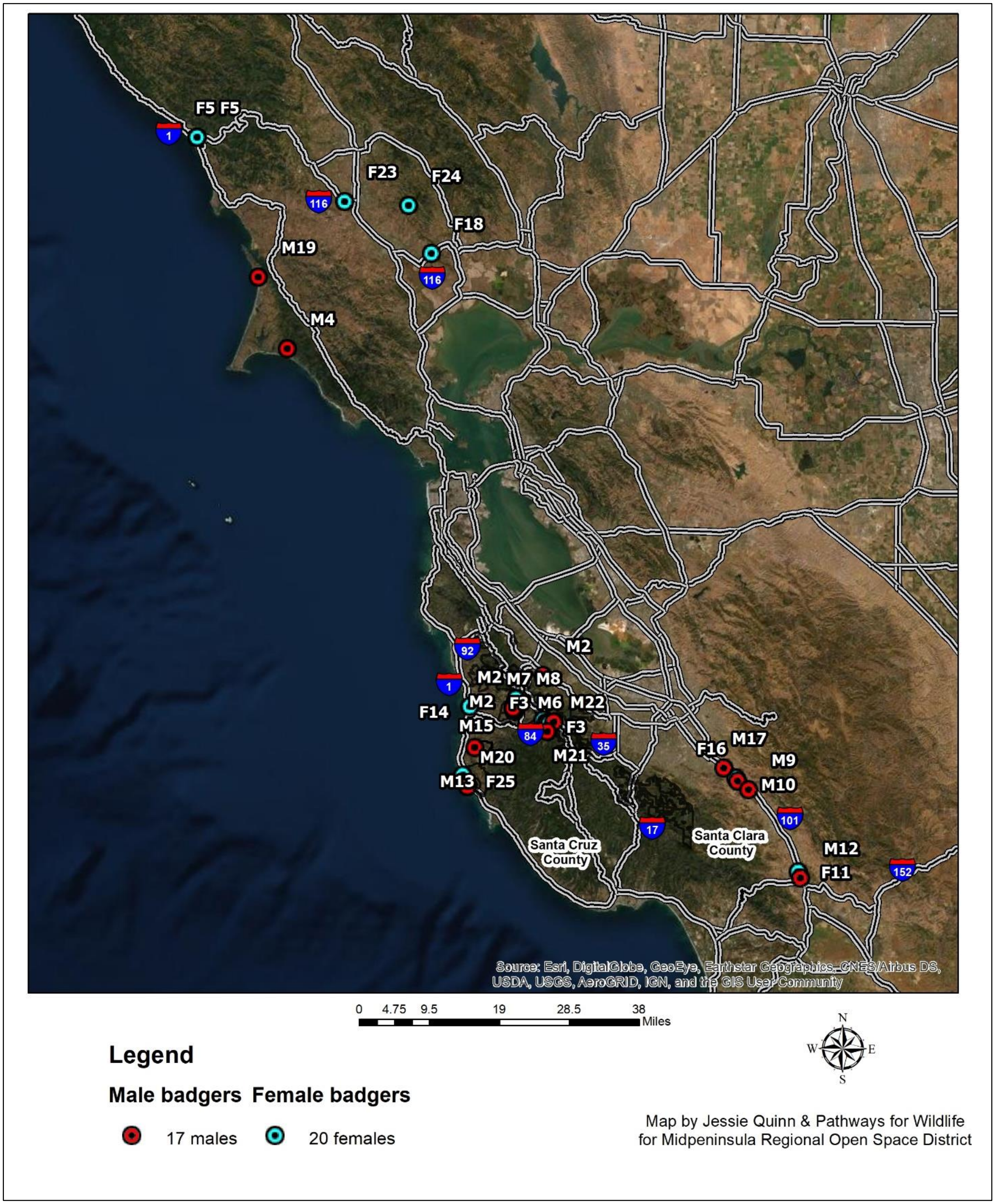

Figure 5-2. Locations of individual badgers identified from genetic analysis. F = female, M = male.

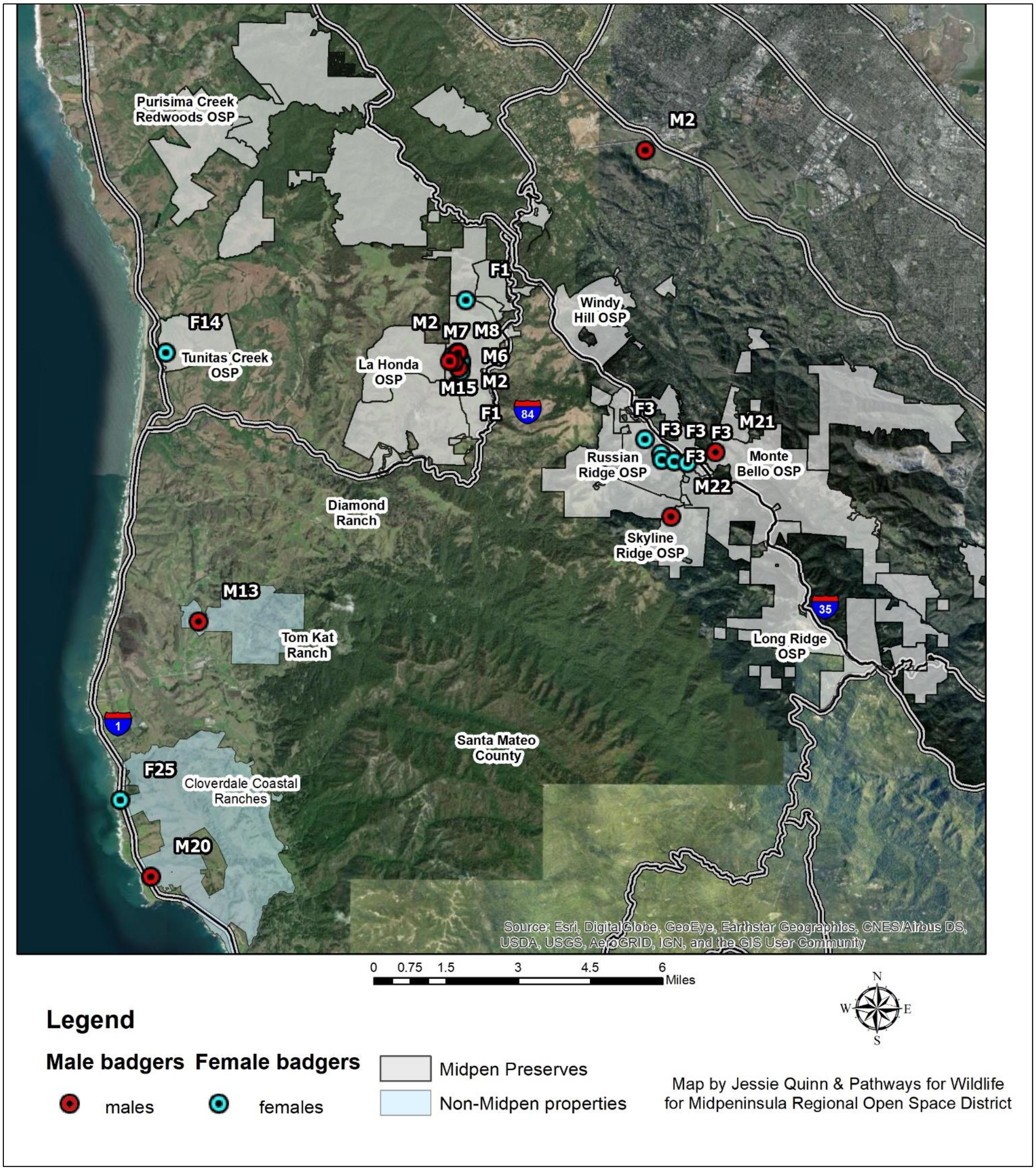

Figure 5-3. Locations of individual badgers identified from genetic analysis within the MROSD preserves. F = female, M = male.

The distances between samples collected for the same individuals showed variation between individuals and landscapes navigated between locations. Two of the three samples from a male badger, M2, were located 5.7 miles apart. The samples were collected approximately 6 months apart (Figure 5-4, but note that the date a hair sample was collected and the actual day the badger was present may differ). One sample was collected from Stanford Collins Ranch (northwest corner of Figure 5-4), the others from La Honda Creek Open Space Preserve (OSP) to the southwest.

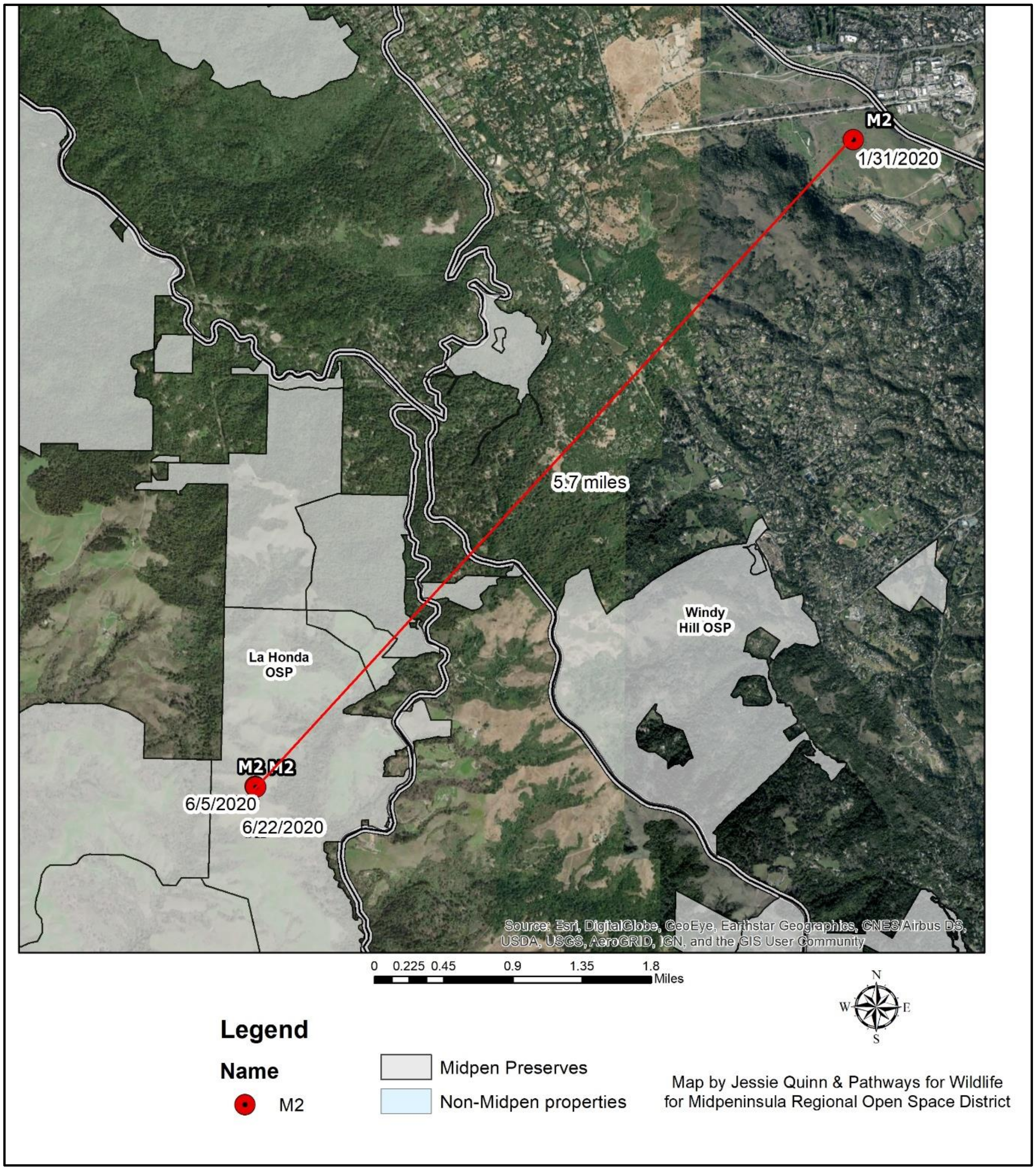

Figure 5-4. Locations and dates of three samples collected from badger M2 (male) approximately 6 months apart.

In contrast to M2, multiple samples collected for two females, F1 and F3, which were each in two different preserves, were closer together. Five samples for F3 at Russian Ridge were collected over the course of approximately 3.5 months and were all within less than approximately a mile of each other, and samples for female F1 at La Honda OSP were collected over the course of approximately one year and were within less than approximately two miles of each other (Figures 5-6 and 5-7).

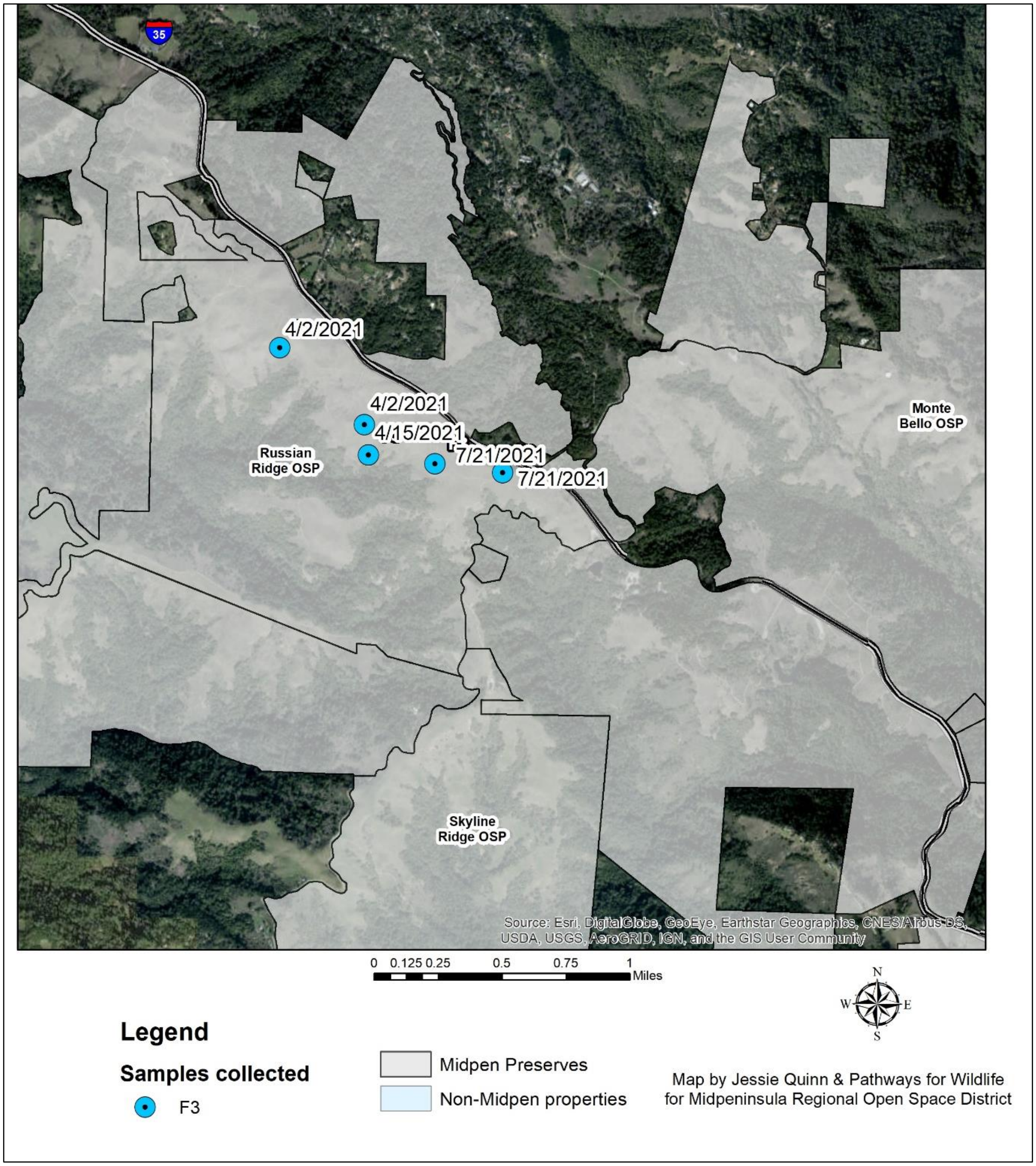

Figure 5-6. Locations and dates of samples collected from badgers F3 at Russian Ridge OSP.

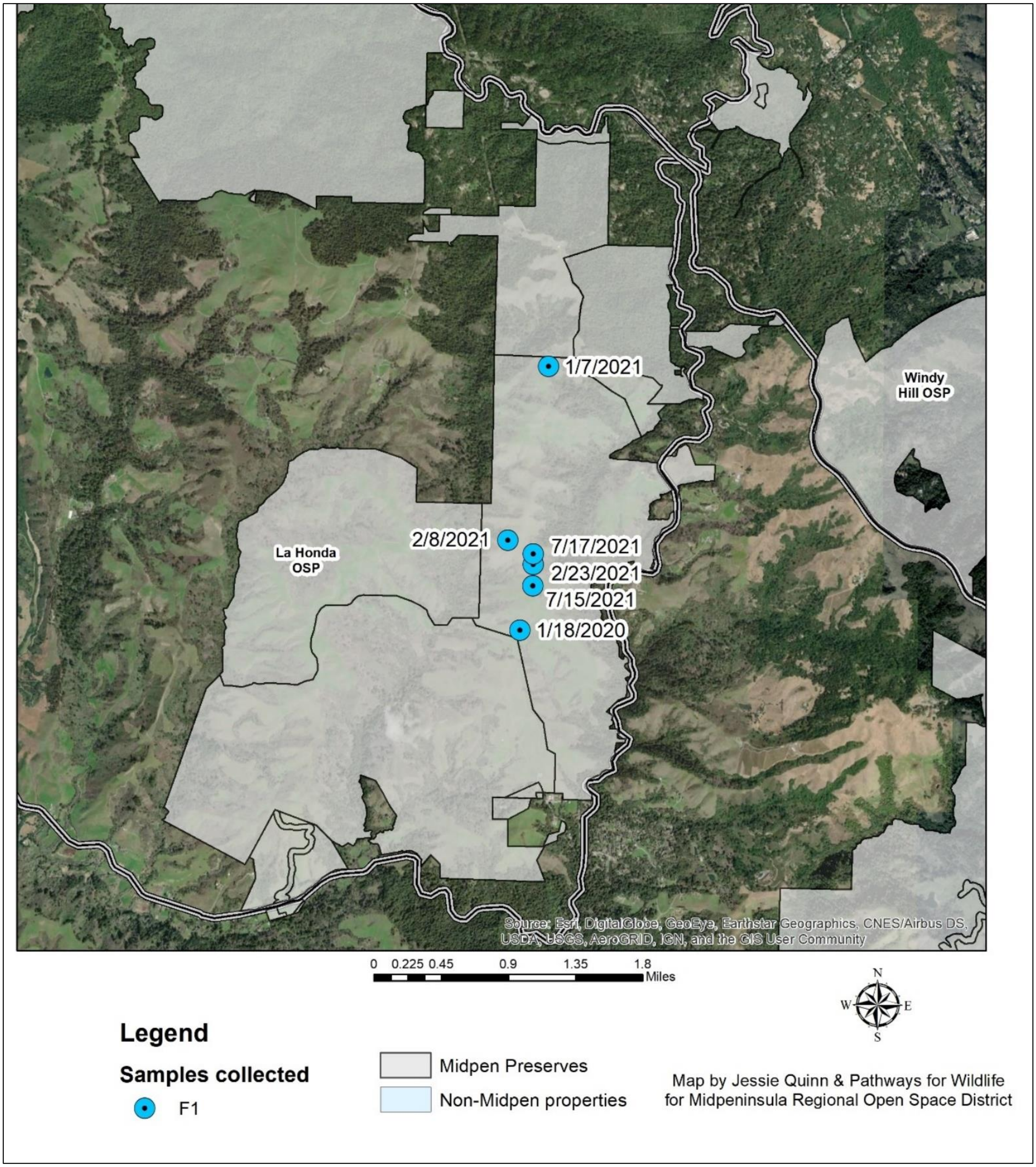

Figure 5-7. Locations and dates of samples collected from badgers F1 at La Honda OSP.

Samples collected for F1 and five male badgers (M2, M6, M7, M8, and M15) were in close proximity to each other, many within approximately 650 feet. Samples from two males, M2 and M15, were collected from the same burrow (Figure 5-8). These samples were collected over the course of 19 months; some on the same day and others the full 19 months apart. We note again that the proximity of the samples, even those collected on the same day, does not mean that the individuals were in the same place at the same time. Badgers are known to use burrows previously used by other badgers; a behavior further addressed in the discussion.

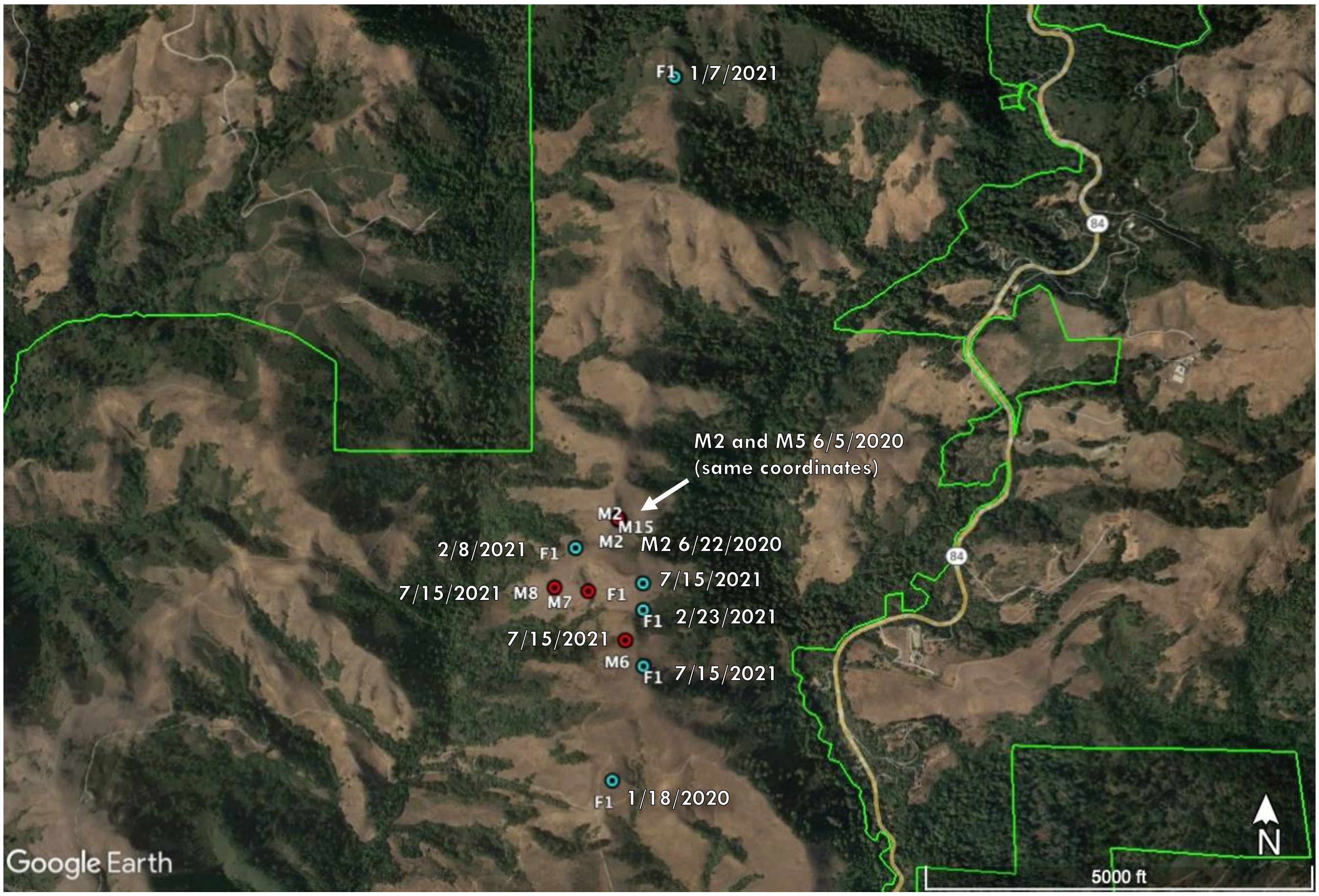

Figure 5-8. Sample locations of 6 badgers at La Honda Creek OSP collected between January 18, 2020, and July 15, 2021.

5.3.3 Relatedness and Population Structure

Relatedness

Among our samples, the PN population had the highest number of related badgers (n = 16) and was the only population from which we sampled first-order relatives – parents, offspring, and siblings (n = 8, Table 5-5). This result likely reflects the difference in sampling effort between the three populations rather than a feature of the populations themselves. We sampled the PN population most intensively, which allowed us to sample more close relatives. There were eight second-order relatives (grandparents, grandchildren, uncles, aunts, nephews, nieces, and half-siblings) sampled in the PN population.

Table 5-5. Maximum likelihood relatedness between PN badger pairs. Yellow highlighting indicates first-order relatives; orange highlighting indicates second-order relatives.

	F1	F14	F25	F3	M13	M15	M2	M20	M21	M22	M6	M7	M8
F1	1												
F14	0	1											
F25	0	0.25	1										
F3	0	0	0.06	1									
M13	0	0	0	0	1								
M15	0.27	0	0	0.19	0	1							
M2	0	0	0	0	0	0	1						
M20	0	0.03	0.5	0	0.04	0	0.02	1					
M21	0	0.54	0.24	0	0	0	0	0.18	1				
M22	0.18	0	0	0	0	0	0.3	0.18	0	1			
M6	0.5	0	0	0	0	0.01	0	0	0	0	1		
M7	0	0	0	0	0.25	0	0.06	0	0	0.11	0.64	1	
M8	0.72	0	0	0	0	0.5	0	0	0	0.5	0.75	0.12	1

There were two pairs of second-order relatives in the NB population (Table 5-6) and no related pairs in the SB population (Table 5-7).

Table 5-6. Maximum likelihood relatedness between NB badger pairs. Orange highlighting indicates second-order relatives.

	F18	F23	F24	F5	M19	M4
F18	1					
F23	0	1				
F24	0	0	1			
F5	0	0	0	1		
M19	0	0.21	0	0	1	
M4	0.11	0	0	0.24	0.05	1

Table 5-7. Maximum likelihood relatedness between SB badger pairs – no related pairs.

	F11	M10	M12	M9	F16	M17
F11	1					
M10	0	1				
M12	0.01	0	1			
M9	0	0.08	0.01	1		
F16	0	0	0	0	1	
M17	0	0	0	0	0.12	1

The locations of related badger pairs for the PN population and NB population are connected with lines labeled with the MLE relatedness values for the pair in Figures 5-9, 5-10 and 5-11. First order relatives (parent-offspring or sibling pairs) at some point in time moved 5.6 and 11.5 miles apart (M22 and M8, samples collected 3 months apart; and M21 and F14, samples collected 1.5 years apart; respectively). Figure 5-7 shows a group of related badgers for whom samples were found in close proximity to each other (note that although samples from F1 and M2 were collected in several locations [see Figure 5-5] within the area mapped in Figure 5-7, only one sample for each individual is included in the Figure 5-for simplicity). These data may indicate some members of a current or previous natal den that have not yet separated. Two of the males in that group also had relatives outside the preserve; M7 had second-order relative 7.6 miles away (M13) and M8 had a first-order relative 5.6 miles away (M22).

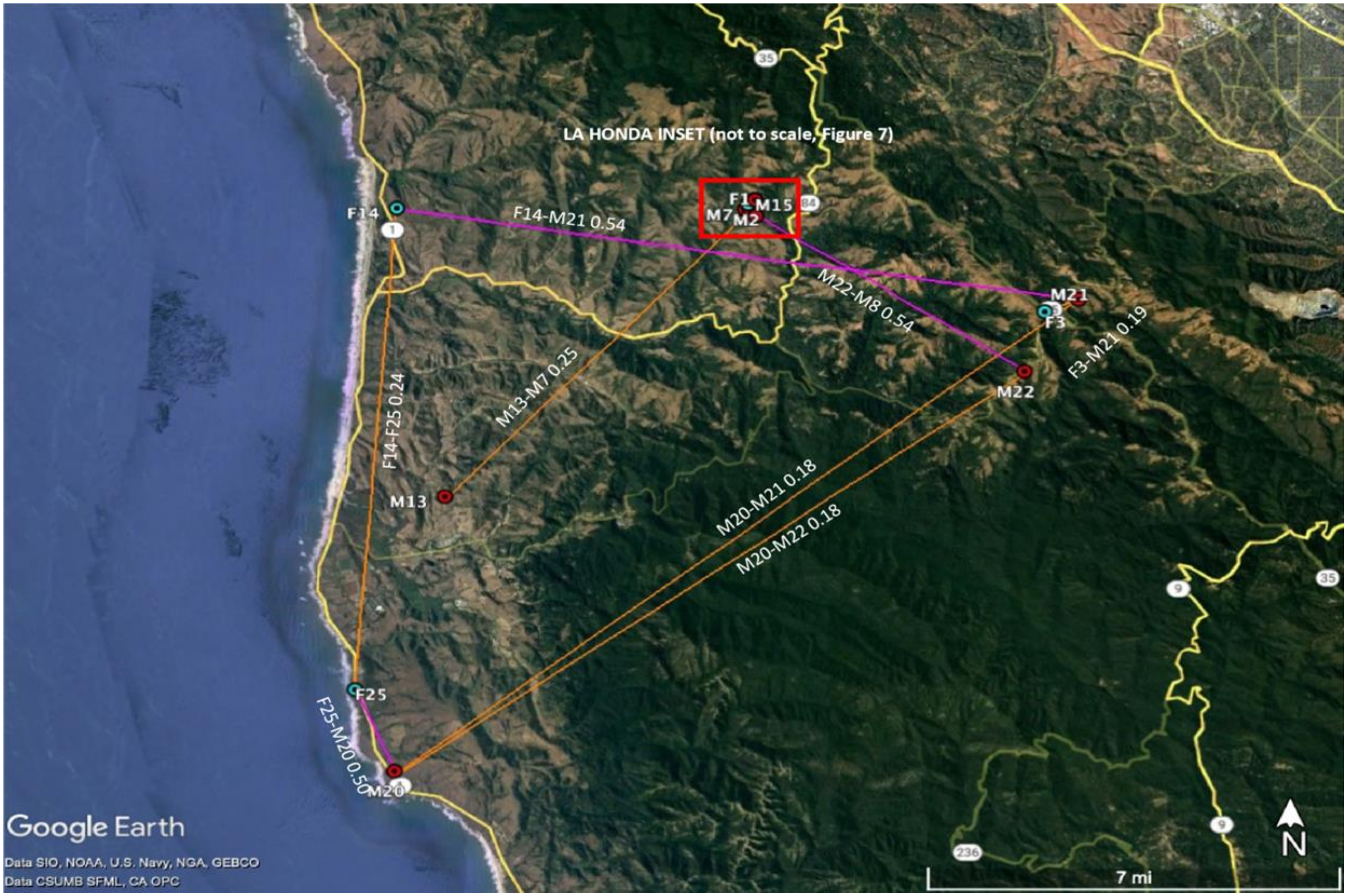

Figure 5-9. Maximum Likelihood Relatedness between pairs of individuals in the PN population.

Figure 5-10. Maximum Likelihood Relatedness between pairs of individuals in the La Honda Creek OSP badger group.

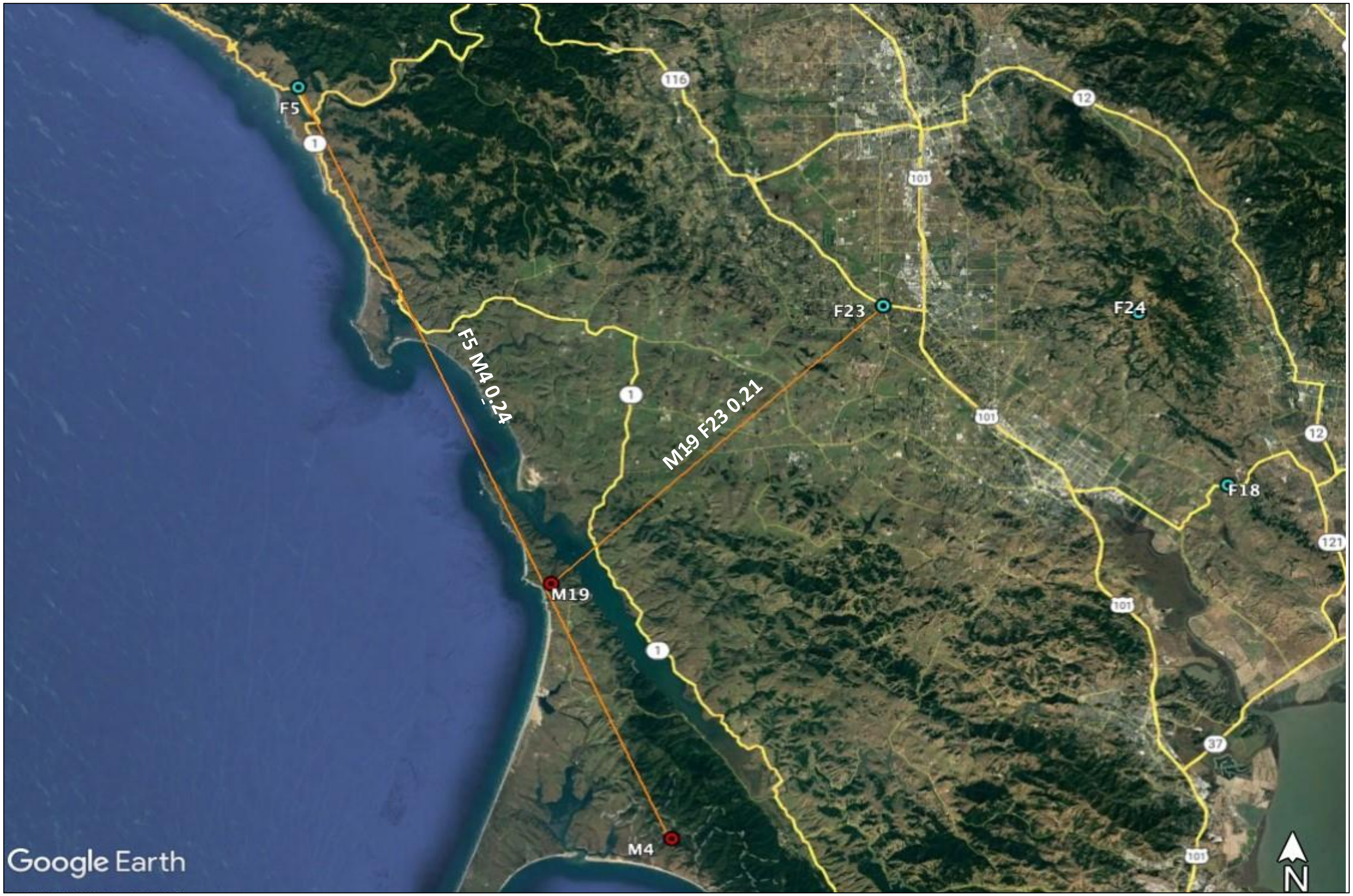

Figure 5-5. Maximum Likelihood Relatedness between pairs of individuals in the NB population.

Genetic diversity and structure

Levels of heterozygosity (Hz) were lower in the PN population than in either of the other two populations, almost two standard deviations (SD) difference, meaning PN badgers are less genetically diverse than other populations. The PN population had the fewest number of alleles of the three populations (Table 5-8 and Figure 5-9).

5.4 Discussion

5.4.1 Badger population gene flow and isolation

Other studies have investigated badger population structure on larger scales across subspecies boundaries in Canada and North America (Kyle et al. 2004, Either et al. 2012, Kierepka and Latch 2016a, Ford et al. 2020), and within subspecies boundaries across states and provinces (Kierepka and Latch 2016b, Ford et al. 2019). Ours is the first such study on a regional scale within California.

Our results show that the badger population on the Peninsula, which includes the MROSD Preserves, is genetically isolated from North Bay and South Bay badger populations. The high F_{ST} values that characterize the three populations we sampled show genetic drift within each of the populations and divergence, or further genetic differentiation due to changes in allele frequencies, between them. The structure analysis also showed strong isolation of the Peninsula badgers for scenarios modeling both two and three populations (as genetic clusters). The three cluster model showed some gene flow (based on the genotype of one individual) only between the North Bay and South Bay populations. Genetic isolation and drift could result in loss of beneficial or adaptive genes or fixation of maladaptive or harmful genes in the Peninsula population.

Limited gene flow between the Peninsula population and the North and South Bay Area populations is likely due to a combination of natural and anthropogenic influences. For example, the North Bay Area (north of the San Francisco Bay in Marin, Sonoma, and Napa Counties) is separated from the Peninsula by approximately one mile of water in the San Francisco Bay at its closest point. While badgers have been documented swimming such distances (e.g. the Snake River [Messick and Hornocker 1981], and Fontanelle Reservoir, Wyoming [CBS News Colorado 2017]), the behavior is not likely common, especially in the open ocean. Even to reach the Bay waters, a badger would have to first traverse over 10 miles of hardscaped, dense urban development that comprises the City of San Francisco. Similarly, while a badger may be able to navigate the steep and forested slopes of the Santa Cruz mountains to the east and southeast, the densely developed cities of San Carlos, San Mateo, Palo Alto, and San Jose at the lower elevations likely limit its ability to reach populations in the South Bay Area (from Coyote Valley in Santa Clara County east into the Diablo Range).

However, badgers within the Peninsula appear to be navigating complex landscapes to some extent. Our results show at least one male badger (M2) with samples almost 6 miles apart, one at the Stanford Collins Ranch and one at the La Honda Preserve (Figure 5-4). M2 likely originated on the Peninsula and moved east, then back again, rather than using a movement path from the South Bay. These samples show that he traveled almost six miles navigating through or around steep, forested terrain, residential development, and roads. While there are no apparent linkages from the Peninsula to the South Bay, there does appear to be linkage from the inland Peninsula to the coast. Samples collected from Highway 1 and Cloverdale Ranch, both on the coast, identified at least one badger with a first-order relative at the Skyline Ridge Preserve, and another with two second-order relatives on the Skyline Ridge and Monte Bello Preserves (Figure 5-9). Additional connections could continue along the coast to the south as far as at least the city of Santa Cruz, based on the extent of contiguous grassland habitat. From there, connection to the South Bay badger population to the east, and known badger populations in northern Monterey County is possible. Confirmation of these connections could have important implications for the Peninsula badgers – potentially by extending the population boundary and size, and alleviating negative effects of genetic drift and inbreeding, as referenced in Section 4.

Compared to badger populations to the North Bay and South Bay, samples from the Peninsula population also had less genetic diversity, as indicated by the lower level of heterozygosity. Small populations of species in general tend to be less genetically diverse (cite). The Peninsula population of badgers is smaller than the populations represented by samples in North and South Bay, which covered broader sampling areas that included hundreds of miles of undeveloped suitable badger habitat. We recognize that our sampling did not cover the entire Peninsula population. There were several preserves where we observed badger activity and either did not collect samples due to lack of a CDFW collection permit, logistical constraints (e.g., insufficient time to both complete transect surveys and search for hair during a field day), or samples collected were not viable, including Long Ridge, Windy Hill, Los Trancos, and Purisima Creek (explained in Section 5.4.3, below). Collecting samples from the many other areas of suitable habitat on the Peninsula owned by other public and private entities was beyond the scope of this project. However, even with data gaps from these areas, we can surmise that the geographic isolation of the Peninsula population likely limits its size, as well as its genetic diversity, compared to the other two populations.

The F_{IS} value of 0.003 (observed heterozygosity almost equal to expected) measured for the Peninsula badger population shows that our samples reflect a single, interbreeding population. Although sometimes referred to as an "inbreeding coefficient," F_{IS} does not directly measure inbreeding; rather, it shows whether a population has more or fewer heterozygotes than expected from an unbiased estimate of heterozygosity. In general, fewer heterozygotes than expected (a higher F_{IS}) can be a result of substructure, over-sampling of close relatives, or inbreeding. Given our near-zero F_{IS} estimate for the Peninsula population, indicating unbiased sampling (i.e., we did not disproportionately sample close relatives), our identification of so many close relatives in this population suggests that the population could be very small. Such an inference is consistent with its low heterozygosity and isolation (as shown in the STRUCTURE analysis) relative to the other two populations. Thus, it is likely that this population is somewhat inbred based on its small size and apparent insularity, which imply that individuals must be mating with close relatives. It is unknown whether the population is becoming – or has become – more inbred over time (recall that inbreeding measures are relative rather than absolute) or already has debilities (e.g., low fertility) caused by interbreeding among close relatives (inbreeding depression). Further population monitoring would be required to assess these scenarios. Ultimately, a measure of genetic effective population size (Ne) is needed, along with a better understanding of survival and reproductive health of the population.

Our sample size of 25 individuals was too small to calculate an effective population size (Ne) for badgers within the Peninsula population, which measures the rate of genetic drift and/or inbreeding. A small sample size would require more loci (for miscrosatellites) or more individuals (with the current number of microsatellites) to better establish or estimate the number of breeding individuals contributing their genes to the population. Tallmon et al. (2010) recommends a sample size of at least 60 to 120 to provide useful information, and suggested the monitoring Ne over time was a more robust way to monitor stable or declining populations. Whole genome sequencing of some hair samples might be possible, and could potentially allow a direct estimate of inbreeding, rather than Ne. While different, the method is related and is an important metric for assessment the genetic risk of the population, particularly if applied to multiple individuals in the three populations.

5.4.2 Badger Movement and Spacing

Badgers' high capacity for movement (e.g., 14 km in a 4-hour period [Hoodicoff et al. 2009, British Columbia]; dispersal distance of 110 km [Messick and Hornocker 1981, Idaho]), which could increase gene flow over a wide geographic area, depends on the drivers and barriers to movement in the areas they occur. Badger home range sizes and dispersal distances can in part be explained by resource distribution, wherein females' movements are dependent on the distribution food resources and males' movements are dependent on the distribution of females (Minta 1993). Where these resources are patchy, a large home range can comprise several widely spaced areas of intense use (Hoodicoff et al., 2009).

Male badgers searching for female mates may have to travel long distances to find them, further necessitating suitable landscape connectivity for gene flow. Female badgers often occupy exclusive home ranges that are smaller than those of males and can be widely dispersed across the landscape (Minta 1993, Quinn 2008). Multiple samples collected for female badgers (F1 and F3) were distributed over small areas, which may reflect their relatively small home ranges, while samples from two locations for M2 showed a longer movement path of almost six miles, with one location within the area of F1's locations. This would be consistent with data from other studies. That said, females do also disperse as indicated in Messick and Hornocker (1981), and expand their home ranges during the late summer breeding season, also contributing to gene flow.

The genetic data provided some potential information on reproduction. The clustered locations of badger F1 samples in La Honda over a period of several months, as well as the near proximity to first-order male relatives in the area in early July, suggest a potential natal den in or nearby the area. Although the exact relationships were not possible to discern from microsatellite data (siblings vs. parent-offspring), a female badger would remain in or near a natal den between late January/early February, and young would emerge but stay close to their mother range between April and late July. Sibling relationships are just as possible, but these samples demonstrate how genetic analysis can identify reproductive patterns in this badger population.

5.4.3 Study methods discussion

The sample collection effort results via contact outreach were positive. The goal of the outreach, which was to collect samples, was achieved. Seven contacts offered eight badger samples, followed by an additional three samples from each of three contacts a few weeks to two years later. Given the general infrequency of badger roadkill sightings over a 3-year period, including opportunities to collect samples from them, the limited number of samples obtained through outreach is not unexpected. Monitoring and/or creating a focused "Project" on the citizen science database iNaturalist may have been a way to obtain more samples from the surrounding region. We incidentally saw a few reports of road-killed badgers, including a report of a badger dying of an unknown cause, weeks or months after they had been reported. Including this resource into the study in a structured way, including scope and budget for daily review, coordination with observer, and follow up to collect a sample could have yielded a higher sample size for genetic analysis – at least for the surrounding regions.

There were other benefits from the outreach effort. The outreach raised awareness of the study amongst researchers and agencies in the region and alerted them to the potential issues facing badger populations in the Bay Area region. We also obtained information on known badger occurrence, including both recent observations and comments regarding having seen activity in the past, but not recently. Several of our contacts invited us to survey their properties (see Table 5-1), which, while not part of the scope of the current study, provides opportunities to expand the study into other areas. The information gathered through continued engagement with this network could offer a more robust understanding of badger populations in the region, including changes in the population over time.

Field collection of genetic samples produced mixed results. The only scat that amplified using badger specific genetic markers was one collected from an animal in a wildlife rehabilitation center. The animal being in captivity influenced two factors that ensure a high-quality DNA sample: 1) the sample was fresh, and 2) there was 100 percent certainty it was from a badger. In the field, locating scat with both of these characteristics is not uncommon for other species, but can be more challenging for badgers. Badgers, as are many mustelids, are secretive with their scat, and often bury it in tailings from digging or in chambers in the burrow. Finding badger scat is usually opportunistic, or in the case of this study, the incidental result of an intensive search for badger activity that may or may not be recent. Older scat samples can have degraded badger DNA in the outer layer, preventing analysis. Badger scat can also be difficult to distinguish from other species' scat, such as coyotes, gray foxes, or bobcats. That other animals often defecate on and around badger diggings to "mark" further reduces certainty that scat located near areas of badger activity is actually from a badger.

Hair samples collected in the field had a higher rate of successful amplification than for scat. Badger hair can be easy to locate and identify with some practice. Opportunistic collection from burrows and mounds yielded the most samples. Once badger activity areas were identified during transect surveys, searches for hair are relatively efficient – it takes only a few minutes to determine if an area is worth searching (i.e., had relatively recent activity, tailings with loose soil not disturbed by rain, etc.), and approximately five minutes at a badger digging to verify whether hair was actually present or not. Though hair searches were productive, they were not without their complications. Intact root bulbs on hairs, from which DNA is extracted, are difficult to see, and either may not be present or can be knocked off the hair when being pulled from the soil. Additionally, ambient moisture, not uncommon around burrows and soil pulled from below ground in the tailing, can damage DNA samples even without rain.

The hair snares showed limited success. We selected the method because the snares have been anecdotally successful in other badger studies (used in known, occupied burrows primarily), and because pulled hair, rather than shed hair, is more likely to have an intact root bulb for DNA analysis. The snares are also relatively cheap to construct and easy to install. Although getting hair on a snare requires that either the burrow is currently occupied, or that a badger will enter an unoccupied burrow after the snare has been placed, we elected to try using snares in the case that older burrows would be reentered in areas of high badger activity levels. Badgers move to different burrows almost nightly throughout most of the year, so the odds of encountering an inbound or outbound badger when the snare is in place are relatively low. Where hair snares were placed in an occupied burrow, in at least two instances, the badger dislodged and/or buried the snare (see photo).

Badger at Long Ridge Preserve. Photo credit: Pathways for Wildlife.

A slightly different design that would anchor the snare to the burrow from the outside as well as the inside may prevent snare loss down the burrow or under the tailing if the snare is dislodged. Use of a scent lure may help to entice a passing badger to a burrow with a snare, reducing the reliance on locating an occupied burrow for the snare to work. However, scent lures may not be recommended in publicly accessible areas like the MROSD Preserves where domestic dogs may be present. Other wildlife species may also be attracted to the scent, resulting in non-target species' hair in the lure rather than badger hair.

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Appendix A. Genotype Table

In the genotype Table below, there are two columns with the same header, one for each of two alleles for the 13 microsatellite loci included in the primer multiplex (mix) referenced in Section 2.2 of this report. "ID" is the identifier for each individual badger. "POP" is the population assigned to individuals based on the sample collection location – Peninsula (PN), North Bay Area (NB), and South Bay Area (SB). "Sex" is either female (F) or male (M). Different numbers at a specific locus represent different allele variants at that locus. Cells with "." Indicate loci in which alleles did not amplify, likely due to DNA sample quality.

ID	POP	Sex	Ma-1	Ma-1	Tt-1	Tt-1	Tt13	Tt13	Tt15	Tt15	Tt17	Tt17	Tt-2	Tt-2	Tt20	Tt20	Tt21	Tt21	Tt22	Tt22	Tt23	Tt23	Tt27	Tt27	Tt-3	Tt-3	Tt-4	Tt-4
F1	PN	F	194	194	158	158	187	199	122	122	174	188	203	203	134	134	202	202	126	132	155	159	167	167	164	164	180	180
M2	PN	M	194	194	158	170	187	199	114	114	188	188	205	207	126	126	206	210	132	132	155	155	157	167	164	164	180	180
F3	PN	F	194	198	158	164	191	199	104	114	178	188	203	203	128	134	206	214	124	126	155	159	167	167	164	164	180	180
M4	NB	M	194	196	158	158	187	193	114	116	178	182	203	205	128	128	204	204	124	134	155	155	165	167	164	164	188	188
F5	NB	F	194	194	158	166	187	193	116	116	178	182	203	203	128	130	204	212	134	134	155	159	165	167	166	166	180	188
M9	SB	M	204	204	168	170	183	191	108	122	174	174	203	203	128	130	202	202	124	132	161	161	157	173	156	156	180	190
M10	SB	M	196	196	168	172	189	193	108	122	182	188	203	203	128	134	202	202	126	128	159	159	159	165	156	158	186	186
F11	SB	F	198	204	164	168	185	195	114	116	.	.	205	205	132	134	206	206	126	132	155	159	161	169	162	166	180	188
M12	SB	M	194	198	170	170	189	189	116	118	178	184	205	205	130	132	206	206	126	134	161	161	161	161	154	172	180	190
M13	PN	M	194	198	164	164	199	199	122	122	174	178	207	207	128	134	212	212	126	132	159	159	167	167	164	164	186	190
F14	PN	F	198	198	164	170	187	199	114	122	188	188	203	207	134	134	202	212	126	126	155	159	157	157	164	164	.	.
M15	PN	M	194	194	158	164	199	199	104	114	174	188	203	203	134	134	202	206	126	132	159	159	159	167	164	164	180	180
F16	SB	F	198	204	158	170	191	193	118	120	174	188	205	205	130	136	202	208	124	128	161	161	161	173	154	156	188	188
M17	SB	M	192	198	158	170	191	199	108	118	174	188	203	203	130	130	202	208	126	126	161	161	169	173	162	162	186	188
F18	NB	F	194	196	158	158	197	201	110	116	178	182	203	203	128	128	198	208	124	134	159	159	165	167	166	166	180	186
M19	NB	M	194	196	158	158	187	195	114	114	178	178	203	203	128	130	198	204	124	124	159	159	159	165	164	166	186	188
M6	PN	M	194	194	158	164	187	199	104	122	174	188	203	207	134	134	202	214	126	132	155	159	167	169	164	164	180	186
M7	PN	M	194	194	164	164	187	199	104	122	174	184	205	207	128	134	202	214	126	132	159	159	167	169	164	164	180	186

ID	POP	Sex	Ma-1	Ma-1	Tt-1	Tt-1	Tt13	Tt13	Tt15	Tt15	Tt17	Tt17	Tt-2	Tt-2	Tt20	Tt20	Tt21	Tt21	Tt22	Tt22	Tt23	Tt23	Tt27	Tt27	Tt-3	Tt-3	Tt-4	Tt-4
M20	PN	M	194	194	164	170	193	199	104	114	188	188	203	207	134	134	212	212	126	132	155	155	167	167	.	.	180	186
M8	PN	M	194	194	158	164	187	199	104	122	174	188	203	207	134	134	202	202	126	132	155	159	167	167	164	164	180	180
M21	PN	M	194	198	164	170	193	199	122	122	188	188	203	203	134	134	204	212	126	126	159	159	157	157	164	164	180	186
M22	PN	M	194	198	158	170	187	199	104	122	.	.	205	207	134	134	202	212	132	134	155	155	167	167	164	164	180	180
F23	NB	F	194	194	158	158	197	197	116	120	178	182	205	205	128	130	198	204	124	124	159	159	159	165	166	166	180	180
F24	NB	F	196	196	166	170	185	197	114	122	182	184	205	207	128	132	204	204	126	126	159	161	157	165	166	166	178	186
F25	PN	F	194	198	164	164	187	193	104	114	188	188	203	203	134	134	202	212	126	126	155	159	161	167	164	164	180	186

Appendix B. Sampling and Hair Snare Protocols

Hair Snare Datasheet

Site Name	Snare #	Initials	Date/Time Set	Location (coordinates or description)	Location in burrow (side, top, depth, etc.)	Check dates/result (no hair, hair collected, snare removed)					

Badger Hair Snare Protocol

Supplies (supplement to Field Equipment List)

- ☐ Snares
- ☐ Nails (2 per snare)
- ☐ Data sheets
- ☐ GPS
- ☐ Copies of access permits, combinations
- ☐ DNA sample kit and collection protocols
    - ☐ Paper bags and coin envelopes
    - ☐ Ziplocs
    - ☐ Hair snares
    - ☐ Latex gloves
    - ☐ CDFW permit
    - ☐ Ethanol tubes (in case scat is found)

1. Before going to the field, sterilize snare "teeth" with a flame (lighter) in a safe location (do NOT do this in the field)
    a. No need to do this for new snares
2. Use gloves to handle snares after sterilization
3. Before installing snare, rub it in the dirt to further mask human scent
4. Install snare in the top (if burrow is fairly oblong) or side (for rounder burrow) of burrow at least 6 inches in from the entrance, or where opening narrows somewhat
    a. Be cautious while reaching into the burrow (for rattlesnakes, black widows, etc.)

Snare set in burrow in ceiling

Snare set in wall (from USGS San Diego)

5. Check snares every 5 to 7 days, as feasible. If burrow seems new enough to be occupied, check sooner (within 1 to 2 days)

6. If hair is in snare, prepare envelope/paper bag PRIOR to placing hair inside; label with location, snare number, date and initials (same as data sheet record)
7. Remove hair strand(s) carefully with gloved hand or forceps if you have them, taking care to keep root bulb intact and place in envelope/paper bag. If hair is in envelope, make sure it is stored so it doesn't get compressed in any way so root bulb stays intact.
8. Take a minute to also look for stray hairs in the burrow entrance and tailing. Store separately and include location (e.g. "in tailing" "side of burrow") on label. This can be done even if there are no hairs in the snare.
9. Remove snare. Re-sterilize before reuse at a new location.

Notes:

- Prioritize areas of recent activity to potentially snare occupied burrows
  - Also – and especially – areas with recent AND prior activity, which could indicate an area being revisited by badgers
- Okay to check snares less frequently over time
- Teams should coordinate for checking/moving snares
- Only permitted members of the Project team may install/remove snares or collect hair from snares

Appendix C. Additional Burrowing Owl and American Badger Records

Table C-1. Summary of all new badger records collected from 2019-2021.

ID	Easting	Northing	Date	Burrow or Transit	Data Source	Maxent Raw Value	Likelihood of badger Presence (1 is low and 3 is high)
185	564470.5	4135010	3/31/2015	Burrow	Ken Hickman's incidental badger burrow data	0.02441	1
222	563641.2	4133543	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.03256	1
217	564020.6	4136517	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.05123	1
199	563748.2	4135423	1/6/2017	Burrow	Ken Hickman's incidental badger burrow data	0.05218	1
212	563317.7	4137316	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.11241	2
198	563731.6	4135749	1/6/2017	Burrow	Ken Hickman's incidental badger burrow data	0.1776	2
218	563962.4	4135902	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.17834	2
234	563960	4133327	3/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.18121	2
241	563958.2	4133327	6/10/2017	Burrow	Ken Hickman's incidental badger burrow data	0.18121	2
219	563974.5	4133393	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.21465	2
204	563424.6	4133731	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.23297	2
197	563739.7	4135733	1/6/2017	Burrow	Ken Hickman's incidental badger burrow data	0.26886	2
239	563731.7	4135731	6/10/2017	Burrow	Ken Hickman's incidental badger burrow data	0.26886	2
176	556179.1	4114662	8/1/2015	Burrow	Ken Hickman's incidental badger burrow data	0.27724	2

170	572765.1	4129651	3/25/2015	Burrow	Ken Hickman's incidental badger burrow data	0.30646	2
224	564639.7	4135231	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.31734	2
171	572828.8	4129656	3/25/2015	Burrow	Ken Hickman's incidental badger burrow data	0.3291	2
172	572863.5	4129646	3/25/2015	Burrow	Ken Hickman's incidental badger burrow data	0.33675	3
225	564628.6	4135410	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.34414	3
220	563840.2	4133356	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.35225	3
174	573278.2	4129451	3/29/2015	Burrow	Ken Hickman's incidental badger burrow data	0.38729	3
230	563719.4	4133396	3/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.38999	3
223	563730.2	4133373	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.39687	3
229	564680	4135289	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.40087	3
181	572161.8	4130692	7/1/2017	Burrow	Ken Hickman's incidental badger burrow data	0.42597	3
189	563641.2	4133547	2/10/2016	Burrow	Ken Hickman's incidental badger burrow data	0.46379	3
237	563654.3	4133340	4/5/2017	Burrow	Ken Hickman's incidental badger burrow data	0.48694	3
213	563517.4	4137134	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.49808	3
232	563635.5	4133368	3/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.5017	3
202	563367.9	4133848	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.51655	3
205	563361.6	4133737	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.52113	3
188	563625.4	4133292	2/10/2016	Burrow	Ken Hickman's incidental badger burrow data	0.52918	3
195	560830.4	4130536	12/1/2016	Burrow	Ken Hickman's incidental badger burrow data	0.53328	3

221	563598.3	4133476	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.53339	3
201	563524	4134171	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.53451	3
226	564503.8	4135631	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.54121	3
196	560602.5	4130550	12/1/2016	Burrow	Ken Hickman's incidental badger burrow data	0.5424	3
236	563656.6	4133965	3/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.54272	3
200	563577.1	4134286	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.54578	3
190	563743.8	4135426	11/15/2016	Burrow	Ken Hickman's incidental badger burrow data	0.55125	3
211	564580.4	4135695	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55212	3
233	563565	4133316	3/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.5525	3
235	563573.7	4133332	3/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.5525	3
187	563533.3	4133998	1/17/2016	Burrow	Ken Hickman's incidental badger burrow data	0.5526	3
203	563310	4133654	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55634	3
206	563311.8	4133656	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55634	3
231	563614.7	4133426	3/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55654	3
209	564598.2	4135685	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55676	3
210	564602.6	4135680	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.55676	3
227	564622	4135692	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.56129	3
169	567217.5	4134264	8/15/2017	Burrow	Ken Hickman's incidental badger burrow data	0.5619	3
238	563609.7	4133265	4/5/2017	Burrow	Ken Hickman's incidental badger burrow data	0.56842	3

208	564376.3	4135741	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.57101	3
184	563855.9	4135015	3/3/2015	Burrow	Ken Hickman's incidental badger burrow data	0.5765	3
242	563555.9	4133692	6/10/2017	Burrow	Ken Hickman's incidental badger burrow data	0.60435	3
175	556193.4	4114652	8/1/2015	Burrow	Ken Hickman's incidental badger burrow data	0.60952	3
186	563600.7	4134679	3/31/2015	Burrow	Ken Hickman's incidental badger burrow data	0.61962	3
183	563575.4	4134627	3/3/2015	Burrow	Ken Hickman's incidental badger burrow data	0.6295	3
240	563755.4	4135298	6/10/2017	Burrow	Ken Hickman's incidental badger burrow data	0.65172	3
216	563708.4	4136823	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.65848	3
182	563607.1	4134764	3/3/2015	Burrow	Ken Hickman's incidental badger burrow data	0.6591	3
215	563622.3	4136840	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.67659	3
180	575251	4130530	1/26/2016	Burrow	Ken Hickman's incidental badger burrow data	0.67896	3
191	563789.3	4135266	11/15/2016	Burrow	Ken Hickman's incidental badger burrow data	0.67968	3
228	564790.3	4135453	2/22/2017	Burrow	Ken Hickman's incidental badger burrow data	0.69036	3
179	575218.8	4130563	1/26/2016	Burrow	Ken Hickman's incidental badger burrow data	0.70346	3
178	575638	4130364	1/26/2016	Burrow	Ken Hickman's incidental badger burrow data	0.70694	3
214	563722.8	4136907	2/21/2017	Burrow	Ken Hickman's incidental badger burrow data	0.70864	3
193	564040.8	4135146	11/15/2016	Burrow	Ken Hickman's incidental badger burrow data	0.7106	3
192	563801.8	4135251	11/15/2016	Burrow	Ken Hickman's incidental badger burrow data	0.72059	3
177	574780.8	4130491	1/26/2016	Burrow	Ken Hickman's incidental badger burrow data	0.72931	3

194	564116.2	4135019	11/15/2016	Burrow	Ken Hickman's incidental badger burrow data	0.7333	3
207	563548.9	4134966	2/7/2017	Burrow	Ken Hickman's incidental badger burrow data	0.7378	3
173	572097.7	4129555	3/29/2015	Burrow	Ken Hickman's incidental badger burrow data	0.90855	3
271	570652	4130566	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.04449	1
272	570677	4130567	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.04546	1
273	570706.7	4130560	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.0559	1
284	571324	4130550	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.08011	1
274	570792	4130526	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.08411	1
256	574254	4130881	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.11057	2
321	566932	4135619	1/11/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.1114	2
307	556045.1	4114922	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat	0.21581	2

					Suitability Study-Transect Data-Pathways for Wildlife and SFBBO		
340	561216	4132646	7/23/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.26909	2
346	574767.6	4127548	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.27455	2
352	574767.6	4127548	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.27455	2
310	556179.1	4114662	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.27724	2
347	574795.3	4127407	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.29549	2
350	574809.5	4127400	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.29549	2
353	574795.3	4127407	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.29549	2
356	574809.5	4127400	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.29549	2

344	574623.3	4127548	10/18/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.33721	3
343	574818.5	4127438	10/18/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.40447	3
282	571205	4130532	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.40713	3
345	574740.4	4127518	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.40726	3
351	574740.4	4127518	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.40726	3
283	571218	4130541	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.40765	3
298	554402.8	4138564	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.42157	3
317	554423	4119163	8/16/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.42399	3
348	574850	4127404	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.43379	3

					Data-Pathways for Wildlife and SFBBO		
354	574850	4127403	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.43379	3
292	564040	4131832	7/26/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.44955	3
281	570966	4130562	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.45733	3
342	574888.5	4127373	10/18/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.46455	3
349	574892.3	4127380	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.46455	3
355	574892.4	4127379	1/15/2021	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.46455	3
338	569945	4131255	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.46897	3
334	570758	4130847	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.47925	3

337	570969	4131243	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.48835	3
333	570786	4130817	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.48878	3
306	553667.9	4139828	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.51008	3
265	563548.6	4133489	7/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.51464	3
300	554156.1	4140298	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.51882	3
305	553773	4139860	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.53443	3
339	554948.5	4116467	6/13/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.53827	3
264	563550.2	4133630	7/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.54672	3
146	563533	4133998	1/18/2016	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.5526	3

					Data-Pathways for Wildlife and SFBBO		
319	566680	4135561	1/11/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55429	3
320	566681	4135559	1/11/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55429	3
311	554602	4134443	8/5/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55553	3
266	563557.8	4133442	7/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55625	3
341	561471	4133147	7/23/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55633	3
148	563614	4133426	3/9/2017	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55654	3
262	563534.4	4133967	7/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.55984	3
269	573899	4130949	7/7/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.56402	3

252	574450	4130677	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.56409	3
250	553866.3	4133631	6/27/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.57913	3
251	553873.5	4133605	6/27/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.57913	3
253	574435	4130696	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.5802	3
331	576391	4129659	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.58089	3
263	563531.1	4133934	7/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.58309	3
249	553739.7	4133622	6/27/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.58432	3
270	573927.8	4130948	7/7/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.58517	3
295	554997.9	4138927	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.59489	3

					Data-Pathways for Wildlife and SFBBO		
291	572013	4130882	7/20/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.60142	3
289	576417	4129636	7/18/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.60449	3
302	553852.6	4140004	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.60579	3
301	553909.6	4140085	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.60595	3
309	556193.4	4114652	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.60952	3
286	576728	4129436	7/18/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61178	3
322	572739	4132143	1/18/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61182	3
299	554367.7	4138512	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61342	3

293	563971	4131735	7/26/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61706	3
303	553832.7	4139931	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61762	3
304	553818.7	4139908	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.61762	3
257	574179	4130994	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.62376	3
314	555718	4124665	8/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.64112	3
315	555722	4124669	8/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.64112	3
316	555734	4124683	8/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.64112	3
285	571387	4130521	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.64563	3
323	576733	4129465	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.6582	3

					Data-Pathways for Wildlife and SFBBO		
324	576753	4129491	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.66036	3
335	570625	4130890	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.66232	3
287	576698	4129481	7/18/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.6646	3
326	576608	4129523	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.67172	3
275	570809	4130502	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.67324	3
276	570805	4130511	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.67324	3
312	554881	4124487	8/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.67588	3
294	555089	4138942	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.68183	3

297	554452.2	4138582	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.68265	3
325	576747	4129509	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.68694	3
277	570919	4130514	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.69435	3
313	555081	4124540	8/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.69533	3
278	570897	4130543	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.69885	3
336	570438	4130997	1/27/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.70352	3
245	573813.7	4130930	6/25/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.70476	3
267	573814.6	4130934	7/7/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.70476	3
268	573816	4130933	7/7/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.70476	3

					Data-Pathways for Wildlife and SFBBO		
244	569994.6	4131471	6/24/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.70844	3
290	576394	4129683	7/18/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71124	3
254	574381	4130700	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71152	3
243	570915.2	4128855	6/24/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.7121	3
332	575992	4129841	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71423	3
247	573988	4131063	6/25/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71523	3
260	573985	4131062	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71523	3
261	573989	4131060	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71523	3

280	570921	4130562	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71668	3
288	576469	4129602	7/18/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.7167	3
328	576464	4129603	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71822	3
329	576452	4129590	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71822	3
330	576438	4129591	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.71822	3
279	570904	4130567	7/14/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.7201	3
246	573822.3	4130965	6/25/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.72225	3
327	576553	4129551	1/24/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.72949	3
296	554609.3	4138667	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.73578	3

					Data-Pathways for Wildlife and SFBBO		
255	574328	4130800	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.73639	3
318	566984	4135512	1/11/2020	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.73972	3
259	574009	4131023	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.7401	3
258	573990	4130983	7/1/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.74299	3
248	574091.7	4130962	6/25/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.74697	3
308	556046.6	4114974	8/2/2019	Burrow	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.86943	3
142	628609	4085303	2/14/2008	Transit	Antonia D'Amore, Elkhorn Slough NERR	0.00471	1
145	563763	4135327	5/14/2017	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.05646	1
144	563762	4135326	5/15/2021	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect	0.05646	1

					Data-Pathways for Wildlife and SFBBO		
150	566956	4135462	10/31/2019	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.12349	2
151	575218	4125321	10/14/2020	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.28099	2
143	568983	4132911	10/15/2019	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.28329	2
152	569828	4131251	9/19/2019	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.37604	3
147	560764	4130783	4/18/2017	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.53151	3
149	563573	4133331	3/23/2017	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.5525	3
153	572253	4130932	9/8/2021	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.57385	3
154	570846	4128723	4/14/2021	Transit	Midpen Badger and Burrowing Owl Habitat Suitability Study-Transect Data-Pathways for Wildlife and SFBBO	0.67158	3
365	609811	4122025	4/7/2021	Transit	Pathways for Wildlife	0	1

141	628224	4082821	8/14/2018	Transit	Pathways for Wildlife	0.00012	1
364	612468	4119911	3/30/2020	Transit	Pathways for Wildlife	0.013	1
140	628850	4090329	12/21/2009	Transit	Pathways for Wildlife	0.06235	1
139	629259	4088121	9/1/2008	Transit	Pathways for Wildlife	0.14346	2
370	639980	4093008	7/29/2019	Transit	Pathways for Wildlife	0.1765	2
363	644716	4096080	6/24/2020	Transit	Pathways for Wildlife	0.1883	2
357	615348.2	4117413	12/16/2017	Transit	Pathways for Wildlife	0.33312	3
358	610300.8	4116360	2/1/2007	Transit	Patrick Congdon	0.08331	1
362	552712	4118693	6/4/2019	Transit	Portia Halbert and Ahiga Snyder	0.21054	2
159	592106	4100881	3/28/2015	Transit	UCSC Puma Project, Chris Wilmers	0.03056	1
160	575932	4104863	4/2/2015	Transit	UCSC Puma Project, Chris Wilmers	0.03779	1
165	564159	4128686	6/11/2017	Transit	UCSC Puma Project, Chris Wilmers	0.0935	1
166	564159	4128686	7/19/2017	Transit	UCSC Puma Project, Chris Wilmers	0.0935	1
164	564078	4125198	4/23/2017	Transit	UCSC Puma Project, Chris Wilmers	0.10517	2
161	560273	4109045	3/15/2015	Transit	UCSC Puma Project, Chris Wilmers	0.12202	2
162	560273	4109045	3/22/2015	Transit	UCSC Puma Project, Chris Wilmers	0.12202	2
167	572548	4129122	3/17/2017	Transit	UCSC Puma Project, Chris Wilmers	0.2114	2
168	572548	4129122	3/17/2017	Transit	UCSC Puma Project, Chris Wilmers	0.2114	2
155	568304	4101024	3/14/2015	Transit	UCSC Puma Project, Chris Wilmers	0.44728	3
156	568304	4101024	4/27/2015	Transit	UCSC Puma Project, Chris Wilmers	0.44728	3
157	568304	4101024	4/27/2015	Transit	UCSC Puma Project, Chris Wilmers	0.44728	3
158	568304	4101024	4/28/2015	Transit	UCSC Puma Project, Chris Wilmers	0.44728	3

163	580375	4093193	8/26/2015	Transit	UCSC Puma Project, Chris Wilmers	0.53642	3

Table C-2 Summary of volunteer led Burrowing Owl surveys.

Site	Trails	mileage	Observer
Russian Ridge	Ridge/HawkRidge/Alder spring/Charquin trail loop	1.9	Howard Higley
Russian Ridge	Ridge Trail (upper)/Ancient Oaks/Bo Gimbal/Ridge Tr (lower) (from Silicon Valley vista trailhead)	2.1	Sirena Lao
Russian Ridge	Ridge/Bo Gimbal/Ancient Oaks trail loop (from Alpine Rd Trailhead)	2.1	Wendy Gibbons
Russian Ridge	Mindego Hill Trail	5	Gabbie Burns + Angelo DiNardi
Monte Bello	Stevens Creek Nature Trail/White Oak Tr	3.3	Laura Coatney
Monte Bello	Bella Vista/Old Ranch/Indian Creek loop	4.3	Susan Salkeld
Windy Hill	Spring Ridge tr	2	Ronnie Eaton
Windy Hill	Anniversary Trail/Lost trail loop	1.5	Cathy Priest
La Honda	Harrington Creek trail (to eucalyptus grove)	2	Leigh Glerum
Long Ridge	Peters Creek/Chestnut Trail	2.8	Roel Funke