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Evaluating the Effectiveness of Established Wildlife Corridors in Southern Orange County, California

THESIS

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DEDICATION

To

my mother and my sister

in recognition of their worth and support

"Raise your words,

not your voice.

It is rain that grows flowers,

not thunder."

Jalāl ad-Dīn Muhammad Rūmī

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ABSTRACT

Intense road development and urbanization have fragmented the natural landscape across coastal Southern California since the middle of the 20th century. As mitigation efforts, in 1992 the Natural Community Conservation Plan and Habitat Conservation Plans I and II (NCCP&HCP I and II) allocated reserves and non-reserve open spaces to connect these fragmented natural habitats and foster the coexistence of wildlife and people in Orange County. Here, I aim to evaluate the effectiveness of two established wildlife corridors (the Sand Canyon Wash Corridor and the Bonita Creek Corridor) in southern Orange County, linking two large reserve areas (Figure 1). I conducted camera trapping surveys by using 11 cameras placed along these two linkage corridors. Additionally, I obtained more photographic data at 10 different camera stations within the Irvine Ranch Water District (IRWD) San Joaquin Marsh & Wildlife Sanctuary. Then, I calculated Relative Abundance Index (RAI) values based on the photographic capture rates of key vertebrate species of concern for each location. I compared the current RAI values with values from a study by Lyren et al. (2008) to illustrate the changes over a decade at three subsets of locations. I also obtained wildlife-vehicle collision (WVC) data from 2005 to 2019 from the City of Irvine Local Animal Services. I found an average of two bobcat mortalities event per year occurred until 2015. After 2015, no bobcat detection or roadkill mortality is observed. Additionally, the number of coyote detections has increased by almost 700% over a decade at these locations. It is likely that this result reflects urban coyotes' greater ability to function in a changing environment and (greater) resilience to anthropogenic effects. The long-term success of wildlife corridors requires understanding how the regional

environment may influence species composition and potential use of these linkage elements reserve designs over extended periods.

INTRODUCTION

Orange County is the sixth most populous county in the United States (United States Census Bureau, 2019). High human demand in the region has also increased overall housing density and road developments. For example, the total number of households in Orange County alone increased by 10.9% between 2000 to 2018 (Southern California Association of Governments [SCAG], 2019). In parallel with these increases, the general need for road network expansion projects has also risen due to elevated traffic volume. For example, two main road construction projects occurred intermittently during the present wildlife monitoring project at the assigned corridors (Figure 1): The University Drive Widening project (from Campus Drive to MacArthur Avenue) and the Culver Drive & University Drive Intersection Improvement projects (Capital Improvement Program [CIP] Status Report, 2018). These two projects alone cost over $25 million. However, the impacts of such development on wildlife and adjacent habitat quality are unknown.

One of the primary threats to biodiversity in Southern California is fragmented natural landscapes (Wilcove et. al., 1998) as a result of intense urbanization and road development (Forman & Alexander, 1998; Spencer et. al., 2010). Roads act as barriers for the dispersal of individuals between habitats and transform large habitats into smaller and isolated refugia (Haas, 2000). Because of the reduction in effective habitat size, fragmentation usually results in these refugia becoming unable to sustain populations (Tigas et. al., 2002). At the population level, fragmentation decreases genetic variation, which increases vulnerability to diseases and anthropogenic disasters (Clevenger &

Huijser, 2011; Spencer et al., 2010). Spatially and temporally, fragmentation hinders adaptation to environmental challenges such as climate change (Crooks et al. 2011; Heller & Zavalenta, 2009; Crooks et al. 2011). Due to these severe ramifications of fragmentation, certain habitat-sensitive species, or species requiring extensive spatial home ranges, such as large carnivores, are more susceptible to local extinction (Crooks, 2002).

Mountain lions, bobcats, and coyotes are considered the remaining top predators in this impacted coastal southern California landscape. The loss of large mammalian carnivores cascade to lower trophic levels (Crooks & Soulé, 1999). For example, a collapsing population of apex predators results in dramatically increased populations of mid-ranking predators, a phenomenon known as the mesopredator release hypothesis. Furthermore, increased numbers of mesopredators pose a threat to a number of key bird pollinators and thus indirectly reduce biodiversity among native grasses and shrubs (Soulé et al., 1988; Soulé & Terborgh, 1999). Overall, fragmentation has serious effects on biodiversity, the adaptive capacity of species, along with ecosystem structure and function.

Increasing threats to local biodiversity in southern California made it obvious that there was an urgent need to conserve wildlife and plant heritage. In response, the County of Orange Environmental Management Agency (EMA) has published Natural Community Conservation Plan and Habitat Conservation Plan I and II (NCCP&HCP I and II) in collaboration with the Fish and Wildlife Service and California Department of Fish and Game in 1992. Through these plans, the habitat Reserve System and additional non-reserve open spaces linked Central and Coastal Subregions of California to protect, restore and conserve identified species and habitats. The supplemental non-reserve open spaces are mostly comprised of parks, golf courses, and irrigated non-natural vegetated or open spaces. Despite their limitations, these areas still facilitate animal movement among the core habitats. The HCP plan provides federal protection for endangered species habitats with a focus on landscape-scale processes. On the other hand, the NCCP plan allows tolerable land uses within the permitted areas and encourages agreed-upon conservation to reduce uncertainty for stakeholders. Under the guidelines of these plans, local and regional urban developments are designed to support the co-existence of wildlife and people. Two wildlife corridors are allocated for safe animal passage within our study area (Figure 1).

During the last forty years, wildlife movement corridors, which link isolated animal populations at the fragmented landscapes, have been used as a primary solution to establish connectivity on local, regional, and national scales (Keeley et al., 2018; Hilty et. al., 2012). Corridors can be in different forms, including a habitat linkage, greenbelt, or existing crossing structures (Haas 2000; Simberloff et al., 1992), depending on hydrology, recreation, or compatible land use. Habitat corridors are usually narrow strips of land allocated to facilitate the animal movement and conservation of the species of interest. On the other hand, greenbelts are broader open areas of land in a linear “belt” shape to protect the land from urban developments. Different from these linkage forms, utilizing the existing crossing structures to connect fragmented landscapes in a region is an economically opportunistic way to facilitate animal migration and dispersal. Despite their differences, the main objective of these structures is to allow animal movement, dispersal, and increase overall connectivity.

Previous research shows that existing drainage culverts, underpasses, and bridges can serve as safe animal crossing structures with minimal to no effort (Noss et al., 1996; Clevenger & Waltho, 2000). As such, conservation planners, including the designers of the Coastal/Central Orange County NCCP have leveraged such landscape features, both existing and planned, to enhance the value of reserve space that is disconnected. What remains to be understood is the real-world functional value of such structures, and which species can benefit.

Connectivity can be provided in many ways. However, the success of landscape connectivity depends on many factors including initial conservation objectives, targeted taxa, structure, and implementation. Connectivity can be structural or functional: Structural connectivity is about the physical properties of a landscape (e.g. topology, hydrology, vegetative land cover, and land-use types), whereas functional connectivity usually refers to gene flow and individual movements (Rudnick et al., 2012). Even if a corridor physically connects the habitats, if it has subtle obstructions and animals cannot freely move among the habitats, the corridor is functionally ineffective. An effective wildlife corridor should be both structural and functional to conserve biodiversity and increase the resilience of species to natural and anthropogenic disturbances. Moreover, multi-taxa population connectivity may be applied to further enhance surrounding habitat mosaics.

Carnivores are usually referred to as focal species because of their ability to stabilize the ecosystem via their high dependency on inter-specific interactions with many other species (Soulé & Terborgh, 1999). Their survival highly depends on the health and functioning level of a habitat. Therefore, scientists frequently use mammalian carnivores as indicators of the level of connectivity in the region (Lyren et al. 2006). In coastal Southern California, bobcats *(Felis rufus)* and coyotes *(Canis latrans)* are often chosen as focal species to determine the region's connectivity (Lyren et al., 2006; Lyren et al., 2008b).

Similar to prior research in coastal Orange County, the current study used bobcats *(Felis rufus)* and coyotes *(Canis latrans),* the most common fragmentation-sensitive mammalian carnivores in this region. With this study, I aimed to evaluate the effectiveness of established habitat corridors via the monitoring of bobcats and coyotes in coastal Orange County, California. To study this, I measured the relative abundance of bobcats and coyotes at the present roadway underpasses as well as two official and two unofficial trails with potential for wildlife usage (Table 1). This study is timely because the conservation plans were established almost 30 years ago but have not been adapted to reflect the recent urban development saturation. Additionally, this initial study will serve as preliminary analyses that will encourage land managers, policymakers, or other scientists to make additional efforts to further enhance the wildlife movement and overall biodiversity.

METHODS

Study Area

The study area encompasses about 32 km^2 of coastal Orange County, CA, including parts of the cities of Irvine and Newport Beach (Figure 1). The study focuses on two corridors, the Bonita Creek and the Sand Canyon Wash Corridors. The Bonita Creek Corridor connects the Upper Newport Bay and San Joaquin Reservoir areas, both extensive open space parcels of Nature- Reserve of Orange County. The Bonita Creek Corridor runs along both sides of the California State Route 73 freeway between the Jamboree and Bonita

Canyon Drive exits. The Sand Canyon Wash Corridor is an allocated non-preserve open space area along University Drive (which is not technically called a *corridor* but allocated to a similar purpose) that connects the NCCP designated reserves of Sand Canyon Reservoir/Quail Hill to San Joaquin Marsh/IRWD Marsh/ Upper Newport Bay core habitats (Figure 1). This *corridor* includes Mason Regional Park, a golf course, and marshes to allow safe animal movement (Figure 1). Three different crossing structures (e.g. drainage culverts) and one underpass (e.g. bridge) were monitored for animal activity along the Sand Canyon Wash Corridor. I will refer to this area as a *corridor* for the sake of easy reference throughout this paper.

The University of California Irvine (UCI) Wildlife Monitoring survey was carried out between November 2019 and June 2020 and the study area is located at 33° 47' N and 117 ° 51'W (Tables 1 & 2 and Figure 1). The study area falls within a Mediterranean climate with distinct dry (June–November) and wet (December–May) seasons. The average monthly rainfall was 54 mm between November 2019 and June 2020 but reached over 135 mm in some months during the wet season. The summer temperature average was approximately 21° C. However, some summer days exceeded 38° C. Winter was mild, with temperatures averaging 20 ° C between November 2019 and June 2020. The IRWD Wildlife Monitoring project was continuously active between January 2015 and March 2020 (Tables 1 and 3). Throughout this time the average temperature was around 21° C and the average rainfall was a little over 38 mm.

The landscape is mainly composed of coastal sage scrub, chaparral, riparian zones, annual grasses, marshland plants, urban parks/golf courses, and open spaces with no vegetation. Some of the native tree species commonly observed in the region include willow *(Salix sp.)*, mulefat *(Baccharis salicifolia),* and Western sycamore *(Platanus racemose)*. However, it should be noted that the study region is highly urbanized and therefore the landscape is intensively altered by human activities. Many exotic trees, shrubs, and low-story plant species are introduced and planted in the area.

Camera Trapping Survey

Camera trapping via motion- and heat-triggered cameras is an established method for detecting wildlife presence and abundance for a wide range of species, especially among habitat-sensitive large carnivores (Haddad et al., 2015). I chose this method to obtain quantitative data about the relative abundance of bobcats and coyotes in these corridors because it is low maintenance, low cost, and non-invasive (Cutler & Swann, 1999). Camera trapping also minimizes disturbances for the wildlife and their immediate surrounding areas. Photographed animals are considered "trapped/captured" via this technique (Henschel & Ray, 2003; Rowcliffe et al., 2008). The number of unique event photographs taken per unit time (trapping rate) holds information about the density of a species (Rowcliffe et al., 2008). Before the establishment of cameras, the camera crew scouted potential installation locations to look for proof of animal activity such as footprints, scat, and animal sightings by locals. In order to place the cameras, we considered the following factors: presence in the assigned corridor areas (by NCCP and HCP plans), being part of a designed corridor, presence of crossing structures, permits, accessibility, recordings of roadkill mortality, and comparison to Lyren's (2008) prior study. In our study, we adopted an opportunistic sampling design, which does not follow strict randomization and replication requirements. However, it is one of the most reasonable and affordable strategies to gather large quantities of valuable data to guide scientific, decision-making on connectivity, and respond to manager needs. During the study, each camera recorded constantly from deployment to collection, with varying numbers of cameras in operation (Table 1). Data loss due to malfunction or vandalism was minor (gaps summed to around 6% of cumulative monitoring time), which was noted during the UCI Wildlife monitoring survey (Tables 1, 2, 3, and 4). There were no time gaps during the IRWD monitoring survey.

1. University of California Irvine (UCI) Wildlife Monitoring Survey

We established eleven cameras (Browning Dark Ops Pro XD Trail Camera and Reconyx HyperFire 2 Professional HP2X) in key locations designed to support safe animal movement among the natural habitats via these corridors (Figure 5 and 6). Seven of these locations were at the entrance of crossing structures (e.g. drainage culverts and bridges) (Table 1). Only one camera was used at the entrance of each crossing structure since the purpose was to detect the utilization of these structures rather than to fully identify each animal. Therefore, it is likely that certain individuals were recorded more than once. The rest of the cameras were placed along either an official or unofficial trail in the assigned corridors (Table 1 and Figures 5 & 6).

During the manual data processing, I noted species, time, date, and the number of individuals at each “trapping” for further analyses. All cameras were run continuously when active. If they were inactive for some reason, such as vandalism, theft, or malfunctioning, it was noted (Table 1& 5 and Figures 5 & 6). Cameras were attached to a metal post between 30-60 cm in height (depending on slope) and set to 60-second delays and three consecutive shots (Grey & Kent, 2013). Camera operational time ranged from 27 to 402 days (Table 5).

We used the Relative Abundance Index (RAI) because it is less complicated than other estimation methods and is preferred when calculating true abundance becomes complex or pricey (O'Brien et al., 2003). Previous studies indicate that there is a significant linear correlation between population abundance and RAI (Haas, 2000; Rovero & Marshall, 2009; Rowcliffe et al., 2008). The RAI, which measures the trapping detection rate of the camera, is one of the easiest and most affordable ways to estimate the abundance of wildlife for large-bodied carnivore species in a given area. To distinguish separate single events from repeated photos of the same event, we treated consecutive images with greater than 30-minute intervals as separate events and those with less than 30 minutes as the same event.

I calculated RAI for each species per location by dividing the total number of photographic events by the sampling effort (measured as active camera days) (Haas, 2000). The following equation was used to calculate this index:

$$\mathrm{I} = \{v_j/n_j\}$$

where, I = index of carnivore activity at camera j

v_j = number of passes by species at camera j

n_j = number of nights that camera j was active

During UCI Camera monitoring, we also recorded raccoon *(Procyon lotor)*, opossum *(Didelphis virgianus),* domestic dog *(Canis familiaris), horse (Equus caballus),* squirrel

(Otospermophilus beecheyi), rabbit *(Sylvilagus audubonii),* woodrat *(Neotoma sp.)*, unidentified bird, insect, mouse, snake, and lizard species as well as humans. However, I did not analyze these data during this project.

1.1. Seasonality in Research Park Culvert (RP) location

The Research Park Culvert (RP) was the only location in the UCI Camera Survey that was active for all four seasons (Table 1 and 2). Hence, I created a bar chart to visually compare the RAI values for each season solely in this location (Figure 2). Based on the available 2019-2020 data, I randomly selected 29 days from each season and calculated seasonal RAI values for this location (Table 6). An average of a month (29 days for each season) is used during this display in order to keep the number of days consistent among seasons. The gaps between the active camera days did not allow us to use it for a longer time.

2. Irvine Ranch Water District (IRWD) Wildlife Monitoring Survey

Active camera days differ from each other during this monitoring project as well (Tables 1, 3, and 5). All these camera locations covered a relatively small (approximately 11 km^2) area of the IRWD Wildlife Sanctuary marsh to document current wildlife activity (Figures 5 and 7). Three of the cameras (C1V2, C5V2, and C6V2) were rotated versions of C1, C5, and C6 respectively because the IRWD experts concluded that these new locations may yield better capture rates (Table 1 and Figure 7). Also, all the IRWD cameras were oriented and placed in a way to record less human activity; either placed out of official and unofficial trails, secluded inner platforms, or close to bodies of water (Table 1 and Figure

7). Therefore, the initial camera placement approaches differ from the UCI wildlife monitoring survey.

2.1. Seasonality across all IRWD Camera Locations

Between 2016 and 2018, I used an average of three months of data for each of the four seasons across all the IRWD camera locations to keep the number of active days equal for each season. Table 7 and Figure 3 illustrate the details of the start and end dates. I treated all the camera locations as one because of the low detection rates, the proximity of camera locations to each other, and the relatively small size of this protected marsh territory. I compared the total large carnivore RAI via a one-way random effects model Analysis of Variance (ANOVA) to determine whether total carnivore RAI would vary by season and across all IRWD camera locations (Table 7 and Figure 3).

Comparison of Current and Lyren's (2008) Survey

One of our main goals was to demonstrate the differences in large carnivore RAI (due to land use and high population density) between our current study and that of Lyren et al. (2008). I gave particular attention to the three shared camera stations: *HB=H1* (64 days), *CH=H2* (134 days), and *MT=H3* (174 days). I subsampled the dates of the historical data to match the dates of my current study in order to control seasonal differences. In so doing, I normalized the active camera days for each location.

Despite frequent gap days, Table 9 illustrates how I subsampled data in a way that utilized all available active camera days. Lyren et al. (2008) used only some parts of their data in their tables, figures, and analyses. However, I obtained and used all the available data for species of interests within the given period of time. Thus, numerical differences occurred between our active camera days, corresponding RAI values, and theirs (Table 1 and 5). For convenience, I refer to this study as the historical study throughout the paper.

Wildlife Vehicle Collision (WVC) Spatial Analysis

I obtained publicly available roadkill data from Caltrans and the City of Irvine Local Animal Services for my study area between the years 2005 and 2019 via *California Public Requests Acts*. I used ArcGIS to display data from the City of Irvine Local Animal Services and calculated the number of animal strikes at each location.

Observational Data Collection for Underpass Improvement Purposes

Specific recommendations are provided to improve the quality of present underpasses based on their current problems (Table 12). Recommendations are made based on observational data compiled throughout the study.

Statistical Analysis

I used RStudio statistical software (Version 4.0.2, 2020) and Microsoft Excel for Office 365 (Version 2002) in my analyses and calculations. I conducted a one-way random effects model Analysis of Variance (ANOVA) to determine whether total carnivore RAI would vary by season and across all IRWD camera locations (Table 7 and Figure 3). I illustrated the data for the RP location as a bar chart (Table 6 and Figure 2).

Previous studies have shown there is a correlation between the Openness Index (*width X height/length* of crossing structure) and the frequency of undercrossing use by wildlife (Reed & Ward 1985; Clevenger & Waltho 2000). I used Pearson-product moment correlation to assess the relationship between the Openness Index (OI) and Relative

Abundance Index (RAI) at each UCI undercrossing structure location, i.e. seven culverts and two bridges (Table 10 and Figure 11).

RESULTS

Camera Trapping Survey Results

1. UCI Wildlife Monitoring Survey Result

I captured 570 coyote photos over 1443 nights across all 11 camera sites. The information on the start and end date along with the number of active camera days for each location can be found in Tables 1 and 5. No bobcats were detected at any of the UCI Camera Survey locations. Location Marsh Trail (MT), which is an official dirt trail in the UCI San Joaquin Marsh, had the highest relative abundance index (RAI=0.91) (Table 5 and Figure 8). Other than our wildlife monitoring crew and some marsh maintenance vehicle activities, we observed no additional human activity in this location during the 176 active camera days. The location is not open to public visitation, only certain people with permission have access to this site. I recorded zero carnivore activity in the locations of Ecopreserve Culvert (EP) and Chinese Church Culvert (CC). The majority of EP culvert (>75%) (Figure 12) is fenced, and the other end of the culvert is inhabited by a homeless person. The CC culvert was flooded perennially (Figure 12).

1.1. Seasonality in RP Location (as a visual display)

The calculated coyote RAI values from the RP camera location, a culvert that connects the UCI campus to the Newport side of the Bonita Creek Corridor, is illustrated as a bar chart to display the visual difference between each season (Figure 2). I observed small visual differences between seasons (Figure 2): Winter 2020 in RP location yielded the highest RAI value (0.76) whereas Summer 2019 yielded the lowest RAI value (0.07) (Table 6 and Figure 2). Winter detection was more than 10 times that of summer detections. I detected similar values for Fall 2019 (RAI=0.48) and Spring 2020 (RAI=0.52), which indicated no meaningful difference. I recorded no human activity in the RP location other than our monthly visits. Since this data is only for one location and only has approximately one year of data, I was not able to assess whether there was a statistically significant seasonal difference for coyote RAI values.

2. IRWD Wildlife Monitoring Survey Result

357 coyote and five bobcat occurrences were recorded over 9445 active camera days at 10 IRWD camera locations (Table 1). The highest relative abundance of carnivores was observed at C8 (RAI=0.11) and C5 (RAI=0.1) locations while the lowest abundance was observed at C5V2 (RAI=0) (Table 5 and Figure 9). Similarly, C1V2, C5V2, and C4 locations displayed very low large carnivore activity (RAI=0.1) (Table 5 and Figure 9). Throughout the monitoring at IRWD, five bobcat visitations were recorded at C2 and C5 locations in 2015 (Table 11). No bobcats were captured during either the IRWD Camera Survey or our UCI Monitoring Survey in 2016-2020 and 2019-2020, respectively.

2.1. Seasonality Result across all IRWD Camera Locations

The seasonality difference test only contains one of the bobcat occurrences that happened in 2015 at the IRWD camera trapping survey; recorded in the C5 location on January 30th, 2015. The rest of them (four other bobcat detections in 2015) were not a part of this illustration because the start date of the seasonal data was on December 1st, 2015 to have an equal number of seasons (three different years of four-season data) during the seasonal difference analysis (Table 7 and 11). Total carnivore RAI did not differ seasonally ($p > 0.05$, Figure 3 and Table 7).

3. Comparison of Current and Lyren's (2008) Survey

After subsampling the historical data based on my current UCI wildlife monitoring effort, I observed eight bobcat and three coyote detections in the (Historical Location 1) H1 location while only seven coyotes in the Historical Bike Path (HB) location (RAI=0.11) within 64 days. Two bobcat and seven coyote visitations were recorded in the historical study, whereas I observed seven coyotes (RAI=0.22) in only 134 days. Lastly, 30 bobcats and 12 coyote visitations were recorded in the historical data in 174 days, but I observed 160 coyote visitations (RAI=1.86) in the same time period.

Overall, there was a 35.3% decrease, 37.1% decrease, and a 272% increase in total large carnivore RAI at HB, CH, and MT locations, respectively (Figure 4 and Table 9). A total of 40 bobcats and 62 coyotes were recorded at these three locations during the historical study while our current study failed to capture any bobcat occurrences (Table 9). However, a 180.6% increase in coyote detection across these three locations was observed in the current study.

Wildlife Vehicle Collision (WVC) Spatial Analysis Result

Data from local animal services indicated a decline in bobcat WVCs since 2005. Of 13 bobcat WVCs recorded from 2005-2019, eight strikes (61.5%) occurred during the 21 months between June 2006 and March 2008 in which Lyren's cameras were active. Zero bobcat strikes have been recorded after 2015 (Appendix B, Figure B-8). The highest large carnivore strikes per location (11) was near the Historical Bike Path (HB) location (by Concordia University) and the second-highest strikes per location (8) was near Culver Boulevard Culvert (CB) location (the intersection of the University Drive and Culver Boulevard).

Crossing Structure Openness Index (OI) Comparison Result

The relative openness of seven UCI camera undercrossing structures is not related to observed large carnivore density during the UCI Wildlife Monitoring Survey ($p > 0.05$, Figure 11 and Table 10).

Observational Data Collection Results for Underpass Improvement Purposes

Culverts are greatly affected by human-related activities including improper runoff release and fencing installation as well as inhabitance. Of the five culverts surveyed, we determined that all would benefit from small to major scale improvements: While simple removal of fencing from the entrance of Ecopreserve Culvert (EP) can improve the animal movement with minimal cost, redirection of water in the Chinese Church (CC) culvert location can easily become pricey. Bridges are no different. The MacArthur Bridge (MB) camera location is inhabited by a homeless person (actively wandering around day and night) that deters animal use of the underpass. A longer wildlife monitoring with at least four cameras at the Bonita Creek Bridge (BC) may be more appropriate to make a stronger conclusion of its permeability and quality for the wildlife movement. Yet, every crossing structure is different and the solutions to their current problems should be assessed case by case. A full list of recommendations for each undercrossing structure is provided in Table 12 by case by case approach.

DISCUSSION

During the study, my main goal was to understand if the wildlife linkage corridors were being used effectively by large mammalian carnivores across the study area (Figure 1). This study fully assessed the effectiveness of the Sand Canyon Wash Corridor, parallel to University Drive, which contains sufficient wildlife to evaluate policy (Table 5 and Figures 1, 8 & 9). However, I recommend an additional study over a longer period of time for the Bonita Creek Corridor to assess. Since each undercrossing structure (specifically bridges) in this corridor have relatively high dimensions to cover, multi-season and multi-year camera trapping effort is required. Yet, no bobcat has captured neither the IRWD Camera Survey nor the UCI Monitoring Survey in 2016-2020 and 2019-2020, respectively. Also, no bobcat roadkill is observed after 2015 in the study region. This indicates that the bobcat population density in these habitat areas that the corridors are designed to connect is alarmingly low. Increasing traffic infrastructure and the spread of human settlements have created impermeable landscapes that restrict animal movement in the region. These stranded animals doom to extinct if the necessary conservation measurements are not taken on time. To understand and eliminate the present internal and external threats to these animals, certain conservation efforts such as regular assessment of the existing wildlife linkages (like mine) should be implemented. During this study, I also compared my current study to Lyren's historical study (2008) to demonstrate the changes that happened over a decade after. The variation of coyote detection rate in the shared locations (and also the rest of the camera stations) points out impediments to animal movements in the region. These impediments including topography, roads and type of crossing structures, fences, outdoor lighting, noise from vehicle traffic, and other human activities need to be assessed and eliminated via local and regional level enhancement projects to have functional ecosystems in the area. Lyren et al. (2008) reported 26 bobcats dead over 32 months and suggested that these animals' persistence in the region will depend on the conservation effort that should be taken immediately such as improvement of habitat connectivity, a regular camera, and WVC surveys, and targeted GPS telemetry studies to evaluate the overall health, productivity, and survival rate from diseases. One might think the decreasing bobcat mortality trend (an average of 2.4 to 0.75 between 2005-2011 and 2012- 2019, respectively) via vehicular collision (Appendix B, Table B-1) may indicate that these animals found a way to travel safely in the region. However, I believe the low bobcat population density in the region lessen due to measurements that are not taken in time, which explains why we did not observe bobcat mortality or roadkill since 2015. My study once again highlights the importance of taking measurements in time to save this pivotal species.

IRWD cameras detected a relatively low number of coyote visitations and corresponding RAI values compared to my UCI camera survey (Figure 9 and Table 7). These differences might have stemmed from multiple factors. Previous literature shows that urban coyotes exhibit bolder and more exploratory behaviors compared to rural coyotes (Breck et al., 2019). This suggests that the coyotes I observed may simply prefer human or dirt trails when it is convenient rather than concealed habitats such as dense shrubby vegetation (Romsos, 1998; Hinton et al., 2015; Mastro et al., 2019; Breck et al., 2019). It should be noted that none of the IRWD cameras were along the human trails (Table 1 and Figure 7). Instead, they were mainly placed near bodies of water or dense thickets (Table 1 and Figure 7). The presence of potential barriers (such as urban edges and roads) around the IRWD Wildlife Sanctuary may also be another explanation of fewer carnivores were observed. Two out of the four sides of the sanctuary are surrounded by crowded residential apartments, the third side is blocked by the San Diego Creek Channel water, and the last side is adjacent to the San Joaquin Marsh (SJM) but separated by a busy road which is improperly fenced (Table A-3, Figures 5 and 7). Once animals make it to the preserved marsh, they must risk crossing high traffic volume roadways to maintain large enough habitats to survive. Even though the adjacent green habitat is right across the street (UCI San Joaquin Marsh), they cannot benefit from it without crossing dangerous roadways. Therefore, an elevated number of roadkill around these two marshes is an indication of the lack of connectivity (Figure 5). Previous studies documented the high number of carnivores strikes in the region. For example, Lyren's historical study (2008) alone documented 26 bobcat strikes in the San Joaquin Hills, Orange County, California between September 2005 and April 2008. In another study, 10 out 29 radio-collared coyotes confirmed dead by WVC in the Chino Hills, Prado Basin, San Bernardino and Riverside Counties between February 1998 and February 2000 (Lyren et al., 2001). As a result, the connectivity between SJM and IRWD Wildlife Sanctuary (but not limited) should be enhanced. An overpass or underpass structure should be built between these two marshes along with proper roadside fencing installation to ensure safe animal crossing between these protected areas.

Some studies have also shown seasonality affects large mammalian detection, undercrossing usage, roadkill mortality rates along with their home-range sizes (Yanes et al., 1995; Rodriguez et al., 1996; Lyren et al., 2001; Gehrt et al., 2009). Sex, age, and social status characteristics are other significant characteristics that affect the large carnivores' landscape use (Gehrt et al. 2009). Yet, other studies' results contradict them: For instance, Franckowiak et al. (2019) did not find any seasonal differences for home range size for residential coyotes. On the other hand, Holzman et al. (1992) found that seasonal variation plays a distinctive role in determining home range sizes for coyotes in Georgia. Similarly, Rodriguez et al. (1997) observed a statistically significant seasonal variation in the crossing rate of carnivores at roadway underpasses, whereas Yanes et al. (1995) found no seasonal variation. I observed no seasonal differences in total carnivore RAI in the IRWD camera stations ($p > 0.05$, Table 7 and Figure 3). Of course, the low detection rate at IRWD camera stations may also explain why I observed an insignificant statistical result in the region. More comprehensive wildlife monitoring surveys (e.g. multi-season and year) are recommended to illustrate how large carnivores are affected by seasonal differences. Since the study area falls within a Mediterranean climate with distinct dry (June–November) and wet (December–May) seasons, I believe it may be even more appropriate to make the comparison particular to these two seasons instead.

Due to the lack of data for multiple years and locations, I was not able to perform a difference test for the data collected during the UCI wildlife monitoring survey to evaluate the seasonality variation. Yet, I found it useful to display what is available as a bar chart. I displayed the seasonal data of the Research Park Culvert location (RP) which is the only location that has four seasons of data during the UCI wildlife monitoring study (Table 8 and Figure 2). The little elevation in summer data compared to other seasons suggests that the number of large carnivores in this region may change seasonally, but similar studies are necessary to make this type of strong conclusion. I hope my efforts in this study encourage future scientists to conduct further seasonality studies.

Openness index (OI) is a significant factor (calculated based on the dimensionality of each undercrossing) determining the type and size of animals that use the existing underpasses (Reed & Ward 1985; Clevenger and Waltho 2000). Since OI is an easy and popular measurement tool to evaluate the performance of undercrossing (Clevenger et al., 2001; Bates et al., 2003; Clevenger & Huijser, 2011), I also used this index to determine whether coyote or bobcat undercrossing passage usage is affected by the dimensionality during my study. I found no relationship between openness and relative abundance (Table 10 and Figure 11), indicating that other variables are likely to be important, which I examined in my observational study of the culverts (Table 12). Based on my observations, I can conclude that present culverts are not just discouraging animals, but most of them are not even suitable for animal movement (Tables 5 &12 and Figures 12, 13 & 14). Besides the overall lack of connectivity in the region, the reasons for the lack of animal movement could be specific to each undercrossing structure. For example, factors that I observed during the UCI monitoring study include the presence of standing water at CC (year-round) and CH (most of the year) locations, human intrusion and improper fencing at the EP location, construction practices at the CB location, and human intrusion (day and night) at the MacArthur Bridge (MB) location (Table 12). I would highly suggest applying mitigation plans in these locations to ensure safer wildlife crossings. For example, redirecting urban runoff in the Chinese Church Culvert (CC) and the removal of fences at the entry of the UCI Ecopreserve Culvert (EP). More detailed recommendations for each underpass are provided in the future directions and the management implications section of the paper (Table 12).

Determining bobcat density via conventional capture-recapture methods in a declining small population requires great effort and financial resources (Ruell et al., 2009). Alternatively, many other noninvasive methods such as transect scat survey, camera trapping survey, and hair snare are proposed and used by scientists to accurately estimate the abundance of the bobcat population (Ruell et al. 2009; Thornton & Pekins, 2015; Satter et al., 2019). While some scientists find it controversial to reliably calculate these secretive, wide-ranging, and low-density carnivores' population via motion-triggered camera survey methods (Sollmann et al., 2013; Meek et al., 2015), other scientists have been using this technique in many widely accepted studies (Heilburn et al., 2006; Long et al., 2011; Welbourne et al., 2016). However, failing to capture these animals in a given area through a camera survey does not correspond with their absolute absence. For example, I did not capture any bobcat detection during my UCI (2019-2020) and the IRWD wildlife monitoring surveys (2016-2020). Although I cannot claim that no bobcat is in the vicinity anymore, it is evident that their abundance has declined over the last decade.

Lack of habitat connectivity between natural habitats and a corresponding genetic disposition to parasitic diseases may explain a potential decline of the bobcat population in coastal southern California and the complete disappearance in certain habitat islands (Haas, 2000; Lyren et al., 2008). Prevalent usage of rodenticide (e.g. anticoagulant toxicants) in urban settings of California is also a known threat to bobcat populations (Hosea, 2000; Riley et al., 2007). Rodenticides lower the survival rate of animals from diseases such as mange in cats. Riley and his colleagues (2007) found that every single mange-related dead bobcat (19 out of 19) was exposed to some levels of anticoagulant rodenticide. The detection rate of bobcats is dependent on the ratio of the total number of cameras to the study area, choice of camera settlement (e.g. dense riparian coverage versus open dirt trail, or high human presence versus low human presence), and the size of the bobcat population (Clare et al., 2015). These factors accompanied by many other implicit factors may influence the detection rate directly or indirectly. I cannot pinpoint why exactly the bobcat populations have declined. Yet, my study suggests that undermaintained crossing structures, loss of connectivity, improper fencing, widespread rodenticide usage, and intense human activity are the main reasons for the bobcat population decline in the study region. Regulation of widespread rodenticide usage and improvement of safe animal movement in this region can stop the extinction of these animals. Fortunately, I received anecdotal information from some residents of Irvine University Hill Housing Community that they had seen bobcats recently (not official data). My recommendation is to make further studies to verify these observations via hair snare or alive animal trapping methods.

Coyotes and bobcats, niche-sharing carnivores, are likely competing for limited resources and space among habitat patches. Bobcats exhibit greater sensitivity to human disturbances than coyotes. For example, female bobcats tend to limit their home range to small areas that lack connectivity and subsequently decrease their foraging boundaries and reproductive rates (Crooks 2002; Tigas et al., 2002; Riley et al., 2003). On the other hand, coyotes exhibit more tolerant behaviors, such as using available undercrossing structures when they are convenient. It is no surprise to observe a very low bobcat detection rate in contrast to the increasing coyote rate, not only in the UCI Marsh Trail (MT) location but also in the rest of the study region. Previous studies also demonstrated that coyotes avoid dense riparian coverage; instead, they prefer to use roads/trails adjacent to developed areas (Romsos 1998; Hinton et al., 2015; Mastro et al., 2019). Since finding an easy anthropogenic source of food (e.g. food left out for pets, fallen fruit in the yard, bird feeders, or free wandering cats and small dogs) is easier near urban areas, the coyote detection rate varied among cameras in different settings even when they are close to each other.

Both species show behavioral plasticity and adaptability to some extent (Tigas et al., 2002) to the biggest challenges in the region: drought and human disturbance (Parren & Clucas, 2019). Due to climate change, California is experiencing more severe and extended droughts during the last decade (Griffin & Anchukaitis, 2014; Dettinger & Cayan, 2014), which significantly influences the number of carnivore population densities (Trenberth et al. 2014, Prugh et al. 2018). As the abundance of small mammals declines during a drought (Chew & Butterworth, 1964; Whitford, 1976; Rosen 2000), the available food resources for large carnivores become scarce. As a result, it is possible this would increase the competition between these niche-sharing animals (Trenberth et al., 2014; Prugh et al., 2018). However, omnivore coyotes are more resilient in urban matrices compared to strictly carnivore bobcats (Tigas et al., 2002; Riley et al., 2003; George & Crooks, 2006; Ordeñana, 2009). Therefore, bobcats are disadvantaged. Water availability and its dispersal in the region (affected greatly by the severity of drought) impacts ecosystem structures and functions at many different levels. Water availability also affects the ecosystem feedbacks and processes, which influence the present fauna and flora (Gaylard et al., 2003). Burns et al. (2003) demonstrated that wildlife changes their behaviors under water scarcity by greatly altering their range distribution. Drought also changes the wildfire frequency and invasive species dispersal range which significantly impacts the survival of both wildlife and plant species (Defalco et al., 2010)

Future Directions and Management Implications

Specific recommendations to improve the quality of present underpasses are provided in Table 12. I believe if underpasses are improved as I outlined in Table 12, many animals will benefit from it.

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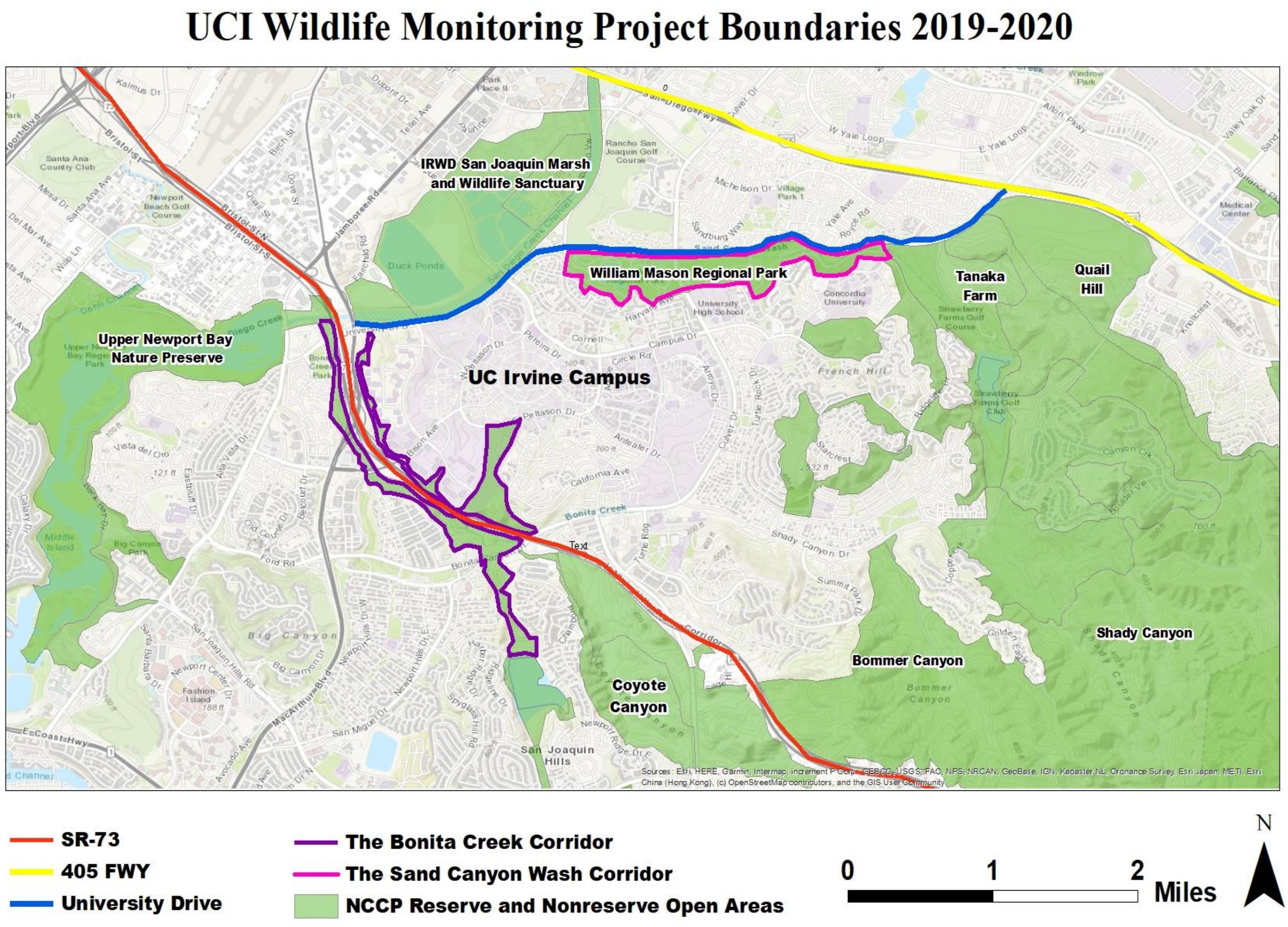

Figure 1 Map of southern Orange County linkages connecting core habitats.

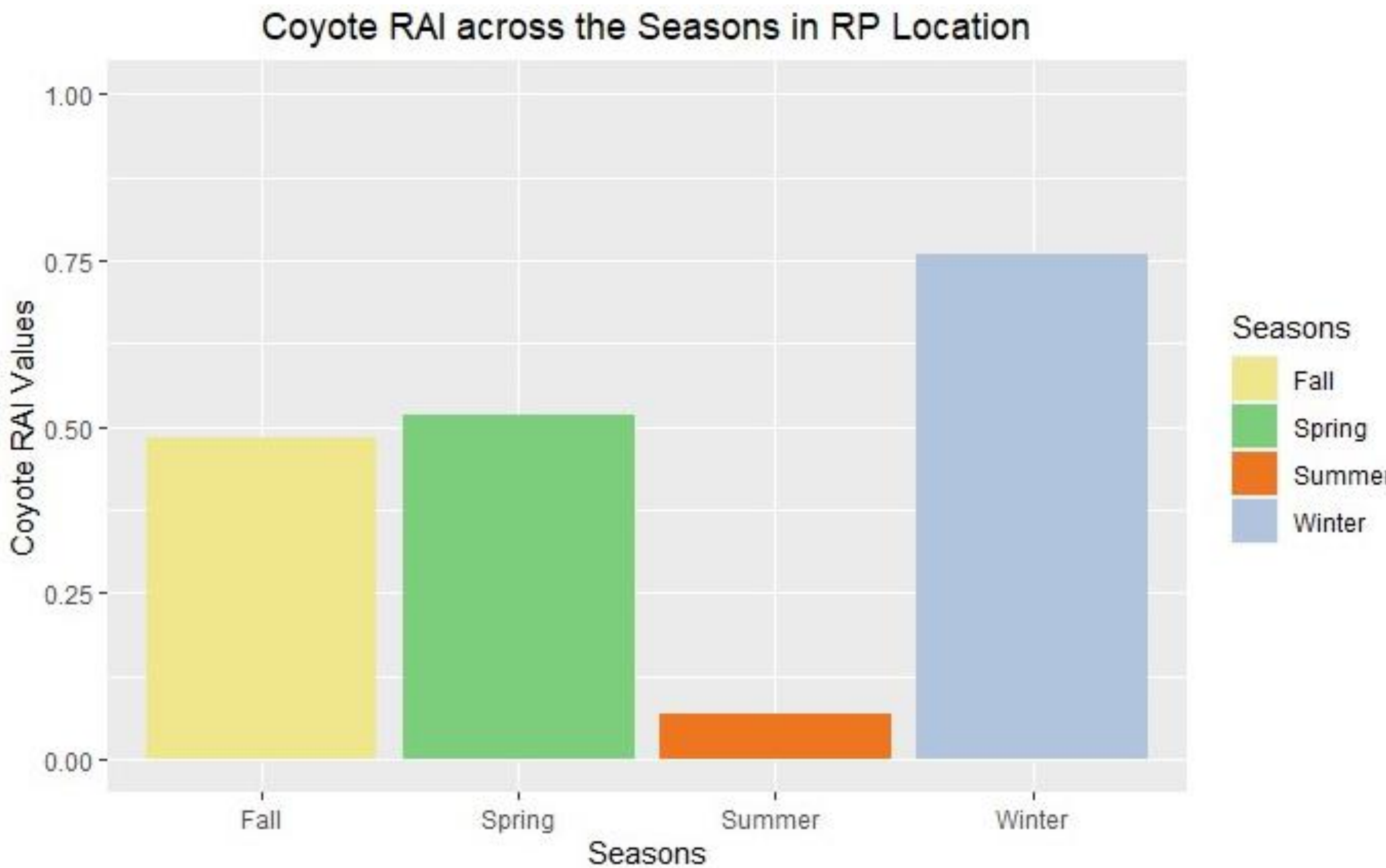

Figure 2 Seasonal variation in coyote RAI at RP (2019-2020)

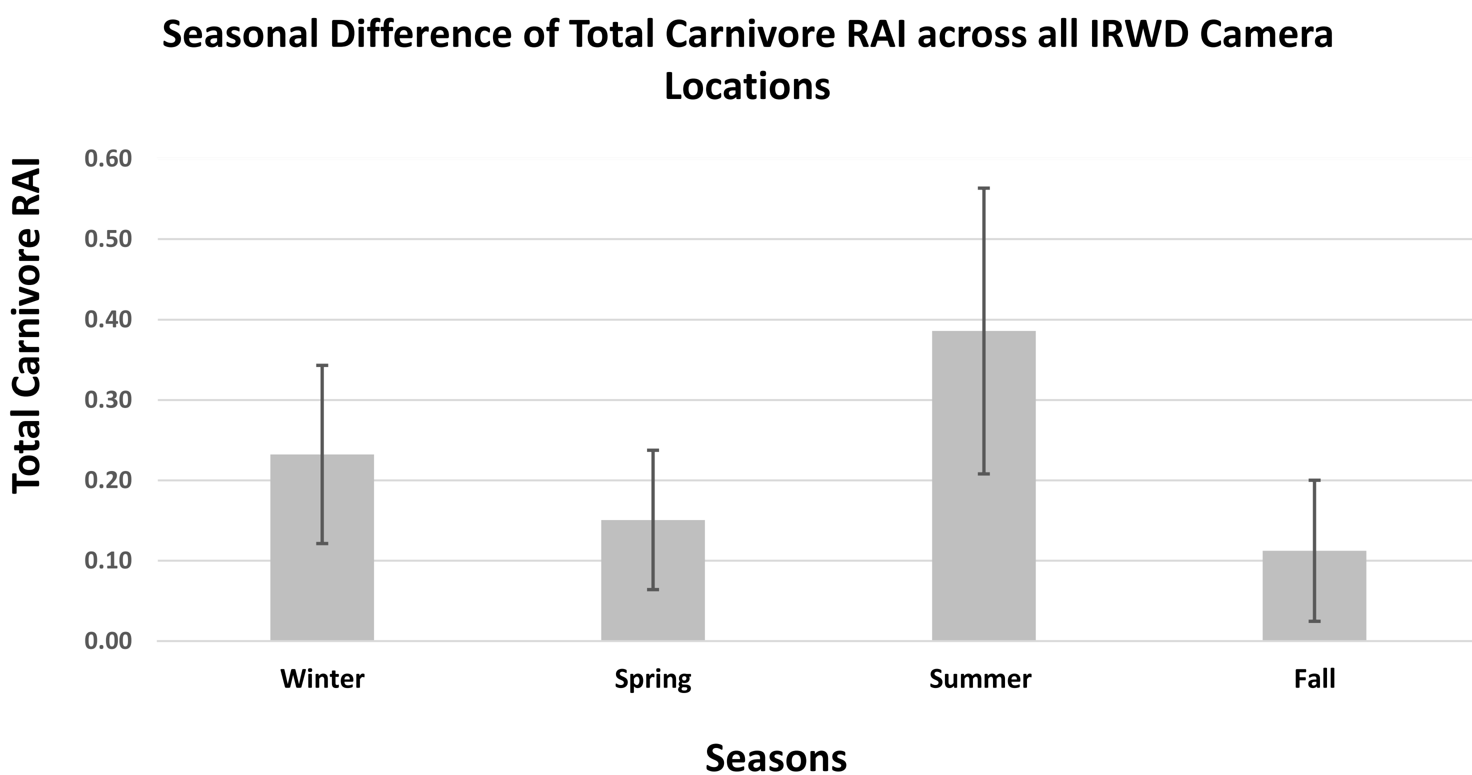

Figure 3 Seasonal Comparison of Total Carnivore RAI values across all IRWD camera locations. A one-way random effects model Analysis of Variance (ANOVA) test was not significant *($p>0.05$).*

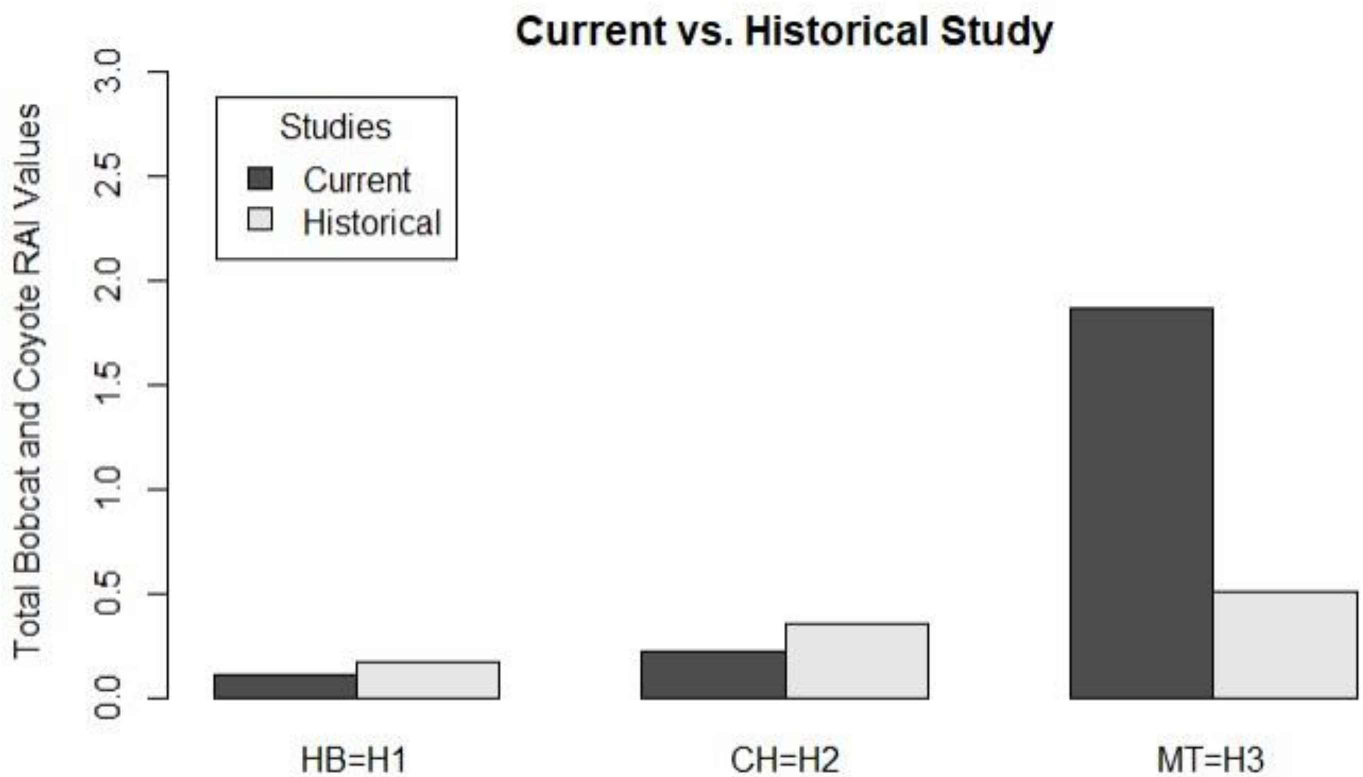

Figure 4 Comparison of Current versus Historical Total Carnivore RAI at three shared locations. *(n=3, HB=H1 64 days, CH=H2 134 days, MT=H3 174 days*

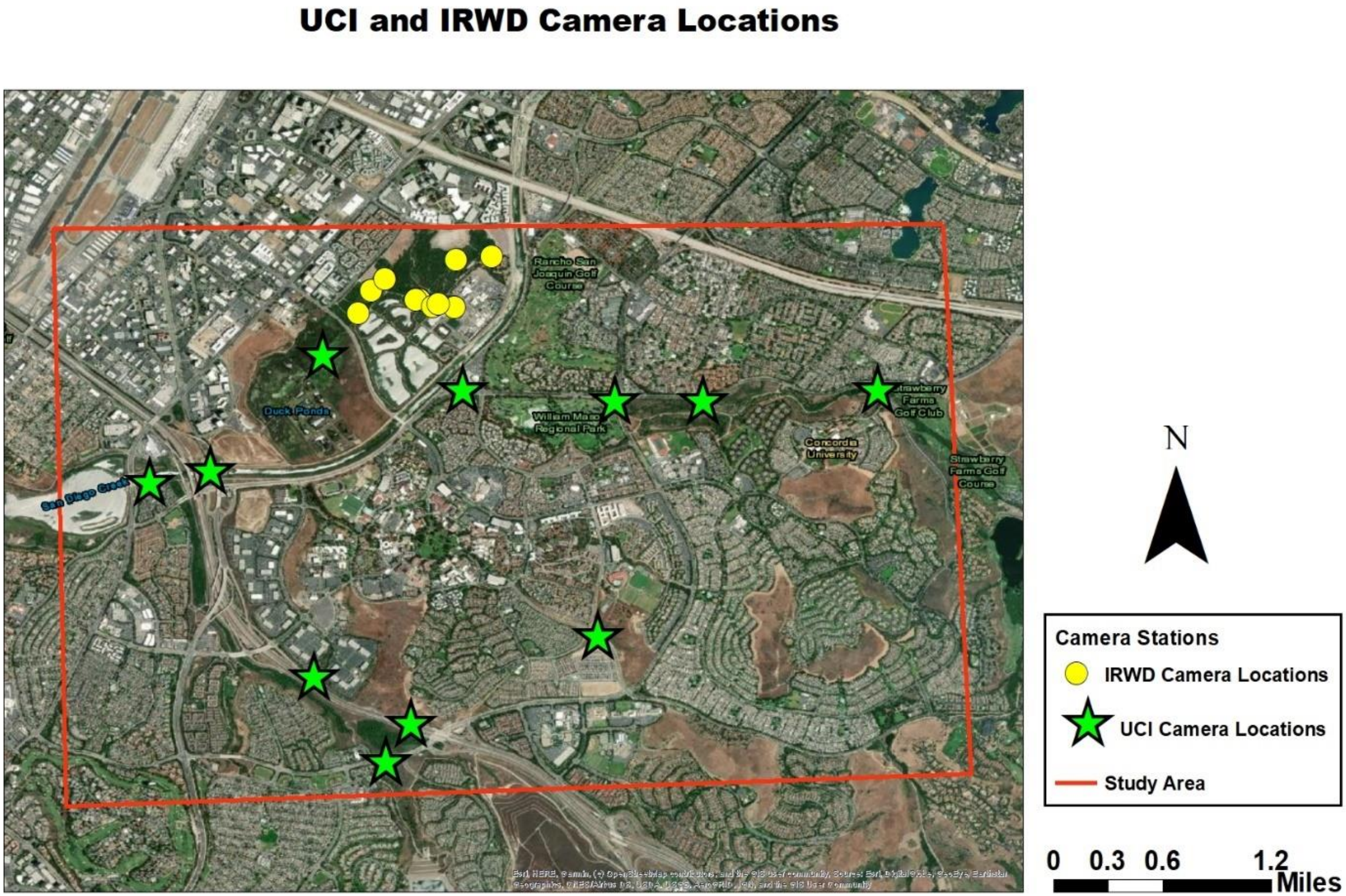

Figure 5 Map of UCI and IRWD camera stations.

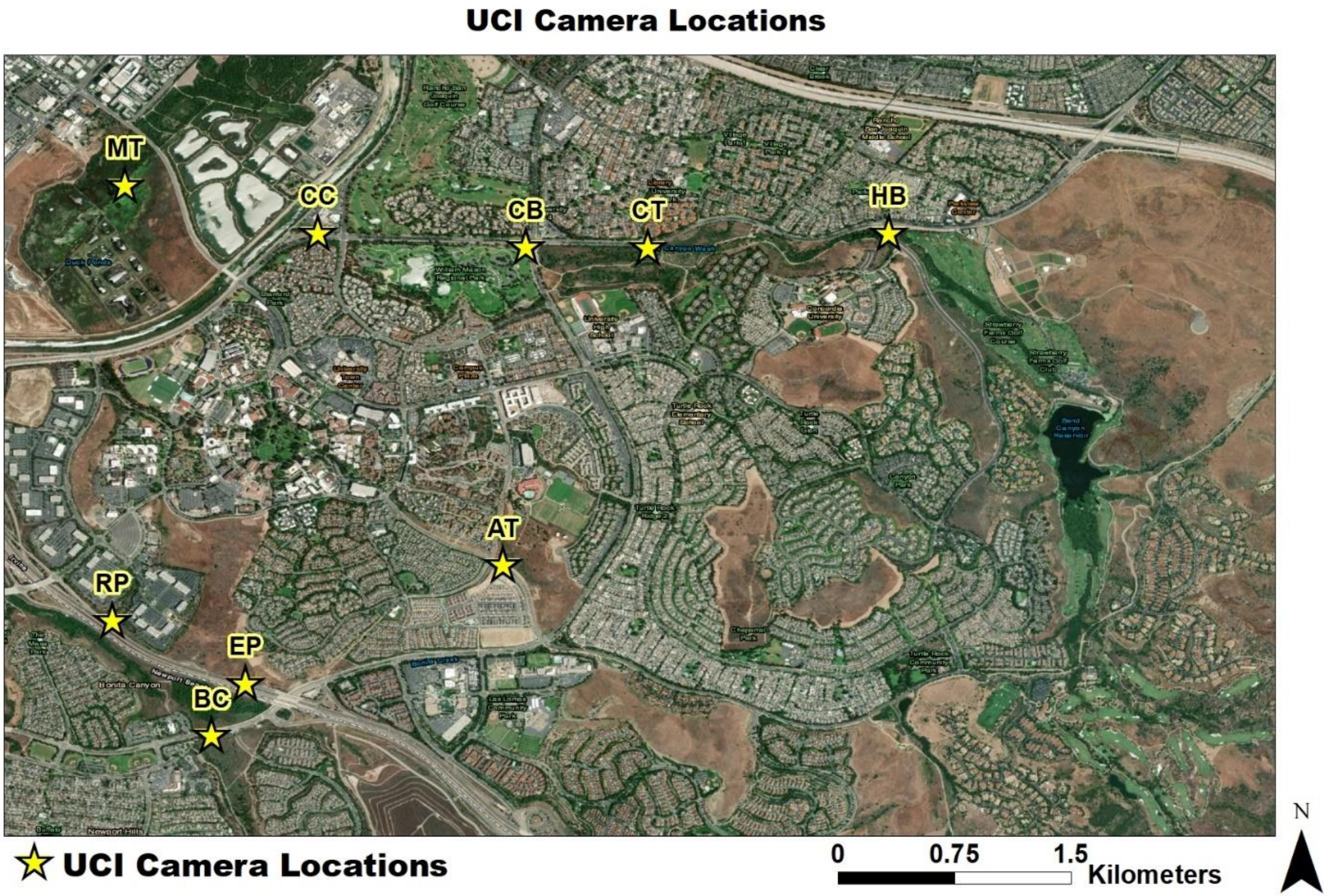

Figure 6 Map of UCI camera stations.

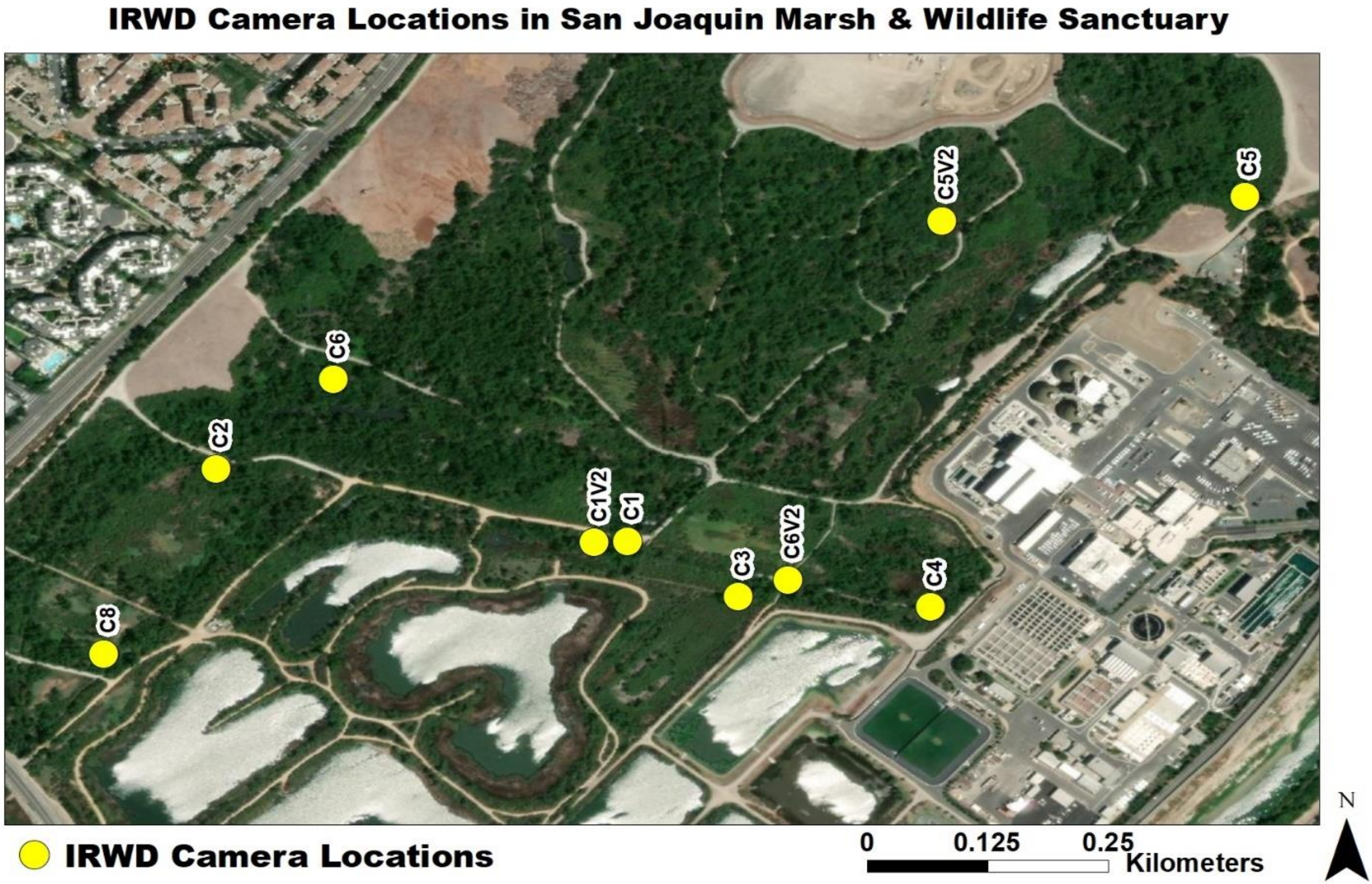

Figure 7 Map of IRWD camera stations.

Coyote RAI Values for Each UCI Camera Locations

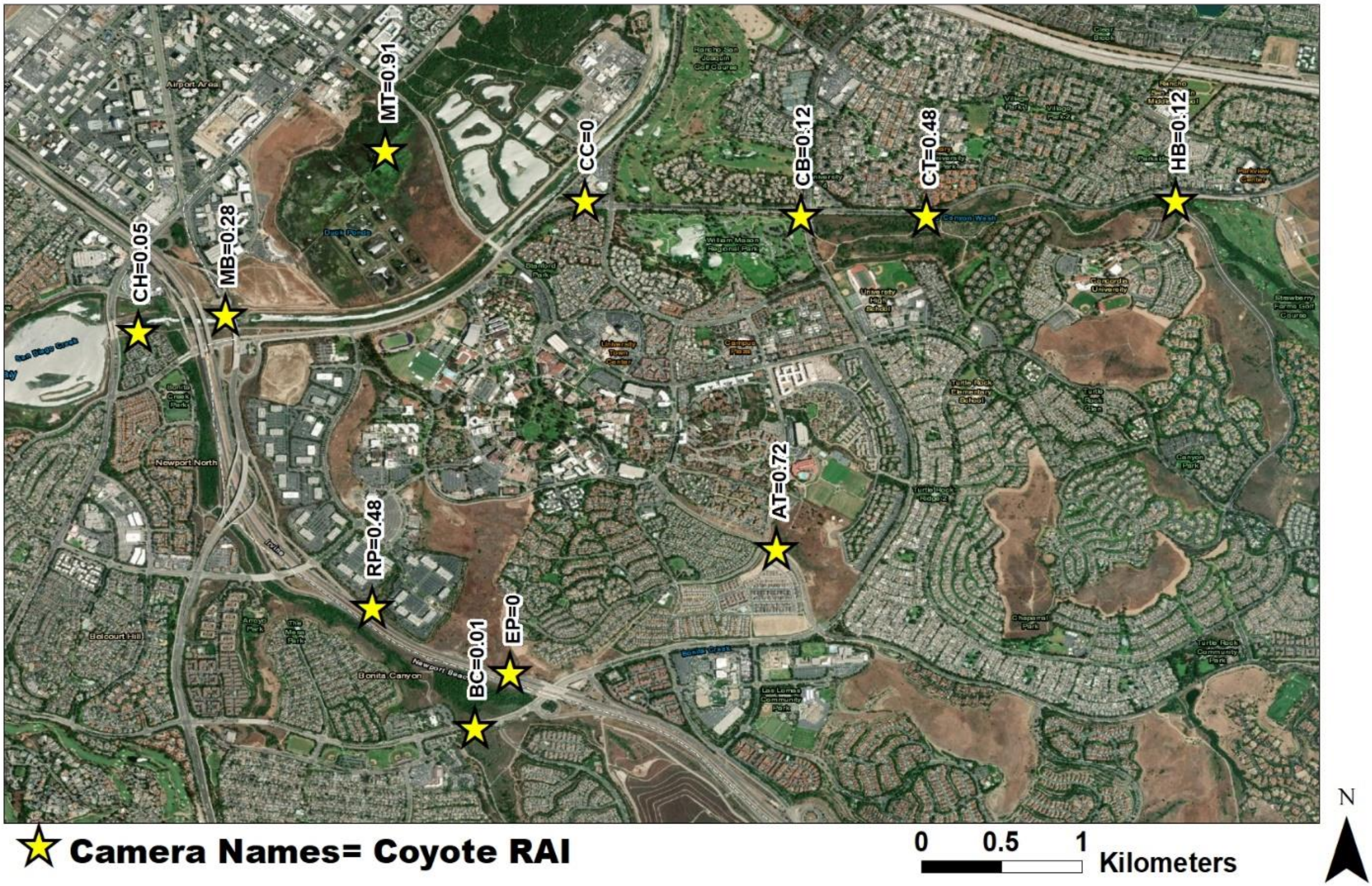

Figure 8 Total carnivore RAI values across each UCI camera locations.

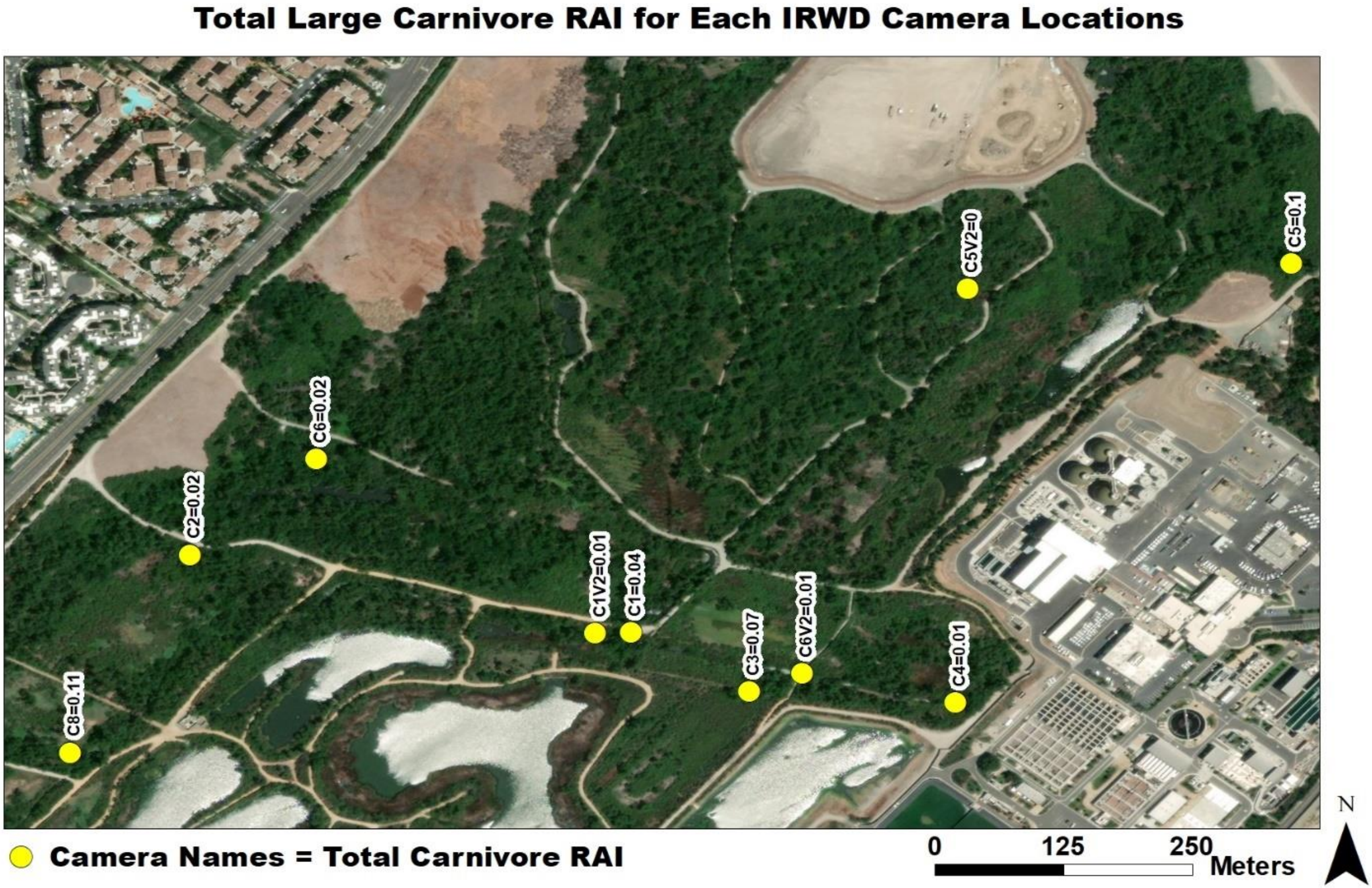

Figure 9 Total carnivore RAI values across each IRWD camera locations.

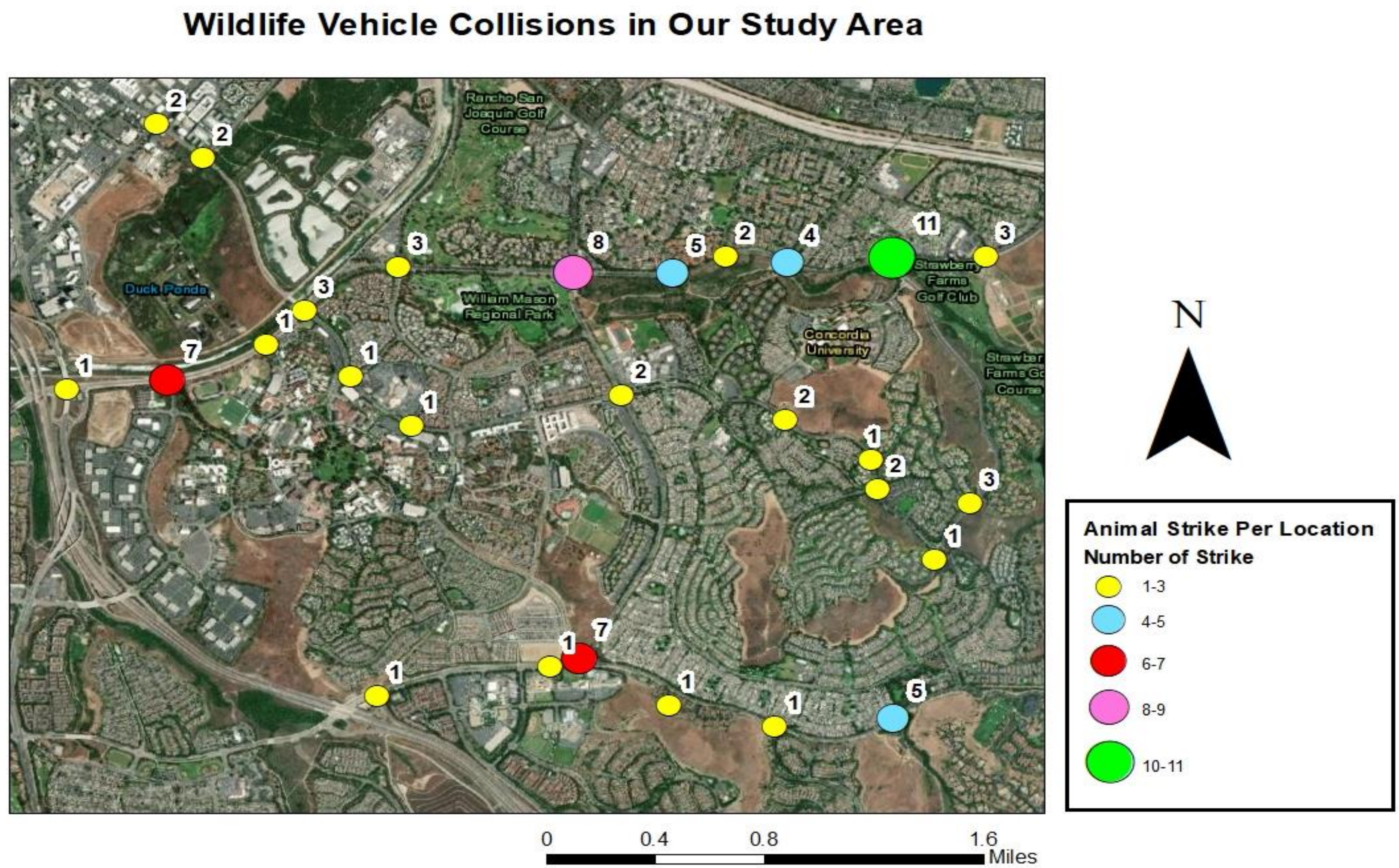

Figure 10 Map of Wildlife Vehicle Collisions (WVCs) per location (2005-2019)

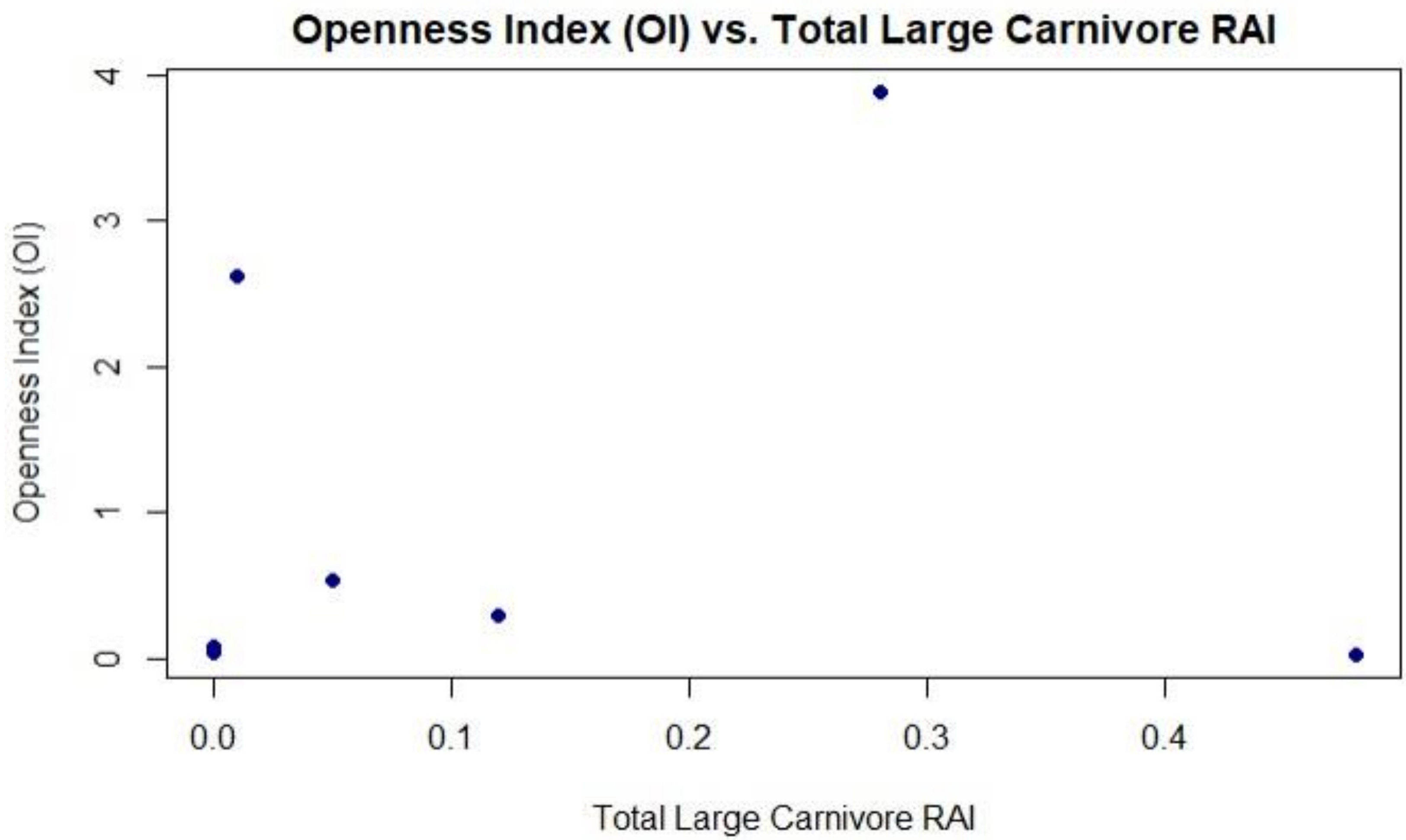

Figure 11 Relationship between Openness Index (OI) and Relative Abundance Index (RAI) at UCI undercrossing structure locations *($p>0.05$)*

Figure 12 Photograph of the fenced entrance of the EP camera station. The bird is seeming to use the culvert.

Figure 13 Photograph of the entrance of the CC location. This location has standing water year-round.

Figure 14 Photograph of CH camera location after a heavy raining event.

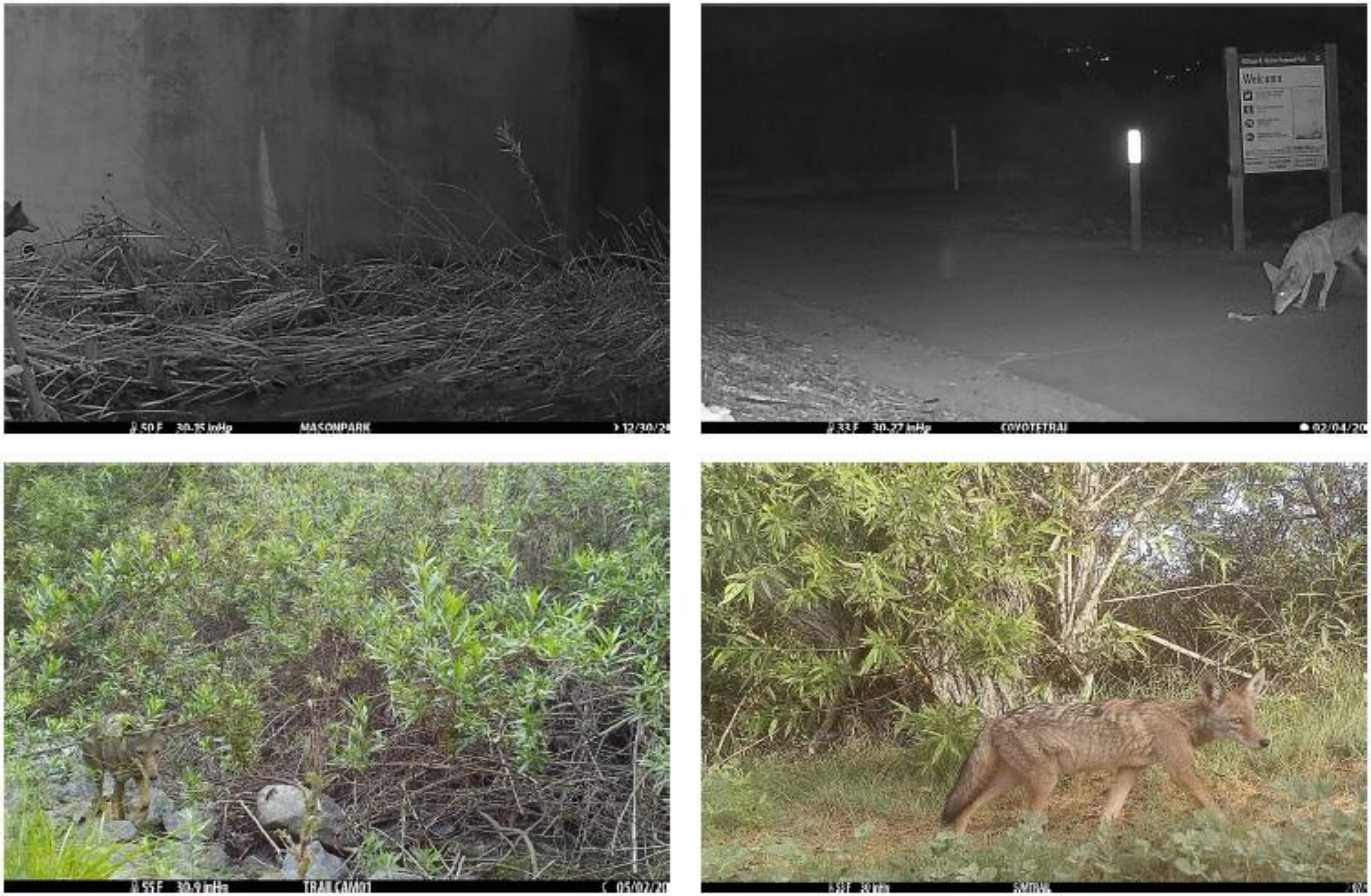

Figure 15 Photograph of Coyote visitations across different UCI camera stations.

Table 1 Project Description, Camera and Crossing Structure Information

Camera Location Name	Location Code	Crossing Structure Type	Latitude	Longitude	Camera Start Date	Camera End Date
MacArthur Bridge	MB	Bridge	33.65167	-117.860417	1/24/2020	5/1/2020
Bonita Canyon Bridge	BC	Bridge	33.629109	-117.846437	2/6/2020	5/1/2020
Culver Boulevard Culvert	CB	Culvert	33.6571303	-117.8281637	12/16/2019	4/2/2020
Concordia Historical Culvert	CH	Culvert	33.65077	-117.8653	12/16/2019	5/28/2020
UCI Research Park	RP	Culvert	33.6357089	-117.8521915	3/22/2019	4/29/2020
UCI Ecopreserve	EP	Culvert	33.632113	-117.844445	5/23/2019	7/9/2019
Chinese Church	CC	Culvert	33.65792543	-117.8402674	10/25/2019	11/26/2019
Historical Marsh Trail	MT	Trail	33.66067	-117.85145	10/8/2019	4/30/2020
Historical Bike Path (SDC)	HB	Trail	33.65798763	-117.8421513	11/12/2019	4/3/2020
Anteater Trail	AT	Trail	33.63890027	-117.829511	10/11/2019	4/22/2020
Coyote Trail	CT	Trail	33.657108	-117.821101	1/24/2020	2/19/2020
Camera 1V1	C1	Trail	33.664817	-117.8438	5/24/2015	7/16/2018
Camera 1V2	C1V2	By a Creek	33.664805	-117.84411	7/17/2018	3/20/2020
Camera 2	C2	Trail	33.665517	-117.84765	1/30/2015	3/4/2020
Camera 3	C3	Trail	33.664283	-117.842767	10/30/2015	3/4/2020
Camera 4	C4	By a Creek	33.664183	-117.840967	5/27/2015	12/31/2018
Camera 5V1	C5	Trail	33.66815	-117.838033	1/1/2015	4/1/2018
Camera 5V2	C5V2	Trail	33.667917	-117.84086	1/1/2018	3/4/2020
Camera 6V1	C6	Trail	33.666383	-117.84655	5/26/2015	11/30/2016
Camera 6V2	C6V2	On a Bridge	33.664443	-117.842305	11/22/2017	2/3/2020
Camera 8	C8	Trail	33.663728	-117.8487	11/1/2019	3/2/2020
Historical Bike Path	H1	Trail	33.65798763	-117.8421513	4/25/2007	1/31/2008
Historical Concordia	H2	Culvert	33.65077	-117.8653	5/31/2006	7/2/2007
Historical Marshtrail	H3	Trail	33.66067	-117.85145	6/1/2006	8/16/2007

Table 2 UCI Camera Project Timeline

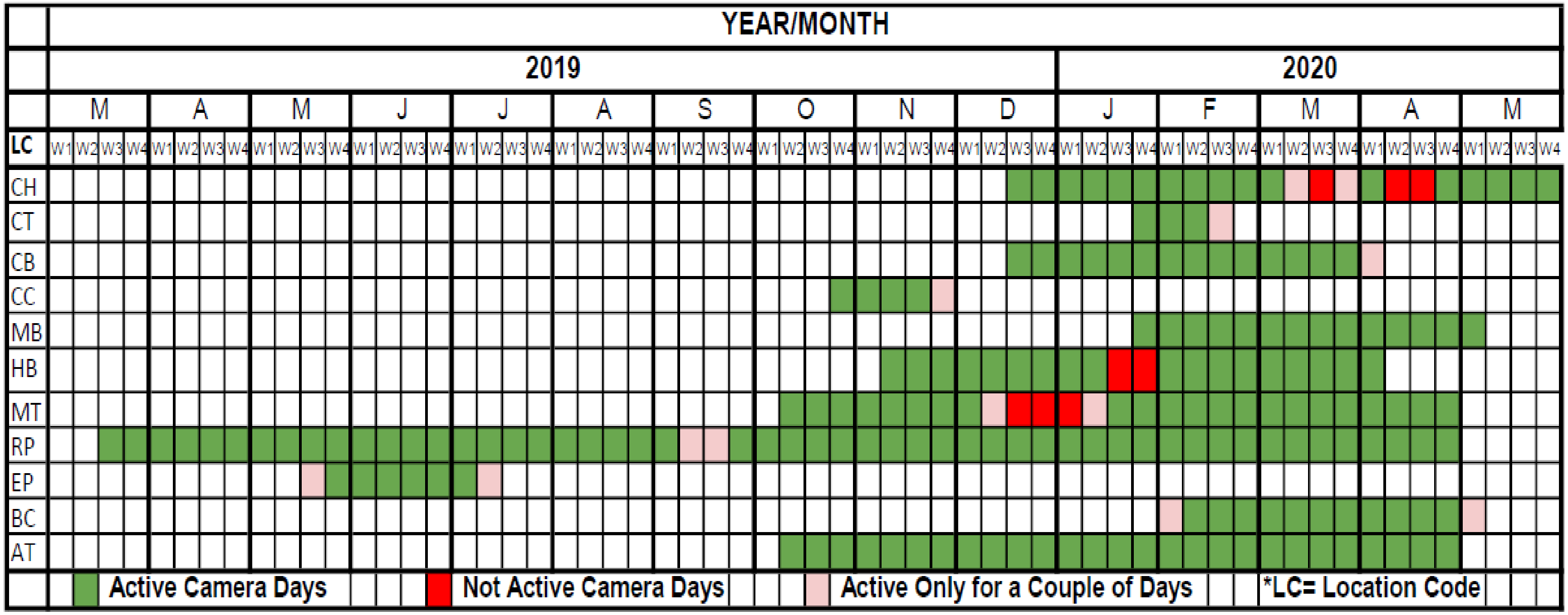

Table 3 IRWD Camera Project Timeline

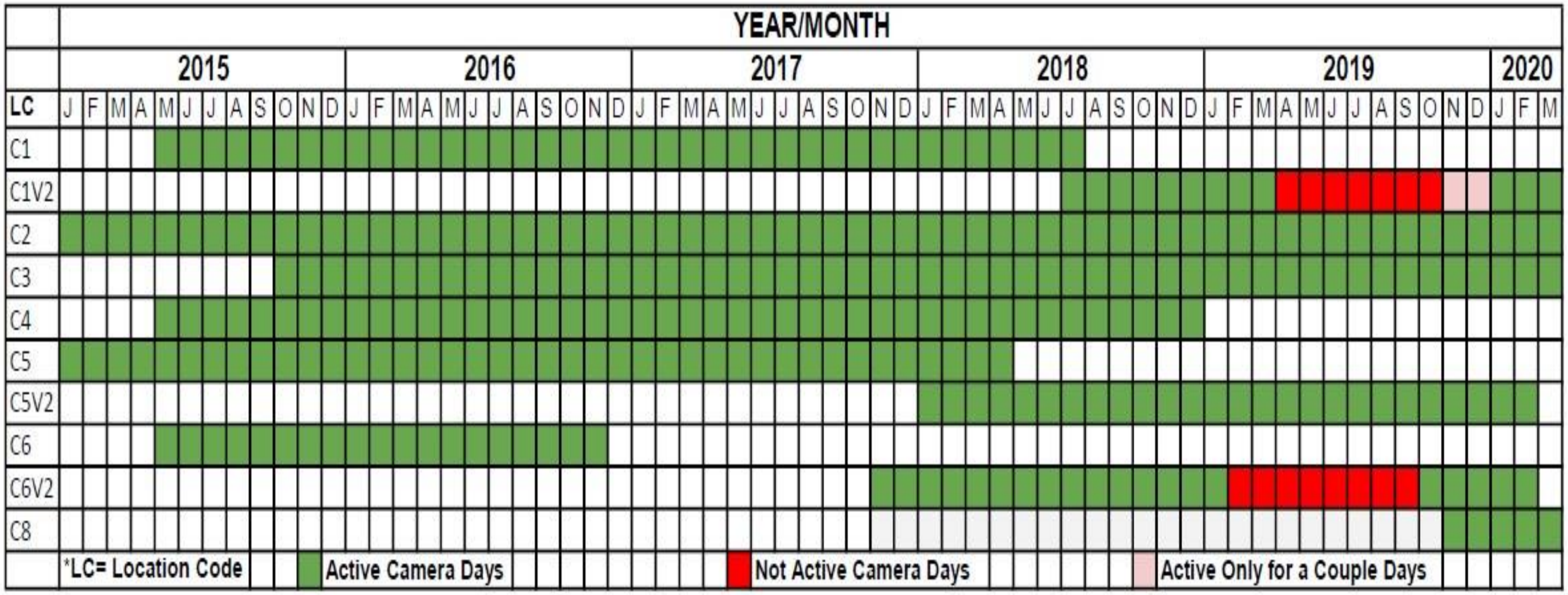

Table 4 Historical Camera Project Timeline

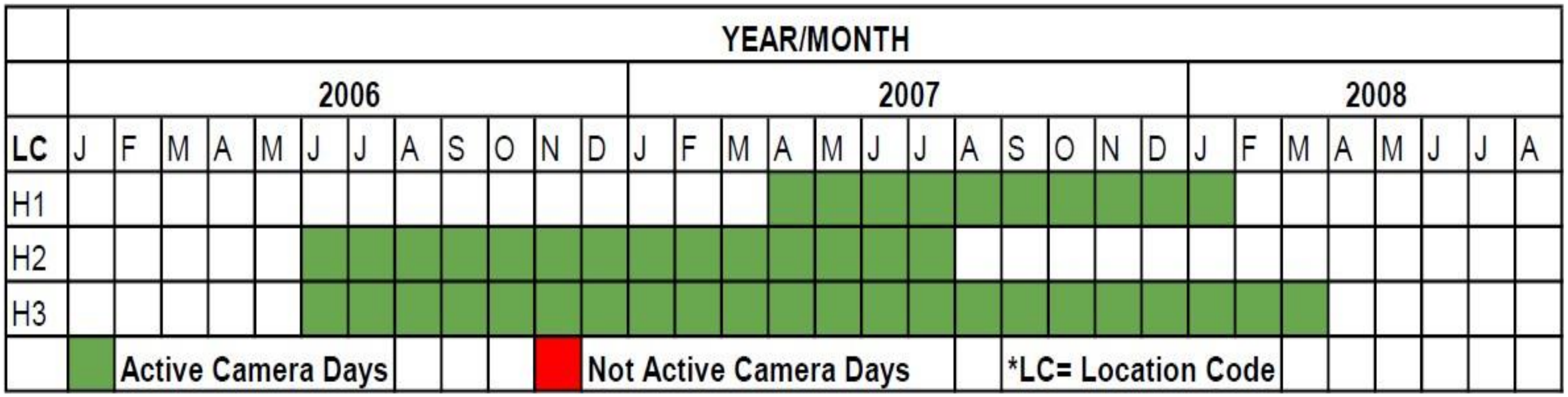

Table 5 Carnivore Observation Summary

Camera Location Name	Location Code	Active Camera Days	Bobcat Occurances	Coyote Occurances	Bobcat + Coyote Occurances	RAI for Coyotes	RAI for Bobcats	RAI for Large Carnivores
MacArthur Bridge	MB	99	0	28	28	0.28	0.0000	0.28
Bonita Canyon Bridge	BC	86	0	1	1	0.01	0.0000	0.01
Culver Blvd Culvert	CB	109	0	13	13	0.12	0.0000	0.12
UCI Research Park	RP	402	0	192	192	0.48	0.0000	0.48
UCI Ecopreserve	EP	48	0	0	0	0.00	0.0000	0.00
Chinese Church	CC	33	0	0	0	0.00	0.0000	0.00
Historical Bike Path	HB	131	0	16	16	0.12	0.0000	0.12
Concordia Historical	CH	137	0	7	7	0.05	0.0000	0.05
Historical Marsh Trail	MT	176	0	160	160	0.91	0.0000	0.91
Anteater Trail	AT	195	0	140	140	0.72	0.0000	0.72
Coyote Trail	CT	27	0	13	13	0.48	0.0000	0.48
Camera 1V1	C1	1150	0	44	44	0.04	0.0000	0.04
Camera 1V2	C1V2	361	0	2	2	0.01	0.0000	0.01
Camera 2	C2	1861	1	30	31	0.02	0.0005	0.02
Camera 3	C3	1588	0	114	114	0.07	0.0000	0.07
Camera 4	C4	1315	0	12	12	0.01	0.0000	0.01
Camera 5V1	C5	1187	4	117	201	0.10	0.0034	0.10
Camera 5V2	C5V2	764	0	3	3	0.00	0.0000	0.00
Camera 6V1	C6	555	0	13	13	0.02	0.0000	0.02
Camera 6V2	C6V2	542	0	8	8	0.01	0.0000	0.01
Camera 8	C8	123	0	14	14	0.11	0.0000	0.11
Lyren's SDC Bike Path	H1	282	21	43	64	0.15	0.0745	0.23
Lyren's Concordia	H2	398	2	18	20	0.05	0.0050	0.05
Lyren's Marshtrail	H3	442	65	101	166	0.23	0.1471	0.38

Table 6 Seasonal variation of total carnivore RAI at RP Location

Seasons	Coyote RAI	Bobcat RAI	Total Carnivore RAI	Total Carnivore Occurances	Active Camera Days	Start Date	EndDate
Summer	0.07	0	0.07	2	29	07/01/2019	07/30/2020
Fall	0.48	0	0.48	14	29	11/01/2019	11/30/2019
Winter	0.76	0	0.76	22	29	01/01/2020	01/30/2020
Spring	0.52	0	0.52	15	29	04/01/2020	04/30/2020

Table 7 Seasonal variation of bobcat, coyote, and total carnivore RAI values across all IRWD camera locations.

Start Date	End Date	Active Camera Days	Season	Total Carnivore Occurances	Coyote RAI	Bobcat RAI
12/1/2015	2/28/2016	89	Winter	32	0.36	0
12/1/2016	2/28/2017	89	Winter	14	0.16	0
12/1/2017	2/28/2018	89	Winter	16	0.18	0
3/1/2016	5/29/2016	89	Spring	10	0.11	0
3/1/2017	5/29/2017	89	Spring	8	0.09	0
3/1/2018	5/29/2018	89	Spring	20	0.25	0
6/1/2015	8/29/2015	89	Summer	44	0.49	0
6/1/2016	8/29/2016	89	Summer	48	0.54	0
6/1/2017	8/29/2017	89	Summer	38	0.43	0
6/1/2018	8/29/2018	89	Summer	17	0.19	0
9/1/2015	11/29/2015	89	Falll	5	0.06	0
9/1/2016	11/29/2016	89	Falll	15	0.17	0
9/1/2017	11/29/2017	89	Falll	14	0.16	0
9/2/2018	11/29/2018	89	Falll	1	0.01	0
9/3/2019	11/29/2019	89	Falll	11	0.12	0

Table 8 Average carnivore RAI and standard deviation (SD) across all IRWD camera locations among seasons.

Season	Average Carnivore RAI	Standard Deviation (SD)
Winter	0.23	0.11
Spring	0.15	0.09
Summer	0.39	0.18
Fall	0.11	0.09

Table 9 Comparison of bobcat, coyote, and total carnivore detection and RAI values between current (HB, CH, and MT) and Historical camera locations (H1, H2, and H3).

Location	Location Code	Active Camera Days	Coyote Detection	Bobcat Detection	Total Carnivore Detection	RAI CALA	RAI LYRU	RAI Total Carnivore	Camera Start and End Dates
Current Bike Path	HB	64	7	0	7	0.11	0.00	0.11	11/12/2019 and 01/15/2020
Current Concordia	CH	134	7	0	7	0.22	0.00	0.22	12/16/2019 and 03/11/2020, 03/24/2020 and 04/05/2020, 04/22/2020 and 05/28/2020
Current Marshtrail	MT	174	160	0	160	1.86	0.00	1.86	10/08/2019 and 12/10/2019, 01/10/2020 and 04/30/2020
Historical Bike Path	H1	64	3	8	11	0.05	0.13	0.17	11/12/2007 and 01/15/2008
Historical Concordia	H2	134	7	2	9	0.26	0.09	0.35	12/16/2006 and 03/12/2007, 03/24/2007 and 04/05/2007, 04/22/2007 and 05/28/2007
Historical Marshtrail	H3	174	12	30	42	0.19	0.31	0.50	10/08/2006 and 12/10/2006, 01/10/2007 and 05/01/2007

Table 10 Openness Index (OI) and Relative Abundance Index (RAI) values at UCI Undercrossing structures.

Location Code	Crossing Category	Type of Crossing	OI	RAI
CH	Culvert	Double Elliptical	0.53	0.05
CB	Culvert	Double Box	0.29	0.12
RP	Culvert	Circular	0.03	0.48
CC	Culvert	Double box	0.08	0
EP	Culvert	Circular	0.04	0
MB	Bridge	Undercrossing	3.89	0.28
BC	Bridge	Trapezoid undercrossing	2.62	0.01

Table 11 Bobcat sightings data and time across the IRWD Camera Locations

Location Code	Date	Time	Number of Individual
C2	4/25/2015	19:15:56	1
C5	1/30/2015	13:34:08	1
C5	4/26/2015	3:31:34	1
C5	5/18/2015	0:49:52	1
C5	5/27/2015	18:47:44	1

Table 12 Recommendations for improvement of undercrossing locations for the UCI Wildlife Monitoring Survey

Location Code	Crossing Type	Current Problems	Recommendations
CH	Culvert	1. Standing water at the culvert > 6 months 2. Increased mesopredator population 3. Improper fencing settlement (not funneling the animals into the assigned riparian corridor)	1. The damaged floor of the culverts needs to be fixed to prevent standing water accumulation in the middle section of the culvert. 2. After a flooding event, the culvert should be cleaned from debris and branches to encourage animal underpass use to a greater extent. 3. Further camera monitoring studies are necessary to document where the connectivity is broken.
CB	Culvert	1. Constant road widening construction 2. Runoff from the surrounding areas 3. Inefficient fencing settlement 4. Human intrusion 5. Riprap presence 6. High animal exposure	1. Proper fencing is required to funnel the animals into this chokepoint 2. Riprap needs to be covered by soil as some animals do not like to walk on them 3. Native shrubby plants should be planted downstream to provide somewhat better vegetation coverage for wildlife.
RP	Culvert	1. A long and dark culvert	1. Increase ambient light in the culvert to encourage wildlife movement.
CC	Culvert	1. Standing water in the culvert during the four seasons 2. Riprap presence 3. No light at the end of the culvert 4. Diversional culvert	1. Controlled runoff release 2. Increasing the ambient light in the culvert
EP	Culvert	1. Fencing at the opening of the culvert 2. Human intrusion	1. Removal of the fencing at the opening of the culvert 2. Discouraging human intrusion
MB	Bridge	1. Human intrusion	1. Discouraging human intrusion
BC	Bridge	1. Human intrusion	1. Discouraging human intrusion 2. Further camera monitoring studies are necessary to understand the animal movement

APPENDIX A

Habitat Assessments

1. *Crossing Structure Assessment*

I assessed the physical characteristics of crossing structures to document possible crossing structures and the relative abundance of carnivore density at the local level. I measured the dimensions of crossing structures (height, width, length) using a meterstick. I used these values to calculate an openness index (height X width/length). I also collected data on crossing structure category (e.g. bridge, culverts, trail), shape (e.g. elliptical, box, or circular), floor type (e.g. dirt, concrete), and the distance from the road (Table A-1 and A-2). I also recorded fencing features (e.g. presence/absence, continuous/noncontinuous, and its height and type), buffer area (whether it is considered as a part of connectivity or part of known linkage), human activity (day and night), traffic volume, canopy cover and landscape/topology (drainage canal, marsh) using methods from Sollmann 2013; Haas 2000; Clevenger 2002; and Vickers et al. 2015) (Table A-2).

Finally, I used ArcGIS to measure 200-m radius buffers around the UCI camera locations (ArcGIS 10.7.1, ESRI, Redlands, California) to visually identify land-use types within the immediate vicinity of cameras (Figures C-1, C-2, and C-3).

2. *Vegetation Ground Cover Assessment*

I established 16 x 25 m^2 plots on each side of each crossing structure and conducted visual estimates of ground cover as percentages (Tables A-4 and A-5). I noted the percentage cover of trees, shrubs, grass, dirt, cement/asphalt, rocks, water, and litter. All these variables are totaled to 100%. If the crossing structure was a culvert or bridge, I assessed both ends of the structures. For trails, I assessed the left and right sides of the camera. The longer side of the plot (25m) is aligned with the “possible wildlife movement direction” (considered as crossing structure in trail locations) while the shorter side is centered based on the camera post. Tables A-1 and A-2 contain information of characteristics that might be important, but I did not evaluate their variation or make a study inference due to the nature of my UCI wildlife monitoring project. The Irvine Ranch Water District (IRWD) camera locations are also evaluated in the same manner to create another descriptive summary table (Table A-3).

Table A-1 *UCI Camera Survey Undercrossing Assessment*

Location	Crossing Category	Type of Crossing	Visible Light	H (m)	W (m)	L (m)	OI	Distance below road (m)	Floor Structure Type	Slope (Degree)	Water Presence
Concordia (Historical)	Culvert	Double Elliptical	High	2	6	23	0.53	0.6	Soil	2	Seasonal
Culver Culvert	Culvert	Double Box	High	3	4	41	0.29	0.3	Concrete floor but dirt on top	5	Seasonal
Research Park	Culvert	Circular	Low	1.5	1.5	72	0.03	12	Concrete	5	Seasonal
Chinese Church	Culvert	Double box	No	3	4	160	0.08	1	Concrete floor but dirt on top	2	Permanent
UCI Ecopreserve	Culvert	Circular	Medium	1.6	1.6	64	0.04	2	Concrete	5	None
MacArthur Bridge	Bridge	Undercrossing	High	7	20.5	37	3.89	2	Concrete	3	None
Bonita Canyon	Bridge	Trapezoid undercrossing	High	4.5	20.4	35	2.62	2	Soil and water	1	Permanent
Anteater	Trail	Unofficial dirt trail	High	NA	NA	NA	NA	2	Soil	15	None
Coyote Trail	Trail	Official concrete paved trail	High	NA	NA	NA	NA	1.5	Concrete floor but dirt on top	10	None
Marsh Trail	Trail	Official dirt trail	High	NA	NA	NA	NA	NA	Herbaceous	1	None
Historical Bike Path	Trail	Unofficial dirt trail	High	NA	NA	NA	NA	NA	Soil	1	None

Table A-2 *UCI Camera Survey Undercrossing Assessment Section 2*

Location	Fencing Presence (within 50m radius)	Fencing Type	Fencing Height (m)	Locations Connected	Part of the Linkages	Canopy Cover (Invisibility for Animals)	Landscape (Topology)	Dominant Vegetation	Night Time Human Activity (at he Crossing)	Human Traffic Around the Crossing (Within 50m radius)	Total Number of Road Lines	Road Traffic Level
Concordia (Historical)	Only on top of the culvert	Chain link	1.83	Quail Hill/Strawberry Farm/ Golf Area	University Drive Linkage	Good	Drainage	Riparian	Low	High	4	High
Culver Culvert	Only on top of the culvert	Chain link	1.83	Quail Hill/Sand Canyon Wash/ Mason Park and San Diego Creek	University Drive Linkage	None	Drainage	None	Low	Medium	8	High
Research Park	Continuous on both side	Chain link	1.83	Upper Newport Bay/Bommer Canyon/Laguna Coast Wilderness	Bonita Canyon Linkage	Good	Drainage	Riparian	Low	None	8	High
Chinese Church	Only on top of the culvert	Chain link	1.83	Mason Park/Golf Course and San Diego Creek Channel	University Drive Linkage	Good	Drainage	Riparian	Low	High	8	High
UCI Ecopreserve	Continuous on both side	Chain link	1.83	Upper Newport Bay/Bommer Canyon/Laguna Coast Wilderness	Bonita Canyon Linkage	Good	Depression	CSS	None	Low	8	High
MacArthur Bridge	None	NA	2	San Diego Creek/San Joaquin Marsh/Upper Newport Bay	University Drive Linkage	Low	Creek Channel	Riparian	High	High	1	High
Bonita Canyon Bridge	25m long fencing one side only	Chain link	3	Upper Newport Bay/Bommer Canyon/Laguna Coast Wilderness	Bonita Canyon Linkage	Good	Drainage	Riparian	Low	High	4	High
Anteater	None	NA	NA	NA	None	Good	Low land Terrestial	Invasive Mustard	High	High	2	High
Coyote Trail	Continuous on both side	Guard rail	0.6	Upper Sand Canyon/Mason Park	University Drive Linkage	Medium	Bowl Shape Depression	Riparian	High	High	4	High
Marsh Trail	None	NA	NA	Upper Newport Bay/IRWD Marsh/UCI Marsh/Quail Hill	University Drive Linkage	Good	Marsh	Upland Species	Low	Low	1	NA
Historical Bike Path	None	NA	NA	Upper Newport Bay/SDC Creek/Quail Hill	University Drive Linkage	Good	Terrestial Inland	Riparian	Medium	High	1	NA

Table A-3 *IRWD Crossing Structure Assessment*

Camera Location Name	Location Code	Crossing Structure Type	Camera Brand	Human Activity	Main Vegetation Coverage	Nearby Fencing	Nearby Water Presence
Camera 1V1	C1	Trail	Browning	High	Mulefat Trees	No	Yes
Camera 1V2	C1V2	By Creek (Riprap Bridge)	Browning	High	Mulefat Trees	No	Yes
Camera 2	C2	Trail	Browning	Low	Asteraceae Family	No	Yes
Camera 3	C3	Trail	Browning	Low	Short Mulefat Trees	No	No
Camera 4	C4	By Creek	Browning	Medium	Mulefat Trees and Reeds	No	Yes
Camera 5V1	C5	Trail (Fenced)	Browning	Low	Mulefat Trees and Backberry (Nearby Restoration Project)	Yes (Barb wire)	No
Camera 5V2	C5V2	Trail	Browning	Low	Unidentified Tall Trees	No	No
Camera 6V1	C6	Trail	Browning	Low	Tall Mulefat Trees and Dense Small understory Trees	No	Yes
Camera 6V2	C6V2	Bridge (on top a creek)	Browning	Low	Mulefat Trees along the Bank	Yes (Bridge only)	Yes
Camera 8	C8	Trail (near a channel)	Bushnell	Medium	Mostly Frankenia, Pickleweed and Mulefat trees	No	Yes

Table A-4 UCI Visual Bird's Eye Ground Cover Assessment

Location	% tree		%shrub		% grass	% dirt	% cement /asphalt	% rocks	% water	% litter
	>3 m	***<3m***	***>3m***	***<3m***						
Marsh Trail (South)	9	1	3	20	36	1	0	0	5	25
Marsh Trail (North)	1	1	0	10	57	1	0	0	10	20
Chinese Church (SDC Side)	8	2	10	30	24	1	0	15	8	2
Chinese Church (Mason Park Side)	14	1	5	15	20	8	7	0	20	10
Culver Culvert (Downstream)	5	1	4	1	20	1	3	55	5	5
Culver Culvert (Upstream)	25	5	10	10	10	25	0	10	0	5
Concordia (Strawberry Farm Side)	25	1	0	5	15	5	0	0	1	48
Concordia (University Side)	25	10	0	5	15	20	0	0	1	24
Coyote Trail (Toward University Drive)	1	0	0	19	5	20	50	0	0	5
Coyote Trail (Inner Mason Park Side)	5	0	0	20	35	10	25	0	0	5
Anteater (toward the road)	0	0	0	2	78	10	0	0	0	10
Anteater (toward ARC/Nursery)	0	0	0	2	68	15	5	0	0	10
MacArthur (Upstream)	0	0	5	20	3	55	1	15	0	1
MacArthur (Downstream)	2	0	10	60	7	10	1	5	0	5
Bonita Canyon (Upstream)	50	0	10	5	5	5	0	0	10	15
Bonita Canyon Downstream)	44	0	10	5	10	10	0	1	10	10
Historical Bike Path (Upstream)	5	0	0	25	45	9	0	0	1	15
Historical Bike Path (Downstream)	0	0	0	1	35	59	0	0	0	5
SDC Bank Trail (Upstream)	10	4	5	15	0	25	0	1	30	10
SDC Bank Trail (Downstream)	5	0	5	25	0	25	0	0	30	10
UCI Ecopreserve (UCI side)	0	0	17	55	22	1	0	0	0	5
UCI Ecopreserve (Other side)	0	0	20	30	25	18	2	0	0	5
Research Park (UCI Side)	45	5	1	25	10	7	1	1	0	5
Research Park (Other side)	20	0	10	0	35	6	0.5	0.5	20	8

Table A-5 *IRWD Visual Bird's Eye Ground Cover Assessment*

Location	% tree		%shrub		% grass	% dirt	% cement/ asphalt	% rocks	% water	% litter
	>3 m	***<3m***	***>3m***	***<3m***						
Cam8 Front	10	4	0	0	80	3	0	0	0	3
Cam8 Back	75	0	0	0	10	0	0	0	11	4
Cam2 Front	70	10	0	0	0	4	0	1	0	15
Cam2 Back	85	0	0	0	11	0	0	0	0	4
Cam1V1 Left	30	14	0	0	1	50	1	1	0	3
Cam1V1 Right	8	85	0	0	0	1	1	0	3	2
Cam1V2 Left	30	47	0	0	5	10	2	3	1	2
Cam1V2 Right	5	92	0	0	0	0	0	2	1	0
Cam5V1 Front	70	8	0	0	2	10	0	0	0	10
Cam5V1 Back	2	2	0	10	0	86	0	0	0	0
Cam5V2 Left	63	10	0	0	2	5	0	0	0	20
Cam5V2 Right	50	1	0	0	0	0	0	0	0	49
Cam4 Front	60	10	0	0	4	10	0	0	10	5
Cam4 Back	80	0	0	0	20	0	0	0	0	0
Cam3 Left	60	10	0	0	10	15	0	0	0	5
Cam3 Right	27	40	0	0	5	20	0	0	0	8
Cam6V1 Front	40	30	0	0	1	5	0	1	0	23
Cam6V1 Back	30	20	0	10	0	0	0	0	0	40
Cam6V2 Front	10	0	0	0	3	5	0	0	80	2
Cam6V2 Back	10	40	0	0	4	5	0	0	80	1

APPENDIX B

1. *Understanding the Association between the Land Use Composition and Roadkill Dynamics in Coastal Southern California*

1.1. Problem Statement

The landscape of Irvine as a master-planned community has dramatically changed in the last 50 years. It has become highly urbanized and created a heavily fragmented habitat across the study area *(Figure 1)*. Large carnivores are forced to cross dangerous roads (with high traffic volume) to survive. This kind of survival behavior creates wildlife-vehicle collision *hotspots*. Understanding where these *hotspots* are and if the land-use classes (e.g. vegetation, pavement, open space, and urban) around these hotspots are playing significant roles in the increasing frequency of animal mortality is necessary for decision-makers to make more effective mitigation plans in the future.

1.2. Specific Research Questions:

a. Where are the roadkill *hotspots*?
b. Is there a statistically significant difference between the total area of 4 distinctive types of land use classes (i.e. Vegetation, Pavement, Open Space, and Urban) within 100m ^{2} buffer zone at the low, medium, and high rate roadkill location?

1.3. Study Focus

The focus of the study is illustrated in Figure 1.

1.4. Data Sources

1.4.1 NCCP Dataset (Established Linkages and Core Habitats)

The NCCP dataset is also available at the following link: http://gisdata-scag.opendata.arcgis.com/datasets/55cde679aeb6479491913f6ffb02716c_0/data

1.4.2. Roadkill Dataset (Coyotes and Bobcats Only)

I obtained the data from Local Animal Services (Irvine). The data was in shapefiles format. The range of the data is starting from 2005 to 2019 and specific to my geographic focus only *(Figures 10 and C-8).* The permission is granted after the application of the *Public Record Act Request* to their website (https://www.irvinequickrecords.com/).

1.4.3. Raster Data for Habitat Classification

I downloaded the ortho from the following link as raster:
http://gisarchive.cnra.ca.gov/iso/ImageryBaseMapsLandCover/NAIP/naip2016/NAIP_2016_County_Mosaics/Data/Orange/

1.5. Methods

1.5.1. NCCP Dataset

The NCCP dataset helped me to illustrate the locations of core habitats and linkages, which eventually let me determine my geographic focus and the associated roads within and around these two main linkages (Figures 1). The data is used to highlight the current situation or animal mortality in the area by simply changing the *Symbology features.*

1.5.2. Roadkill Data

To reveal which roadkill point has more than 1 roadkill strike per location throughout the years (2005-2019), first, I calculated the number of strikes per location *(Attribute Table > Add Field > manual entry of unique numbers to find the number of strikes per location)*. Once I got it, I use *(Properties > Symbology > Quantities > Graduate Colors (based on the Count of Strikes)*. Lastly, I changed the color and the size of the graduated colors to make it more appealing for my purposes (Figure 10).

I created 2 different point shapefiles *(Select by Attribute > "Animal" = Bobcat and "Animal" = Coyote"*) for bobcat and coyotes *(Data > Export Data (as shapefile)).* I changed the symbology to distinguish them from each other *(Appendix B, Figure C-4).* The overlay revealed that there are 26 different locations in the study area where road mortality occurred during the last 12 years. This allowed me to distinguish the dispersal behaviors of the species. For example, the proximity to the residential areas does not affect coyote's dispersal range whereas bobcats require vegetation cover for the dispersal.

I created $100m^2$ buffers around the point roadkill data *(Geoprocessing > Buffer > 100m).* Later, I also used these buffers to extract the raster data by mask for land use classification purposes.

1.5.3. Land Use Classification

First, I clipped the raster to my study area to reduce the size and the time to process it *(Search > Data Management Tool (to clip raster)).* $100m^2$ buffer zones across the roadkill points are created. For this purpose, I used the "Extract by Mask" tool to extract only the $100m^2$ buffer zones around each roadkill point. I got a mosaic raster outcome at the end of this step The Iso Cluster Unsupervised Classification Tool (with 15 different classes option), which performs unsupervised classification on a series of input raster bands using the Iso Cluster and Maximum Likelihood Classification tools, gave me the most "accurate" result. After that, I manually compared the outcome of 15 classes raster data to the real-time base map to combine them into 4 different meaningful classes: Vegetation (Irrigated grass and Shrubs/ Tress), Pavement (Roads and Parking Lots), Open Spaces (Bare grounds), and Urban (Residential and Industrial Areas). It is combined into these four classes because these classes are the best major representatives of current land composition in the study area.

Lastly, I converted the raster into a vector (Search > Raster to Polygon Conversion Tool). The vector also has the same four land use classes, which also allowed me to calculate the total area of each class for each location. Since I had 26 different locations, I decided to pick 3 different locations that have different mortality frequency to make comparison analyses: Low mortality locations have only 1-2 strikes, medium mortality locations have between 3-5 strikes, and high mortality locations have 6 or more strikes per location. I examined all 26 points of roadkill data and compared it to the color gradient roadkill per location data (Figure 10) to pick the best representative samples from each category. Based on the land use classification accuracy and the rate of mortality results, I picked one sample from each group. I defined these places by creating circle polyline shapefiles at those locations. Then, I used the attribute table of the vector to select each class one by one and extract a *dBASE Table* for vegetation, pavement, open space, and urban classes for each location. After that I used these tables to calculate the sum of the area of each class by again extracting them as *dBASE Table (Attribute Table > Highlight Area Field > Right Click > Summarize (dBASE Table Outcome)).*

After this point, I used Excel to create a table *(Appendix B, Figure B-8).* to organize my data for Chi-square analyses via RStudio.

1.5.4. Statistical Analysis

Research Question: Is there a statistically meaningful difference between the total percentages of four classes in the low, medium, and high mortality locations?

Hypothesis: There is a difference between the location in terms of the distribution of the 4 different types of land use classes.

Method: I used RStudio to perform a Chi-square test to determine if there is a meaningful difference among the groups.

1.6. Results

1.6.1. Roadkill Spatial Analyses Results

Figure 10 shows all 26 different locations where the WVC happened in the study area. *Table 2* summarizes the number of strikes at those locations in detail. 5 locations have more than 6 strikes at the same location over the 12 years' time periods. These places can be considered as roadkill "hotspots". These locations are not providing safe animal passages for large carnivores. There could be many reasons that yield increased road mortality at this location.

1.6.2 *Land Use Classification Spatial and Statistical Analyses Results*

While figures C-5, C-6 and C-7 demonstrate the results of landscape composition classification compared to their real-time base map overlays, Figure C-8(Appendix B) shows the graph of total areas of surrounding habitat composition in four pre-determined classes at low, medium, high mortality rate locations in a color-coded manner.

The difference between the total percentages of each class at these particular groups is tested by Chi-square analyses and there seems to be no statistically significant difference among them ($X^2 = 5.4532$, $df = 6$, $p\text{-value} = 0.4871$ $[p<0.05]$). However, I cannot reject my hypothesis at this point because my sample size is very small (n=1 from each group).

1.7. Conclusion

To make a better conclusion, I need to calculate all these 26 points and compare them based on their mortality level (i.e. low, medium, high). Including major freeways in the area (405, 73, and 5) would also be another way of increasing the sample size and therefore the plausibility of the results. However, it is obvious from my study that the linkages are not providing safe passages for bobcats and coyotes. Enhancement at these linkages is necessary to reduce the roadkill in general. My study cannot pinpoint the exact reason(s) at this point, but it clearly shows that there is an urgent need for enhancement at these locations. Additional variables such as traffic volume, noise levels, the physical features of crossing structures, fencing presence along the roads should be tested to understand underlying reasons for high mortality at these particular locations. Feedback giving studies (like mine) can help policymakers to act more efficiently, especially at local level mitigation plans. Usually, large-scale mitigation plans are missing the small nuances of study area-dependent factors, which is the leading reason for local extinctions. An adaptive conservation planning strategy should be adopted by the policymakers for the increase in the efficiency of these plans.

Although this research area is relatively new, many young scientists across the world also showed a great passion for this subject. Further research is necessary to make healthy mitigation decisions in future projects.

Figure B-1 Map of 200 m radius remote sensing buffer zone at CH, MB, CT, and HB locations

Figure B-2 Map of 200 m radius remote sensing buffer zone at MT, RP, EP, and BC locations

Figure B-3 Map of 200 m radius remote sensing buffer zone at AT, CC, and CB locations

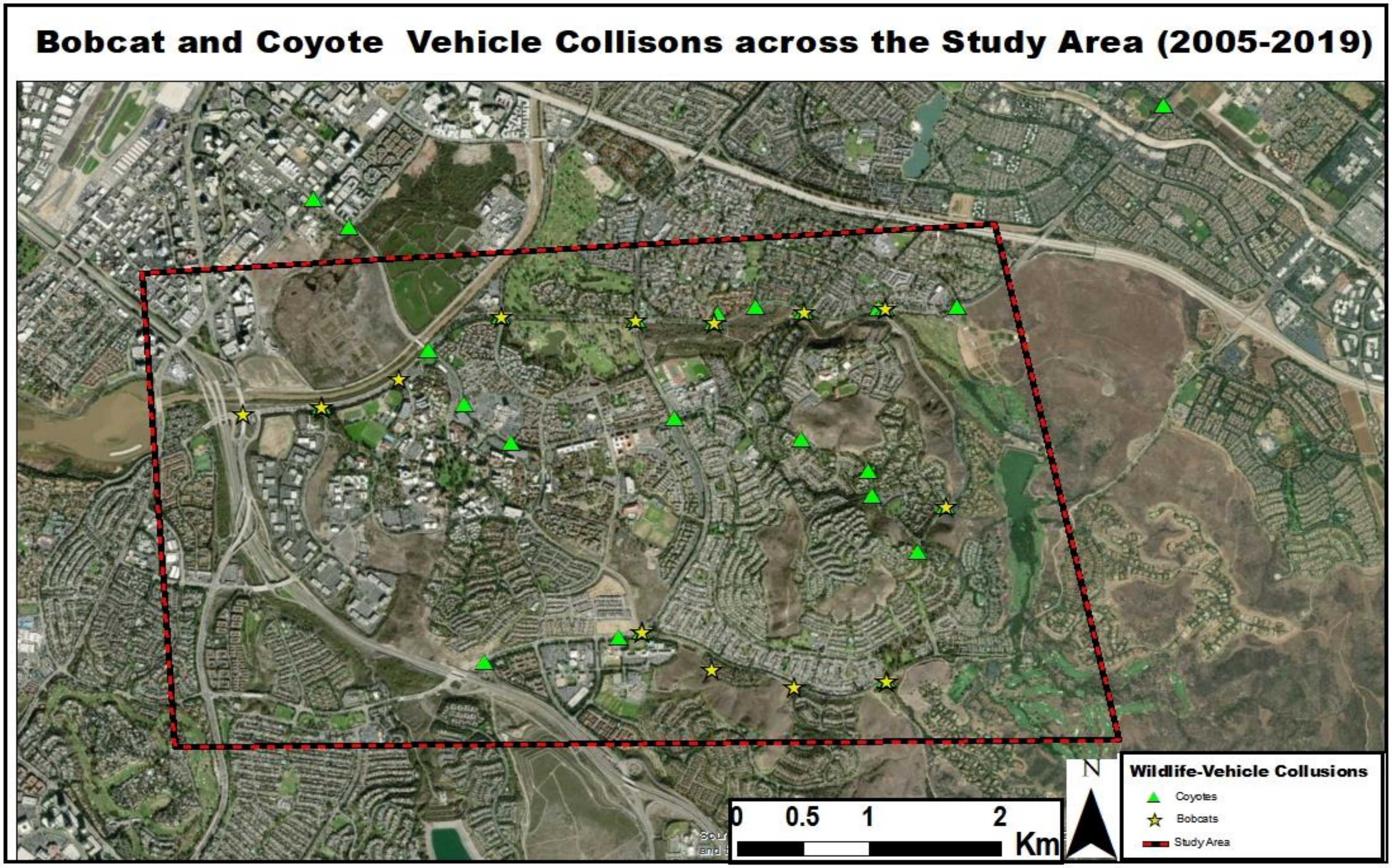

Figure B-4 Map of bobcat and coyote strikes per location across the study area (2005-2019)

Figure B-5 Map of an ISO Cluster Unsupervised Classification results in a low mortality location

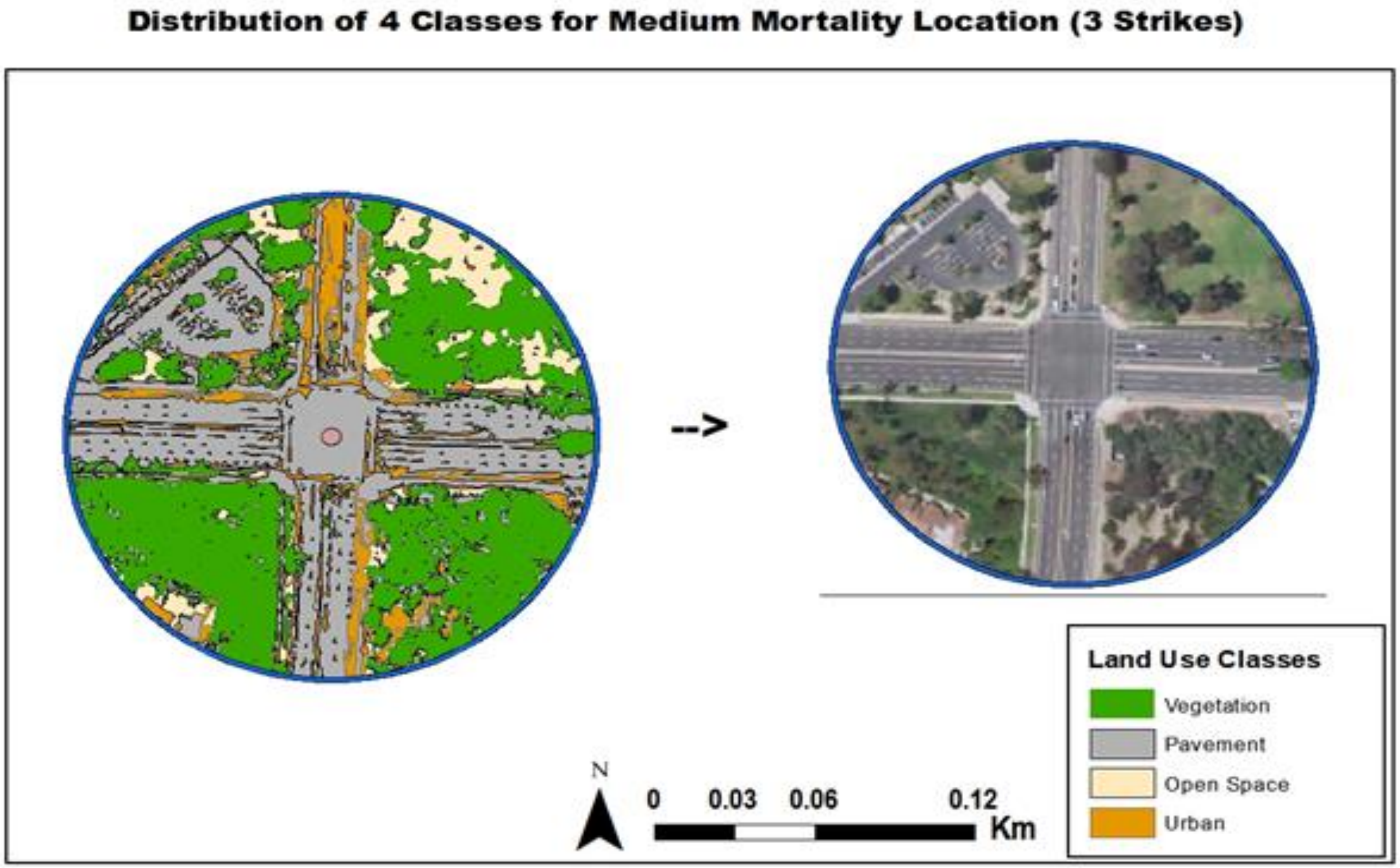

Figure B-6 Map of an ISO Cluster Unsupervised Classification results in a medium mortality location

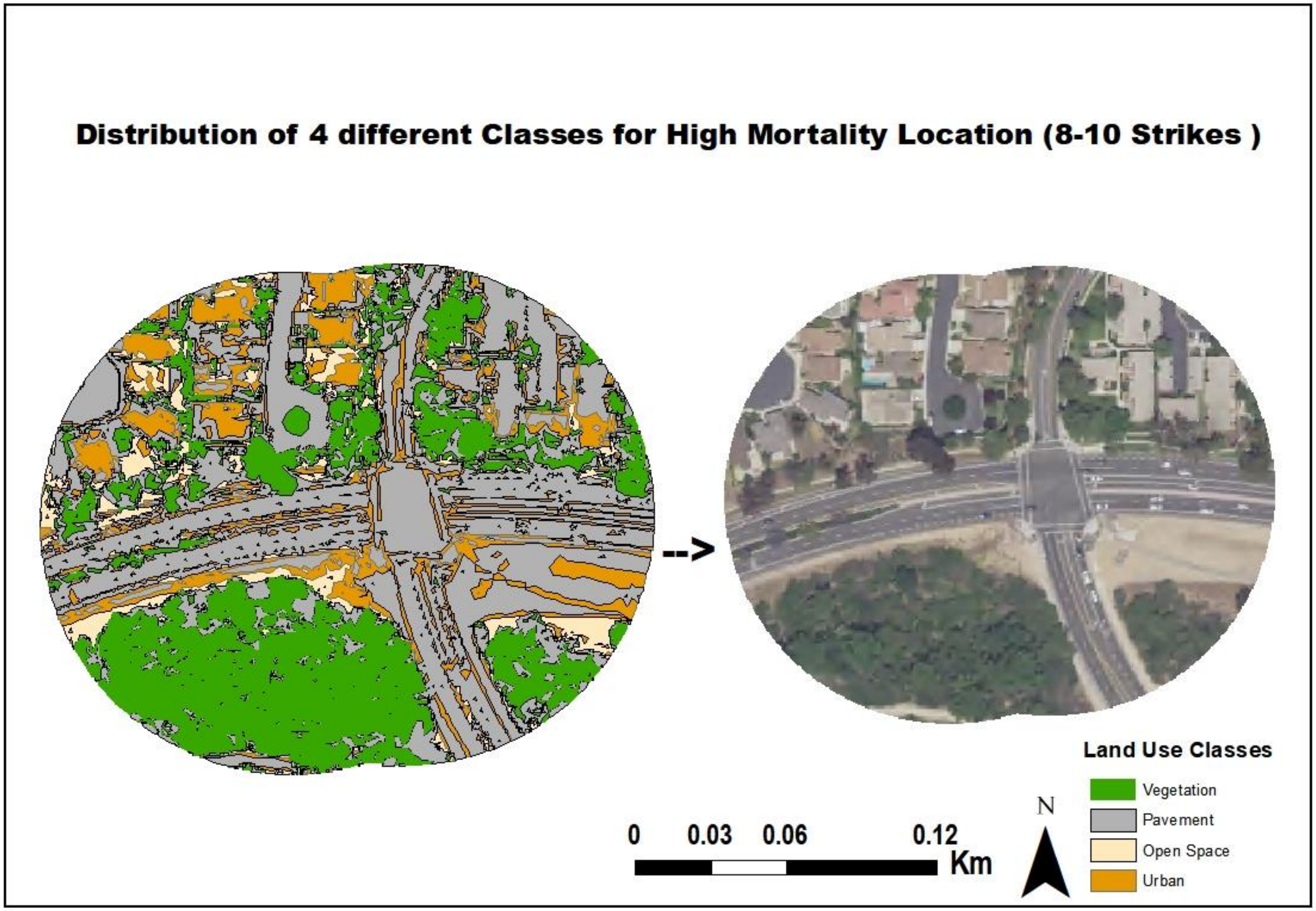

Figure B-7 Map of an ISO Cluster Unsupervised Classification results in a high mortality location

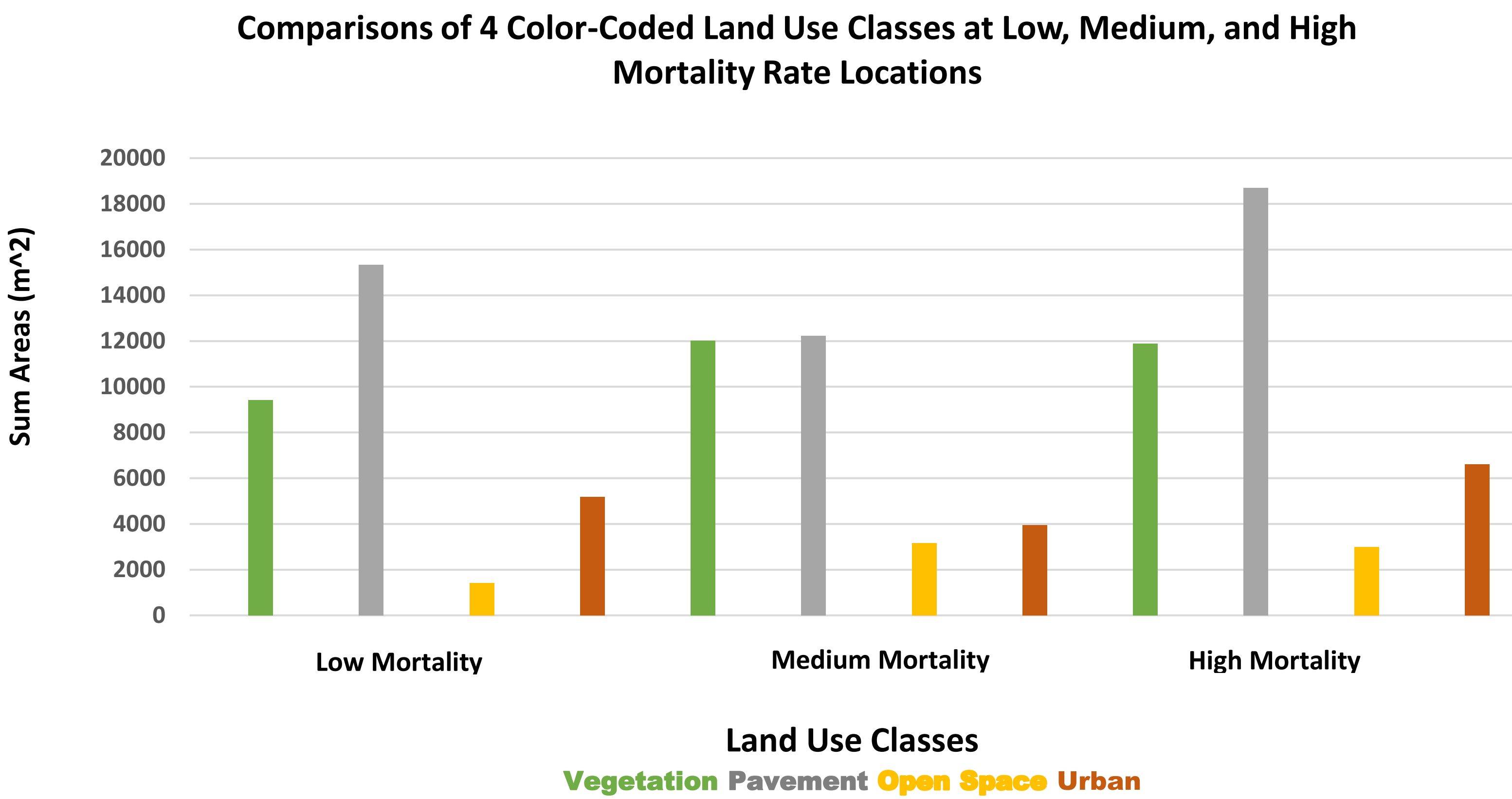

Figure B-8 Comparison of four classes of land use at low, medium, high mortality rate locations in a color-coded concept *($p > 0.05$)*

Table B-1 The GPS coordinates of bobcat and coyote strikes (2005-2019)

Number	Date	Animal	X Coordinate	Y Coordinate
1	2/25/2005	Coyote	6073571	2189743.75
2	5/6/2005	Coyote	6073739	2184174.25
3	9/2/2005	Bobcat	6075659.5	2184932
4	10/9/2005	Coyote	6085667	2183217
5	10/11/2005	Bobcat	6089239.5	2181373.25
6	11/15/2005	Bobcat	6087761.97	2186728.28
7	1/9/2006	Coyote	6084553.89	2186776.98
8	1/22/2006	Coyote	6083518.98	2186383.39
9	1/30/2006	Bobcat	6087724.95	2176711.94
10	1/30/2006	Bobcat	6087724.95	2176711.94
11	3/5/2006	Bobcat	6087761.97	2186728.28
12	3/8/2006	Coyote	6089586.04	2186742.94
13	3/8/2006	Coyote	6089586.04	2186742.94
14	7/6/2006	Bobcat	6073738.94	2184174.19
15	8/5/2006	Coyote	6081087.89	2177897.92
16	12/8/2006	Bobcat	6073738.94	2184174.19
17	3/21/2007	Coyote	6087437.46	2181693.4
18	5/7/2007	Coyote	6078221.96	2186585.9
19	5/19/2007	Coyote	6076394.41	2185660.33
20	6/5/2007	Coyote	6082513.4	2183783.34
21	8/14/2007	Coyote	6078436.89	2183157.42
22	8/28/2007	Coyote	6089586.04	2186742.94
23	9/30/2007	Coyote	6087324.9	2182341.43
24	10/20/2007	Bobcat	6083518.98	2186383.39
25	3/26/2008	Bobcat	6078221.96	2186585.9
26	6/3/2008	Coyote	6083609.88	2186593.82
27	10/13/2008	Bobcat	6078221.96	2186585.9
28	11/12/2008	Coyote	6081646.46	2178065.89
29	12/20/2008	Coyote	6081568.94	2186443.28
30	12/21/2008	Coyote	6087761.97	2186728.28
31	12/21/2008	Coyote	6087761.97	2186728.28
32	12/22/2008	Coyote	6087761.97	2186728.28
33	1/27/2009	Coyote	6089239.41	2181373.36
34	6/20/2009	Coyote	6077733.46	2177280.95
35	9/30/2009	Coyote	6087761.97	2186728.28
36	11/26/2009	Coyote	6087615.96	2186717.97
37	12/9/2009	Bobcat	6073738.95	2184174.19
38	1/11/2010	Coyote	6081646.46	2178065.89
39	10/9/2010	Coyote	6081568.94	2186443.28
40	10/21/2010	Bobcat	6081568.94	2186443.28
41	11/25/2010	Bobcat	6087761.97	2186728.28
42	12/12/2010	Coyote	6087761.97	2186728.28
43	3/13/2011	Bobcat	6081646.46	2178065.89
44	7/10/2011	Coyote	6087761.97	2186728.28
45	8/8/2011	Bobcat	6083518.98	2186383.39
46	9/23/2011	Bobcat	6085428.03	2176571.8
47	3/14/2012	Bobcat	6073738.95	2184174.19

48	3/24/2012	Coyote	6074453.56	2188985.44
49	4/12/2012	Coyote	6081646.46	2178065.89
50	4/15/2012	Coyote	6073570.98	2189743.79
51	5/3/2012	Coyote	6085736.88	2186636.82
52	5/24/2012	Coyote	6087437.46	2181693.4
53	7/18/2012	Coyote	6088542.93	2180155.08
54	8/30/2012	Coyote	6083518.98	2186383.39
55	8/30/2012	Coyote	6087761.97	2186728.28
56	9/27/2012	Coyote	6073738.95	2184174.19
57	10/6/2012	Bobcat	6081646.46	2178065.89
58	11/10/2012	Coyote	6081646.46	2178065.89
59	11/25/2012	Coyote	6076394.41	2185660.33
60	11/30/2012	Coyote	6084553.89	2186776.98
61	3/15/2013	Coyote	6087724.95	2176711.94
62	4/11/2013	Bobcat	6087724.95	2176711.94
63	7/20/2013	Bobcat	6081646.46	2178065.89
64	7/30/2013	Coyote	6081568.94	2186443.28
65	9/23/2013	Bobcat	6071787.41	2183987.58
66	12/8/2013	Coyote	6085740.11	2186634.6
67	11/15/2014	Bobcat	6083377.75	2177036.81
68	8/6/2015	Coyote	6081581.1	2186447.65
69	8/21/2015	Coyote	6081581.1	2186447.65
70	11/24/2015	Coyote	6073751.09	2184178.56
71	12/21/2015	Bobcat	6085752.29	2186638.98
72	6/20/2016	Coyote	6077281.7	2184224.28
73	8/4/2017	Coyote	6085679.23	2183221.42
74	9/12/2017	Coyote	6082525.56	2183787.7
75	9/15/2017	Coyote	6085752.29	2186638.98
76	10/8/2017	Coyote	6081581.1	2186447.65
77	2/14/2018	Coyote	6076406.57	2185664.7
78	10/11/2018	Coyote	6081581.1	2186447.65
79	11/8/2018	Coyote	6087737.12	2176716.29
80	12/18/2018	Coyote	6089251.59	2181377.72
81	8/31/2019	Coyote	6074465.71	2188989.82