A Tale of Two Habitats: Habitat Restoration and Its Impact on Biodiversity, Wildlife Use, and Human Presence in the Presidio, San Francisco

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ABSTRACT

Growing urbanization is drastically changing urban environments and impacting urban wildlife. Habitat restoration is being used with a greater frequency. Urban green spaces are vital to urban ecosystems but are often overlooked in restoration efforts. This study looked at the effects of habitat restoration on when wildlife use urban green spaces, when humans are present in urban green spaces, and biodiversity. I found that wildlife frequented the partially and fully restored sites much more than the unrestored site. On the other hand, human presence was greater at the unrestored site than the restored sites. The only non-human mammals detected across the sites were rodents, coyotes, and raccoon. There was not a significant difference in which mammals visited which sites, except that the partial restoration was the only site with rodents detected. The unrestored site had an overlap between human and wildlife visitation that was not observed in the restored sites. Species richness and the Shannon's index were highest in the partially restored site, but the unrestored site had the greatest Simpson's index. These observations indicate that human presence and restoration status both have influence wildlife and human presence alike. In my study I found that there was a significant difference between wildlife presence in urban green spaces across the site types. However, I found that there was no significant difference between human presence in urban green spaces across the site types. All in all, these findings indicate that habitat restoration influences wildlife but not humans, further research needs to be done to understand why human presence is not influenced by restoration.

KEYWORDS

Habitat restoration, biodiversity, urban green spaces, temporal analysis, human impact

INTRODUCTION

Growing urbanization is drastically changing urban environments and impacting urban wildlife. In a global model of increasing urbanization, urban land is expected to increase by double from its 2015 extent in 2050 (Simkin et al. 2022). Urbanization is a significant driver of land-use change, habitat fragmentation, and introduction of non-native species, therefore negatively impacting biodiversity (McDonald et al. 2013). Simultaneously, the high density of human population, growing extinction threats, and critical biodiversity make urban environments important as a focal point for biodiversity conservation (Douglas et al. 2020). Therefore, not only is urbanization increasing without signs of stopping, but it is also drastically changing urban environments and is expected to have long-lasting effects on urban biodiversity.

Urban green spaces have a variety of different ecosystem services, for instance, they are vital in regulating urban heat island effect, air and water filtration, and serving as habitats which maintain biodiversity in an ecosystem (Gallo et al. 2017). The implementation of habitat restoration as a conservation practice has been increasing in recent years and has multiple implications. For instance, habitat restoration efforts in urban green spaces revitalize soil microbiota biodiversity (Mills et al. 2020). Similarly, habitat restoration in urban green spaces is expected to lead to greater density and diversity of native tree species (Collas et al. 2017). However, the efficacy of habitat restoration is not entirely clear, for example in forest regions that underwent habitat restoration, not all new forest areas could be used as habitat for species (Wang et al. 2021). Furthermore, studies looking at the outcomes of restoration are limited (Wortley et al. 2013) and they often do not consider wildlife biodiversity or wildlife use changes.

As urbanization increases, mammals are entering urban areas because of habitat destruction and limited access to other habitat patches, they are also experiencing ongoing adaptation which allows them to infiltrate urban areas (Chatelain and Szulkin 2020). Habitat fragmentation due to urbanization results in human-wildlife conflict as wildlife is forced to traverse through human-dominated areas (Young et al. 2010). Part of evaluating human-wildlife interactions is understanding the impacts that humans have on when wildlife use habitats. For example, in looking at the temporal and spatial use of water sources by elephants, it was found that elephants visited water sources more at night times when there were greater buildings present in the area (Buchholtz et al. 2021). This highlights how wildlife might adapt to human impact by shifting when they visit or use habitats. However, similar studies have found contradictory evidence, for instance one study found that the presence of humans and dogs largely did not have a significant effect on the spatial and temporal activity of wildlife on urban green spaces (Beasley et al. 2023). Temporal patterns of wildlife in urban green spaces can have a significant effect on human-wildlife interactions, as it can facilitate human-wildlife coexistence or conflict (Gaynor et al. 2018). Furthermore, the effect of habitat restoration on such patterns is not well-researched.

In this study I focused on understanding how effective habitat restoration is at increasing biodiversity in urban green spaces. To answer this question, I sought to understand when wildlife utilized urban green spaces, whether the implementation of habitat restoration also affected human presence in urban green spaces. Understanding when wildlife used urban green spaces allowed me to evaluate the efficacy of habitat restoration. Similarly in evaluating urban green spaces it is important to understand the extent of human impact, this helped me understand the effectivity of habitat restoration as a conservation method. I predicted that wildlife would frequently visit restored sites in comparison to unrestored site. I also predicted that habitat restoration would decrease human presence and impact. To conduct my research, I used a quasi-experimental design that compared restored areas with control areas. In restored and control areas I used camera traps to monitor wildlife use and human impact through the study period and calculated biodiversity metrics.

METHODS

Study Site

The study site was Presidio Parks located in northern San Francisco, California. The Presidio historically was home to a variety of different habitats, notably, tidal marshes, coastal prairies and scrub, grasslands, serpentine slope wetlands, and coastal live oak woodlands (Figure 1). The Presidio falls within the Mediterranean climate zone that is characterized by cool, wet winters and hot, dry summers.

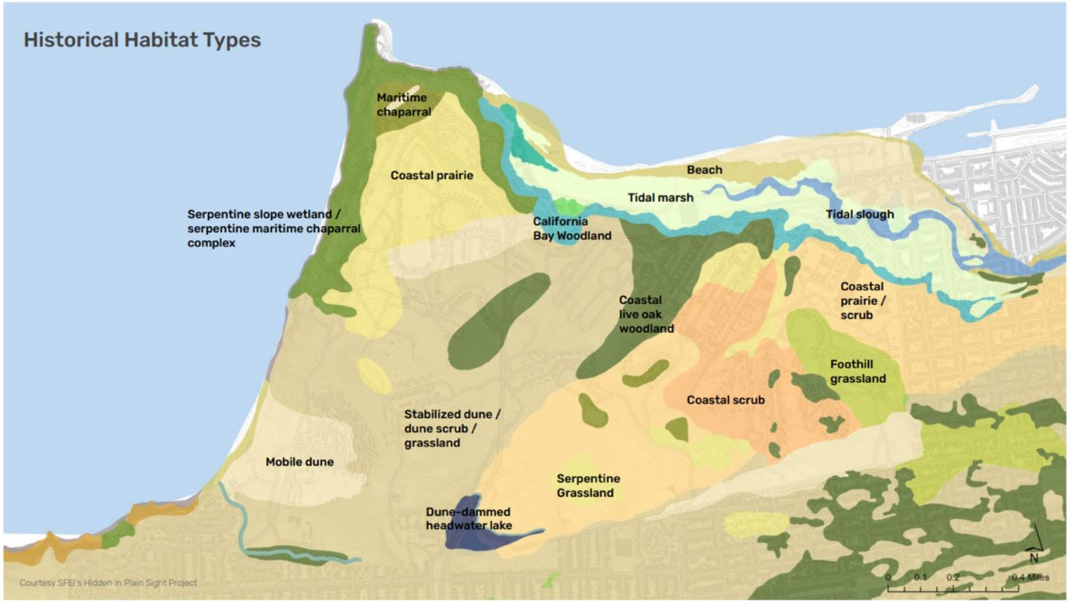

Figure 1. Map of the historical habitat types of the Presidio area from the "Ecological Horticulture at the Presidio" presented by the San Francisco Estuary Institute.

In the pre-colonial era, the indigenous Ohlone people used fire to clear brush in the pre-colonial era. Post-colonial periods saw the establishment of a fort by the Spanish which eventually expanded into a military site under the U.S. Army in the 19th to 20th centuries. During this time, non-native trees (including pine, cypress, and eucalyptus species) were planted to act as windbreaks, prevent erosion, and to beautify the area (Presidio Forest). The Presidio was established as a national park site in 1994, since then restoration efforts have taken place primarily focusing on changing habitat types and returning the area to its pre-colonial state. In 2021, around 7.4 million people visited the Presidio, making it a highly trafficked urban green space.

The overall study design was quasi-experimental and includes data from camera traps and a brief site analysis using GIS. Study sites were the urban green spaces in the Presidio Parks in San Francisco, California (Figure 2). Four sites were chosen initially, one restored site, one unrestored site, and two partial restoration sites. However, due to an equipment malfunction, one of the partial restoration sites was excluded from the study.

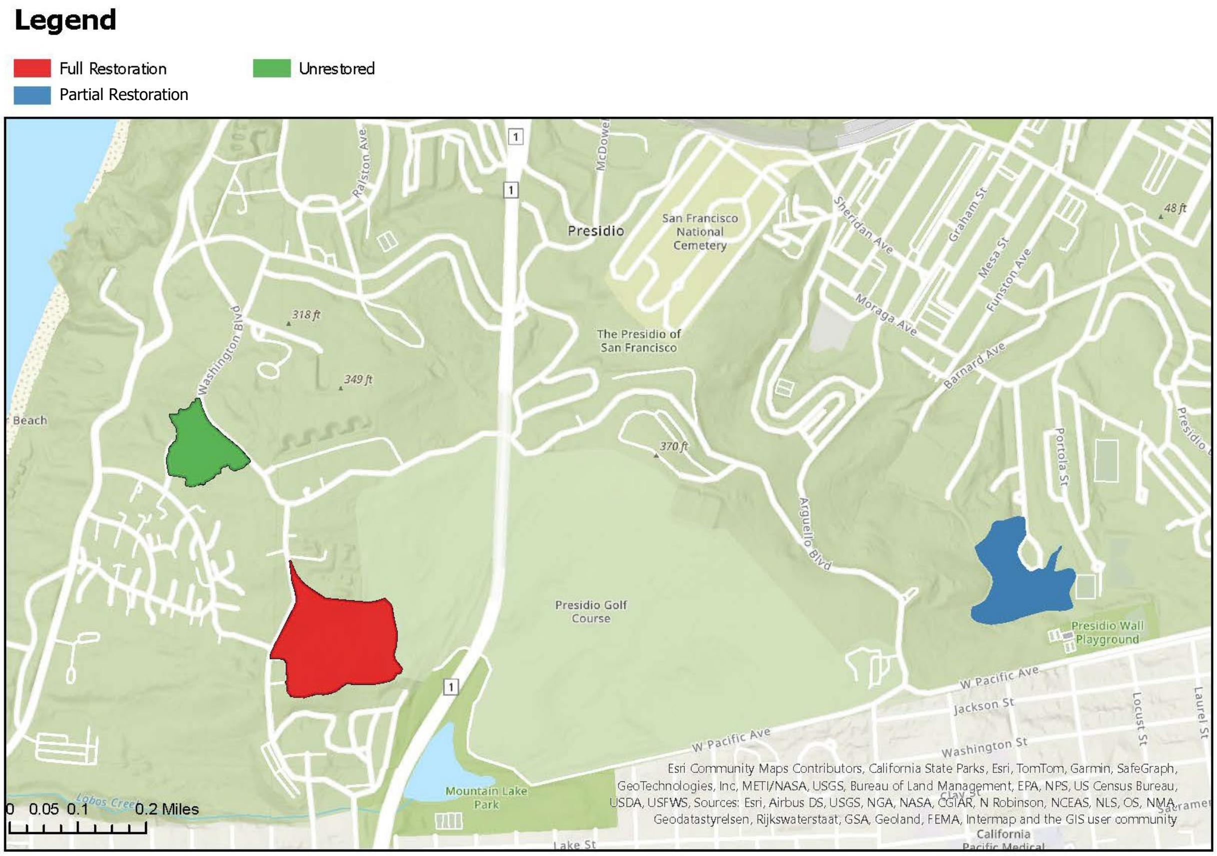

Figure 2. Map of the Presidio showing the study sites.

The unrestored site was located at Immigrant Point, straddled between a scenic overlook, roads, hiking trails, and human residences. The camera trap was located around fifty feet from the nearest trail. The partially restored site was located at the Tennessee Hollow watershed, closed off by several hiking trails, roads, and sports fields. The camera trap was located around 100 feet off the closest trail. Finally, the fully restored site was situated between roads, trails, and the Presidio Golf Course. The camera trap here was located around 150 feet off trail.

Camera Trap Observations

To measure when and what wildlife use urban green spaces, human presence, biodiversity and whether these aspects were affected by habitat restoration I collected observations using camera traps to quantify the species present, and capture when they visited the site. I mounted camera trails near established travel corridors. I used the Bushnell Core DS-4K No Glow Trail

Camera enclosed within Bushnell Trail Camera Security Box (Non-Cellular) which I mounted to trees or existing structures around two to three feet off the ground using cable locks and zip ties. The camera traps were deployed from February 16th to March 31st. When triggered, I set the camera traps to collect photographs and videos with a three second delay. I set the illumination mode on the camera traps to long range and were active at all hours.

Data Processing and Calculating Biodiversity

Subjects of the observations are the wildlife in the Presidio Parks. I processed the data, making note of the date and time, species captured, site type, and any additional notes. I extracted the audio files from the camera trap videos and subsequently used eBird to identify bird calls (Sullivan et al. 2009). Using the bird call observations from the camera trap, I calculated species richness, Shannon's Index, and Simpson's Index. Birds are known to be sensitive to environment changes and are indicators of environment health, which is why I used birds to calculate the biodiversity metrics across the different sites. I analyzed the data using simple statistics (mean, standard deviation, etc.) to test for normality, and the Kruskal-Wallis rank sum test to identify if study sites had an influence on human and wildlife presence. I also analyzed when humans and wildlife visited the sites to see if there was an overlap between when humans visit the study sites and when wildlife visit the study sites.

RESULTS

Site Analysis

Using the San Mateo Fine Scale Vegetation Map, which was developed in 2018 by the Golden Gate National Parks Conservancy, I developed a map that shows the vegetation found at each site (Figure 3) (Golden Gate National Parks Conservancy et al. 2022). The San Mateo Fine Scale Vegetation Map broke down the vegetation types in each site according to the vegetation alliance according to the U.S. National Vegetation Classification. An alliance is defined as the composition of plant species. The three study sites had a somewhat similar makeup of vegetation. For example, all three sites had a significant portion of land classified as Baccharis pilularis Alliance (Coyote brush). However, the three sites also contrast significantly in the makeup of vegetation. For instance, the unrestored site contained a significant portion of Mesembryanthemum spp. – Carpobrotus spp. Semi-Natural Alliance (Ice plant and Sour fig). The unrestored site and the fully restored sites also had significant portions that were classified as Eucalyptus (globulus, camaldulensis) Provisional Semi-Natural Association (Eucalyptus).

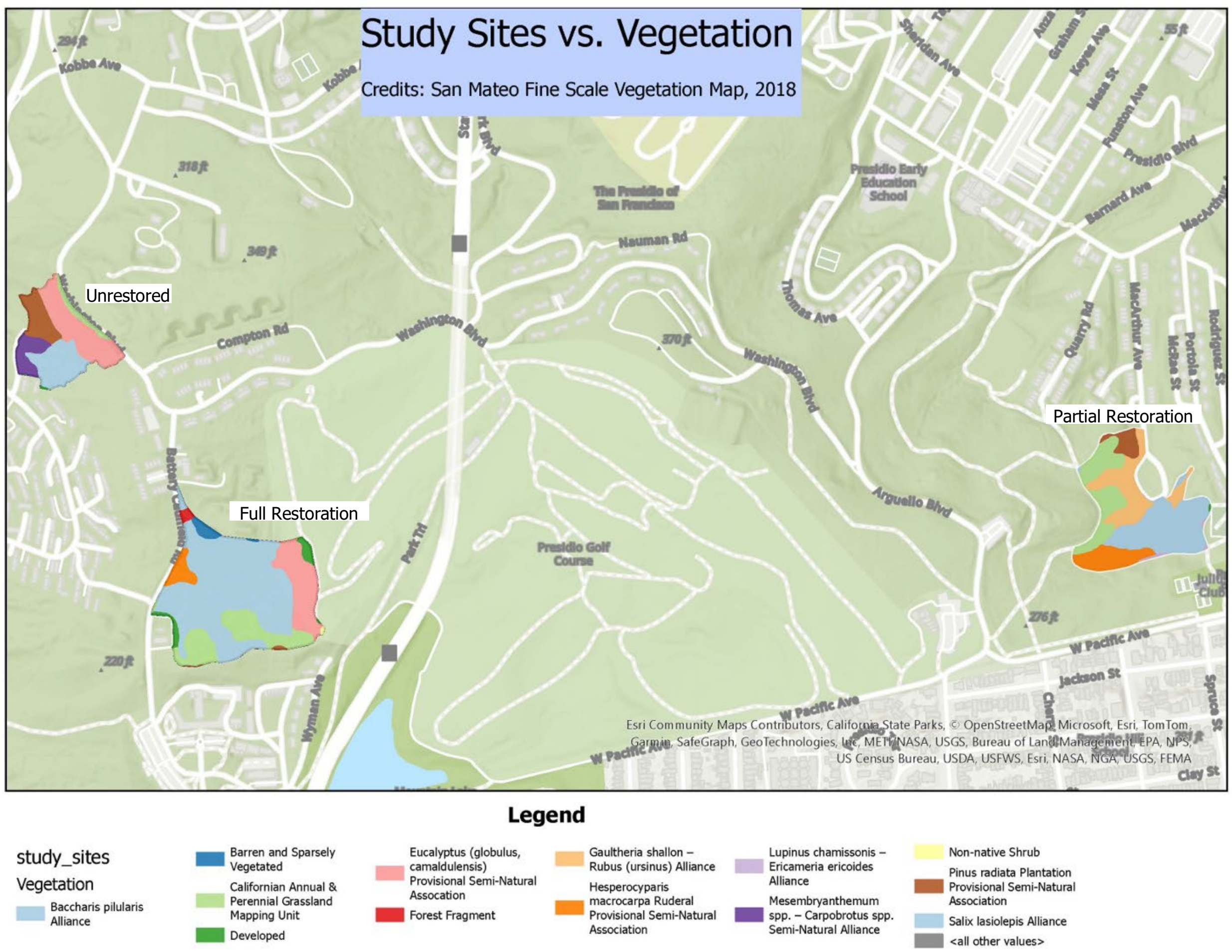

Figure 3. Map showing the vegetation classifications for each study site. The unrestored site primarily contained Baccharis pilularis Alliance, Pinus radiata Plantation Provisional Semi-Natural Association, Eucalyptus (globulus, camaldulensis) Provisional Semi-Natural Association, and Mesembryanthemum spp. – Carpobrotus spp. Semi-Natural Alliance classifications. The fully restored site contained primarily Baccharis pilularis Alliance, Eucalyptus (globulus, camaldulensis) Provisional Semi-Natural Association, California Annual & Perennial Grassland Mapping Unit, Hesperocyparis macrocarpa Ruderal Provisional Semi-Natural Association, and Barren and Sparsely Vegetated classifications. The partially restored site primarily contained Baccharis pilularis Alliance, Hesperocyparis macrocarpa Ruderal Provisional Semi-Natural Association, California Annual & Perennial Grassland Mapping Unit, Pinus radiata Plantation Provisional Semi-Natural Association, and Gaultheria shallon – Rubus (ursinus) Alliance classifications.

Wildlife Detections

Most wildlife detections were composed of birds (Table 1). The partial restoration site had the greatest number of mammals detected (25 detections) followed by the fully restored site (17 detections) and the unrestored site (5 detections). The partially restored site had the greatest number of bird detections (191 detections), followed by the fully restored site (136 detections) and the unrestored site (4 detections).

Table 1. Wildlife detections at each site type. This table shows the species detected and the number of individuals detected per species. Bird, Unknown tag was used for birds that were visually captured in the photos or videos but could not be identified likely because they were too far or obscured from the camera.

Tag	Full Restoration	Partial Restoration	Unrestored
Allen's Hummingbird	6	3	
American Crow	1	1	
American Pipit		1	
American Robin	9	4	
Anna's Hummingbird	1	3	
Bachman's Sparrow		1	
Bewick's Wren	21	19	1
Bird, Unknown	62	57	12
Black Phoebe	2	2	
Blue-grey Gnatcatcher		1	
Bridled Titmouse		1	
Bushtit		1	1
California Scrub-Jay	2	3	
California Towhee		1	
Cave Swallow		1	
Cedar Waxwing	1		
Chestnut-backed Chickadee	2	3	
Chipping Sparrow		1	
Common Chaffinch	1		
Common Raven		1	
Coyote	3	14	2
Dark-eyed Junco	6	2	
Domestic Dog	5	1	1
Elegant Euphonia	1		
Gilded Flicker	1	2	
Golden-crowned Sparrow		1	
Gray Catbird			1
Graylag Goose		2	
Hermit Thrush		1	
House Finch	16	20	
House Wren	1	2	
Hutton's Vireo		1	
Indigo Bunting	1		
Killdeer		2	
Lesser Goldfinch	1	4	
Mangrove Fireo	1		
Mangrove Vireo	1		

Tag	Full Restoration	Partial Restoration	Unrestored
(Ctd.)			
Mitred Parakeet	1		
Northern Flicker	2	2	
Nuttall's Woodpecker		1	
Orange-crowned Warbler	1		
Pine Siskin	5	2	
Purple Finch	14	6	
Pygmy Nuthatch	1		
Raccoon	1	9	2
Red-breasted Nuthatch	1		
Red-necked Pheasant		1	
Red-shouldered Hawk		1	
Red-winged Blackbird	1		
Redwing	1		
Rodent, Unknown	7	2	
Ruby-crowned Kinglet		3	
Say's Phoebe		2	
Song Sparrow	19	22	2
Spotted Towhee		1	
Swainson's Thrush		1	
Swamp Sparrow	1		
Townsend's Warbler	1		
Western Bluebird	29	12	1
Western Grebe		1	
White-crowned Sparrow	5	21	
Wilson's Warbler	2	1	
Yellow-eyed Junco	1	1	

Mammals

The mammals that were detected were coyotes, raccoons, domestic dogs, and rodents. Of the coyote detections, the partially restored site had the greatest number of coyotes (9 detections) followed by the fully restored site (7 detections) and the unrestored site (3 detections). Domestic dogs were detected across all sites with the unrestored site having the most dog detections (4 detections) followed by the partially restored (2 detections) and unrestored sites (1 detection). Raccoons were equally detected in the partially restored (6 detections) and unrestored sites (6 detections). Rodents were only found in the partially restored site (9 detections).

Birds

The only two species that were detected across all three sites were the White-crowned Sparrow and the House Finch. At the fully restored site, the most observed bird species were Western Bluebird (29 detections), Bewick’s Wren (21 detections), and Song Sparrow (19 detections). At the partially restored site the most observed bird species were Song Sparrow (22 detections), White-crowned Sparrow (21 detections), and House Finch (20 detections). The most observed bird species at the unrestored site was Song Sparrow (2 detections).

Human Presence and Temporal Analysis

Humans visited the unrestored site (49 detections) more than the partially restored (18 detections) and the fully restored (17 detections) sites. Human presence across the sites was sporadic. In the unrestored site, human presence peaked between 10:00 AM and 12:00 PM (Figure 5). In the partially restored site, human presence peaked between 1:00 PM and 4:00 PM. Finally, in the fully restored site, human presence peaked between 2:00 AM and 9:00 AM. Between the hours of 6:00 PM and 2:00 AM, humans were not detected at any of the study sites.

Given that the distribution of data was not normal, I used the Kruskal-Wallis rank sum test in RStudio to compare the number of human detections per hour of the day as a function of the site type. The results of the test indicated that there was not a significant difference between the median human detections across site types (p-value=0.08332) (Posit Team 2024).

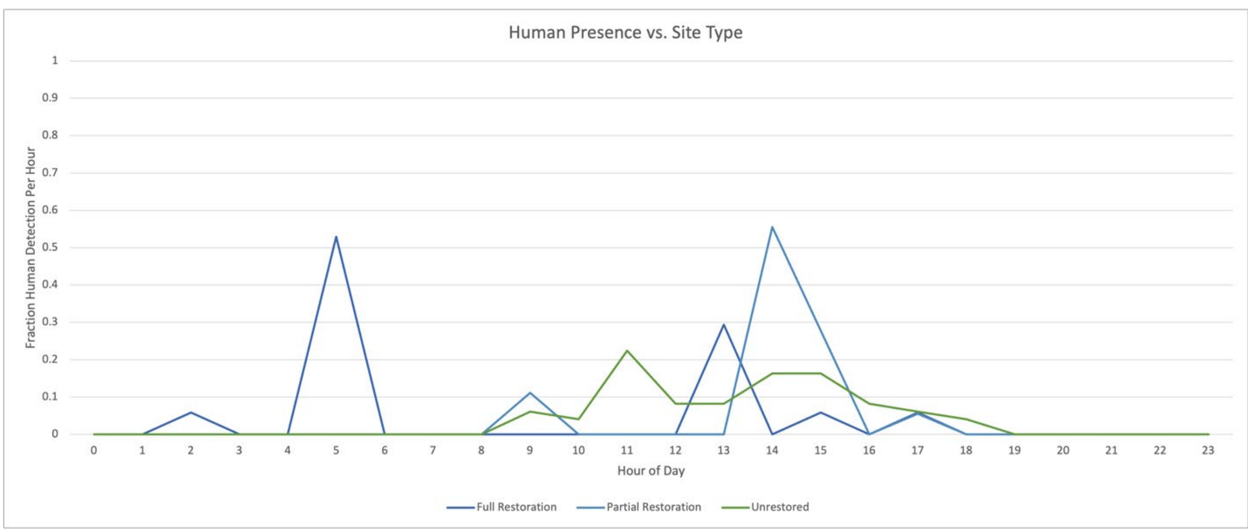

Figure 4. Graph plotting the fraction of the number of detections of humans per time of day per study site. The full restoration site peaks in detections at 5:00 AM and 1:00 PM. The partial restoration site peaks at 9:00 AM and at 2:00 PM. The unrestored site peaks in detections at 11:00 AM and between 2:00 PM and 3:00 PM. No human detections are recorded in any site between 6:00 PM and 2:00 AM.

In comparing the relationship between human and wildlife presence across the different sites, the unrestored site had the greatest overlap between human presence and wildlife presence

(Figure 6). In looking at the unrestored site, generally human and wildlife followed a similar pattern of visitation with the biggest peak between 10:00 AM and 12:00 PM. However, while wildlife was detected at all hours, human visitation stopped between 7:30 PM and 7:00 AM.

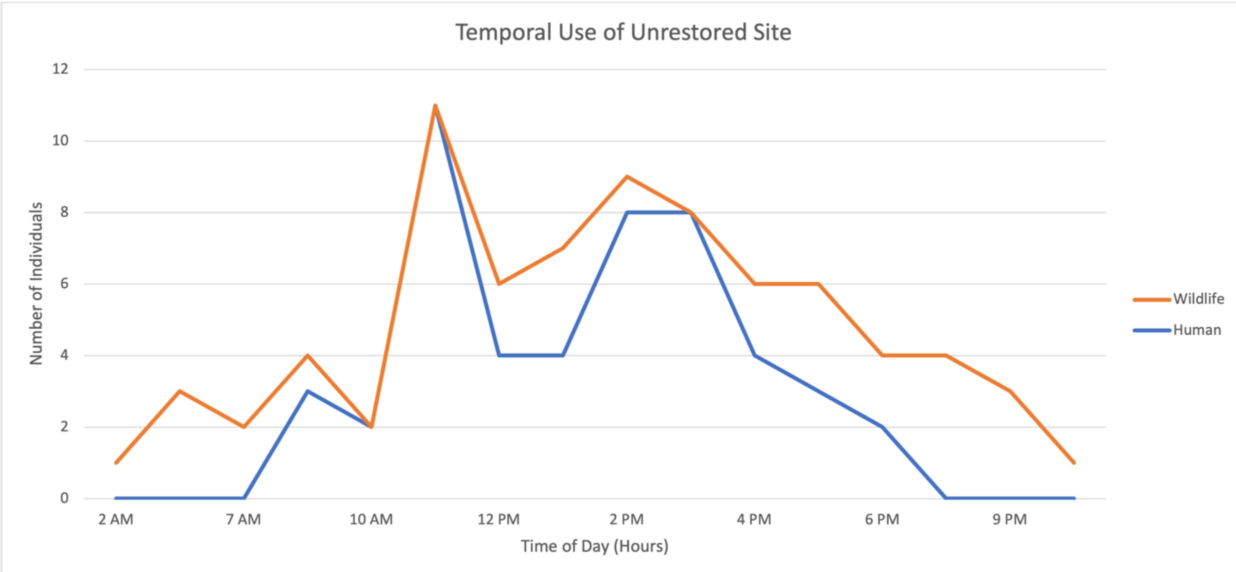

Figure 5. Total number of human and wildlife detections per time of day at the unrestored site. The wildlife detections generally increase between 2:00 AM until 11:00 AM. At 2:00 PM the wildlife detections experience another peak before decreasing until 9:00 PM. Human detections generally increase between 7:00 AM until 11:00 AM. At 2:00 PM there is another peak in human detections before decreasing. There are no detections between 10:00 PM and 2:00 AM.

In looking at the partially restored site, wildlife presence peaked between 10:00 AM and 2:00 PM (Figure 7). On the other hand, humans were largely absent from the site with a minor peak in visitation between 8:00 AM and 10:00 AM, and a larger peak in visitation between 1:00 PM and 4:00 PM.

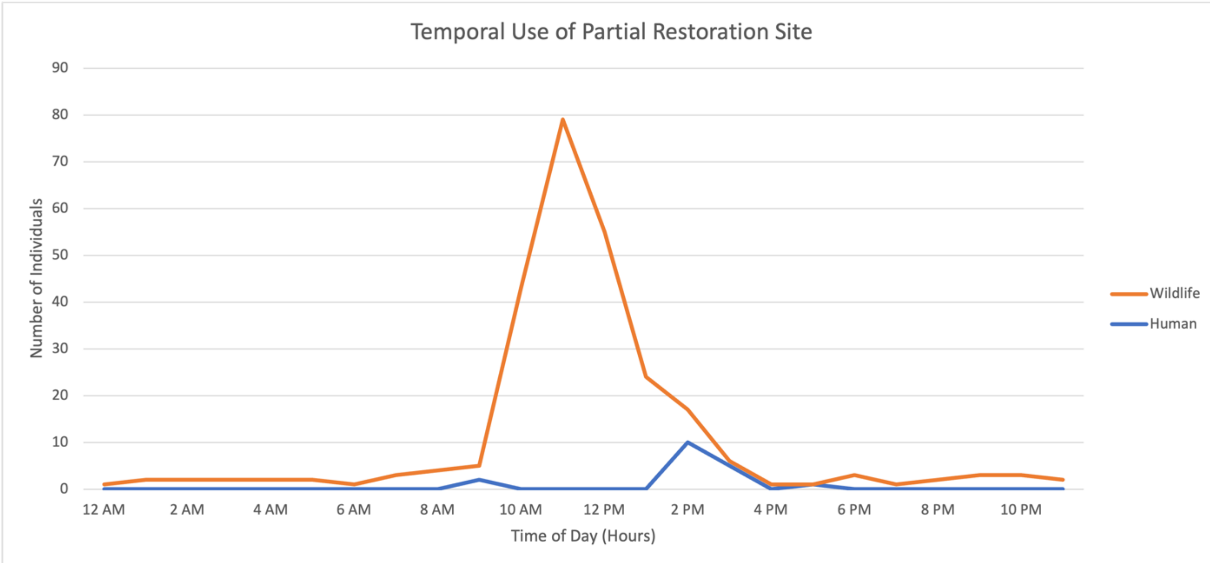

Figure 6. Total number of human and wildlife detections per time of day at the partial restoration site. Wildlife detections are low between the hours of 4:00 PM and 8:00 AM. There is a significant increase in wildlife detections around 12:00 PM. Human detections peak around 9:00 AM and 2:00 PM. Between 6:00 PM and 8:00 AM there are no human detections.

Similar to the partially restored site, the fully restored site experienced a peak in wildlife presence between 9:00 AM and 3:00 PM (Figure 8). Human visitation peaked between 2:00 AM and 6:00 AM, with another peak between 12:00 PM and 2:00 PM.

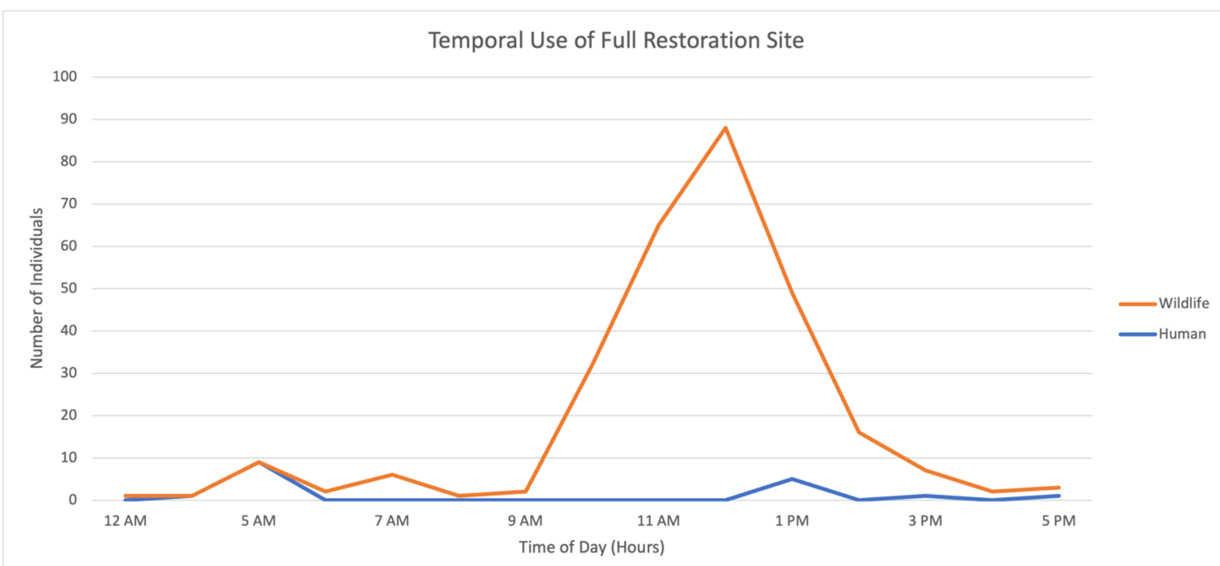

Figure 7. Total number of human and wildlife detections per time of day at the full restoration site. At 5:00 AM there is a peak in human and wildlife detections before decreasing. At 7:00 AM there is a slight peak in wildlife detections. At around 12:00 PM there is a significant peak in wildlife detections before decreasing. Human detections

are constantly low with another peak at 1:00 PM before decreasing. There are no wildlife or human detections between 5:00 PM and 12:00 AM.

Temporal Wildlife Visits

When looking at wildlife visitations across the study sites, the restored sites experienced greater wildlife presence and visitations than the unrestored site. Specifically, the partially restored site had the greatest wildlife visitations (267 detections), the fully restored site had roughly 8% less wildlife presence (246 detections), and the unrestored site had 89% less wildlife presence (28 detections) compared to the partially restored site. Wildlife presence peaked between 10:00 AM and 2:00 PM at the fully restored and partially restored sites (Figure 4). Wildlife presence was detected across all hours of the day.

Given that the data did not have normally distributed data, I used the Kruskal-Wallis rank sum test in RStudio to compare the number of wildlife detections per hour of the day as a function of the site type. The Kruskal-Wallis rank sum test yielded a statistically significant result (p-value=0.002761) indicating that there was a difference between the distribution of wildlife detections across the different site types (Posit Team 2024).

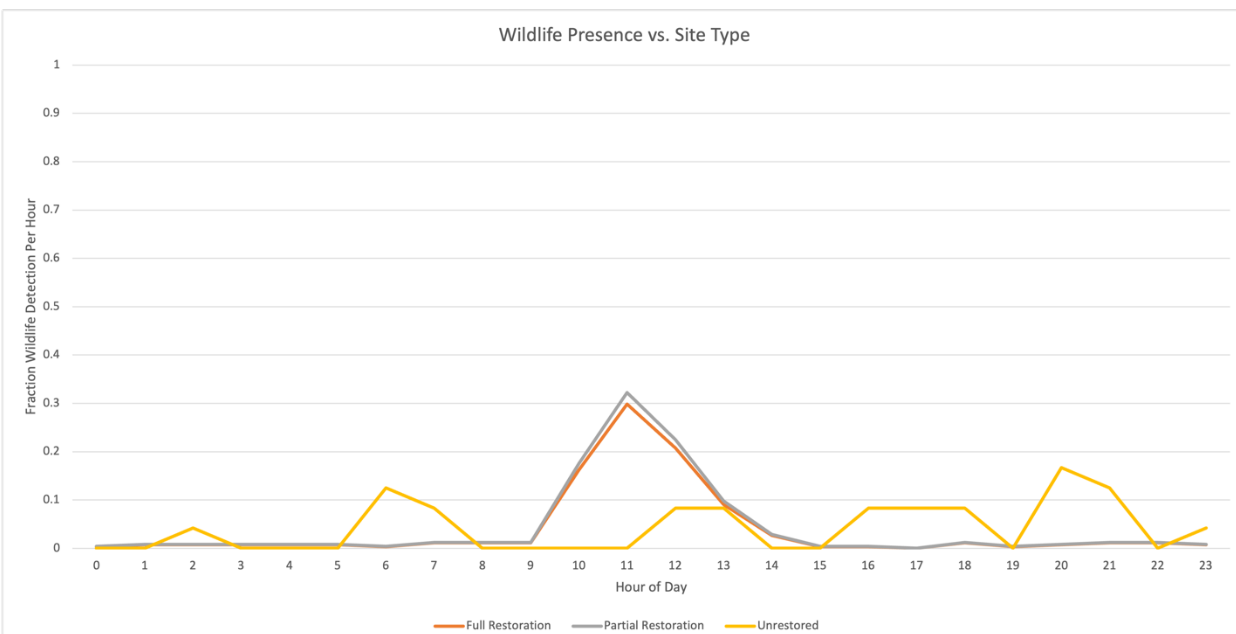

Figure 8. Fraction of the number of detections of wildlife per time of day per study site. The full and partial restoration sites experienced a peak in detections at around 12:00 PM. The unrestored site experienced a peak in detections around 2:00 AM, 6:00 AM, 1:00 PM, 5:00 PM, and 8:00 PM.

Biodiversity

Species richness among the sites differed greatly. The partially restored site had the highest species richness (46 species) with the restored site having around 43% less and the unrestored site having around 91% less species richness (Figure 9).

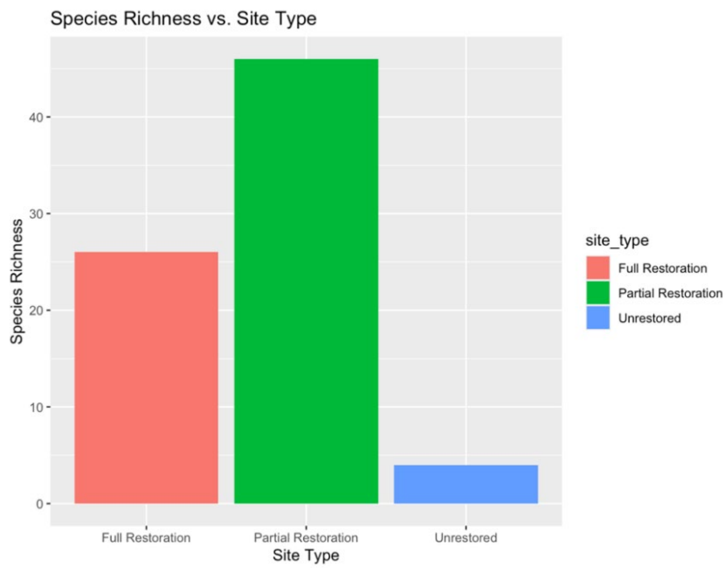

Figure 9. Species richness at each site type. The full restoration site had a species richness of 26, the partial restoration had a species richness of 46, and the unrestored site had a species richness of 4.

The partially restored site had a Shannon's Index of 2.87, the fully restored site 22% less, and the unrestored site had 51% less biodiversity (Figure 10).

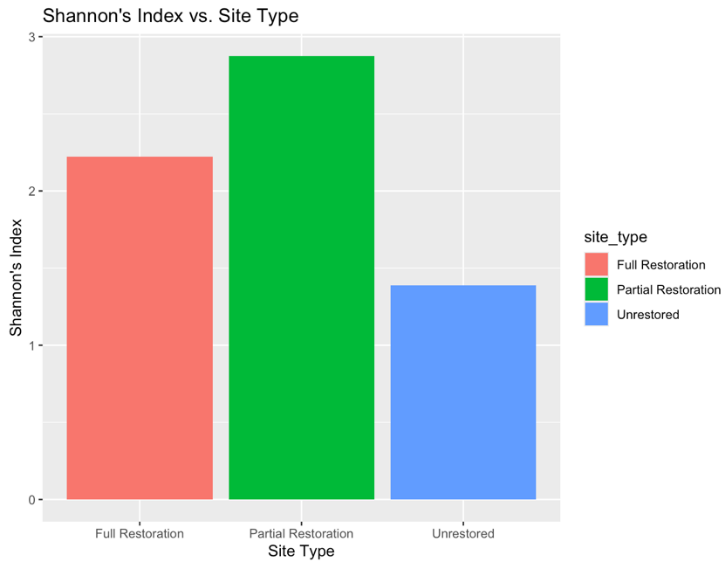

Figure 10. Shannon's Index at each site type. The full restoration site had a Shannon's Index of 2.2, the partial restoration had a Shannon's Index of 2.9, and the unrestored site had a Shannon's Index of 1.4.

The unrestored site had a Simpson's Index of one, the partial restoration site had less biodiversity by 10%, and the full restoration site had around 17% less biodiversity (Figure 11).

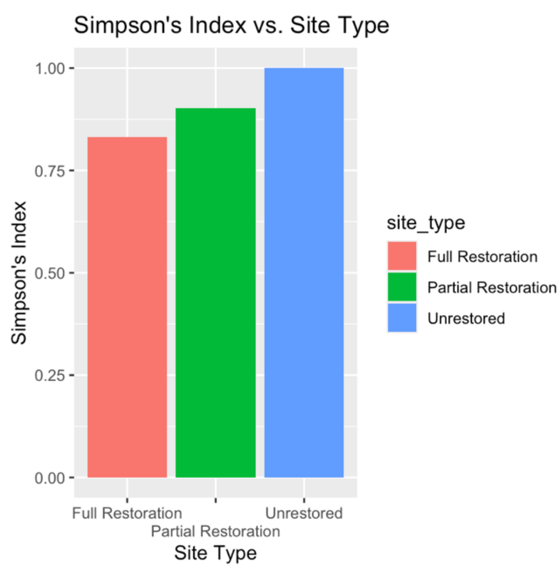

Figure 11. Simpson's Index at each site type. The full restoration site had a Simpson's Index of 0.83, the partial restoration had a Simpson's Index of 0.90, and the unrestored site had a Simpson's Index of 1.

DISCUSSION

There was a significant difference between the wildlife presence at the different site types, however, this was not the case for human presence across the sites. Human presence at the unrestored site was greater than the unrestored site but there was no significant difference between the median human detections across site type. In the site-by-site comparison of human and wildlife use of the sites, there was a greater overlap between human and wildlife presence at the unrestored site. Finally, the biodiversity metrics were quite mixed when comparing them on a site-by-site basis. The partially restored site had the highest species richness and Shannon's Index, but the unrestored site had the greatest Simpson's Index.

Human Presence Across Study Sites

Statistical analysis indicated that human presence was not significantly different across the study sites, regardless of restoration status. This indicates that habitat restoration might not affect human impact in urban greenspaces. Part of this can be attributed to the close proximity of all study sites to trails, roads, and human development. All the camera traps were located within 150 feet from the nearest human trail, this indicates that humans were often going off of the trails despite the restored sites having low-lying fences. This indicates that humans in urban green spaces might be indifferent to the presence of fences which are used to prevent humans from disturbing wildlife habitats. Looking at the overlaps between wildlife and human presence across the study site, across the sites there were instances of overlaps between wildlife and human presence across all sites, however, the unrestored site saw the greatest overlap between humans and wildlife. This indicates that there is a high potential for human-wildlife conflict in the unrestored site. Yet, the lack of reported human-wildlife conflicts reinforces findings that wildlife is flexible in their use of habitats (Bagheriyan et al. 2023). These results suggest that human presence in urban green spaces does not impact urban species' use of urban green spaces. However, if resources become constrained, the overlap between human and wildlife presence in the sites could become a source of human-wildlife conflict. Furthermore, given that habitat restoration didn't affect human presence at the site, it is clear that human activity needs to be accounted for in conservation methodology.

Temporal Analysis of Wildlife Use

Restored sites shared similar patterns of wildlife use while the unrestored site had more variable wildlife use. Throughout all the site types, birds made up most wildlife detected. The mammals that were detected at the sites were coyotes, domestic dogs, raccoons, and rodents. These mammal species tend to be common in urban landscapes and are typically bolder. The restored sites had greater wildlife presence and visitations than the unrestored site, with the partial restoration having the greatest number of wildlife detections. Unrestored sites had 89% fewer detections compared to the partially restored site. While coyotes, domestic dogs, and raccoons were detected in the unrestored site similar to the restored sites, the total number of species detected at the site were Wildlife detections across all site types peaked between 10:00 AM and 2:00 PM. Statistical analysis using the Kruskal-Wallis rank sum test indicates that habitat restoration did affect when wildlife uses urban green spaces.

Analyzing when wildlife uses urban green spaces is vitally important because as urbanization and land-use change pushes wildlife into urban landscapes there is a greater potential for human-wildlife conflict. For example, in looking at human-coyote interactions in San Francisco a study found that there was an increase in the temporal overlap between reports with human-coyote conflict and reports without human-coyote conflict (Wilkinson et al. 2023). Although wildlife is known to be flexible in using both natural and human-created habitats (Bagheriyan et al. 2023), the case of habitat restoration in urban green spaces is unique and understudied. There is not enough research on how habitat restoration can affect human-wildlife interactions in urban landscapes. All in all, the results highlight that restoration does significantly alter when wildlife uses urban green spaces.

Biodiversity

The biodiversity of bird species across the sites was quite different when looking at species richness, but not when looking at Shannon's Index or Simpson's Index. Species richness in the unrestored site was 91% less compared to the partially restored site. The species at the unrestored sites that were represented at the restored sites were House Finch, White-crowned Sparrow, and Anna's Hummingbird. Only one species was found at the unrestored site and not at the other sites, which was Nutall's Woodpecker. This is likely because the unrestored site had a great number of tall Eucalyptus trees which were situated closer to the camera traps than at the other sites. Although the species richness and Shannon's Index indicate that the partially restored site had the greatest biodiversity followed by the fully restored site and the unrestored site, the Simpson's Index was quite different. Shannon's Index differs from species richness in that it takes into account the abundance and evenness of the detected species. Simpson's Index is similar to Shannon's Index but it values evenness over species richness. Simpson's Index ranked the unrestored site as having the greatest biodiversity, followed by the partial restoration site and the full restoration sites. This is likely because Simpson's Index looks at the distribution of individuals across species and given that there were only four individuals across four bird species in the unrestored site it had the best biodiversity according to Simpson's Index.

Some of the reasons for the differing biodiversity across the sites could be primarily because of the methodology. In calculating biodiversity, bird calls were used from the videos taken by the camera traps. Birds, however, do have long ranges. Furthermore, the unrestored site experienced less bird presence which could have influenced the calculation of the biodiversity metrics for the unrestored site. One study investigating the effects of river restoration on biodiversity had found that increasing habitat heterogeneity is not the primary factor that affects invertebrate diversity (Palmer et al. 2010). While this study focused on river habitats, this study indicates that conservation must focus on increasing biodiversity, not just improving habitat qualities. My results reinforce that there is a larger problem with the widespread implementation of habitat restoration. For instance, as one study found, most restoration studies look at biodiversity as a response rather than integrating it into habitat restoration (Hughes et al. 2018). The restoration efforts that were the subject of this study focused on returning the sites to its pre-colonial state, it is unclear whether biodiversity was a key aspect of this restoration effort. Nonetheless, biodiversity must be a key factor in indicating the success of habitat restoration projects.

Management Implications

In looking at the effects of habitat restoration on biodiversity, wildlife use, and human presence, wildlife management in urban green spaces needs to balance wildlife needs and human needs. Habitat restoration did have a significant impact on wildlife use of urban green spaces, but it doesn't have the same effect on human use of urban green spaces. Another implication is that habitat restoration needs to better account for biodiversity by including it as an explicit goal of habitat restoration projects. Furthermore, the results of this study indicate that wildlife management must also anticipate human disturbance in restored sites, especially in areas that are easily accessible. This study also serves as a precaution against using habitat restoration as the sole conservation strategy as it does not adequately address factors like human disturbance or human-wildlife conflict. Finally, this study highlights the importance of monitoring programs after implementing habitat restoration as a conservation method, without monitoring programs it is difficult to ascertain the success of restoration.

Limitations

There are several limitations to this study that must be accounted for when evaluating the implications. First, the Presidio Parks is not representative of all urban green spaces but is more representative of highly urbanized green spaces located in a Mediterranean climate. Furthermore, there are many confounding factors that could have affected the results of this study. For instance, the differential presence of water across study sites, differences in the rates of human presence, and different levels of restoration (partial vs. full), restoration maintenance, and restoration methodology were not accounted for due to time constraints. In that vein, given that coyotes and birds have large ranges it is possible that the same individuals were detected across all three sites which presents an additional confounding factor. It is important to note that the unrestored site was underrepresented in the data that was collected. Additionally, the data collection period took place over six weeks in the months of February and March, this presents a further limitation to the study. Additionally, the study itself was restricted to three sites which represents a weakness in this study's internal validity. These limitations could be addressed by finding sites that are more similar to each other in their physical features, proximity to human disturbance, and restoration methodology. Furthermore, the internal validity could be strengthened by including a greater number of sites and increasing the data collection period.

Some gaps within this study are concerning human-wildlife interactions, human presence, wildlife use, and biodiversity. Future directions building off of this study could focus specifically on whether human-wildlife interactions are changed by habitat restoration. Another future direction would be looking at why humans seemingly prefer unrestored spaces over restored ones, and testing whether human visitation of different urban green spaces is impacted by its restoration status. An additional future direction could specifically focus more on wildlife use of urban green spaces, specifically, whether wildlife behavior changes between different site types. Lastly, further research could look at whether habitat restoration effectively increases biodiversity based on whether biodiversity was explicitly addressed in the methodology of the restoration.

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