Science Support to Improve Conservation Outcomes for Coastal Cactus Wren (*Campylorhynchus brunneicapillus*) in Western San Diego County

Prepared for:

San Diego Association of Governments Environmental Mitigation Program

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Cover: Photograph of Coastal Cactus Wren (*Campylorhynchus brunneicapillus*) at Lake Jennings, San Diego County. Photograph by Alexandra Houston, U.S. Geological Survey, July 2020.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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International System of Units to U.S. Customary Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

Datum

Horizontal coordinate information is referenced to the World Geographic System of 1984 (WGS 84).

Abbreviations

Caltrans	California Department of Transportation
MSP	Management and Monitoring Strategic Plan
SANDAG	San Diego Association of Governments
SDMMP	San Diego Management and Monitoring Program
TNC	The Nature Conservancy
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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Executive Summary

This document was developed based on recent scientific findings and analyses to support improved conservation outcomes for the Coastal Cactus Wren (Cactus Wren; *Campylorhynchus brunneicapillus*) in western San Diego County. This is accomplished by a science-based management strategy consisting of prioritized management options that land managers can select from when developing projects to improve Cactus Wren habitat. A year-round resident of coastal sage succulent scrub (cactus scrub) in coastal southern California, the Cactus Wren has declined over the last several decades in response to habitat loss, fragmentation, and degradation. The Cactus Wren is a target species for multiple species conservation planning begun in the 1990s that has led to the conservation of remaining patches of cactus scrub in the region. Despite conservation efforts, decline and disappearance of wren populations and loss of genetic diversity have continued due to population isolation, drought, wildfire, and invasive non-native annual plants. This analysis updates management options and expands the spatial extent of a previous management plan developed by The Nature Conservancy and San Diego Management and Monitoring Program for Cactus Wrens in south San Diego County. Implementation of habitat management detailed in the South County management plan has helped to increase Cactus Wren populations. The management strategy is to enhance, restore, and expand cactus scrub habitat to increase existing Cactus Wren populations and to enhance connectivity between wren populations. This document compiles and analyzes data collected by USGS scientists on population size, distribution, demography, and genetic variability, as well as on habitat condition, and uses this information to score Cactus Wren locations relative to several threat metrics and other attributes that relate to spatial proximity to other locations. The scores are used to prioritize location-specific management needs and habitat expansion opportunities based on the contribution of each location to the overall strategic goals of bolstering populations and improving genetic connectivity. The results of this updated and expanded analysis can be used by land managers to plan their habitat management projects and support restoration success.

Introduction

The Cactus Wren (*Campylorhynchus brunneicapillus*) is a non-migratory songbird endemic to the arid regions of southwestern United States and northern and central Mexico (Hamilton et al., 2020). The coastal Cactus Wren (*C. b. sandiegensis*) occurs from coastal Orange County south into San Diego County, U.S.A. and northwestern Baja California, Mexico. This subspecies and other wren populations west of the desert in southern California are unique as they occur exclusively within coastal sage scrub habitat that supports patches of cholla (*Cylindropuntia prolifera*) or prickly pear cactus (*Opuntia littoralis*, *O. oricola*) for nesting (Rea and Weaver, 1990). While inland desert populations have been considered fairly abundant, populations of coastal Cactus Wrens have declined dramatically since the late 1980s, with extirpation from many locations as a result of habitat loss, habitat fragmentation, edge effects of development, and catastrophic fires (Rea and Weaver, 1990; Solek and Szijj, 2004, Hamilton et al., 2020).

The coastal Cactus Wren (hereafter "Cactus Wren") is a California Species of Special Concern (CNDDB 2023) and is a covered species under several regional habitat conservation plans, which in San Diego County include the Multiple Species Conservation Program (MSCP) in southwestern San Diego County (City of San Diego, 1998) and the Multiple Habitat Conservation Program in coastal north County (MHCP) (AMEC et al., 2003; fig. 1). Established in the early 1990's, these plans called for conservation of lands within a preserve system that included lands with important habitat values, sensitive species, and that improved connectivity between core preserve areas (City of San Diego, 1998; AMEC et al., 2003). These plans include requirements for preserve-level monitoring and management of lands conserved by participating jurisdictions. They also recognized the need for coordinated regional monitoring and management across plan boundaries. This regional coordination is facilitated by the San Diego Association of Governments (SANDAG) Environmental Mitigation Program, which funds the San Diego Management and Monitoring Program (SDMMP) to develop and coordinate regional management and monitoring plans. Working collaboratively with state and federal wildlife agencies, tribes, land and resource managers, preserve managers, scientists, non-governmental and non-profit organizations, and others, SDMMP produced a *Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County* (MSP; San Diego Management and Monitoring Program [SDMMP] and The Nature Conservancy [TNC], 2017), which provides a biologically-based foundation to support decision making and funding priorities for managing species and vegetation communities across western San Diego County. The MSP designated the coastal Cactus Wren as a "Category SO" species - a species whose persistence at one or more significant occurrences in the planning area is at high risk of loss without immediate management action above and beyond that of daily maintenance activities. Daily maintenance activities include stewardship actions such as ranger patrols, installing fencing and signage, trash cleanup, and occasional invasive plant control. Within the County, the Cactus Wren is found almost entirely within the MSP Area (MSPA; fig. 1).

To help fulfill the MSP goals and objectives established for the Cactus Wren, TNC and SDMMP (2015) prepared a habitat conservation and management plan (hereafter "South County management plan") for southern San Diego County to serve as a 5-year action plan to ensure

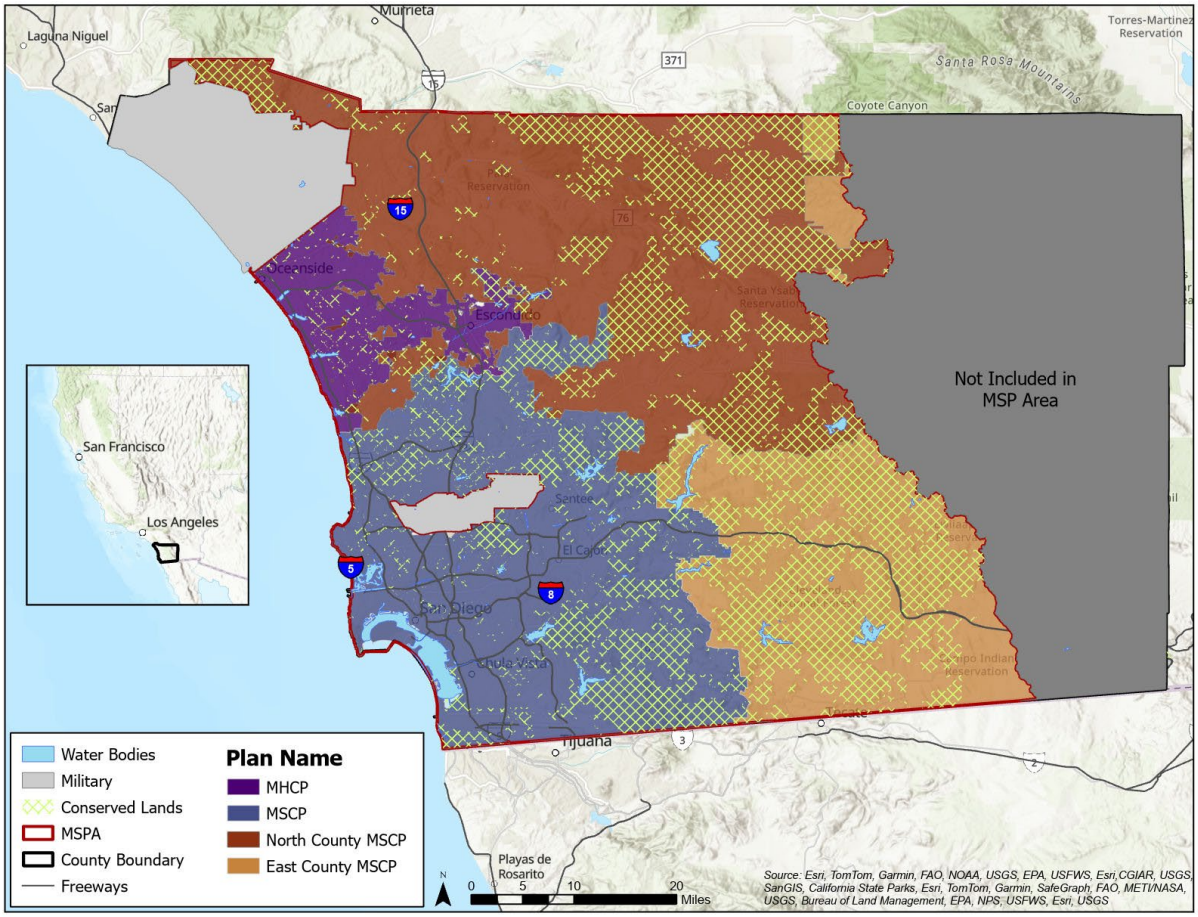


Figure 1. Habitat conservation plan boundaries and the MSP Area as of 2022 in San Diego County, California. MSP: Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County; MSPA: MSP Area; MHCP: Multiple Habitat Conservation Plan; MSCP: Multiple Species Conservation Program.

persistence of the species over the next 100 years. Specifically, the plan identified and prioritized management and restoration needs to benefit Cactus Wrens in southern San Diego County. In addition, it assessed connectivity of those populations to Cactus Wren populations elsewhere in the MSP Area, using a framework of genetic clusters (Barr et al., 2015) shown to reflect genetically and geographically distinct assemblages of wrens (fig. 2). The South County management plan used a two-pronged approach to achieve these objectives:

1. Develop a Cactus Wren habitat suitability model for southern California (Preston et al., 2020; Appendix A) to inform the following:
    - Identify potential cactus scrub restoration sites to augment habitat availability.
    - Identify and prioritize suitable sites for cactus scrub enhancement/expansion to increase connectivity *within* genetic clusters.
    - Identify and prioritize suitable sites for restoring cactus scrub *between* genetic clusters.

2. Conduct surveys on conserved lands to:
    - Document Cactus Wren occupancy, abundance, and distribution.
    - Assess cactus scrub habitat conditions.
    - Characterize threats.
    - Evaluate restoration efforts and outcomes to update established Best Management Practices for cactus scrub restoration.
    - Identify sites for salvage of cactus pads or entire plants for transplantation or nursery propagation.

The South County management plan provided a baseline for tracking Cactus Wren population trends and assessing habitat conditions in southern San Diego County, and centralized information to evaluate restoration needs, opportunities, and outcomes. Population and habitat monitoring have continued since the plan was completed, and new research on Cactus Wren demography, diet and food availability, and population genetic structure undertaken. The results of this research allow a re-evaluation of threats to Cactus Wren persistence and management options to alleviate those threats.

Here, we update the 2015 plan to integrate the results of recent research and monitoring, and update management needs and prioritizations. We continue the use of genetic clusters as an organizing framework for identifying conservation and management needs, and expand the scope of the analyses to include populations in the San Pasqual genetic cluster not covered in the previous plan. This document is structured in two parts. The first part summarizes the current knowledge regarding Cactus Wren population status and trends, demography (including productivity, survival, and dispersal), genetic structure and variability, habitat condition (including food availability and arthropod-vegetation associations), and previous habitat restoration efforts. The second part details site-specific threat rankings and management needs, and prioritizes sites according to their contribution to an overall management strategy to bolster Cactus Wren populations and improve genetic connectivity. This second part provides prioritized management options that land managers can select from to develop habitat management projects likely to improve Cactus Wren conservation outcomes.

Study Area

This expanded analysis covers Cactus Wrens and cactus habitat within the MSP Area delineated by four of the five genetic clusters in San Diego County identified in a study of rangewide population structure (Barr et al., 2015; fig. 2). Cactus Wrens are genetically distinct across the four clusters, likely a reflection of habitat loss and fragmentation, low gene flow, and poor dispersal capabilities of juvenile wrens (Barr et al., 2015; Lynn et al., 2022). Some of these genetic clusters are comprised of multiple local populations or aggregations that show more genetic distinctiveness from one another (Barr et al. 2015), In this analysis, we refer to birds occupying a location as a “population” and do not imply genetic differentiation from populations at other locations.

Thirty-eight locations supporting cactus scrub within the Otay, Sweetwater/Encanto, and Lake Jennings genetic clusters were established as monitoring plots in 2015 (SDMMP and TNC,

2015) (table 1; fig.3). In 2019, a fourth genetic cluster, San Pasqual, was added to the study area, bringing the total number of locations to 46 (table 1; fig. 3). Within these locations, a total of 476 plots were delineated and 314 to 475 of these plots were visited annually to collect data on Cactus Wren occurrence and habitat condition. The number of plots surveyed varied from year to year as new plots were added upon the discovery of wrens outside of established plots. Plots varied in size from 0.07 to 58.6 acres (0.03 to 23.7 hectares [ha]) according to the size of the particular cactus patch(es) at each location. Lake Jennings, Sweetwater/Encanto, and Otay plots were surveyed in 2015 and 2017-2022, while San Pasqual plots were surveyed in 2019 and 2022.

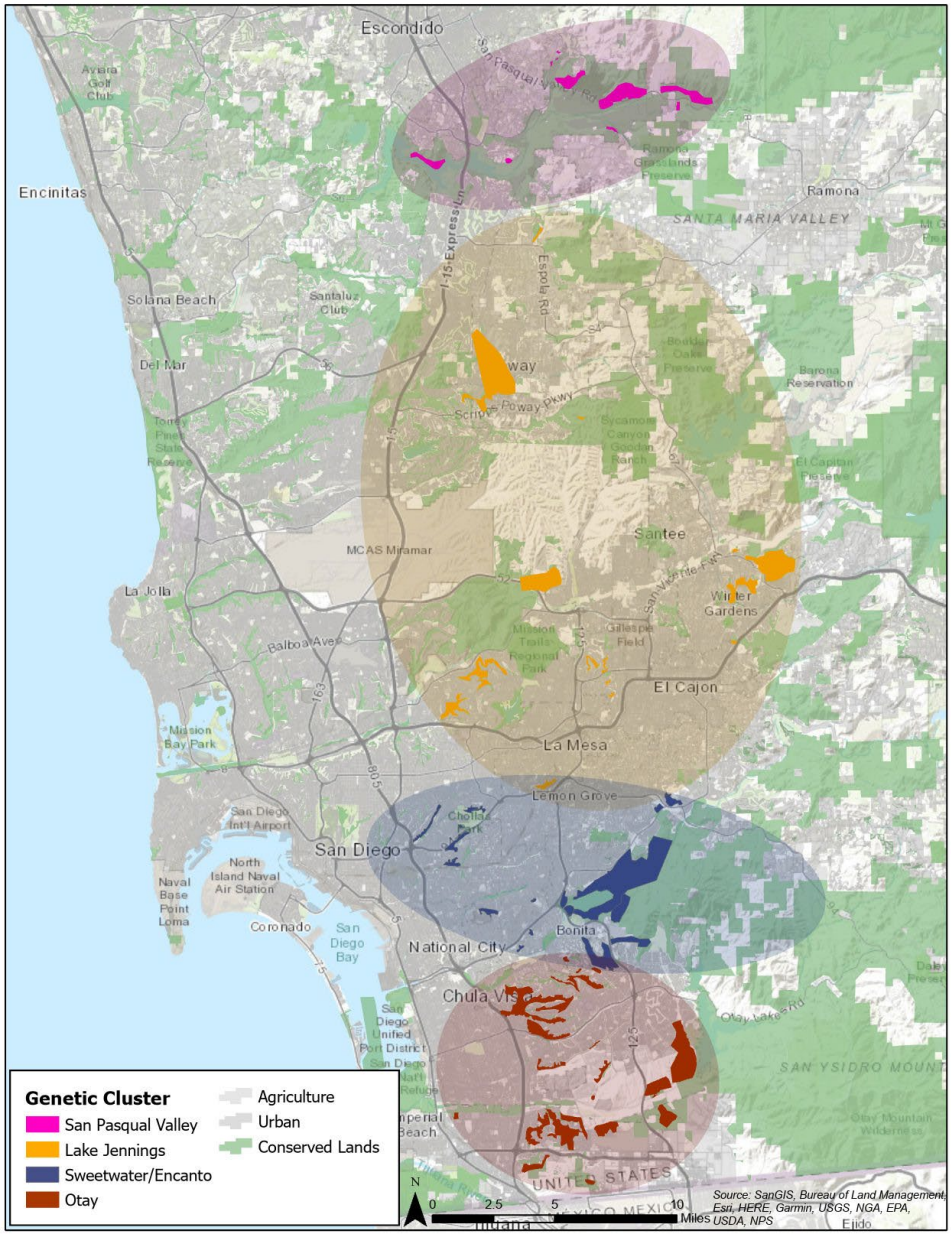


Figure 2. Cactus Wren survey locations within genetic clusters in San Diego County, California. Adapted from Barr et al., 2015.

Table 1. Survey locations on Conserved Lands and associated land managers within each coastal Cactus Wren genetic cluster in the MSP area during 2015–2022. Private parcels not on Conserved Lands are not included. Clusters are organized from north to south, and locations within the clusters are organized approximately from west to east.

Location	Land Manager
	San Pasqual Cluster
Lake Hodges	City of San Diego Public Utilities Department, San Dieguito River Valley Conservancy, San Dieguito River Park Joint Powers Authority
Mule Hill	City of San Diego Public Utilities Department
Cloverdale/Rockwood	City of San Diego Public Utilities Department
Safari/Battlefield Park	City of San Diego Public Utilities Department, California State Parks, San Diego Zoo Safari Park, San Dieguito River Park Joint Powers Authority
Safari Park West	San Dieguito River Park Joint Powers Authority, City of San Diego Public Utilities Department
Bandy Canyon	City of San Diego Public Utilities Department
Academy	City of San Diego Public Utilities Department
Whitman Ranch	City of San Diego Parks and Recreation Department, City of San Diego Public Utilities Department
	Lake Jennings Cluster
Poway	California Department of Fish and Wildlife, City of Poway, County of San Diego Department of Parks and Recreation
Navajo Canyon	City of San Diego Parks and Recreation Department
Mission Trails	City of San Diego Parks and Recreation Department
La Mesa	Helix Water District, Federal Lands
Sycamore Canyon	City of San Diego Parks and Recreation Department
El Cajon	City of El Cajon
Hillside Park	Fletcher Terrace Association
Cactus Park	County of San Diego Department of Parks and Recreation
Lakeside	California Department of Transportation
Lakeside Linkages	California Department of Transportation, County of San Diego Department of Parks and Recreation
Lake Jennings	Helix Water District, San Diego Gas and Electric, Endangered Habitats Conservancy
	Sweetwater/Encanto Cluster
Chollas Valley	City of San Diego Parks and Recreation Department
Market St/Encanto Canyon	City of San Diego Parks and Recreation Department
Martin Luther King	City of San Diego Parks and Recreation Department
Chollas Reservoir	City of San Diego Parks and Recreation Department
Paradise Valley	City of San Diego Parks and Recreation Department, County of San Diego General Services
Emerald Ranch Open Space	Emeral Ranch Homeowners Association
Winnetka Open Space	Bonita Bluffs Homeowners Association
San Diego National Wildlife Refuge	U. S. Fish and Wildlife Service
Skyline	Skyline Wesleyan Church
Sweetwater Quarry	County of San Diego Department of Parks and Recreation

Sweetwater County	County of San Diego Department of Parks and Recreation
Sweet Caltrans	City of Chula Vista, Eastlake Community Association, U.S. Fish and Wildlife Service
Sweetwater Authority	Sweetwater Authority
	Otay Cluster
Rice Canyon	City of Chula Vista
Furby North	County of San Diego Department of Parks and Recreation, City of San Diego Parks and Recreation Department
Ocean View Hills	City of San Diego Parks and Recreation Department
Telegraph Canyon	City of Chula Vista
Poggi Canyon	City of Chula Vista
Dennery Canyon	City of San Diego Parks and Recreation Department
Long Canyon	City of Chula Vista
Wruck Canyon	City of San Diego Parks and Recreation Department
Wolf Canyon	City of Chula Vista
Brown Airfield	City of San Diego Parks and Recreation Department
Otay	County of San Diego
Otay Ranch Preserve	County of San Diego Department of Parks and Recreation, City of Chula Vista
Johnson Canyon	U. S. Fish and Wildlife Service, County of San Diego Department of Parks and Recreation, San Diego Habitat Conservancy, California Department of Transportation, Otay Ranch Preserve Owner Manager
Salt Creek	City of Chula Vista, County of San Diego Department of Parks and Recreation

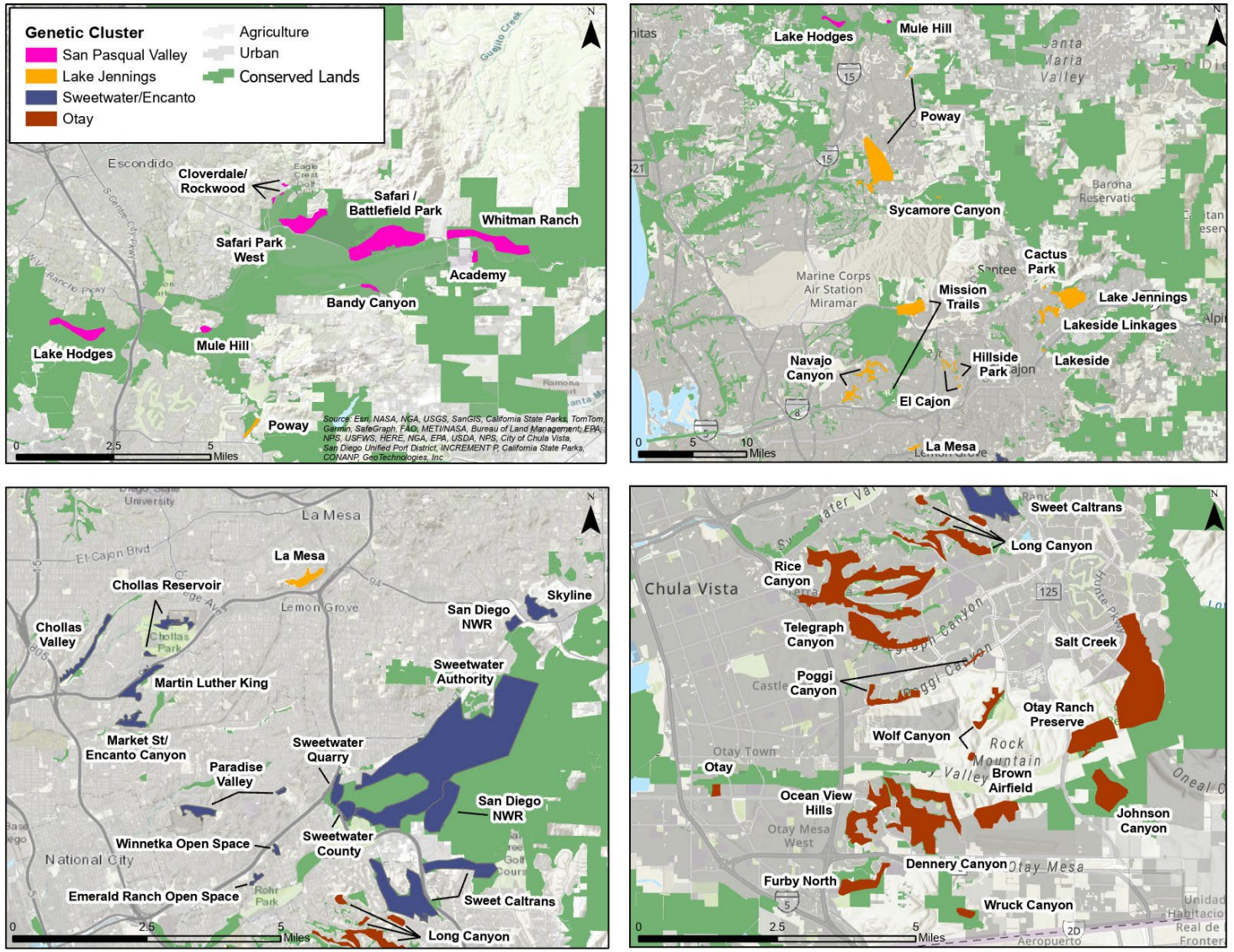


Figure 3. Cactus Wren survey locations by genetic cluster in San Diego County, California, as of 2022.

Factors Affecting Cactus Wren Population Dynamics

Coastal Cactus Wrens have declined over the last half-century in San Diego County in response to habitat loss associated with urbanization throughout their former range (Rea and Weaver, 1990; Solek and Szijj, 2004; Hamilton et al., 2020). Currently, cactus scrub habitat is fragmented and exists in small patches within an urban matrix, with the result that Cactus Wren populations are small and geographically isolated from one another. This puts Cactus Wrens at risk of multiple biotic and abiotic threats to continued persistence, which is the focus of the analyses described herein.

Small, isolated populations, such as those of Cactus Wrens, are vulnerable to disruption of ecological and genetic processes that can reduce long-term viability. Small populations are vulnerable to stochastic events that can result in local extinctions, and spatial isolation can impede dispersal and recolonization of unoccupied habitat (Barr et al., 2015). Moreover, spatial isolation can reduce gene flow needed to maintain genetic diversity and capacity to adapt to changing conditions (Barr et al., 2015; Vandergast et al., 2022).

While Cactus Wren distribution and abundance are largely a consequence of habitat fragmentation resulting from urbanization, other threats are emerging as major drivers of habitat condition and availability. Wildfires are an increasing threat to remaining coastal sage scrub in San Diego County, further reducing suitable habitat for Cactus Wrens (Mitrovich and Hamilton, 2007; Preston and Kamada, 2012; Barr et al., 2015; Preston et al., 2022). Depending on their intensity, wildfires cause immediate habitat loss that requires decades to recover, and with this slow recovery can produce longer-term effects associated with post-fire invasion of non-native annual vegetation which reduces suitability for wrens and increases future fire risk (D'Antonio and Vitousek, 1992; Minnich and Dezzani, 1998; Mitrovich and Hamilton, 2007; Talluto and Suding, 2008; Fleming et al., 2009; Keeley et al., 2011). Drought, particularly prolonged drought, reduces native vegetation cover and condition, and likely reduces arthropod food resources (Preston and Kamada, 2012). Future climate projections for California predict warmer and drier conditions with more frequent, intense, and prolonged droughts, exacerbating the frequency and intensity of wildfires (Diffenbaugh et al., 2015).

Habitat availability, dispersion, and condition, as well as weather, interact to affect demographic processes that ultimately determine Cactus Wren persistence. In particular, annual survival and productivity of wrens are influenced by weather, likely through indirect effects on vegetation condition and food availability (see below). Productivity is a determinant of population growth and expansion, which is limited by the dispersal capabilities of wrens relative to the configuration of habitat patches and connections between them (see below). These inter-relationships provide the basis for identifying strategies to conserve and manage cactus scrub habitat to promote Cactus Wren persistence.

Cactus Wren Occupancy, Distribution, and Abundance

Regional monitoring of Cactus Wren populations is conducted annually in western San Diego County using standardized wren survey and habitat assessment protocols at established

sampling locations (https://sdmmp.com/view_project.php?sdid=SDID_201612021615.34). Cactus scrub locations were surveyed annually between 2015 and 2022 to determine Cactus Wren presence-absence ("occupancy") and abundance, measured as the number of territories detected (Lynn et al., 2022; Lynn and Kus 2021, 2022, 2023). Plots were visited twice between April and July by surveyors using call playbacks to enhance wren detectability. Occupancy provides information on the dispersion of wrens across the landscape, while abundance provides a more refined metric of population size that allows for instances where a cactus scrub plot includes more than one wren territory, or a wren territory spans more than one plot.

We consider two datasets when evaluating Cactus Wren occupancy and abundance. To document population trends, we analyze only plots that were surveyed every year between 2015 and 2022 (except 2016, when there were no surveys). However, the number of plots surveyed in a given year may exceed the number surveyed every year because new plots were added periodically when wrens were detected outside of established plots. Although not appropriate for trend analyses, these additional plots provide useful information on the status of Cactus Wrens in the study area, and we thus present results for "all plots" in addition to those surveyed every year.

Occupancy varied across the study area (fig. 4). By far the highest occupancy was observed at northern locations in the San Pasqual cluster, where wrens were present at more than 80 percent of all plots (fig. 4) and at all eight locations (fig. 8). In contrast, occupancy was lowest in the southernmost cluster (Otay) at approximately 20 percent of plots (fig. 4) and only 57 percent of locations (fig. 8). Occupancy in the Lake Jennings and Sweetwater/Encanto clusters was intermediate, at approximately 40 percent.

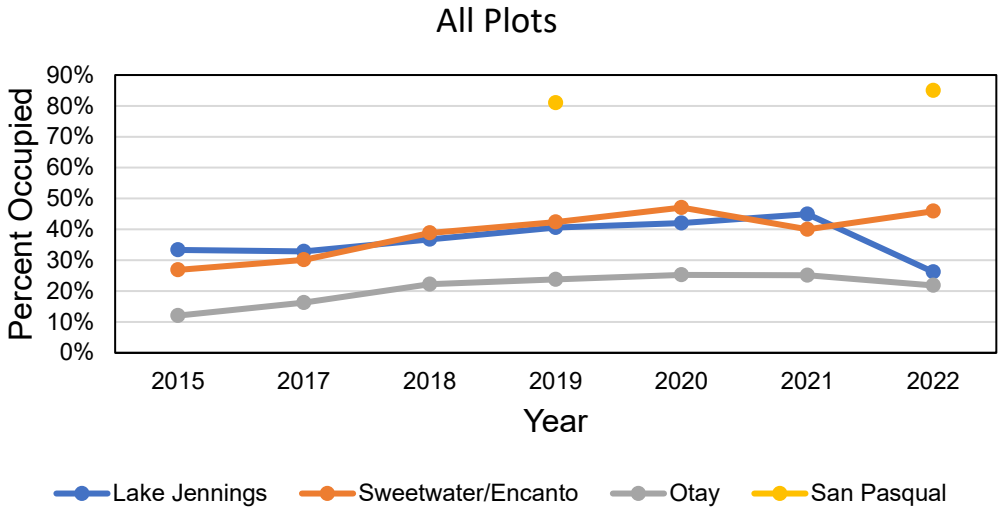


Figure 4. Percent of plots occupied by Cactus Wrens by year and cluster for all plots surveyed each year (2015, 2017-2022). See Appendix 2, Table 2.1 for number of plots surveyed and occupied. Sources: Lynn and Kus 2021, 2022, 2023; Lynn et al., 2022.

Cactus Wren populations in three of the four genetic clusters increased between 2015 and 2022 (fig. 5). The most dramatic increase occurred in the Sweetwater/Encanto cluster, where occupancy of plots surveyed every year doubled from 27 percent in 2015 to 54 percent in 2022 (fig. 5, fig. 8). Population expansion, while more modest, also occurred at the Otay cluster, where occupancy grew from 12 percent to 20 percent during the same period. Although an increase in occupancy at the Lake Jennings cluster was observed between 2019 and 2020, this increase was not sustained, and by 2022 occupancy was lower than it had been in 2015. A comparison for these years between plots surveyed every year (fig. 5) and all plots (fig. 4) reveals that overall occupancy in the Lake Jennings cluster is higher than that shown in Figure 4, suggesting that wrens may be shifting their distribution; nevertheless, wren occupancy by both estimates declined in 2022. Although only surveyed twice, occupancy at San Pasqual locations increased slightly from 81 percent in 2019 to 85 percent in 2022.

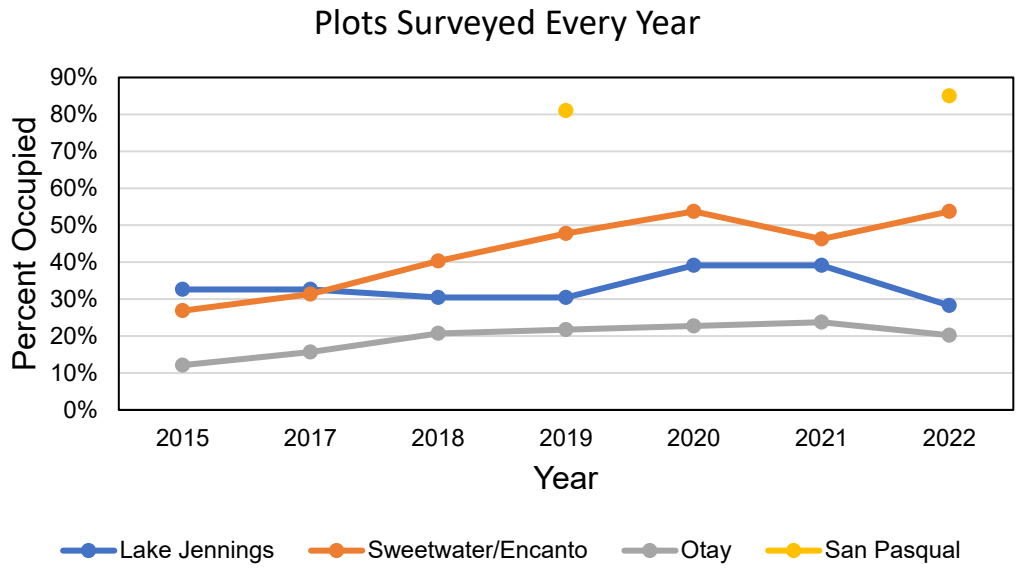


Figure 5. Percent of plots occupied by Cactus Wrens by year and cluster for plots that were surveyed every year (2015, 2017–2022). See Appendix 2, Table 2.2 for number of plots surveyed and occupied. Sources: Lynn and Kus 2021, 2022, 2023; Lynn et al., 2022.

As with occupancy, Cactus Wren abundance was highest in the San Pasqual cluster, where the number of territories in 2019 and 2022 was at least twice as high as at the three southern clusters (fig. 6). Across all plots, numbers of wren territories in each of the three southern clusters ranged from a low of 10-20 to a high of 30-45. Cactus Wren abundance increased between 2015 and 2022 at all but the Lake Jennings cluster (fig. 7), similar to the trend seen for occupancy (fig. 5). This increase was attributable to population growth in 2020 following a wet winter preceding the 2019 breeding season, and to a lesser extent, growth in 2018 following a wet winter preceding the breeding season of 2017. Cactus Wren abundance was highest in the Otay cluster, in contrast to occupancy, which was the lowest of the three southern clusters (fig. 5, fig. 8). This indicates that wren population growth in that cluster is occurring as populations expand within occupied locations rather than through expansion into unoccupied cactus scrub. In contrast, occupancy in the Sweetwater/Encanto cluster is the highest

among the three southern clusters (fig. 5, fig. 8), but abundance within each occupied location is low relative to the Otay cluster (fig. 7).

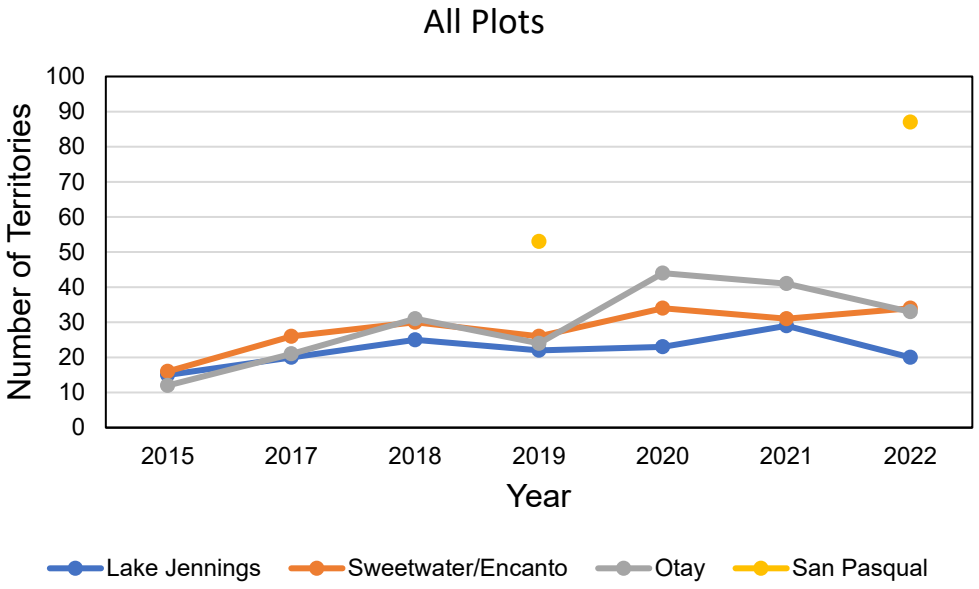


Figure 6. Number of Cactus Wren territories detected in plots by cluster and year for all plots surveyed each year (2015, 2017-2022). See Appendix 2, Table 2.1 for number of plots surveyed and occupied. Sources: Lynn and Kus 2021, 2022, 2023; Lynn et al., 2022.

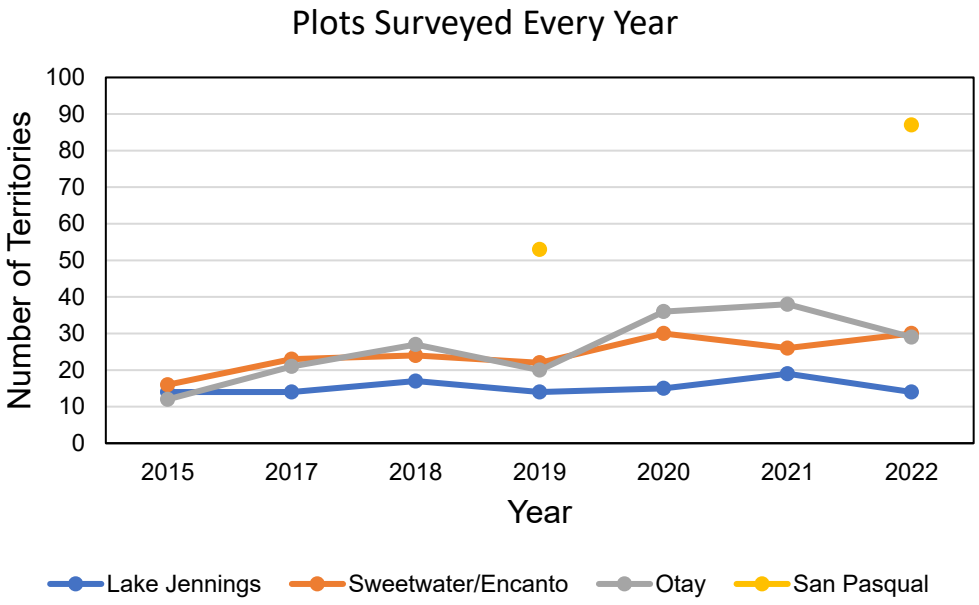
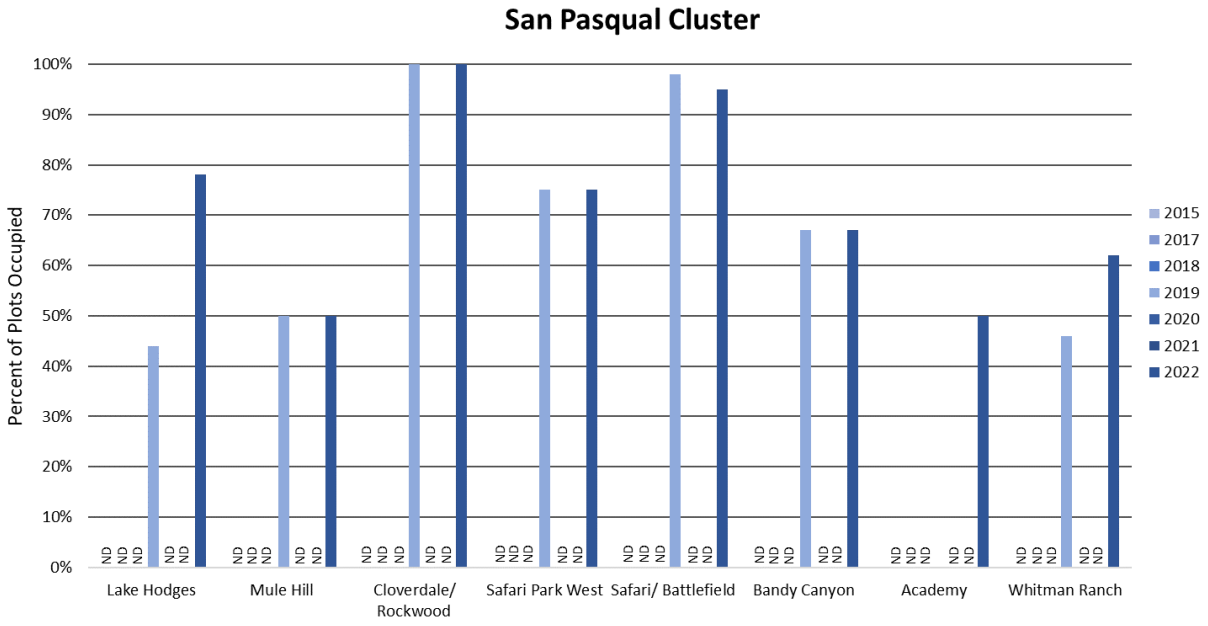
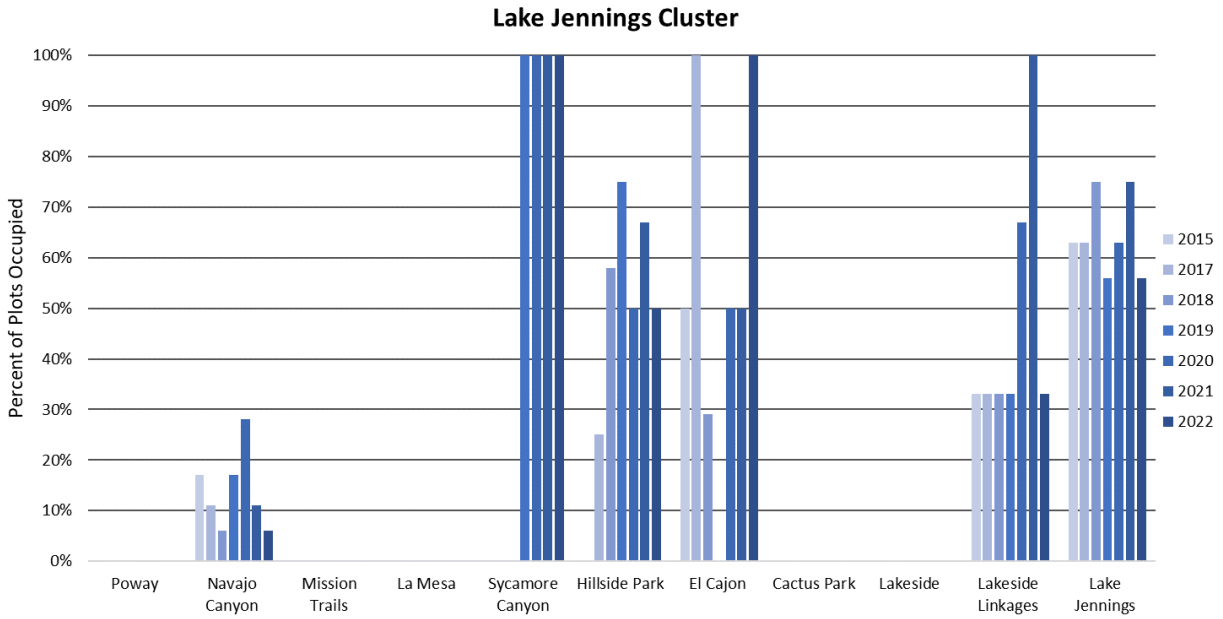


Figure 7. Number of Cactus Wren territories detected in plots surveyed every year (2015, 2017–2022) by cluster and year. See Appendix 2, Table 2.2 for number of plots surveyed and occupied. Sources: Lynn and Kus 2021, 2022, 2023; Lynn et al., 2022.


San Pasqual Cluster
Percent of Plots Occupied
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
ND
Lake Hodges
Mule Hill
Cloverdale/ Rockwood
Safari Park West
Safari/ Battlefield
Bandy Canyon
Academy
Whitman Ranch
2015
2017
2018
2019
2020
2021
2022


Lake Jennings Cluster
Percent of Plots Occupied
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Poway
Navajo Canyon
Mission Trails
La Mesa
Sycamore Canyon
Hillside Park
El Cajon
Cactus Park
Lakeside
Lakeside Linkages
Lake Jennings
2015
2017
2018
2019
2020
2021
2022

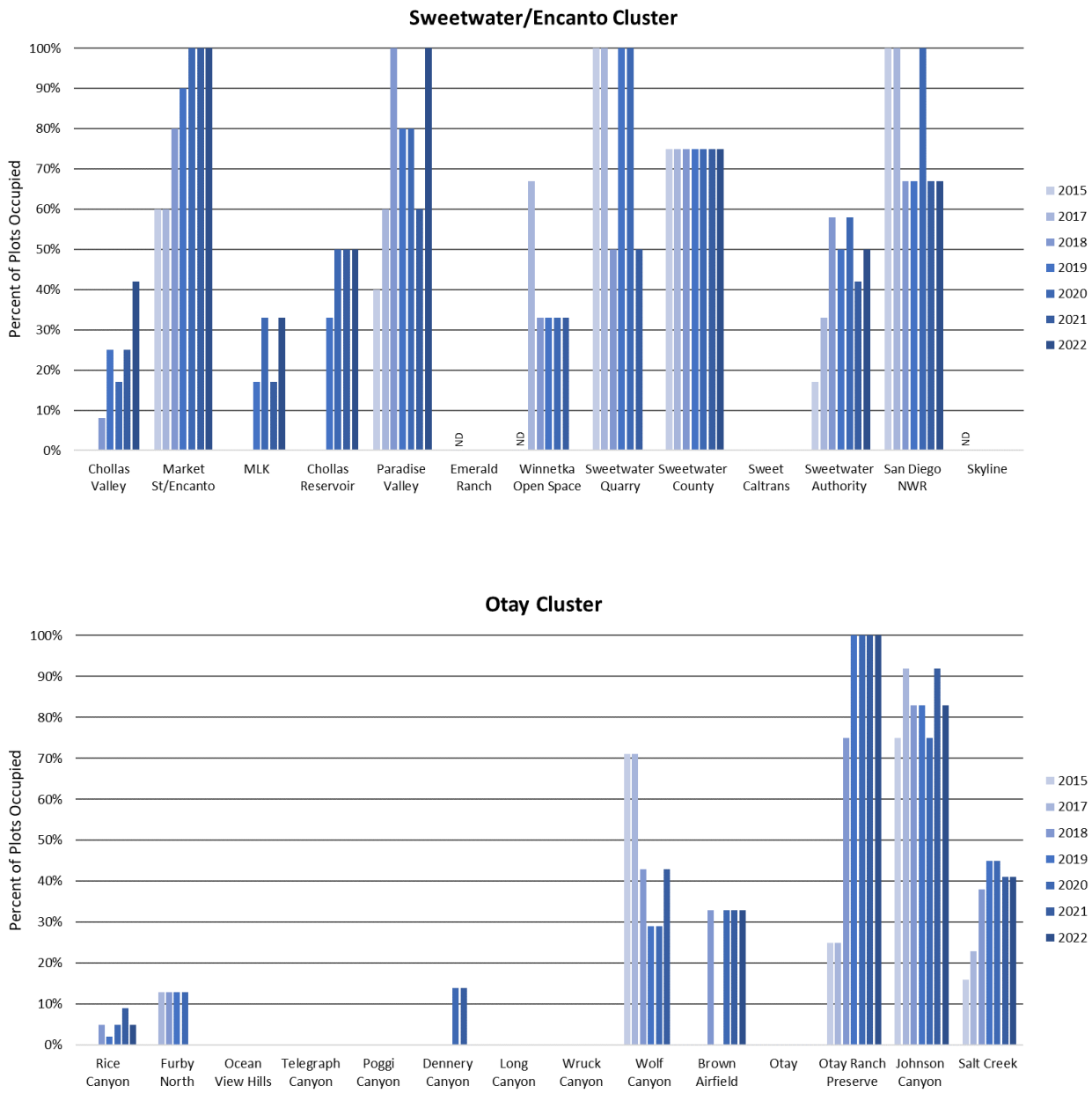


Figure 8. Percent of plots surveyed every year that were occupied by Cactus Wrens at locations in the San Pasqual, Lake Jennings, Sweetwater/Encanto, and Otay genetic clusters in San Diego County, California, 2015, 2017–2022. ND stands for "No Data". See Appendix 2, Table 2.2 for number of plots surveyed and occupied.

Total Cactus Wren abundance in the two years when all four clusters were surveyed ranged from 125 territories across all plots in 2019 to 174 in 2022, with over half the population in the San Pasqual cluster in both years. Overall, 30 percent of locations were never occupied by wrens between 2015 and 2022 (fig. 9). Based on the maximum population size observed at each location during this period, 73 percent of locations supported fewer than five territories. Twenty-

two percent of locations supported 5-14 territories, and only three locations supported more than this.

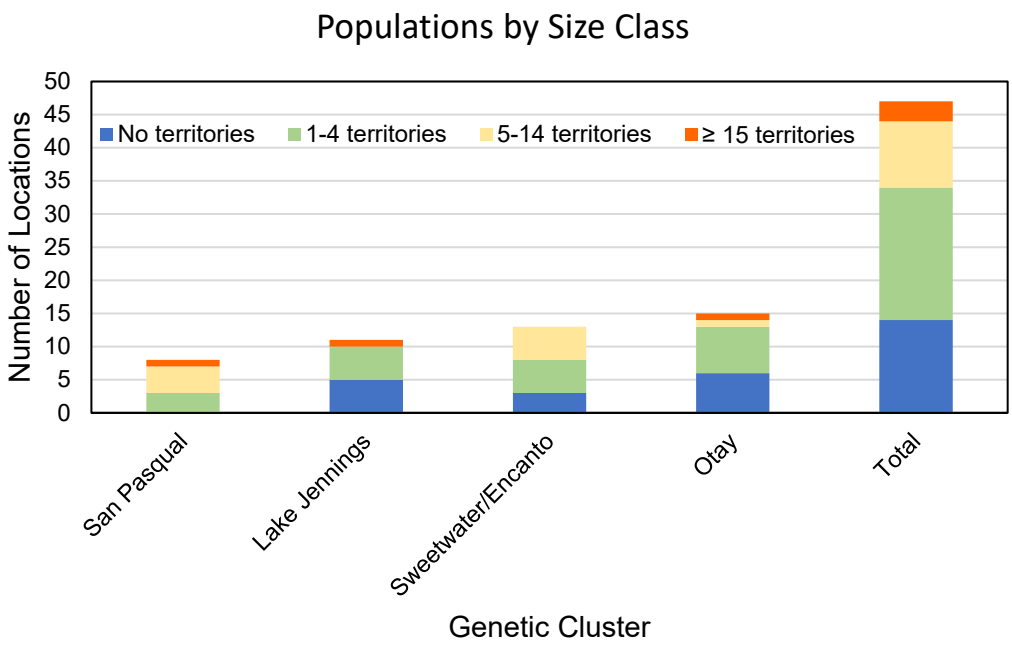


Figure 9. Cactus Wren population size classes for locations within genetic clusters on conserved lands in western San Diego County. The population size class is based on the maximum number of territories observed at a location from 2015 through 2022.

Cactus Wren Productivity, Survival, and Dispersal

Lynn et al. (2022) conducted a 5-year demographic study of Cactus Wrens to examine possible causes for population declines. Between March 2015 and July 2019, investigators monitored the nesting activities of wrens in two groups: the Otay group, including birds at Salt Creek and Johnson Canyon, where numbers had suffered recent declines, and the San Diego group, including Lake Jennings and Sweetwater locations where populations were relatively stable. The study focused on two primary determinants of population size: productivity and survival. Cactus Wren nests were located and monitored weekly to collect data on clutch size, nest success, and annual productivity of breeding pairs. Adults and nestlings were individually color banded with unique combinations to generate data on annual survival and dispersal. Vegetation data were collected in wren territories to analyze the effects of vegetation structure and composition on breeding productivity. The effects of precipitation on productivity, survival, and vegetation structure were assessed by comparing these parameters across years varying in annual rainfall (Lynn and others, 2022). Annual precipitation was calculated for the "bio-year" (July 1 - June 30) ending in the current breeding season year. The years 2015, 2016 and 2018 were considered "dry" years with bio-year precipitation below average, while 2017 and 2019

were “wet” years with above-average precipitation (National Oceanic and Atmospheric Administration, 2020).

Productivity

Between 46 and 74 nests were monitored annually within 10-13 territories in the Otay group and 14-18 territories in the San Diego group (Lynn and others, 2022). The number of nest attempts by Cactus Wren pairs in a given season ranged from zero to four and was influenced by precipitation; for every 1-cm increase in precipitation, there was a 1-percent increase in the number of nests per pair. Both clutch size and the percent of eggs that hatched were positively related to precipitation. The percent of nests that successfully fledged young ranged from 50 percent in 2015 (a dry year) to 72 percent in 2017 (a wet year) and increased significantly with annual precipitation. Cactus Wren pairs fledged from 0 to 12 young per year, with the average number of fledglings positively related to annual precipitation. The highest number of young fledged occurred in the wet years of 2017 and 2019, while the lowest was in 2018, an extreme dry year (fig. 10). Annual productivity was significantly higher in the Otay group than the San Diego group, suggesting that previous declines in the Otay cluster were not attributable to demographic failure.

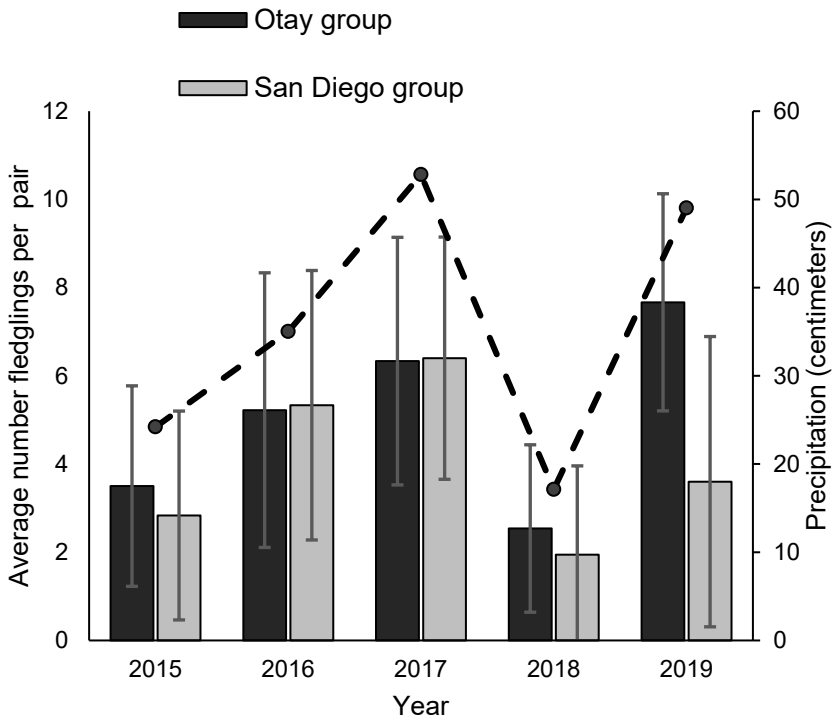


Figure 10. Average number of Cactus Wren fledglings per pair by year, group, and precipitation, southern San Diego County, 2015-2019. Bars represent standard deviations. Adapted from Lynn et al., 2022.

Survival

A total of 579 nestling Cactus Wrens and 50 adults were uniquely color banded between 2015 and 2019 (Lynn et al., 2022). Of these, 153 individuals were resighted during surveys and monitoring. Adult annual survival ranged from 60 to 70 percent and was approximately twice as high as that of first-year birds (20-28 percent), as is typical of songbirds. Survival of both age classes was weakly correlated with precipitation in the previous bio-year, primarily the result of a decline in survival between 2018 and 2019 following an extreme dry year. Cactus Wren survival appears to be less affected by precipitation than is productivity except under extreme dry conditions.

Dispersal

Adult Cactus Wrens monitored between 2015 and 2019 exhibited high territory fidelity, with 87 percent overall remaining in the same territory from year to year (Lynn et al., 2022). Adults in the San Diego group that did move between years generally moved short distances averaging 0.2±0.1 miles (0.3±0.2 km). Average distance moved by adults in the Otay group was higher (1.7±1.6 miles; 2.7±2.5 km) and more variable, with some wrens moving up to 3.5 miles (5.7 km) between years. Precipitation was a weak driver of adult movement, with adults more likely to remain in the same territory following wet bio-years.

First-year Cactus Wren dispersal distance between their natal sites and their first breeding territories was similar across the two groups, averaging 1.2±1.6 miles (1.9±2.6 km) in the Otay group and 1.0±1.6 miles (1.6±2.6 km) in the San Diego population (Lynn et al., 2022). Most dispersing first-year birds remained within their natal groups; however, five instances of dispersal between the Otay and San Diego groups were observed during the 5-year study, with distances moved of up to 7.8 miles (12.5 km; table 2). In a separate investigation, a bird banded as a nestling at Lake Jennings was detected as an adult in the San Pasqual Valley, a distance of 16.4 miles (26.4 km; Lynn et al., 2022).

Table 2. First-year Cactus Wren dispersal between natal and adult populations, southern San Diego County, 2015-2019. From Lynn et al., 2022.

Years	Natal site, population	Adult site, population	Sex	Distance moved (kilometers)
2015–16	Johnson Canyon, Otay	Sweetwater, San Diego	F	11.0
2016–17	Sweetwater, San Diego	Salt Creek, Otay	F	9.9
2017–18	Sweetwater, San Diego	Johnson Canyon, Otay	M	12.5
2017–18	Sweetwater, San Diego	Salt Creek, Otay	M	10.3
2017–18	Sweetwater, San Diego	Salt Creek, Otay	F	8.0
2018–19	Lake Jennings, San Diego	San Pasqual Valley, San Pasqual Valley	F	26.4

Vegetation Composition

Vegetation data were collected annually at permanent plots consisting of 30 sampling points within a 60 x 70 m grid within 23 Cactus Wren territories (Lynn et al., 2022). Presence or absence at each point was recorded for three herbaceous species (native bunch grasses, non-native annual grasses, and mustard [*Brassica nigra*]), five shrub species (cactus, blue elderberry

["elderberry"; *Sambucus nigra* spp. *Cerulea*], lemonade berry [*Rhus integrifolia*], California sagebrush ["sagebrush"; *Artemisia californica*], California buckwheat ["buckwheat"; *Eriogonum fasciculatum*), and for bare ground. Percent cover of each species was calculated as the percent of the 30 points at which the species was present. Overall, most of the cover in wren territories was made up of cactus, sagebrush, buckwheat, and non-native grasses, while cover of elderberry, lemonade berry, and native bunch grasses was low. Cover of bare ground varied annually and was lowest in wet years. Vegetation composition varied across territories and influenced Cactus Wren productivity. Cover of sagebrush had a positive effect on the number of young fledged per pair, while cover of non-native grasses and mustard had negative effects. Vegetation composition also varied across years, particularly that of non-native grasses and mustard, reflecting the effects of precipitation on cover of herbaceous vegetation. This interannual variation challenges attempts to differentiate between the overall positive effect of precipitation on productivity (see above) and the effects of vegetation, which varied from year to year. When years were analyzed separately, the negative effects of non-native grasses and mustard cover were found in three of the five years, suggesting that these effects are separate from those of precipitation. However, compared to vegetation effects, the effect of precipitation on productivity was 2.6 times stronger, indicating that other factors, such as prey availability, are contributing to the effect.

Cactus Wren Diet and Food Availability

Diet Analysis and Prey Availability

Two recent studies investigated Cactus Wren diet and arthropod prey availability by plant cover type in wren territories. Lynn et al. (2022) collected nestling fecal sacs produced during color banding and used DNA (deoxyribonucleic acid) barcoding to identify prey taxa in the diet. In 2016, pitfall traps and vacuum sampling were used to assess arthropod availability by vegetation type in 23 Cactus Wren territories in the Otay and San Diego populations. The most abundant arthropod order in vegetation samples was Hymenoptera, which made up 36 percent of total individuals, followed by Isopoda, Diptera, Coleoptera, and Hemiptera. Of the 29 arthropod families identified in their diet, Cactus Wrens avoided ants (Hymenoptera Formicidae) and woodlice (Isopoda Porcellionidae); all other families were consumed in proportion to their availability in territories. Within the Cactus Wren diet, Diptera were the most abundant order, followed by Coleoptera, Hemiptera, Hymenoptera, and Araneae. Arthropod abundance varied among plant cover types, but the differences were minor, and plant cover type by itself was not a significant predictor of arthropod abundance. Rather, plant cover type interacted with sampling period such that arthropod abundance was highest in the early (courtship, nest building, egg laying; February-early March) and peak (feeding nestlings; May-June) Cactus Wren nesting seasons and lowest in the late nesting season (feeding fledglings, independent fledglings; September; fig. 11). During the early season, arthropods were most abundant in native bunch grass and elderberry, both of which were uncommon in wren territories, while in the late season, arthropod abundance was highest in elderberry and non-native grass and lowest in lemonade berry and mustard. Although non-native grass supports prey abundance comparable to that in other studied plant cover types, wren foraging success may be hampered by dense thatch making prey less available for consumption. During the peak nesting season, native bunch grass and to a lesser extent, bare ground supported the highest arthropod abundance, and cactus and elderberry supported the lowest. Thus, it appears that a mix of vegetation types differing in the seasonality

of prey availability, as well as bare ground, provides the most stable food resource for breeding Cactus Wrens.

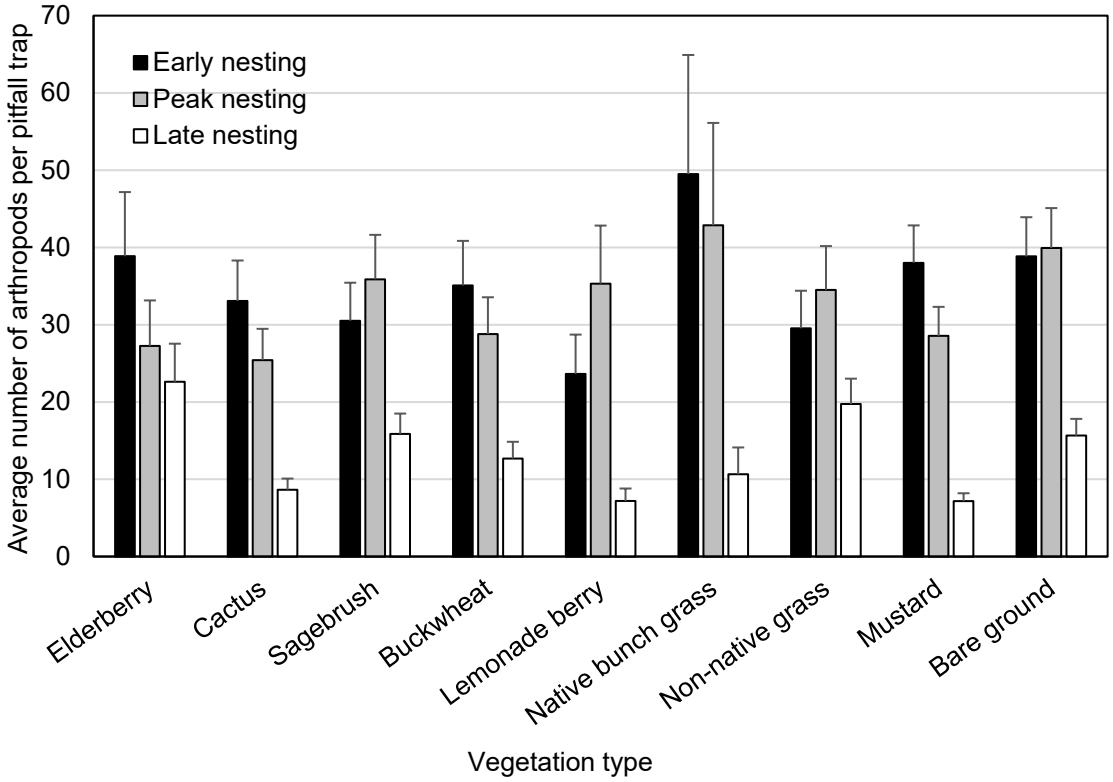


Figure 11. Mean number of arthropod prey collected in pitfall traps by sampling period and vegetation type, southern San Diego County, 2016. Bars represent standard errors. From Lynn et al., 2022.

In a similar study in Orange County, Nell et al. (2023) compared arthropod availability in territories to that in the Cactus Wren diet, and used arthropod-plant species associations to estimate prey availability in territories. As in the San Diego study (Lynn et al., 2022), Hymenoptera and Isopoda made up most of the arthropod biomass on the ground, while Diptera and Lepidoptera were the most represented orders in the diet, occurring in much higher proportion than in the environment. Diptera abundance was highest on sagebrush, buckwheat, and cactus, while Lepidoptera were most commonly sampled from buckwheat and mustard. Although not a major prey item, Hymenoptera biomass in territories was positively related to the lay date of the pair's first egg, a metric correlated with reproductive performance. Earlier nest initiation allows for a longer breeding season with time for multiple nests, which increases the number of young fledged. Thus, high Hymenoptera biomass, primarily non-native Argentine ants (*Linepithema humile*) delayed the onset of nesting and had a negative effect on reproductive performance. Similarly, high biomass of the non-native pillbug (*Armadillidium vulgare*) delayed reproduction. These invasive arthropods are found near urban edges and modified habitats with high soil moisture (Menke et al., 2007; Warburg, 1987).

Population Genetic Structure and Diversity

Research on the genetic structure and diversity of southern California Cactus Wren populations has provided a valuable supplement to ecological studies investigating the nature and extent of threats facing a species occupying a fragmented landscape. Barr et al. (2015) analyzed tissue samples from 371 individuals at virtually every known Cactus Wren aggregation in coastal southern California, and documented a high degree of genetic structure mirroring underlying land-use and cactus scrub habitat configuration. Throughout the range, 12 genetic clusters, 5 of which occur in San Diego County (fig. 1), were identified; further separation within clusters revealed a total of 20 populations with low connectivity among them. Genetic differentiation was higher in habitat fragmented by urbanization than in contiguous habitat, and increased with distance between fragments. Within populations, allelic richness, a measure of genetic diversity, was positively related to amount of suitable habitat. In some cases, differentiation occurred over small spatial distances; for example, the distance between the genetically distinct Otay and Sweetwater populations is less than 10 km, but recent urbanization has created a barrier limiting dispersal between them. Wildfire during the past few decades has exacerbated the loss of connectivity among populations, and genetic bottlenecks were detected in areas with high fire frequency.

Recently, Vandergast et al. (2022) revisited four genetic clusters in San Diego County previously analyzed by Barr et al. (2015) to test for changes in genetic diversity. Analysis of tissue samples collected 6-8 years after the original study revealed that indices of genetic diversity were stable with the exception of the San Pasqual cluster, where heterozygosity was lower and inbreeding higher, and the Sweetwater/Encanto cluster, where allelic richness was nearly 10 percent lower in 2017 than in 2011. Moreover, effective population size had declined significantly at the Sweetwater/Encanto cluster, and showed a downward trend at the Otay and San Pasqual clusters, but a slight increase at the Lake Jennings cluster. Effective population size in 2017, as in 2011, remained below 100 individuals in all clusters.

Dispersal of Cactus Wrens was inferred from 16 family groups in the 2017 dataset with individuals sampled in different territories. With two exceptions, dispersal only occurred within genetic clusters, where it ranged from 0.2 to 3.7 miles (0.2 to 6.0 km), consistent with observations of dispersal by color banded birds (Lynn et al., 2022). Two individuals of mixed ancestry were detected in 2017, revealing gene flow between the San Pasqual and Lake Jennings clusters, and between the Otay and Sweetwater/Encanto cluster, again reflecting patterns based on intensive monitoring of banded birds (see above).

Overall genetic structure in 2017 was unchanged from that in 2011 with the exception that Lake Jennings and Sweetwater/Encanto formed a single cluster under the best model, differentiated from the San Pasqual and Otay clusters. While an encouraging sign that connectivity has improved recently, Vandergast et al. (2022) predict, based on simulations, that gene flow and population size are still insufficient to prevent future loss of genetic diversity by random genetic drift. In simulations, translocation of individuals between populations slowed the loss of heterozygosity. This suggests that assisted gene flow through active management coupled with habitat restoration to facilitate dispersal could reduce genetic differentiation among Cactus Wren populations across the entire San Diego region.

Cactus Scrub Habitat Condition

Habitat condition was assessed annually at plots surveyed for Cactus Wrens using a regional monitoring protocol for cactus scrub habitat data collection as described here (https://sdmmp.com/view_project.php?sdid=SDID_201612021615.34). Six metrics associated with habitat quality (TNC and SDMMP, 2015) were recorded:

1. Species of top two dominant non-cactus shrubs or trees
2. Presence or absence of elderberry
3. Percent of cactus overtopped or crowded by shrubs or vines (hereafter "shrub crowding")
4. Percent of cactus that was dead
5. Percent of cactus that was unhealthy
6. Percent of the plot that was covered by non-native annual plants

Metrics 3-6 were visually estimated and assigned to one of seven categories: 0 percent, < 1 percent, 1-5 percent, >5-25 percent, >25-50 percent, >50-75 percent, and >75 percent. We summarize habitat condition at cactus scrub locations in 2022 based on these metrics, and analyze Cactus Wren occurrence at plots relative to habitat condition.

Dominant Shrub and Tree Species

Overall, common coastal sage scrub shrub species were the dominant or co-dominant species at most of the plots (table 2), including California sagebrush, California buckwheat, lemonade berry, jojoba (*Simmondsia chinensis*), and San Diego County sunflower (*Bahiopsis laciniata*; Lynn and Kus 2023). San Pasqual locations differed from the other three clusters in the predominance of sagebrush and buckwheat, and the relatively high occurrence of laurel sumac (*Malosma laurina*), which was dominant in 20 percent of plots. In contrast, Otay plots included more lemonade berry and jojoba, while Lake Jennings supported more broom baccharis (*Baccharis sarothroides*) than plots in other clusters.

Table 3. Dominant and co-dominant shrubs at Cactus Wren survey plots in 2022. Proportion of plots within the cluster containing the plant species is shown in parentheses. A plot may have more than one co-dominant plant species so proportions do not add to 1. Dash (-) means not present. Only plant species dominant or co-dominant in at least 1 percent of total plots are shown. Number of plots sampled: Otay cluster: 209, Lake Jennings cluster: 87; Sweetwater/Encanto cluster: 100, San Pasqual cluster: 111. Adapted from Lynn and Kus, 2023.

	Number of Plots				
Dominant shrub species	Otay cluster	Lake Jennings cluster	Sweetwater/ Encanto cluster	San Pasqual cluster	Total
California sagebrush	131 (0.63)	55 (0.63)	65 (0.65)	74 (0.67)	325 (0.64)
California buckwheat	42 (0.20)	31 (0.36)	21 (0.21)	87 (0.78)	181 (0.36)
Lemonade berry	57 (0.27)	11 (0.13)	13 (0.13)	–	81 (0.16)
Jojoba	68 (0.33)	–	13 (0.13)	–	81 (0.16)
San Diego sunflower	32 (0.15)	11 (0.13)	13 (0.13)	–	56 (0.11)
Broom baccharis	4 (0.02)	28 (0.32)	14 (0.14)	–	46 (0.09)
Laurel sumac	–	12 (0.14)	7 (0.07)	22 (0.20)	41 (0.08)
San Diego bursage (*Ambrosia chenopodiifolia*)	12 (0.06)	–	–	1 (0.01)	13 (0.03)
Bush sunflower (*Encelia californica*)	10 (0.05)	–	1 (0.01)	3 (0.03)	14 (0.03)
Black sage (*Salvia mellifera*)	–	5 (0.06)	2 (0.02)	–	7 (0.01)

Presence of Elderberry

Although not a dominant species in cactus scrub plots, the presence of elderberry influenced occupancy by Cactus Wrens. Observations suggest that elderberry might enhance habitat suitability by providing perches for territorial advertising, cover for fledgling wrens, and serve as a source of arthropod prey (Winchell et al., 2021; Nell et al., 2023). In 2022, elderberry was present in 39 percent of cactus plots across the four clusters but was present in 57 percent of plots occupied by wrens. Cactus Wrens occupied 61 percent of plots with elderberry in contrast to 30 percent of plots without it, a difference that was statistically significant (Lynn and Kus, 2023).

Shrub Crowding

Many cactus scrub locations throughout southern California are experiencing shrub crowding, whereby cactus is overtopped or crowded by vines and shrubs such that it becomes inaccessible to Cactus Wrens (fig. 12; TNC and SDMMP, 2015). This crowding can cause competition for light and water resources and can result in cactus die-back or desiccation. A previous assessment of cactus scrub habitat (TNC and SDMMP, 2015) found that sagebrush, lemonade berry and California buckwheat were among the most common species for shrub

crowding and overtopping; these are also the species found in 2022 to be the most common dominant shrubs in plots across the four clusters (table 2).

Figure 12. Shrub crowding at Chollas Creek, San Diego County (photographed by Suellen Lynn).

Shrub crowding in 2022 was variable across the four clusters (fig. 13). Crowding was comparatively low at San Pasqual locations, and highest in the Lake Jennings and Otay clusters. Overall, shrub crowding exceeded 5 percent in 79 percent of 507 plots (fig. 13; Lynn and Kus, 2023). Cactus Wrens occupied 61 percent of plots where 5 percent or less of the cactus was crowded compared to 37 percent of plots where crowding was greater than 5 percent (fig. 14; Lynn and Kus, 2023).

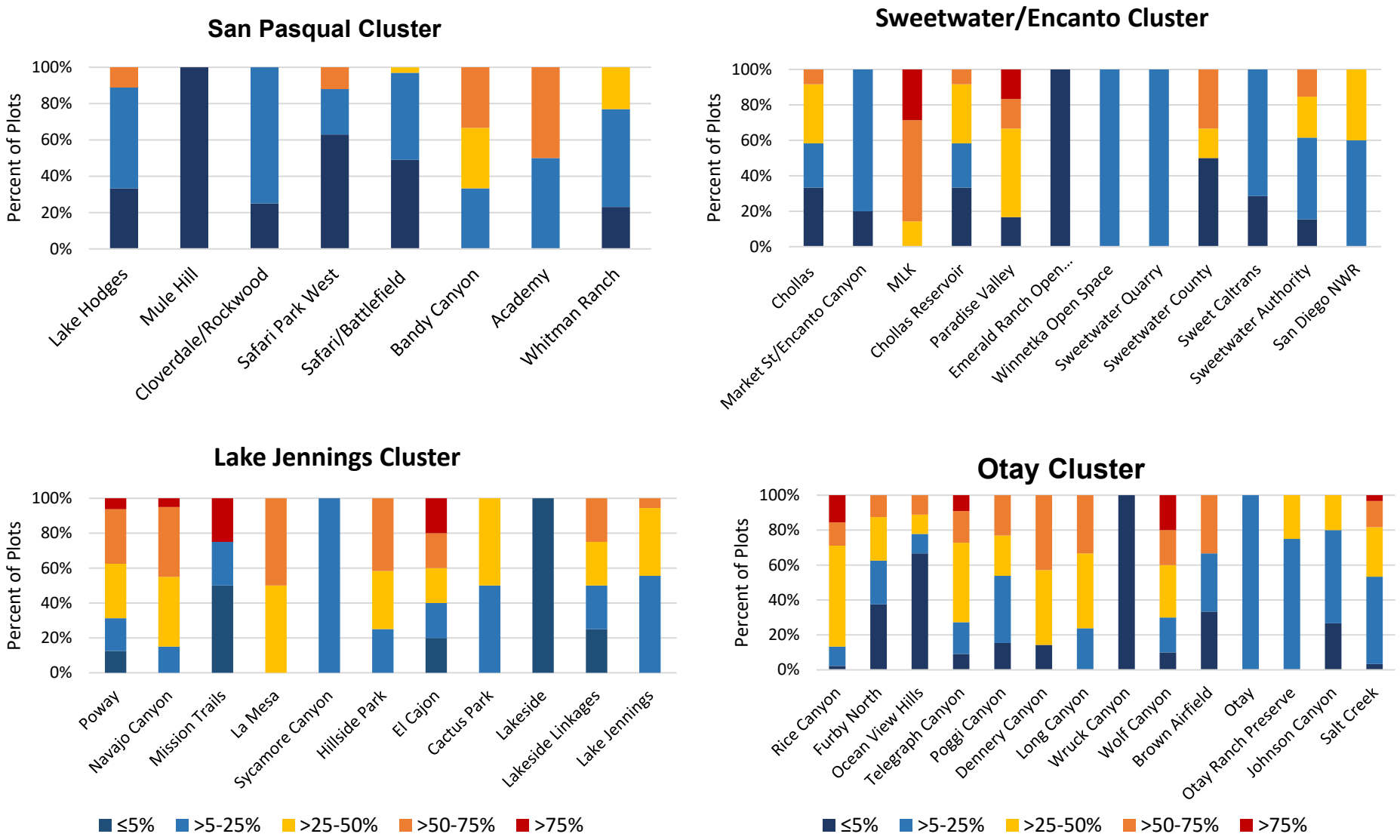


Figure 13. Percent of plots with different cover categories of shrub crowding assessed in 2022 and arranged by genetic cluster and survey location, San Diego County, California.

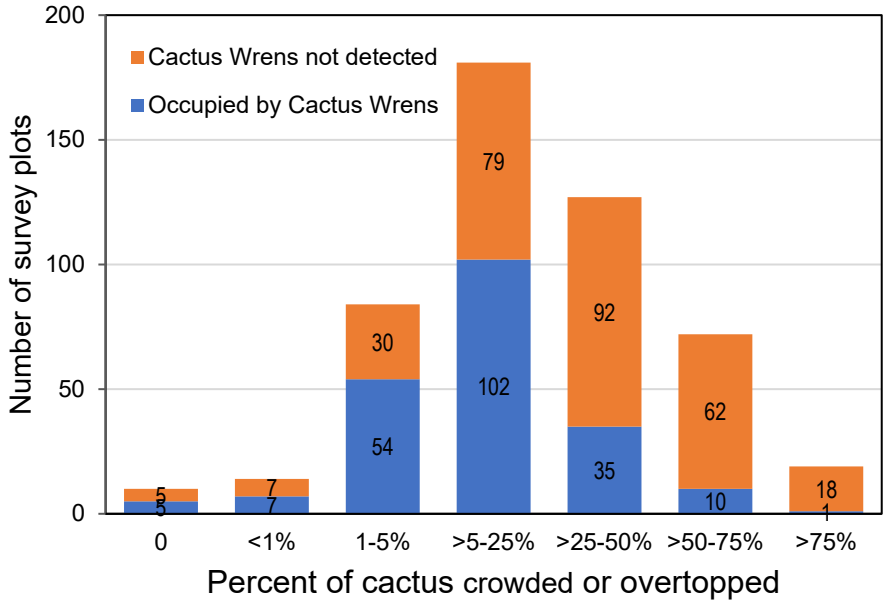


Figure 14. Number of plots occupied by Cactus Wrens by the percent of cactus that was crowded or overtopped by vines and shrubs, San Diego County, 2022. From Lynn and Kus, 2023.

Unhealthy and Dead Cactus

Cactus die-back and desiccation have been noted in the past few decades throughout southern California (fig. 15), likely in response to prolonged multi-year drought. This drought stress is brought on by low precipitation and elevated temperatures, and may be exacerbated by resource competition associated with shrub crowding and invasive plants (TNC and SDMMP, 2015). Cactus die-off can also be related to disease, such as fungal pathogens, and to wildfire.

Figure 15. Left: Unhealthy cactus at Chollas Creek, San Diego County (photographed by Suellen Lynn). Right: Dead cactus at Otay River Valley (photographed by Trish Smith).

Very little unhealthy or dead cactus was observed at cactus scrub plots in 2022 (figs. 16 and 17). No definitive signs of fungal pathogens were observed on cactus within and around survey plots during the surveys in 2022 (Lynn and Kus, 2023). Eighty percent of plots across the four clusters had less than 5 percent unhealthy cactus, and 78 percent of plots had less than 5 percent of dead cactus (Lynn and Kus, 2023). No difference in occupancy by wrens was observed between plots with less than versus greater than 5 percent unhealthy cactus; however, wrens preferentially occupied plots with fewer dead cactus (Lynn and Kus, 2023).

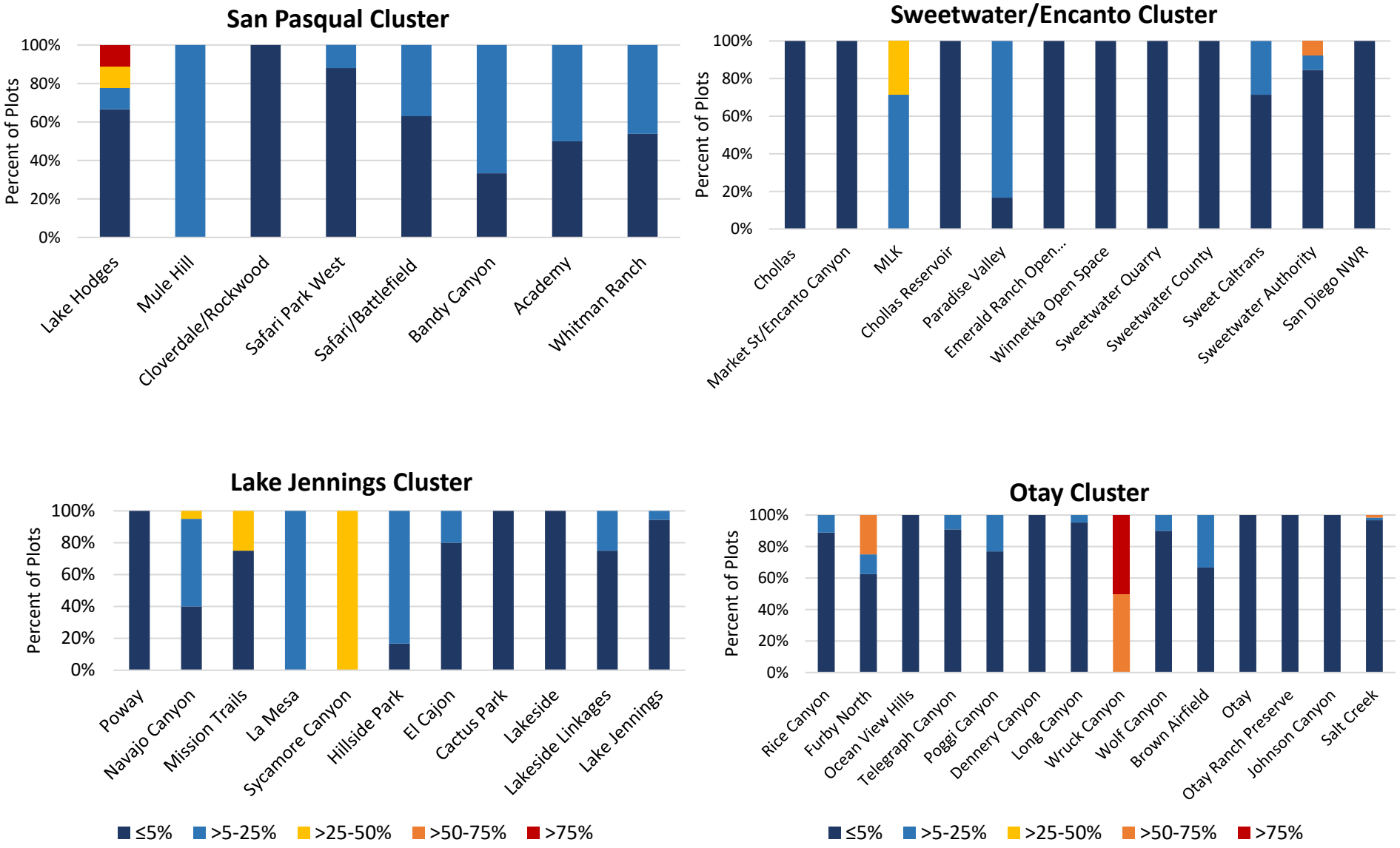


Figure 16. Percent of plots with different cover categories of unhealthy cactus assessed in 2022 and arranged by genetic cluster and survey location, San Diego County, California.

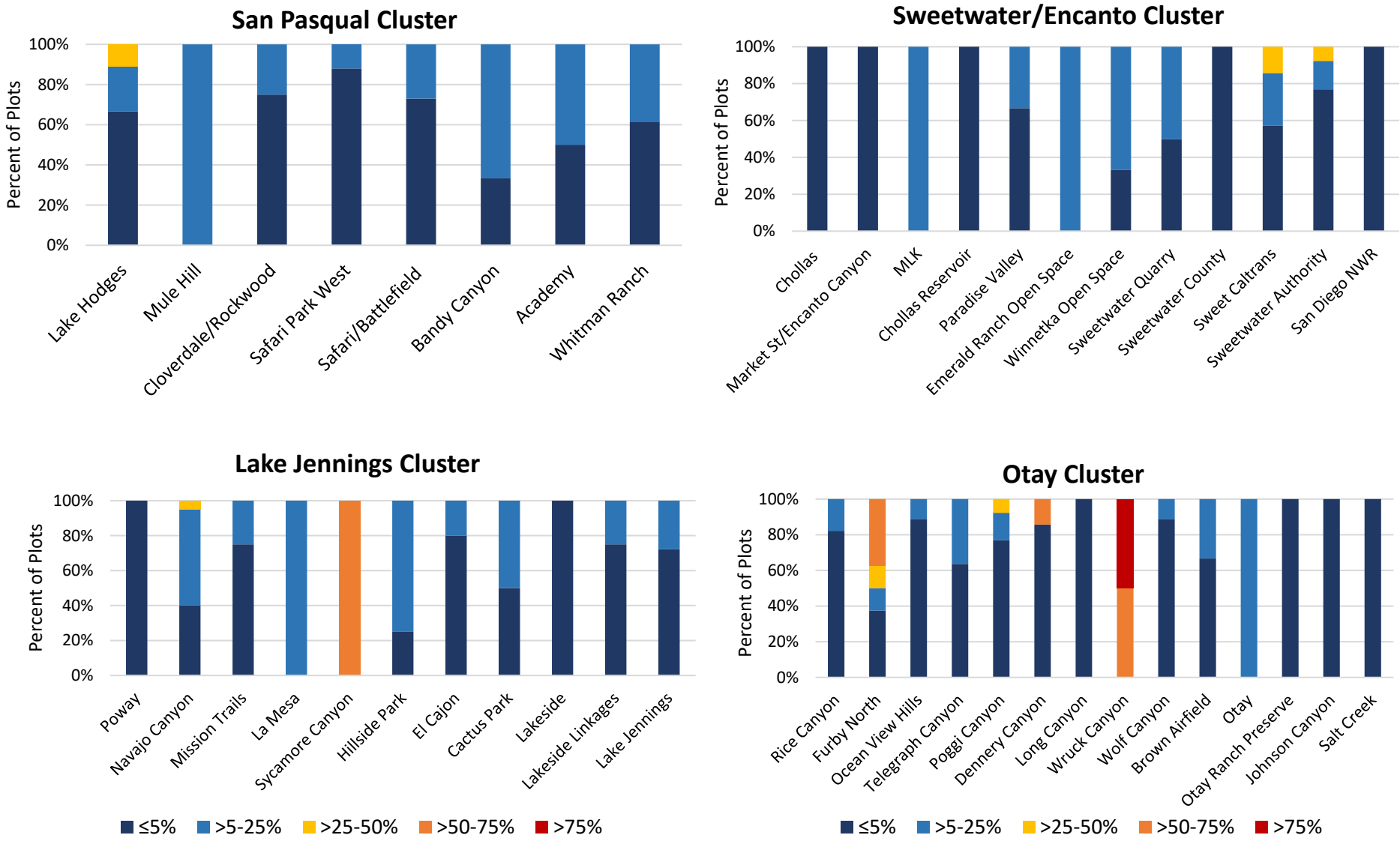


Figure 17. Percent of plots with different cover categories of dead cactus assessed in 2022 and arranged by genetic cluster and survey location, San Diego County, California.

Non-native Annuals

Non-native grasses and forbs can become established where cactus is sparse and bare ground is extensive (fig. 18). Cactus scrub is vulnerable to invasion of non-native grasses and forbs during drought as well as following wildfire. Non-native grasses and forbs may compete for water and nutrients, affecting cactus health, and also can create flashy fuels that can carry a wildfire. Preston and Kamada (2012) hypothesized that a dense cover of non-native plants creates unsuitable ground foraging conditions for Cactus Wrens.

Figure 18. Non-native invasive plants in cactus scrub at Dennery Canyon, San Diego County (photographed by Suellen Lynn).

Cover of non-native grasses and forbs in cactus plots was 5 percent or less at 48 percent of plots, and was less than 25 percent at 88 percent of plots (fig. 19). Cactus wren occupancy did not differ among plots with more or less than 5 percent cover of non-natives (Lynn and Kus, 2023).

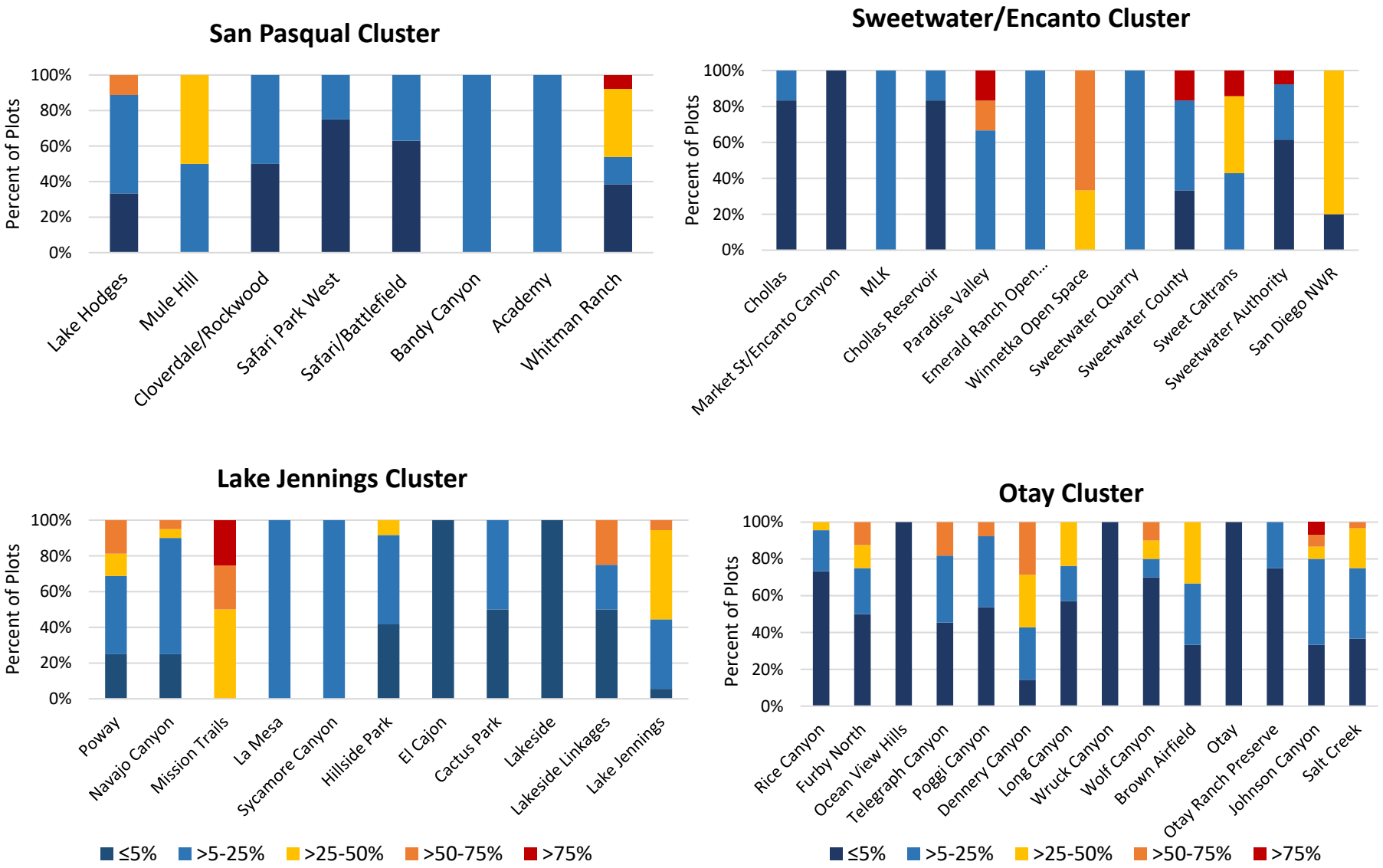


Figure 19. Percent of plots with different cover categories of non-native annuals assessed in 2022 and arranged by genetic cluster and survey location, San Diego County, California.

Summary of Regional Cactus Scrub Habitat Restoration Efforts

Habitat management to increase Cactus Wren populations and improve connectivity consists of enhancing existing cactus scrub, restoring existing and historic cactus scrub, and expanding cactus scrub. Cactus scrub is coastal sage scrub or maritime succulent scrub that contains cactus plants. Historic cactus scrub is defined as no longer supporting cactus but either had mapped cactus in the past or was previously occupied by wrens. Historic cactus scrub may have been altered by fire, drought, or clearing and could be replanted to become cactus scrub again.

Cactus scrub enhancement improves the quality of cactus scrub by reducing cover of non-native annual grasses and forbs, removing thatch, and thinning shrubs and vines that overtop and crowd cactus. Enhancement does not include seeding or planting cactus or other native plants. Restoration involves planting rooted cactus and cactus propagules (i.e., pads and segments) in cactus scrub or historic cactus scrub and may incorporate seeding or planting of other native shrubs, forbs and grasses. Restoration typically includes enhancement actions such as weed control before and after planting and seeding have taken place. Cactus scrub expansion is the creation of new cactus scrub and involves the same activities as restoration except it is conducted in areas with no previous record of cactus scrub or cactus wren occupancy. Sometimes a large location (e.g., Lake Hodges after a 2007 wildfire) may have a mixture of existing and historic cactus scrub as well as areas where wrens have never been mapped but where cactus scrub could be expanded. Differentiating between cactus scrub restoration and cactus scrub expansion can be complicated by the scale at which these activities are delineated.

From 2008 through 2023, there were one or more regionally funded projects and one mitigation project at 12 locations on conserved lands in western San Diego County that enhanced, restored or expanded cactus scrub and had Cactus Wren survey data available to assess bird use of the managed habitat (table 4). These projects increased existing Cactus Wren populations, aided in post-fire habitat recovery, and expanded stepping stone linkages to increase connectivity among wren populations. Collectively these projects spent over $3,039,285 to enhance, restore and expand 906 acres (367 ha) of habitat (table 4). The amount spent on habitat management does not include the cost of the California Department of Transportation's SR 905 and SR 125 mitigation project at Lonestar Ridge, which while focused on vernal pools and Quino checkerspot (*Euphydryas editha quino*) habitat creation planted cactus over a large area.

These restoration projects resulted in approximately 156 acres (63 ha) of habitat restoration and expansion and 753 acres (305 ha) of enhancement. Often projects planted clumps of cactus over large areas that were enhanced to control invasive nonnative plants and thinning of overgrown and overcrowded shrubs. The largest type of enhancement action was invasive nonnative plant control in existing and restored cactus scrub as well as in adjacent areas to reduce sources of invasive plant propagules (table 4). Over 400 acres of invasive plant management were conducted at the San Diego Zoo Safari Park in an intensive effort to control stinknet (*Oncosiphon piluliferum*). In addition, postfire invasive plant management was carried out in large areas of the San Diego National Wildlife Refuge and Lake Hodges. Shrub thinning was the second enhancement action that was implemented at locations such as Rice Canyon and Salt Creek.

These management efforts collectively added 49 new territories to San Diego County's wren population on conserved lands and improved habitat for 41 existing territories. While some of these new territories tended to persist for only a year or two, it is anticipated that as the wren population increases and cactus matures there will be greater use of restored habitat. The new Cactus Wren territories are important in initiating population recovery in areas burned by wildfire such as Lake Hodges (Bernardo Mountain), Bandy Canyon, Safari Park, and San Diego National Wildlife Refuge (NWR). These projects also helped to expand small or medium wren populations (i.e., Lakeside Linkage, Rice Canyon, Otay River Valley, Johnson Canyon) and to begin recovery of the Salt Creek population, which was historically much larger. The time period over which the regionally funded management projects were implemented between 2008 and 2022 ranged from 3 to 14 years, averaging 7 years duration.

These summary statistics underrepresent acres managed and Cactus Wren territories created for several projects that are either ongoing or for which we do not have acres of habitat managed or there are no Cactus Wren monitoring data. Funding sources included TransNet Land Management Grants, often coupled with matching land manager funds or in-kind contributions, and other grant programs.

Cactus plants can take many years to grow to sufficient size to support breeding wrens (Mitrovich and Hamilton, 2007). It is anticipated that as Cactus Wren populations grow under favorable environmental conditions and the managed habitat matures, additional territories will be added at these managed locations. Once cactus scrub has been enhanced, restored, or expanded, it often needs follow up enhancement actions on a periodic basis to control invasive non-native plants and shrub crowding of cactus.

Table 4. Regional cactus scrub restoration projects and a mitigation project implemented from 2008 through 2023 on Conserved Lands in western San Diego County. Organized by genetic cluster and location, the table provides a summary of one or more cactus scrub management projects at that location including the land managers implementing the projects, funding sources, total cost of projects per location, period of time over which management occurred, total acres (ha) enhanced and restored, the number of new wren territories created, number of existing territories managed, and citations for project reports.

Genetic Cluster	Location	Land Manager(s)	Funding Source(s)	Total Cost	Management Period	Acres (Ha) Enhanced Only	Acres (Ha) Restored	Total Acres (Ha) Managed	Number of New Wren Territories[1]	Number of Existing Territories Managed[2]	Project Report(s) Citations
San Pasqual	Lake Hodges (also known as Bernardo Mountain; multiple projects)	• San Dieguito River Park • San Diego Zoo Institute Conservation Research (SDZ ICR)	• San Diego Foundation • TransNet Grants • SDZ ICR	$409,087	2008-2014	52 (21)	23 (9)	75 (30)	7	2	•Lopez 2008, 2010, 2013 •Endress 2014 •SDRVJPA 2009
	Safari Park (multiple projects)	• San Diego Zoo Wildlife Alliance (SDZWA) • City of San Diego Public Utilities District (PUD)	• TransNet Grants • SANDAG Regional Invasive Plant Funds • SDZ ICR	$597,315	2010-2023	387 (157)	46 (19)	433 (175)	6	23	•Endress et al.,2011 •Endress 2010, 2011 •Endress and Motheral 2013 •Heineman and Maschinski 2018
	Bandy Canyon	• San Dieguito River Park • SDZ ICR	• San Diego Foundation • TransNet Grants	ND	2009-2016	0	10.0 (4)	10.0 (4)	1	0	•Lopez 2010, 2013 •Heineman and Maschinski 2018

Lake Jennings	Navajo Canyon	• City of San Diego Parks and Recreation Department	• TransNet Grant	$40,000	2018-2020	0.2 (0.1)	0.8 (0.3)	1.0 (0.4)	1	2	•City of San Diego 2020
	Lakeside Linkage (multiple projects)	• County of San Diego Department of Parks and Recreation	• TransNet Grants	$200,824	2011-2020	63 (26)	6 (2)	69 (28)	2	0	•ICF International 2016 •Price 2020
Sweet-water/ Encanto	Market Street (multiple projects)	• Groundworks • City of San Diego Parks and Recreation Department	• TransNet Grants	$535,981	2009-2020	0	9 (4)	9 (4)	1	4	•AECOM and Groundwork 2011, 2013 •AECOM 2014, 2015 •City of San Diego 2020
	San Diego NWR	• U.S. Fish and Wildlife Service	• TransNet Grant	$180,000	2010-2014	162 (66)	3 (1)	165 (67)	7[4]	0[4]	•Martin 2014
Otay	Rice Canyon	• City of Chula Vista	• TransNet Grant	$373,048	2009-2014	9 (4)	1 (0.4)	10 (4)	2	0	•Dodero 2011a,b, 2012, 2014
	Salt Creek (multiple projects)	• County of San Diego Department of Parks and Recreation • City of Chula Vista	• TransNet Grants • Otay Ranch POM	$547,090	2009-2024	24 (10)	48 (19)	72[5] (29)	12	10	•Merkel and Associates, Inc 2010, 2011a,b, 2013, 2014 a,b,c, 2015 •Dodero 2015, 2019 •City of Chula Vista 2018
	Otay River Valley	• County of San Diego Department of	• TransNet Grant	$66,480	2016-2018	0	3 (1)	3 (1)	2	0	•Dodero 2018

	Parks and Recreation									
Otay River Valley (Millenia)	• RECON	• ND	ND	2017-2018	1 (0.4)	1 (0.4)	2 (0.8)	2	0	•RECON 2024
Lonestar Ridge/ Johnson Canyon	• California Department of Transportation	• SR 905 and SR 125 Road Construction Mitigation Project	ND	2005-?	53 (21)	2[6] (0.8)	54 (22)	6	0	•TNC and SDMMP 2015

[1] Data sources for the number of new Cactus Wren territories within areas of cactus scrub management include: Hamilton 2009; Mahrdt and Weaver 2014, 2016, 2017, 2018, 2019, 2021; Kus and Lynn 2022a; Winchell et al.,2021; Lynn et al.,2022; RECON 2024; SDZWA 2024.

[2] Existing territories where habitat enhancement or restoration were conducted.

[3] Grant was for a cactus nursery to supply 7,065 rooted cactus and 1,000 cactus pads to multiple projects, including Lake Hodges (Bernardo Mountain), Mule Hill, Bandy Canyon.

[4] A total of 3 acres of cactus was planted as scattered clumps over an area of 165 acres and only a portion of this area was surveyed for wrens.

[5] There is substantial additional and ongoing management that is conducted by the Preserve Owner Manager and not reflected in the total cost.

[6] A total of 1.5 acres of cactus was planted as scattered clumps over a much larger unknown size area.

Management Strategy for Improved Conservation Outcomes

The long-term regional management goal for Cactus Wrens on conserved lands in western San Diego County (SDMMP and TNC, 2017) is to:

"*Protect, enhance, and restore suitable coastal sage scrub habitat for Coastal Cactus Wrens to increase effective population size in each genetic cluster at a short term sustainable level (e.g. 50–100 wrens), rehabilitate habitat destroyed by wildfire, improve habitat quality to maintain populations during drought, enhance connectivity within and between genetic clusters to increase genetic diversity and rescue small populations, and manage anthropogenic predation risk to ensure the long term persistence (>100 years) of Cactus Wrens on Conserved Lands in the MSP Area.*"

The South County management plan for Cactus Wrens (TNC and SDMMP, 2015) laid out a regional management strategy for south San Diego County that has been successful in restoring cactus scrub habitat to expand wren populations (table 4). This updated and expanded analysis follows the general management strategy of bolstering populations and improving connectivity but expands the geographic area and develops new location-specific regional management priorities, threat analyses, and management options that can guide cactus habitat management and support restoration success. Refinements are based on information from research studies and monitoring conducted since 2015 and on evaluation of cactus scrub management outcomes over the last 18 years. The regional management strategy and management options are a resource land managers can use when designing habitat management projects to benefit Cactus Wrens. Some of the key factors considered in the updated Cactus Wren management strategy include:

- Coastal Cactus Wren populations have a well-documented history of decline in San Diego County due to habitat loss and fragmentation from urban development. The species was a target of conservation starting in the early 1990s and many locations with cactus scrub and wren populations were conserved. However, compared to the 1990s there are currently many unoccupied cactus scrub patches and smaller wren populations.
- Small Cactus Wren populations of fewer than five territories at a location are vulnerable to local extinction. Thirty percent of 46 locations surveyed for Cactus Wrens from 2015 through 2022 did not have wrens and 43 percent had fewer than five territories. Only three locations supported 15 or more wren territories during this period (i.e., Safari/Battlefield Park, Salt Creek, and Lake Jennings).
- Cactus Wren productivity and survivorship are positively associated with precipitation. Multiple years of severe drought between the 1990s and 2015 likely contributed to population declines on conserved lands in southern San Diego County. Populations in all but the Lake Jennings cluster grew between 2015 and 2022 in response to a few years of above-average rainfall and because of habitat enhancement and restoration.
- Avian territories can vary in size in response to environmental conditions and population density. When food is limited, such as during drought, a larger territory may be needed to

provide sufficient food resources for a breeding Cactus Wren pair. In north San Diego County, wren territories averaged 3.3 acres (1.3 ha) in the late 1980s, a period without severe drought (Rea and Weaver, 1990). In contrast, in Orange County during an extreme drought, the average territory size was five times larger (Kamada, 2008).

- Most Cactus Wren juveniles disperse short distances or remain at their natal location. Wren dispersal is constrained in highly urbanized and fragmented landscapes. There is low potential for colonization of isolated cactus patches, especially when wren populations are small and there are few dispersing juveniles.
- Cactus Wren genetic clusters covered by this analysis do not meet the minimum effective population size of 50–100 individuals per genetic cluster to prevent inbreeding depression. Genetic diversity further declined between 2012 and 2019 in the San Pasqual and Sweetwater/Encanto genetic clusters, dispersal between genetic clusters was limited, and differentiation between clusters increased. Increasing genetic diversity will require expanding wren populations by increasing movement of individuals between populations through creation of stepping stone linkages.
- Vegetation composition has an influence on Cactus Wren productivity. Wren productivity is positively associated with sagebrush cover and negatively associated with cover of invasive non-native annual grasses and mustard.
- Cactus Wren use of a cactus plot in western San Diego County is positively associated with the following factors: close proximity to another cactus plot, the size of the area of cactus in which the plot is situated, the presence of elderberry, and dominance of buckwheat versus white sage (*Salvia apiana*) or black sage (Winchell et al., 2021).
- Different plant species support abundant arthropod prey at varying times in the breeding cycle. A diverse composition of plant species within a territory and the presence of bare ground are important to support arthropod prey availability throughout the nesting cycle. Important plants in a restoration palette, in addition to cactus, include native bunch grasses, elderberry, sagebrush, and buckwheat.
- Cactus Wrens are more likely to occupy cactus plots containing elderberry and with 5 percent or less of cactus overtopped by shrubs, unhealthy, or dead.
- Invasive non-native Argentine ants and pillbugs have an adverse effect on Cactus Wren reproductive performance.
- Habitat management is successful in increasing existing Cactus Wren populations in San Diego County and shows promise for improving connectivity within and between genetic clusters.
- Modeling different restoration strategies in the San Pasqual Valley showed that for smaller restoration efforts of <50 acres (20 ha) the best strategy is to expand/augment habitat for existing wren populations to increase population size. For very large restoration projects of 250 acres (200 ha) or larger, the best strategy is to expand/augment habitat for existing populations and create a stepping stone corridor to improve connectivity (Conlisk et al., 2014).

Based on these findings, it is important to continue managing cactus scrub habitat to ensure the persistence of Cactus Wrens in western San Diego County. Populations are vulnerable to further decline in size and genetic diversity, especially when subjected to drought and habitat degradation. Based on the analysis of data presented in the first part of this document, a regional strategy with options for management to consider is described in the next two sections. This is followed by evaluation of Cactus Wren locations for the following elements: a matrix scored for different types of habitat threats; a decision tree prioritizing management; a prioritization and analysis of cactus scrub expansion opportunities; and identification of management options that can benefit wrens. The last section provides guidelines, based on the updated analysis, for managing cactus scrub and maintaining cactus nurseries.

Priority 1: Bolster Existing Populations through Habitat Enhancement, Restoration, and Expansion

The highest priority in the regional management strategy is to increase cactus scrub and improve habitat quality to bolster and stabilize existing Cactus Wren populations on conserved lands in western San Diego County. Focusing on managing habitat at locations supporting wrens is an efficient way to increase population size and prevent existing populations from becoming extirpated. Managing cactus scrub habitat can increase resilience of Cactus Wren populations to threats like drought, wildfire, and invasive species and potentially prevent populations from declining to 2015 levels.

Improving and expanding cactus scrub habitat can lead to greater stability of Cactus Wren populations. Increasing the amount of cactus scrub increases carrying capacity at a location and improving habitat quality is likely to support more abundant arthropod prey to provide greater resilience during drought. Expanding high quality habitat has the potential to improve wren productivity and survival (Lynn et al., 2022). With more cactus scrub habitat, juvenile wrens have greater opportunities to establish a territory, find a mate, and recruit into the breeding population. Large populations can serve as a source of wrens that disperse to other locations to recolonize unoccupied habitat and augment small populations. Larger populations also help to maintain and slow the loss of genetic diversity (Vandergast et al., 2022).

The target minimum population size for a population is five territories. It is estimated that a location with 25 acres (10 ha, hereafter referred to in the English system of measurement as 25 acres) of cactus scrub can support at least five wren territories with an average territory size of 3.2 acres (1.3 ha) and leave room to expand in drought years (Rea and Weaver, 1990; Kamada, 2008).

The objective for this element of the strategy is to:

Manage cactus scrub supporting Cactus Wrens to maintain high occupancy (>50 percent) at locations with ≥25 acres of cactus scrub and to increase small (<5 territories) and medium (5-14 territories) size populations at locations with <25 acres of scrub.

The threshold amount of 25 acres of cactus scrub is based on high quality scrub as degraded scrub is likely to sustain wrens at a lower density. Habitat management has the

potential to increase wren carrying capacity even during unfavorable conditions such as drought. Improving habitat quality can be accomplished by planting more cactus to create dense thickets providing protected nesting and roosting sites. Habitat quality can be enhanced by controlling invasive non-native plants and providing a diverse native plant community to support a greater abundance of arthropod prey throughout the breeding cycle (Lynn et al., 2022; Nell et al., 2023). Thinning crowded or overtopping shrubs can improve nest sites by reducing access to predators. Selective shrub thinning can also boost the size and health of cactus by reducing competition with shrubs for soil moisture (Dodero, 2012). Argentine ants and pillbugs can negatively impact Cactus Wren reproductive performance (Nell et al., 2023) but are dependent on moist urban edges receiving irrigation and stormwater runoff. Argentine ants typically are not present in natural habitats in drier inland valleys, although they do extend a greater distance into natural habitats in more mesic coastal areas (Richmond et al., 2021). To promote native arthropod prey communities, management actions can include drying out urban edges ≤660 feet (200 m) from cactus scrub.

Habitat management to maintain and expand existing Cactus Wren populations consists of different actions that provide options to land managers in developing their own management programs. We use the terms, “options” and “actions” interchangeably in the following sections. We propose three types of management actions, as described below.

Enhancement is aimed at reducing threats in existing cactus scrub. It includes actions such as thinning shrubs crowding and overtopping cactus (“shrub crowding”) and reducing invasive non-native annual plant cover (“non-native annuals”) and non-native arthropod abundance, such as Argentine ants and pillbugs. Enhancement does not include seeding and planting native plants.

Restoration is the planting of cactus and other native shrubs, forbs, and grasses to fill in or enlarge patches of existing cactus scrub or to aid in recovery of historic scrub destroyed by wildfire or clearing. Restoration takes place in areas with current or historic mapped cactus scrub and/or records of wren occupancy. It includes enhancement actions to prepare the site for planting and to control invasive non-native plants during native plant establishment.

Expansion of cactus scrub is the creation of new cactus scrub in areas with no documentation of wrens or cactus scrub. It incorporates enhancement actions to prepare the site and control invasive annual plants and restoration actions such as the planting of cactus and other native plants to provide high quality cactus scrub.

The delineation of existing, historic, and newly expanded cactus scrub boundaries can be complicated if there is little information on previous vegetation communities or a lack of historic wren location data. Distinguishing between these categories of management actions is also dependent on the scale being considered. Large locations may employ a combination of all three types of management actions.

Specific details of management options are outlined in the South County management plan (TNC and SDMMP, 2015) and the section below entitled "Enhancement and Restoration Considerations and Guidelines".

Priority 2: Improve Connectivity by Creating Stepping Stone Linkages

The second priority of the regional management strategy is to improve connectivity of Cactus Wren populations within and between genetic clusters in western San Diego County through creation of stepping stone habitat. The strategy is to develop linkages encompassing natural habitats (e.g., shrublands, riparian woodlands) interspersed with stepping stone patches of cactus scrub supporting live-in populations of wrens that allow for incremental gene flow between populations along the linkage.

The regional management objective is to:

Establish natural habitat linkages with stepping stone patches of ≥25 acres cactus scrub supporting ≥5 Cactus Wren territories and spaced ≤3 miles (5 km) apart to improve connectivity between prioritized populations.

This involves enlarging small existing wren populations through habitat management to serve as stepping stones to other populations within or between genetic clusters. Ideally, cactus scrub stepping stones will be within the dispersal capability of many wrens, no more than 3 miles (5 km) apart, in a pathway of largely natural habitats (Preston and Kamada, 2012; TNC and SDMMP, 2015; Lynn et al., 2022). Juvenile wrens can use these stepping stone linkages to disperse from natal locations to other locations where they can recruit into breeding populations and increase population size and genetic diversity. In highly urbanized areas, there may be little opportunity to create a functional linkage that includes natural habitats or stepping stone populations. There may also be other barriers to dispersal between populations, such as large freeways.

Threat Matrix

We developed a threat matrix to rank the risk of different threats affecting Cactus Wren habitat quality at each survey location and assigned a corresponding threat level. Threats included shrub crowding, cover of non-native annuals, and percent of cactus that was unhealthy or dead. The matrix includes severity rankings of each threat measured in the field in 2022 and an overall threat ranking. Annual Cactus Wren monitoring data for each location includes threat cover class values and is available for download at the SDMMP website (https://sdmmp.com/view_project.php?sdid=SDID_201612021615.34#data-files-tab). Threat scores can vary over time due to changing environmental conditions and habitat management. The threat analyses are based on 2022 conditions but could change in the future. These data can be used by land managers to update threat assessments and to refine management needs.

For shrub crowding and non-native annuals, we determined the cover class (e.g., >5–25 percent) per survey plot using 2022 field data and then calculated the proportion of plots within a location for each cover class. We multiplied the proportion of plots that have each of the five

cover classes by an incremental value as the cover classes increased to assign a corresponding threat score. The intention was to assign scores to all locations based on how high the intensity of each threat was and use those scores to characterize management needs. Cover classes of ≤5 or >5–25 percent were multiplied by 1. Cover class >25–50 percent was multiplied by 3. Cover class >50–75 percent was multiplied by 5. Cover class >75 percent was multiplied by 7. These values were totaled for each location and were used as scores for each threat. Thus, the scores used to create threat levels within each of the four threats theoretically could range from 100–700, although most were much lower than the maximum. This highlighted areas of most concern by weighting the higher categories of threats with larger values. The scores were plotted on a frequency distribution graph. We used natural breaks in the data to assign rankings reflecting relative levels of management concern from *Low* to *Very High* and assigned a color code (table 5). As an example, when looking at shrub crowding at the Academy location, 50 percent of plots were in the cover class >5–25 percent and 50 percent were in the cover class >50–75 percent. With the multipliers, the values become 50 (50 x 1 for >5–25 percent) and 250 (50 x 5 for >50–75 percent), totaling a score of 300 or "High" for shrub crowding.

The same procedure was followed for the threats of unhealthy and dead cactus; however, since the variance of data for those threats was low, we used a binary threshold of threat scores to assign *Of Concern* or *Not of Concern* (table 5) as indicated by red and green, respectively.

Table 5. Assignments of threat levels and corresponding color codes based on the calculated threat scores per threat.

Threat Score	Threat Level	Color Code
Shrub Crowding		
350+	*Very High*	Red
>200–350	*High*	Orange
>100–200	*Medium*	Yellow
100	*Low*	Green
Non-native Annuals		
300+	*Very High*	Red
>200–300	*High*	Orange
>100–200	*Medium*	Yellow
100	*Low*	Green
Unhealthy Cactus		
130+	*Of Concern*	Red
<130	*Not of Concern*	Green
Dead Cactus		
150+	*Of Concern*	Red
<150	*Not of Concern*	Green

Next, we calculated an overall threat score and ranking by combining threat scores for individual threats. We summed the scores for the shrub crowding and non-native annuals per location, as described above. Since the threat scores for unhealthy and dead cactus were quite

low across most locations (appendix 4), we gave a lower weight to those threats in the overall score to avoid inflation. We added 100 points to a location's overall score if it was deemed *Of Concern* for unhealthy cactus and another 100 if it was *Of Concern* for dead cactus. This resulted in a range in scores of 0 to 200 for these two threats. For example, the score we obtained for the Academy location was 300 for shrub overcrowding, 100 for non-native annuals, and 0 for both unhealthy and dead cactus, totaling 400 points. This total score is called the overall threat score based on habitat conditions in 2022, where higher values are of more concern to management. These values can range from 200 to 1600 (maximum scores of 700 for cactus crowding, 700 for non-native annuals, 100 for unhealthy cactus, 100 for dead cactus). Total scores that ranged from 200–350 were considered a *Low* overall threat score (table 6), meaning the threats are of a low concern (table 6). Scores that ranged from >350-450 were given a *Medium* threat score, >450-550 *High*, and >550 was considered *Very High* (table 6).

Table 6. Overall threat scores for the threat matrix based on each threat score totaled. Relative threat levels and corresponding color codes were assigned based on its distribution.

Overall Threat Score	Threat Level	Color Code
>550	*Very High*	Red
>450–550	*High*	Orange
>350–450	*Medium*	Yellow
200–350	*Low*	Green

Overall threat rankings across the four genetic clusters on conserved lands in western San Diego County included five locations (11 percent) with *Very High* threat ranking, 12 (26 percent) with *High*, 13 (28 percent) with *Medium*, and 16 (35 percent) with *Low* based on 2022 survey data (table 7).

The greatest threat to Cactus Wren habitat is shrub crowding with *Medium* to *Very High* threat rankings at 76 percent of 46 locations followed by non-native annuals at 54 percent of locations (table 7). Unhealthy cactus is *Of Concern* at seven (15 percent) locations and dead cactus at 5 (11 percent).

Table 7. Location-specific Cactus Wren threat matrix and management prioritization. The threat matrix includes individual and overall threat rankings based on 2022 survey data and the management priority ranking is based upon regional management prioritization decision tree criteria. Cactus Wren survey locations are grouped in genetic clusters. Threat rankings are labeled and color coded as *Low* (green), *Medium* (light orange), *High* (orange) and *Very High* (red) for shrub crowding and non-native annuals. For unhealthy and dead cactus, red means *Of Concern* and green means *Not of Concern*. For the decision tree criteria, connectivity was only assessed when a location was less than 25 acres with "Y" = Yes, important for connectivity and "N" = No, not important for connectivity. We used 2015-2022 survey results to determine if a plot was recently occupied, with "Y" = Yes, occupied and "N" = No, unoccupied. Survey acres is the size of the location's Cactus Wren survey area based on existing cactus patches. Percent acreage occupied and number of wren territories are calculated from 2022 survey data. The Management Priority column for a location has values ranging from *Very Low* to *Very High*, depending on the location ranking using the management prioritization decision tree (fig. 20).

Location	Shrub Crowding	Non-native Annuals	Unhealthy Cactus	Dead Cactus	Overall Threat Ranking	Connectivity *Between* Clusters	Connectivity *Within* Clusters	Ever Occupied ?	Survey Area Acres (Ha)	% Survey Area Occupied	Number of Wren Territories	Management Priority
San Pasqual Cluster												
Lake Hodges	Medium	Medium	Very High	Very High	High			Y	261 (11)	96%	8	*Very High*
Mule Hill	Low	Medium	Low	Low	Low	Y	Y	Y	0.6 (0.2)	52%	1	*High*
Cloverdale/ Rockwood	Low	Low	Low	Low	Low	N	N	Y	8(3)	100%	6	*Medium*
Safari Park West	Medium	Low	Low	Low	Low			Y	34(14)	84%	8	*Very High*
Safari/ Battlefield Park	Medium	Low	Low	Low	Low			Y	235 (95)	94%	54	*Very High*
Bandy Canyon	High	Low	Low	Low	Medium	N	N	Y	13 (5)	57%	1	*Medium*
Academy	High	Low	Low	Low	Medium	N	N	Y	16 (6)	55%	1	*Medium*
Whitman Ranch	Medium	High	Low	Low	Medium			Y	42 (17)	73%	8	*Very High*
Lake Jennings Cluster												
Poway	High	Medium	Low	Low	High			N	177 (72)	0%	0	*Very Low*
Navajo Canyon	Very High	Medium	Low	Low	High			Y	99 (40)	2%	1	*Very High*
Mission Trails	High	Very High	Very High	Low	Very High			N	32 (13)	0%	0	*Very Low*
La Mesa	Very High	Low	Low	Low	High	N	N	N	0.5 (0.2)	0%	0	*Low*
Sycamore Canyon	Low	Low	Very High	Very High	Medium	Y	Y	Y	3 (1)	100%	1	*High*

Hillside Park	High	Medium	Low	Low	Medium	N	Y	Y	18 (7)	44%	3	*Medium*
El Cajon	High	Low	Low	Low	Medium	N	Y	Y	8/3	49%	2	*Medium*
Lakeside	Low	Low	Low	Low	Low	N	N	N	8/3	0%	0	*Low*
Cactus Park	Medium	Low	Low	Low	Low	N	N	N	1/0.4	0%	0	*Low*
Lakeside Linkages	High	Medium	Low	Low	High	Y	N	Y	7 (3)	57.7%	1	*High*
Lake Jennings	High	High	Low	Low	Medium			Y	103 (42)	61%	12	*Very High*
Sweetwater/Encanto Cluster												
Chollas Valley	Medium	Low	Low	Low	Low	N	N	Y	18 (7)	35%	3	*Medium*
Market St/ Encanto Canyon	Low	Low	Low	Low	Low			Y	31 (13)	100%	10	*Very High*
Martin Luther King	Very High	Low	Very High	Low	Very High	N	Y	Y	14 (6)	74%	2	*Medium*
Chollas Reservoir	Medium	Low	Low	Low	Low	N	Y	Y	22 (9)	56%	2	*Medium*
Paradise Valley	Very High	High	Low	Low	Very High			Y	26 (11)	100%	5	*Very High*
Emerald Ranch Open Space	Low	Low	Low	Low	Low	N	N	N	2 (0.8)	0%	0	*Low*
Winnetka Open Space	Low	Very High	Low	Low	High	N	N	Y	8 (3)	0%	0	*Low*
Sweetwater Quarry	Low	Low	Low	Low	Low	N	N	Y	9 (4)	0%	0	*Low*
Sweetwater County	High	High	Low	Low	High			Y	42 (17)	84%	4	*Very High*
Sweet Caltrans	Low	High	Low	Low	Medium			N	41 (17)	0%	0	*Very Low*
Sweetwater Authority	High	Medium	Very High	Very High	High			Y	64 (26)	64%	5	*Very High*
San Diego NWR	Medium	High	Low	Low	Medium	Y	Y	Y	24 (10)	58%	5	*High*
Skyline	Medium	Low	Low	Low	Low	N	N	N	29 (12)	0%	0	*Very Low*
Otay Cluster												
Otay	Low	Low	Low	Low	Low	N	N	N	3 (1)	0%	0	*Low*
Rice Canyon	Very High	Medium	Low	Low	High			Y	188 (76)	18%	2	*Very High*

Furby North	High	Medium	Very High	Very High	Very High	N	N	Y	16 (6)	0%	0	*Medium*
Ocean View Hills	Medium	Low	Low	Low	Low			N	44 (18)	0%	0	*Very Low*
Telegraph Canyon	High	Medium	Low	Low	High			N	46 (19)	0%	0	*Very Low*
Poggi Canyon	High	Medium	Low	Low	Medium			N	51 (21)	0%	0	*Very Low*
Dennery Canyon	Very High	High	Low	Very High	Very High	N	Y	Y	19 (8)	0%	0	*Medium*
Long Canyon	High	Medium	Low	Low	High			N	93 (38)	0%	0	*Very Low*
Wruck Canyon	Low	Low	Very High	Very High	Medium	N	N	N	1 (0.4)	0%	0	*Low*
Wolf Canyon	Very High	Medium	Low	Low	High			Y	42 (17)	15%	1	*Very High*
Brown Airfield	High	Medium	Low	Low	Medium	N	Y	Y	7 (3)	17%	1	*Medium*
Otay Ranch Preserve	Medium	Low	Low	Low	Low			Y	27 (11)	100%	3	*Very High*
Johnson Canyon	Medium	Medium	Low	Low	Low			Y	62 (25)	95%	13	*Very High*
Salt Creek	High	Medium	Low	Low	Medium			Y	175 (71)	44%	15	*Very High*

It is important to consider that these threat evaluations are based on 2022 survey data collected in a year of below-average rainfall. Plant growth is greater in years of above-average rainfall in this semi-arid region. Invasive non-native annual plant cover is often greater in wet years, whereas shrub crowding can be higher in a year of above-average rainfall and remain higher in subsequent years. This could lead to more severe rankings in shrub crowding and cover of invasive non-native annual grasses and forbs in years with or following above-average rainfall. Conversely, during a prolonged drought there may be more unhealthy and dead cactus from low soil moisture. When prioritizing future management actions, the most current threat data can be evaluated to be sure that management is relevant for these current conditions. Similarly, management actions can reduce threat levels. For example, some locations (e.g., Safari Park, Salt Creek) are being managed to control non-native annuals so that the cover and threat magnitude are lower than they would be without management. Cessation of management could result in re-emergence of the threat of invasive non-native annuals at these locations in the future.

Threat Evaluations by Genetic Cluster and Location

San Pasqual Cluster

Based on 2022 survey data, the San Pasqual cluster has the lowest overall threat rankings with 50 percent of eight locations ranked as *Medium* to *High* risk from threats (table 7). The primary threat is shrub crowding at six locations followed by non-native annuals at three locations, and unhealthy and dead cactus at one location. Lake Hodges has a *High* overall threat risk that includes threats of shrub crowding, non-native annuals, and unhealthy and dead cactus. Three locations have a *Medium* overall threat level, including Bandy Canyon and Academy locations facing shrub crowding, while Whitman Ranch has shrub crowding and non-native annuals. Locations with a *Low* level of threat include Mule Hill, Cloverdale/Rockwood, Safari Park West and Safari/Battlefield Park.

Lake Jennings Cluster

The Lake Jennings cluster has the highest threat risk with 81 percent of eleven locations categorized with a *Medium* to *Very High* overall threat ranking in 2022 (table 7). The top threat is shrub crowding, followed by non-native annual plants, unhealthy cactus, and dead cactus. Mission Trails has a *Very High* threat ranking from shrub crowding, non-native annual plants, and unhealthy cactus. Four locations (Poway, Navajo Canyon, La Mesa, and Lakeside Linkages) have a *High* overall threat ranking with threat of shrub crowding and non-native annual plants. Four other locations face an overall *Medium* level of threats. Sycamore Canyon has unhealthy and dead cactus, Hillside Park and Lake Jennings are affected by crowding shrubs and non-native annuals, and El Cajon has crowding shrubs. Lakeside and Cactus Park have a low level of threats.

Sweetwater/Encanto Cluster

Seven (54 percent) of the Sweetwater/Encanto locations have *Medium* to *Very High* overall threat rankings based on the 2022 data (table 7). Paradise Valley has a *Very High* level of threat from shrub crowding and non-native annuals. Martin Luther King is at *Very High* risk from shrub crowding and unhealthy cactus. Three locations have a *High* threat ranking. Sweetwater County and Sweetwater Authority are affected by shrub crowding and non-native annual plants with Sweetwater Authority also having unhealthy cactus. Winnetka Open Space is affected by non-native annual plants. San Diego NWR is ranked as a *Medium* overall threat due to shrub crowding and non-native annuals. The six other locations have an overall *Low* threat ranking.

Otay Cluster

The Otay cluster has the second highest percentage of locations (71 percent) with overall threat rankings of *Medium* to *Very High* (table 7). Two locations, Furby North and Dennery Canyon, face overall *Very High* threat risk from shrub crowding, non-native annual plants, and unhealthy and/or dead cactus. Rice Canyon, Telegraph Canyon, Long Canyon, and Wolf Canyon face a *High* overall threat and are affected by shrub crowding and non-native annual plants. Poggi Canyon, Brown Airfield, and Salt Creek have a *Medium* threat ranking due to crowding shrubs and non-native annuals, whereas Wruck Canyon faces *Medium* risk associated with unhealthy and dead cactus. Four locations (Otay, Ocean View Hills, Otay Ranch Preserve, and Johnson Canyon) have a *Low* level of overall threat.

Management Prioritization Decision Tree

The regional management strategy is designed to achieve the management goal through incremental steps over time. Periodically, the strategy is revisited as new information becomes available, and this updated and expanded analysis is an example of that process. As part of this update, we developed a decision tree to determine location-based regional priorities for implementing management objectives (fig. 20).

We combined the two management strategy objectives of expanding existing populations and improving connectivity into a decision tree to rank locations by regional management priority as *Very Low*, *Low*, *Medium*, *High*, and *Very High* (fig. 20). We first assigned locations that had a relatively large survey area with existing or historic cactus scrub, using a threshold of ≥25 acres, and that were occupied as *Very High* priority on the right side of the tree. Locations that met the size threshold but were not documented as being occupied by Cactus Wrens between 2015 and 2022 are a *Very Low* priority. Our aim is to prioritize habitat management options at locations that support wrens and not spend scarce resources where there is habitat but no wrens. While both branch ends on the right side of the tree are assigned *Very High* management priorities, their difference lies in the percent of surveyed acreage that is occupied and the types of management actions needed. Locations with high occupancy (≥50 percent) can benefit from habitat enhancement when necessary to maintain that level of high occupancy. For locations with low occupancy (<50 percent), enhancement and restoration actions can increase wren

populations by improving habitat quality or rehabilitating historic cactus scrub, such as that burned in a wildfire. Both the low and high occupancy scenarios are a *Very High* management priority given the relatively large amount of cactus scrub and an existing population of wrens. Expanding cactus scrub through creation of new patches beyond the existing or historic cactus scrub footprint may also be a management option to substantially increase wren populations at these locations. Regional priorities to expand cactus scrub habitat are evaluated separately; see "Cactus Scrub Habitat Expansion and Expansion Priorities by Genetic Cluster and Location".

On the left side of the decision tree (fig. 20) are locations that have <25 acres of cactus scrub survey area and can potentially be managed to support larger populations of Cactus Wrens. We first prioritized occupied locations for regional management that could improve connectivity *between* genetic clusters. Cactus patches at these locations can be expanded to increase existing wren populations and reduce the risk of extirpation. Initially, in this management strategy, these patches may be more than 3 miles (5 km) from another occupied location. However, as we make progress in habitat restoration over time, future priorities can include establishing new cactus patches at locations without wrens to shorten distances between locations occupied by wrens. Within this category, locations that also improved *within* cluster connectivity and were occupied by wrens were given High priority while unoccupied locations received *Medium* priority. Locations that did not improve within cluster connectivity but were occupied received *High* priority, while unoccupied locations received *Low* priority. The next level of prioritization for the remaining locations was whether they improved *within* cluster connectivity. Locations that improve within cluster connectivity and are occupied are *Medium* priority, while those that are unoccupied are *Low* priority, regardless of whether they improve within cluster connectivity.

Table 7 shows the regional management priority rankings based on decision tree criteria for each location and Table 8 lists locations by management priority ranking. Of the 46 locations evaluated with the decision tree, 15 (33 percent) ranked as *Very High* priority, 11 of these locations with ≥25 acres of cactus scrub had high Cactus Wren occupancy and four had low occupancy (tables 7, 8). There were four (9 percent) *High* priority management locations, 11 *Medium* (24 percent), eight *Low* (17 percent) and eight (17 percent) *Very Low*. Locations with *Low* and *Very Low* management priority could consume valuable resources for habitat management with little effect on wren populations. Regional resources can instead be directed to higher ranked locations for greater overall benefit to Cactus Wren population persistence over time.

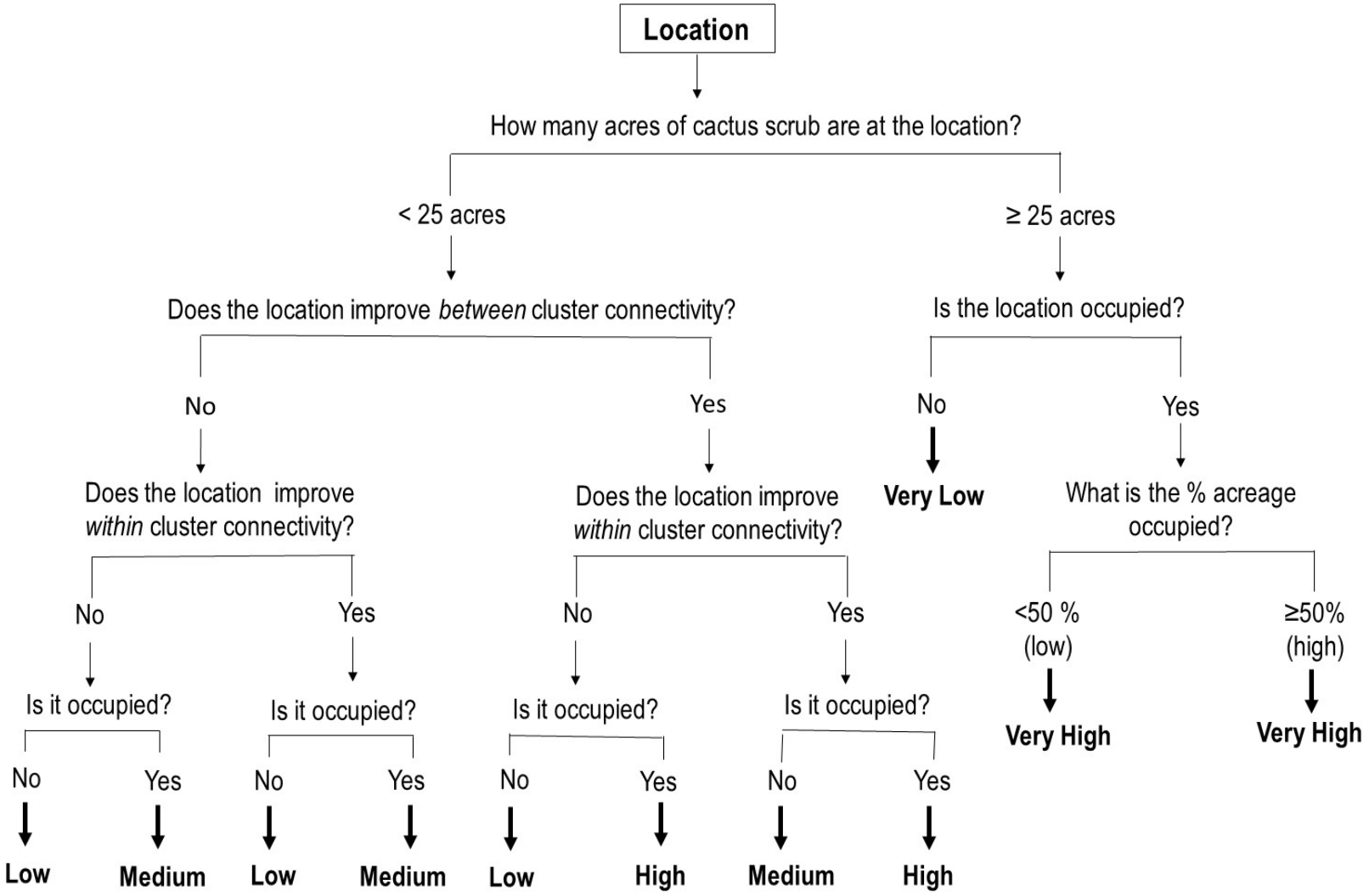


Figure 20. Regional management prioritization decision tree developed for Cactus Wren locations on conserved lands in western San Diego County.

Table 8. Regional management priority by location derived from the decision tree. Regional management priority by location derived from the decision tree. The asterisk indicates that this is the current assignment for Poway but it is data deficient and requires more surveys to best assign its management priority at a later date.

Very High, High Occupancy	Very High, Low Occupancy	High	Medium	Low	Very Low
Lake Hodges	Navajo Canyon	Mule Hill	Cloverdale/ Rockwood	La Mesa	Poway*
Safari Park West	Rice Canyon	Sycamore Canyon	Bandy Canyon	Lakeside	Mission Trails
Safari/Battlefield Park	Wolf Canyon	Lakeside Linkages	Academy	Cactus Park	Sweet Caltrans
Whitman Ranch	Salt Creek	San Diego NWR	Hillside Park	Emerald Ranch Open Space	Skyline
Lake Jennings			El Cajon	Winnetka Open Space	Ocean View Hills
Market St/ Encanto Canyon			Chollas Valley	Sweetwater Quarry	Telegraph Canyon
Paradise Valley			Martin Luther King	Otay	Poggi Canyon
Sweetwater County			Chollas Reservoir	Wruck Canyon	Long Canyon
Sweetwater Authority			Furby North		
Otay Ranch Preserve			Dennery Canyon		
Johnson Canyon			Brown Airfield		

Management Priority Ranking by Genetic Cluster and Location

San Pasqual Cluster

The San Pasqual genetic cluster has four of eight locations (50 percent) ranked as *Very High* priority for regional cactus scrub management and with high Cactus Wren occupancy (Lake Hodges, Safari Park West, Safari/Battlefield Park, and Whitman Ranch; tables 7, 8). Mule Hill is ranked a *High* priority as it is an important location to create a stepping stone patch of cactus scrub (≥25 acres) to support a population of wrens and improve connectivity between and within clusters. Three locations (37 percent) are ranked *Medium* priority with relatively small amounts of cactus scrub occupied by Cactus Wrens that do not improve connectivity.

Lake Jennings Cluster

The Lake Jennings cluster has two locations (20 percent) in the *Very High* priority category for regional management: Lake Jennings and Navajo Canyon (tables 7, 8). The Lake Jennings location has a high percentage of occupied cactus scrub, whereas Navajo Canyon has very low occupancy. Sycamore Canyon and Lakeside Linkages are small populations that rank as *High* priority to expand as stepping stones for between and within cluster connectivity. Hillside Park and El Cajon rank as *Medium* priority with small populations that could collectively be expanded to promote within cluster connectivity. *Low* priority La Mesa, Lakeside, and Cactus Park locations contain small amounts of unoccupied cactus scrub. Poway and Mission Trails are *Very Low* regional management priorities with large survey areas and scattered cactus patches that do not support wrens. Potential linkage areas in Poway were only surveyed in 2022 and the management priority could change if future surveys detect more birds and cactus scrub habitat.

Sweetwater/Encanto Cluster

Four of 13 (31 percent) locations (Market/Encanto Canyon, Paradise Valley, Sweetwater County and Sweetwater Authority) rank as *Very High* regional Cactus Wren habitat management priority for the Sweetwater/Encanto cluster (tables 7, 8). All meet the criteria for a large cactus scrub area with high wren occupancy. The San Diego NWR is *High* priority for management as this site is crucial to supporting a large stepping stone population of wrens to promote between and within cluster connectivity, especially, as it is part of a larger integrated population of Cactus Wrens at several locations around Sweetwater Reservoir. Three locations are of *Medium* management priority (Chollas Valley, Chollas Reservoir, Martin Luther King) and have smaller areas of cactus scrub in urban fragments that could be managed to support larger populations and improve within cluster connectivity. Three locations rank as *Low* (Emerald Ranch Open Space, Winnetka Open Space, Sweetwater Quarry) as they were not occupied by wrens in 2022. However, both Winnetka and Sweetwater Quarry intermittently supported single Cactus Wren territories between 2015 and 2022. Sweetwater Caltrans and Skyline rank as *Very Low* with a relatively large amount of unoccupied cactus scrub.

Otay Cluster

The Otay cluster supports the most *Very High* priority locations (five) for regional Cactus Wren habitat management: Rice Canyon, Wolf Canyon, Salt Creek, Otay Ranch Preserve, and Johnson Canyon (tables 7, 8). Rice Canyon, Wolf Canyon, and Salt Creek all have large areas of cactus scrub but low occupancy. However, the wren population at Salt Creek has been growing steadily since 2015 under improved environmental conditions and with extensive habitat enhancement and restoration. Otay Ranch Preserve and Johnson Canyon locations support ≥25 acres of cactus scrub and high wren occupancy. Three locations in the Otay Cluster rank as *Medium* management priority (Furby North, Dennery Canyon and Brown Airfield). All three support few wren territories on an irregular basis and if expanded could improve within cluster connectivity. Otay and Wruck Canyon are *Low* management priority with small amounts of cactus scrub and no history of wren occupancy. Ocean View Hills, Telegraph Canyon, Long

Canyon, and Poggi Canyon are *Very Low* management priority with relatively large areas of cactus scrub but no recent records of wrens.

Cactus Scrub Habitat Expansion

Cactus scrub habitat expansion is a management option that can provide more habitat to increase Cactus Wren carrying capacity at a location. In previous sections, locations were prioritized for enhancement and restoration of existing or historic cactus scrub based on management priority decision tree criteria. Cactus scrub condition was assessed to determine management needs. This section prioritizes locations for optional expansion of cactus scrub in areas that are not documented currently or historically to support wrens or cactus scrub.

Habitat expansion opportunities and priorities were evaluated for each location with ArcGIS software using aerial imagery, a habitat suitability model (Preston et al., 2020), mapped cactus (Winchell et al., 2021), and historic and current cactus wren location data (e.g., REGSS Database: Ogden 1995; Kus and Lynn, 2022; Lynn and Kus 2021, 2022, 2023; Lynn et al., 2022). Cactus expansion polygons were delineated where there was sufficient modeled suitable habitat and prioritized for management. Acres of potential habitat expansion were calculated for each location.

Prioritization of cactus scrub expansion polygons is based upon 1) the number of mapped wrens observed historically (i.e., 1980s and 1990s) and the number and location of wren observations and territories detected from 2009 to 2020; 2) the importance of sites for population expansion, connectivity, and fire refugia; and 3) the opportunity to expand habitat based on the size of the location, configuration of mapped cactus scrub and historic and current wren observations, and prevalence of modeled suitable habitat. Model predictions of Habitat Similarity Index (HSI) values ≥0.5 were defined as potentially suitable habitat (0.5-0.74 = High suitability and ≥0.75 = Very High suitability: Appendix 1; Preston et al., 2020). The following considerations were used to prioritize locations for optional cactus scrub expansion:

- Locations without Cactus Wrens are not a regional priority for cactus scrub expansion. These locations already support cactus scrub, so the addition of more scrub represents an inefficient use of scarce management resources.
- Locations are not a regional priority for cactus scrub expansion if the locations are smaller than 25 acres in size, if there is little or no room to add cactus scrub, or there is a lack of suitable habitat to expand cactus scrub.
- Locations with intermittent occupancy or on the periphery of the current Cactus Wren distribution are a lower priority for cactus scrub expansion than locations where habitat can more efficiently be expanded to support a stable wren population. These lower priority sites may benefit from cactus scrub enhancement or restoration and if a positive wren population response is observed, then these sites can become a higher regional priority for creation of more cactus scrub.
- Locations with small Cactus Wren populations (<5 territories) lacking sufficient cactus scrub to support a larger population are prioritized for cactus scrub expansion to increase

the population and improve stability. Prioritization is higher for locations that are part of a stepping stone linkage to improve connectivity within and/or between genetic clusters.

- Locations with medium (5-14 territories) and large (>15 territories) Cactus Wren populations are prioritized for cactus scrub expansion at key locations to build larger populations for greater stability, to maintain genetic diversity, and to serve as a source of wrens to disperse to other locations. The intent is to have at least one large population per genetic cluster.
- Locations with the potential to serve as fire refugia are prioritized for expansion to support medium or large size Cactus Wren populations to maintain genetic diversity and serve as a source of wrens to recolonize areas burned in wildfire. Potential fire refugia are locations with some surrounding urban development that may be actively defended to prevent wildland fire spread in the cactus scrub because of the risk to nearby development. Fire refugia are also locations with medium sized populations within the urban matrix (e.g., urban canyons) and separated from large expanses of open space at high risk of wildfire.
- All identified locations for cactus scrub habitat expansion will require detailed field assessments to evaluate accessibility, the presence of sensitive species, soils, aspect, and landscape position to select the best areas for habitat expansion.

A total of 46 locations/sublocations were evaluated for cactus scrub expansion opportunity (appendix 5; table 5.1-5.4). Overall, 27 (59 percent) of the locations rank *Low* to *Very High* and 19 are not a regional priority for cactus scrub expansion. Seven locations (15 percent) rank *Very High*, six (13 percent) as *High*, 10 (22 percent) as *Medium*, and 4 (9 percent) as *Low*. All four genetic clusters have three to four locations considered *Very High* or *High* regional priority for cactus scrub expansion.

Expansion Opportunities by Genetic Cluster and Location

San Pasqual Cluster

The San Pasqual cluster has two locations ranked as *Very High* regional priority for cactus scrub expansion, one as *High*, two as *Medium,* two as *Low*, and one that is not a priority (appendix 5 table 5.1). The Lake Hodges location is a *Very High* regional priority with extensive suitable habitat to create cactus scrub, support a large population to maintain genetic diversity and population stability, and improve connectivity with populations to the east. Mule Hill is a *Very High* priority for creation of stepping stone habitat to sustain a wren population and improve connectivity between Lake Hodges and Safari/Battlefield Park. Safari Park West is a *High* priority to expand cactus scrub to support a large stepping stone linkage. This area did not burn in the 2007 wildfire and could provide protection in future fires. Bandy Canyon and Whitman Ranch are *Medium* priorities for expansion while Safari/Battlefield Park and Academy locations are *Low* priority. The Safari/Battlefield Park has had extensive habitat expansion, restoration and enhancement and supports the largest wren population on conserved lands in

western San Diego County. It is a *Low* priority for cactus scrub expansion so that other locations with smaller and more vulnerable populations can be prioritized for management resources.

Lake Jennings Cluster

In the Lake Jennings cluster, two locations are *Very High* priority for cactus scrub expansion, one location is *High* priority, two are *Medium*, and six are not a priority (appendix 5 table 5.2). Sycamore Canyon is ranked a *Very High* priority to increase cactus scrub carrying capacity from one to at least five territories to function as a stepping stone population between the Lake Jennings and San Pasqual clusters. The Lake Jennings location has a medium size wren population, the largest in this cluster, and is a *Very High* priority for cactus expansion to increase wren population size to a large population, maintain genetic diversity, and provide a source of wrens to disperse to other populations. Lakeside Linkages is a *High* priority for cactus scrub expansion because it is a fire refugium and stepping stone for between and within cluster connectivity. Navajo Canyon and El Cajon locations each have small populations that rank as a *Medium* priority for expansion of cactus scrub.

Sweetwater/Encanto Cluster

In the Sweetwater/Encanto cluster two locations rank as *Very High* regional priority for cactus scrub expansion, two as *High*, four as *Medium*, and five as not a priority (appendix 5 table 5.3). Market Street/Encanto Canyon is a *Very High* priority for cactus scrub expansion into a side canyon to maintain population stability and genetic diversity and serve as a source of wrens to disperse to less stable populations in canyons to the north. The San Diego NWR location is also a *Very High* priority with extensive suitable habitat to expand cactus scrub and boost the size of the existing large, interconnected population of wrens around Sweetwater Reservoir. This large population is critical to maintain genetic diversity and provide wrens for dispersal to other areas within the cluster and south to the Otay cluster. Paradise Valley and Sweetwater Authority are *High* priorities for cactus scrub expansion to increase wrens and improve population stability, maintain genetic diversity, and provide a source of wrens to other locations. Four locations with small wren populations (Martin Luther King, Cholla Reservoir, Sweetwater Quarry and Sweetwater County) are *Medium* priority for creating new cactus scrub to support larger wren populations.

Otay Cluster

The Otay cluster has one location that is a *Very High* regional priority for cactus scrub expansion, two locations ranked as *High*, two ranked *Medium*, two ranked *Low*, and seven as not a priority (appendix 5 table 5.4). Salt Creek is a *Very High* priority location for cactus scrub expansion to recover a formerly large concentration of wrens to improve population stability, maintain genetic diversity, and produce wrens to disperse to surrounding locations and to the Sweetwater/Encanto cluster. There are large areas of suitable habitat with no previous wren locations or mapped cactus where habitat expansion can be integrated with existing scrub. Cactus scrub expansion, restoration and enhancement efforts are ongoing at Salt Creek and have helped to increase the population. Johnson Canyon is a *High* priority for cactus scrub expansion as it is a

stable medium-size population and can be increased to a large population to maintain genetic diversity and serve as a source of dispersing wrens. The population at this location has increased by 150 percent since 2008 in response to cactus scrub expansion at Lonestar Ridge, an adjacent mesa. The Otay Ranch Preserve location is also a *High* priority as it has a small population that increased from one to three territories with cactus scrub expansion and could be further increased with additional habitat expansion.

Location Specific Management Options to Benefit Cactus Wrens

Location-specific management options to benefit Cactus Wrens include cactus scrub enhancement, restoration, and expansion as described in the previous sections. These actions are focused on increasing the size and stability of cactus wren populations. For land managers developing a Cactus Wren habitat management project, this document prioritizes locations for regional management and identifies general management options to improve cactus scrub habitat. Land managers and restoration experts can consider these management options and refine their management planning to reflect current site conditions. The first step is to review this report's sections on threat evaluation, management prioritization, and opportunity for cactus scrub expansion for the location of interest. This will determine if the project is a regional priority for management. It will also target the types of management actions that could benefit wrens at the location. Land managers can also download regional Cactus Wren and habitat monitoring data for their location to view wren status and habitat threat levels over time, including from the most recent monitoring year. The next step is for land managers and restoration practitioners to visit the location to assess current cactus scrub configuration and condition and tailor specific management actions to achieve desired management outcomes and funding considerations. Preparing a project plan is helpful in determining the type of enhancement actions needed to improve the habitat (e.g., thatch removal, invasive plant control) and prepare it for planting if restoration or expansion of coastal sage scrub is the goal. The next section provides guidelines for project planning, best management practices, and information on cactus nurseries to provide plants and propagules for cactus scrub restoration and expansion projects.

Table 9 lists location-specific management options based on information from the threat matrix, management prioritization, and expansion opportunity sections. The Overall Threat Ranking indicates magnitude of cumulative threats to existing cactus scrub. For locations ranked as *Medium* management priority or higher, "Enhance" is indicated for managing shrub crowding, non-native annuals, and unhealthy cactus where the threat rankings are *Medium* or greater. If there is dead cactus ranked as *Medium* or greater threat, then "Restore" is indicated as an option for replacing dead cactus with new cactus plantings. If the location has burned in a wildfire or is known to have disturbed cactus scrub, then "Restore" is selected as a management option to add cactus and potentially other native plants into existing cactus scrub. The specific management options are listed based on the threat analyses. Even a *Low* overall threat ranking may warrant management for a particular threat ranked as *Medium* or greater. Argentine ant control is listed as a potential management action for locations ranked as *Medium* management priority or higher that are near reservoirs or urban development. Locations can be evaluated to see whether Argentine ants are present and if management control actions are feasible. Expansion priorities in

Table 9 come from appendix 5, tables 5.1, 5.2, 5.3 and 5.4. If the expansion priority is *Medium* or higher, then expansion of new cactus scrub is a suggested management option.

Management Options by Genetic Cluster and Location

San Pasqual Cluster

The San Pasqual cluster has seven of eight locations with identified management options (table 9). Cloverdale/Rockwood has no suggested management actions as threats are low and it is not prioritized as a location for restoration or expansion of cactus scrub. Lake Hodges has the greatest management needs with a *High* overall threat ranking that includes management options for four habitat threats, restoration of existing cactus scrub, and expansion of new cactus scrub. Creating a stepping stone at Mule Hill to improve connectivity includes expansion of cactus scrub and control of non-native annuals. Safari Park West could benefit from expansion of cactus scrub and thinning of crowded shrubs. Safari/Battlefield Park are not prioritized for cactus scrub restoration or expansion but could use thinning of crowded shrubs and evaluation of Argentine ants to see if control is needed near irrigated plants and developed areas. Bandy Canyon, Academy and Whitman Ranch locations could benefit from enhancement and restoration of burned cactus scrub and thinning of crowded shrubs.

Lake Jennings Cluster

Six of 11 locations in the Lake Jennings genetic cluster are a priority for habitat improvements (table 9). Navajo Canyon and Lakeside Linkages have a *High* overall threat ranking and could benefit from cactus scrub restoration and enhancement (e.g., thinning crowded shrubs and controlling non-native annuals) and expansion of new scrub. Sycamore Canyon is threatened by unhealthy and dead cactus with improvement options of planting new cactus and expansion of cactus scrub to increase the wren population and improve connectivity. Hillside Park and El Cajon locations could benefit from enhancement actions, particularly thinning crowded shrubs, with restoration and expansion of cactus scrub as potential options for El Cajon. Lake Jennings is a *Very High* management priority and cactus wren populations could be recovered and increased through cactus scrub restoration and expansion and management of shrub crowding and non-native annuals.

Sweetwater/Encanto Cluster

The Sweetwater/Encanto cluster has the most locations (nine of thirteen) prioritized for management (table 9). Market St/Encanto Canyon and Sweetwater Quarry do not need enhancement or restoration of existing cactus scrub but could increase wren populations with expansion of new cactus scrub. Existing cactus scrub at the remaining seven locations could be improved by thinning overcrowded shrubs, evaluating the need for Argentine ant control, and four locations could benefit from control of non-native annuals. Martin Luther King, Paradise Valley, Sweetwater Authority and San Diego NWR are also candidates for cactus scrub

restoration and expansion while Chollas Valley could benefit from addition of cactus to existing scrub.

Otay Cluster

The Otay cluster has the second highest number of prioritized locations (eight of fourteen) that could benefit from management (table 9). Habitat at Rice Canyon, Furby North, Dennery Canyon, Brown Airfield and Salt Creek could be restored and enhanced while habitat at Wolf Canyon, Otay Ranch Preserve, and Johnson Canyon could be enhanced. All prioritized locations could benefit from thinning of crowded shrubs, and all but one could benefit from control of non-native annuals. Furby North and Dennery Canyon could benefit from management of unhealthy cactus and planting live cactus to replace dead ones. Otay Ranch Preserve, Johnson Canyon and Salt Creek are the highest priorities for expansion of cactus scrub to increase wren populations.

Table 9. Location-specific management priorities, overall threat rankings, general types of management actions, and specific management options. These rankings and priorities are based on table 7 and appendix tables 5.1-5.4. For the Expansion Priority column, "NAP" = Not a Priority. Specific management options are based on an assessment of habitat threat data and the likelihood of Argentine ants at a location. Specific management options are defined as: CAA = control Argentine ants, CNA = control non-native annuals, MUC = manage unhealthy cactus, RDC = replace dead cactus, TCS = thin crowded shrubs.

Location	Overall Threat Ranking	Management Priority	Expansion Priority	Restore	Enhance	Specific Management Options
San Pasqual Cluster						
Lake Hodges	High	Very High	Very High	X	X	TCS, CNA, MUC, RDC
Mule Hill	Low	High	Very High		X	CNA
Cloverdale/ Rockwood	Low	Medium	NAP			
Safari Park West	Low	Very High	High		X	TCS
Safari/Battlefield Park	Low	Very High	Low		X	TCS, CAA
Bandy Canyon	Medium	Medium	Medium	X	X	TCS
Academy	Medium	Medium	Low	X	X	TCS, CAA
Whitman Ranch	Medium	Very High	Medium	X	X	TCS, CNA, CAA
Lake Jennings Cluster						
Poway	High	Very Low	NAP			
Navajo Canyon	High	Very High	Medium	X	X	TCS, CNA, CAA
Mission Trails	Very High	Very Low	NAP			
La Mesa	High	Low	NAP			
Sycamore Canyon	Medium	High	Very High	X	X	MUC, RDC
Hillside Park	Medium	Medium	NAP		X	TCS, CNA, CAA
El Cajon	Medium	Medium	Medium	X	X	TCS, CAA
Lakeside	Low	Low	NAP			
Cactus Park	Low	Low	NAP			
Lakeside Linkages	High	High	High		X	TCS, CNA
Lake Jennings	Medium	Very High	Very High	X	X	TCS, CNA, CAA

Sweetwater/Encanto Cluster						
Chollas Valley	Low	Medium	NAP	X	X	TCS, CAA
Market St/ Encanto Canyon	Low	Very High	Very High			
Martin Luther King	Very High	Medium	Medium	X	X	TCS, MUC, CAA
Chollas Reservoir	Low	Medium	Medium		X	TCS, CAA
Paradise Valley	Very High	Very High	High	X	X	TCS, CNA, CAA
Emerald Ranch Open Space	Low	Low	NAP			
Winnetka Open Space	High	Low	NAP			
Sweetwater Quarry	Low	Low	Medium			
Sweetwater County	High	Very High	Medium		X	TCS, CNA, CAA
Sweet Caltrans	Medium	Very Low	NAP			
Sweetwater Authority	High	Very High	High	X	X	TCS, CNA, MUC, CAA
San Diego NWR	Medium	High	Very High	X	X	TCS, CNA
Skyline	Low	Very Low	NAP			
Otay Cluster						
Otay	Low	Low	NAP			
Rice Canyon	High	Very High	Medium	X	X	TCS, CNA, CAA
Furby North	Very High	Medium	Medium	X	X	TCS, CNA, MUC, RDC
Ocean View Hills	Low	Very Low	NAP			
Telegraph Canyon	High	Very Low	NAP			
Poggi Canyon	Medium	Very Low	NAP			
Dennery Canyon	Very High	Medium	Low	X	X	TCS, CNA, RDC, CAA
Long Canyon	High	Very Low	NAP			
Wruck Canyon	Medium	Low	NAP			
Wolf Canyon	High	Very High	Low		X	TCS, CNA
Brown Airfield	Medium	Medium	NAP	X	X	TCS, CNA
Otay Ranch Preserve	Low	Very High	High		X	TCS
Johnson Canyon	Low	Very High	High		X	TCS, CNA
Salt Creek	Medium	Very High	Very High	X	X	TCS, CNA

Enhancement and Restoration Considerations and Guidelines

Best management practices for cactus scrub habitat management are detailed in the South County management plan (TNC and SDMMP, 2015), particularly in Appendix D. Here, these practices are briefly summarized and expanded upon where there is new information from recent studies and monitoring data. These management options are based upon the collective expertise of many land managers and restoration practitioners. They are also informed by studies of habitat relationships relevant to wren occupancy, reproduction and survival, foraging, and arthropod communities. These guidelines are an optional resource meant to be refined by land managers and restoration practitioners to meet their management objectives and for greatest effect based on site conditions. In many cases, best management practices and research results for the broader

coastal sage scrub community are used to inform cactus scrub management, since cactus scrub is a type of coastal sage scrub.

Invasion of Coastal Sage Scrub by Non-Native Annuals and Management Options

The integrity of coastal sage scrub vegetation is threatened by invasive non-native annual grasses and forbs (Diffendorfer et al., 2007; Preston et al., 2022). Since the 1930s, there has been a landscape-scale increase of invasive non-native annual grasses into southern California shrublands often leading to type conversion to non-native annual grassland (Freudenberger et al., 1987; Minnich and Dezzani, 1998; Dewes et al., 2022). This process is driven by disturbance such as increased wildfire frequency, drought, over-grazing, land clearing, and nitrogen deposition from air pollution (Keeley et al., 2005; Talluto and Suding, 2008; Fleming et al., 2009; Cox et al., 2014). Following are some important results from recent research studies aimed at controlling non-native annual grasses and forbs and restoring native coastal sage vegetation.

- Non-native annual plants compete more with native shrubs during seedling establishment when both use moisture from the shallow soil layer (Davis and Mooney, 1985; Eliason and Allen, 1997; Bell et al., 2019; Ta et al., 2024). Non-native annual plants successfully compete for soil moisture in semi-arid shrublands by germinating and growing earlier in the season than native plants and using up water in shallow soil layers, thereby preventing native annual and perennial plants from establishing (Davis and Mooney, 1985; Bell et al., 2019). However, once shrubs can establish and become deep-rooted they can outcompete non-native annuals for resources such as soil moisture and light (Eliason and Allen, 1997; Cione et al., 2002; Ta et al., 2024).
- Controlling non-native annual grasses in degraded coastal sage scrub with grass-specific herbicide is effective in reducing grass biomass and cover; however, it often results in an increase in non-native forbs, such as *Erodium* species (Cox 2008, 2011; Bell et al., 2016; Dickens et al., 2016; Ta et al., 2024). Herbicide application and thatch removal plus herbicide application are more effective and longer lasting treatments to reduce non-native grass cover than mowing (Cox and Allen, 2008). Controlling non-native annual plants to allow recovery of coastal sage scrub can take years of control efforts targeting both non-native annual grasses and forbs (Cox and Allen, 2008, 2011; Bell et al., 2016; Dickens et al., 2016).
- Controlling non-native annuals is most effective at increasing native plant density and species richness in degraded coastal sage scrub where native plant cover is between 20 and 39 percent (Ta et al., 2024). With too little native plant cover there is an insufficient native plant seed bank for passive restoration such that active restoration of seeding or planting native plants is needed. Controlling non-native annuals when native plant cover is above 40 percent does not have a significant influence on native plant richness or density and scarce resources could be better allocated to areas that would show more of a benefit. The authors recommend non-native annual plant control at transition sites (20-39% native cover) to achieve a diverse native coastal sage scrub community and to forgo management and avoid disturbing sites with ≥40% native cover (Ta et al., 2024).

- Non-native plant control was also found to reduce mortality of established shrubs during severe drought (Ta et al., 2024). Native grasses and shrubs benefited from the non-native plant control, whereas native forbs showed no effect.
- In addition to invasive plant control, seeding of native plants may be needed to restore coastal sage scrub (Bell et al., 2019). Seeding of native plants after control of non-native plants may allow the native plants to outcompete non-native plants (Dickens et al., 2016). Seed mixes can have a lasting effect on the composition and sustainability of native plant communities over time (Bell et al., 2019). Seeding of native perennials with deeper root systems while controlling for non-native annuals can be effective in two years in reducing forbs such as highly competitive *Brassica nigra* (Bell et al., 2019). Native annual forbs with shallower root systems can be added in after native perennials are established and have outcompeted *B. nigra* and other non-native annuals.
- At sites where non-native species were controlled, native species richness was greater at inland compared to coastal sites (Ta et al., 2024). There was also greater shrub density and smaller shrubs at inland sites.
- An experiment with seeding a mix of native shrubs showed no lasting effect of irrigation with the exception that sagebrush irrigated year-round was the only shrub species present after two growing seasons (Padgett et al., 2000). The authors concluded that irrigation could be more effective during extreme droughts or for establishing certain species such as sagebrush.
- One study conducted 2016 to 2018 showed that seeding a site resulted in greater shrub diversity and growth than when container shrubs were planted (McGuire et al., 2022). Container shrubs had higher survival over the two years and percent cover was similar for the two methods. Deep rooted shrubs like lemonade berry, laurel sumac, and Menzies' goldenbush were better established from container plants whereas other species such as black sage, bush sunflower, buckwheat and deerweed (*Acmispon glaber*) did better from seed. Sagebrush did equally well with both methods. The study concludes that restoring diverse coastal sage scrub from seed is less costly, but some plants may be more successfully established from container plants.
- Intact biological soil crusts in coastal sage scrub can inhibit non-native annual grasses from establishing (Hernandez and Sandquist, 2011). One study showed that disturbed soil crusts had more than three times greater emergence of non-native plants and three times less of native plants compared to undisturbed crusts (Hernandez and Sandquist, 2011). Emergence of sagebrush seedlings was six times greater in intact biological crusts than in disturbed, and sagebrush shrub canopies are often found with well developed biological soils. In contrast, early successional deerweed established more seedlings in disturbed soils. Based on physical and physiological traits, native plants appear to be better adapted to intact biological soil crusts whereas non-native grasses are better adapted to disturbed soils. Disturbing soil crusts could have a large effect on coastal sage scrub as it takes many years for soil crusts to recover to an undisturbed state. Hernandez and Sandquist (2011) point out the importance of reducing foot traffic, biking, off-road vehicles and management actions that disturb soils in areas with intact or recovering coastal sage scrub.

- A study of coastal sage scrub recovering from disturbances such as wildfire, grazing, and vegetation clearing found that non-native annual plant abundance was moderately related to disturbance, with the strongest effect from wildfire (Fleming et al., 2009). Woody species and native annual herbaceous plants were more negatively associated with invasive annual abundance than with disturbance. The authors recommend managing invasive annual plants and focusing more on understory herbs that are most affected by non-native annuals.
- One study showed that in degraded coastal sage scrub, drought favored non-native annual grasses at the expense of native plants (Purrity et al., 2019). Non-native annuals are especially adapted to invading resource-rich environments and can be reduced in biomass and cover by drought. However, non-native annuals are also more resilient and can rebound after a year of good rainfall, whereas native perennials tolerate drought better but do not recover from disturbance as quickly as the non-native annuals. Drought could facilitate invasion through a decrease in native biomass and cover so that there is less competition for light, soil moisture, and other resources that can benefit non-native annuals when there is higher rainfall.
- During post-fire recovery, drought also increases cover of invasive non-native annual plants with reduction of native shrub cover (Thomsen et al., 2021; Kimball et al., 2023). One study found that while native shrub cover increased over four years post-fire, drought and nitrogen deposition slowed down shrub recovery (Kimball et al., 2014). Non-native grass cover was high post-fire, increased after drought and was higher in high nitrogen deposition treatments (Kimball et al., 2014). Higher rainfall and weeding non-native annual grasses and forbs led to increased sagebrush seedling and small adult survival; non-native removal also increased shrub cover after fire and several years of drought (Thomsen et al., 2021).
- At least two years of invasive plant control before active restoration or seeding can enhance the success of native plant establishment for restoration and expansion projects (TNC and SDMMP 2015). Follow-up invasive plant control is often needed to allow native plants to grow and outcompete invasive nonnative annuals.

Developing a Location-specific Management Workplan

The previous research findings can inform development of project workplans to obtain the greatest management effect. The studies highlight the importance of evaluating site conditions and determining management goals prior to implementing a project (Orloff et al., 2015; Ta et al., 2024). Mapping areas for invasive plant control, shrub thinning, and planting/seeding of cactus and other native plants is helpful for determining labor, equipment and material needs. This type of pre-planning also can reduce adverse effects of management actions on sensitive natural resources at the site including native plants, cryptobiotic soil crusts, nesting birds, and arthropods. A project plan is important for clearly delineating the type and timing of management actions throughout the project period, estimating the cost, and increasing effectiveness of management actions.

Enhancement Management Options

Enhancement includes management to improve existing cactus scrub that do not involve planting of cactus or other native plants. Enhancement actions can be sufficient to improve the quality of existing cactus scrub. Enhancement actions can also occur in conjunction with cactus scrub restoration and expansion projects to prepare a site for planting cactus and other native plants and maintaining favorable conditions after planting to allow native plants to establish. Examples of enhancement actions include shrub thinning in and around cactus patches, reducing invasive non-native annual plants, controlling Argentine ants along mesic habitat edges, and taking measures to improve the health of cactus impacted by drought or disease pathogens.

Large shrubs and vines can crowd and overtop cactus patches resulting in competition for moisture and light, shrub dieback or desiccation, increased predator access to nests, reduced availability of sites for the placement of Cactus Wren nests, and increased severity of wildfire leading to cactus mortality. The most prevalent shrub species prone to crowding and crowding cactus are lemonade berry, sagebrush, and buckwheat (TNC and SDMMP, 2015). Sagebrush and buckwheat are important components of the federally-threatened Coastal California Gnatcatcher (*Polioptila californica californica*) habitat and management of these shrub species is selective and limited in impact. Shrub thinning is best targeted within the cactus patch or in the immediate vicinity and is not intended to be implemented throughout the territory. Shrub thinning is meant to remove shrubs and vines within cactus patches and to selectively trim and remove larger shrubs within a 3-5 m buffer of the cactus patch (TNC and SDMMP, 2015). It is important to have a biologist survey for active bird nests prior to habitat management and ideally conduct these actions outside the breeding season (September to February) to avoid impacts to nesting birds.

Managing invasive non-native annual grasses and forbs in San Diego County is difficult as many of these species are widespread and abundant, some species having been introduced into coastal sage scrub vegetation communities hundreds of years ago (Cox and Allen, 2008; Bell et al., 2016). See the previous section on “Invasion of Coastal Sage Scrub by Non-native Annuals and Management Options” for a discussion of management approaches.

Restoration Management Options

Restoration involves the planting of cactus and as needed other native shrubs, forbs, and grasses to improve existing and historic cactus scrub. Historic cactus scrub is scrub destroyed by a disturbance such as fire or mechanical clearing. It can be delineated using pre-disturbance cactus scrub mapping and wren locations. Restoration includes enhancement actions such as invasive non-native annual plant control and thatch removal to prepare a site for planting and continued control after planting to support the establishment and growth of native plants. It includes seeding or planting cactus and native plants. Other actions might involve temporary irrigation of plantings until they are established or during extreme drought, removal of dead cactus and shrubs, shrub thinning around cactus patches, and Argentine ant control along mesic edges. See the previous section on Invasion of Coastal Sage Scrub by Non-native Annuals and Management” for a discussion of management approaches.

To restore high quality cactus scrub careful consideration is made of the existing cactus scrub components and what can be added or removed. Control of invasive annual grasses and forbs before and after planting native plants is essential to increasing bare ground and successful establishment of native plants. Selecting restoration areas that avoid dense invasive non-native annual plants and with a matrix of bare ground for foraging and cryptobiotic or biological crusts can lead to a more successful restoration outcome. Cryptogamic crust helps to retain soil moisture and inhibit invasive non-native grasses (TNC and SDMMP, 2015), whereas bare ground provides arthropod prey in early and mid-nesting periods (Lynn et al., 2022). It is critical to avoid disturbing soil crusts when conducting restoration activities.

A diverse plant community is important in restoring high quality cactus scrub. Restoring cactus scrub to include plant species providing abundant arthropod prey at different points in the breeding cycle is one way to achieve higher overall Cactus Wren productivity and greater population resilience during future droughts. Because different plant species vary seasonally in the abundance of arthropod prey they support, it is important to include these species in the plant palette if they are not already present. Plants important for supporting arthropod prey, in addition to cactus, include native sagebrush, bunch grasses, and buckwheat. Prickly pear cactus can be an important food source in late summer and fall when food is limited, as it has large abundant fruit that attracts many insects. Other plants included in cactus scrub restoration palettes include lemonade berry, elderberry Menzies' goldenbush, deerweed, bush sunflower, foothill needle grass (*Stipa lepida*), goldfields (*Lasthenia californica*), gum plant (*Grindelia camporum*), miniature lupine (*Lupinus bicolor*), purple needle grass (*Stipa pulchra*) (Nakae and Sons and NewFields LLC, 2012; TNC and SDMMP, 2015). Clustered tarweed (*Deinandra fasciculata*), a late blooming annual, can provide insect activity late in the season but should be planted carefully as it can become too abundant and interfere with the growth of other native plants.

Winchell et al. (2021) mapped cactus patches and surveyed for Cactus Wrens in western San Diego County in 2009 and 2011. Cactus patches were defined as three or more cactus at least 2 feet (0.75m) tall or a single cactus at least 6 feet (2 m) in width and 2 feet (0.75 m) tall. Cacti were mapped into a patch if they were within 45 (15 m) feet of each other. Thus, these patches were not always contiguous stands of cactus but could be groupings of cactus within a larger patch. The study found that cactus patches of 0.4 acres (0.15 ha) or larger had a 60 percent or higher probability of use by Cactus Wrens. Typically, cactus suitable for nesting are 1 m or taller (Hamilton et al., 2020).

Restoration projects have used various configurations of cactus to recover cactus scrub habitat. Generally, the most successful projects are those that restore or create cactus patches within coastal sage scrub near existing wren territories. Often the number of acres of cactus planted is relatively small and spread out as cactus patches within "territory units" over a larger restoration project area. For example, the San Diego National Wildlife Refuge used 10m x 10m patches of 100 cactus with 1 cactus/m^2 for a total of about 3 acres of cactus planted (Martin, 2014). Two of these clusters or patches were placed within 5-acre units (2 ha), the estimated wren territory size, and spread out over many acres of refuge land. Invasive plant control was conducted at cactus patches and in some surrounding areas. Cactus Wrens occupy three of these clusters (table 4) near other wren territories at the Sweetwater Reservoir.

From 2010 through 2012, the San Diego Zoo Wildlife Conservation Alliance planted cactus and treated invasive non-native annual plants to aid in recovery of wren habitat burned in a 2007 wildfire at the Safari Park location (Endress and Motheral, 2013). In this project 45 different 3-4 acre "enhancement areas" contained a one-acre plot in which cactus were planted. These enhancement plots, similar to a territory, were placed adjacent or near existing lightly burned cactus scrub occupied by wrens. Each cactus plot had 5 circular subplot "islands" with 10 larger propagated and rooted cactus and 100 cactus pads spread throughout the plot. As of 2022, there were at least six new territories in these restored areas (table 4).

The California Department of Transportation augmented existing open scrub habitat with small cholla clumps (total of 1.5 acres) adjacent to Johnson Canyon and created six new territories (table 4).

All of these projects have maximized the area that can be restored to increase the wren population using a strategy of clumping cactus in patches within a larger "territory" size area of three to five acres. It is expected that more wrens will use these restored areas over time as the cactus mature and become larger and as the wren population is more productive in good rainfall years.

Cactus Scrub Expansion Management Options

Cactus scrub expansion is essentially restoration but in relatively large areas of a location with no records of current or historic cactus scrub or wren occupancy. Winchell et al. (2021) found that cactus patches spaced farther than 0.5 miles (800 m) apart were unlikely to be occupied. All of the locations where cactus scrub expansion is prioritized (appendix 5, tables 5.1-5.4) are much closer than 800 m to existing cactus scrub supporting wrens. Cactus scrub expansion can occur next to existing or historic scrub. Distinguishing between restoration and expansion depends largely on scale and decisions about how to delineate these two types of management. For example, cactus scrub expansion may include adding cactus to existing coastal sage scrub or creating new cactus scrub by planting cactus and native shrubs, grasses and forbs. The management actions for cactus scrub expansion are described above in the description of restoration management options.

Additional considerations for creating cactus scrub include selection of the area for cactus scrub expansion (TNC and SDMMP, 2015). Typically, cactus scrub is found on valley bottoms, low to moderately steep south- and west-facing slopes, and occasionally on steeper slopes. The extreme drought in 2014 showed that at some locations cacti were susceptible to desiccation and even death, especially in hotter and drier areas. Micro-topographic diversity might increase resilience under a changing climate with rising temperatures and increasing drought frequency and intensity. Diversity in micro-topography provides a greater array of micro-climates that can better retain soil moisture. Cactus can be planted to take advantage of areas with higher soil moisture by planting in more mesic areas of a site, such as southeast-facing slopes, at the toe of the slope, and in shallow ravine bottoms with deeper soils.

Maintain Cactus Nurseries in North and South San Diego County

The MSP has regional objectives to support cactus nurseries in north and south San Diego County. There are differences in the types of dominant cactus species, soil characteristics, microclimate, and other environmental conditions between north, southcentral, and southwest San Diego County. For these reasons, nurseries are best situated in each geographic area to supply cactus for nearby cactus scrub restoration and expansion projects. Nurseries provide a source of rooted cactus plants and unrooted cactus segments and pads for use in cactus scrub post-fire recovery, restoration, and expansion projects.

Regional funding has been used to fund operations and refurbishment of the North San Diego County Cactus Nursery at Lake Hodges on City of San Diego Public Utility District (PUD) lands. This nursery has a new shade cloth and irrigation system and a stand of planted prickly pear cactus. Regional grant funding also supported a temporary cactus nursery at Lower Otay Lake in south San Diego County for growing cholla for a City of San Diego PUD cactus scrub expansion project. The USFWS also maintains a nursery at CDFW's Rancho Jamul Ecological Reserve in south San Diego County. This nursery is largely cholla salvaged from a south San Diego County development project. Ideally, another nursery could be established in the Lake Jennings area to provide a mixture of cholla and prickly pear cactus grown in environmental conditions suitable for cactus restoration and expansion at locations within this genetic cluster.

Sources of cactus include collection of propagules from existing conservation areas and salvaged cactus plants from habitat that is being developed. At existing conservation areas, cactus propagule collection focuses on lower limbs of unoccupied cactus and collection of no more than five percent of the individual cactus (TNC and SDMMP, 2015). Based on observations of experienced biologists conducting cactus wren nest monitoring studies, dense cholla thickets can have branches so thick and close together that wrens appear not to use them for nesting (K. Moore, D. Kamada, S. Lynn, K. Preston, pers. comm). It is advantageous to collect cholla segments from these patches so that they can more easily support nests and to provide propagules for restoration. The City of San Diego has an ordinance to salvage succulents such as cholla and prickly pear from areas approved for development and to use this collected cactus in restoration projects within the City. This includes salvage of large (~1 m tall), mature cactus that can be added to restoration sites for immediate use by Cactus Wrens. The nurseries can be a repository for salvaged rooted cactus plants and propagules that can be planted and grown into larger cactus for future restoration projects. Planting large cactus promotes quicker recovery of burned habitat as well as more rapid expansion of new habitat. This can be critical for expanding wren populations that have been impacted by fire or are so small as to be at risk of local extirpation.

Several criteria for maintaining the nurseries are described below with several guidelines adapted with some modifications from the South County management plan (TNC and SDMMP, 2015):

- Nurseries are ideally situated on lands that can serve as refugia from wildfire, such as developed areas likely to be defended from wildfire. The Rancho Jamul Ecological Reserve Cactus Nursery is adjacent to buildings that house offices for land managers and that can serve as a staging area for fire fighters during fires. The North San Diego County Cactus Nursery is in a commercial nursery next to Lake Hodges with easy road access, municipal water supply, and irrigation systems.
- Each of the nursery sites requires access to reliable water, irrigation infrastructure, and outside areas to plant cactus in the ground that can grow to a large size to provide propagules, segments, and large rooted plants for restoration projects. Shade cloth is desirable for initial growth of potted cactus pads and segments.
- Most of the planted cactus at the Rancho Jamul nursery and North San Diego County Cactus Nursery are nearing maturity (~1 m tall) and currently require little irrigation, except during prolonged drought periods. Irrigating future cactus plantings can promote sufficient annual growth to reach 1 m height within five growing seasons.
- Species composition of rooted cactus plants and unrooted segments and pads for planting match those of cactus scrub habitat in each genetic cluster. This composition is about 70 percent cholla and 30 percent prickly pear in the Otay and Sweetwater/Encanto clusters and the opposite percentages in the Lake Jennings cluster. In San Pasqual Valley, only prickly pear species are used.
- Following best management practices, cactus propagules used for restoration projects or to stock the nurseries are collected from within the genetic cluster where the restoration takes place.
- In the cactus nursery, propagules are grouped by collection location and maintained separate from propagules collected at other locations. This preserves the genetic provenance and ensures cactus planted at a restoration site is from the closest collection site within the same Cactus Wren genetic cluster.
- The cactus nurseries are best kept free of weeds and Argentine ants.
- Propagules planted directly in the ground are spaced so they can be removed from the ground without impacting other plants. Rooted cactus are often removed from the soil two weeks before bareroot transplanting to let their roots harden before transportation to the restoration location.
- Cactus plants are regularly inspected for symptoms of pathogens such as *Alternaria* fungal species, for effects of drought stress, and for other signs of ill health or die-off.

In April 2021, AECOM biologists and the City of San Diego land manager observed signs of disease in coastal prickly pear cactus plants at North San Diego County Cactus Nursery at Lake Hodges (fig. 21). Surveys and tissue collection were undertaken in 2022 at the nursery and 10 cactus scrub sites throughout north San Diego County (AECOM, 2022). These sites included four that were a source of cactus plants for the nursery. Three of these source sites also received out-plantings of rooted cactus and propagules grown from the collected plants. Four other sites received cactus grown at the nursery for a total of seven restoration sites receiving 8,000 rooted cactus and propagules from the nursery. Two sites are considered “wild” as they had neither contributed nor received cactus plants from the nursery. All eleven sites were

surveyed for signs of disease and ten of the eleven had at least one symptomatic cactus sample collected. The Safari Park was the only site with no symptomatic cactus observed. There were not many of symptomatic plants detected at sites, except for Torrey Pines State Park.

Samples were sent to the University of California, Davis for identification of the disease organism and for pathogenicity tests. Fungal species in the *Alternaria* genus were found in 81 percent of 21 samples. Other fungal species were found in a high percentage of samples but are not considered pathogenic. *Alternaria* species were shown to cause the symptoms observed in the nursery cactus (Castillo and Arndt-Truong, 2023). The *Alternaria* species were found not to be highly pathogenic and did not intrude deep into the plant tissue (Castillo and Arndt-Truong, 2023 and personal communication). Cactus plants at the nursery have recovered and are no longer showing many symptoms (fig. 22). Greenhouse trials are in progress to evaluate the effects of water and humidity on pathogen expression.

In summary, while signs of disease were temporarily observed and widespread in distribution, the symptoms occurred in low numbers of plants across restored and wild sites in north San Diego County. The effects of the *Alternaria* infections were not lethal, and cactus plants appear to have recovered.

Figure 21. Coastal prickly pear at North San Diego County Cactus Nursery showing symptoms of *Alternaria* fungal infection in April 2020. Photograph by Kim Wehinger, City of San Diego PUD.

Figure 22. Coastal prickly pear at North San Diego County Cactus Nursery recovered from *Alternaria* fungal infection in September 2021. Photograph by Kim Wehinger, City of San Diego PUD.

Conclusions and Future Directions

This updated and expanded analysis can guide and support Cactus Wren regional habitat management projects for the next 10-15 years. An online GIS tool is being added to the SDMMP webportal with Cactus Wren monitoring data on wren population status and habitat conditions from 2015-2024 and will be updated in future years. This tool can be used by land managers to refine their projects and priorities over time. As projects are accomplished, they will be adding to the growing database of Cactus Wren management actions so that progress and effectiveness of management actions can be tracked.

To evaluate how effective cactus management is, the 2009 and 2011 cactus mapping (USFWS, 2011a) could be updated to include cactus scrub restoration and expansion areas. Updated cactus mapping could also document changes in cactus patches since 2011 across the monitoring locations and include a greater diversity of slope aspects, not just southwest, south and southeast facing slopes (Winchell et al., 2021). Wren monitoring could also be expanded to encompass enhanced, restored and newly created cactus scrub in areas not currently monitored to document whether these managed areas are being used. Cactus mapping and monitoring could include new locations with wrens that have not been previously monitored. It is expected that the effects of habitat management will grow with time as the restored and newly created cactus scrub habitat matures and wrens begin to use this habitat. Concerted efforts to manage Cactus Wren habitat over the last 15 years is helping increase wren populations. It is anticipated this management can increase population resilience to threats of wildfire, drought, and invasive non-native annual plants.

Because of the continued decline in Cactus Wren genetic diversity and the threat of inbreeding (Vandergast et al., 2022), the MSP has objectives not just for habitat management but to also actively assist gene flow between genetic clusters. This latter objective may require a separate management approach with details on methods to conduct reciprocal egg transfer between populations and pilot studies to test best practices and assess effectiveness of the methods.

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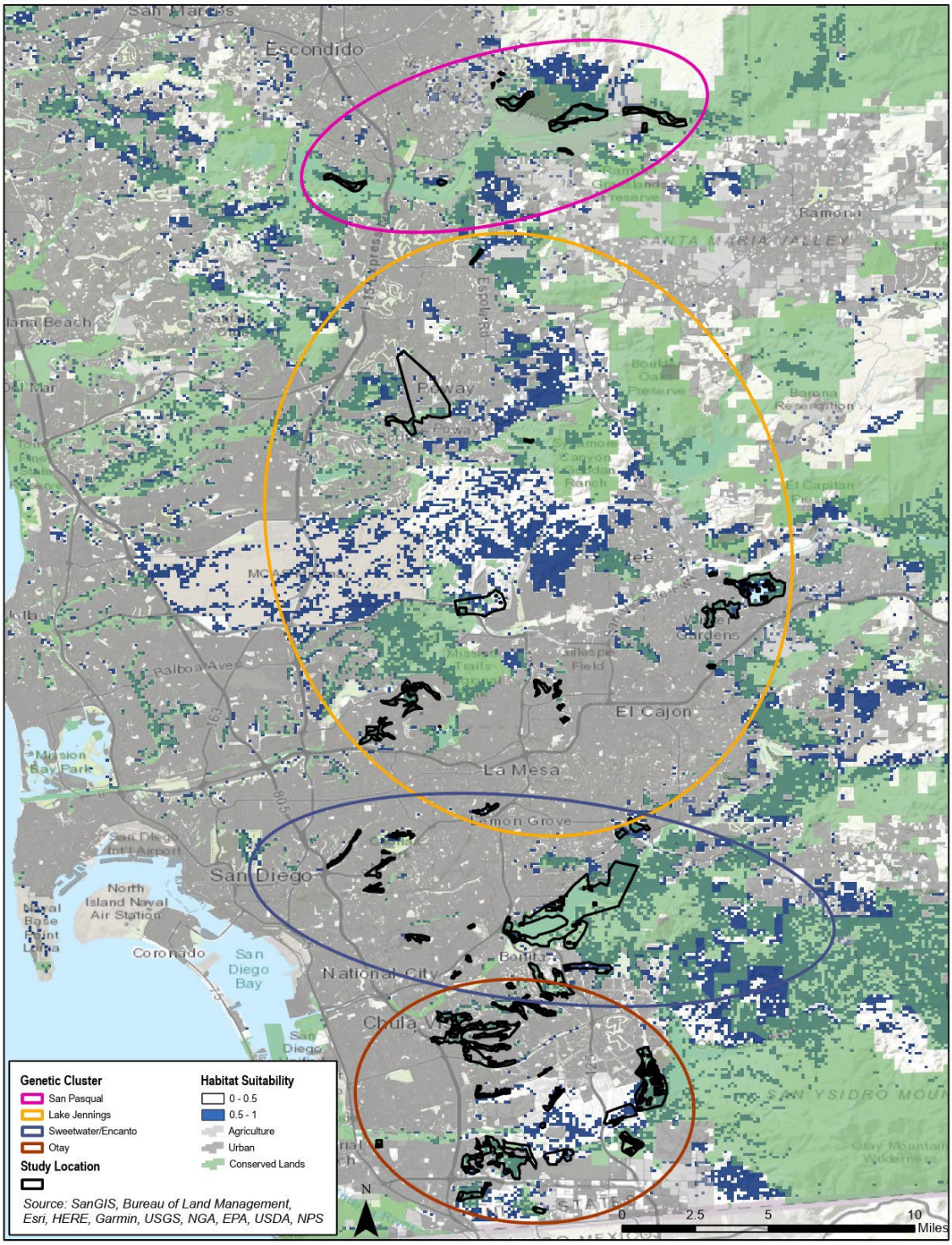
Appendix 1. Habitat suitability in proximity to Cactus Wren study locations within genetic clusters in San Diego County, California. Source: Preston et al., 2020.



Appendix 2. Cactus Wren occupancy data 2015-2022

Table 2.1 Number of plots occupied by Cactus Wrens/number of all plots surveyed, and percent occupied by Cactus Wrens (in parentheses) by location and year (2015, 2017-2022), San Diego County, California. No surveys were conducted in 2016. ND means there were no data collected that year or location.

Location	2015	2017	2018	2019	2020	2021	2022
San Pasqual Cluster							
Lake Hodges	ND	ND	ND	4/9 (44)	ND	ND	7/9 (78)
Mule Hill	ND	ND	ND	1/2 (50)	ND	ND	1/2 (50)
Cloverdale/Rockwood	ND	ND	ND	4/4 (100)	ND	ND	4/4 (100)
Safari/Battlefield Park	ND	ND	ND	58/59 (98)	ND	ND	56/59 (95)
Safari Park West	ND	ND	ND	6/8 (75)	ND	ND	6/8 (75)
Bandy Canyon	ND	ND	ND	2/3 (67)	ND	ND	1/3 (33)
Academy	ND	ND	ND	0/2 (0)	ND	ND	1/2 (50)
Whitman Ranch	ND	ND	ND	6/13 (46)	ND	ND	8/13 (62)
Total by Year	***ND***	***ND***	***ND***	***81/100 (81)***	***ND***	***ND***	***85/100(85)***
Lake Jennings Cluster							
Poway	ND	ND	ND	ND	ND	ND	0/16 (0)
Navajo Canyon	3/18 (17)	2/20 (10)	1/20 (5)	3/20 (15)	5/20 (25)	2/20 (10)	1/20 (5)
Mission Trails	0/2 (0)	0/3 (0)	0/3 (0)	0/3 (0)	0/3 (0)	0/3 (0)	0/3 (0)
La Mesa	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)
Sycamore Canyon	ND	ND	ND	1/1 (100)	1/1 (100)	1/1 (100)	1/1 (100)
Hillside Park	ND	3/12 (25)	7/12 (58)	9/12 (75)	6/12 (50)	8/12 (67)	6/12 (50)
El Cajon	2/4 (50)	4/6 (67)	2/7 (29)	4/7 (57)	3/7 (43)	3/7 (43)	2/5 (40)
Cactus Park	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)
Lakeside	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)
Lakeside Linkages	1/3 (33)	1/3 (33)	1/3 (33)	1/3 (33)	2/3 (67)	3/3 (100)	1/3 (33)
Lake Jennings	10/16 (63)	10/16 (63)	12/16 (75)	10/18 (56)	12/18 (67)	14/18 (78)	11/18 (61)
Total by Year	***16/48 (33)***	***22/67(33)***	***25/68 (37)***	***28/69 (41)***	***29/69 (42)***	***31/69 (43)***	***22/84 (26)***
Sweetwater/Encanto Cluster							
Chollas Valley	0/12 (0)	0/12 (0)	1/12 (8)	3/12 (25)	2/12 (17)	3/12 (25)	5/12 (42)
Market St/Encanto Canyon	6/10 (60)	6/10 (60)	8/10 (80)	9/10 (90)	10/10 (100)	10/10 (100)	10/10 (100)
Martin Luther King	0/6 (0)	0/7 (0)	0/7 (0)	1/7 (14)	2/7 (29)	1/7 (14)	2/7 (29)
Chollas Reservoir	0/6 (0)	0/6 (0)	0/6 (0)	2/6 (33)	3/6 (50)	3/6 (50)	3/6 (50)
Paradise Valley	2/5 (40)	4/6 (67)	6/6 (100)	5/6 (83)	4/6 (67)	3/6 (50)	6/6 (100)
Emerald Ranch Open Space	ND	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)
Winnetka Open Space	ND	2/3 (67)	1/3 (33)	1/3 (33)	1/3 (33)	1/3 (33)	0/3 (0)
Sweetwater Quarry	2/2 (100)	2/2 (100)	1/2 (50)	2/2 (100)	2/2 (100)	1/2 (50)	0/2 (0)
Sweetwater County	3/4 (75)	4/5 (80)	5/6 (83)	4/6 (67)	4/6 (67)	4/6 (67)	4/6 (67)
Sweet Caltrans	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)
Sweetwater Authority	2/12 (17)	4/13 (31)	7/13 (54)	6/13 (46)	8/13 (62)	5/13 (38)	6/13 (46)
San Diego NWR	3/3 (100)	3/4 (75)	4/5 (80)	3/5 (60)	4/5 (80)	3/5 (60)	3/5 (60)
Skyline	ND	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)
Total by Year	***18/67 (27)***	***25/83 (30)***	***33/85 (39)***	***36/85 (42)***	***40/85 (47)***	***34/85 (40)***	***39/85 (46)***

	Otay Cluster						
Rice Canyon	0/44 (0)	0/45 (0)	2/45 (4)	1/45 (2)	2/45 (4)	4/45 (9)	2/45 (4)
Furby North	0/8 (0)	1/8 (13)	1/8 (13)	1/8 (13)	1/8 (13)	0/8 (0)	0/8 (0)
Ocean View Hills	0/9 (0)	0/9 (0)	0/9 (0)	0/9 (0)	0/9 (0)	0/9 (0)	0/9 (0)
Telegraph Canyon	0/11 (0)	0/11 (0)	0/11 (0)	0/11 (0)	0/11 (0)	0/11 (0)	0/11 (0)
Poggi Canyon	0/13 (0)	0/13 (0)	0/13 (0)	0/13 (0)	0/13 (0)	0/13 (0)	0/13 (0)
Dennery Canyon	0/7 (0)	0/7 (0)	0/7 (0)	0/7 (0)	1/7 (14)	1/7 (14)	0/7 (0)
Long Canyon	0/21 (0)	0/21 (0)	0/21 (0)	0/21 (0)	0/21 (0)	0/21 (0)	0/21 (0)
Wruck Canyon	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)	0/2 (0)
Wolf Canyon	5/7 (71)	5/7 (71)	3/7 (43)	2/7 (29)	2/7 (29)	3/7 (43)	0/7 (0)
Brown Airfield	0/3 (0)	0/3 (0)	1/3 (33)	0/3 (0)	1/3 (33)	1/3 (33)	1/3 (33)
Otay	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)	0/1 (0)
Otay Ranch Preserve	1/4 (25)	1/4 (25)	3/4 (75)	4/4 (100)	4/4 (100)	4/4 (100)	4/4 (100)
Johnson Canyon	9/12 (75)	12/13 (92)	13/15 (87)	12/14 (86)	12/15 (80)	13/15 (87)	13/15 (87)
Salt Creek	9/57 (16)	14/57 (24)	23/57 (38)	29/60 (48)	29/60 (48)	26/60 (43)	25/60 (42)
Total by Year	***24/199 (12)***	***33/203 (16)***	***46/207 (22)***	***49/206 (24)***	***52/206 (25)***	***52/207 (25)***	***45/206 (22)***

Table 2.2 Number of plots occupied by Cactus Wrens/number of plots surveyed every year, and percent occupied by Cactus Wrens (in parentheses), by location and year (2015, 2017–2022) in San Diego County, California. See Table 2.1 for data on San Pasqual cluster.

Location	# plots	2015	2017	2018	2019	2020	2021	2022
				Lake Jennings Cluster				
Navajo Canyon	18	3 (17)	2 (11)	1 (6)	3 (17)	5 (28)	2 (11)	1 (6)
Mission Trails	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
La Mesa	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
El Cajon	2	1 (50)	2 (100)	0 (0)	1 (50)	1 (50)	1 (50)	2 (100)
Cactus Park	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lakeside	1	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lakeside Linkages	3	1 (33)	1 (33)	1 (33)	1 (33)	2 (67)	3 (100)	1 (33)
Lake Jennings	16	10 (63)	10 (63)	12 (75)	9 (56)	10 (63)	12 (75)	9 (56)
Total by Year	***46***	***15 (33)***	***15 (33)***	***14 (30)***	***14 (30)***	***13 (28)***	***18 (39)***	***13 (28)***
				Sweetwater/Encanto Cluster				
Chollas Valley	12	0 (0)	0/12 (0)	1/12 (8)	3/12 (25)	2/12 (17)	3/12 (25)	5/12 (42)
Market St/Encanto	9							
Canyon		5 (56)	6 (67)	8 (89)	8 (89)	9 (100)	9 (100)	9 (100)
Martin Luther King	6	0 (0)	0 (0)	0 (0)	1 (17)	2 (33)	1 (17)	2 (33)
Chollas Reservoir	6	0 (0)	0 (0)	0 (0)	2 (33)	3 (50)	3 (50)	3 (50)
Paradise Valley	5	2 (40)	3 (60)	5 (100)	4 (80)	4 (80)	3 (60)	5 (100)
Sweetwater Quarry	2	2 (100)	2 (100)	1 (50)	2 (100)	2 (100)	1 (50)	0 (0)
Sweetwater County	4	3 (75)	3 (75)	3 (75)	3 (75)	3 (75)	3 (75)	3 (75)
Sweet Caltrans	7	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Sweetwater Authority	12	2 (17)	4 (33)	7 (58)	6 (50)	7 (58)	5 (42)	6 (50)
Total by Year	***63***	***14 (22)***	***18 (29)***	***19 (30)***	***29 (46)***	***32 (51)***	***28 (44)***	***33 (52)***
				Otay Cluster				
Rice Canyon	44	0 (0)	0 (0)	2 (5)	1 (2)	2 (5)	4 (9)	2 (5)
Furby North	8	0 (0)	1 (13)	1 (13)	1 (13)	1 (13)	0 (0)	0 (0)
Ocean View Hills	9	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Telegraph Canyon	11	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Poggi Canyon	13	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dennery Canyon	7	0 (0)	0 (0)	0 (0)	0 (0)	1 (14)	1 (14)	0 (0)
Long Canyon	21	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Wruck Canyon	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Wolf Canyon	7	5 (71)	5 (71)	3 (43)	2 (29)	2 (29)	3 (43)	0 (0)
Brown Airfield	3	0 (0)	0 (0)	1 (33)	0 (0)	1 (33)	1 (33)	1 (33)
Otay	1	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Otay Ranch Preserve	4	1 (25)	1 (25)	3 (75)	4 (100)	4 (100)	4 (100)	4 (100)
Johnson Canyon	12	9 (75)	11 (92)	10 (83)	10 (83)	9 (75)	11 (92)	10 (83)
Salt Creek	56	9 (16)	13 (23)	21 (38)	25 (45)	25 (45)	23 (41)	23 (41)
Total by Year	**198**	***24 (12)***	***31 (16)***	***41 (21)***	***43 (22)***	***45 (23)***	***47 (24)***	***40 (20)***

Appendix 3. Habitat condition in 2022 at Cactus Wren survey plots by genetic cluster

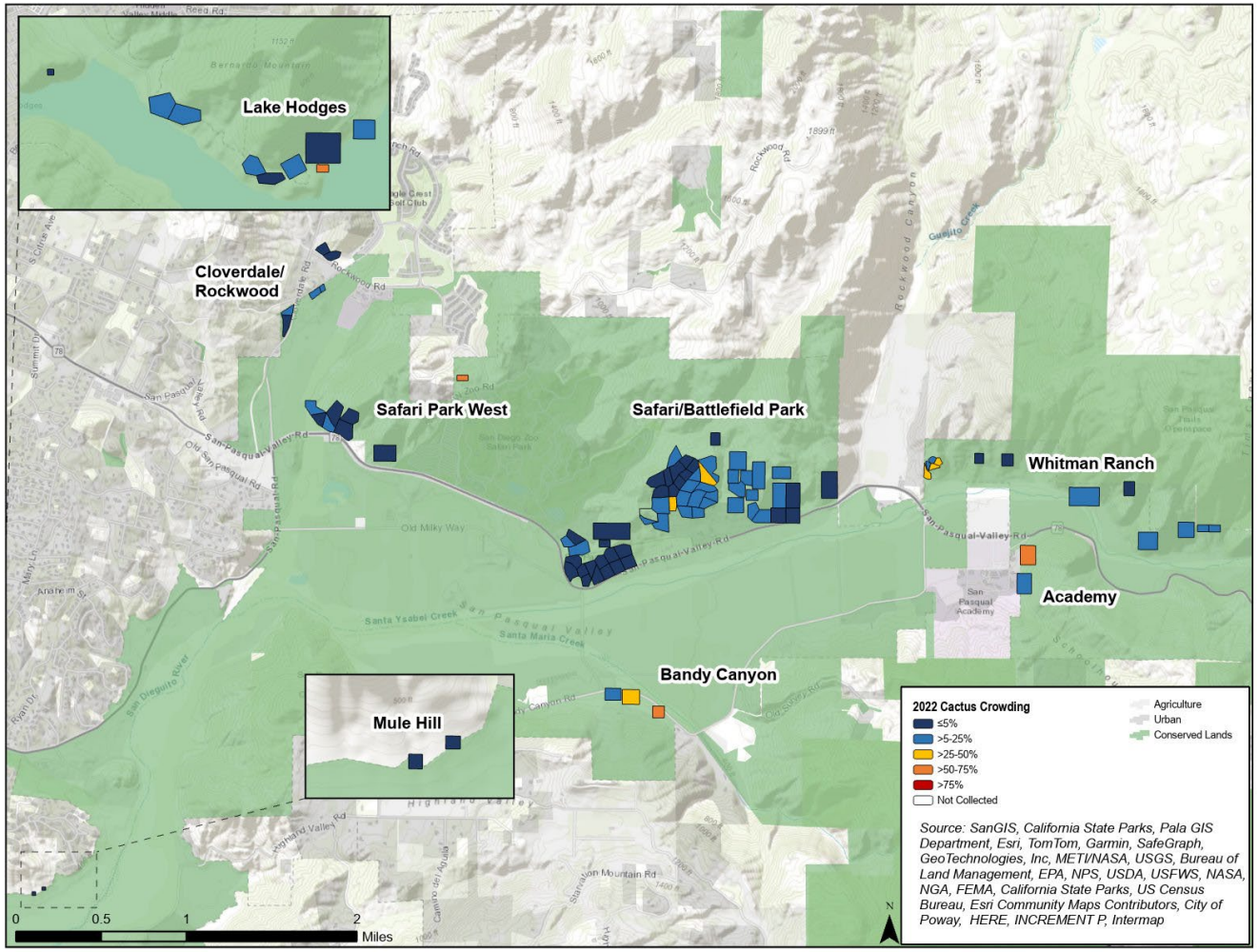


Figure 3.1. Percent of cactus crowded by shrubs in cactus plots in the San Pasqual cluster, San Diego County, California, 2022.

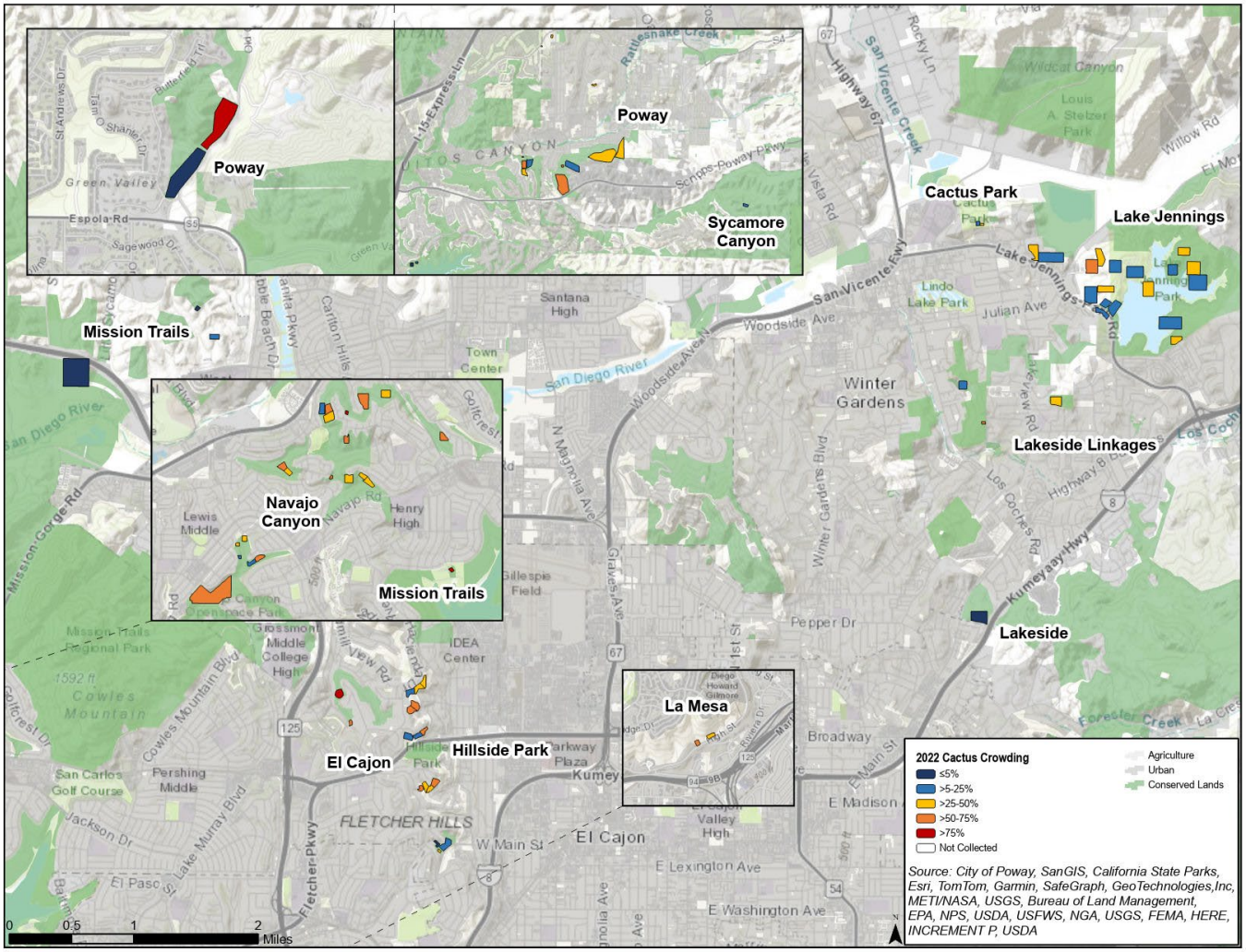


Figure 3.2. Percent of cactus crowded by shrubs in cactus plots in the Lake Jennings, San Diego County, California, 2022.

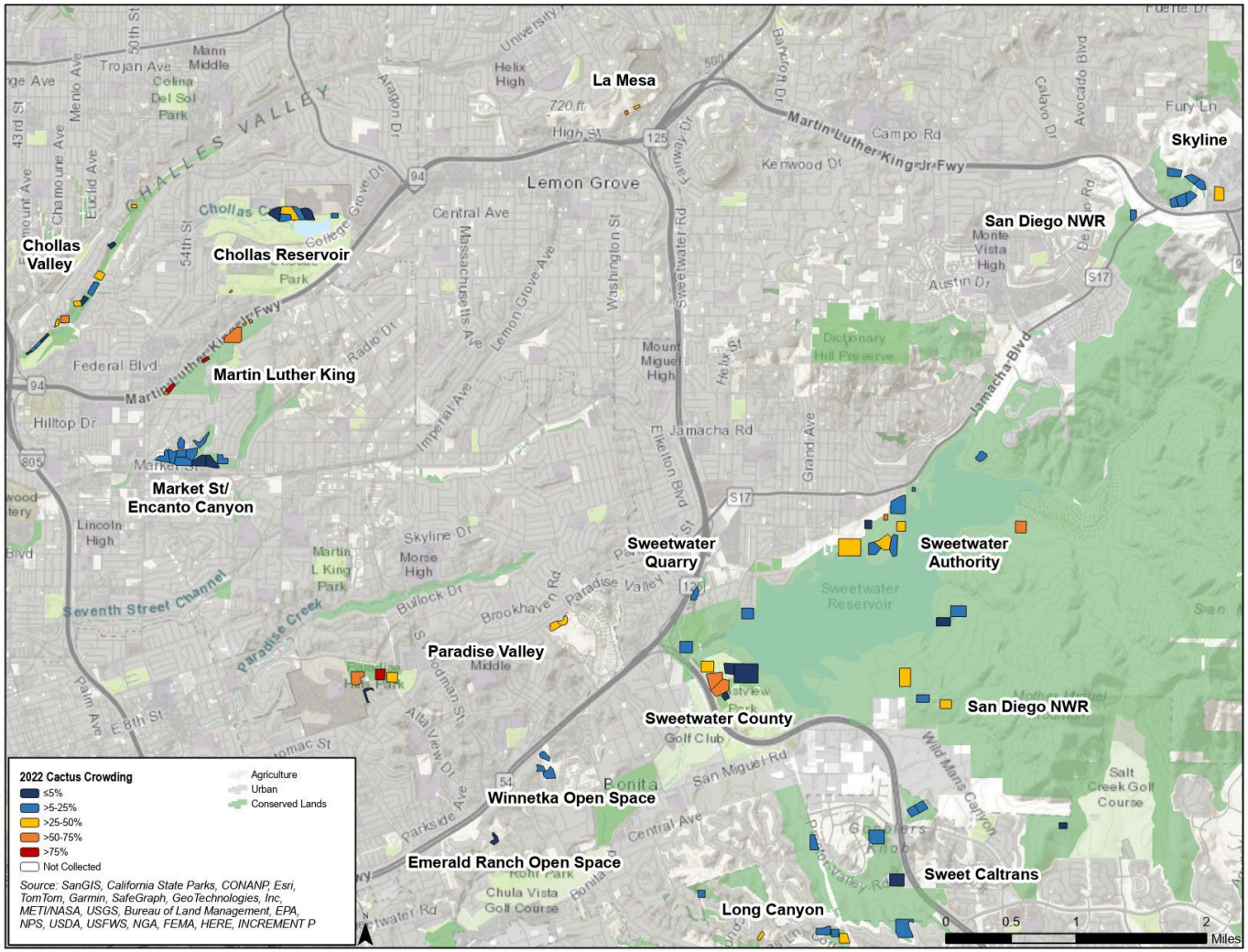


Figure 3.3. Percent of cactus crowded by shrubs in cactus plots in the Sweetwater/Encanto cluster, San Diego County, California, 2022.

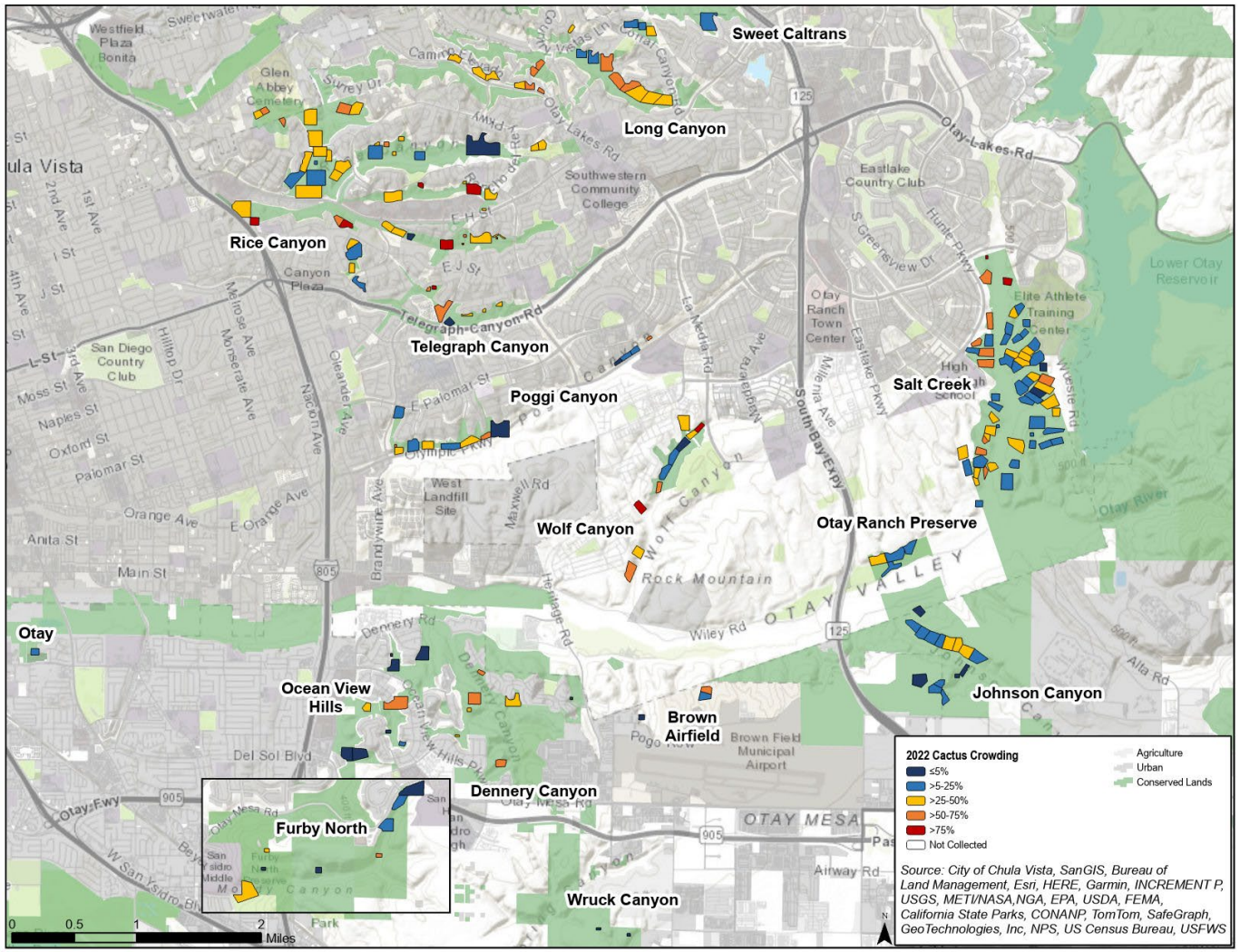


Figure 3.4. Percent of cactus crowded by shrubs in cactus plots in the Otay cluster, San Diego County, California, 2022.

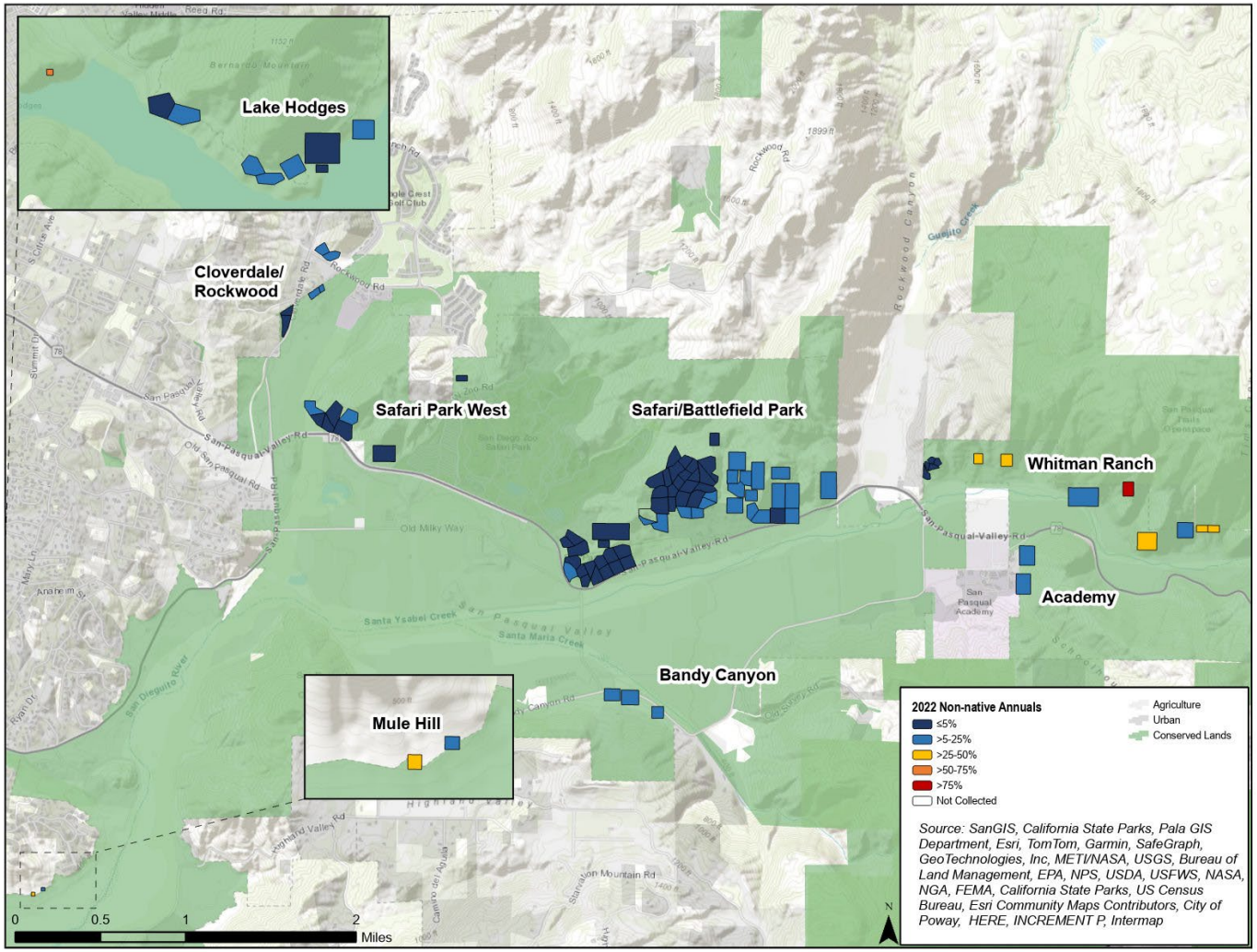


Figure 3.5. Percent cover of non-native annuals in cactus plots in the San Pasqual cluster, San Diego County, California, 2022.

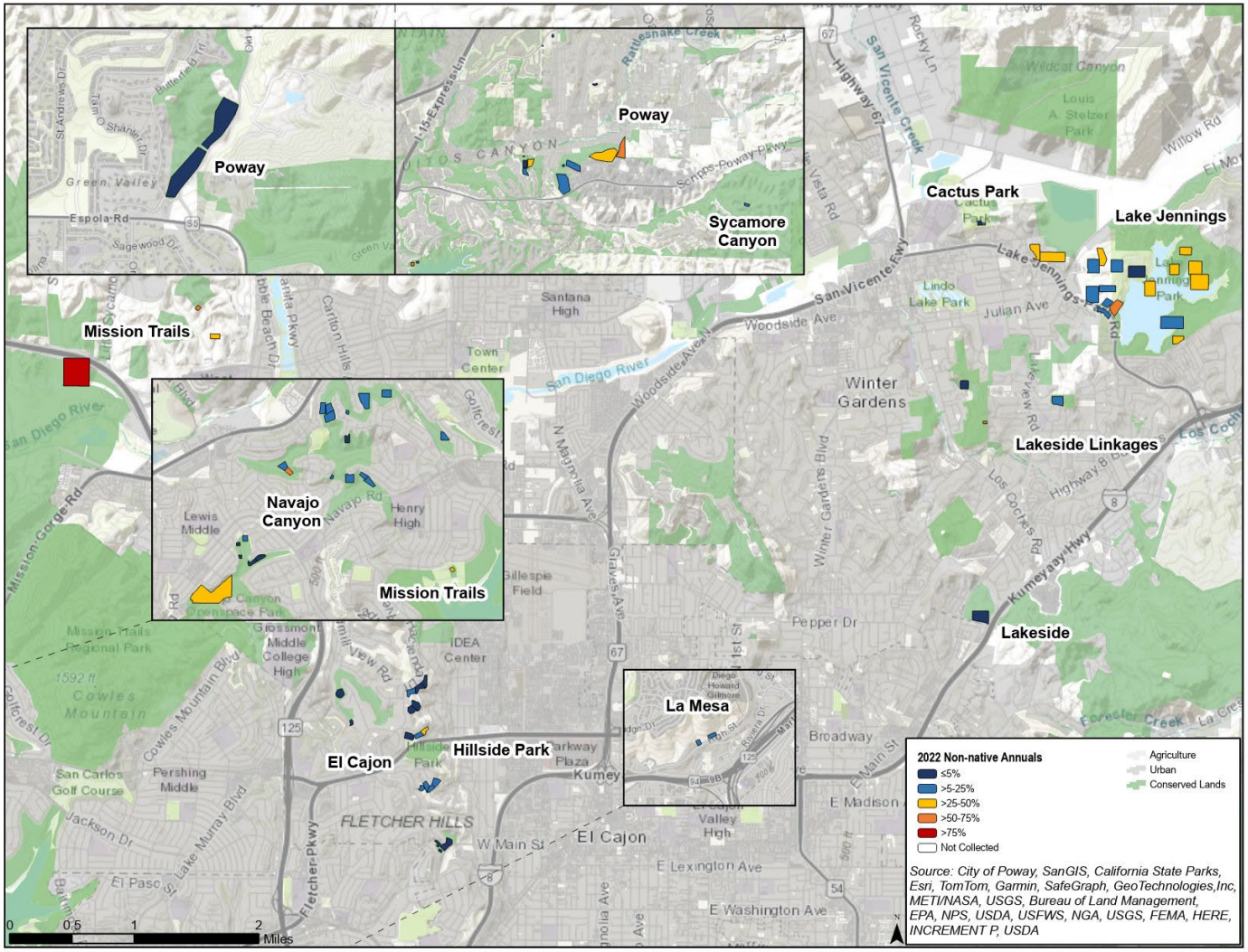


Figure 3.6. Percent cover of non-native annuals in cactus plots in the Lake Jennings cluster, San Diego County, California, 2022.

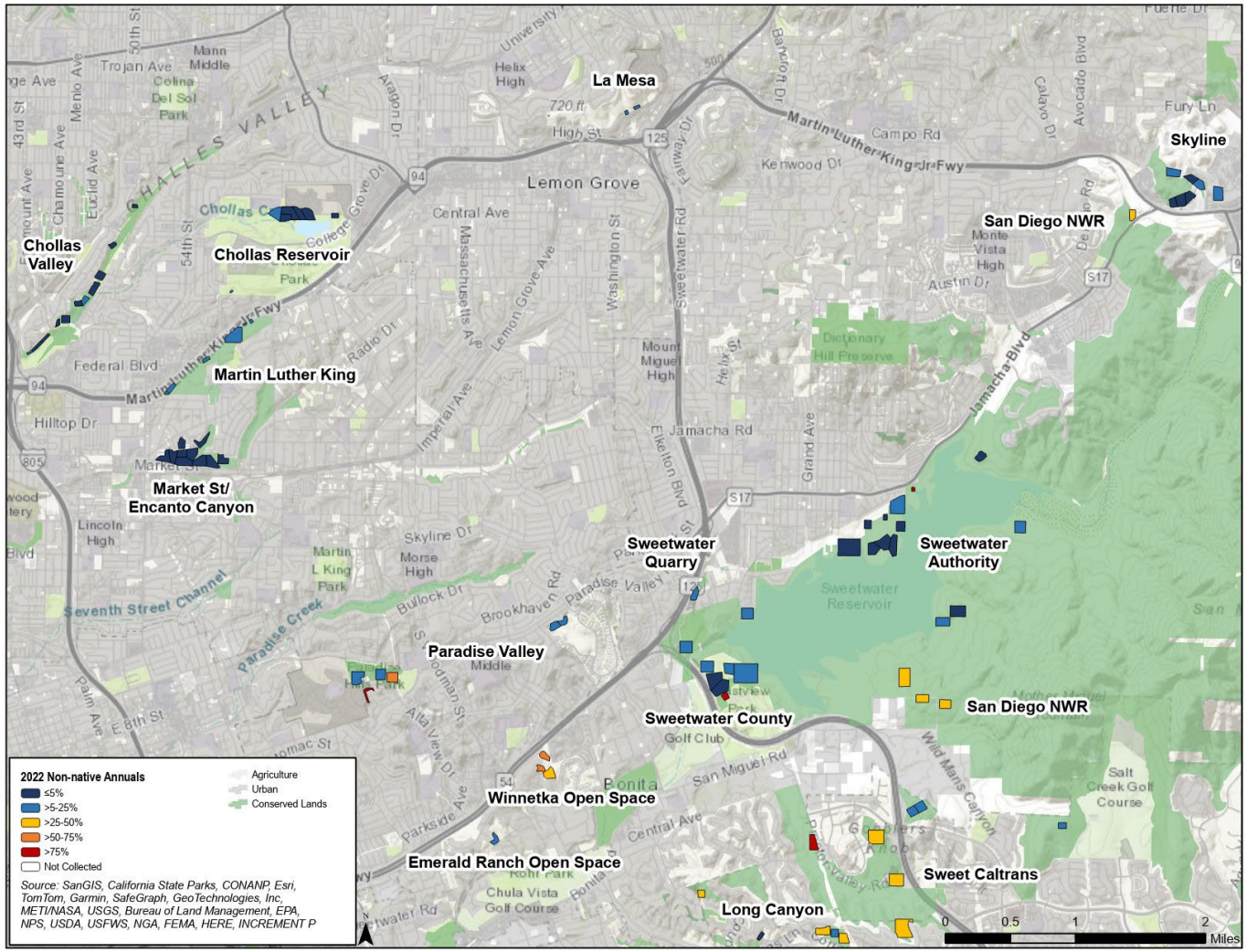


Figure 3.7. Percent cover of non-native annuals in cactus plots in the Sweetwater/Encanto cluster, San Diego County, California, 2022.

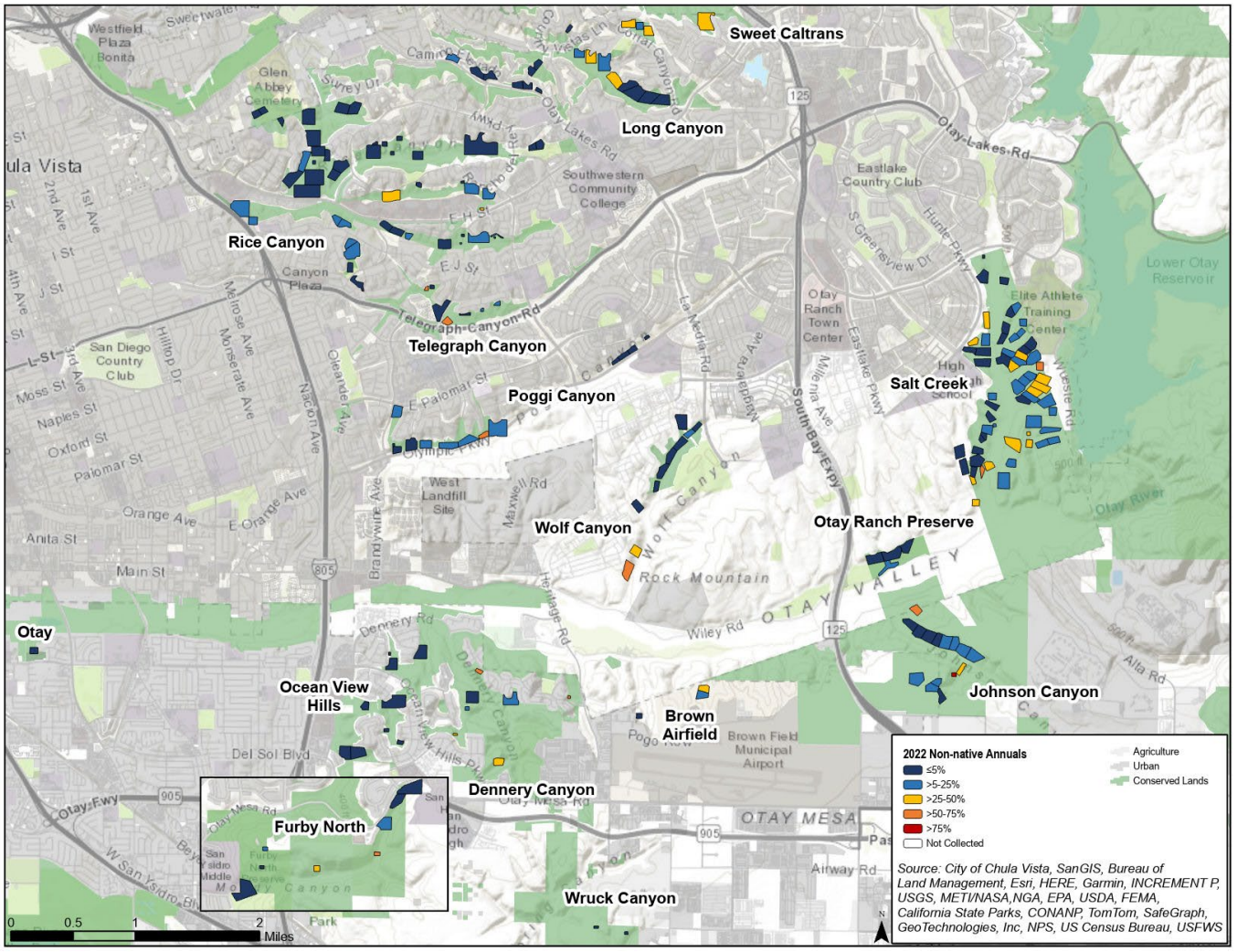


Figure 3.8. Percent cover of non-native annuals in cactus plots in the Otay cluster, San Diego County, California, 2022.

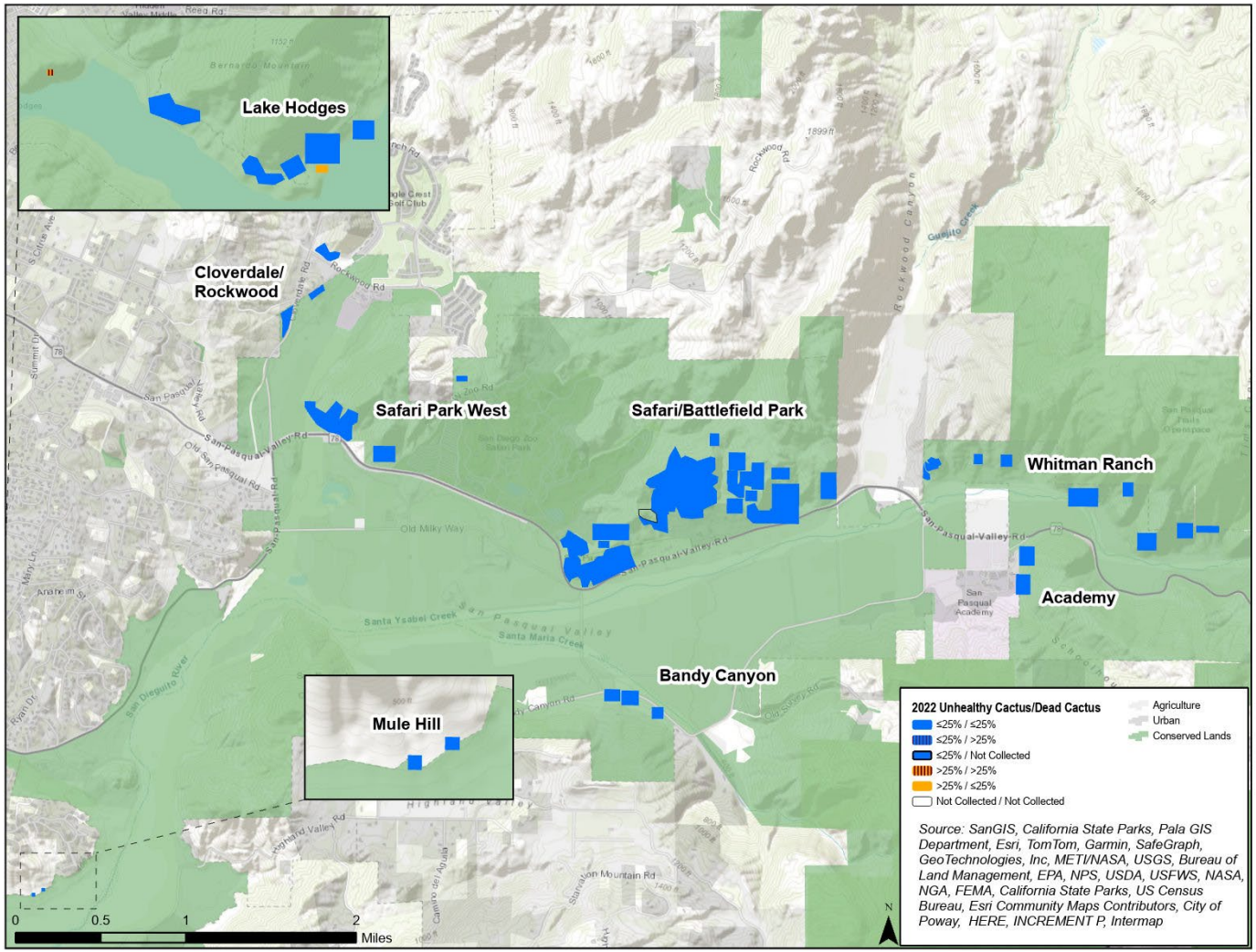


Figure 3.9. Percent of cactus that was unhealthy or dead in cactus plots in the San Pasqual cluster, San Diego County, California, 2022.

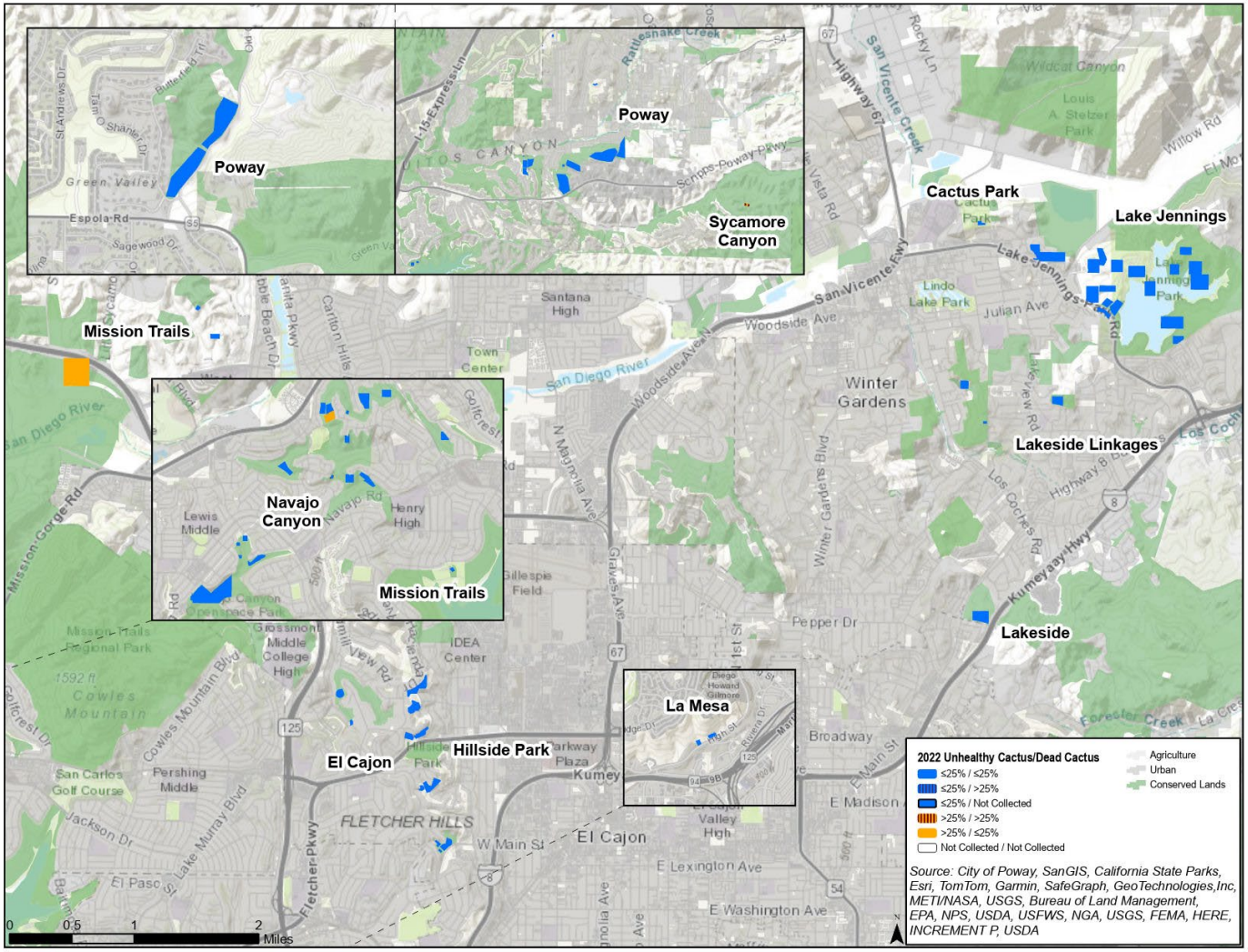


Figure 3.10. Percent of cactus that was unhealthy or dead in cactus plots in the Lake Jennings cluster, San Diego County, California, 2022.

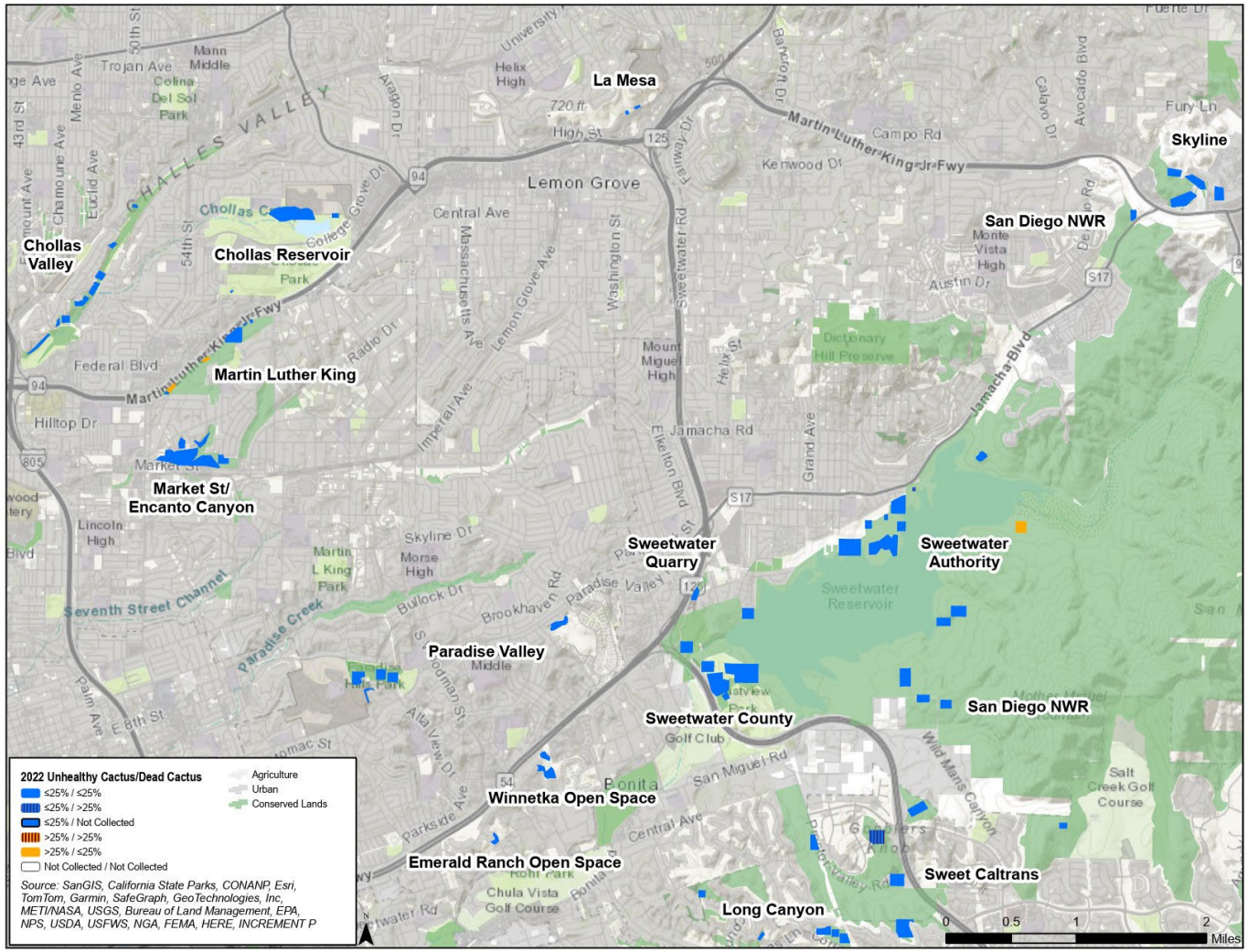


Figure 3.11. Percent of cactus that was unhealthy or dead in cactus plots in the Sweetwater/Encanto cluster, San Diego County, California, 2022.

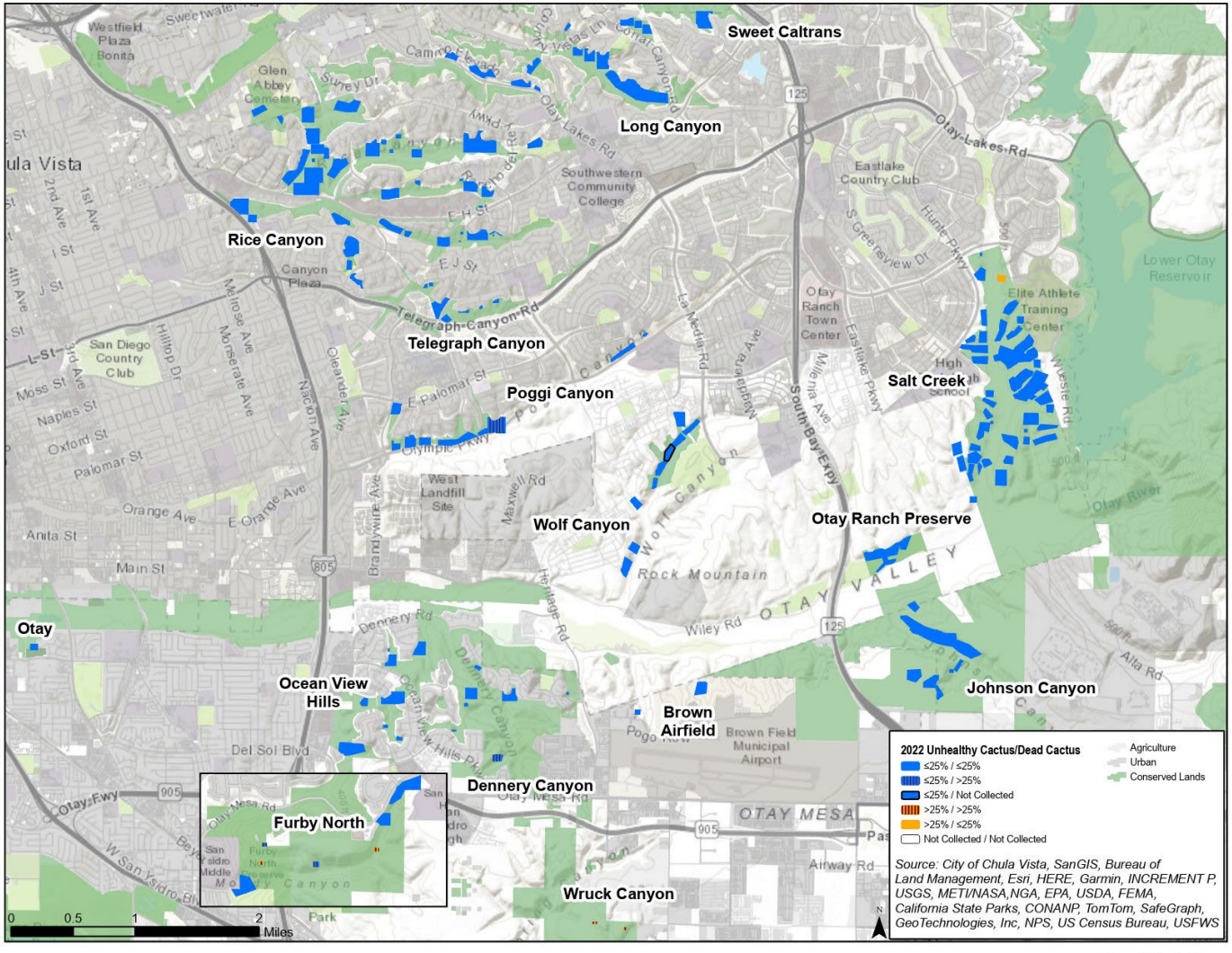


Figure 3.12. Percent of cactus that was unhealthy or dead in cactus plots in the Otay cluster, San Diego County, California, 2022.

Appendix 4. Overall threat scores at Cactus Wren locations.

Overall Threat Scores are compiled from four different habitat threat scores. The Threat Matrix section describes the methodology for calculating location-specific habitat threat scores and the Overall Threat Score from data collected during 2022 Cactus Wren surveys.

Location	Shrub Crowding	Non-native Annuals	Unhealthy Cactus	Dead Cactus	Overall Threat Score
San Pasqual Cluster					
Lake Hodges	144	144	100	100	488
Mule Hill	100	200	0	0	300
Cloverdale/Rockwood	100	100	0	0	200
Safari Park West	153	100	0	0	253
Safari/Battlefield Park	106	100	0	0	206
Bandy Canyon	300	100	0	0	400
Academy	300	100	0	0	400
Whitman Ranch	146	223	0	0	369
Lake Jennings Cluster					
Poway	325	201	0	0	526
Navajo Canyon	370	130	0	0	500
Mission Trails	250	450	100	0	800
La Mesa	400	100	0	0	500
Sycamore Canyon	100	100	100	100	400
Hillside Park	333	116	0	0	449
El Cajon	340	100	0	0	440
Cactus Park	200	100	0	0	300
Lakeside Linkages	297	165	0	0	462
Lakeside	100	100	0	0	200
Lake Jennings	203	225	0	0	428
Sweetwater/Encanto Cluster					
Chollas Valley	197	100	0	0	297
Market St/Encanto Canyon	100	100	0	0	200
MLK	530	100	100	0	730
Chollas Reservoir	134	100	0	0	233
Paradise Valley	371	271	0	0	642
Emerald Ranch Open Space	100	100	0	0	200
Winnetka Open Space	100	433	0	0	533
Sweetwater Quarry	100	100	0	0	200
Sweetwater County	266	202	0	0	468
Sweet Caltrans	100	270	0	0	370
Sweetwater Authority	205	149	100	0	454
San Diego NWR	180	260	0	0	440
Skyline	129	100	0	0	229

Location	Shrub Crowding	Non-native Annuals	Unhealthy Cactus	Dead Cactus	Overall Threat Score
Otay Cluster					
Otay	100	100	0	0	200
Rice Canyon	364	107	0	0	471
Furby North	203	179	100	100	582
Ocean View Hills	167	100	0	0	267
Telegraph Canyon	315	171	0	0	486
Poggi Canyon	238	132	0	0	370
Dennery Canyon	358	271	0	100	729
Long Canyon	318	148	0	0	466
Wruck Canyon	100	100	100	100	400
Wolf Canyon	360	160	0	0	520
Brown Airfield	231	165	0	0	396
Otay Ranch Preserve	150	100	0	0	250
Johnson Canyon	140	185	0	0	325
Salt Creek	238	165	0	0	403

Appendix 5. Expansion opportunities

Table 5.1. Expansion opportunities for each location in the San Pasqual cluster identified using aerial imagery, a habitat suitability model (Preston et al., 2020), mapped cactus (USFWS 2011a), and historic and current cactus wren location data with sources indicated by numbers in the table: 1 = Christianson unpublished data; 2 = Hamilton 2009; 3 = Kus and Lynn 2022; 4 = REGSS 2002; 5 = K. Preston, pers. comm). The management areas include cactus scrub expansion areas and often encompass mapped cactus and monitoring plots within their perimeters. In most cases, the expansion areas are broadly drawn and will require further field-based assessment to determine optimal areas for expanding cactus scrub. "NA" is not applicable and "NAP" is not a priority for expansion.

San Pasqual Cluster				
Location	**Room to expand?**	**Expansion Prioritization Rationale**	**Management Area Size (Acres)**	**Decision Tree Priority/ Expansion Priority**
Lake Hodges	Yes	Formerly a large population with 24 mapped Cactus Wrens in 1996 (1), this location burned severely in the 2007 Witch Fire leading to loss of wrens and cactus scrub. From a postfire low of two territories in 2008 (2), the wren population expanded to eight territories in 2022 (3). Over 80 acres of burned cactus scrub has been restored (table 4). Extensive areas of historic cactus scrub destroyed by the fire remains to be restored. Large areas of modeled high and very high suitability habitat unknown to support wrens or cactus scrub are available to create new cactus scrub near existing and historic cactus scrub (figure 5.1.1). Currently, wrens occupy less than 50 percent of the area supporting wrens in the 1990s. Expanding cactus scrub just west of I-15 could enhance connectivity with wrens east of I-15. Priority for expansion at this large location is *Very High* to increase population size to pre-fire status and for greater connectivity, stability and genetic diversity.	467	*Very High/ Very High*
Mule Hill	Yes	Ranked as a *Very High* priority for creating new cactus scrub, this location is important for establishing a stepping stone population (≥5 territories) to improve connectivity between the Lake Hodges location and Cactus Wren locations to the east, and to the Lake Jennings genetic cluster to the south. This location supports one pair of wrens (3) with limited cactus scrub. There are several pairs on nearby HOA and private lands. Habitat suitability is modeled as high to very high for about 65 percent of this location (figure 5.1.2). A small amount of cactus scrub expansion has been initiated (table 4).	97	*High/ Very High*
Cloverdale/ Rockwood	No	This medium size peripheral Cactus Wren population with six territories in 2022 (3) is not a priority for cactus scrub expansion. There is limited modeled suitable habitat near occupied habitat and the Safari Park West location is nearby with greater opportunity for expansion. There were a few territories on nearby private lands in 1991 (4) that remain today	NA	*Medium/ NAP*

		(3). Most surrounding land is agricultural and residential development.		
Safari Park West	Yes	This location did not burn in the 2007 Witch Fire, whereas nearly all other locations in San Pasqual Valley burned. It is a *High* priority for expansion as it serves as an important stepping stone for east to west Cactus Wren movement in the San Pasqual Valley. In 1991, there were three wren observations (4) and in 2022 there were eight territories (3). Expanding cactus into a large area of modeled high and very high suitability habitat (figure 5.1.3) could increase wren population size.	297	*Very High/ High*
Safari/ Battlefield Park	Yes	This location includes the Safari Park Biodiversity Reserve and Battlefield State Park, which in 1991 had 42 mapped Cactus Wrens (4). This area burned in the 2007 Witch Fire, although not as severely as other locations, such as Lake Hodges. There were 15 territories immediately after the fire and considerable intact cactus (2). Since the fire, 45 acres (18.2 ha) of cactus scrub have been restored or created (table 4) along with extensive management of invasive non-native plants (e.g., *Oncosiphon pilulifer*). The population in this area grew to 54 territories in 2022 (3). There is plenty of room for cactus scrub expansion into modeled high and very high suitability habitat with no previous records of wrens (figure 5.1.4). While this location is a *Very High* priority for habitat maintenance and enhancement as needed, it is currently a Low priority for cactus scrub expansion compared to locations with smaller more vulnerable wren populations.	705	*Very High/ Low*
Bandy Canyon	Yes	In the 1991 this location supported four Cactus Wren territories (4). It burned in the 2007 Witch Fire. Ten acres of habitat restoration including four acres of cactus scrub expansion have added sufficient habitat to support a new wren pair outside the historically occupied area (table 4). Large patches of cactus scrub remaining after the fire support another two territories. There is potential for five or more territories based on the distribution of pre-fire territories and newly created cactus scrub, with plenty of room to expand cactus scrub into high suitability areas to support a larger wren population (figure 5.1.5). In 2022, there was one territory at this location (3), although the newly created habitat was not surveyed. At least one nesting pair was observed in the newly created habitat in 2017 (5). This location is a *Medium* priority for expansion given the modeled high and very high habitat suitability and previous restoration efforts that could be augmented for a larger, more stable wren population.	64	*Medium/ Medium*
Academy	Yes	This area burned in the 2007 Witch Fire. In 1991, there was one mapped Cactus Wren observation in existing cactus patch and two other undated observations to the east in an area with no currently mapped cactus (4). In 2022, there was one territory (3). This is a *Low* priority for expansion as there is not much modeled suitable habitat near existing cactus scrub	72	*Medium/ Low*

		(figure 5.1.6) and other nearby locations have greater potential for cactus scrub expansion.		
Whitman Ranch	Yes	This location burned in the 2007 Witch Fire and has steep slopes with abundant non-native grasses. In the early 1990s there were four mapped Cactus Wren observations (4), and eight territories in 2022 (3). There is limited modeled high and very high suitability habitat between cactus plots (figure 5.1.7). Cactus expansion onto shallow slopes is constrained by agriculture. This location is a *Medium* priority for expansion. It is a peripheral location at the east edge of the cactus wren distribution without much modeled suitable habitat.	156	*Very High/ Medium*

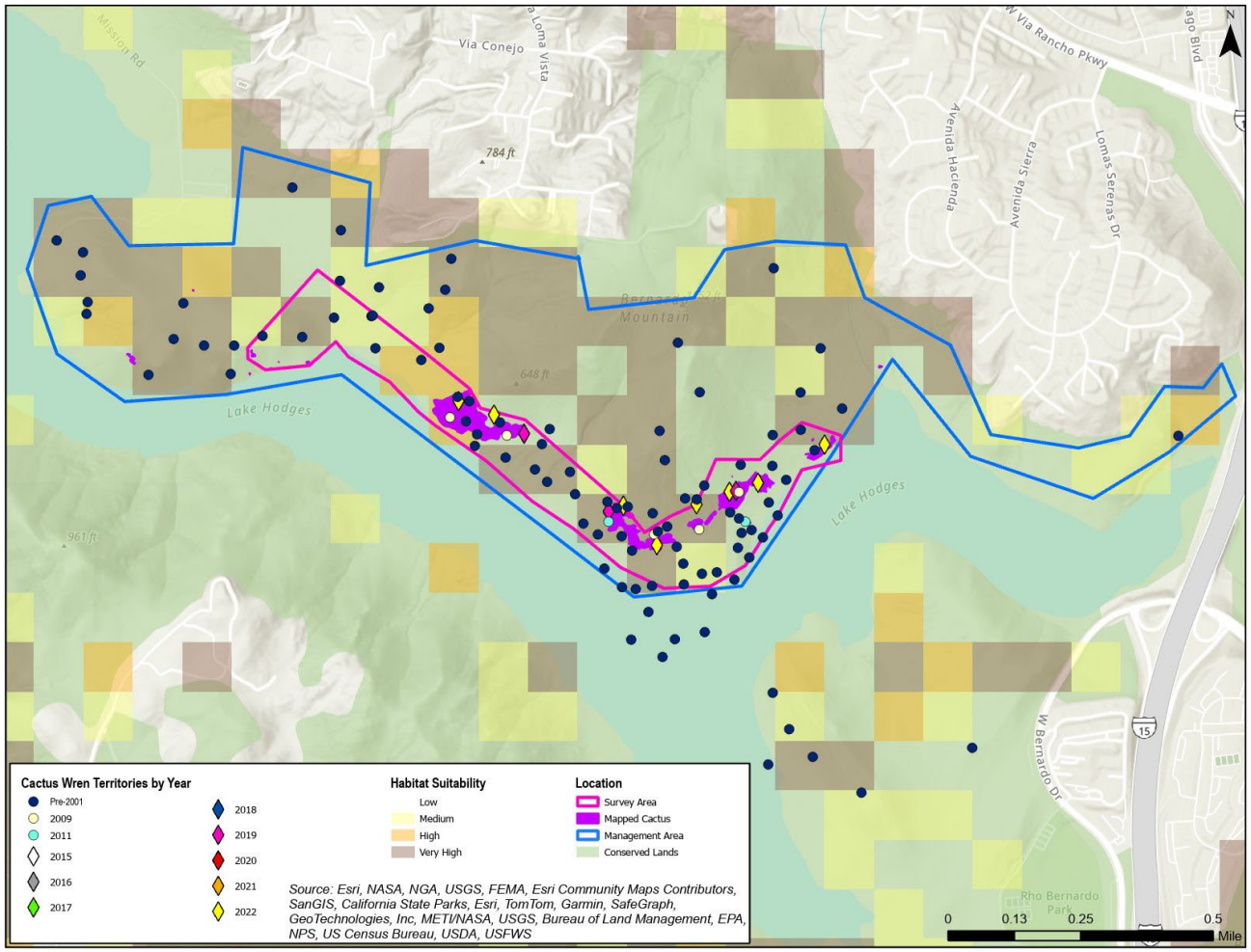


Figure 5.1.1. Lake Hodges management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022)

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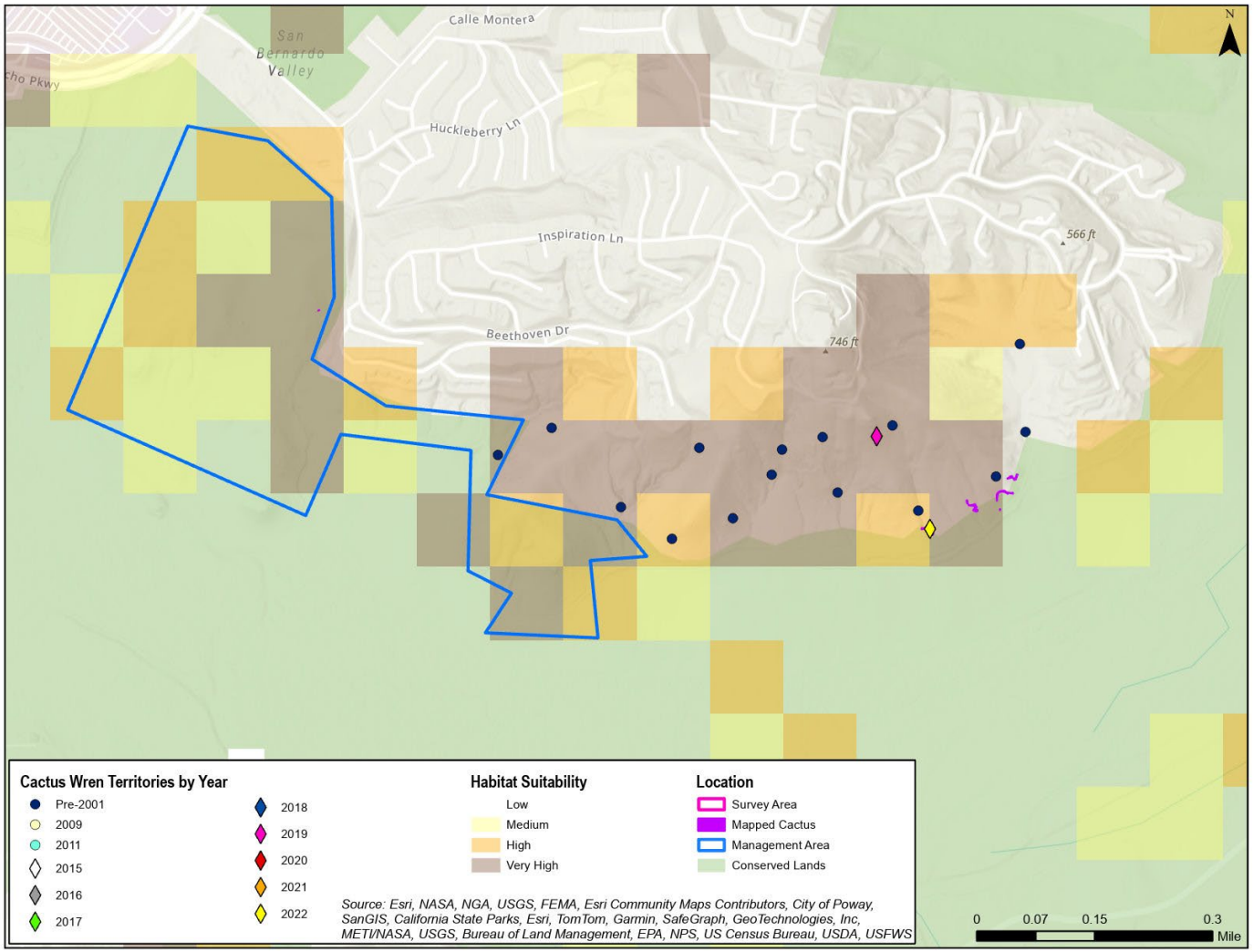

Figure 5.1.2. Mule Hill management area with potential cactus scrub expansion in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

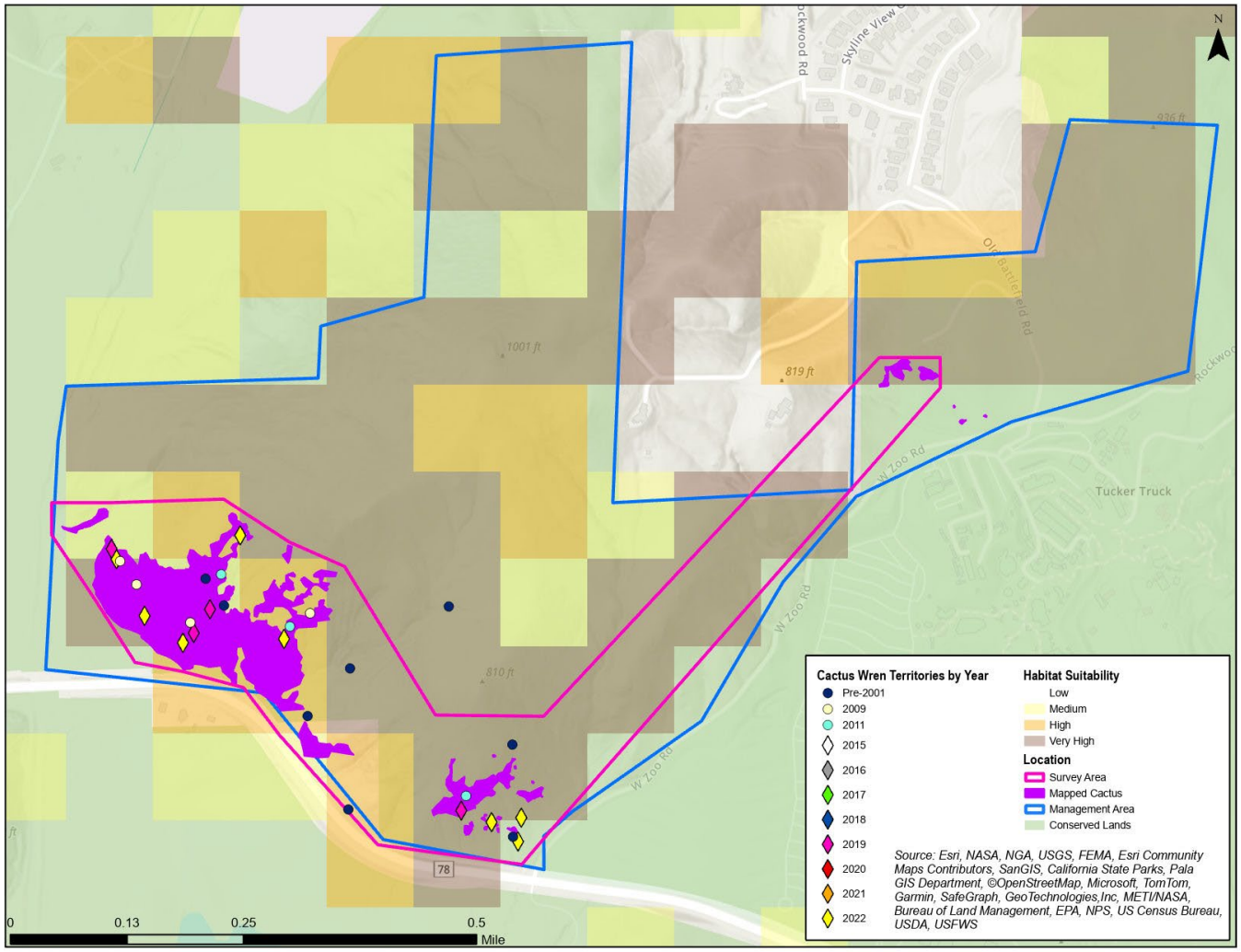

Figure 5.1.3. Safari Park West management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

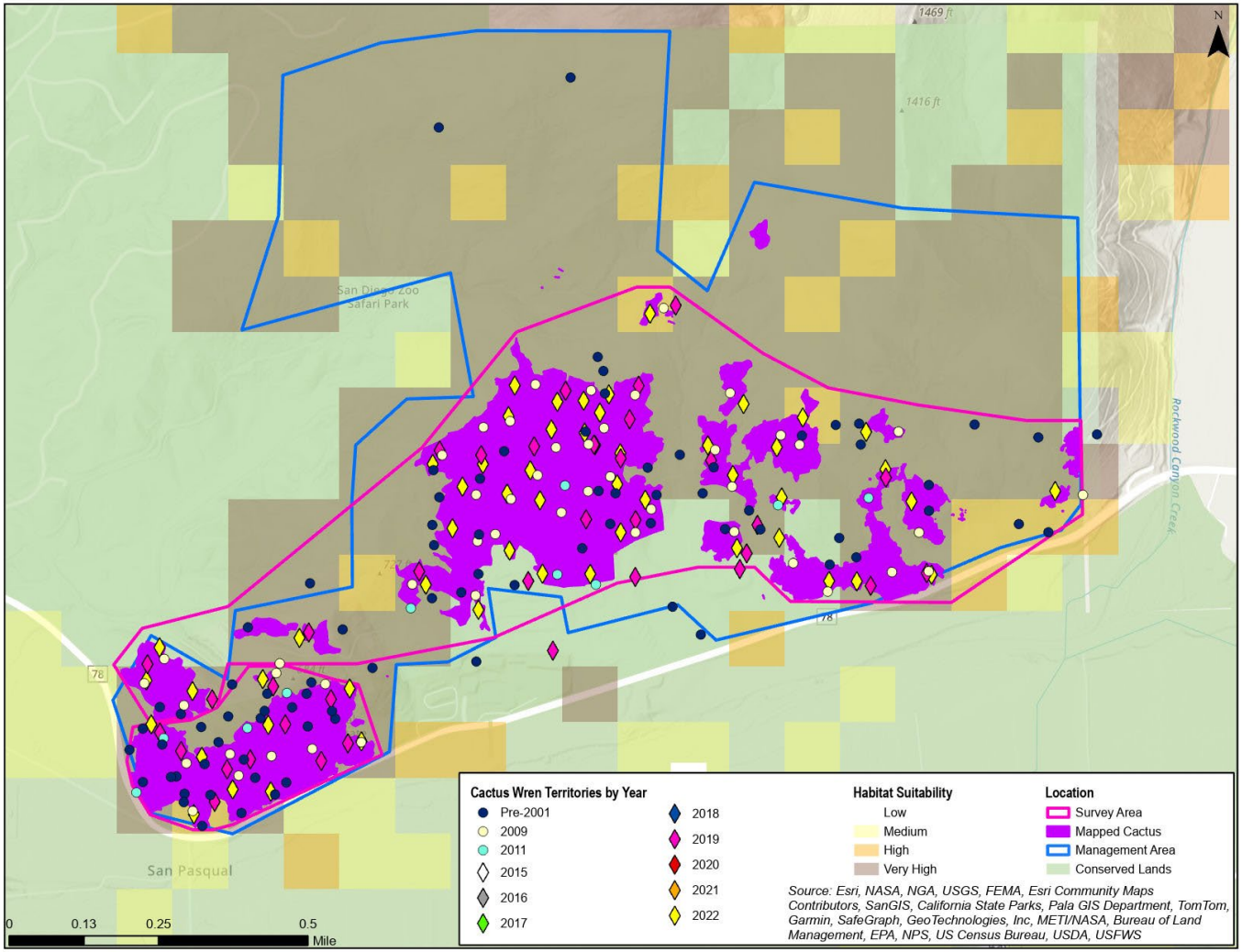

Figure 5.1.4. Safari/Battlefield Park management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

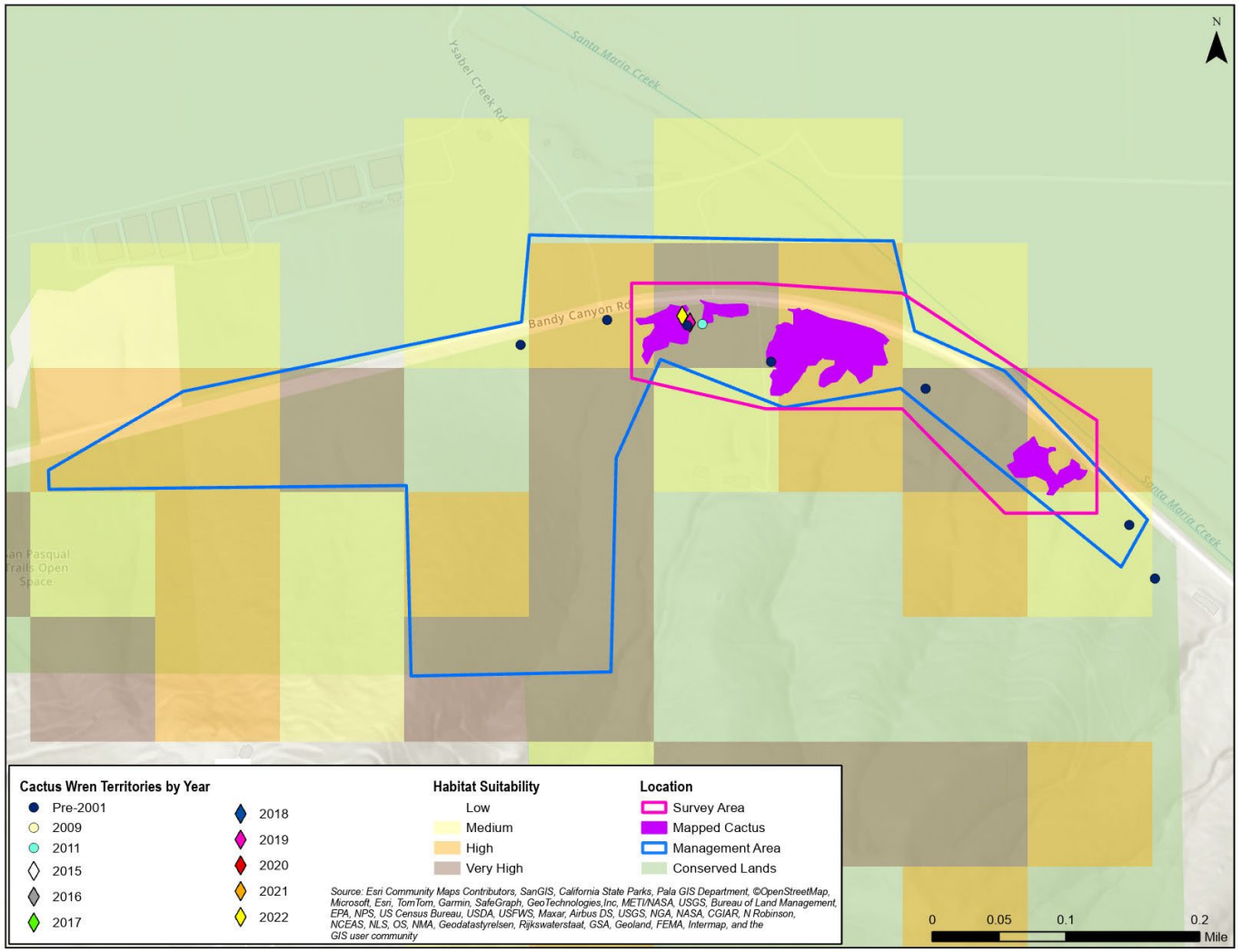

Figure 5.1.5. Bandy Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

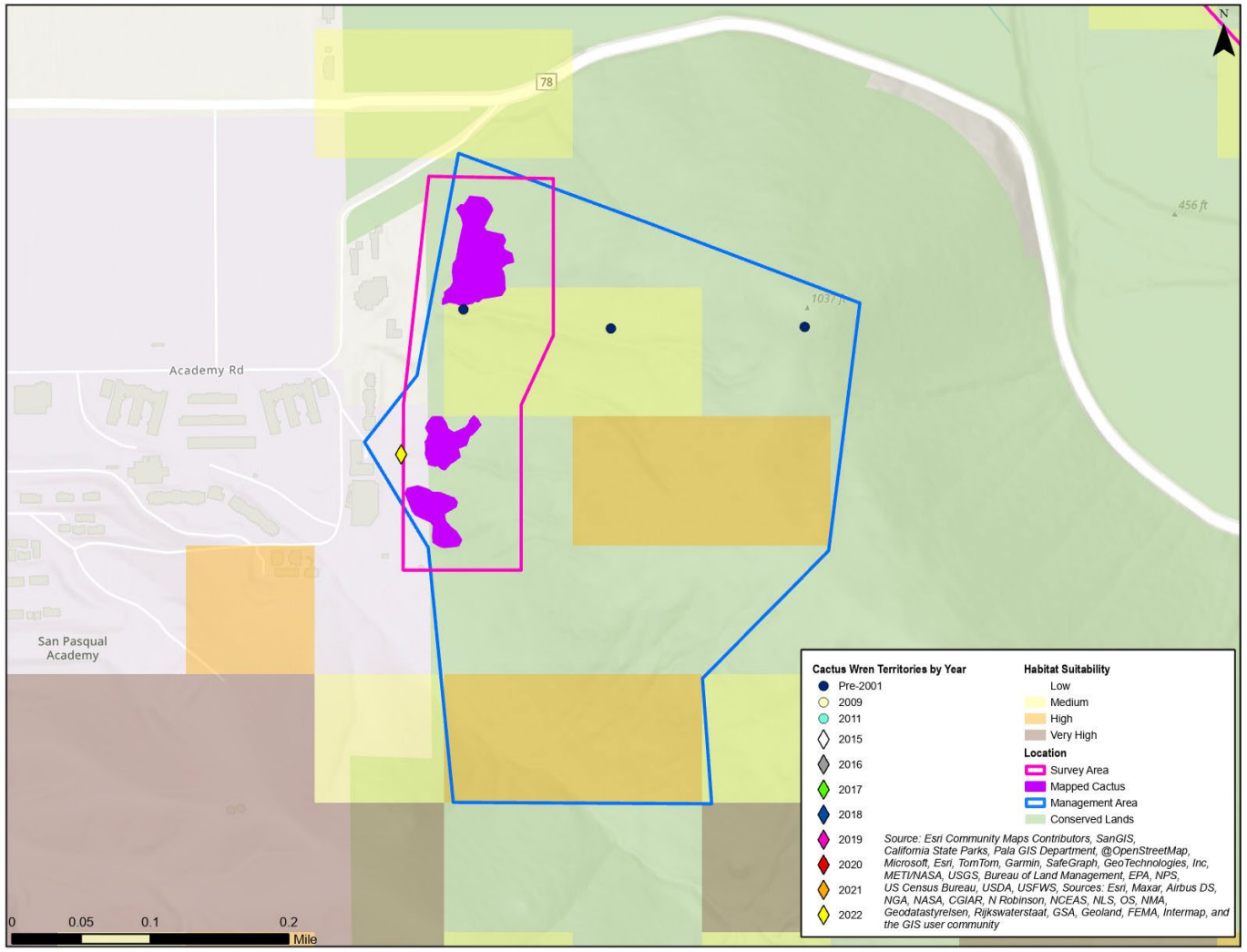

Figure 5.1.6. Academy management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

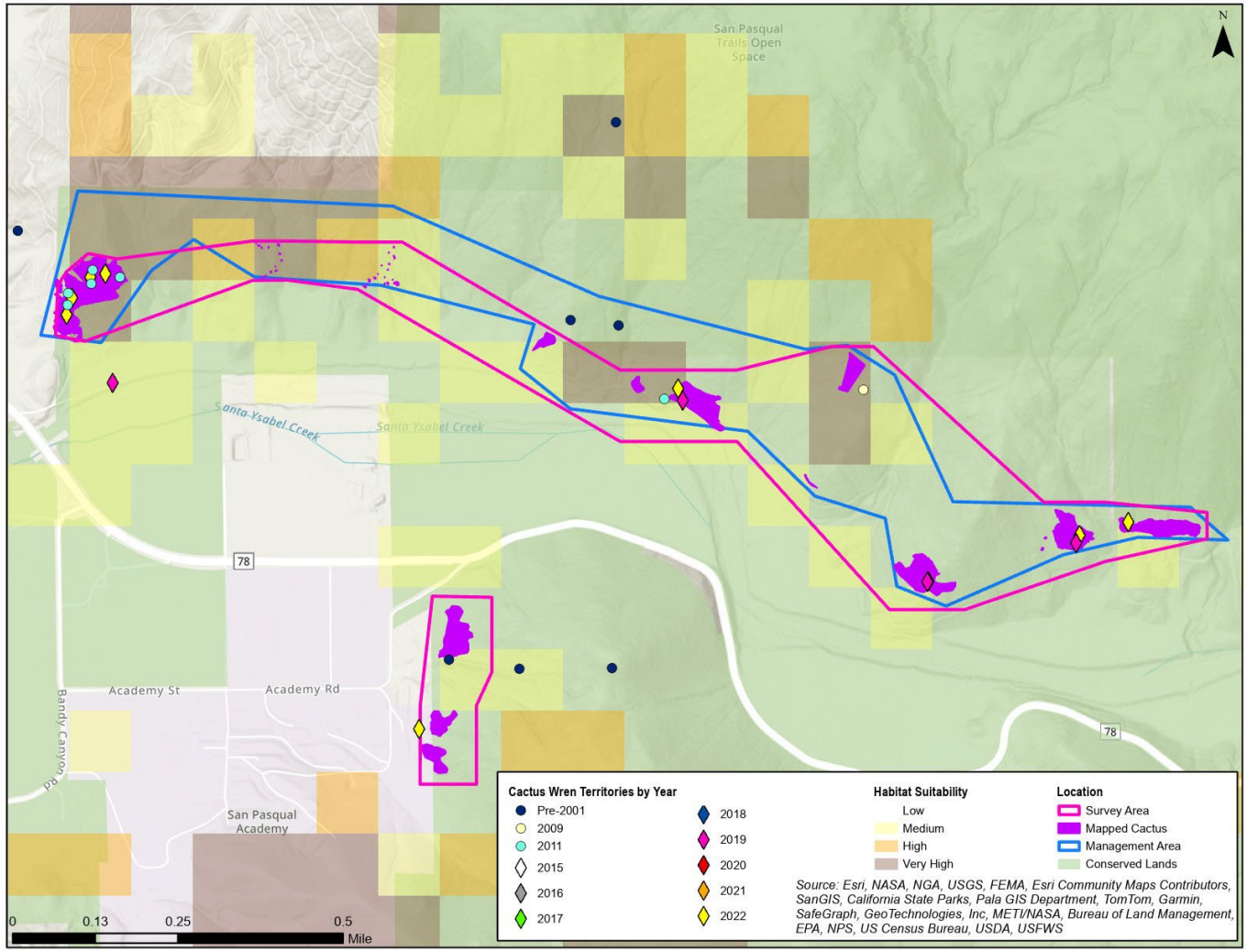

Figure 5.1.7. Whitman Ranch management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019 and 2022 (Kus and Lynn, 2022).

Table 5.2. Expansion opportunities for each location in the Lake Jennings cluster identified using aerial imagery, a habitat suitability model (Preston et al., 2020), mapped cactus (USFWS, 2011a), and historic and current cactus wren location data (1 = REGSS, 2002; 2 = Kus and Lynn, 2022; 3 = Lynn et al., 2022; 4 = USFWS, 2011b). The management areas include cactus scrub expansion areas and often encompass mapped cactus and monitoring plots within their perimeters. In most cases, the expansion areas are broadly drawn and will require further field-based assessment to determine optimal areas for expanding cactus scrub. "NA" is not applicable and "NAP" is not a priority for expansion.

Lake Jennings Cluster				
Location	**Room to Expand?**	**Expansion Prioritization Rationale**	**Management Area Size (Acres)**	**Decision Tree Priority/ Expansion Priority**
Poway	Yes	There are no REGSS Cactus Wren observations in Poway for the 1980s-1990s (1) and no wrens were detected in 2022 (2; 3). Most conserved open space lacks cactus scrub but serves as a potential linkage between wren populations in San Pasqual and Lake Jennings genetic clusters. There is existing connectivity, although the specific route is unknown. A wren color banded at Lake Jennings was discovered in the San Pasqual Valley in 2019, a record straight-line distance of 16.4 miles (28.9 km) (3). Creating a linkage is currently not a management priority given the considerable resources needed to create four stepping stones ≥25 acres (10 ha) approximately 3 miles (5 km) apart along this 8.7 mile (14.7 km) portion of the linkage. This impracticality is further compounded by the lack of nearby wren populations to colonize and establish stable populations in newly created stepping stone habitat.	NA	*Very Low/ NAP*
Navajo Canyon	Yes	The southern undeveloped fragment of the Navajo Canyon system supported two to three Cactus Wren territories from 2015 to 2020 but dropped to one territory in 2021 and 2022 (2; 3). No birds have been detected in the northern undeveloped fragment which is larger and contains several substantial cactus patches (2). Cactus were recently planted in a small area in the southern fragment (table 4). Additional cactus could be added to areas of modeled high and very high habitat suitability in this fragment to support a larger wren population (figure 5.2.1). This is a *Medium* priority for cactus scrub expansion.	39	*Very High/ Medium*
Mission Trails	Yes	Cactus Wrens have not been detected at the Mission Trails location (2). This is not a priority for cactus scrub expansion given the absence of birds at this location.	NA	*Very Low/ NAP*
La Mesa	Yes	This location has no records of Cactus Wren occupancy (2). It is surrounded by urban development extending for miles and isolated from the closest locations with wrens approximately 2miles (3 km) away. It is not a priority for cactus scrub expansion.	NA	*Low/NAP*

Sycamore Canyon	Yes	A single Cactus Wren territory was mapped at this location in 1993 (1) and in 2019 and 2022 (2; 3). This location burned in the 2003 Cedar Fire. It is a *Very High* priority for expanding cactus scrub as a stepping stone to facilitate wren movement between San Pasqual and Lake Jennings genetic clusters. There are large areas of modeled high and very high habitat suitability where cactus scrub could be expanded to support a medium size wren population (figure 5.2.2).	467	*High/ Very High*
Hillside Park	No	This location has supported three to four Cactus Wren territories between 2017 and 2021, with three territories in 2022 (2). It is not a priority for cactus scrub expansion as it is a small location and most of it is already cactus scrub.	NA	*Medium/ NAP*
El Cajon	Yes	Two to four Cactus Wren territories were documented at this location from 2015 to 2021, with two territories in 2022 (2). Part of a larger network of small habitat patches of cactus scrub embedded in residential and urban development. The location has some modeled very high habitat suitability areas with little mapped cactus (figure 5.2.3). This is a *Medium* priority for expansion of cactus scrub to increase the wren population and make it a stepping stone to enhance connectivity within the Lake Jennings cluster.	32	*Medium/ Medium*
Lakeside	No	This location has only a small amount of conserved land that is insufficient for establishing a stable wren population. There are no records of wrens at this site, and it is not a priority for cactus scrub expansion.	NA	*Low/NAP*
Cactus Park	No	This location has only a small amount of conserved land that is insufficient for establishing a stable Cactus Wren population. There are no current records of wrens at this site, and it is not a priority for cactus scrub expansion.	NA	*Low/NAP*
Lakeside Linkages	Yes	In 2009 there were no Cactus Wrens detected at this location and in 2011 there was one occupied patch (4). Cactus scrub restoration was conducted 2011-2016, with follow up habitat enhancement in 2019 and 2020 (table 4). The number of Cactus Wren territories at the site ranged from one to two from 2015 to 2020 (2). In 2021, the restored habitat supported two wren territories (table 4) for a total of four territories at this location (2). There was only one territory in 2022 (2). There is a large area of modeled high and very high habitat suitability where cactus scrub could be created (figure 5.2.4). This is a *High* priority for cactus scrub expansion to increase the population to improve stability, enhance potential connectivity between the Lake Jennings and Sweetwater genetic clusters, and to serve as a refugium from wildfires.	157	*High/High*
Lake Jennings	Yes	This location had eight mapped Cactus Wrens in 1991 (1) and nine to sixteen territories between 2015 and 2021, with twelve in 2022 (2). *Very High* priority for cactus restoration in existing scrub and expansion of new cactus scrub to increase and maintain a large population of wrens for genetic diversity and providing dispersing wrens to other locations within the genetic cluster and to other clusters. There are large areas of	248	*Very High/ Very High*

modeled high and very high suitability habitat where cactus could be planted (figure 5.2.5).

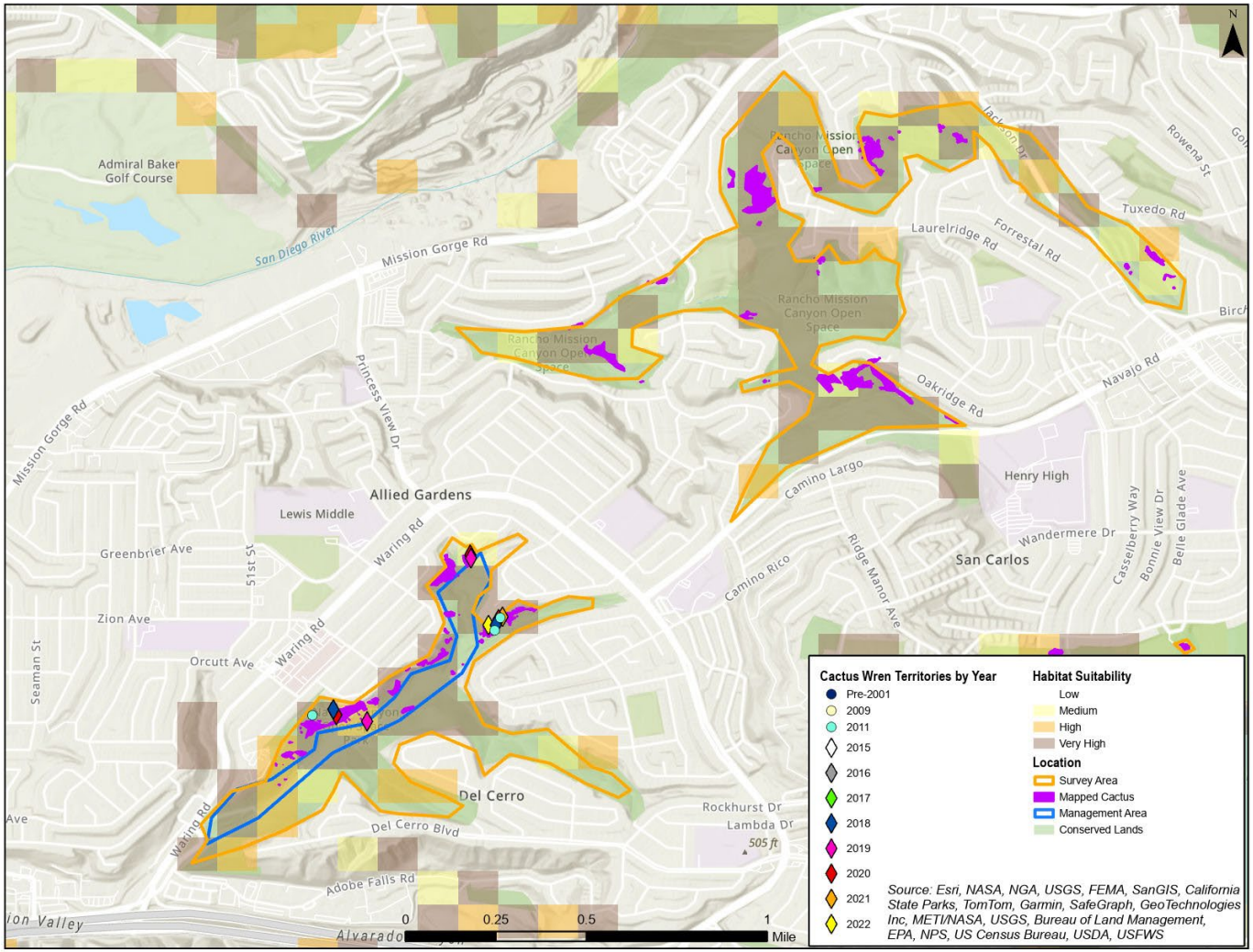

Figure 5.2.1. Navajo Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015 and 2017-2022 (Kus and Lynn, 2022).

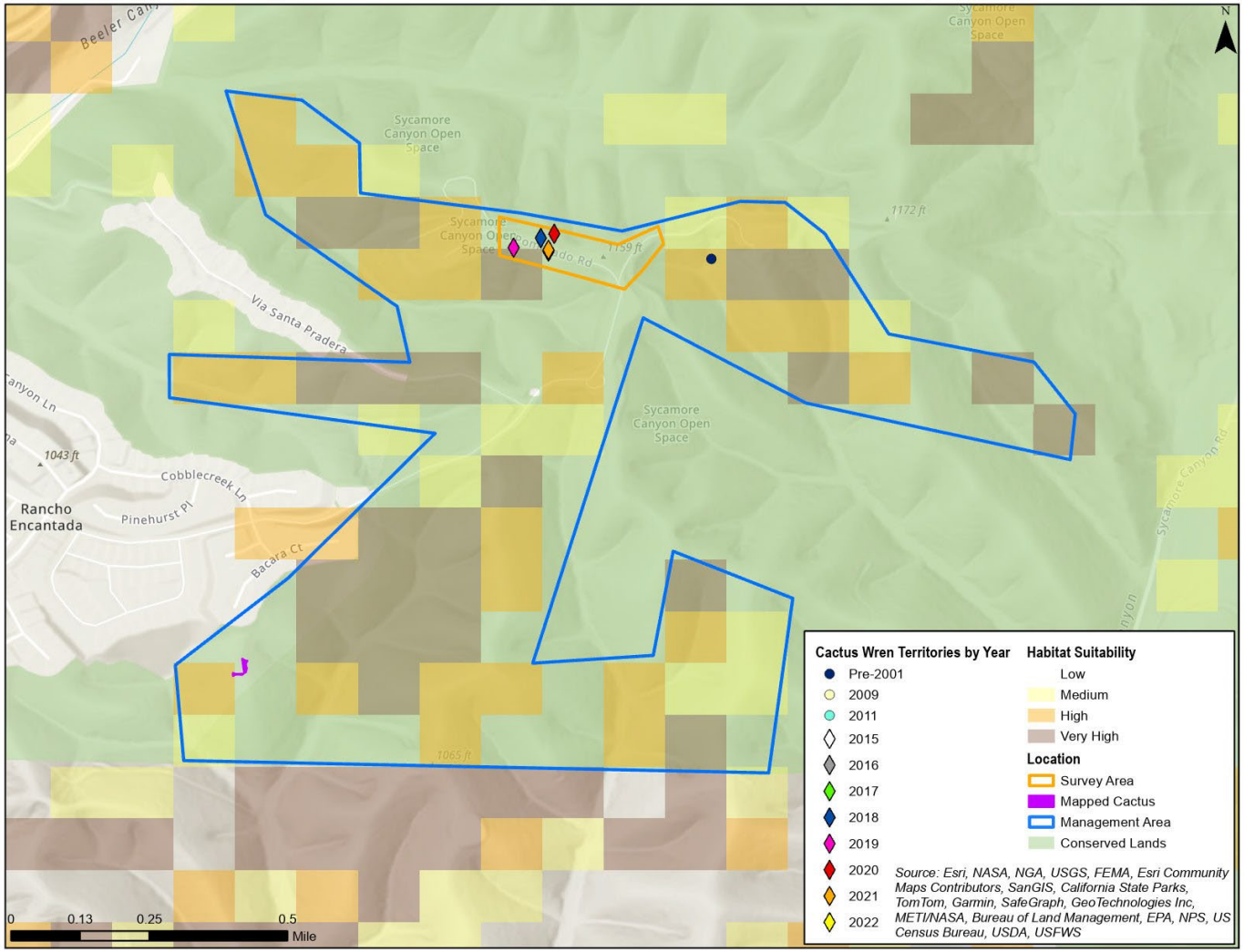

Figure 5.2.2. Sycamore Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2018-2022 (Kus and Lynn, 2022).

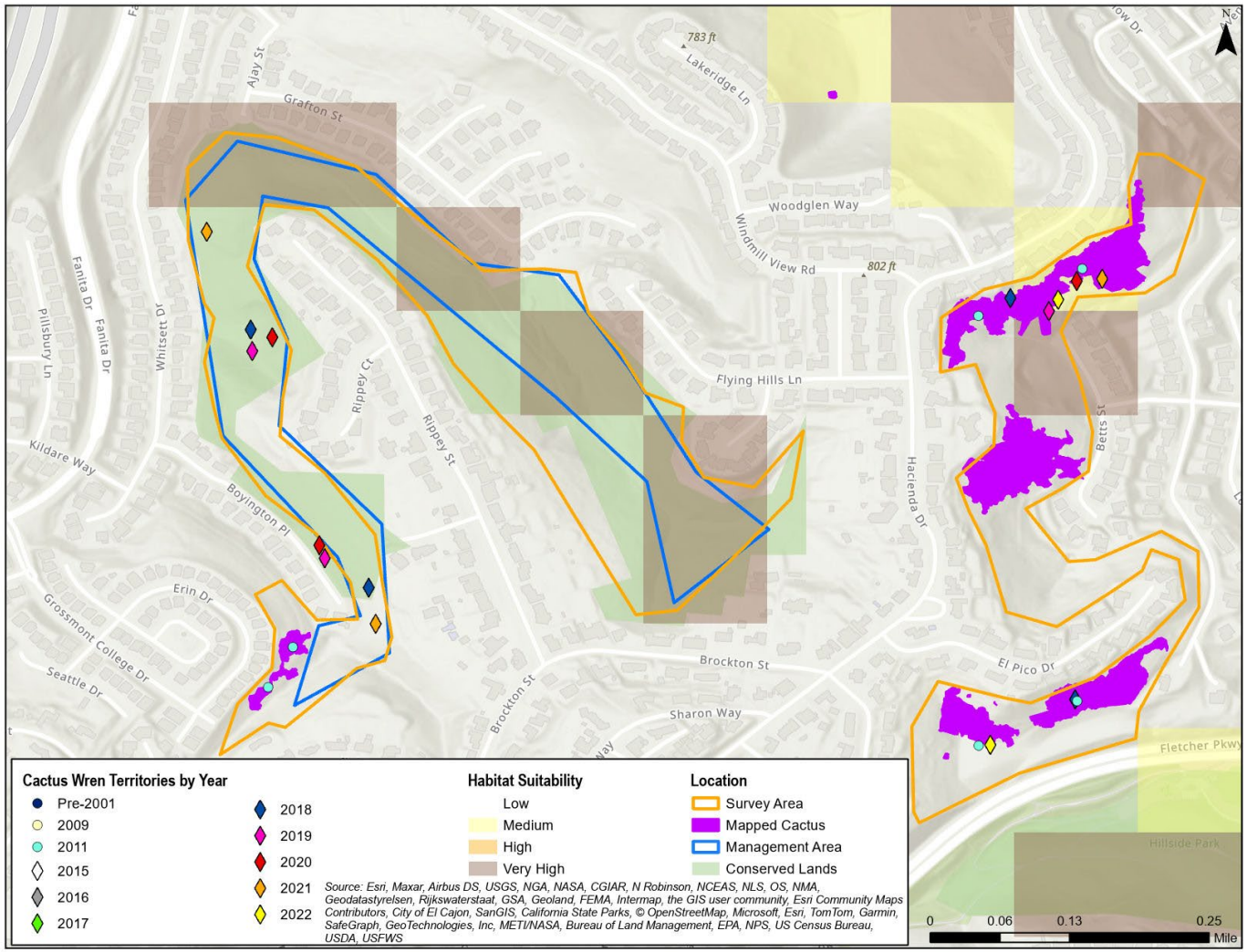

Figure 5.2.3. El Cajon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015 and 2017-2022 (Kus and Lynn, 2022).

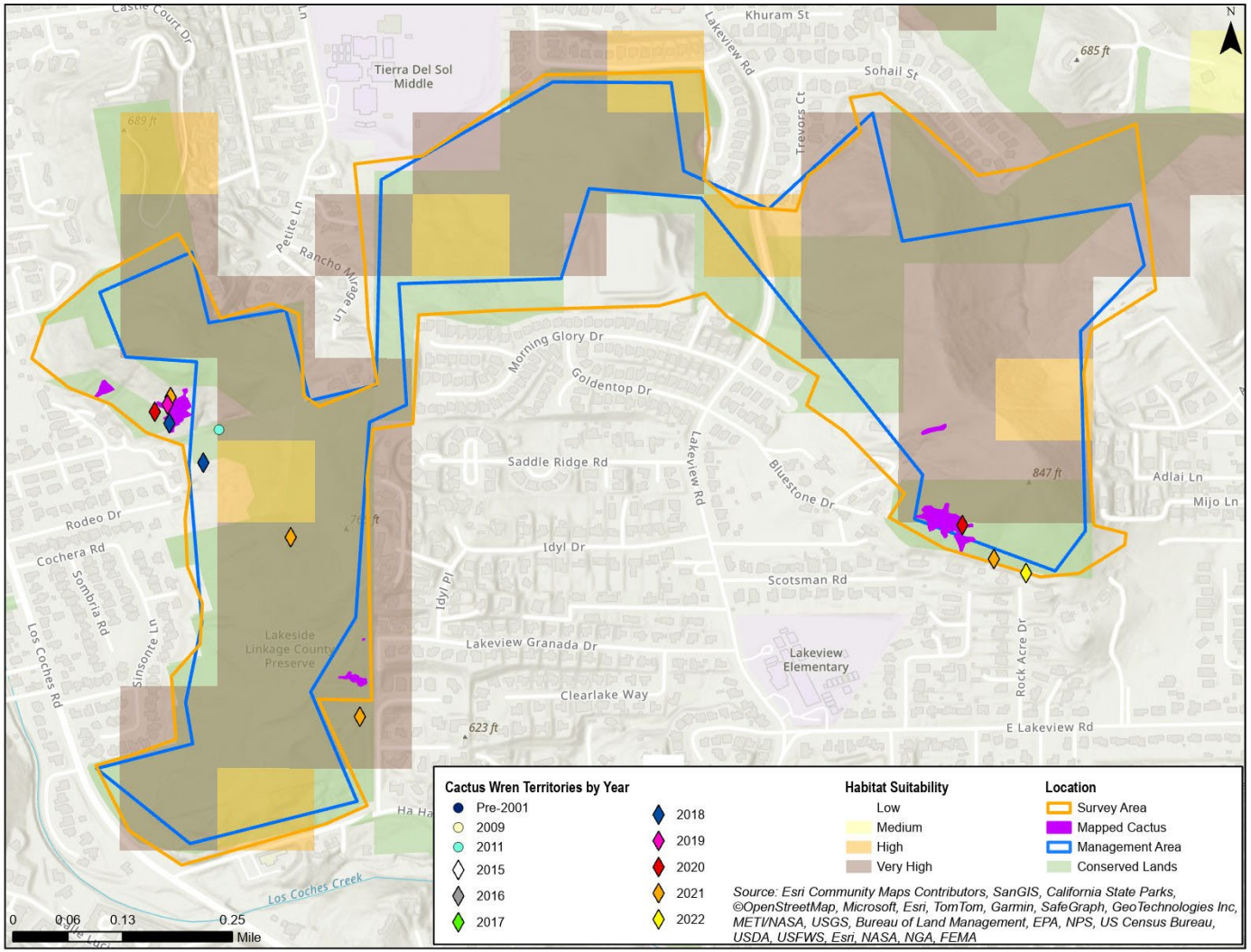

Figure 5.2.4. Lakeside Linkages management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015 and 2017-2022 (Kus and Lynn, 2022).

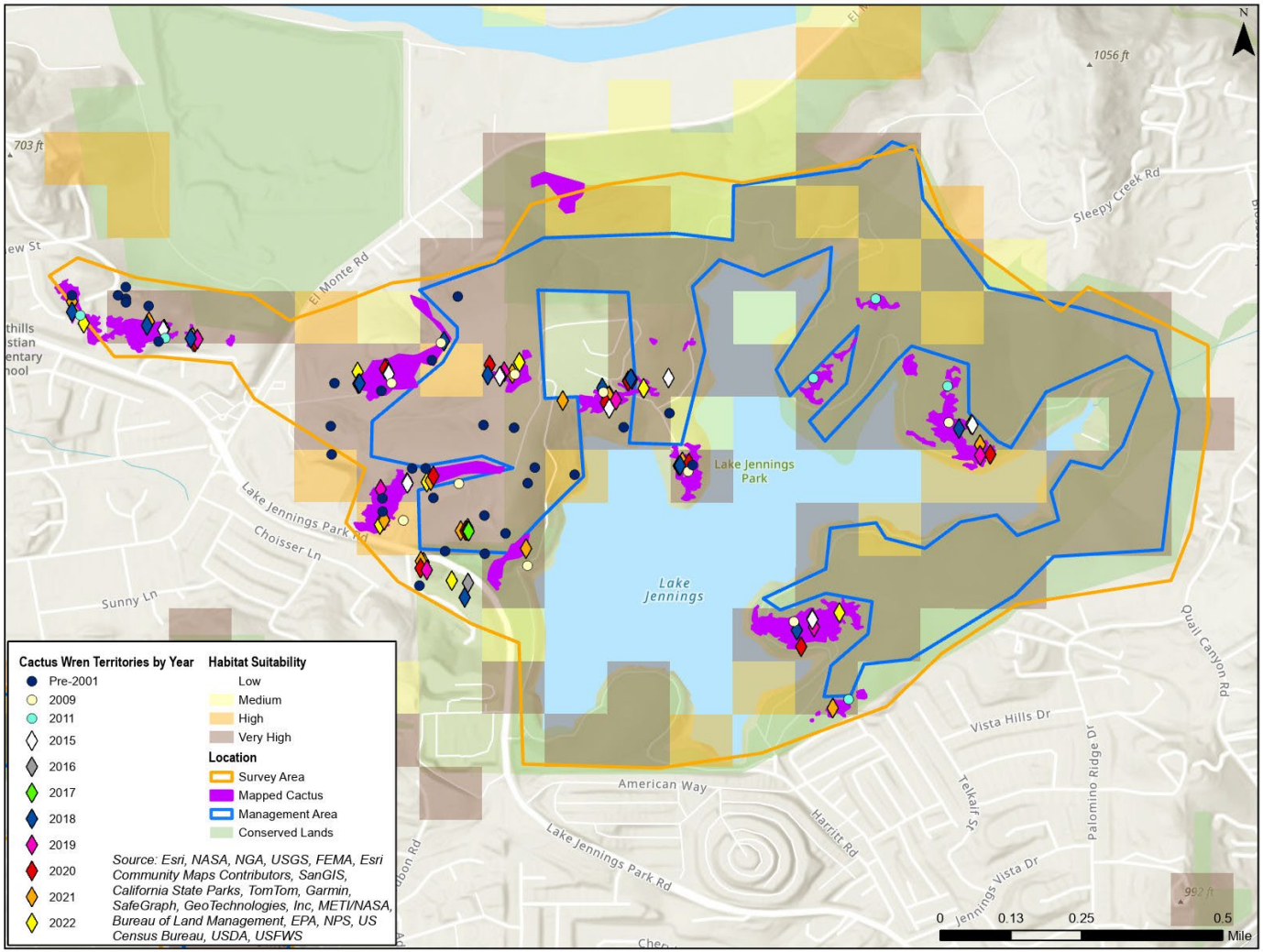

Figure 5.2.5. Lake Jennings management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

Table 5.3. Expansion opportunities of each location at the Sweetwater/Encanto cluster identified using aerial imagery, a habitat suitability model (Preston et al., 2020), mapped cactus (USFWS, 2011a), and historic and current cactus wren location data (1 = Kus and Lynn, 2022; 2 = Lynn et al., 2022; 3 = USFWS, 2011b; 4 = REGSS, 2022). The management areas include cactus scrub expansion areas and often encompass mapped cactus and monitoring plots within their perimeters. In most cases, the expansion areas are broadly drawn and will require further field-based assessment to determine optimal areas for expanding cactus scrub. "NA" is not applicable and "NAP" is not a priority for expansion.

Sweetwater/Encanto Cluster				
Location	**Room to Expand?**	**Expansion Prioritization Rationale**	**Management Area Size (Acres)**	**Decision Tree Priority/ Expansion Priority**
Chollas Valley	No	Cactus Wrens were not detected at this location until 2018 when a single territory was established (1; 2). There were three territories in 2022 (1). The site is long and narrow surrounded by urban development with little room to expand new cactus scrub. There are opportunities to add cactus within existing scrub.	NA	*Medium/ NAP*
Market St/Encanto Canyon	Yes	This location contained six Cactus Wren territories in 2015, decreased to four in 2018 and 2019, and then increased to ten territories in 2022 (1). The increase is attributed to habitat restoration supporting new territories (table 4). There is room to expand cactus scrub to support a few more wren territories in modeled high and very high suitability habitat (figure 5.3.1). The location is a *Very High* priority for expansion to increase population size and stability and as a source of dispersing wrens into canyons to the north.	8	*Very High/ Very High*
Martin Luther King	Yes	This location had no Cactus Wrens from 2009 to 2018 and was colonized by one pair in 2019 (1; 2; 3). In 2022, there were two territories (1). It is a *Medium* priority for cactus scrub expansion in modeled high and very high habitat suitability to increase population size to improve stability and make it part of a stepping stone linkage within the Sweetwater/Encanto genetic cluster (figure 5.3.2).	52	*Medium/ Medium*
Chollas Reservoir	Yes	Formerly a landfill with a reservoir and park. This location was unoccupied by Cactus Wrens from 2009 to 2018, with a pair of wrens detected in 2019, and two territories in 2022 (1; 2; 3). It is *Medium* priority for cactus expansion in modeled high and very high suitability habitat to increase wren population size and stability and make it a stepping stone within the Sweetwater/Encanto genetic cluster (figure 5.3.3).	39	*Medium/ Medium*
Paradise Valley	Yes	The western of two parcels at this location had no Cactus Wrens in 2009, 2011, 2015 and 2016 (1; 2; 3). In 2017 two territories were established in the western parcel and a third was found on a hillside in the adjacent neighborhood (1). From 2018 to 2021 there were two to three territories at the western parcel and in 2022 there were three territories with one in the adjacent neighborhood (1). This parcel has room to expand cactus scrub in modeled suitable habitat and increase	25	*Very High/ High*

		the size of the wren population (figure 5.3.4). The eastern parcel is an old county owned landfill and is not conserved and not considered for cactus expansion. The western parcel is a *High* priority for cactus scrub expansion to increase the wren population and improve stability.		
Emerald Ranch Open Space	No	Cactus wrens have not been detected at this location. This is not a priority for cactus expansion as it is too small to support a viable population.	NA	*Low/NAP*
Winnetka Open Space	No	This location was first surveyed in 2017 and supported one Cactus Wren territory 2017-2021 with no birds in 2022 (1; 2). This location is not a priority for expansion as it is too small to support a viable population.	NA	*Low/ NAP*
Sweetwater Quarry	Yes	This location has supported one Cactus Wren territory since 2009 (1; 2; 3). There is a lot of modeled high and very high suitability habitat, and it is a *Medium* priority to expand cactus scrub and increase the wren population (figure 5.3.5). It is connected to Sweetwater Authority and Sweetwater County locations to form a larger interconnected population around Sweetwater Reservoir.	35	*Low/ Medium*
Sweetwater County	Yes	This location supported two Cactus Wren territories from 2009 to 2016, fluctuated between three and five territories from 2017 through 2021 and had three territories in 2022 (1; 2; 3). This location is a *Medium* priority for expansion of cactus scrub in modeled suitable habitat (figure 5.3.6). It is directly connected to Sweetwater Authority and Sweetwater Quarry locations and is part of a larger population around Sweetwater Reservoir.	32	*Very High/ Medium*
Sweet Caltrans	Yes	This location is unoccupied by Cactus Wrens (1; 2; 3). There is a large area of modeled high and very high suitability habitat with a few small patches of mapped cactus. This is not a near term expansion priority due to the lack of wrens. It could be a future priority for creating cactus scrub to establish a new wren population after more urgent restoration priorities are achieved.	NA	*Very Low/ NAP*
Sweetwater Authority	Yes	From 2009 to 2021, this location supported three to eight Cactus Wren territories, with five in 2022 (1; 2; 3). There is extensive modeled high and very high suitability habitat where cactus could be planted to increase this wren population (figure 5.3.7). It is a *High* priority for cactus scrub expansion as it is connected to four other locations in a large integrated population that can provide birds to disperse to smaller surrounding populations.	386	*Very High/ High*
San Diego NWR	Yes	This location burned in 2007 and since then cactus have been planted to recover wren territories (table 4). From a low of one Cactus Wren territory in 2011 to a high of five territories in 2018, 2020, 2021, and 2022 (1; 2; 3). There are two large areas with modeled high and very high habitat suitability in which cactus scrub could be expanded (figure 5.3.8). The	1,300	*High/ Very High*

		location is adjacent to the Sweetwater Authority location and along with other locations around Sweetwater Reservoir forms a large population. It is a *Very High* priority for creating more cactus scrub to support a larger wren population to provide dispersing birds to smaller surrounding populations and to the Otay genetic cluster to the south.		
Skyline	No	This location has no record of occupancy by Cactus Wrens from 2009 to 2022 (1; 2; 3). It is not a priority for cactus scrub expansion.	NA	*Very Low/ NAP*

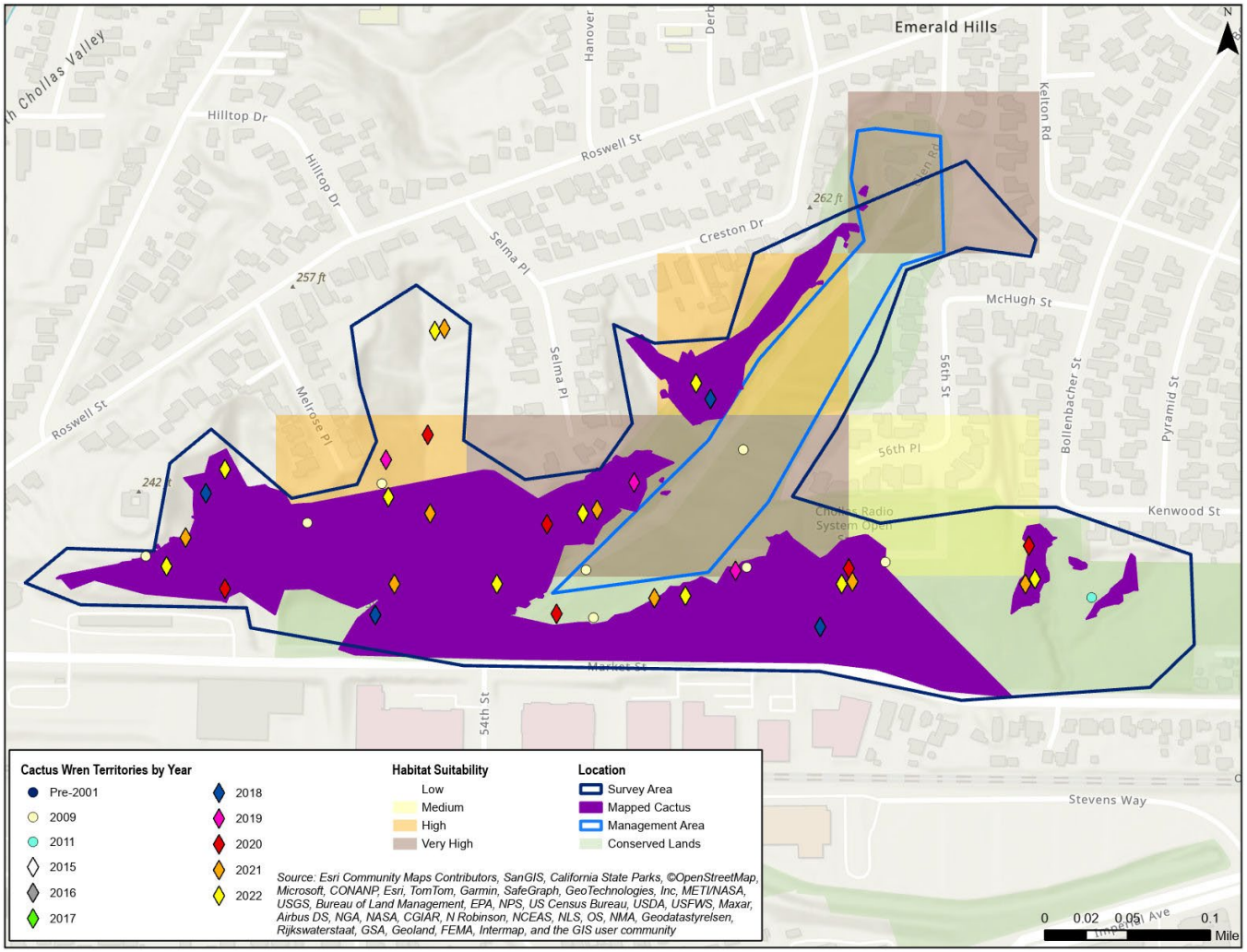

Figure 5.3.1. Market Street/Encanto Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015 and 2017-2022 (Kus and Lynn, 2022).

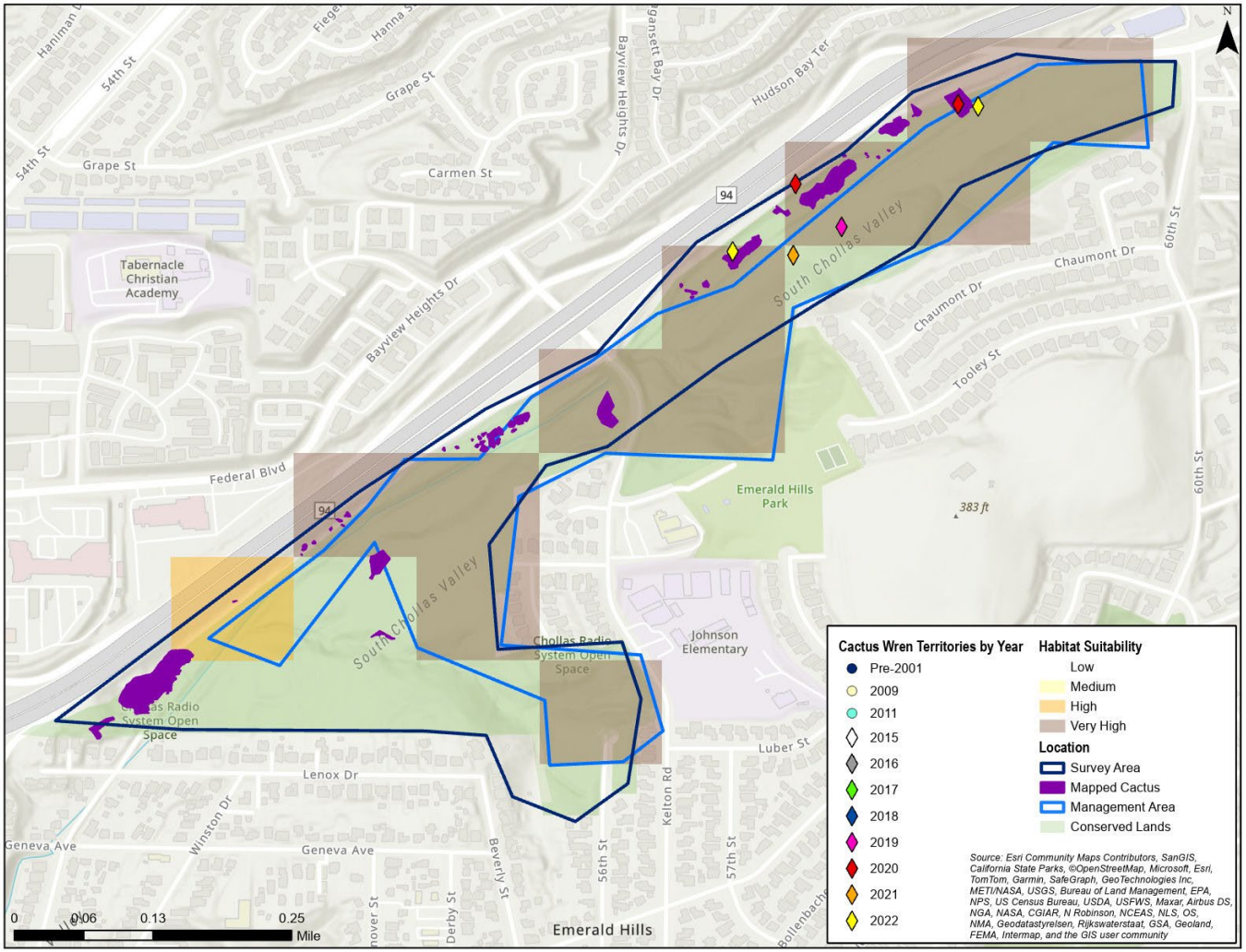

Figure 5.3.2. Martin Luther King management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019-2022 (Kus and Lynn, 2022).

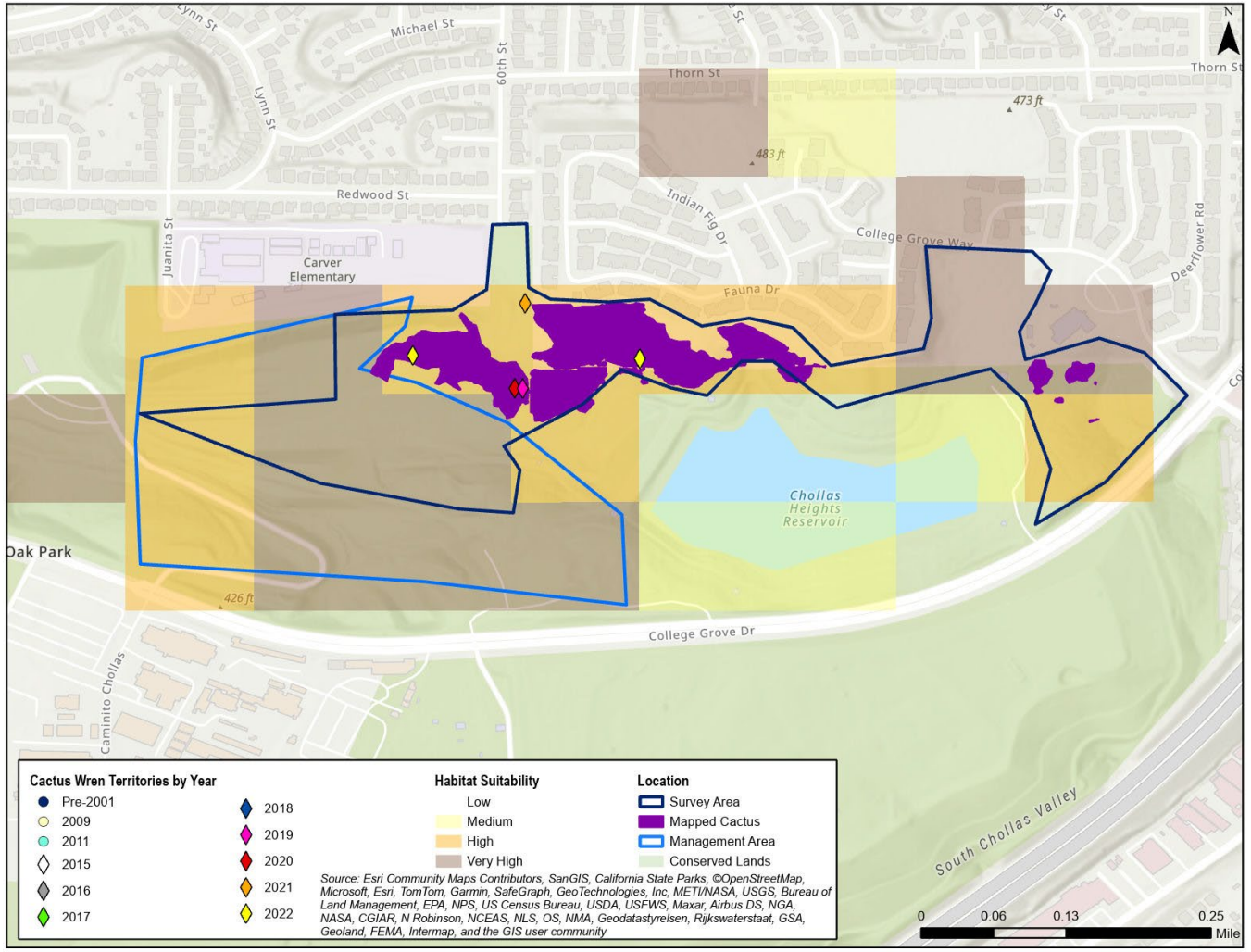

Figure 5.3.3. Chollas Reservoir management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2019-2022 (Kus and Lynn, 2022).

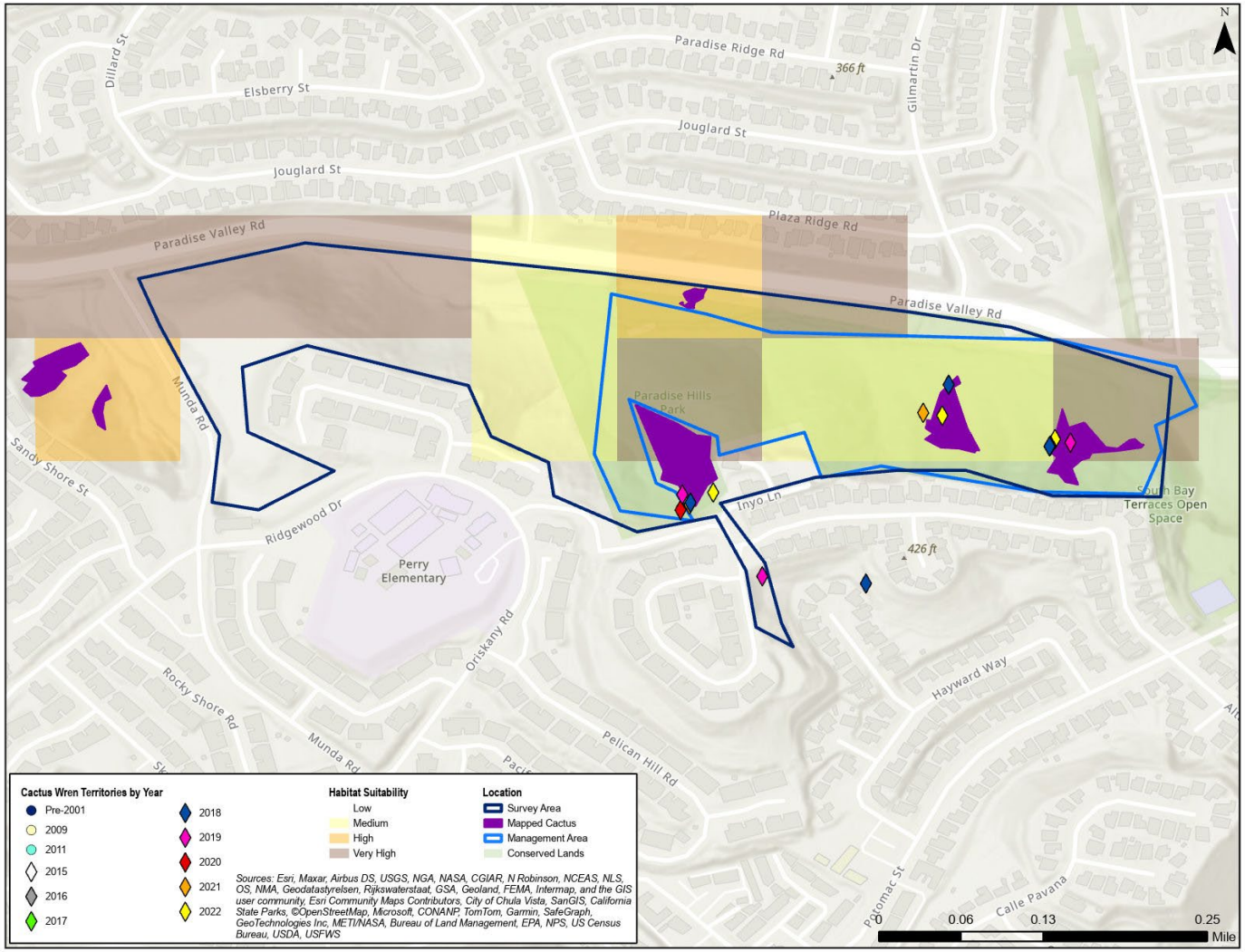

Figure 5.3.4. Paradise Valley management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2017-2022 (Kus and Lynn, 2022).

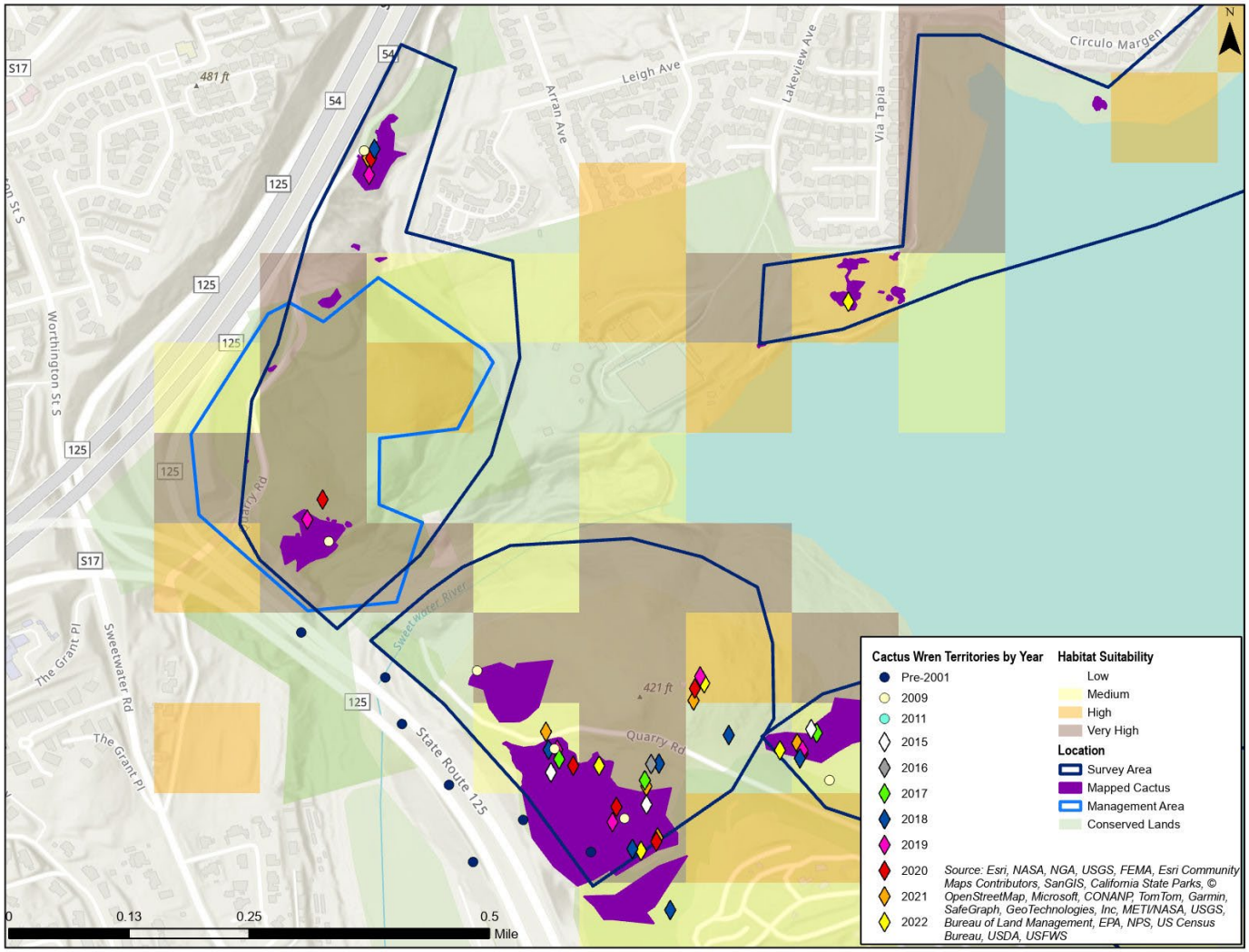

Figure 5.3.5. Sweetwater Quarry management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

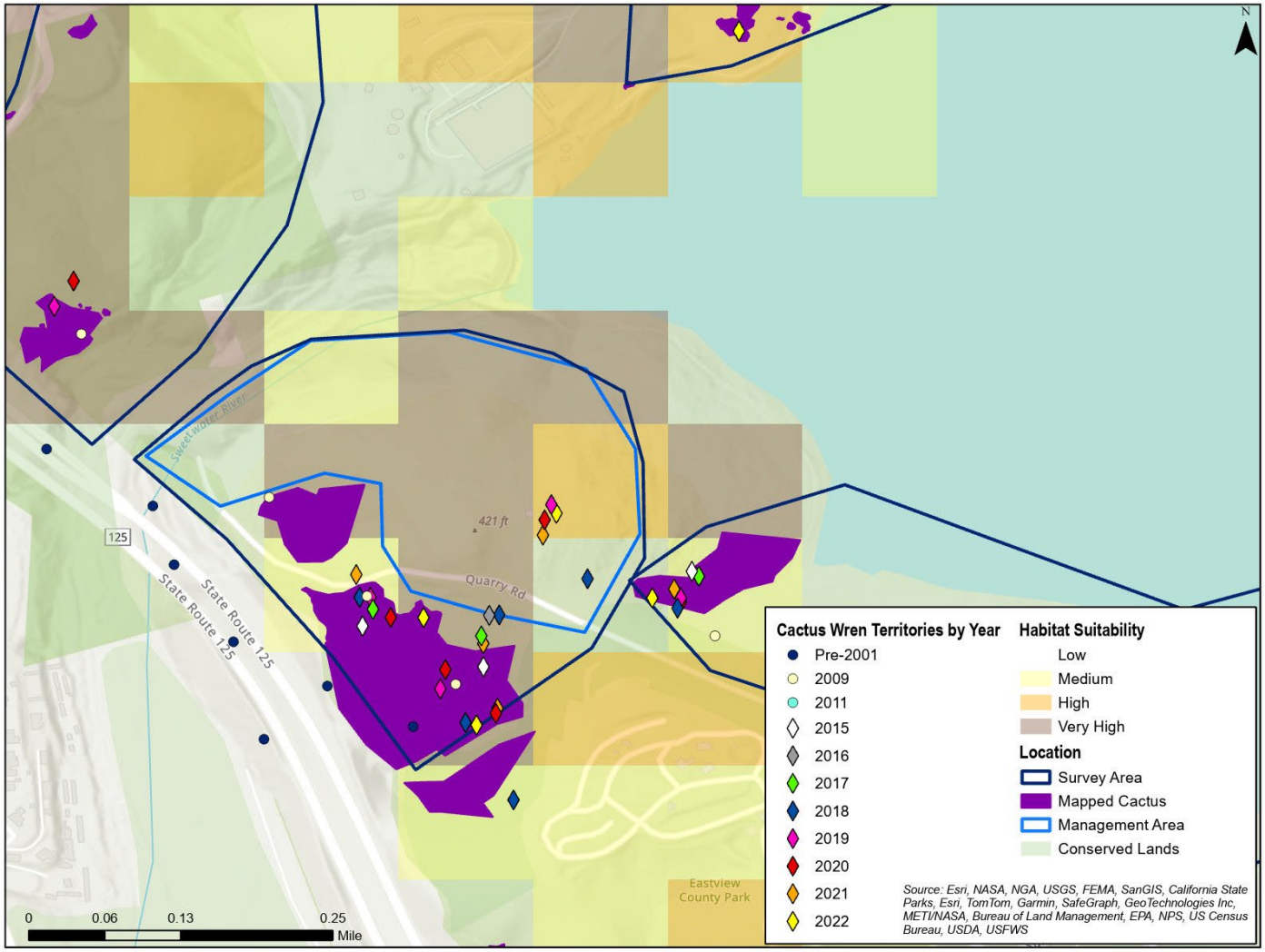

Figure 5.3.6. Sweetwater County management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

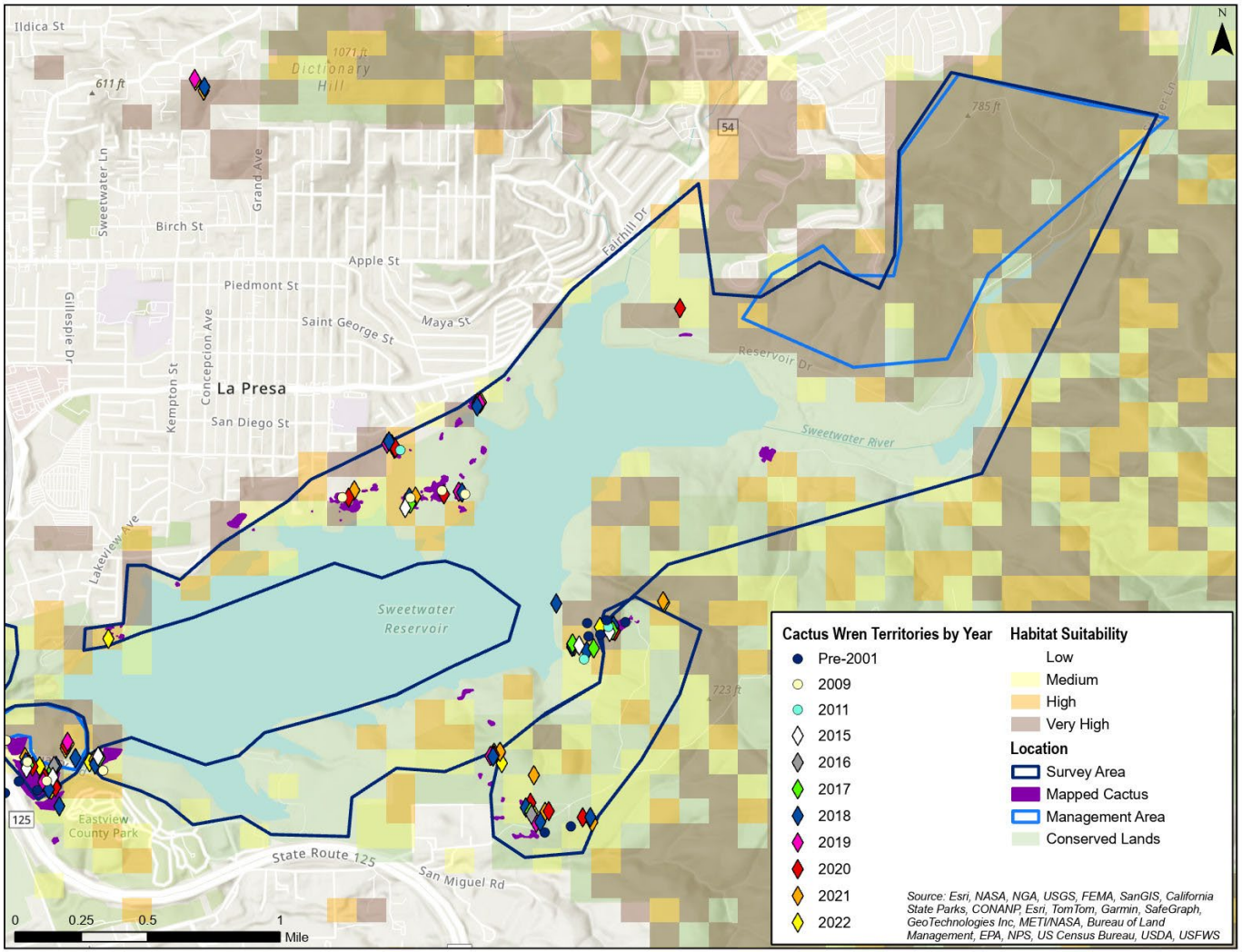

Figure 5.3.7. Sweetwater Authority management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

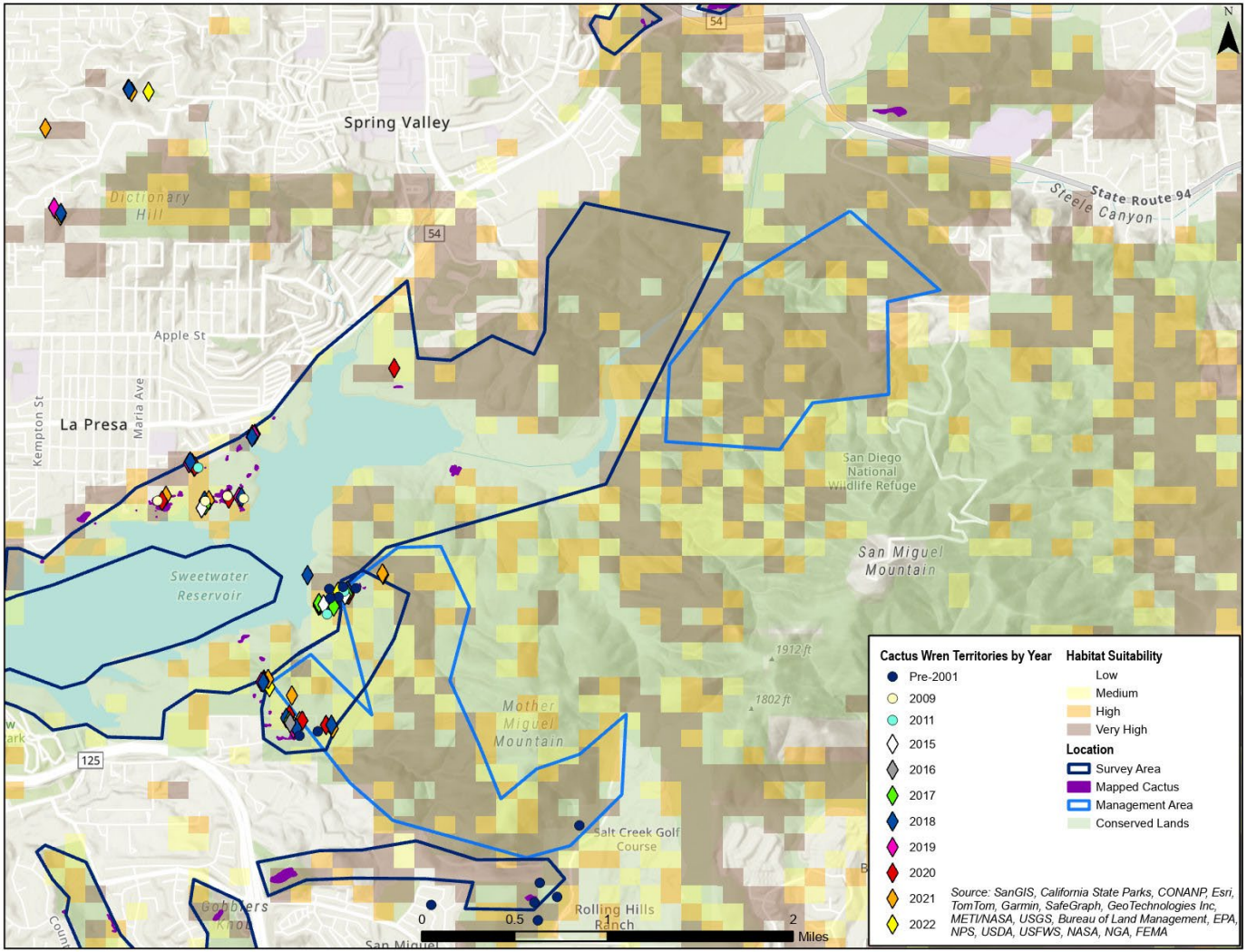

Figure 5.3.8. San Diego NWR management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

Table 5.4. Expansion opportunities of each location at the Otay cluster identified using aerial imagery, a habitat suitability model (Preston et al., 2020), mapped cactus (USFWS 2011a), and historic and current cactus wren location data (1 = USFWS, 2011b; 2 = Kus and Lynn, 2022; 3 = REGSS, 2002; 4 = Lynn et al., 2022). The management areas include cactus scrub expansion areas and often encompass mapped cactus and monitoring plots within their perimeters. In most cases, the expansion areas are broadly drawn and will require further field-based assessment to determine optimal areas for expanding cactus scrub. "NA" is not applicable and "NAP" is not a priority for expansion.

Otay Cluster				
Location	**Room to Expand?**	**Expansion Prioritization Rationale**	**Management Area Size (Acres)**	**Decision Tree Priority/ Expansion Priority**
Otay	No	This location has no record of occupancy by Cactus Wrens (1; 2). It is not a priority for cactus scrub expansion.	NA	*Low/ NAP*
Rice Canyon	Yes	Rice Canyon had seven mapped Cactus Wrens in 1988 (3), with no wrens detected 2009, 2015, and 2017, and one occupied cactus plot in 2011 (1; 2; 4). From 2018 to 2022 there have been one to four wren territories, with two territories in 2022 (2; 4). From 2009 to 2014, three acres of cactus were planted with thinning of shrubs in cactus patches (table 4). Extensive modeled high and very high suitability habitat is a *Medium* priority for cactus scrub expansion to increase the wren population (figure 5.4.1).	159	*Very High/ Medium*
Furby North	Yes	Between 2009 and 2022, this location had a single Cactus Wren territory (2009 and 2011 and 2017-2020; 1; 2; 4). There is a large area of modeled high and very high habitat suitability with some small patches of mapped cactus (figure 5.4.2). This location is a *Medium* priority for cactus scrub expansion as it is isolated in an urban setting at the southern end of Cactus Wren distribution in San Diego County and there is a lack of birds in the surrounding area.	160	*Medium/ Medium*
Ocean View Hills	Yes	There was a medium size Cactus Wren population at this location (9 mapped observations) in 1992 (3), with one territory in 2011, and no wrens detected since (1; 2). It is not a priority for cactus scrub expansion given the existing cactus scrub and lack of birds at this location and in the surrounding area.	NA	*Very Low/ NAP*
Telegraph Canyon	No	This location is like Rice and Long Canyons, but with less modeled suitable habitat. It is bordered by development with no record of Cactus Wrens from the late 1980s to present (1; 2; 4). It is not a priority for cactus expansion given the large amount of unoccupied cactus scrub.	NA	*Very Low/ NAP*

Poggi Canyon	No	No Cactus Wrens have been detected since the early 1990s in this location (1; 2; 3). This location is not a priority for cactus expansion given the large amount of cactus scrub and lack of birds at this location and surrounding area.	NA	*Very Low/ NAP*
Dennery Canyon	Yes	This location had a single Cactus Wren observation in 1993 (3), with no birds detected between 2009 and 2019, and a single territory 2020 to 2022 (1; 2). There is a lot of modeled high and very high suitable habitat with multiple patches of mapped cactus (figure 5.4.3). This location connects to the Ocean View Hills location. This is a *Low* priority for cactus scrub expansion due to the lack of birds at this location and in the surrounding area.	256	*Medium/ Low*
Long Canyon	Yes	This location had two mapped Cactus Wrens in 1991 and in 2009, with no subsequent records (1; 2; 3). It is not a priority for expansion of new cactus scrub given the large amount of existing cactus scrub and lack of wrens in the surrounding areas.	NA	*Very Low/ NAP*
Wruck Canyon	Yes	There are no records of Cactus Wrens at this location (1; 2). It has little mapped cactus and it is not close to other locations with wrens. It is not a priority for cactus scrub expansion given the lack of wrens and distance from other locations.	NA	*Low/ NAP*
Wolf Canyon	Yes	There were four mapped Cactus Wrens in 1992 (3), with two in 2009 and five in 2011 (1). For 2015 through 2022 the number of wren territories ranged from 0 (2022) to four (2017; 2;4). Cactus restoration in the early 2000s resulted in dense cholla thickets. This is a *Low* priority for cactus expansion as there is only a small area to expand cactus scrub (figure 5.4.4).	13	*Very High/ Low*
Brown Airfield	Yes	One Cactus Wren territory was documented 2018-2022 (2; 4). This location is not a priority for cactus scrub expansion as there are only two small patches of mapped cactus with limited modeled suitable habitat.	NA	*Medium/ NAP*
Otay Ranch Preserve	Yes	There were four mapped Cactus Wrens at this location in 1992 (3), three in 2009 and four in 2011 (1). There were no territories (2015) with two territories in 2016 and expansion to three territories in 2018 and 2020-2022 (2; 4). Cactus was planted over three acres in 2016 (table 4). This is a *High* priority for expansion as there is room for two more patches of cactus to support a medium size wren population (figure 5.4.5).	21	*Very High/ High*
Johnson Canyon	Yes	There were nine mapped Cactus Wrens in 1992 (3) and from 2015-2021 the number of territories increased from five to 14 (2; 4). In 2022, there were 13 territories (2). The Lonestar Ridge restoration site on the mesa top bordering the west side of the canyon has six new territories included in these totals. There is substantial modeled high and very high	165	*Very High/ High*

		suitability habitat for further cactus scrub expansion to support a larger stable population of wrens (figure 5.4.6). This location is a *High* priority for cactus expansion to increase this population from medium to large size and maintain genetic diversity and provide a source of wrens to disperse to surrounding locations.		
Salt Creek	Yes	There were 38 mapped Cactus Wrens at this location in 1992 (3). Between 2015 and 2021, the number of wren territories grew from four in 2015 to 20 in 2020 (2; 4). In 2022 there were 15 territories (2). There has been considerable cactus scrub restoration and enhancement since 2009 (table 4). There is a lot of modeled high and very high suitability habitat where cactus could be planted to expand habitat to support a large stable population of wrens (figure 5.4.7). This is a *Very High* priority for cactus scrub expansion to increase the population to at least its' former size to improve stability, genetic diversity, and serve as a source of wrens to disperse to other locations.	571	*Very High/ Very High*

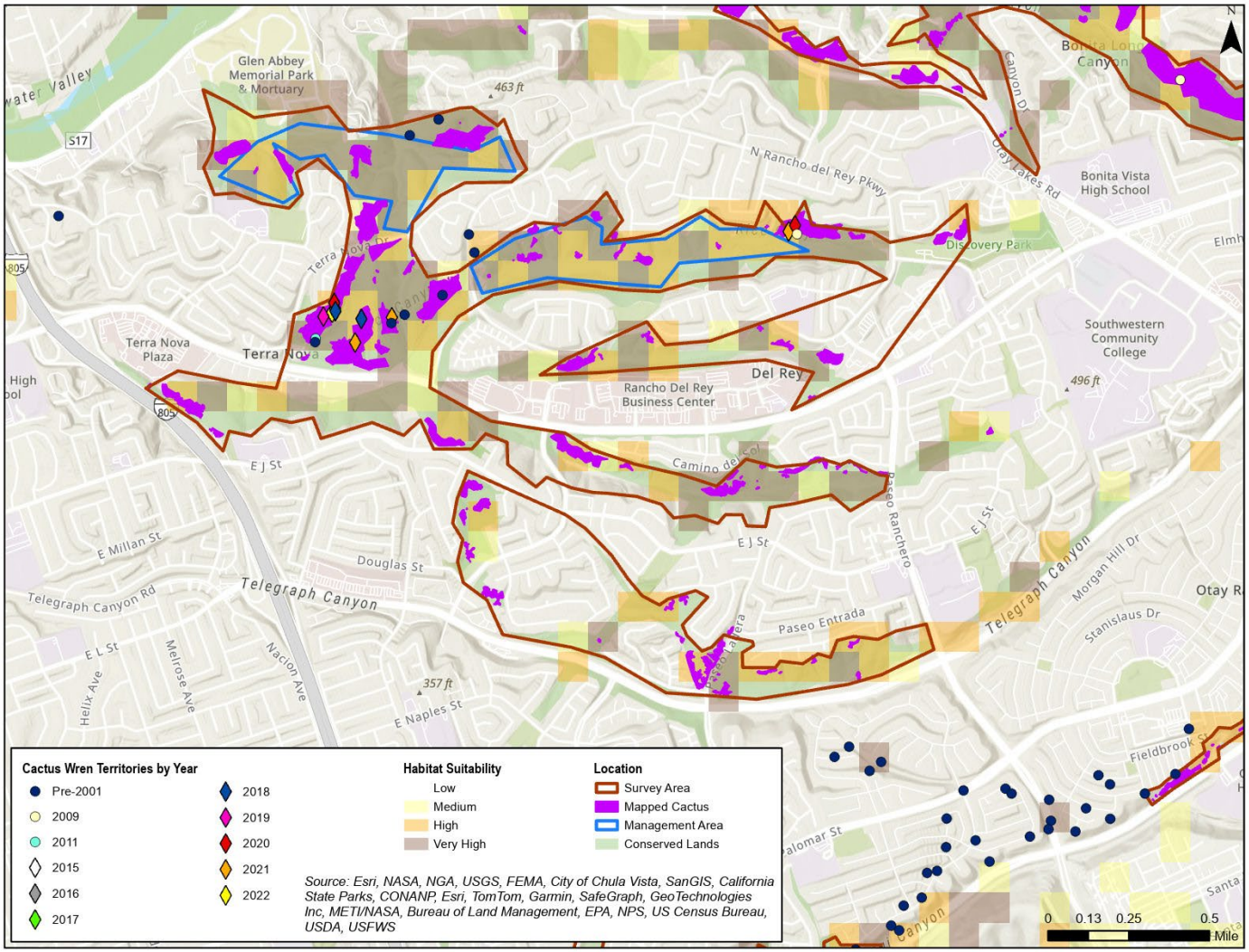

Figure 5.4.1. Rice Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2018-2022 (Kus and Lynn, 2022).

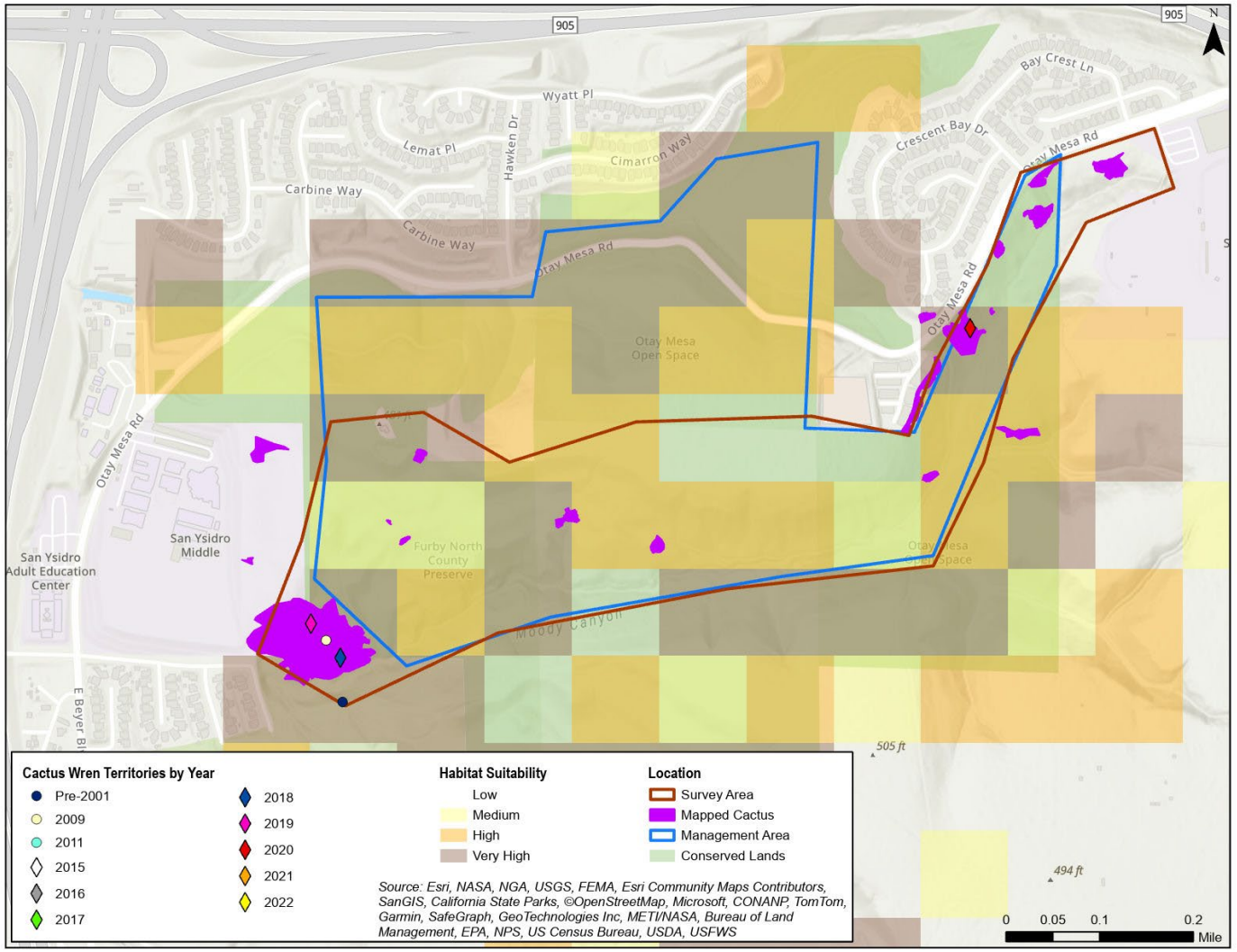

Figure 5.4.2. Furby North management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2017-2022 (Kus and Lynn, 2022).

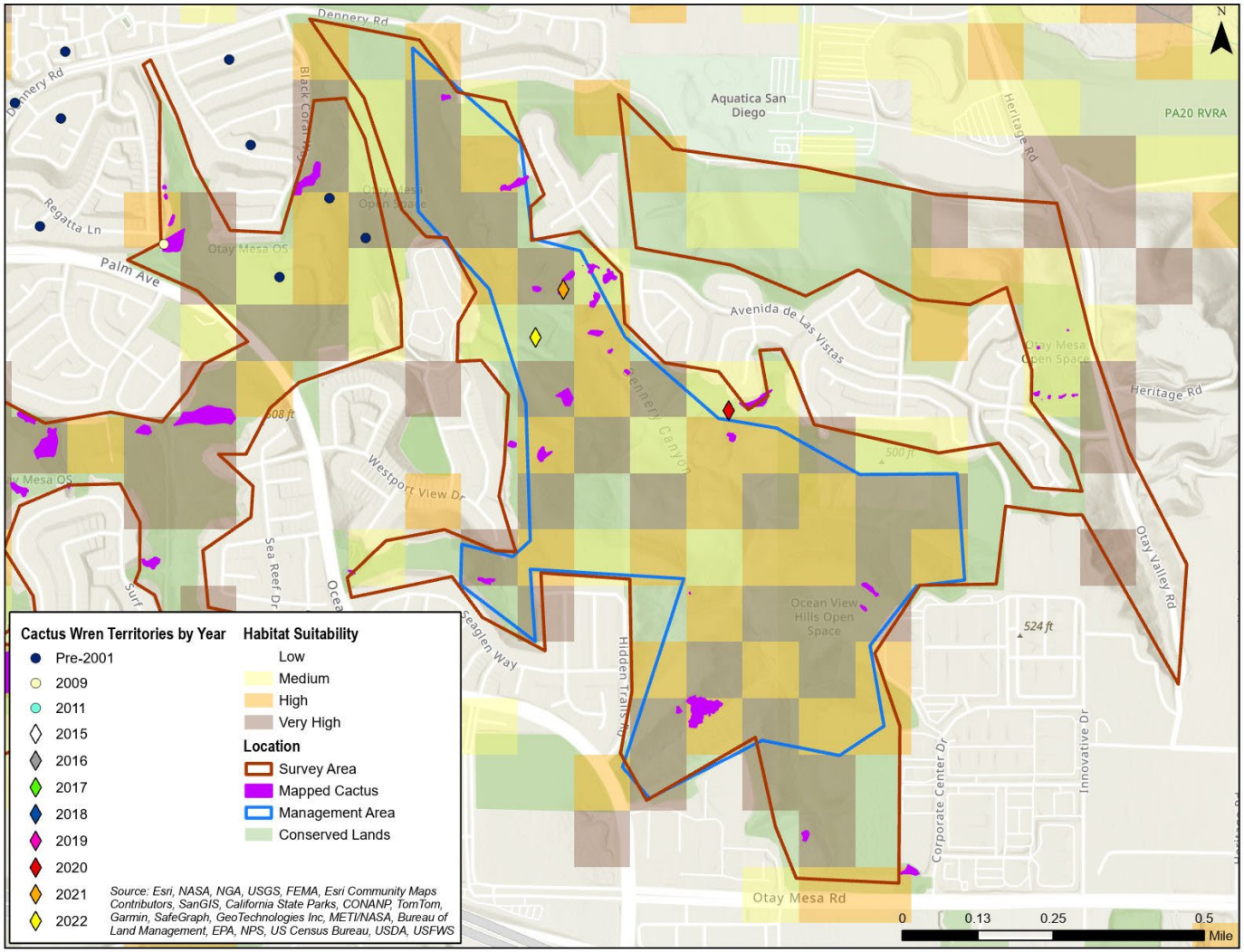

Figure 5.4.3. Dennery Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2020-2022 (Kus and Lynn, 2022).

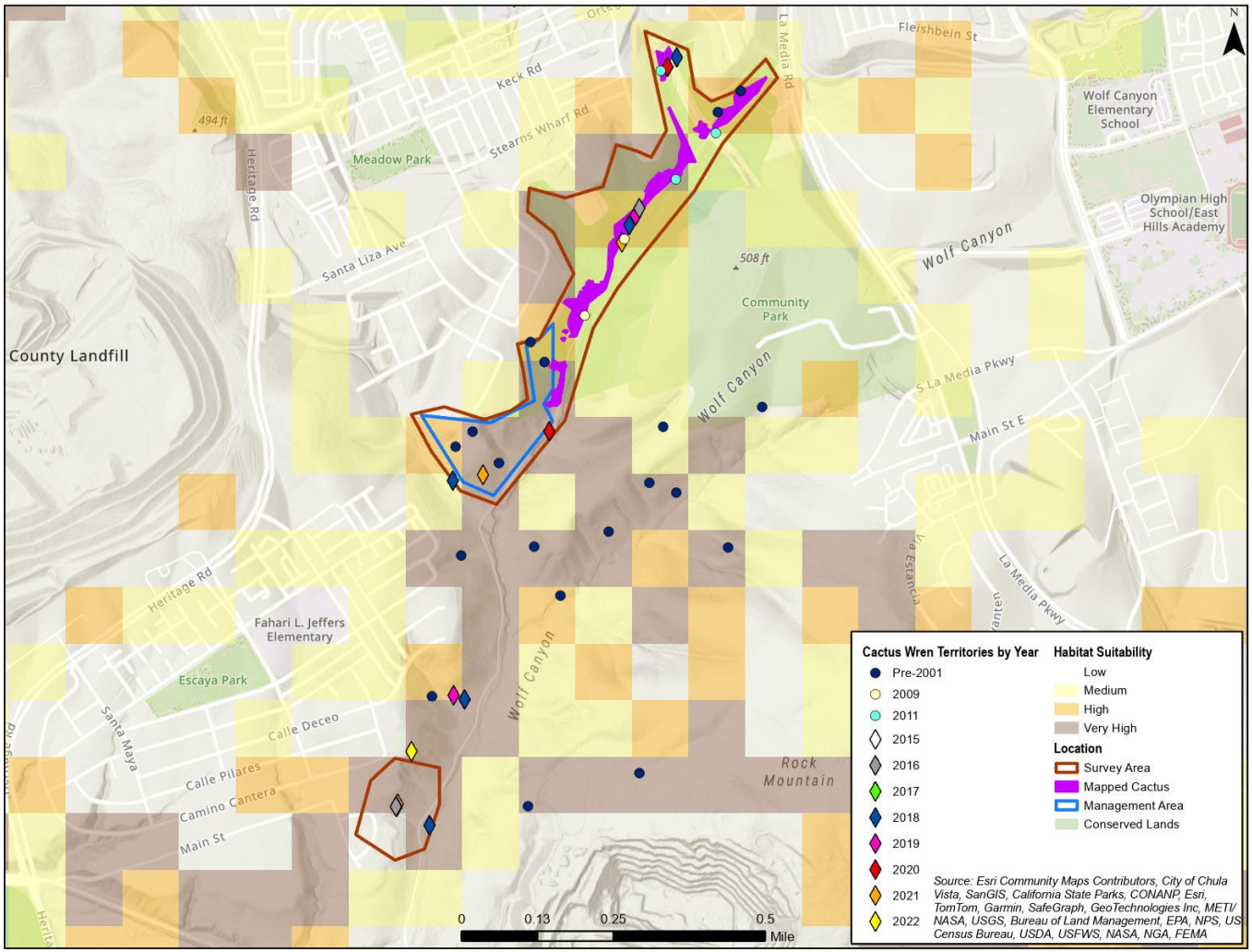

Figure 5.4.4. Wolf Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

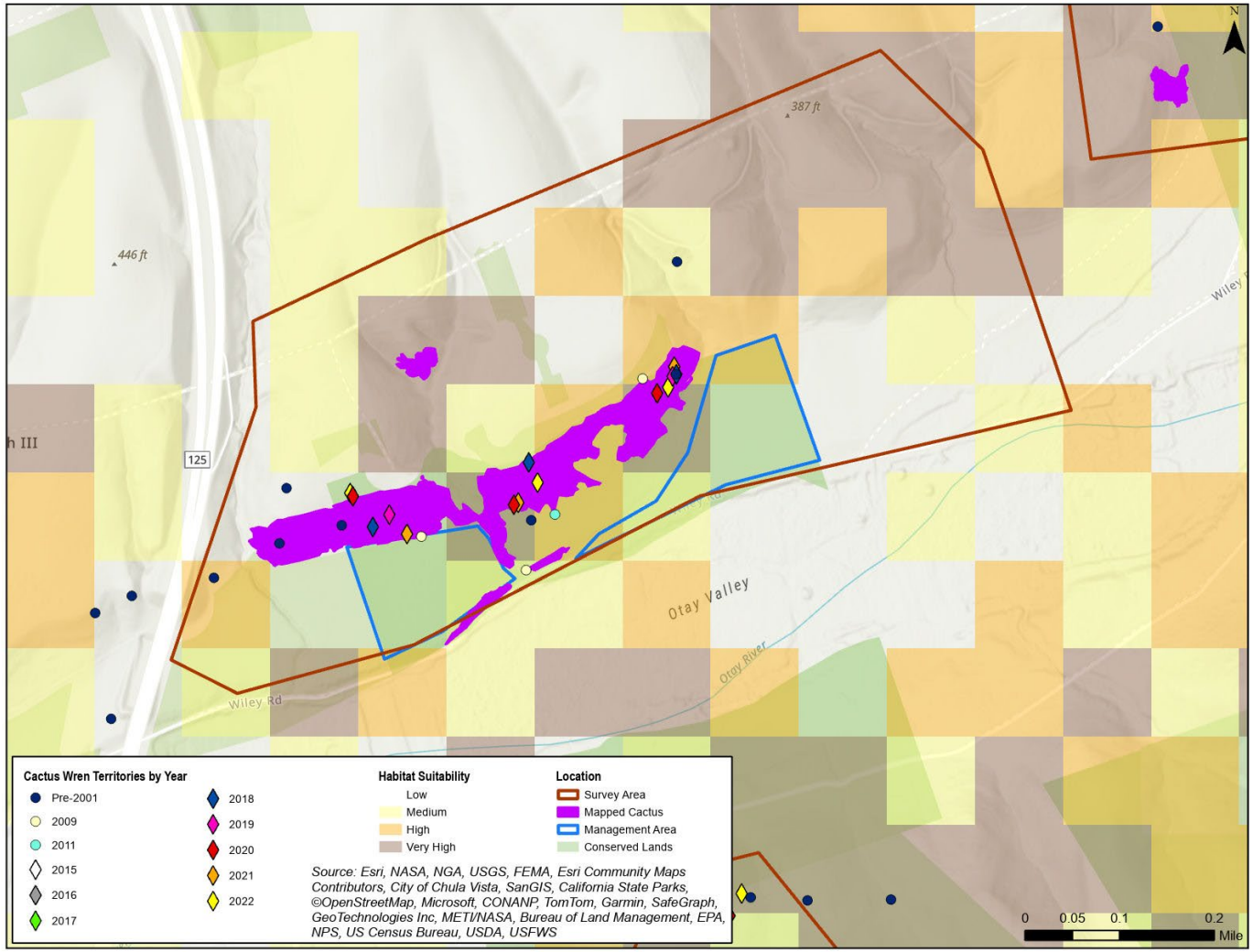

Figure 5.4.5. Otay Ranch Preserve management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

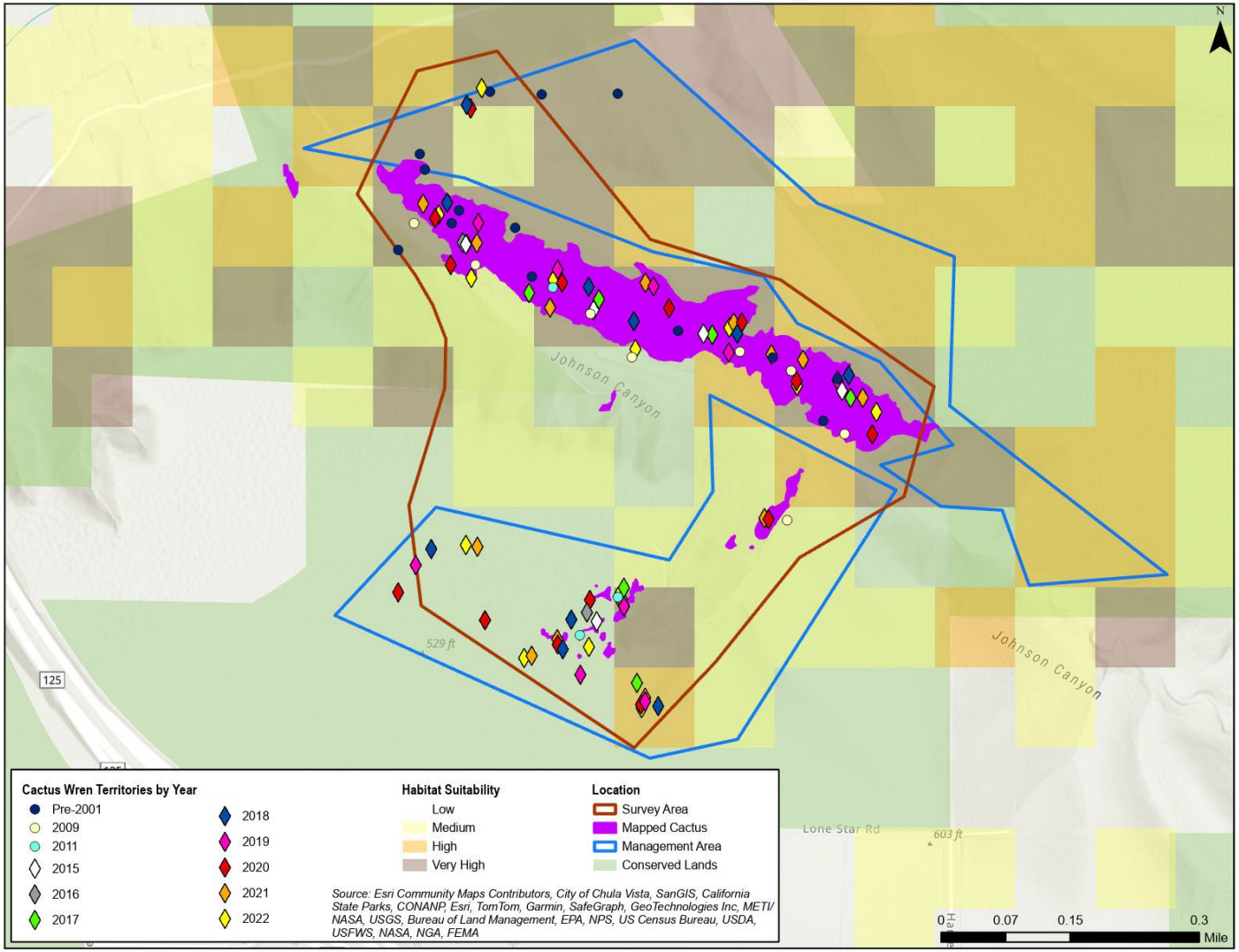

Figure 5.4.6. Johnson Canyon management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).

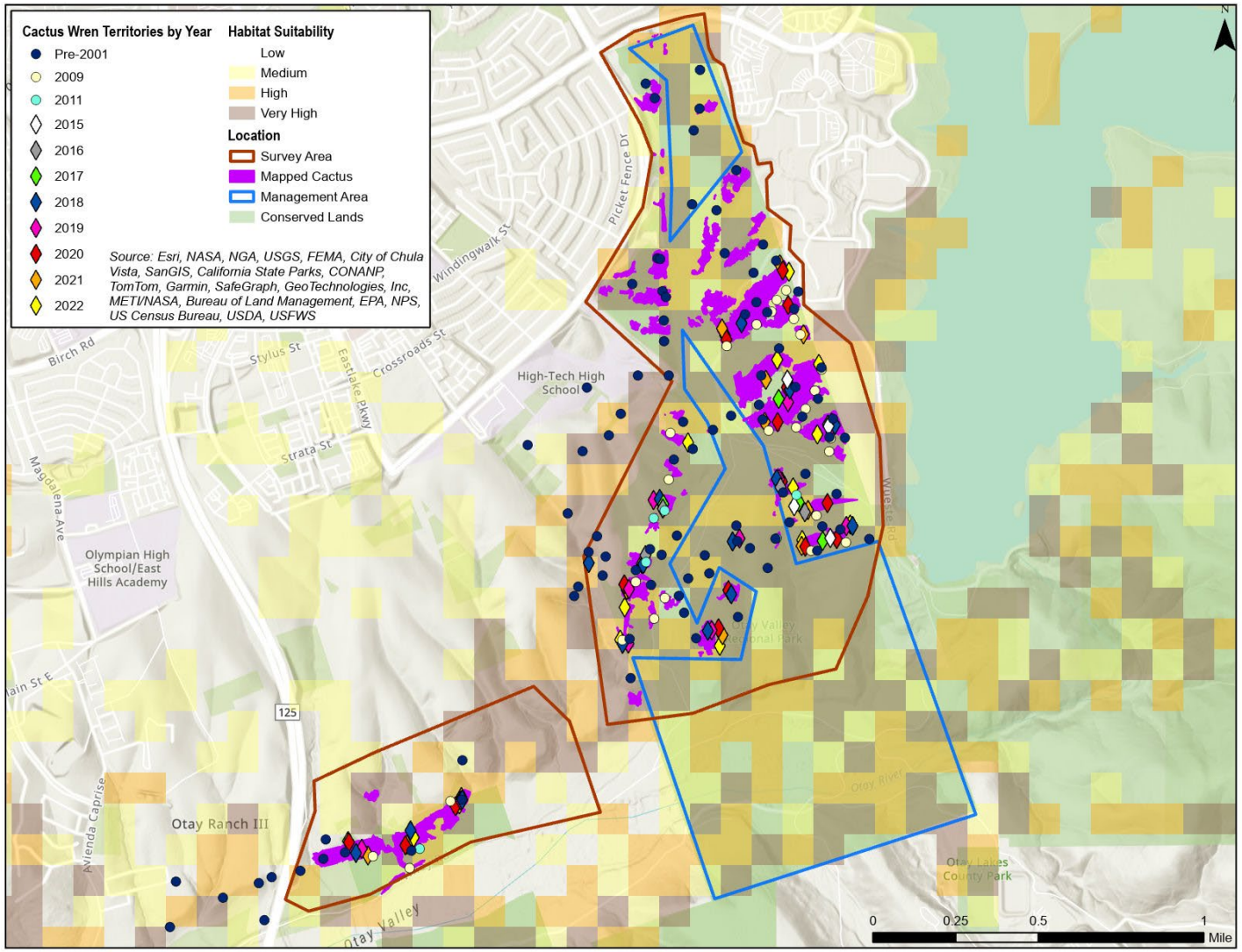

Figure 5.4.7. Salt Creek management area with mapped cactus patches (USFWS, 2011a) and potential cactus scrub expansion areas in suitable habitat with no documented Cactus Wrens. Wren locations are from the 1990s (REGSS, 2002), 2009 and 2011 (USFWS, 2011b), and 2015-2022 (Kus and Lynn, 2022).