SANTA CLARA VALLEY HABITAT PLAN
2023 BURROWING OWL MANAGEMENT REPORT

January 2024

Photo credit: Ryan Phillips

SANTA CLARA VALLEY
HABITAT AGENCY

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City of Morgan Hill

City of San José

County of Santa Clara

Santa Clara Valley Water District

Santa Clara Valley
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Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

In this report Talon Ecological Research Group (Talon) summarizes management activities for burrowing owls (*Athene cunicularia*) in Santa Clara County, California, implemented as Tier 3 Conservation Actions under the Santa Clara Valley Habitat Plan (Habitat Plan), which is both a habitat conservation plan and natural community conservation plan, or HCP/NCCP. To preserve the burrowing owl as a breeding species in the Santa Clara Valley Habitat Plan Area (Plan Area), the Santa Clara Valley Habitat Agency (Habitat Agency) has coordinated the implementation of Tier 3 Conservation Actions under the Habitat Plan since 2017. Tier 3 Conservation Actions were described in the Plan as "consisting of more experimental and active methodologies such as population augmentation and owl relocation within the permit area to increase owl numbers and expand distribution... These actions will be coordinated with the Wildlife Agencies and will only be implemented upon their approval."

REPORT OVERVIEW

Chapter 2 describes burrowing owl distribution and abundance in the Plan Area. Comprehensive long-term survey data inform adaptive management of this species and help prioritize use of funds for burrowing owl conservation under the Habitat Plan.

Chapter 3 summarizes results of a Banding Study. Banding has been conducted consistently at all breeding sites in the Plan Area under the Habitat Plan since 2014.

Chapter 4 describes the Juvenile Burrowing Owl Overwintering Project (Overwintering Project) that was initiated in 2019. This project entails capturing juvenile burrowing owls in the wild and overwintering them in captivity. The goals of this project include (1) increasing the juveniles' chance of survival to adulthood, (2) increasing genetic diversity by selecting breeding pairs based on genomic analysis, (3) releasing selected pairs the following spring at both extant breeding colonies and at reintroduction sites, and (4) ultimately increasing the number of breeding burrowing owls in the Plan Area.

Chapter 5 summarizes the Burrowing Owl Captive Breeding Program that was initiated in 2021. Based on genomic analysis, four burrowing owls (2 pairs) were selected from the group of juveniles from the Overwintering Project and they have successfully reproduced in captivity each year.

Chapter 6 includes the Supplemental Feeding Study. The Habitat Agency worked with the Wildlife Agencies to initiate this first Tier 3 Conservation Action in 2017. The goal of this project is to improve nesting success, brood size, and health of adults and their offspring. This action has generally supported increased reproductive success and reproductive rates of breeding pairs.

Chapter 7 introduces a tracking study that was initiated in 2023 to discern movement patterns and habitat use of burrowing owls post soft-release as part of the Juvenile Overwintering Project. This is the first time a tracking study on burrowing owls has been conducted in the greater San Francisco Bay area.

Chapter 8 provides a discussion of challenges for preserving burrowing owls at extant breeding sites and proposed conservation actions for 2024.

BACKGROUND

The number of breeding burrowing owls in the greater San Francisco Bay area—and the South Bay area in particular—is in decline (DeSante et al. 2007, Townsend and Lenihan 2007, California Natural Diversity Database [https://www.wildlife.ca.gov/data/cnddb]). During a statewide survey for burrowing owls during 1991–1993, researchers estimated 150–170 pairs breeding in the San Francisco Bay area (DeSante and Ruhlen 1995; DeSante et al. 1997) and estimated a 53% decline from the previous census period of 1986–1990 (DeSante et al. 1997). Findings of the 1991–1993 statewide census showed that 75% of the burrowing owl population in the San Francisco Bay area occurred in Santa Clara County and that nearly all owls were located around the southern edge of the San Francisco Bay (DeSante et al. 1997). About a third (43– 47 pairs) of these breeding pairs occurred inside what is now the Habitat Plan study area (City of San José 2000). Results of the 2006−2007 statewide census, (Wilkerson and Siegel 2010) showed similar findings in distribution of burrowing owls around the southern edge of the Bay. For the "San Francisco Bay Area Interior" survey area, which included seven counties from Sonoma in the north to Santa Clara in the south, and inland stretching from Napa to Alameda counties, the "best estimate" for the number of burrowing owl pairs in the region was 119, which represented a nearly 28% reduction from the 165 pairs estimated from the 1991−1993 survey (Wilkerson and Siegel 2010).

The Habitat Agency is implementing measures aimed at reversing the declining trend of the burrowing owl population in Santa Clara County. To date, the area of modeled nesting habitat protected in the Plan Area encompasses approximately 2,161 acres and modeled protected non-breeding habitat includes approximately 5,242 acres. As described in the Conservation Strategy (Appendix M of the Habitat Plan, ICF International 2012), conservation actions are grouped into three "tiers" of priority, and during the first years of Plan implementation, the focus had been on Tier 1 conservation actions which were designed to stabilize the existing population by protecting and/or managing occupied burrowing owl nesting habitat in areas within 0.5 mile of established breeding sites. Since 2017, Tier 2 and Tier 3 conservation actions have also been implemented. Tier 2 actions include facilitating "growth and expansion of existing colonies, the number of colonies, and the range of the species in the permit area by protecting and managing potential burrowing owl nesting habitat in all portions of the permit area." Tier 3 conservation actions consist of "more experimental and active methodologies such as population augmentation and owl relocation within the permit area to increase owl numbers and expand distribution" (Appendix M of the Habitat Plan, ICF International 2012).

STUDY AREA

The Habitat Plan Study Area (519,506 acres) is located in Santa Clara County in the central California Coast Range (Figure 1). The primary valley in the area is the Santa Clara Valley, extending from the south end of the San Francisco Bay to San Benito County. The Santa Clara Valley is bounded by the Diablo Range to the east, the Santa Cruz Mountains to the west, the San Francisco Bay shoreline to the north, and the Pajaro Basin to the south. The study area excludes tidally influenced portions of the Baylands (Figure 1). For a description of the political, ecologic, and hydrologic factors used to define the Study Area, see Chapter 1 of the Habitat Plan (ICF International 2012).

During the development of the Habitat Plan, it was determined that opportunities for increasing the local population of burrowing owls were very limited within the Study Area. After extensive discussions with the California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), and species experts, it was decided that one way to increase the local population was to include conservation areas outside the Study Area. An Expanded Study Area for burrowing owl conservation was identified at the northern edge of Santa Clara County in portions of the cities of San José, Santa Clara,

Mountain View, Milpitas, and Sunnyvale, as well as in Fremont in Alameda County, and in a small portion of San Mateo County (Figure 1). The Expanded Study Area for burrowing owl conservation added 48,464 acres where burrowing owl surveys and conservation actions can occur.
The North San José/Baylands region contains the largest remaining populations of breeding burrowing owls in the South Bay area. As in previous years, surveys in 2023 were primarily conducted in this region, specifically at Shoreline at Mountain View, San José-Santa Clara Regional Wastewater Facility (RWF), Don Edwards San Francisco Bay National Wildlife Refuge – Warm Springs Unit (Warm Springs), NASA Ames Research Center at Moffett Field (Moffett), San José International Airport, Sunnyvale Baylands Park, and Sunnyvale Landfill.

PERMITS

For this work, we obtained the following permits:

- CDFW Scientific Collecting Permit #S-190420019-20142-011
- USFWS Raptor Propagation Permit #MB83731D
- Bird Banding Laboratory Master Banding Permit #24310.

PERMIT AUTHORIZED INDIVIDUALS

- Sandra Menzel[1]: Principal Investigator; involved in all aspects of the work covered under the SCP.
- Philip Higgins[1]: Involved in all aspects of the work covered under the SCP.
- Ryan Phillips[1]: Involved in all aspects of the work covered under the SCP.
- Lynne Trulio[2]: Coordinator for genomic testing.
- Ashley Quick[3]: Executive Director at Wildlife Education and Rehabilitation Center (WERC).
- Kristin Ruegg[4]: Genomic analysis (blood samples).
- Marcia Nikolik[5]: Sex determination (feather samples).
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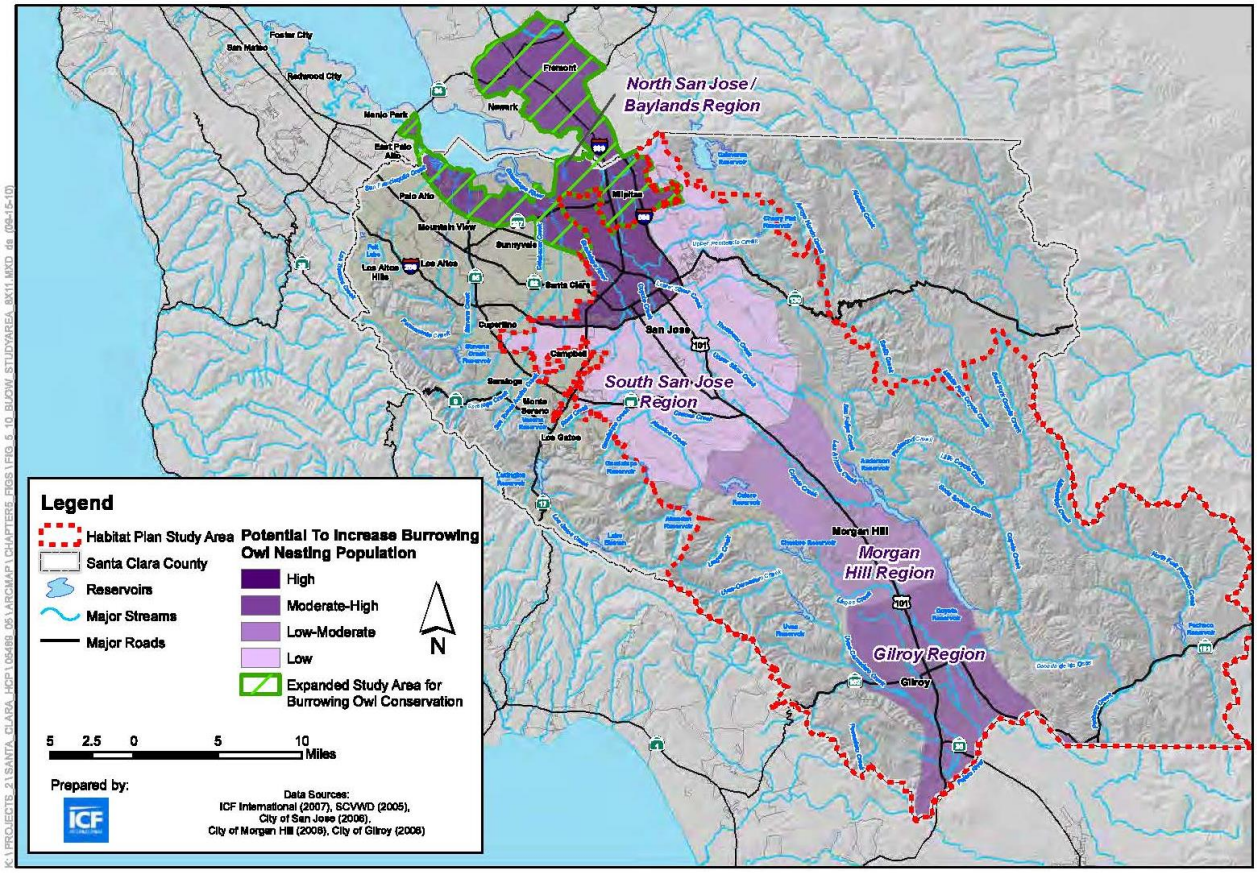

Figure 1. Santa Clara Valley Habitat Plan Study Area and Expanded Study Area for burrowing owl conservation.

CHAPTER 2: BREEDING BURROWING OWL ABUNDANCE AND DISTRIBUTION

The Habitat Agency is required to monitor the number and distribution of burrowing owls in the Plan Area and has coordinated annual breeding burrowing owl surveys. In collaboration with resource agencies, cities, and other local jurisdictions, the South Bay Burrowing Owl Survey Network (Survey Network) was formed and has jointly contributed population data since 2014. The Survey Network enabled extensive survey area coverage and provided the Habitat Agency with confident estimates of the number of breeding burrowing owls and their reproductive rates in the region. Estimates included the number of pairs and single adults observed during the breeding season, as well as the number of juveniles produced per pair. Below, we present the results of the 2023 breeding season surveys. Talon Ecological Research Group (Talon) conducted all the surveys, except at San José International Airport. The Habitat Agency, in coordination with USFWS and CDFW, uses the survey results to allocate burrowing owl conservation funds and to assess compliance with the conservation program outlined in the Western Burrowing Owl Conservation Strategy.

CURRENTLY OCCUPIED BREEDING SITES

Burrowing owls were observed at three sites in the South Bay area during the 2023 breeding season: Shoreline at Mountain View (Figure 2), NASA Ames Research Center at Moffett Field (Figure 3), and San José-Santa Clara Regional Wastewater Facility (RWF) (Figure 4). For the first time in decades, no burrowing owls were observed at the San International Airport. As in previous years, no burrowing owls were observed at Don Edwards San Francisco Bay National Wildlife Refuge – Warm Springs Unit. In total, surveyors observed 12 adults, forming five pairs, four of which successfully produced 16 offspring in the wild (3.2 young per pair).

This year, four pairs of breeding burrowing owls were soft-released at RWF as part of the Juvenile Burrowing Owl Overwintering Project. An additional three pairs and three single females were soft-released at Shoreline. For the first time, we also soft-released nine pairs at two reintroduction sites in the southern part of the county that were not occupied by wild burrowing owls prior to reintroduction; Peninsula Open Space Trust (POST)/Santa Clara Open Space Authority (OSA) Reintroduction Site (Figure 5) and the Santa Clara County Parks and Recreation Department (SCCP) Reintroduction Site (Figure 6).

In total we soft-released 16 pairs, 15 of which successfully reproduced a total of 77 offspring (4.8 young per pair). An additional two pairs produced nine offspring in captivity (4.5 young per pair) as part of the Captive Breeding Program (Table 1−7). The 35 released overwintered owls represented 69% of the total breeding population in the Plan Area in 2023. The two pairs in the Captive Breeding Program, initiated in 2021, contributed 9% (9 of 102) of the total offspring. More detailed information on these projects is included in Chapter 5 and 6 below.

Table 1. 2023 Breeding burrowing owl survey results for the Santa Clara Valley Habitat Plan Study Area and Expanded Study Area for Burrowing Owl Conservation.

Site Name/Location	Number of adults	Number of juveniles	Number of pairs	Number of successful pairs
San José International Airport	0	0	0	0
San José-Santa Clara Regional Wastewater Facility	10*	23	5*	5
POST/OSA Reintroduction Site	10**	26	5	5
SCCP Reintroduction Site	8**	21	4	4
Study Area subtotal	*28*	*70*	*14*	*14*
Shoreline at Mountain View	17***	23	7**	5
Don Edwards SFB National Wildlife Refuge - Warm Springs Unit	0	0	0	0
NASA Ames Research Center at Moffett Field	2	0	0	0
Expanded Study Area subtotal	*19*	*23*	*7*	*5*
Captive Breeding Program	4	9	2	2
Totals	51	102	23	21

*8 adults (4 pairs) were released on site as part of the Juvenile Burrowing Owl Overwintering Project.
**all adults were released on site as part of the Juvenile Burrowing Owl Overwintering Project.
***9 adults (3 pairs and 3 single females) were released on site as part of the Juvenile Burrowing Owl Overwintering Project.

Figure 2. Occupied burrow locations at Shoreline Park during the 2023 breeding season.

Table 2. Location, pair, and reproductive information for Shoreline at Mountain View, 2023.

	Burrow #						
	E1	**E2**	**E3**	**223**	**227**	**241**	**259**
Female	Blue M71	Blue M38	Blue C85	Red/blue 6P	Blue M63	Blue M07	Blue M30
Male	Blue M04	Blue M13	Blue C79	Red/blue 2P	Red/blue 5N	Red/blue 6C	Red/blue 4B
No. of owlets	5	0	6	4	4	4	0
Owlet band # (not all were captured for banding)	Red 89P Red/blue 6M Red/blue 5W Red/blue 4K Red/blue 6A		Red 90P Red/blue 4C Red/blue 7K Red/blue 7M Red/blue 5E Red/blue 2D	Red 81P Red 82P	Red 77P Red 78P	Red 79P Red 80P Red/blue 4H	

Figure 3. Occupied burrow locations at Moffett Field during the 2023 breeding season.

Table 3. Location and reproductive information for Moffett Field, 2023.

	Burrow #	
	280	**282**
Female	none	none
Male	Red/black A9	Red/black 5P
No. of owlets	0	0

Figure 4. Occupied burrow locations at San Jose-Santa Clara Regional Wastewater Facility during the 2023 breeding season.

Table 4. Location, pair, and reproductive information for San Jose-Santa Clara Regional Wastewater Facility, 2023.

	Burrow #				
	E1	**E2**	**E3**	**E4**	**51**
Female	Blue C86	Red 70P	Blue M34	Blue C89	Black/green 5P
Male	Blue C95	Red 74P	Blue C92	Blue M31	Black/green
No. of owlets	6	4	3	6	4
Owlet band # (not all were captured and banded)	Black/green KR Black/green ND Black/green HX Black/green RW Black/green MZ Red 85P	Black/green PM Black/green KV Black/green NE Red 86P	Black/green MK Black/green MP Red 87P	Red 88P Black/green MA Black/green MV Black/green SK Black/green KH Black/green NB	Red 83P Red 84P

Figure 5. Occupied burrow locations at the POST/OSA reintroduction site during the 2023 breeding season.

Table 5. Location, pair, and reproductive information for the POST/OSA reintroduction site, 2023.

	Burrow #				
	E1	**E2**	**E3**	**E4**	**E5**
Female	Blue M40	Blue C87	Blue M27	Blue C98	Blue C83
Male	Blue M22	Blue M52	Blue M42	Blue M41	Blue C94
No. of owlets	3	6	5	6	6
Owlet band #	Red 91P Black/green RR Black/green SC	Red 92P Blue 08BC Black/green MB Black/green NU Black/green KM Black/green HW	Red 93P Blue 06BC Black/green PK Black/green MM Black/green RA	Red 94P Blue 27BC Black/green NC Black/green KS Black/green RZ Black/green PP	Red 95P Blue 02BC Black/green KC Black/green SB Black/green MX Black/green RV

Figure 6. Occupied burrow locations at the SCCP reintroduction site during the 2023 breeding season.

Table 6. Location, pair, and reproductive information for the SCCP reintroduction site, 2023.

	Burrow #			
	E1	**E2**	**E3**	**E4**
Female	Blue C80	Blue C93	Blue C99	Blue M54
Male	Red 71P	Blue C84	Blue C76	Blue M23
No. of owlets	7	4	4	6
Owlet band #	Black/green SU Black/green SM Black/green MD Black/green PW Black/green KE Black/green RE Black/green RS	Black/green MW Black/green KU Black/green PB Black/green NA	Black/green SE Black/green PS Black/green NV Black/green KZ	Black/green RC Black/green PA Black/green NZ Black/green ME Black/green RD Black/green PD

Table 7. Pair and reproductive information for WERC Captive Breeding Facility, 2023.

	Enclosure #	
	1	2
Female	Blue C78	Red 76P
Male	Blue C81	Red 72P
No. of owlets	5	4
Owlet band #	Red 96P Red 97P Red 98P Red 99P Blue 21BC	Blue 89BC Blue 97BC Blue 25BC Blue 31BC

BURROWING OWL HABITAT FOR FORAGING, DISPERSAL, AND MIGRATORY BURROWING OWLS

Besides the use of nest burrows during the breeding season as illustrated in Figures 2–6 above, burrowing owls require suitable habitat for year-round foraging and areas to disperse to from their natal burrows. With the decline of suitable grassland habitat in the south San Francisco Bay area, especially those areas supporting and surrounding the remaining burrowing owl breeding colonies, it is imperative that adjacent areas are conserved for the recovery effort. Based on band resightings, we can confirm that resident burrowing owls move not only within the boundaries of one site but also disperse to other local areas. Some owls have been observed to move seasonally. For example, a male burrowing owl that hatched at Shoreline (red over blue 2P), spent the past three non-breeding seasons at Moffett Field and returned to Shoreline for each breeding season. This owl moved up to 2.4 miles between the breeding and non-breeding seasons each year from 2021–2023. Another burrowing owl (female blue M49) moved 1.4 miles from Shoreline to Moffett Field. Analysis of local banding data also showed that burrowing owls have moved between Shoreline and Warm Springs in Fremont (~7 miles), between Alviso in San Jose and Warm Springs (~4.7 miles), between San Jose International Airport and Moffett Field in Mountain View (~7.0 miles) as well as the Santa Clara Golf Club in Santa Clara (~3.2 miles).

Tracking studies confirmed that burrowing owls may forage 1.5 miles away from the nest burrow and their home range can encompass 1.9 square miles (Table 8). Suitable foraging habitat is especially important during the breeding season when pairs need to find additional food for their offspring. Depending on the number of breeding pairs at a site, competition for resources increases. Seasonal movements to and from adjacent sites have been recorded up to 9.31 miles (Table 8). These movements may include dispersal away from the natal burrow in search for suitable nest burrows for the following breeding season, searching for a mate, moving to higher ground during the non-breeding season to avoid inundated burrows on the valley floor during periods with high precipitation levels, and/or depletion of prey availability especially toward the end of a breeding season.

When habitat is converted, fragmented, and degraded, carrying capacity (number of burrowing owls a site can support based on necessary resources) is reduced thereby limiting suitable breeding habitat. Eventually, burrowing owls are forced to move to marginal areas and eventually vanish. While adults show high site fidelity, natal dispersal has been documented at San Jose Airport, where 48% of 120

young burrowing owls dispersed further than 1 km (0.62 mi) and 7% were resighted within 15 km of the airport (9.32 mi) during the following breeding season (Menzel 2014, Table 8). Owls moved from the airport to Moffett Field, Devcon Court near Tully Road in San Jose, and the Santa Clara Golf Club (Menzel 2014, Table 8).

While some local sites no longer support breeding owls, suitable habitat still supports an influx of migratory burrowing owls each year during approximately October−March. At Warm Springs for example, we observed 17 burrowing owls during a survey in October 2020. The number of burrowing owls also increases at Shoreline each year with a as many as 25 owls observed in December 2023, of which at least 5−6 were migratory (unbanded) owls. During the non-breeding season, we also observed burrowing owls at other locations on the valley floor as well as in the foothills. During the migratory season 2014−2018, surveys conducted in the foothills in eastern Santa Clara County confirmed dozens of migratory owls in open grassland habitat at higher elevations each fall and winter, but owls did not remain in those areas for the breeding season; only few migrants have remained to breed at extant breeding sites (Trulio et al. 2023).

Table 8. Burrowing owl movements recorded in various study areas, 1941−2023.

Distances/Areas	How Observed	Comments	Reference
0.14 – 4.81 km^2 (0.052 mi^2 – 1.857 mi^2)	6 radio tagged owls	Home Range	Haug and Oliphant 1990
Up to 2.4 km for juveniles and 1.1 km for an adult (1.49 mi and 0.68 mi)	Direct Observation	Observed from the nest burrow	Butts 1973
1.6 km (0.99 mi)	Direct Observation	Observed from nest burrow	Hamilton 1941
98 ha – 172 ha (242 ac – 425 ac)	33 radio tagged owls	Home Range	Gervais 2002
Average 70 ha (172.9 ac)	17 radio tagged owls	Home Range	Valdez-Gomez et al. 2018
Adaptive kernel home range mean 49.8 ha. range 13.7 – 79.3 ha (123 ac, range 33.85 ac – 193.95 ac	4 male radio tagged owls	Home Range	Sissons et al. 2002
48% of burrowing owls from San Jose Airport dispersed farther than 1 km (0.62 mi), 7% dispersed within 15 km of the airport (9.32 mi).	Band resightings	Distance dispersed from natal burrow	Menzel 2014
Burrowing owl movements from Shoreline Park to Moffett Field from 2021−2023. Individual movements include: 1.68 mi (2021), 1.61 mi (2022), 1.36 mi (2022) & 2.38 mi (2023).	Band resightings	Distance dispersed, some individual owls move seasonally from Moffett to Shoreline or vice versa.	SCVHP. Annual Reports 2021–2023.

POPULATION DYNAMICS 2014–2023

During this tenth annual breeding season survey, the number of owls has increased from a total of 33 adults in 2022 to 51 adults in 2023 (Table 9, Figure 7). The number of young increased from 64 to 102 during the same timeframe. Nonetheless, small populations such as this are inherently more vulnerable to external environmental perturbations, inbreeding, and chance fluctuations in local survival and fecundity (Keller and Waller 2002).

Table 9. Comparison of adult burrowing owls observed in the Santa Clara Valley Habitat Plan Area during the breeding season, 2014–2023. In parentheses are the number of owls released as part of the Juvenile Burrowing Owl Overwintering Project, 2020–2023.

	Year									
Location	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
San José International Airport	34	18	12	8	10	4	9	4	3	0
Regional Wastewater Facility	16	22–23	25–26	35–37	18	12	8 (3)	12 (9)	13 (11)	10
Shoreline at Mountain View	6	6	4	5	4	2	16 (10)	11	10 (6)	17
Don Edwards-Warm Springs Unit	11	6	8	11–12	5–6	3	2	0	0	0
Moffett Field	24	17	12	13	15	12	4	6	3	2
Other Locations	16	5	0	2	0	0	0	0	0	0
POST/OSA reintroduction site	–	–	–	–	–	–	–	–	–	10
SCCP reintroduction site	–	–	–	–	–	–	–	–	–	8
Captive Breeding Program	–	–	–	–	–	–	–	4	4	4
Total	107	75	62	77	52–53	33	38	36	33	51

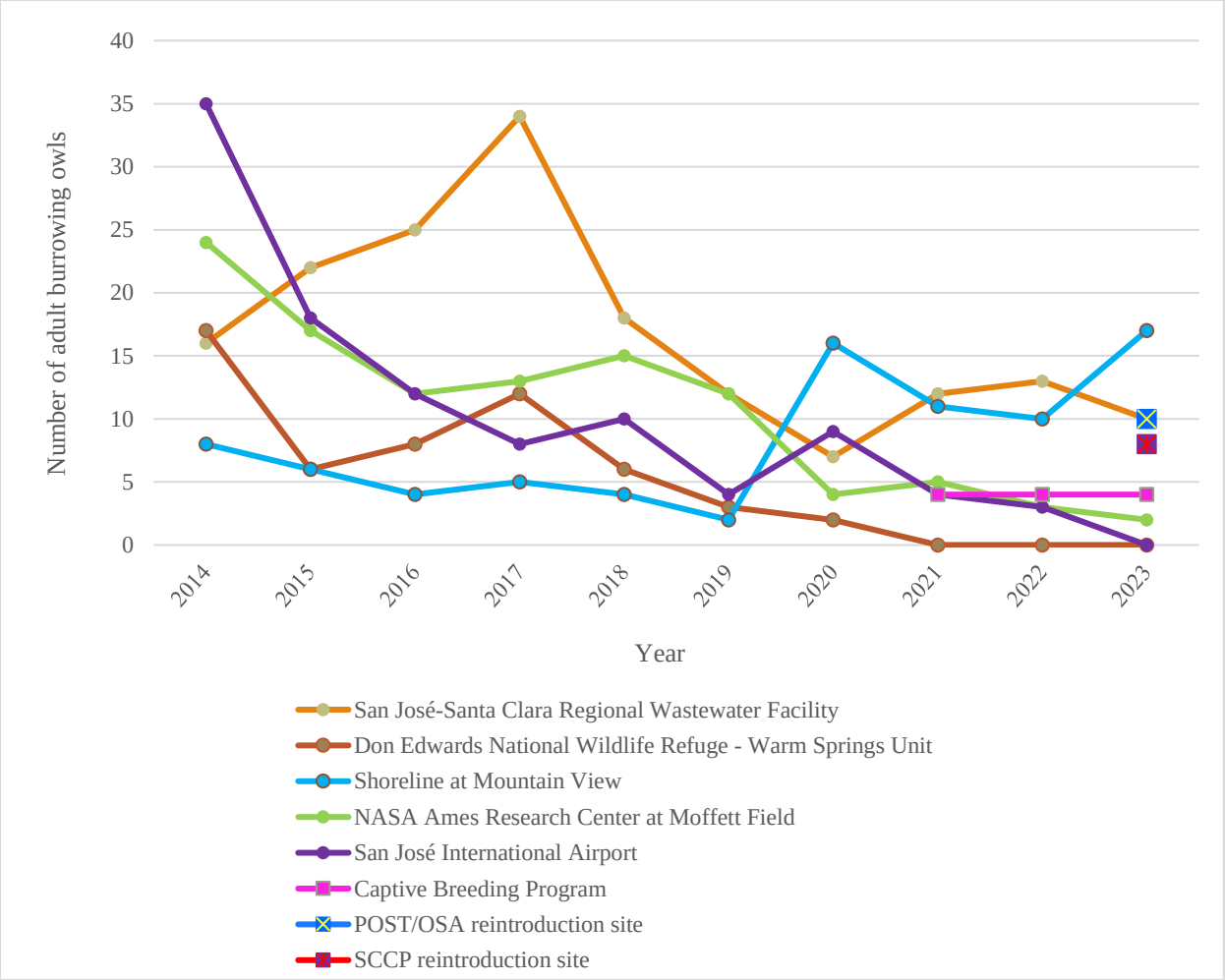

Figure 7. Number of adult burrowing owls at five breeding sites and in the Captive Breeding Program in the Santa Clara Valley Habitat Plan Study Area and Expanded Study Area for burrowing owl conservation, 2014–2023.

Of the 51 breeding adults, 35 (69%) were released as part of the Juvenile Burrowing Owl Overwintering Project in 2023 (Figure 8). In 2022, 17 of 35 adults (51.5%) were released as part of the Juvenile Burrowing Owl Overwintering Project and in 2021, nine of 36 adults (25%). Evidence from banding studies across the burrowing owl range suggests that annual survival of juvenile owls is approximately 30% (James et al. 1997, Johnson 1997, Millsap 2002, Rosenberg and Haley 2004). Thus, without protection of these juveniles in captivity, many of them would likely have perished during fall and winter and thus the number of breeding adults in 2023 would likely have been lower.

In 2021, we also initiated a Captive Breeding Program. Four owls from the Juvenile Overwintering Project were retained in 2021 to form two breeding pairs. These two captive pairs successfully reproduced in 2021 and 2022 (Figure 7). In 2023, both pairs were soft-released at Shoreline in Mountain View and we retained four different owls from the Overwintering Project for the 2023 Captive Breeding Program; both pairs successfully produced a total of nine offspring. The success of the Juvenile Burrowing Owl Overwintering Project and the Captive Breeding Program are essential for establishing a viable long-term population in the Plan Area.

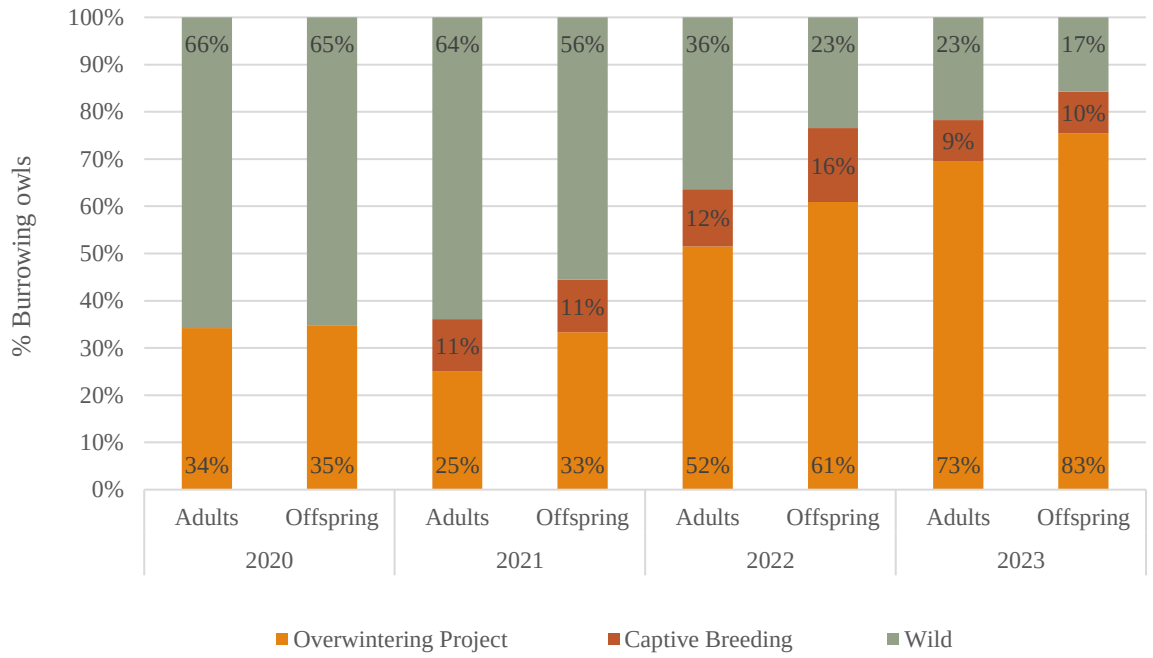

Figure 8. The total number of breeding burrowing owls and their offspring observed in the Santa Clara Valley Habitat Plan Area 2020–2023, represented in percentages based on source affiliation: owls breeding in the wild, released as part of the Juvenile Overwintering Project, or retained for the Captive Breeding Program.

Productivity Estimates

We estimated productivity for each pair based on the maximum number of young observed at the nest burrow throughout the breeding season. In 2023, 21 of a total of 23 pairs successfully reproduced a total of 102 young, resulting in a reproductive rate of 4.4 young per pair (Table 10).

In comparison, during the 2022 breeding season, surveyors observed 29 adults (14 pairs), 10 of which successfully reproduced in the wild and an additional two pairs that reproduced in captivity. In total, the 16 pairs produced 64 young resulting in a reproductive rate of 4.0 young per pair. During the 2021 breeding season surveys, surveyors observed a total of 36 adult (17 pairs) and 36 juvenile burrowing owls (2.1 juvenile per pair), and in 2020 the number of adults observed was 38 and 66 juvenile burrowing owls, resulting in an average productivity of 3.67 juveniles per pair (Table 10).

Table 10. Productivity estimates for burrowing owls in Santa Clara County, 2020–2023.

Year	Number of pairs	Number of offspring	Reproductive rate (young/pair)
2023	23	102	4.4
2022	16	64	4.0
2021	17	36	2.1
2020	17	66	3.7

DISCUSSION

A Population Viability Analysis (PVA) for burrowing owls completed during preparation of the Habitat Plan suggested that in order to change the population trend from negative to positive within a 10-year time period at the three sites included in the PVA (Moffett Field, San Jose International Airport, and Shoreline), there would have to be an increase of three adult owls per year for all three sites combined (Appendix M and N of the Habitat Plan, ICF International 2012). The baseline count was 51 adult owls in 2009. In 2023, the combined count of adult owls at these three breeding sites was 19 adults, 10 of which were released this year as part of the Juvenile Overwintering Project. In 2022, the combined count of adult owls at these three breeding sites was 16 adults, down from 20 adults in 2021, and 29 adults in 2020.

Inbreeding has been observed in the Plan Area over the last decade and may contribute to the overall population decline through inbreeding depression. Inbreeding depression is defined as "the reduction in the average fitness of offspring born to parents that are closely related to each other, compared to the fitness of offspring born to unrelated parents." Inbreeding depression occurs because closely related parents share more genes, and thus their offspring are more likely to receive two copies (one from each parent) of alleles that cause deleterious traits or genetic diseases. Inbreeding data from bird and mammal populations suggest that inbreeding depression often significantly affects birth weight, survival, reproduction, resistance to disease, predation, and environmental stress (Keller and Waller 2002). Releasing breeding pairs as part of the Juvenile Overwintering Project, alleviates some of the inbreeding depression. Each pair is selected based on genomic analysis and the least related individuals are paired up.

In addition to a low number of individuals, wild pairs of burrowing owls in the South Bay were limited to only two breeding sites. This regional contraction in range exposes the breeding population to stochasticity and therefore a high risk of local extirpation, especially because all these sites are facing increasing pressure from encroaching development. While burrow availability and foraging habitat have been reduced, the rate of disturbance and predation pressure has increased. Habitat protection and management at current breeding sites is imperative.

Additional pressures arise from the effects of climate change and extreme weather conditions. During the 2022/2023 winter, the area experienced record precipitation levels and widespread flooding. Groundwater levels were high into April and many ground squirrel burrows and artificial burrows were flooded. Conversely, the previous three years brought extreme drought conditions. During drought years, prey availability for burrowing owls is limited and competition for these reduced resources is increased. During 2021 and 2022, some grass species were dormant or had limited growth and we noticed an increased distribution of some invasive weedy species (mustard spp., stinkwort, and pepperweed) at most sites. In addition, we observed few if any grasshoppers during transect surveys. In prior years, grasshoppers were abundant during the summer. Grasshoppers and other invertebrates are essential prey items for burrowing owls (Higgins 2007, Trulio and Higgins 2012) especially during the breeding season when adults are feeding their young. Scarcity of invertebrates during these drought years could have contributed to the reduced number of breeding owls in the Plan Area. Severe and changing weather events, including precipitation and temperature patterns, must be anticipated in the future, but will be challenging to predict and alleviate.

CHAPTER 3: BANDING STUDY

This long-term banding study was initiated to provide a scientific baseline for collecting demographic data and is critical to assist the Habitat Agency in monitoring burrowing owl population trends. In this chapter, we summarize trapping and banding data, owl abundance and distribution, band resightings, owl dispersal between breeding seasons and breeding sites, and nest monitoring to evaluate reproductive success and estimate productivity for the 2023 breeding season.

METHODS

The main objectives of this study were resighting alphanumeric study band codes on previously banded owls and banding unbanded adults and nestlings. Nest monitoring, trapping, and banding sessions occurred during the peak of the 2023 breeding season from May 1 through July 31.

Surveys to Identify Nest Locations

Biologists with Talon Ecological Research Group (Talon) conducted monthly walk-through transect surveys to locate burrows with sign of owl activity, including whitewash, regurgitated pellets, molted feathers, burrow decoration, and/or prey remains. When burrowing owls were detected during the breeding season, we conducted weekly site visits and installed motion-sensor trail cameras at active burrows to determine which burrows were used by a pair of owls as a nest burrow. We conducted surveys at four extant colonies: Shoreline at Mountain View (Shoreline), San Jose-Santa Clara Regional Wastewater Facility (RWF), NASA Ames Research Center at Moffett Field (Moffett), and Don Edwards National Wildlife Refuge – Warm Springs Unit (Warm Springs). Surveys at Mineta San Jose International Airport (SJC) were conducted by US Department of Agriculture (USDA) staff. They reported that no owls were sighted during the 2023 breeding season. In 2021 and 2022, we had access to band owls at SJC. Post soft-release of overwintered owls, Talon also conducted monthly surveys at the reintroduction sites: Peninsula Open Space Trust (POST)/Santa Clara Open Space Authority (OSA) site and the Santa Clara County Parks site in 2023.

Nest Monitoring to Evaluate Reproductive Nest Status

We conducted focused surveys at each nest burrow location during dusk to evaluate each female's reproductive stage, determine nest status, observe nestling emergence, and estimate clutch size and age of young. We conducted direct observations during the day from inside our vehicles, using a spotting scope or binoculars from a distance of at least 100 feet to limit disturbance and not alter the owls' behavior.

We also used motion-sensing trail cameras that we installed near the burrow entrance for confirming presence of a pair of owls, determining the number and age of nestlings, and verify nest abandonment or predation events. We categorized a pair as successful when they raised at least one nestling to 14 days and older. We also used images from the cameras to confirm banding status, identify previously banded adults, detect nestlings as they emerged from their natal burrow for timing of trapping and banding. For camera maintenance and data retrieval, we approached an active burrow at 1−2-week intervals to minimize disturbance. Cameras yielded continual, cost-effective, and detailed observations.

Trapping

In 2023, we banded 95 young and five adults. We observed nestlings to determine their approximate age and attempted to capture them when they were 20−24 days old. We used push-door traps (Winchell 1999) and bow nets for trapping. At most of the artificial burrow sites, we had direct access to the nest chambers and caught owls inside the nest chamber by hand. We occasionally placed a MP3

player near the trap, broadcasting vocalizations of a female during feeding. Vocalizations may prompt nestlings to emerge from the burrow and walk into the trap. All trapping equipment was removed after each trapping session.

Banding

We carefully removed each owl from the trap or the nest chamber and placed it head-first into a sock to keep it contained and reduce stress during banding and biometric measurement procedures. A silver non-locking No. 4 United States Geological Survey (USGS) band with a unique numeric code was crimped around the right tarsus. A colored type-3 Acraft metal study band with a unique alphanumeric code was secured to the left tarsus by pop-riveting the flanged ends of the band together with two rivets. Different colors were used for owls banded at different sites or for a specific project, as follows: red over blue for Shoreline, red over black for Moffett, and black over green for RWF. Blue or red bands were used for all owls as part of the Juvenile Overwintering Project and Captive Breeding Program.

We determined the sex of adults by evaluating the absence (male) or presence (female) of a brood patch, bleached (male) or dark (female) plumage, behavior, and banding records. Age (adult or young) was determined exclusively by plumage, body development, and behavior. The age of previously banded young (hatch year) was definitive. The age of individuals banded as adults (after hatch year) was assigned the age of ≥1 year, denoting the first year banded for ease in recording an individual's life history. We weighed each owl on a digital scale. A metric banding ruler was used to obtain tarsus and wing chord measurements. If necessary, we kept owls in an animal carrier for up to two hours before release while we were attempting to capture additional owls. Owls were released into the same burrow where they were captured (Figure 9).

Figure 9. After banding, burrowing owls were released into the same burrow where they were captured.

Identifying Previously Banded Owls

For identifying a banded individual, we used binoculars or spotting scopes during direct observation to read alphanumeric codes on colored Acraft study bands (Figure 10). We also reviewed photos from the trail cameras to identify band codes.

Figure 10. Two banded adult burrowing owls.

RESULTS

We banded a total of 95 nestling burrowing owls during the 2023 breeding season (Table 11 and 12). Thirty of the banded young were retained and taken to the Peninsula Humane Society Wildlife Care Facility for initial intake as part of the Juvenile Overwintering Project. Nine young were banded at the Captive Breeding facility at the Wildlife Education and Rehabilitation Center (WERC). The Overwintering Project and Captive Breeding Program are described in Chapters 5 and 6 below.

Table 11. Number of banded juvenile burrowing owls during the 2023 breeding season in the Santa Clara Valley Habitat Plan Study Area and Expanded Study Area for Burrowing Owl Conservation.

Site Name/Location	Adults	Juveniles	Banded in 2023
San José International Airport	0	0	0
San José-Santa Clara Regional Wastewater Facility	10*	23	21
POST/OSA Reintroduction Site	10**	26	26
SCCP Reintroduction Site	8**	21	21
Study Area subtotal	*28*	*70*	*68*
Shoreline at Mountain View	17***	23	18
Don Edwards National Wildlife Refuge Warm Springs Unit	0	0	0
NASA Ames Research Center at Moffett Field	2	0	0
Expanded Study Area subtotal	*19*	*23*	*18*
Captive Breeding Program WERC	4	9	9
Totals	51	102	*95*

*8 adults (4 pairs) were released on site as part of the Juvenile Burrowing Owl Overwintering Project.
**all adults (9 pairs) were released on site as part of the Juvenile Burrowing Owl Overwintering Project.
***9 adults (3 pairs and 3 single females) were released on site as part of the Juvenile Burrowing Owl Overwintering Project.

Table 12. Banding data for 100 (95 juveniles and five adults) burrowing owls banded in 2023. (Age: HY=hatch year, AHY=after hatch year).

Site/Burrow #	Date	USGS Band	Acraft Band	Sex	Age
SH 277	30-May	115447508	Red 77P	Female	HY
SH 277	30-May	115447509	Red 78P	Female	HY
SH 241	20-Jun	115447510	Red 79P	Female	HY
SH 241	20-Jun	115447511	Red 80P	Male	HY
SH 233	20-Jun	115447512	Red 81P	Female	HY
SH 233	20-Jun	115447513	Red 82P	Female	HY
RWF 51	10-Jul	115447514	Red 83P	Male	HY
RWF 51	10-Jul	115447515	Red 84P	Male	HY
RWF E1	13-Jul	115447516	Red 85P	Male	HY

Site/Burrow #	Date	USGS Band	Acraft Band	Sex	Age
RWF E2	13-Jul	115447517	Red 86P	Female	HY
RWF E3	13-Jul	115447518	Red 87P	Female	HY
RWF E4	13-Jul	115447519	Red 88P	Female	HY
SH E1	19-Jul	115447520	Red 89P	Male	HY
SH E3	19-Jul	115447521	Red 90P	Male	HY
SP E5	21-Jul	115447528	Red 95P	Female	HY
SP E2	21-Jul	115447525	Red 92P	Male	HY
SP E3	21-Jul	115447526	Red 93P	Female	HY
SP E4	21-Jul	115447527	Red 94P	Male	HY
SP E1	21-Jul	115447522	Red 91P	Male	HY
SP E1	21-Jul	115447523	Black/green RR	Male	HY
SP E1	21-Jul	115447524	Black/green SC	Unknown	HY
RWF E3	22-Jul	115447529	Black/green MP	Unknown	HY
RWF E4	22-Jul	115447530	Black/green MA	Unknown	HY
RWF E4	22-Jul	115447531	Black/green MU	Male	HY
RWF E4	22-Jul	115447532	Black/green SK	Male	HY
RWF E4	22-Jul	115447533	Black/green KH	Male	HY
RWF E4	22-Jul	115447534	Black/green NB	Female	HY
SH E1	24-Jul	115447535	Red/blue 6M	Female	HY
SH E1	24-Jul	115447536	Red/blue 5W	Male	HY
SH E1	24-Jul	115447537	Red/blue 4K	Male	HY
SH E1	24-Jul	115447538	Red/blue 6A	Female	HY
SH E3	24-Jul	115447539	Red/blue 4C	Female	HY
SH E3	24-Jul	115447540	Red/blue 7K	Female	HY
SH E3	24-Jul	115447541	Red/blue 7M	Male	HY
SH E3	24-Jul	115447542	Red/blue 5E	Female	HY
SH E3	24-Jul	115447543	Red/blue 2D	Male	HY
HB E4	27-Jul	115447549	Black/green RD	Male	HY
HB E4	27-Jul	115447550	Black/green PD	Male	HY
HB E3	27-Jul	11547548	Black/green KZ	Male	HY
HB E2	27-Jul	115447546	Black/green PB	Male	HY
HB E2	27-Jul	115447547	Black/green NA	Female	HY
HB E1	27-Jul	115447544	Black/green RE	Male	HY
HB E1	27-Jul	115447545	Black/green RS	Female	HY

Site/Burrow #	Date	USGS Band	Acraft Band	Sex	Age
RWF E1	28-Jul	115447551	Black/green KR	Male	HY
RWF E1	28-Jul	115447552	Black/green ND	Female	HY
RWF E1	28-Jul	115447553	Black/green HX	Female	HY
RWF E1	28-Jul	115447554	Black/green RW	Female	HY
RWF E1	28-Jul	115447555	Black/green MZ	Female	HY
RWF E2	28-Jul	115447556	Black/green PM	Female	HY
RWF E2	28-Jul	115447557	Black/green KV	Female	HY
RWF E2	28-Jul	115447558	Black/green NE	Male	HY
RWF E3	28-Jul	115447559	Black/green MK	Male	HY
W E2	29-Jul	115447560	Red 96P	Male	HY
W E2	29-Jul	115447561	Red 97P	Female	HY
W E2	29-Jul	115447562	Red 98P	Female	HY
W E2	29-Jul	115447563	Red 99P	Female	HY
W E2	29-Jul	115447564	Blue 21BC	Male	HY
W E1	29-Jul	115447565	Blue 89BC	Female	HY
W E1	29-Jul	115447566	Blue 97BC	Female	HY
W E1	29-Jul	115447567	Blue 25BC	Male	HY
W E1	29-Jul	115447568	Blue 31BC	Female	HY
SP E5	4-Aug	115447583	Blue 02BC	Male	HY
SP E5	4-Aug	115447583	Blue 02BC	Male	HY
SP E5	4-Aug	115447584	Black/green KC	Male	HY
SP E5	4-Aug	115447585	Black/green SB	Female	HY
SP E5	4-Aug	115447586	Black/green MX	Female	HY
SP E5	4-Aug	115447587	Black/green RV	Female	HY
SP E2	4-Aug	115447569	Blue 08BC	Female	HY
SP E2	4-Aug	115447570	Black/green MB	Male	HY
SP E2	4-Aug	115447571	Black/green NU	Unknown	HY
SP E2	4-Aug	115447572	Black/green KM	Female	HY
SP E2	4-Aug	115447573	Black/green HW	Female	HY
SP E3	4-Aug	115447574	Blue 06BC	Male	HY
SP E3	4-Aug	115447575	Black/green PK	Male	HY
SP E3	4-Aug	115447576	Black/green MM	Male	HY
SP E3	4-Aug	115447577	Black/green RA	Female	HY
SP E4	4-Aug	115447578	Blue 27BC	Female	HY

Site/Burrow #	Date	USGS Band	Acraft Band	Sex	Age
SP E4	4-Aug	115447579	Black/green NC	Male	HY
SP E4	4-Aug	115447580	Black/green KS	Female	HY
SP E4	4-Aug	115447581	Black/green RZ	Male	HY
SP E4	4-Aug	115447582	Black/green PP	Female	HY
HB E4	5-Aug	115447588	Black/green RC	Male	HY
HB E4	5-Aug	115447589	Black/green PA	Female	HY
HB E4	5-Aug	115447590	Black/green NZ	Male	HY
HB E4	5-Aug	115447591	Black/green ME	Female	HY
HB E3	5-Aug	115447592	Black/green SE	Male	HY
HB E3	5-Aug	115447593	Black/green PS	Female	HY
HB E3	5-Aug	115447594	Black/green NV	Male	HY
HB E2	5-Aug	115447595	Black/green MW	Female	HY
HB E2	5-Aug	115447596	Black/green KU	Female	HY
HB E1	5-Aug	115447597	Black/green SU	Male	HY
HB E1	5-Aug	115447598	Black/green SM	Male	HY
HB E1	5-Aug	115447599	Black/green MD	Male	HY
HB E1	5-Aug	115447600	Black/green PW	Female	HY
HB E1	5-Aug	109485101	Black/green KE	Male	HY
SH 241	29-Aug	109485103	Red/blue 4H	Female	HY
SH 204	10-Oct	109485102	Red/blue 7B	Unknown	AHY
SH 13	19-Oct	109485104	Red/blue 6Z	Unknown	AHY
SH 84	30-Oct	109485105	Red/blue 3K	Unknown	AHY
RWF 35	2-Nov	109485106	Black/green RK	Unknown	AHY
SH 13	9-Nov	109485107	Red/blue 7A	Unknown	AHY

Resighting Previously Banded Burrowing Owls

We resighted a total of 12 burrowing owls during the 2023 breeding season (Table 13). We resighted eight banded owls at Shoreline at Mountain View. Of these eight owls, three were released as part of the Juvenile Overwintering Project during past years and the remaining five owls were wild individuals. At the San Jose-Santa Clara Regional Wastewater Facility, we resighted two owls; for one of these owls we only confirmed the band color not the alphanumeric code. At NASA Ames Research Center at Moffett Field, we resighted another two owls; both were banded as young at Moffett Field. We included details on resighted owls in Table 13.

Movements

One male burrowing owl (red/blue 2P) hatched at Shoreline in 2021, was observed at Moffett during the early part of 2023, before returning to Shoreline where he paired up with a female and successfully raised young. This owl travelled a distance between sites of 2.4 miles.

Table 13. 2023 resightings of previously banded burrowing owls.

Band ID	2023 Site (Burrow #)	Sex	Banding year, age, site, burrow #	Comments
Blue M63	Shoreline (227)	Female	2019, nestling, Moffett, #272	Part of Juvenile Overwintering Project, released at Shoreline in 2020 at #225
Red/blue 5N	Shoreline (227)	Male	2021, adult, Shoreline, #86	
Blue M30	Shoreline (259)	Female	2021, nestling, SJC #W15	Part of Juvenile Overwintering Project, released at Shoreline 2022 at #E1
Red/blue 2P	Shoreline (223)	Male	2020, nestling, Shoreline, #243	
Red/black 5P	Moffett (282)	Male	2019, nestling, Moffett, #236	
Red/black A9	Moffett (280)	Male	2020, nestling, Moffett, #122	
Black/green SP	RWF (51)	Female	2020, nestling, RWF #89	
Red/blue 6P	Shoreline (223)	Female	2022, nestling Shoreline, #E1	
Blue M07	Shoreline (241)	Female	2021, nestling, SJC, #W12	Part of the Juvenile Overwintering Project, released at Shoreline in 2022 at #E1
Red/blue 6C	Shoreline (241)	Male	2022, nestling Shoreline, #E1	
Red/blue 4B	Shoreline (259)	Male	2022, nestling Shoreline, #E2	
Black/green (code?)	RWF (51)	Male	Unknown	alpha numeric code not confirmed

DISCUSSION

In 2023, we banded 95 juvenile and five adult burrowing owls. This is the highest number of owls we have banded in a single year. The high reproductive rate and number of juveniles this year resulted from a combination of management actions, including habitat enhancements, supplemental feeding, and soft-releases from the Juvenile Overwintering Project.

CHAPTER 4: JUVENILE BURROWING OWL OVERWINTERING PROJECT

In 2019, we initiated a Juvenile Burrowing Owl Overwintering Project as a Tier 3 conservation action under the Habitat Plan. In 2023, we continued this successful project originally permitted by the Wildlife Agencies Regional Letter of Approval 24 April 2019; USFWS permit MB32250D-0). In March 2022, we submitted an amendment application to our CDFW Scientific Collecting Permit # S-190420019-20142-001 to cover the Overwintering Project under our Permit. CDFW approved the amendment in November 2022.

METHODS

Sites at which we collected juvenile owls for this project in 2023 included San José-Santa Clara Regional Wastewater Facility (RWF) and Shoreline at Mountain View. We overwintered all juveniles at the Wildlife Education and Rehabilitation Center (WERC) in Morgan Hill after an initial intake exam and quarantine period at Peninsula Humane Society (PHS) in Burlingame.

The main objectives of this project are to:

- reduce juvenile mortality by overwintering juveniles in captivity for approximately nine months for release back into the wild the following spring
- augment extant breeding colonies by introducing additional adult owls
- establish new breeding locations in Coyote Valley
- increase genetic diversity by pairing males and females based on genomic analysis.

In collaboration with WERC, we constructed a spacious, custom-built facility specifically designed to house burrowing owls for the Overwintering Project and the Captive Breeding Program. This facility was completed in March 2022.

Release Sites in Currently Unoccupied Habitat in Coyote Valley

In 2022, we secured two protected release sites in the southern, more rural part of Santa Clara County that were not occupied by wild burrowing owls prior to reintroduction. Both sites are protected in perpetuity and the Habitat Agency signed long-term management agreements with the Santa Clara County Parks and Recreation Department (SCCP) and with the Peninsula Open Space Trust (POST)/Santa Clara Open Space Authority (OSA). Funding for habitat management, maintenance, and monitoring is provided through the SCVHA for the duration of the HCP/NCCP. California ground squirrels are present at both sites. Vegetation management included cattle grazing at both sites. Prior to the release of burrowing owls, we used rapid field assessment methods, adapted from the methods employed by the San Diego Zoo Institute for Conservation Research (*Project Report: Advancing Burrowing Owl Conservation in San Diego County through Mitigation Measures using Science and Adaptive Management,* 2018; see report at https://institute.sandiegozoo.org/burrowing-owl/burrowing-owl-recovery-program), to assess important habitat qualities for burrowing owls, including the abundance and density of California ground squirrels, vegetation height and quality, soil types, presence/abundance of prey and predator species, and potential for/degree of human disturbance.

We initiated reintroduction of burrowing owls in 2023, and soft-released nine pairs at these two sites. Pairs were placed into hacking enclosures in April. All pairs successfully produced a total of 47 offspring. As of December 2023, owls remained at both sites. We are planning on releasing additional pairs at each site in 2024.

POST/OSA Reintroduction Site

This 100-acre property is owned by POST and managed by OSA. The site is flat and on the valley floor with Fisher Creek demarking the eastern property line. The treeless upland habitat contains native and non-native grassland flora and is grazed and/or mowed. The property is fenced and is not open to the public. Adjacent lands provide excellent foraging habitat for burrowing owls. Land uses include agricultural fields, and cattle and horse ranching. Overall, the property and surrounding parcels provide high quality habitat for nesting burrowing owls.

SCCP Reintroduction Site

This 31-acre site is flat at approximately 330 ft above sea level on the Coyote Valley floor. The treeless habitat contains native and non-native grassland flora and is grazed annually by cattle. The parcel is fenced and is not open to the public. Adjacent lands provide excellent foraging habitat for burrowing owls. Land uses include agricultural fields, cattle and horse ranching, and county park land. The proposed reintroduction site and surrounding parcels provide high quality habitat for nesting burrowing owls.

Site Preparation for Soft-Release

Site preparation for soft-release as part of the Juvenile Overwintering Burrowing Owl Project started during the fall of 2022, with the installation of the artificial burrows (Figure 11). We installed two artificial burrows for each hacking enclosure, so the owls would have a choice of nest burrows. We chose the locations for the placement of the enclosures based on several factors:

- each location needed to be outside of an historical flood area
- presence of adjacent high density ground squirrel burrows
- spacing between enclosures of at least 250 feet.

We designed the artificial burrows so that the lids of the nest chambers were easily accessible to allow observation of the number and timing of egg production and to facilitate easy capture of young for banding later in the season. We installed additional artificial satellite burrows proximate to the nest burrows. During the spring of 2023, we installed hacking enclosures as described in previous annual reports at all four sites (Figure 12).

Banding of Young

We banded all the young with standard USGS metal bands on one leg, and Acraft color bands on the other leg as described in Chapter 3 above. We banded between 30 May and 29 August. We provided banding methodology in Chapter 3 and banding data in Table 12, Chapter 3. All the young with blue or red color bands were retained (Figure 13) during banding and transported to the Peninsula Humane Society (PHS) facility in Burlingame. Staff at PHS conducted an initial intake exam, checked body condition, and provided minor treatment if needed. All owls were kept in quarantine in accordance with Wildlife Rehabilitation Standard Operating Procedures (https://theiwrc.org/wp-content/uploads/2011/05/Standards-4th-Ed-2012- final.pdf) while they were closely monitored. Upon completion of the quarantine period, all the young were relocated to the WERC facility in Morgan Hill.

Figure 11. Site preparation for the soft-release of burrowing owl pairs.


Figure 12. Installation of hacking enclosures for the soft-release of burrowing owl pairs.

Figure 13. Juvenile burrowing owl retained for the Overwintering Project in a transport box.

Feather Samples for Sexing

During banding, we collected feather samples from all the banded young during the 2023 breeding season. We sent the samples to the Bird Sexing Solutions lab for sex identification. The lab reported that of the 30 young, 14 were female and 16 were male (Table 14). The nine young from the Captive Breeding Program were six females and three males.

Burrowing Owl Weights

During banding, we weighed all owls prior to their transfer to PHS. PHS staff monitored each owl's weight during quarantine, ensuring that they all reached an adequate weight prior to transferring them to the outdoor facility at the WERC facility in Morgan Hill. We collected subsamples of the owls' weight on a monthly basis throughout the overwintering period. We subsampled the weight instead of weighing all owls to reduce stress of capture and processing. We also checked the owls visually to ensure healthy body condition and presence/absence of ectoparasites.

Genomic Analysis/Genealogy

The Ruegg Lab (Christen Bossu and Kristen Ruegg) at Colorado State University conducts genomic analyses for each owl each year. They analyze blood samples for relatedness and inbreeding and provide statistical ranges for these parameters. Genomic data for juveniles retained during the 2023 breeding season, is expected by the end of February 2024.

Mate Selection for the 2024 Breeding Season

Each year, pair selection is based on the genomic analysis conducted by the Ruegg Lab at Colorado State University combined with the observed genealogy results. Recommendations for pairings for juveniles retained during the 2023 breeding season, is expected by the end of February 2024.

RESULTS

Soft-Release

In 2023, we soft-released a total of 35 adult burrowing owls, 16 pairs and three single females. We soft-released three single females and three pairs at Shoreline, four pairs at RWF, five pairs at POST/OSA, and four pairs at SCCP (Table 14). Placing the adults into the hacking enclosures was delayed because excessive precipitation amounts caused the groundwater level to be high into April. Artificial burrows inside the enclosures were flooded and we needed to wait until conditions improved. The three single females (blue M39, blue C91, and blue C97) were placed into one hacking enclosure on 23 April and were released to the wild on 18 May. These three females were not resighted after release. We placed one male into each of the hacking enclosures on April 15 and added one female each on April 23. Subsequently, we periodically checked inside the nest chambers at all enclosures to check the number of eggs and/or hatchlings. All pairs produced eggs, but one pair failed to successfully fledge young. The fifteen successful pairs produced a total of 77 fledglings (Table 14).

Table 14. Soft-released pairs of burrowing owls and reproductive outcome as part of the 2023 Juvenile Burrowing Owl Overwintering Project.

Site and enclosure number	Female Acraft band color and code	Male Acraft band color and code	Number of fledglings
Shoreline E1	Blue M71	Blue M04	5
Shoreline E2	Blue M38	Blue M13	0
Shoreline E3	Blue C85	Blue C79	3
RWF E1	Blue C86	Blue C95	6
RWF E2	Red 70P	Red 74P	4
RWF E3	Blue M34	Blue C92	3
RWF E4	Blue C89	Blue M31	6
POST/OSA E1	Blue M40	Blue M22	3
POST/OSA E2	Blue C87	Blue M52	6
POST/OSA E3	Blue M27	Blue M42	5
POST/OSA E4	Blue C98	Blue M41	6
POST/OSA E5	Blue C83	Blue C94	6
SCCP E1	Blue C80	Red 71P	7
SCCP E2	Blue C93	Blue C84	4
SCCP E3	Blue C99	Blue C76	4
SCCP E4	Blue M54	Blue M23	6

Observations in 2023 of owls from previous releases

We observed three burrowing owls that were part of the Juvenile Overwintering Project in previous years, released in 2020 or 2022 (Table 15). In total 2019−2023, we have overwintered 99 juveniles which were released as 31 pairs and 12 singles who collectively produced 151 fledglings (Table 16).

Table 15. Burrowing owls observed in 2023 that were released as part of the Overwintering Project in 2020 and 2022.

Band ID	2023 resighting site, burrow #	Banding year	Sex, age at banding	Banding site, burrow #	Comments
Blue M63	Shoreline #227	2019	Female, HY	Moffett, #272	Retained for Juvenile Overwintering Project, released at Shoreline 2020 at #225
Blue M07	Shoreline #241	2021	Female HY	SJC, Burrow #W12	Retained for Juvenile Overwintering Project, released at Shoreline 2022 at #E1
Blue M30	Shoreline #259	2021	Female HY	SJC #W15	Retained for Juvenile Overwintering Project, released at Shoreline 2022 at #E1

Table 16. Summary of the Juvenile Burrowing Owl Overwintering Project results, 2019−2023.

Year	Juveniles retained for overwintering	Adults soft-released	Breeding results
2019	13 juveniles		
2020		5 pairs; 3 single females	25 fledglings
2020	16 juveniles		
2021	(2 pairs retained for Captive Breeding Program)	3 pairs; 3 single males; 1 rehab female added	15 fledglings
2021	17 juveniles		
2022		7 pairs; 3 single females	34 fledglings
2022	23 juveniles		
2023		16 pairs; 3 single females	77 fledglings
2023	30 juveniles		
Total	99 juveniles	31 pairs; 12 singles 1 rehab owl	151 fledglings

Banding and Retention of Young

We banded all the young produced from soft-released pairs. In total, we retained 30 young for the Juvenile Overwintering Project during the 2023 breeding season for soft-release during the 2024 breeding season. We also added nine offspring produced from two pairs in the Captive Breeding Program (Chapter 6) to the overwintering cohort.

DISCUSSION

In 2019, we initiated the Juvenile Burrowing Owl Overwintering Project to meet the objectives for breeding burrowing owl recovery under the *Santa Clara Valley Habitat Plan NCCP/HCP (Habitat Plan)* and described in *Appendix M of the Habitat Plan, Western Burrowing Owl Conservation Strategy* (ICF 2012). Each year, since 2021 we have increased the number of overwintered owls and these owls have produced an increasing number of offspring.

This project has been imperative in meeting the goal of assisting in recovering the burrowing owl population in Santa Clara County. With the soft-release of 35 burrowing owls this year, the total number of breeding burrowing owls increased from 33 adults in 2022 to a total of 51 adults in 2023. Without the implementation of this Tier 3 Conservation Action, the number of breeding adults and their offspring would likely have been much lower. Continuation of this project is crucial for meeting conservation goals.

CHAPTER 5: BURROWING OWL CAPTIVE BREEDING PROGRAM

This Captive Breeding Program is part of a multi-year plan, designed to promote a viable, self-sustaining breeding burrowing owl population in Santa Clara County, as required under the *Santa Clara Valley Habitat Plan NCCP/HCP (Habitat Plan)* and described in *Appendix M of the Habitat Plan, Western Burrowing Owl Conservation Strategy* (ICF 2012). Despite habitat management, monitoring, and research efforts implemented under the Habitat Plan, existing breeding colonies continue to decline. In response, we have implemented Tier 3 Conservation Actions including captive breeding and the establishment of new breeding colonies in rural areas of Santa Clara County. All activities are coordinated with state and federal wildlife agencies.

Captive breeding is a well-established, often effective method to increase the number of individuals in critically small wildlife populations. Other captive breeding programs for burrowing owls in Canada and San Diego demonstrated that this species can successfully reproduce in captivity. Burrowing owls have been bred in captivity by government and non-profit organizations in British Columbia, Canada for nearly 30 years (Meads and Brodie, 2009; Mitchell, et al., 2011; Environment Canada, 2021). Using methods developed by the Burrowing Owl Conservation Society of British Columbia and the San Diego Zoo Wildlife Alliance (formerly the San Diego Zoo Institute for Conservation Research), we initiated a Captive Breeding Program in March 2021.

We transferred two males and two females from the Juvenile Overwintering Project to specially-designed breeding enclosures at Wildlife Rehabilitation Center (WERC). These two pairs successfully reproduced in 2021 and 2022 and were subsequently soft-released at Shoreline during the 2023 breeding season. Based on genomic analysis, we selected four new individuals (two males and two females) from the Juvenile Overwintering Project and retained them as captive breeders. These two pairs successfully produced a total of nine offspring this year. Captively-bred offspring are transferred into the Juvenile Overwintering Project for soft-release into the wild to augment extant breeding colonies and initiate new breeding colonies at reintroduction sites.

CAPTIVE BREEDING FACILITY

In February 2022, we completed the construction of a new custom-built facility (Figure 14) at WERC in Morgan Hill, funded by the Habitat Agency. Each specially-designed breeding enclosure contains four subterranean artificial nest burrows in natural soil. The nest chambers have removable lids ensuring easy access for nest monitoring. Aviaries are approximately 384 ft^2 in size (~24 ft wide by 16 ft long) and approximately 8 foot tall. The aviaries were installed free-standing in a grassland setting, providing exposure to natural conditions, airflow, and outdoor stimuli, including sight and sound of predatory species and exposure to invertebrate prey species. A motion triggered camera was installed in each aviary providing photos of activities near the burrow entrances. The photos were transmitted via cell data for instant remote viewing.

Figure 14. Custom-built facility at the Wildlife Education and Rehabilitation Center, completed in February 2022, for the Juvenile Overwintering Project and the Captive Breeding Program.

METHODS

In April 2023, we transferred two male and two female burrowing owls from the Juvenile Overwintering Project into the Captive Breeding Program. These individuals hatched during the 2022 breeding season and were reared in captivity at WERC as part of the Juvenile Overwintering Project. One of the males (blue C81) was one of the offspring from the captive breeding program, the second male (red 72P) was the offspring of a juvenile overwintering pair from enclosure #E2 at Shoreline, one female (blue C78) was the offspring of a juvenile overwintering pair from enclosure #E4 at the RWF, and the second female (red 76P) was from a wild pair at nest #87 at Shoreline. Marcia Nikolik at Bird Sexing Solutions analyzed feather samples to determine the sex of each owl. We selected the individuals for the two breeding pairs based on genomic analysis conducted by the genomics laboratory of Dr. Kristen Ruegg of Colorado State University, supported by observed genealogical information.

WERC's Executive Director, Ashley Quick, oversaw daily care of the owls, including provision of food and water, cleaning enclosures, and visual checks of body condition and behavior. Owls were fed dead mice, as well as live mealworms and crickets. The daily feeding amounts were based on the protocols used by the Living Coast Discovery Museum/San Diego Zoo Wildlife Alliance. Daily amounts were increased as soon as eggs hatched, and growing nestlings required additional food. We diligently followed the Burrowing Owl Care Protocol outlined in our SCP and approved by the wildlife agencies. We limited disturbance of the breeding pairs as much as possible. Starting in early May, we checked nest boxes approximately once every two weeks, or as needed, to determine the number of eggs and/or nestlings

in each nest chamber. The lids of the nest chambers were easily opened from the top for quick inspection. Once the owlets were banded, we integrated them into the cohort of owlets from the Juvenile Overwintering Project. The cohort will be soft-released to the wild in spring 2024. We will retain these two captive pairs for one more breeding season before soft-releasing them to the wild in 2025.

RESULTS

In April, we paired male blue C81 with female blue C78, and male red 72P with female red 76P (Table 17).

Table 17. The Burrowing Owl Captive Breeding Program in 2023 included four adults, cared for at the Wildlife Education and Rehabilitation Center.

Acraft Band #	USGS Band #	Sex	Age (years)	Enclosure	Number of Eggs	Number of Fledged Offspring
Blue C81	109431947	M	1	A	8	4
Blue C78	109431943	F	1			
Red 72P	109431973	M	1	B	8	5
Red 76P	115447506	F	1			

Throughout the breeding season, we regularly observed all four adults on the remote cameras and during feeding. We detected the first eggs on 7 May, four eggs in the nest chamber in Enclosure A and two eggs in Enclosure B. By 16 May, we detected a maximum number of eight eggs in each of the enclosures. We observed the first nestlings in each enclosure on 5 June. The pair in Enclosure A fledged four owlets, the pair in enclosure B fledged five owlets (Table 17, Figure 15).

In July, we captured all young for banding (Table 11 in Chapter 3) and feather collection for sexing. All owlets were in good body condition. Staff from PHS conducted blood sampling for genomic analysis following the Colorado State University sampling protocol. Blood samples were sent to CSU's lab. Feather samples were sent to Bird Sexing Solutions for analysis. The results showed that three of the owlets were male and six were female. After banding, we integrated all nine young into the cohort of young retained for the Juvenile Overwintering Project where they will be cared for until release in spring 2024. As of December 2023, all nine captively-bred juveniles were healthy, and their weights were comparable to their wild-caught peers.

Figure 15. Fledged young from the Captive Breeding Program in 2023.

DISCUSSION

In March 2021, we initiated a Burrowing Owl Captive Breeding Program to meet the objectives for breeding burrowing owl recovery under the *Santa Clara Valley Habitat Plan NCCP/HCP (Habitat Plan)* and described in *Appendix M of the Habitat Plan, Western Burrowing Owl Conservation Strategy* (ICF 2012). The first three years of the program were successful with encouraging results, as the breeding adults remained in good condition, laid eggs, and produced offspring each year.

At the spacious WERC facility, the owls are exposed to outdoor stimuli, getting flight exercise, and exposure to hearing and seeing other species. Each pair has four artificial burrows inside the breeding enclosure, thus providing a choice of nest burrows and subsequent "dispersal" to satellite burrows. The substrate for subterranean artificial burrows is native soil with clay content.

As the goal of this program is to assist in recovering the burrowing owl population in Santa Clara County, this program falls squarely in the realm of "conservation breeding". According to Browne, et al. (2011), conservation breeding programs are meant to "prevent species extinction through maintaining genetically representative populations and providing animals for supplementation, rehabilitation, or translocation projects". Our program joins conservation efforts around the world designed to preserve imperiled biodiversity.

CHAPTER 6: SUPPLEMENTAL FEEDING PROJECT

Here, we summarize the methods and results of the Burrowing Owl Supplemental Feeding Study that Talon Ecological Research Group conducted for the Habitat Agency during the peak of the 2023 breeding season. The Supplemental Feeding Study was initiated during the 2017 breeding season and includes feeding for both the Juvenile Burrowing Owl Overwintering Project and wild owls. The initial study design was intended to compare breeding success and productivity of unfed pairs compared to fed pairs, but the number of pairs decreased to a concerning level by the second year of the study, and we decided to feed all pairs to increase breeding success and productivity.

During the 2023 breeding season, we fed burrowing owls at four sites, all located within the Santa Clara Valley Habitat Plan Area: Shoreline at Mountain View, San Jose-Santa Clara Regional Wastewater Facility (RWF) in Alviso, the POST/OSA reintroduction site north of Morgan Hill, and the SCCP reintroduction site south of Morgan Hill. No breeding burrowing owls were observed at the Don Edwards National Wildlife Refuge - Warm Springs Unit (Warm Springs) in Fremont, as well as Moffett Field in Mountain View, thus no supplemental feeding occurred at these sites.

METHODS

Early during the 2023 breeding season, we started to conduct walk-through transect surveys at all sites to locate burrowing owl pairs. We assigned each burrow location (primary nest as well as satellite burrows) a unique identifying number (either a previously assigned or new number) and recorded all activity at that location (number of individuals, behavior, nesting material, decoration, prey remains etc.). We also recorded the banding status of each owl as either banded, unbanded, or unknown). If banded, we noted the band color and alphanumeric code of each Acraft band on a data sheet. We recorded GPS coordinates for each burrow and marked the location on a map. Motion detection trail cameras were installed at each nest burrow to assist with band identification of adults, detection of nestlings, brood size, approximate age of young, and predator activity.

We started supplemental feeding (Figure 16) in early April, when we soft-released three single females into hacking enclosures at Shoreline as part of the Juvenile Overwintering Project. In mid-April, we started feeding 16 overwintered pairs once we placed them into hacking enclosures. We began feeding wild owls as soon as we observed them pairing up or we detected evidence of breeding activity (decoration and nesting material at the burrow entrance) at potential nest burrows at Shoreline and the RWF. Supplemental feeding was discontinued when we confirmed that a nest burrow was no longer active or hatchling owls had fledged and dispersed.

Supplemental Feeding Study Protocols

We ordered large frozen mice at Layne's Lab and/or RodentPro and kept the mice in a freezer until feeding day. We also ordered mealworms at Rainbow Mealworms and fed those in addition to the mice. Before approaching each nest burrow, we first scanned the area and ensured that no predators of burrowing owl were nearby. Especially aerial predators are of concern because they could prey on burrowing owls if flushed from their burrow. If predators were present, we did not approach the burrow until the predators had moved out of sight. We placed all mice deep inside the burrow entrance so predators/scavengers could not see the mice near the burrow. At each feeding location, we recorded the number of owls observed, both adults and young, and noted the number of mice provided during each feeding.

Figure 16. Burrowing owl with a supplementally fed mouse.

Weekly Supplemental Feeding Schedule

We fed burrowing owls in the hacking enclosures three times a week. We fed mice to each wild pair of owls according to the following schedule (Table 18).

Table 18. Supplemental feeding schedule for burrowing owls.

Week	Number of mice/week	Number of feedings/week
1	2	1
2	4	1
3	8	2
4+	14	2–3

During the first week, each pair received two mice to get the owls used to dead mice inside the burrow entrance. When feeding increased to four mice twice per week during Week 3, we waited at least three days between feedings. From the fourth week onward, each pair received 14 mice per week over 2–3 feedings. Feeding at each nest burrow continued until the young were observed foraging for themselves, had moved a significant distance from the natal burrow (> 200 feet), or no young were observed near the burrow.

RESULTS

In 2023, we supplementally fed a total of 21 breeding pairs across four sites. In comparison, during the 2022 breeding season, we fed 11 pairs and in 2021, we fed 14 pairs (Table 19). Releases from the Juvenile Burrowing Owl Overwintering Project during 2023 contributed a total of 16 pairs and three single females.

Table 19. Number of breeding pairs, number of successful pairs, and percent nest success at six sites where burrowing owls were supplementally fed during the breeding season, 2015−2023.

Site	Year	Number of Pairs	Number of Successful Pairs	Percent Nest Success (%)
Shoreline	2015	3	1	33
	2016	2	1	50
	2017	2	0	0
	2018	2	2	100
	2019	1	1	100
	2020	8*	8*	100*
	2021	5	2	40
	2022	4	3	75
	2023	**7**	**5**	**71**
Moffett Field	2015	8	3	38
	2016	6	3	50
	2017	5	4	80
	2018	6	6	100
	2019	5	1	20
	2020	2	1	50
	2021	3	2	67
	2022	1	0	0
	2023	**0**	**0**	**0**
RWF	2015	10	9	90
	2016	13	12	92
	2017	17	9	53
	2018	9	7	78
	2019	5	4	80
	2020	3	2	67

Site	Year	Number of Pairs	Number of Successful Pairs	Percent Nest Success (%)
	2021	6	2	33
	2022	7	6	86
	2023	**5**	**5**	**100**
Warm Springs	2015	3	3	100
	2016	4	2	50
	2017	4	2	50
	2018	3	1-2	33-67**
	2019	1	0	0
	2020	0	0	0
	2021	0	0	0
	2022	0	0	0
	2023	**0**	**0**	**0**
POST/OSA	**2023**	**5**	**5**	**100**
SCCP	**2023**	**4**	**4**	**100**

DISCUSSION

We supplementally fed a total of 23 pairs during the 2023 breeding season, 21 of which were successful and produced a total of 102 offspring The Supplemental Feeding Study was crucial to the survival of breeding burrowing owls and their offspring during the 2023 breeding season, and we recommend continuation of this work during the 2024 breeding season.

CHAPTER 7: TRACKING STUDY

In 2023, Talon Ecological Research Group (Talon) initiated a tracking study to discern movement patterns and habitat use of burrowing owls post soft-release as part of the Juvenile Overwintering Project (see Chapter 4). This is the first time a tracking study on burrowing owls has been conducted in the greater San Francisco Bay area. Other methods of monitoring released owls included direct observation/band resighting and reviewing photos from motion-triggered trail cameras at nest burrows or active burrows. While data collected through direct observation and trail camera photos is valuable, these methods do not provide detailed information on movement patterns such as foraging, dispersal, and home range. Tracking in 2023 was conducted as a pilot study to refine methodology and materials, including which models of backpack GPS units would work best for released burrowing owls in Santa Clara County. Colleen Wisinski, Conservation Program Manager of the Burrowing Owl Recovery Program at the San Diego Zoo Wildlife Alliance, who has extensive experience with tagging burrowing owls with transmitters, trained and assisted us during the first deployment of units.

Previously, numerous studies have demonstrated that outfitting burrowing owls with transmitter-backpacks is effective (Haug and Oliphant 1990, King and Belthoff 2001, Sissons et al. 2001, Gervais et al. 2003, Todd et al. 2003, Davies and Restani 2006, Mrykalo et al. 2007, Holroyd et al. 2010, Griffin et al. 2018, Valdez-Gomez et al. 2018, Santos et al. 2021, Doublet et al. 2022, Hennessy et al. 2022) and the tracking technology has evolved greatly since some of the earlier studies have been conducted. In general, previous studies reported no observed significant negative impacts on tagged owls.

The goals and objectives of this study were to 1) deploy GPS tracking units on burrowing owls to determine if tagging and tracking owls was feasible and achievable, 2) detect movement patterns of breeding burrowing owls released as part of the Juvenile Overwintering Project in the Santa Clara Valley Habitat Plan Area, 3) use results to recommend additional conservation management actions necessary to protect the species, 4) define foraging areas, home ranges, and distances traveled from natal burrows, 5) determine dispersal patterns of owls that move from release sites to potentially unoccupied sites, 6) delineate potential foraging areas that could be protected and managed to benefit burrowing owls, 7) increase understanding of the impacts from urbanization pressures and habitat loss/fragmentation, and 8) identify main threats to the viability of the population.

Conducting this study on movement patterns is critical for understanding ecological needs of burrowing owls in Santa Clara County and to determine which additional conservation actions may best support recovery of this species. Combining tracking technology with already existing management programs offers a unique opportunity for answering key questions on burrowing owl movement and thus supporting the success of the Juvenile Overwintering Project. This study provides essential information about habitat use to better assess, and hopefully alleviate, some of the threats to this small population.

METHODS

Burrowing owls were fitted with GPS tracking units from May−November 2023 at four sites in Santa Clara County. Tracking units weighed ≤ 3% (~5 grams) of the body mass of burrowing owls. We purchased tracking units from two manufacturers, Ecotone Telemetry and Cellular Tracking Technologies. All tagged owls were supplementally fed (see Chapter 6) during the tracking period.

Tracking Units

We used Ecotone solar PICA GPS-UHF 5g loggers (Figure 17). These units store data on the loggers which are downloaded via a base station that uses radio data transmission. With the base station being connected to a computer, the unit's operating parameters (i.e., time between GPS fixes, number of positions taken at once, accuracy of fixes, time it transmits to base station, GPS work time limit or if no signal than turns off transmitter to save battery, and hours of operation) could be changed by using the base station software. Units were set to take a fix every hour from sunset to sunrise. However, if the battery life was running low, they were set to obtain fewer daily points. Base stations with a battery grip were placed at active burrow locations, so data were downloaded daily, and unit battery life was conserved. The advantage of the Ecotone tag was the solar-charge, thus longer-lasting battery, allowing for numerous fixes. Other benefits were that if the unit was in proximity of a base station, it turns off to save battery life, has high GPS accuracy, and the specific operational time can be programed. The disadvantage was that data transmission was via radio and required data to be downloaded to a base station within a range of 10 meters for the short-range station, or 400 meters up to 5 kilometers for the long-range base station. Thus, if a tagged owl was beyond 5,000 meters from the station, then data did not download. Also, if the unit's battery drained the owl cannot be located and data cannot be downloaded.

The other tracking units that we used were the solar (Figure 17 and 18) and non-solar Cellular Tracking Technology (CTT) 5g Flicker GPS. These Flicker transmitters use the global cell network for data transmission. The added GPS receiver in the unit stored up to 420 GPS fixes and when it was in cellular range it transmitted stored fixes through the cell towers. Therefore, these units collect both cellular (low accuracy) and GPS data (high accuracy). Data were automatically uploaded to the CTT application and could be viewed and uploaded from there. Units were set to obtain 1−3 fixes per night, every 3−4 hours; these transmitters' batteries drained quicker than the Ecotones'. The non-solar units obtained more fixes on a single battery charge, but the advantage of the solar-powered units was that they had the potential for solar recharge. However, for the charge to occur, the owls needed to be exposed to and the unit positioned toward the sun, while no feathers covered the tag. The advantages of these CTT Flickers were their high accuracy of GPS fixes, data transmission through cellular towers, data access through a user-friendly mobile application, rapid unit-charge if directly exposed to the sun for multiple hours, and no software needed. The disadvantage was the battery drained rapidly, and the number of fixes was low.

Tagging

We fitted burrowing owls with tracking units at all four soft-release sites, which included Shoreline at Mountain View, RWF in Alviso, POST/OSA Reintroduction Site, and SCCP Reintroduction Site. Early during the breeding season, when owls were still in their hacking enclosures, we caught them by hand and tagged them at two of the four release sites. Ideally, we would have liked to tag owls at all four sites at that time, but due to a manufacturing delay, we did not have enough tags. Post-release, we trapped owls using the following methods: 1) lightweight bow nets lured with a live mouse in a protective cage with a callback MP3 player and speaker, 2) a walk-in trap placed at the burrow entrance, and/or 3) if they were using an artificial burrow that had access to the nest chamber, we blocked the burrow entrance and extracted the owl from the nest chamber by hand.

We attached the units to the owls with a backpack-style harness (Figure 17). We used a 0.1 inch (2.5 mm) tubular Spectra strap; two ribbons went over the head, crossed at the breast at the top of the keel (strap glued together at the keel), and then went under each wing to connect to the loops at the bottom

and top of the transmitter (knots were secured with glue). This technique was refined by Colleen Wisinski, Conservation Program Manager of the Burrowing Owl Recovery Program at the San Diego Zoo Wildlife Alliance. She trained us in applying this technique and assisted us with the first deployment of units.

Attaching each transmitter took no longer than 45 minutes, but on average it took fewer than 30 minutes. When the tracking unit's battery life was getting low or was completely drained, we targeted those owls for trapping to remove the unit. All owls that we tagged were banded with a standard federal USGS band and an Acraft color band with a unique alphanumeric code (see Chapter 3 for banding information). We analyzed data and produced maps with QGIS 3.32.2-Lima (www.qgis.org).

Figure 17. Burrowing owls with fitted backpack harness. Left: Cellular Tracking Technology solar tracking unit. Right: Ecotone Telemetry solar tracking unit.

Figure 18. Female burrowing owl M30 at Shoreline at Mountain View outfitted with Cellular Tracking Technology unit.

RESULTS

Between 29 May and 12 December 2023, we tagged six burrowing owls (5 males and 1 female) during the breeding and non-breeding seasons at all four soft-release sites. One male was tagged twice (drained tag removed and a new one attached). Three owls (2 males and 1 female) were tagged at Shoreline at Mountain View, and one owl each at RWF in Alviso, POST/OSA Reintroduction Site, and SCCP Reintroduction Site.

A total of 1,106 GPS fixes were obtained from five burrowing owls (4 males and 1 female) with a mean of 224.8 fixes per owl (range = 32–745 fixes per owl; Table 20). Owls on average were tracked for 34.6 ± 31.8 SD days with a range of 6–89 days per owl (*n* = 5; Table 20. The average home range size of individual burrowing owls, calculated based on the Minimum Convex Polygon (MCP) method, was 7.64 ± 5.64 SD ha (*n* = 5; Table 20). The longest distance moved by an individual owl was 578 meters, which occurred at Shoreline. All five tracked owls remained at their respective burrow they were tagged at during the tracking period. We were unable to collect data from the sixth tagged owl, outfitted with an Ecotone PICA unit at the SCCP Release Site. Either this owl departed the release site beyond reach for data transmission, or the owl remains on site, but the transmitter battery drained and did not solar recharge. Recapture rate of tagged owls was 83% (5 out of 6 owls that were attempted to be trapped were successfully trapped).

Regarding habitat selection, tracked owls stayed within 600 meters of their primary burrows and within grassland with <12 inches of vegetation height with various land uses (Figure 19). During foraging forays owls visited both areas with tall vegetation (~1 meters) and short vegetation (<3 inches), which included native restoration areas, a golf course, and paved (Bay Trail) and unpaved trails (Figure 20). However,

the primary foraging areas were within undisturbed grassland habitat with both native and non-native vegetation.

Figure 19. Example of habitat used by burrowing owls at release sites. Owl blue M13 with his mate at their natal release burrow at Shoreline at Mountain View on 12 July 2023.

At Shoreline at Mountain View, which was the only site to have multiple owls tracked, three burrowing owls had distinct delineated home ranges with very little overlap (Figure 20). Distance between primary use burrows that each owl used during the time of tracking were 152 meters (M13 from C79), 292 meters (C79 from M30), and 319 meters (M13 from M30).

Table 20. Summary of track periods, number of fixes, tag type, and home ranges of burrowing owls during 2023.

Band ID (Sex)	Track Period (No. of Days)	No. of Fixes	Tag Type	MCP Home Range (ha)
Blue M13 (M)	29 May–30 August (89)	745	Ecotone	12.6
Blue M31 (M)	22–27 July (6)	32	Ecotone	2.8
Blue M52 (M)	4 August–12 December (30)	58	CTT*	4.4
Blue M30 (F)	29 August–17 December (20)	56	CTT-solar	5.7
Blue C79 (M)	6 September–3 October (28)	233	Ecotone	35.7
Blue M23 (M)	no data	0	Ecotone	--
Mean	***34.6***	***224.8***		***7.6***
SD	***31.8***	***301.7***		***5.6***

*Owl was tagged twice with both solar and non-solar CTT units

Male Blue M13

Male burrowing owl blue M13 hatched at Shoreline at Mountain View in 2020 and retained for the Juvenile Overwintering Project. In 2021 and 2022, M13 was part of the Captive Breeding Program, and was subsequently released at Shoreline in 2023. We tagged him with a solar Ecotone UHF logger. A total of 745 GPS fixes were obtained during 89 tracking days from 29 May– 30 August 2023 (Table 20). Home range size was 12.6 ha (Figure 20). M13 used the release burrow as his primary burrow during the entire data collection period. He foraged frequently along the Bay Trail on the edge of salt pond A2W, where vegetation was >12 inches tall. Out of 745 fixes, one fix was on the adjacent golf course. His unit was removed on 30 August 2023 and there were no signs of physical impacts from the transmitter.

Male Blue M31

Male burrowing owl blue M31 hatched at San Jose International Airport in 2022. He was soft-released at RWF in 2023. We tagged him with a solar Ecotone UHF logger. A total of 32 GPS fixes were obtained during six tracking days from 22– 27 July 2023 (Table 20). Home range size was 1.1 ha for 6 days post release (Figure 21). M31 used the natal release burrow, as well as an adjacent mound with artificial and natural burrows. He foraged within 100 meters of the natal burrow. As of December, he was still outfitted with the unit as trapping attempts were unsuccessful. When the 2024 breeding season commences, we will attempt to trap M31 to remove the transmitter.

Male Blue M52

Male burrowing owl Blue M52 hatched at RWF in 2022. M52 was released at the POST/OSA Reintroduction Site in 2023. He was tagged on two occasions: 21 July 2023 with a CTT non-solar Flicker and 10 November 2023 with a CTT solar Flicker. A total of 58 GPS fixes were obtained during 30 tracking days from 4 August– 12 December 2023 (Table 20). Home range size was 4.4 ha (Figure 22). M52 used the natal release burrow (Enclosure 2) for a few days post release before moving to an adjacent artificial burrow where another pair was released at (Enclosure 3), which was ~100 meters away. His primary foraging location was in the middle of the field with taller vegetation (>12 inches and as tall as 36 inches. He also frequented the fence line that divided the release field with a field that, at the time of tracking, was a disced fallow field with no vegetation. He never went past the fence line into the disced field (Figure 23). We trapped M31 on 10 November 2023 and removed his unit. The battery on this unit was drained and we replaced it with a new solar powered CTT unit. On 14 December 2023, we trapped M52 again and removed the unit. He had no signs of physical impacts from the transmitters.

Female Blue M30

Female burrowing owl Blue M30 hatched at San Jose International Airport in 2021. She was released at Shoreline at Mountain View site in 2022. She was the only female we tracked, and we tagged her with a CTT solar Flicker unit on 29 August 2023 (Figure 18). A total of 56 GPS fixes were obtained during 20 tracking days from 29 August– 17 September 2023 (Table 20). Home range size was 5.7 ha (Figure 20). M30 used two primary artificial burrows during the tracking period. She foraged primarily on the adjacent golf course and crossed Shoreline Boulevard to do so (Figure 20). She also foraged in a native plant restoration site adjacent to her burrows. We trapped M30 on 17 October 2023 and removed her unit; there were no signs of physical impacts from the transmitter.

Male Blue C79

Male burrowing owl blue C79 hatched at RWF in 2022. He was soft-released at Shoreline at Mountain View in 2023. We tagged him with a solar Ecotone UHF logger on 6 September 2023. A total of 233 GPS fixes were obtained during 28 tracking days from 6 September–3 October 2023 (Table 20). Home range size was 14.4 ha (Figure 20). C79 used a single artificial burrow ~90 meters from the nest burrow during

the tracking period. He foraged primarily where vegetation was <12 inches tall. Out of 233 fixes, one fix was on the adjacent golf course, and he frequently foraged in a native plant restoration site. We removed his unit on 19 October 2023 and there were no signs of physical impacts from the transmitter.

Male Blue M23

Male burrowing owl blue M23 hatched at RWF in 2022. He was soft-released at the SCCP Reintroduction Site in 2023. We tagged him with a solar Ecotone UHF logger on 10 November 2023. We did not obtain any data from this unit. Either the transmitter battery drained prior to data uploading to the base station or the owl departed the release site beyond reach for data transmission. Potentially, this male will return to the release site during the 2024 breeding season and hopefully we can trap him then and remove the unit.

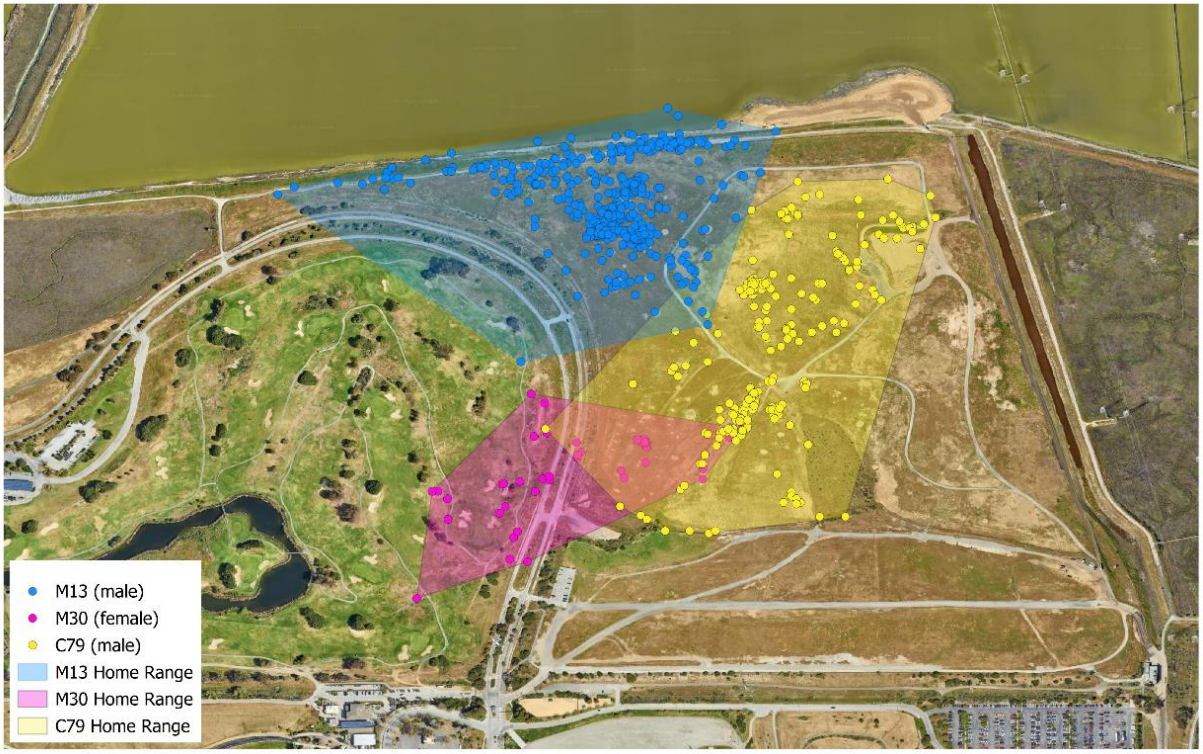

Figure 20. Home range (MCP) and GPS fixes of three tracked burrowing owls (M13, M30, and C79) at Shoreline at Mountain View in 2023.

Figure 21. Home range (MCP) and GPS fixes of tracked burrowing owl blue M31 at RWF in 2023.

Figure 22. Home range (MCP) and GPS fixes of tracked burrowing owl blue M52 at the POST/OSA Reintroduction Site in 2023.

Figure 23. Comparison of land uses of adjacent fields. Left of the fence line was not disced where owls were present and right of the fence line was a disced field, void of vegetation and ground squirrel burrows, where owls were absent and did not forage.

DISCUSSION

During this first year of the tracking study in 2023, we successfully tagged and tracked burrowing owls, with a high recapture/unit retrieval rate. We were able to test different models of current tracking technology. The results underscore the success of the Juvenile Overwintering Project and our soft-release methodology; 83% (5 of 6) of released owls that were tracked, remained at or near the nest burrows that they were released in. These results confirm high burrow fidelity and survivorship.

Tracked burrowing owls from this study did not move farther than 500 meters from their release burrows which is similar to the finding in other studies. Home ranges, however, averaged 7.6 ha, which was much smaller in size than in other study areas where average home ranges were between 33.5 and 241 ha. In Saskatchewan, Canada, Haug and Oliphant (1990) observed that 95% of all movements of six tagged owls were within 600 meters of the nest burrows, with an average home range size of 241 ha, which was considerably greater than our findings. Sissons et al. (2001), also in Saskatchewan, found an average home range size of 33.5 ha of four tracked owls. However, they recorded one owl with a home range of 7.9 ha. In Mexico, Valdez-Gómez et al. (2018) observed average distance from burrows to foraging grounds to be 514–751 meters of 17 tracked owls with one owl moving as far as 1,981 meters. They also found that the average home range size was 70 ha. In California's Central Valley, which is most comparable to our study, Gervais et al. (2003) observed 80% of foraging activities occurred within 600 meters of the nest burrow with a maximum distance traveled 1,337 meters of 31 tracked burrowing owls. Similarly, in the Imperial Valley of California, Rosenberg and Haley (2004) observed owls foraging primarily (>80%) 600 meters from their nests. The smaller home range size at our sites could be a result of ongoing supplemental feeding (described in Chapter 6) with dead house mice (*Mus musculus*) during the study period, or high-quality foraging habitat at the release sites, or a combination of both. We

speculate that it is a combination, but primarily driven by prey supplementation, as home range size is related to food abundance (Gervais et al. 2008).

Furthermore, two of the release sites, Shoreline and RWF, are surrounded by developed urban areas, so movement to nearby suitable habitat beyond the release sites is limited or nonexistent. However, no exploratory movements were observed of tracked owls. Our study and the cited tracking studies exemplify the importance of having high-quality foraging habitat near nest burrows, as owls tend to not move far from their nest burrows and foraging locations are best predicted by distance from nests (Gervais et al. 2003, Rosenberg and Haley 2004, Gervais et al. 2008). At Shoreline, where multiple burrowing owls (*n*= 3) were tracked, we observed little overlap of home ranges and each owl foraged in different areas (Figure 20). These findings highlight the importance of native plant restoration and habitat enhancement for the burrowing owls' prey for long-term survival, viability, and site fidelity. Also critical is that high quality foraging habitat is distributed throughout burrowing owl management sites.

Burrowing owls were observed foraging in native plant restoration areas. An untagged owl at RWF was observed foraging at night in a native vegetation restoration area planted by Grassroots Ecology. This supports the importance of suitable land use adjacent to release sites for foraging. At the POST/OSA Reintroduction Site, the tagged owl blue M52 spent much time along the fence line but did not cross over into the adjacent disced field which was void of vegetation (Figures 22 and 23). The land use at the time of tracking was not suitable for burrowing owls due to a lack of vegetation, thereby presumably lack of prey, and the lack of ground squirrels and burrows. This exemplifies the importance of land management for burrowing owls on lands adjacent to release sites for dispersal and to increase colony size to maintain viable breeding colonies.

The two different types of tracking units had their own set of benefits and drawbacks as described in the methods section. The Ecotone UHF-data loggers were ideal to deploy post removal of hacking enclosures and when the owls established themselves at a burrow. This allowed the base station to be placed at the primary burrow so data could be uploaded daily to the station. The unit was turned off when the tagged owl was in proximity to that base station, so battery life was saved and more fixes could be obtained. This also increased the chance to recover the transmitters for use on other owls. These tags are not ideal for owls that disperse from the release site due to the shorter range for data transmission. In comparison, the CTT units are ideal for owls that move away from the release site as the data are uploaded via cellular towers. Also, this is one of the lightest GPS cellular units available. However, the battery life is much shorter than the Ecotones reducing the number of fixes.

We recommend continuation of this important study to obtain additional data, a greater sample size, and a better understanding of movement patterns of the soft-released owls as part of the Juvenile Overwintering Project.

CHAPTER 8: DISCUSSION

With the soft-release of 35 burrowing owls this year, the total number of breeding burrowing owls increased from 33 adults in 2022 to a total of 51 adults in 2023. Without the implementation of Tier 3 Conservation Actions, the number of breeding adults and their offspring would likely have been much lower this year. While the number of adults has increased, breeding burrowing owls in the South Bay were limited to only two extant breeding sites. This regional contraction in range exposes the breeding population to stochasticity and therefore a high risk of local extirpation, especially because these sites are facing increasing pressure from encroaching development. While burrow availability and foraging habitat have been reduced, the rate of disturbance and predation pressure has increased. A recent study of predator frequency in Santa Clara County showed that urban settings had over double the rate of predator sightings compared to open space and agricultural areas (Tomes 2019). Habitat protection and management at current breeding sites is imperative.

New developments in recent years have further diminished adjacent burrowing owl foraging habitat around extant breeding sites. Tall buildings and light posts provide perches for raptors that prey on burrowing owls, such as red-tailed hawks (*Buteo jamaicensis*). Lights from parking lots, streets, and buildings are on all night every night causing light pollution. Ornamental trees planted along buildings offer additional perches for raptors. These developments may also attract mammalian predators including feral cats, raccoons, opossums, and rats. Furthermore, the destruction of the adjacent habitat pushes more predatory wildlife species, such as coyotes and large raptors near breeding burrowing owls. More species on the remaining islands of grassland habitat compete for limited resources, including prey items such as small rodents, and such competition is especially pronounced during drought periods. Use of anticoagulant rodenticides in the neighboring urbanized areas is of concern to burrowing owl survival. We saw numerous bait boxes at buildings near the extant breeding sites containing 0.005% Bromadiolone, a potent second-generation anticoagulant rodenticide, 4-hydroxycoumarin derivative and vitamin K antagonist, often called a "super-warfarin" for its added potency and tendency to accumulate in the liver of the poisoned organism. Such rodenticides can cause secondary poisoning.

This year we started implementing a strategy to hopefully alleviate the issues these urban owls face and started establishing breeding colonies at currently unoccupied sites in more rural areas of the County. Such sites provide more area for dispersal and foraging. Since burrowing owls are one of the few raptor species that does well in agricultural settings (Rosenberg and Haley, 2004; Wilkerson and Siegel, 2010), the expansive rural matrix, which includes protected grasslands and rangelands, in south Santa Clara County provides hope for preserving burrowing owls as a breeding species in this County. As authorized by our permits, the reintroduction to these new breeding sites will continue to be the focus of Tier 3 Conservation Actions in 2024.

Additional pressures arise from the effects of climate change and extreme weather conditions. During the 2022/2023 winter, Santa Clara County experienced record precipitation levels and widespread flooding. Groundwater levels were high into April, causing flooding of ground squirrel burrows and artificial burrows and limiting foraging habitat. Conversely, the previous three years brought extreme drought conditions. During drought years, prey availability for burrowing owls was limited and competition for these reduced resources increased. During 2021 and 2022, some grass species were dormant or had limited growth and we noticed an increased distribution of some invasive weedy species (mustard spp., stinkwort, and pepperweed) at most sites. In addition, we observed few if any

grasshoppers during transect surveys. In prior years, grasshoppers were abundant during the summer. Grasshoppers and other invertebrates are essential prey items for burrowing owls (Higgins 2007, Trulio and Higgins 2012) during the breeding season while adults feed their young. Scarcity of invertebrates could have contributed to the reduced breeding success and productivity of the owls in 2021 and 2022. Severe and changing weather events, including precipitation and temperature patterns, must be anticipated in the future, but will be challenging to predict or alleviate. Installation of artificial burrows in raised soil mounds and berms can prevent flooding of burrows as long as they are installed above the water table and flood levels.

Inbreeding has been observed in the Plan Area over the last decade and likely contributes to the overall population decline through inbreeding depression. Inbreeding depression is the reduction in the average fitness of offspring from parents that are closely related to each other, compared to the fitness of offspring from unrelated parents. Genomic analysis (Barr et al. 2023, Trulio et al. 2023) of all burrowing owls in the Juvenile Overwintering Project enables us to select least related owls for breeding pairs thus increasing genetic diversity as much as possible. We have asked to amend our current CDFW permit allowing translocation of burrowing owls from outside of Santa Clara County into the Juvenile Overwintering Project to further increase genetic diversity. Since we started this project, we have received inquiries to accept rehabilitated juveniles from Santa Clara County as well as outside the County into the Overwintering Project. We have also received inquiries to accept burrowing owls that were being evicted from development sites, where no suitable, protected habitat for relocation was available nearby. Following are significant benefits to accepting both rehabilitated and/or evicted owls from inside and outside the County into our program:

1. We specifically manage suitable burrowing owl habitat at several protected sites within the Santa Clara Valley Plan Area where these owls could be safely released, thereby increasing their chance of survival.
2. Protecting and caring for juveniles (and adults) during the winter as part of our project and soft-releasing them as pairs in protected/suitable habitat the next spring, drastically increases the fitness (survival, mate-finding, reproduction) of each owl.
3. Bringing burrowing owls into the Santa Clara County breeding population not only boosts the number of pairs, but can add genetic diversity to our resident population, which shows indications of inbreeding.
4. During soft-release, burrowing owls are supplementally fed while they adjust to their new environment. The owls are more likely to stay on site once the hacking enclosure is removed which enables continued feeding and monitoring. A hard-release does not offer these benefits and owls may disperse from the selected release site as soon as they are released.

Because of these benefits, we have received permission from the USFWS (Permit Number: MBPER0019493) to conduct burrowing owl translocations into the Santa Clara Valley Plan Area from neighboring counties in California outside Santa Clara County; CDFW has not granted permission.

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- Peninsula Humane Society Wildlife Care Center
- Peninsula Open Space Trust
- Phillips Builders Guild
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- San José-Santa Clara Regional Wastewater Facility
- Santa Clara County Parks and Recreation Department
- Santa Clara Valley Open Space Authority
- US Fish and Wildlife Service
- US Fish and Wildlife Service/Don Edwards San Francisco Bay National Wildlife Refuge
- Wildlife Rehabilitation and Education Center (WERC)

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