

San Diego Association of Governments
North County Cactus Nursery and Coastal Cactus Wren Habitat Restoration
Final Report

Project Period: May 30, 2015 – August 30, 2018

SANDAG Contract Number: 5004728

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Executive Summary

The primary goal of this three-year project was to support the restoration and recovery of coastal cactus wren (CACW) populations in the San Pasqual Valley/Lake Hodges region including locations identified under coordination with the South San Diego County Coastal Cactus Wren Conservation Implementation Plan. In pursuit of this goal, the San Diego Zoo Institute for Conservation Research aspired to accomplish two tasks: 1) establish and maintain a cactus nursery to supply cacti for habitat restoration to land managers in North County and 2) control invasive species and restore habitat in potential cactus wren nesting habitat.

In fulfillment of Task 1, we established a cactus nursery that supplied 8,056 locally sourced cacti (7056 rooted and 1000 unrooted) to restoration projects in north San Diego county. We encountered no major hurdles in either the propagation, planting, or establishment of nursery cacti; there was little to no mortality of cactus pads in the nursery and no restoration site had greater than 80% first year mortality. We documented our propagation experiences in a protocol included within this report. While several North County sites received cactus from the nursery, the Lake Hodges received the majority of the nursery propagated cacti (over 5,000 individuals). Lake Hodges contains hundreds of acres of conserved coastal sage scrub habitat that will provide excellent potential nesting habitat in the future.

In fulfillment of Task 2, we conducted invasive plant removal in the vicinity of our newly planted restoration sites at Lake Hodges and also within cactus restoration habitat at the Safari Park that had been established under a previous SANDAG grant. Higher than average rainfall prior to the 2017 growing season precipitated large infestations of invasive weeds at both sites, especially *Hirschfeldia incana* at Lake Hodges and *Oncosiphon piluliferum* at the Safari Park. At Lake Hodges, we followed manual removal of *H. incana* with baseline vegetation monitoring to evaluate the current vegetation community and provide a baseline for future evaluation of habitat restoration outcomes. At the Safari Park, we conducted hand removal and herbicide application to *O. piluliferum* to 5.5 acres of cactus wren habitat. Management of *Oncosiphon* at the Safari Park will continue through 2023, as part of a recently funded SANDAG grant.

This project created wide ranging positive impacts for the conservation of CACW not only by providing large-scale habitat restoration across the region, but also by documenting lessons learned during the development of the cactus nursery, which can serve as a guide for the future establishment of other large scale cactus nurseries. Because the cacti propagated for this project are now largely concentrated at Lake Hodges, we recommend that future restoration plantings augment habitat on the region between Lake Hodges and the Safari Park to foster better connectivity between these two large potential nesting sites. Finally, management to the emerging the *Oncosiphon* invasion in the San Pasqual Valley will be needed to safeguard existing wren habitat from competition and fire.

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Project Background

The coastal cactus wren (*Campylorhynchus brunneicapillus sandiegensis*, CACW) is a bird species native to the coastal sage scrub ecosystems of southern Orange County and northern San Diego Counties in California. This species has strict habitat requirements, only nesting in thick patches of cholla (*Opuntia prolifera*) or prickly-pear cacti (*O. littoralis*, *O. oricola*) (Rea and Waver 1990). Cactus wren populations face many threats in southern California. The primary threats to coastal cactus wren core habitat include frequent, intense wildfires and conversion to exotic species of grasses and forbs. Threats are exacerbated by the fragmented landscape, which increasingly isolates CACW populations, making it more difficult to disperse, colonize and/or move in response to disturbances. The 2007 Witch Creek fire burned extensive areas within the subwatershed. While some areas recovered well (San Diego Zoo Safari Park), others did not (particularly around Lake Hodges). Other threats include invasive plant species that reduce open foraging habitat, decreased productivity during drought, and predation by domestic cats, roadrunners, snakes, Cooper's hawks, etc.

As a result of these threats, the San Diego Management and Monitoring Program (SDMMP) lists CACW at priority level “SO”: at high risk of loss without immediate management action above and beyond that of daily maintenance activities. The MSP Management Goals for MU's 5 & 6 are: 1) to protect and enhance suitable cactus scrub and coastal sage scrub habitat within the San Pasqual/Lake Hodges genetic cluster, 2) to expand the occurrence to a sustainable effective size so that inbreeding is avoided and 3) to enhance habitat connectivity within the genetic cluster. Each goal is designed to improve coastal cactus wren persistence in the strategic plan area over the long-term (>100 years).

Our restoration project made critical steps in advancing the management goals of the MSP by addressing threats associated with loss of habitat and invasive annual plant species. Moreover, this restoration increased ecosystem resistance to future wildfires by replacing the flammable exotic annuals with succulent cacti. The augmented restoration site has been shown to be a priority site for the San Pasqual/Lake Hodges genetic cluster of wrens and is within a broader coastal sage scrub landscape being restored with a variety of drought resistant species, which should not only reduce fire risk but also provide a more robust foraging environment in drought years. In addition, the Cactus Nursery addressed these same issues by making cactus propagules readily available to land managers, thereby increasing their capacity to implement restoration. The following table illustrates the MSP objectives and actions for the San Pasqual Valley/Lake Hodges Area (MU's 5 & 6) that we proposed for this project.

Table 1. Cactus wren MSP objectives and related proposed actions for this restoration project.

MSP Objective	Actions
<p>Develop and maintain two cactus nurseries at approved facilities in MU3/4 and in MU6 and grow cactus pads, segments, and entire plants sufficient for restoration projects in the South County and the San Pasqual Valley as identified in cactus restoration implementation plans. (MSP Vol. 2, P. 2-165).</p>	<ul style="list-style-type: none"> • Prepare a plan with specifications of BMPs for harvesting and growing cactus at a nursery in preparation for transplant into natural lands. • Develop and maintain a nursery for growing cactus harvested/salvaged from MUs 5, 6, and 8 for use in restoration projects in North County and other SDMMP approved locations. The nursery will be set up in accordance with the SDMMP "Cactus Nursery Design Criteria" to grow and supply cactus pads, segments and entire plants from locally harvested native cactus and the composition of species (<i>Opuntia</i> spp. and <i>Cylindropuntia</i>) will reflect those found in the geographic area. • Coordinate with land managers in North County to ensure the nursery inventory we will meet their project needs
<p>Implement pre-fire management actions identified in the Strategic Fire Plan in order to reduce the effects of an altered fire regime on coastal cactus wrens and cactus scrub habitats on Conserved Lands in MUs 3, 4, 5, and 6. (MSP Vol. 2, P.2-166)</p>	<ul style="list-style-type: none"> • Perform pre-fire actions applicable to coastal cactus wrens and cactus scrub, including specific actions to protect cactus scrub from high intensity fires and recurrent fires. Specifically, we will implement restoration activities that include removal of highly flammable non-native annual plants and reestablishment of fire-resistant cactus scrub habitat. We will also dethatch any areas where there has been a substantial buildup of annual exotics. • Our restoration site will be located within a broader restoration project restoring coastal sage scrub (enhancement plantings of various drought-resistant species and weed control) to increase fire resistance and resilience in the areas in the face of climate change – giving the cactus scrub an even lower likelihood of being affected by fire. • Support cactus scrub restoration in the San Pasqual/Lake Hodges genetic cluster through active restoration and expansion of critical cactus wren habitat at Lake Hodges and by developing a North County Cactus Nursery that will supply propagules.
<p>Continue the ongoing cactus scrub restoration projects for the San Pasqual/Lake Hodges genetic cluster in MU6. (MSP Vol. 2, P. 2-166)</p>	<p>Support cactus scrub restoration in the San Pasqual/Lake Hodges genetic cluster through active restoration and expansion of critical cactus wren habitat at Lake Hodges and by developing a North County Cactus Nursery that will supply large quantities of local native cactus propagules for restoration throughout the strategic plan area.</p>

Project Goals

Table 2. Project goals and deliverables outlined in grant proposal and a corresponding description of how we achieved each deliverable.

Goal/Deliverable	Result
<i>Task #1: Cactus Nursery Establishment and Maintenance</i>	
Establishment of North County Cactus Nursery	We established a cactus nursery at Lake Hodges, which was maintained by the ICR from Sep 2015 through June 2018. This nursery is currently controlled by the City of San Diego.
Submit quarterly and Final reports	We submitted 12 reports including 11 quarterly reports and this final synthetic report.
All data associated with cactus nursery including start-up and maintenance costs, cactus sourcing, and distribution data submitted to the SC-MTX database	Relevant datasets are posted on the SDMMP project page for the North County Cactus Nursery at the direction of Emily Perkins at SDMMP.
Best practice recommendations for large-scale cactus propagation	We submitted a propagation protocol for <i>Opuntia littoralis</i> (coast prickly pear) to SDMMP and the Native Propagation Network Propagation Protocol Database.
3,000 propagated cacti and 500 unrooted cuttings available per year for SDMMP approved restoration projects for two consecutive years	We propagated 4,008 rooted cactus in 2016 and 3,048 in 2017. We distributed 500 unrooted cuttings in both 2016 and 2017. In total, we distributed 8,056 cacti over the term of the grant.
<i>#2: Invasive Species Control and Habitat Restoration</i>	
Habitat management and data submitted to the SC-MTX database	Relevant datasets are posted on the SDMMP project page for the North County Cactus Nursery at the direction of Emily Perkins at SDMMP.
Invasive species control within restoration area	We hand removed invasive weeds in the area of new planting sites and conducted invasive monitoring at Bernardo Bay at Lake Hodges. We contracted professionals to apply herbicide to areas invaded by <i>Oncosiphon piluliferum</i> (stinknet) at the Safari Park Biodiversity Reserve in regions with restoration cactus.
1,000 large 2-3 ft tall cacti planted at Lake Hodges	We distributed 5,485 large rooted cacti for planting at Lake Hodges during the course of this grant.

Work Performed by Task

Task 1- Cactus Nursery Establishment and Maintenance

Budget: \$162,595

Spent: \$179,364

Match for Task: \$39,786

Timeline of Cactus Nursery Activities

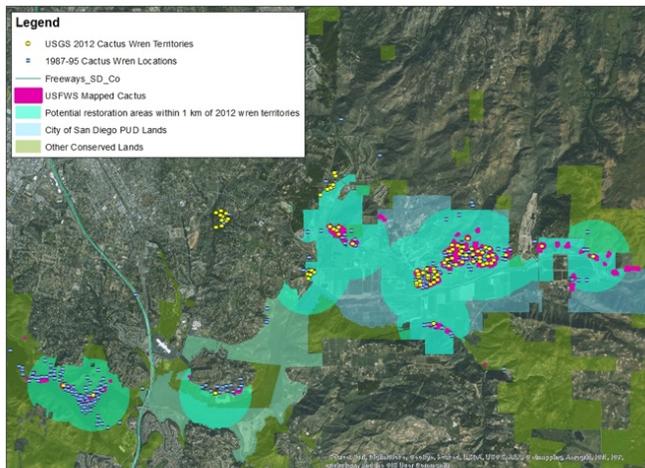
October 2015 – Cactus Nursery Site Established at Lake Hodges



Nursery establishment commenced on October 15, 2015. The nursery was established at Big Trees Nursery near the intersection of Pomerado Rd & Highland Valley Rd. We graded the area for the nursery with sufficient room for a 25'x50' shade house, a work table, and a weed-cloth covered space for potted cactus. The total area prepared for the nursery was 120'x180'.

Photo 1: Cactus nursery establishment at Lake Hodges (10/15/2015)

January 2016 – Restoration Sites Planned



Potential Restoration Areas for Coastal Cactus Wrens on Conserved Lands in San Pasqual Valley and Lake Hodges

ICR staff met with SDMMP staff and other land managers in north San Diego County. We delineated potential restoration areas within the San Pasqual Valley, and one additional site at Whelan Preserve, near Camp Pendleton. We selected sites by overlaying conserved lands on cactus wren territories buffered to 1 km. Restoration focused on expanding existing wren territories rather than creation of new habitat and all sites to be within the average dispersal distance of wrens (1km). Interest in cactus restoration after the initial meeting led to planting cactus at two sites outside the San Pasqual valley including Lakeside and San Marcos.

March 2016 – Cactus Nursery Construction Completed



Photo 2: Completed North County Cactus Nursery Shade House (03/15/2016)

We installed the shade house, work benches, and a shade cloth base for the cactus.

June 2016 – Cactus Pad Collection and Planting Completed for Year 1



Photo 3a: Volunteers from San Diego Zoo Institute for Conservation Research pot cactus pads for propagation (06/10/2016).
Photo 3b: Andrea Gatch from San Diego Zoo Institute for Conservation Research waters newly planted cacti (06/15/2016).

We collected 4,008 total cactus propagules from the Safari Park Biodiversity Reserve, Lake Hodges, and Whelan Lake (Oceanside) from March 21, 2018 to June 30, 2018.

November 2016 – First Restoration Plantings of Cactus Propagated in the Nursery



Photo 4a: Volunteers plant cacti from the North County Cactus nursery at South Shore Point (11/4/2016)
Photo 4b: North Glider Hill at Lake Hodges after invasive removal and restoration planting (11/4/2016).

We planted 1000 total rooted cactus between two sites at Lake Hodges (North Glider Hill and South Shore Point). We distributed 500 potted cacti to the Center for Natural Lands Management to plant at Whelan Lake, 500 potted cacti to San Dieguito River Park to plant in Bandy Canyon, 500 loose cacti to San Dieguito River Park to plant on Mule Hill, and 1960 potted cacti to the City of San Diego to plant at Lake Hodges.

June 2017 – Cactus Propagation Completed



We completed our propagation goal for the grant by collecting 2900 cactus pads from the Safari Park Biodiversity Reserve January-March 2017 and 100 cactus pads from the Center for Natural Land Management's Woodridge Site near Lake Jennings in Santee.

Photo 5: Volunteers pot cactus pads for propagation in the North County Cactus Nursery (06/07/2017)

June 2017 – April 2018 Remaining Cacti Maintained and Distributed



We continued to water, control weeds, and manage pests in the cactus nursery. We distributed cactus to land managers such as San Dieguito River Park, CNLM, and the City of San Diego. The ICR coordinated cactus plantings at Lake Hodges.

Photo 6: Inventory of the North County Cactus Nursery (11/11/2017)

May 2018 – Last of Propagated Cactus Planted & Nursery Returned to City of San Diego



We planted the final cacti propagated at the North County Cactus Nursery with the help of High Tech High Middle School at Bernardo Bay in Lake Hodges. We turned off utilities and removed the Porta Potty from the cactus nursery site. We officially returned land to City of San Diego, who may continue cactus propagation in the future.

Photo 7: Students from High Tech High Middle School plant cactus from the North County Cactus Nursery at Bernardo Bay in Lake Hodges (05/10/2018). This was the final planting site in the project.

Lessons Learned from Cactus Nursery

Overall, we experienced no major hurdles in the propagation of prickly pear cactus from wild collected pads, perhaps owing to a wealth of past institutional experience with cactus habitat restoration. However, through our experience maintaining the North County Cactus Nursery, we documented a number of tips and tricks for propagating prickly pear cactus for large scale habitat restoration. We submitted this information to the Native Plant Network (NPN) Propagation Protocol Database (maintained by the US Forest Service). Below we outline the major points from this protocol, and we attached the print version of the NPN protocol to our SDMMP project website.

Collection from Source: We removed pads from mature plants by twisting at the joint of two pads with tongs. We collected pads from native source populations of *Opuntia littoralis* from a variety of locations around San Diego County. We selected young, fully expanded pads from near the top of the plant as propagules.

Processing: We stored pads horizontally in bins until processing. To heal the wound created by collection, we "calloused" pads by laying them in the sun on shade cloth for a week to dry. Longer drying times may be necessary in high humidity environments. Note that if pads are left to callous for too long, they will begin to root in the ground or curve toward the sun.

Nursery Specifications: We constructed an open air nursery for growing cactus in pots. We installed weed cloth beneath pots to prevent the plants from rooting and to prevent weeds from invading the pots.

Potting: For growth media we used sunshine mix #4 with additional perlite. Any well drained potting soil would likely be appropriate. We planted pads vertically in shallow 8" pots with the callous pointing toward the bottom of the pot. We planted pads to a depth that allowed the pot to stay upright. We placed pots immediately adjacent to each other on the weed-cloth covered ground of the nursery, a practice that helped support top-heavy cactus as they grew. For inventory purposes, we organized pots in groups of 50.

Watering Regime: During establishment (while plants were rooting), we watered pots once weekly, always allowing pots to dry fully between watering. After cactus were established, we watered biweekly. We used overhead watering techniques, as drip-line watering seemed to increase the frequency of cochineal scale.

Pest Control: When cochineal scale was present, we used high-pressure overhead spraying for both watering the cactus and removing any cochineal scale. A previous project that used drip-line rather overhead watering had a larger problem with cochineal scale. We also established a four-meter-wide, weed-free barrier surrounding all sides of the cactus growing area at the nursery to reduce the chance of weed seeds germinating in cactus propagule pots and discourage snails from invading the nursery area.

Establishment Timeline: *Opuntia* pads should be well-rooted within 2 months (often much sooner). *Opuntia* pads will grow to the size of their pot and transplanting large plants may be

difficult. Therefore, we advise selecting the size of pot that is consistent with the size of plant desired for outplanting. In our case, the cactus in our shallow 8" pots grew to 0.5 m tall.

Outplanting: During planting, dig holes to 1 ½ times the depth of the pot and create basins around plants to retain moisture. Using tongs can avoid spines while planting and handling cactus. Planting with two people allows one person to support the top of the cactus, while the other person secures the cactus in the soil. After planting, cactus will typically dry out relative to their condition in the nursery.

Final Inventory of Cactus Nursery Distribution

From 2016-2018, we successfully distributed 8056 cactus (1000 pads + 7056 rooted cacti) from four main source populations: Whelan Lake (Oceanside), Lake Hodges, Woodridge (Santee), and the Safari Park Biodiversity Reserve (Table 1). We returned propagules collected at Whelan Lake, Woodridge, and Lake Hodges to their source site, with plantings at these same sites supplemented by individuals sourced from the Safari Park (Table 2). Lake Hodges received the lion’s share of the cacti planted for this grant (5,485 rooted individuals).

Of the 7056 rooted cacti propagated for this grant, 147 have undetermined planting associated with a specific site in Table 2. We suspect that several sources may contribute to this discrepancy, such as 1) land managers taking a few extra cactus when picking up plants, 2) an unrecorded planting event, or 3) accounting errors in the documentation of cactus inventory.

Table 3. Locations where we collected cactus pads for propagation during the term of the grant.

Provenance Site #	Pad Collection Location	Total Collected by location	Quantity Collected and Potted	Collection Date(s)	Latitude	Longitude
<i>Potted Propagules</i>						
1	Whelan Lake (Oceanside)	185	185	21-Mar-16	33.26176	-117.31615
2	Lake Hodges - Bernardo Mt	1556	760	09-Mar-16	33.05824	-117.08712
3			796	27-Apr-16	33.06222	-117.09604
4	Safari Park Biodiversity Reserve	5211	487	09-Feb-16	33.09625	-116.98057
5			260	16-Mar-16	33.09086	-116.98621
6			660	30-Mar-16	33.08901	-116.99097
7			315	01-Apr-16	33.09632	-116.97787
8			545	19-May-16	33.09264	-116.98076
9			2,944	Mar-17	Various	Various
10	Woodridge (Santee)	104	104	30-Mar-17	32.84854	
<i>Loose Pads</i>						
11	Safari Park	500	500	16-Jan-17	33.09685	-116.98122
12	Biodiversity Reserve	500	500	17-Apr-18	N/A	N/A

Table 4. Restoration Planting Events of Potted Restoration Cactus from the North County Cactus Nursery. Sites are georeferenced in the final GIS layer on SDMMP project site. Provenance Sites refer to Table 1.

Planting Agency	Number Planted	Planting Location	Planting Date	Provenance Sites
Center for Natural Land Management	370	Whelan Lake (Oceanside)	Nov. 2016	1,7
	104	Woodridge (Lakeside)	2017	10
	200	Lake San Marcos	2017	9
City of San Diego	1960	Bernardo Bay (Lake Hodges)	2017	6,9
	300	Bernardo Bay (Lake Hodges)	May 2018	9
	25	Cactus Nursery Site (Lake Hodges)	May 2018	9
Institute for Conservation Research	500	South Shore Point (Lake Hodges)	4. Nov. 2016	2
	500	North Glider Hill (Lake Hodges)	20 Nov. 2016	3
	1350	Glider Hill West (Lake Hodges)	Feb. 2017	5
	400	Glider Hill South (Lake Hodges)	11 Dec 2017	9
	200	Glider Hill South (Lake Hodges)	10 May 2018	9
San Dieguito River Preserve	500	San Pasqual Valley (Bandy Canyon)	Dec. 2016	4
	250	Bernardo Mountain (Lake Hodges)	2018	9
	250	San Pasqual Valley (Bandy Canyon)	2018	9

Total Rooted Cactus Propagated: 7056

Total Cactus Remaining in Nursery: 0

Total Planted (known location): 6909

Total Planted (unknown location): 147

Summary of Community Outreach Activities

We had the opportunity to engage members of the community in our cactus planting and habitat restoration effort. Volunteer groups included Boy Scout Troop 664 of Scripps Ranch, the Preuss School UCSD, the San Dieguito River Valley Conservancy, CarMax Escondido, the Zoo Corps and Conservation Corps student programs, Zoo Volunteer program, Advance Inquiry Program from San Diego Zoo Global & Miami University, and High Tech High Middle School. In total, these volunteers logged over 1,000 volunteer hours. We posted photos from these events on our SDMMP project page.

Task 2- Invasive Species Control and Habitat Restoration

Budget: \$33,763

Spent: \$16,993

Match for Task: \$31,964

Maps of Cactus Restoration Planting Sites in North County

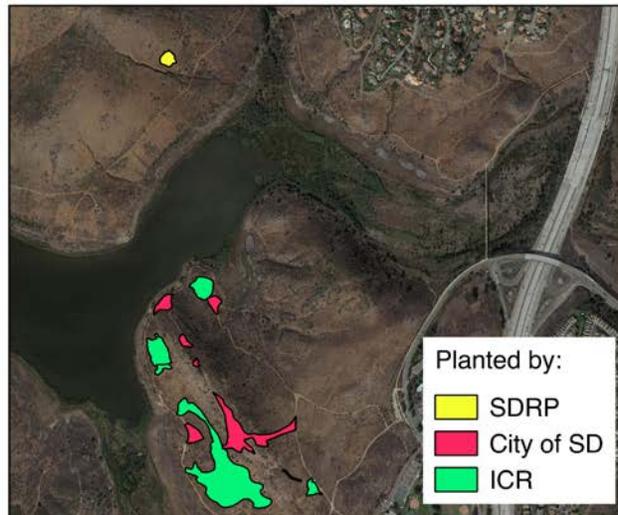
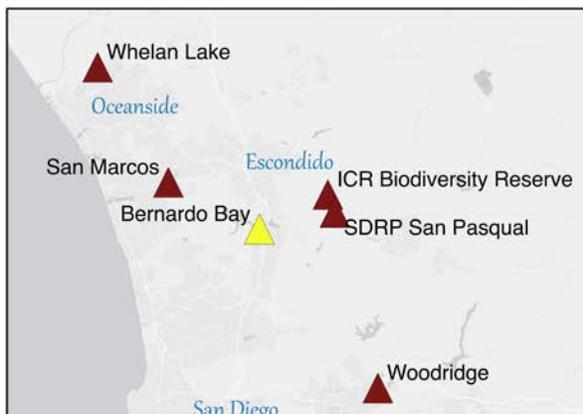
To facilitate follow up monitoring and evaluation of our habitat restoration effort, we created detailed maps and took photos of three of the four main restoration sites approximately one year after restoration planting: Bernardo Bay at Lake Hodges, Lake San Marcos, and Woodridge in Lakeside (Figure 1). We were unable to obtain access to map and photograph the Whelan Lake site in Oceanside. Below we show the results of our mapping outings, including site descriptions and estimates of survivorship. The shapefiles we created in for this project are located on our SDMMP project page.

Figure 1: Maps and associated photos and descriptions of restoration sites planting from the North County Cactus Nursery.
A) Bernardo Bay at Lake Hodges, B) Lake San Marcos, C) Woodridge in Lakeside

Bernardo Bay at Lake Hodges

The Bernardo Bay/Bernardo Mountain area of Lake Hodges received the vast majority of cactus propagated for this grant. The total area will represent a 20 acres of potential nesting habitat for coastal cactus wren. Three organizations carried out cactus planting in this area: San Diego Zoo Institute for Conservation Reserach (ICR), San Dieguito River Preserve (SDRP), and the City of San Diego.

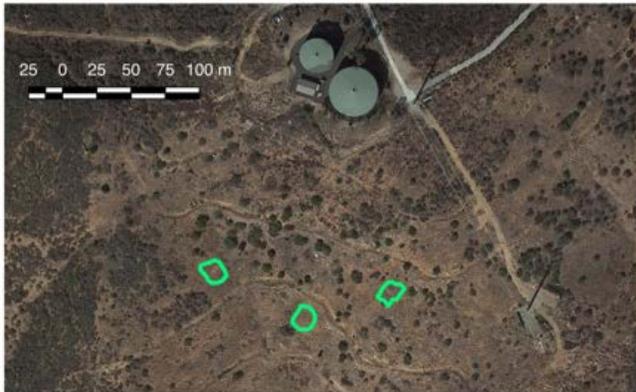
In addition to cactus planting, we conducted extensive invasive species removal in the area, especially focused on the invasive weed *Hirschfeldia incana*.



Lake San Marcos Cactus Habitat Restoration



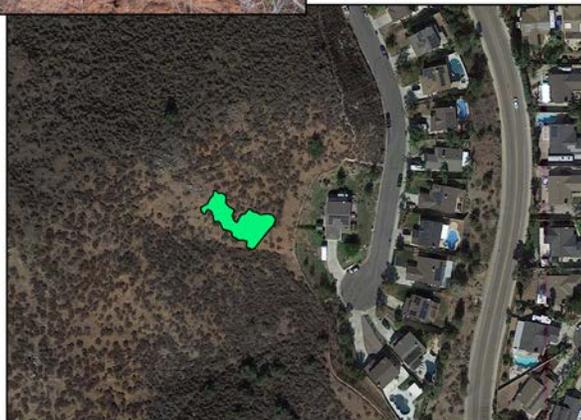
In the final quarter of 2017, CNLM planted 200 rooted cactus in three sites approximately 0.6 km east of Rancho Santa Fe Rd and 1.2 km west of Lake San Marcos. When we visited to map on March 20, 2018, there was about 90% survivorship of planted cactus and the surviving cacti looked healthy and well established. The area surrounding the restoration sites is heavily invaded by invasive weeds, and invasive forbs are reinvading planted areas, although not yet obscuring the planted cacti.



Woodridge Site in Lakeside

In 2017, CNLM planted 104 cactus at Woodridge in Lakeside over 0.15 acres. These cacti consisted primarily of plants propagated from pads collected at a nearby population, with some individuals collected from San Pasqual valley.

This site has lower invasive species coverage than the Bernardo Bay and San Marcos sites, with many mature Coastal Sage Scrub shrubs. The cactus at this site are very healthy, plump, and green, which may be due to either source population genetics or the deep rich soil.



Invasive Species Removal & Monitoring at Newly Planted Sites at Lake Hodges

The presence of invasive weeds was a significant challenge to our habitat restoration efforts. San Diego County experienced much higher than average precipitation during the winter of 2016-2017, which may have triggered an increase in the cover of invasive plants during the 2017 growing season. Specifically, our planned restoration sites at Lake Hodges were experience a large infestation of *Hirschfeldia incana*, with plants growing higher than three feet in many areas. This type of invasive growth is especially problematic, give that CACW prefers low-growing and open vegetation between cactus and CSS shrubs.

Prior to restoration plantings, we conducted hand removal of invasive weed as needed. Volunteers played an essential role of this effort. In cactus planting areas with patchy and low to moderate weed growth, such as all the cactus planting areas along the western side of Glider Hill, we hand pulled and bagged weeds. At South Shore Point, *H. incana* growth was very heavy allowing for little time for hand pulling before seed set. We repeatedly cut weeds to prevent *H. incana* from setting seed, thereby buying time for us to cut out the remaining portions of the weeds with shovels.



Photo 8: Before (4/18/2017) and after (6/16/2017) hand removal of *Hirschfeldia incana* at South Shore Poin at Lake Hodges. We are looking NW at Bernardo Mount.

In Spring 2017, we conducted vegetation monitoring at two planting sites at Lake Hodges: South Shore Point, which is approximately 0.4 hectares (1 acre) in size with 500 cacti planted in early November 2016 and North Glider Hill, which is approximately 0.5 hectares (1.3 acre) in size with 500 cacti planted in early November 2016 (see site maps Figure 2 and 3 below). We established five transects at each site at randomly select meter marks along a line running roughly parallel to the main trail. Each transect encompassed several meters before and after the cactus planting area where we removed weeds. We did not remove weeds in the area of the control plots, as they had few weeds. Along each transect, we randomly selected seven to eight locations for quadrat placement, which included 3-5 locations inside the planting area (treatment group) and 3-5 locations outside the planting area (control group). We sampled 20 control plots and 19 treatment plots at South Shore Point and 20 control plots and 25 treatment plots at North Glider Hill. (See Figure 2 and 3.)

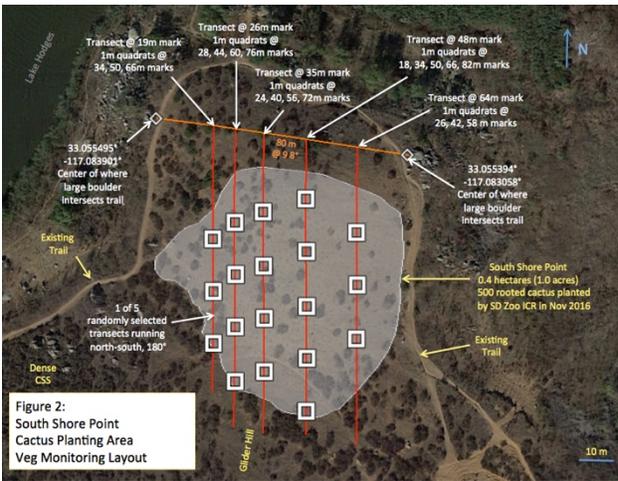


Figure 2: South Shore Point Cactus Planting Area Veg Monitoring Layout

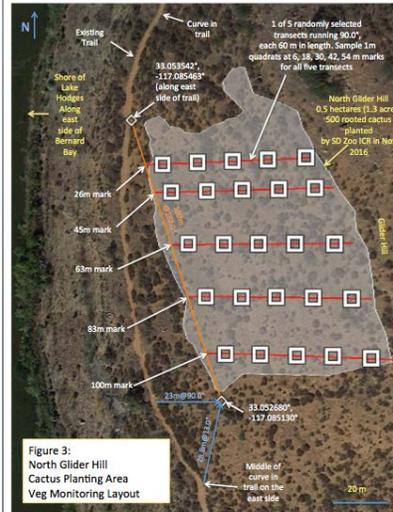


Figure 3: North Glider Hill Cactus Planting Area Veg Monitoring Layout

Figure 3: Map of vegetation monitoring transects at North Glider Hill at Lake Hodges
 Figure 2: Map of vegetation monitoring transects at South Shore Point at Lake Hodges

Our analysis of the Spring 2017 monitoring data produced two main products: 1) a species list of exotic and native plants at each site and 2) a comparison of percent cover of main vegetation types between control and treatment plots. These data are posted on our SDMMMP project page and will provide a baseline for future study into the long-term effects of cactus habitat restoration.

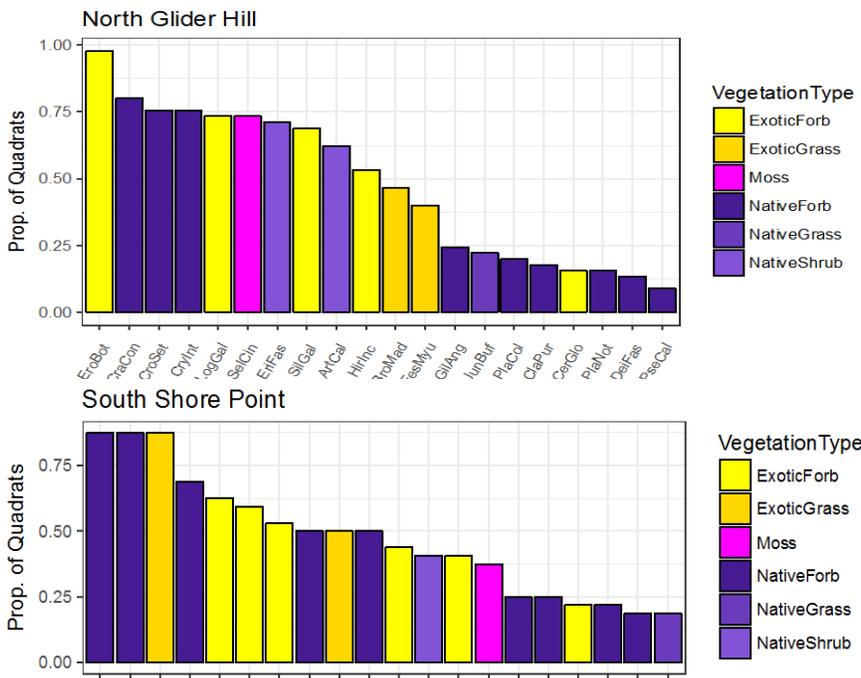


Figure 4: Proportion of quadrats with plant species present at A) North Glider Hill and B) South Shore Point. See Appendix I for species code definitions.

The dominant plant at each site was an invasive species: exotic forb *Erodium botrys* had the highest abundance and average percent cover across quadrats at North Glider Hill and exotic grass *Festuca myuros* had the highest total cover and abundance in quadrats South Short Point (Figure 4). Live vegetation covered 50% of the land area at both sites, however, exotic grasses and forbs made up a higher proportion of cover at South Shore Point (29%) than at North Glider Hill (18%). Among native plants, shrubs made up the highest proportion of native vegetation cover at North Glider Hill (14%), while native forbs made a higher proportion of cover at South Shore Point (17%).

The mean percent cover (+/- one standard error) of vegetative functional groups in unplanted and planted vegetation plots at the two restoration sites varied little after weed

management (Figure 5). The species that comprise five functional groups (Native Shrubs, Native Grass, Native Forbs, Moss, Exotic Forb and Exotic Grass) are listed in Appendix 1. We found that while the relative cover of functional groups differed drastically among sites, planted plots did not significantly differ from unplanted plots in percent cover of any vegetative functional group at either site. Considering that the planted plots were highly disturbed and invaded before weed management, this result is a positive indication that our management actions were able to restore the community to the same composition as the relatively undisturbed surrounding areas. These baseline data will be useful for re-assessing invasive cover in future growing seasons and for testing the long-term effects of restoration planting on the vegetative community at Lake Hodges.

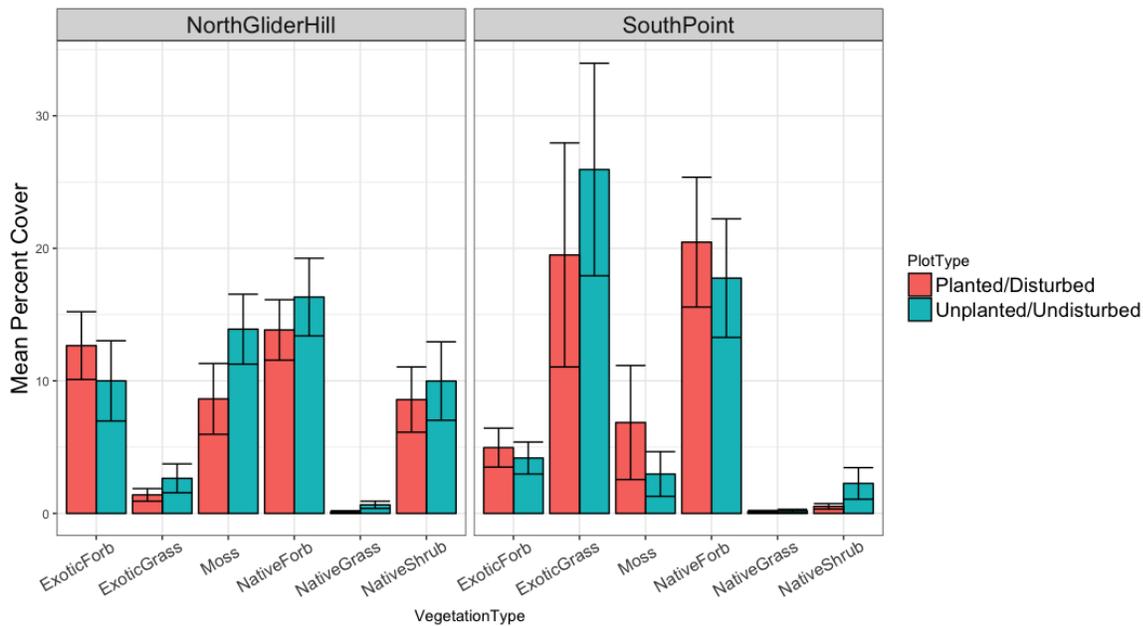


Figure 5: Mean percent cover by treatment group at two monitoring sites at Bernardo Bay at lake Hodges

Invasive Removal at Restoration Sites in Safari Park Biodiversity Reserve

In addition to removing invasive plants at the restoration sites established during this grant period, we also sought to control the spread of the invasive weed *Oncosiphon piluiferum*, commonly known as stinknet, in cactus wren habitat of the Safari Park Biodiversity Reserve that had been augmented under a previous SANDAG Grant (SANDAG 5001966). The wet conditions prior to the 2017 growing season led to an unprecedented outbreak of *Oncosiphon* in the Biodiversity Reserve and elsewhere in the San Pasqual Valley. Consequently, we decided it was prudent to invest resources into protecting previous cactus restoration plantings from

competition by *Oncosiphon* and from susceptibility to burning in such a high fuel environment.

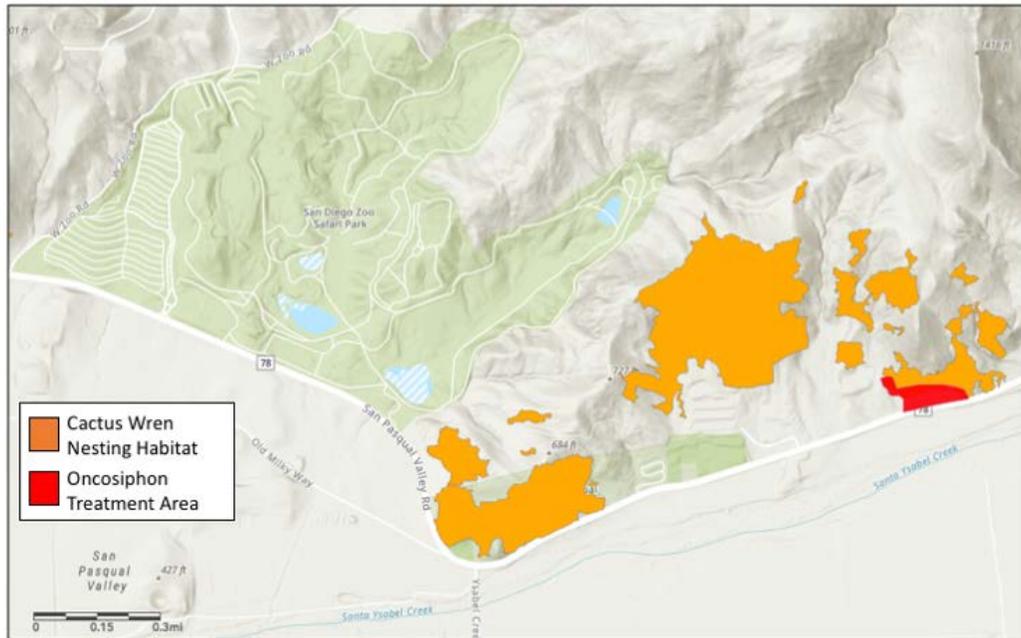


Figure 6: Map of *Oncosiphon* Treatment Area in the Safari Park Biodiversity Reserve.

We focused on a treatment area that was both within a large naturally occurring patch of cactus wren habitat and an area that had also received supplemental cactus planting in 2011 (Figure 6). We contracted CalFire for four days (1 crew per day) to remove *Oncosiphon* biomass from two acres of heavily invaded cactus habitat at the southern edge of the Biodiversity Reserve. ICR staff assisted with the biomass removal effort for 24 total work hours. ICR Conservation Program Specialist Christa Horn supervised the invasive species removal and coordinated the purchase of necessary tools including two weed whackers, hoes, and rakes. After removal, *Oncosiphon* biomass was bagged and tarped to solarize seeds before disposal.

Following manual removal and solarization, *Oncosiphon* seedlings present in the seed bank emerged (see Photo 9 on left below). To treat the new flush of seedlings, we contracted Black Sage to apply glyphosate in the 5.5 acre treatment area during the week of April 3rd, 2018, with follow up spraying on April 26th, 2018 (see Photo 9 on right below). Black sage crews applied herbicide over the treatment area and installed 35 straw wattles (8" x 25') to prevent erosion following the removal of large amounts of senesced *Oncosiphon* biomass. The erosion precaution was necessary given the close proximity of our treatment site to Highway 78. In total, crews applied 211 gallons of a 3% glyphosate solution to the treatment area (approximately 810 ounces of glyphosate). We will continue to monitor the area for *Oncosiphon* and retreat if necessary.



Photo 9: Before (04/01/2018) and after (04/20/2018) *Oncosiphon* hand removal in the cactus restoration habitat at the Safari Park Biodiversity Reserve.

Conclusions

The North County Cactus Nursery project was a definite success that will substantially aide the recovery of the coastal cactus wren. The cactus nursery produced over 8000 locally sourced cacti, which were distributed to establish dozens of acres of new cactus habitat in North County. Particularly encouraging for this species is the establishment of a large restoration site at Bernardo Bay at Lake Hodges, which had been identified as an area that will be especially important in facilitating the genetic health of CACW populations (Conlisk et al. 2014). The invasive species control carried out under this project will help protect these cactus wren sites from loss to fire and increase the chance of future nesting if maintained.

Not only are the restoration sites established with this grant a positive step for the coastal cactus wren, but the lessons learned here will also substantially benefit MSP goals and the success of future restoration projects. Our protocol for largescale propagation provides a template for future land managers and conservationists to follow. In addition, the experience we gained in the management of *Hirschfeldia incana* and *Oncosiphon piluiferum* from our restoration sites will be useful for developing new management plans for these threats in the San Pasqual Valley. Finally, the outreach opportunities provided by the planting and propagation of the cactus for this project increased the awareness of coastal cactus wren restoration and illustrated the general importance of coastal sage scrub in Northern San Diego County to hundreds of volunteers.

We recommend that future cactus restoration efforts in this region focus on better connecting the large restoration habitats established at the Safari Park Biodiversity Reserve and Lake Hodges, including sites such as BeeWise Farms. This area was not logistically feasible to plant at the end of our granting period, but would serve as a useful corridor that would aid wren migration between these two important areas. We also recommend that land managers in the San Pasqual Valley remain vigilant about the emerging threat of invasive weed, *O. piluiferum* (stinknet). This relatively new threat has the potential to jeopardize the investment in these cactus restoration projects in the region. As a response, the Institute for Conservation Research will increase its management of this weed through 2023 thanks to a new round of SANDAG funding and the hiring of a natural lands manager for the Safari Park Biodiversity Reserve.

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Appendices:

Appendix I. List of plant species observed during Spring 2017 monitoring of cactus planting sites in Lake Hodges. Names in brackets represent alternative names of species.

SppCode	Species ID	Form	Status
AcmAme	<i>Acmispon americanus</i>	Forb	Native
AcmMic	<i>Acmispon micranthus</i>	Forb	Native
AcmStr	<i>Acmispon strigosus</i>	Forb	Native
AmsMen	<i>Amsinckia menziesii</i>	Forb	Native
AntNut	<i>Antirrhinum nuttallianum</i>	Forb	Native
ArtCal	<i>Artemisia californica</i>	Forb	Native
BroHor	<i>Bromus hordeaceus</i>	Grass	Exotic
BroMad	<i>Bromus madritensis</i>	Grass	Exotic
CenMel	<i>Centaurea melitensis</i>	Forb	Exotic
CerGlo	<i>Cerastium glomeratum</i>	Forb	Exotic
ClaPur	<i>Clarkia purpurea</i>	Forb	Native
Claytonia sp.	<i>Claytonia Sp.</i>	Forb	Native
CorFil	<i>Corethrogyne filaginifolia</i>	Forb	Native
CraCon	<i>Crassula connata</i>	Forb	Native
CroSet	<i>Croton setiger [Croton setigerus] [Eremocarpus setiger]</i>	Forb	Native
CryInt	<i>Cryptantha intermedia</i>	Forb	Native
CryMic	<i>Cryptantha micromeres</i>	Forb	Native
DauPus	<i>Daucus pusillus</i>	Forb	Native
DeiFas	<i>Deinandra fasciculata</i>	Forb	Native
DicCap	<i>Dichelostemma capitatum</i>	Forb	Native
DisSpi	<i>Distichlis spicata</i>	Grass	Native
EriCan	<i>Erigeron canadensis</i>	Forb	Native
EriFas	<i>Eriogonum fasciculatum</i>	Shrub	Native
EroBot	<i>Erodium botrys</i>	Forb	Exotic
EroCic	<i>Erodium cicutarium</i>	Forb	Exotic

SppCode	Species ID	Form	Status
EroMos	<i>Erodium moschatum</i>	Forb	Exotic
FesMyu	<i>Festuca myuros</i>	Grass	Exotic
GalAng	<i>Galium angustifolium</i>	Forb	Native
GilAng	<i>Gilia angelensis</i>	Forb	Native
GutCal	<i>Gutierrezia californica</i>	Shrub	Native
HerHir	<i>Herniaria hirsuta</i>	Forb	Exotic
HirInc	<i>Hirschfeldia incana</i>	Forb	Exotic
HypGla	<i>Hypochaeris glabra</i>	Forb	Native
JunBuf	<i>Juncus bufonius</i>	Grass	Native
LinDia	<i>Linanthus diathiflores</i>	Forb	Native
Liverwort	<i>Liverwort</i>	Cover	Native
LogGal	<i>Logfia gallica</i>	Forb	Exotic
LupBic	<i>Lupinus bicolor</i>	Forb	Native
LysArv	<i>Lysimachia arvensis</i> [Anagallis arvensis - AnaArv]	Forb	Exotic
MirLae	<i>Mirabilis laevis</i>	Forb	Native
OpuLit	<i>Opuntia littoralis</i>	Shrub	Native
PecLin	<i>Pectocarya linearis</i>	Forb	Native
PhaDis	<i>Phacelia distans</i>	Forb	Native
PlaCol	<i>Plagiobothrys collinus</i>	Forb	Native
PlaNot	<i>Plagiobothrys nothofulvus</i>	Forb	Native
PseCal	<i>Pseudognaphalium californica</i>	Forb	Native
Pseudog sp.	<i>Pseudognaphalium sp.</i>	Forb	Native
PsiTen	<i>Psilocarphus tenellus</i>	Forb	Native
PteDry	<i>Pterostegia drymarioides</i>	Forb	Native
SalApi	<i>Salvia apiana</i>	Shrub	Native
SchBar	<i>Schismus barbatus</i>	Grass	Exotic
SelCin	<i>Selaginella cinerastins</i>	Cover	Native
SenCal	<i>Senecio californicus</i>	Forb	Native
SilGal	<i>Silene gallica</i>	Forb	Exotic
SonAsp	<i>Sonchus asper</i>	Forb	Exotic
SonOle	<i>Sonchus oleraceus</i>	Forb	Exotic
Stepha Sp.	<i>Stephanomeria species</i>	Forb	Native
TriLan	<i>Trichostema lanatum</i>	Forb	Native
VioPed	<i>Viola penculata</i>	Forb	Native
ZelVen	<i>Zeltnera venusta</i>	Forb	Native