RESTORATION OF THE S-SERIES VERNAL POOLS ON THE SHINOHARA PARCEL OF SAN DIEGO NATIONAL WILDLIFE REFUGE

Final Summary Report for
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INTRODUCTION

San Diego National Wildlife Refuge (SDNWR or Refuge) has been working to restore approximately 30 acres of vernal pool habitat on the former Shinohara parcel for several years. The Shinohara parcel is about 700 meters south of Sweetwater Reservoir in San Diego County (Figure 1), and encompasses a portion of the "S" series vernal pools as described by Bauder (1986). Vernal pool species recorded in this complex of pools include spreading navarretia (*Navarretia fossalis*), wooly marbles (*Psilocarphus brevissimus*), toad rush (*Juncus bufonius*), and water pygmyweed (*Crassula aquatic*) (Bauder 1986), San Diego fairy shrimp (*Branchinecta sandiegoensis*), American pillwort (*Pilularia americana*), smooth spike (*Epilobium pygmaeum*), toothed downingia (*Downingia cuspidate*), longstock water-starwort (*Callitriche longipedunculata*), creeping spike rush (*Eleocharis macrostachya*), and annual hairgrass (*Deschampsia danthanoides*) (John Martin, pers. obs.).

Summary of the work

De-thatching

The initial de-thatching of the site was initiated on April 2, 2007 (San Diego National Wildlife Refuge 2007). Areas that did not have the mounded topography characteristic of vernal pool areas were initially mowed with a rotary mower, driven by a rubber-tracked tractor (Figure 2). The rubber tracks cause less soil surface disturbance than an metal-tracked tractor of comparable size. The mowed areas were subsequently raked with garden rakes with flexible sheet-metal tines that removed the cut vegetation without digging into the soil surface as deeply as a heavy metal rake might. After the first raking, the mower stubble was removed with weed-whackers, raked and removed. In areas with vernal pool topography, all vegetation cutting was done with weed-whackers. Cut vegetation was raked up, loaded into containers, removed from the site and disposed of as green waste. When the de-thatching was finished, dead exotic annual vegetation had been removed essentially to bare soil (Figure 3). Remaining stalks of rooted annual exotics were only1-5 mm tall. Cut-off trunks and branches of salt cedar (*Tamarix ramossissima*) that had previously been killed on the site were piled in non-vernal pool areas where they might provide cover for wildlife. Native vegetation, including shrubs, sedges, cacti, and aggregations of native perennial bunchgrass (*Nassella* sp.) were retained (Figure 4). The de-thatching work was completed in early June of 2007, and approved after inspection by SDNWR personnel.

Topographic re-contouring of basins

We evaluated where contouring could enhance or create vernal pools, and modified the topography of the site accordingly (San Diego National Wildlife Refuge 2008). In some areas mounded topography was evident and we thought that pools were likely to form naturally (Figure 5). However, it is likely that the mounded topography had been degraded by past agricultural practices of grazing and discing since broken farm implements were found on site. In some areas, pooling areas had been degraded by

livestock congregating in them, since hoof prints, at least 10 years old, were still prominent (Figure 5). Thus, clay soils appropriate for vernal pools occur over most of the site and existing pooling potential might be enhanced by minor grading.

Low areas that would benefit from slight topographic enhancement were identified and flagged. In September 2007, thirty-two such areas were scooped out with box scraper attached to a tractor. In November 2009, an additional 30 basins were created, for a total of 63 basins (including one that was not re-contoured) (Figures. 6 and 7). Topography was assessed during and after the work using a laser level. We attempted to create a range of depths of vernal pools, to provide a diversity of habitats for different vernal pool organisms. Topographic enhancement was focused on edges of areas with existing mound topography to minimize impact to native plants potentially in the soil. Not all potential pooling areas were deepened, some were left alone.

Weed control

Beginning in summer 2007 and continuing through May 2014, weeds on the site were controlled using selective application of glyphosate with hand-held sprayers (backpacks or truck-mounted hoses) (San Diego National Wildlife Refuge 2007, 2008; RECON 2009). Number and timing of applications has varied with weather and consequent phenology of weeds, but essentially, seasonal weed control efforts begin when the first cohort of exotic annuals reach approximately 10-20 cm in height, well before set seed. Subsequent applications are usually required, as new cohorts of weeds germinate in response to rain events later in the season, and some species of weeds (e.g., Russian thistle (*Salsola tragus*)) tend to grow later in the season.

Planting

About 4,000 container shrubs and 25,000 plugs of native perennial grasses were planted on the site in the winter of 2010-2011. All plants originated from seed collected in southern coastal San Diego County. Planted stock was irrigated as necessary for the following 2 years. Generally, survival and growth of container shrubs has been good, and areas of the site dominated by rocky silt loam soils have developed into diverse stands of coastal sage scrub. Survival and growth of native grasses has been poor: easily 90% of the planted grass plugs have died, most of them eaten by rabbits. However, deer grass (*Muhlenbergia rigens*) survived and grew much better than did purple needlegrass (*Stipa pulchra*) which constituted the bulk of the planted grasses.

Soil inoculum was collected from each of the thirty-two potential pooling areas prior to their topographic enhancement. Those soil samples and the seeds and cysts they may contain were distributed in pool basins in December 2008, after the weed seed bank had been reduced.

In addition to the container plants, seed of four species of federally listed vernal pool obligate plants were hand-broadcast: Otay Mesa mint (*Pogogyne nudiuscula*) (Figures 8, 9, and 12); California Orcutt grass (*Orcuttia californica*) (Figures 9 and 12); spreading

navarretia (*Navarretia fossalis*) (Figure 10); and San Diego button celery (*Eryngium aristulatum* var. *parishii*) (Figure 11) into several basins that were selected for their low weed abundance, in November 2010. In 2011 and 2012, all of these species grew in the pools in which they were seeded. In 2013 and 2014, only *P. nudiuscula* and *E. a. parishii* grew. Low rainfall in these years likely led to the low expression of vernal pool obligate plants. *P. nudiuscula* has grown abundantly in every year since 2011, and expanded its distribution into pools in which it was not initially seeded.

Monitoring

Ten randomly-placed 10-meter permanent transects were established on the site in 2008, and were used to monitor change in the upland vegetation community in 2008, 2009, 2010 (J. Martin, unpubl. data), and 2013 (AECOM 2013). In addition, vernal pool flora were assessed in each pool, by creating a species list of native and exotic species and assigning a cover class (0-1%, 2-5%, 6-25%, 26-50%, 51-75%, or >76%) to each. Pool-specific inventories of federally listed vernal pool obligate plants were conducted in 2013 and 2014 (J. Martin, unpubl. data).

Fairy shrimp were monitored by sweep-netting the pools in 2008-2011 (Allen 2008, 2009, J. Martin, unpubl. data). Initially, all pools were sampled. In 2008, San Diego fairy shrimp (*Branchinecta sandiegonensis*) were found in seven pools. To reduce impacts to shrimp, in subsequent years we only sampled pools in which fairy shrimp had not been previously documented. The number of occupied pools expanded from 7, to 14, to 25. Since 2011, inundation has been insufficient to support fairy shrimp, and no sampling was conducted. The distribution of fairy shrimp is anticipated to continue to expand to more basins. No branchiopod species other than *B. sandiegonensis* were detected, nor was any sign of hybridization or gynadromorphy (Lisa Allen, U.S. Geological Survey, pers. comm.).

Overall effectiveness of the project

As of late July 2014, the project is going well. Weed control has been effective, in that weed cover throughout the site has been greatly reduced, and exotic annual grasses have been nearly eliminated. Native plants are responding to reduced weed competition. Bulbous perennials observed on the site include bluedicks (*Dichelostemma capitata*) and chaparral brodiaea (*Brodiaea jolonensis*). Native perennial grasses (e.g., *S. pulchra*), that were on the site prior to initiation of the project, responded to the reduced weed competition by fruiting early and profusely. Figure 13 shows other native annual plants present on site including canchalagua (*Centaureum venustum*), doveweed (*Croton setigerus*), and tall willowherb (*Epilobium brachycarpum*). Federally threatened Otay tarplant (*Deinandra conjugens*) has responded spectacularly to the restoration work, increasing in abundance by 2-3 orders of magnitude, growing to unusually large size, and presumably setting large numbers of seed. Small-flowered morning glory (*Convolvulus simulans*; clay soil obligate plant; CNPS rank 4.2) is abundant throughout the clay soil areas. Sixty-two topographically-enhanced pools all appear to function hydrologically well enough to support sensitive vernal pool obligate plants and animals. At least 25

basins support or have supported federally endangered San Diego fairy shrimp, and one unenhanced, natural vernal pool on the site consistently supports approximately 500-1,000 fairy shrimp when rainfall is sufficient. In addition to the federally listed plants we introduced, vernal pool flora including *J. bufonius*, *E. macrostachys*, *P. brevissimus*, *C. aquatica*, *D. danthanoides*, *D. cuspidata*, *E. pygmaeum*, hairy water-clover (*Marsilea vestita*) and *C. longipedunculata* occur in multiple pools. Primarily on rocky silt loam soils, cryptobiotic crusts are developing. Initially, crusts consist almost entirely of unidentified cyanobacteria and mosses.

In September 2007, 10 underground nest boxes for burrowing owls (*Athene cunicularia*) were installed on the site (Figure 14). Burrowing owls using other such nest boxes on adjacent Sweetwater Authority lands began using the boxes on the Shinohara site within days of their installation. Since then, burrowing owl numbers on the site grew to 3 breeding pairs, producing 12 young in 2009. In mid-January 2008, five captive-bred burrowing owls from the Chula Vista Nature Center were released onto the site, one of which persisted until at least September 2009. Since 2009, the number of owls on site has gradually declined, and they have not been known to breed there since 2011. Burrowing owls winter there annually. Decline in breeding is attributed to the development of the sage scrub habitat on the site. During initial restoration, the site was very open with sparse vegetation. With time, vegetation on the site has filled in, making the area less attractive for owls.

Removal of the thatch of dead grass created habitat for birds that we had not anticipated seeing on the site. In December, January, and February, up to 200 Canada geese (*Branta canadensis*) and up to four cackling geese (*Branta hutchinsii*) frequented the site, feeding on the exotic grasses. Up to 200 horned larks (*Eremophila alpestris*) resided on the site from September 2007 to February 2008. In late November 2007, two chestnut-collared longspurs (*Calcarius ornatus*) and one Lapland longspur (*C. lapponicus*) were seen repeatedly among the larks. Sensitive vertebrate species observed on the site include San Diego black-tailed jackrabbit (*Lepus californicus bennettii*; regularly observed); California gnatcatcher (*Polioptila californica californica*; federally threatened; observed on multiple occasions); loggerhead shrike (*Lanius ludovicianus*; California bird species of Special Concern; observed repeatedly over multiple years); cactus wren (*Campylorhynchus brunneicapillus*); and San Diego ring-necked snake (*Diadophis punctatus similis*; listed as Sensitive by the U.S. Forest Service).

Future management

Weed control will be necessary for the foreseeable future. Although exotic annual grasses have been effectively controlled on the site, sources of seed for these grasses occur throughout much of the surrounding landscape, and abut the site for approximately 40% of its perimeter. Exotic annual grasses are likely to recolonize the site. In addition, several species of dicotyledonous weeds (e.g., *Salsola tragus*, tumbleweed (*Amaranthus albus*), bristly oxtongue (*Picris echioides*), sow thistle (*Sonchus oleraceus*), horseweed (*Conyza canadensis*), and small flowered nightshade (*Solanum americanum*)) are prevalent through much of the site. These species are likely to require control until

numbers are greatly reduced. Within several vernal pool basins, hyssop loosestrife (*Lythrum hyssopifolium*) is a problematic weed. In basins that also harbor sensitive vernal pool obligate flora and fauna, *L. hyssopifolium* should be controlled by hand-weeding until its abundance is eliminated or reduced to the degree at which sensitive native vernal pool species can successfully compete with it. Although weed cover in general throughout the site is much lower than it was in the initial years of the restoration project, it is not clear how much of the current low weed abundance is due to diligent weed control, and how much is due to unusually low rainfall for the last two years.

Augmentation of the abundance and diversity of native forbs in the non-pool areas dominated by clay soils (e.g., by direct seeding) would enhance the biological value of the site, and potentially suppress weeds to some degree through natural competition. Currently, relatively few native clay soil obligate species (i.e., *D. conjugens* and *C. simulans*) are widespread and abundant on clay soils outside of pool basins.

Additional direct seeding of *N. fossalis* and *O. californica* may be required to sustain these species on the site. It is difficult to determine if failure to observe these species for the last two years is due to their failure to "take", or to low expression associated with sparse rainfall. There may be larger populations of these species on the site than are apparent, in the form of seed banks in the soil of the pool basins.

It may be desirable to control some native plants on the site, as some have responded dramatically to weed control, and threaten to dominate the site by competitively excluding many other native species. Both *D. conjugens* and fascicled tarplant (*D. fasciculata*) form near monocultures over large areas dominated by clay soil. In addition to competing for light, soil moisture, and nutrients with other plants, they provide extensive cover for rabbits (*Sylvilagus audubonii* and *Lepus californicus bennettii*), which eat planted native plants, especially grasses. At the outset of the restoration work, there was a patch of arrowweed (*Pluchea sericea*) approximately 100 m^2 in extent. It has expanded to approximately 2,500 m^2, to the detriment of other native species that are competitively excluded from the patch. Seedling broom baccharis (*Baccharis sarothroides*) has been controlled in vernal pool basins since this aggressive pioneer native shrub has the potential to dominate the site.

Access to the site should continue to be restricted, to minimize damage to resources by trampling (hikers, horse riders, cyclists, vehicles), littering, and risk to wildlife from domestic dogs.

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Figure 1. Upper: San Diego National Wildlife Refuge (green outline), San Diego County, California. Lower: Thirty-acre vernal pool restoration area (red outline) on San Diego National Wildlife Refuge (green shading).

Figure 2. Rubber-tracked mower used at Shinohara vernal pool restoration site.

Figure 3. After de-thatching on Shinohara vernal pool restoration site.

Figure 4. Retained native grasses after removal of dead exotic grass (de-thatching) on Shinohara vernal pool restoration site.

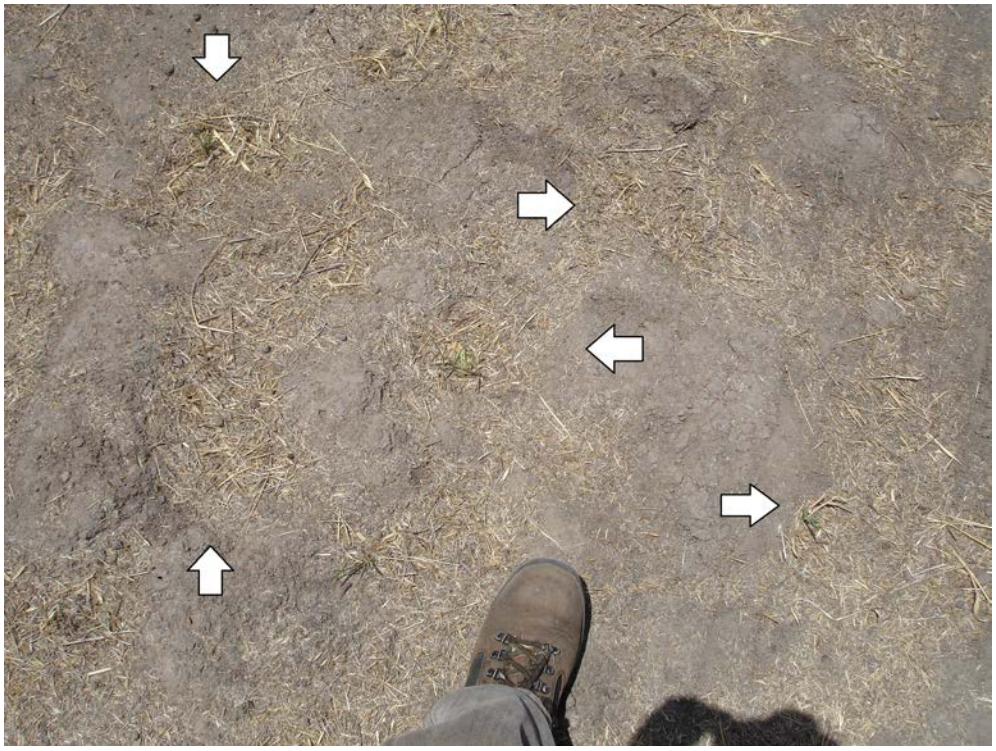

Figure 5. Past agricultural practices may have altered soil surface microtopography on Shinohara vernal pool restoration site. Arrows show hoof prints in ponding areas.

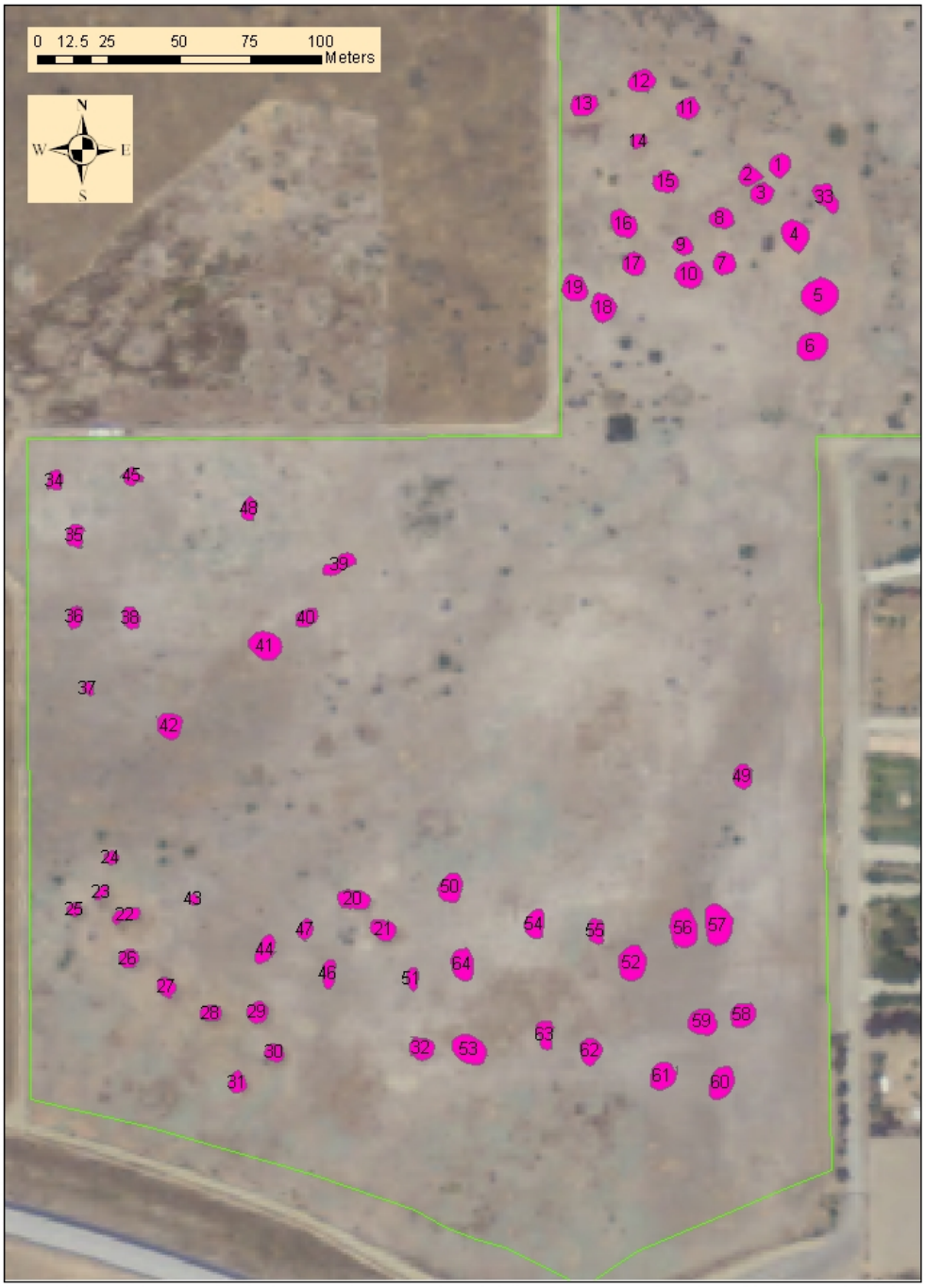

Figure 6. Location of topographically enhanced vernal pools on Shinohara parcel, San Diego National Wildlife Refuge.

Figure 7. Pools at Shinohara vernal pool restoration site in January 2008.

Figure 8. Otay Mesa mint (*Pogogyne nudiuscula*) on the Shinohara vernal pool restoration site.

Figure 9. Otay Mesa mint (*Pogogyne nudiuscula*) and California Orcutt grass (*Orcuttia californica*) on the Shinohara vernal pool restoration site.

Figure 10. Spreading navarretia (*Navarretia fossalis*) on the Shinohara vernal pool restoration site.

Figure 11. San Diego button celery (*Eryngium aristulatum* var. *parishii*) on the Shinohara vernal pool restoration site.

Figure 12. Otay Mesa mint (*Pogogyne nudiuscula*) and California Orcutt grass (*Orcuttia californica*) protected from rabbit herbivory by a chicken wire barrier, on the Shinohara vernal pool restoration site.

Figure 13. Native annual plants including canchalagua (*Centaureum venustum*), doveweed (*Croton setigerus*), and tall willowherb (*Epilobium brachycarpum*), on the Shinohara vernal pool restoration site.

Figure 14. Burrowing owl at vernal pool restoration site at artificial burrow entrance.