Western Riverside County
Multiple Species Habitat Conservation Plan
Biological Monitoring Program

2016 Delhi Sands Flower-loving Fly
(*Rhaphiomidas terminatus abdominalis*)
Survey Report

27 September 2017

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NOTE TO READER:

This report is an account of survey activities conducted by the Biological Monitoring Program for the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP). The MSHCP was permitted in June 2004. Reserve assembly is ongoing and is expected to take 20 or more years to complete. The Conservation Area includes lands acquired under the terms of the MSHCP and other lands that have conservation value in the Plan Area (called public or quasi-public lands in the MSHCP). In this report, the term "Conservation Area" refers to these lands as they were understood by the Monitoring Program at the time the surveys were conducted.

The Monitoring Program monitors the status and distribution of the 146 species covered by the MSHCP within the Conservation Area to provide information to Permittees, land managers, the public, and the Wildlife Agencies [i.e., the California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) and the U.S. Fish and Wildlife Service]. Monitoring Program activities are guided by defined conservation objectives for each Covered Species, other information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees. A list of the lands where data collection activities were conducted in 2016 is included in Section 7.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies.

The primary author of this report was the 2016 Delhi Sands flower-loving fly Project Lead, Tara Graham. This report should be cited as:

Biological Monitoring Program. 2017. Western Riverside County MSHCP Biological Monitoring Program 2016 Delhi Sands Flower-loving Fly Survey Report. Prepared for the Western Riverside County Multiple Species Habitat Conservation Plan. Riverside, CA. Available online: http://wrc-rca.org/about-rca/monitoring/monitoring-surveys/.

While we have made every effort to accurately represent our data and results, it should be recognized that data management and analysis are ongoing activities. Any reader wishing to make further use of the information or data provided in this report should contact the Monitoring Program to ensure that they have access to the best available or most current data.

Please contact the Monitoring Program Administrator with questions about the information provided in this report. Questions about the MSHCP should be directed to the Executive Director of the RCA. Further information on the MSHCP and the RCA can be found at www.wrc-rca.org.

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INTRODUCTION

The Delhi Sands flower-loving fly (*Rhaphiomidas terminatus abdominalis*; Delhi fly) is federally listed as endangered, and is narrowly distributed in portions of Riverside and San Bernardino Counties in areas with Delhi series soils. The species is known to have occurred within 3 Core Areas defined by the Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP): Jurupa Hills, Agua Mansa Industrial Center, and Mira Loma (Dudek & Associates 2003). To date, conservation of the species within the MSHCP Plan Area has only occurred at the Teledyne site within the Jurupa Hills Core Area. There are no lands that are currently part of the Conservation Area within the other 2 Core Areas for this species; however, the Rivers and Lands Conservancy has been actively procuring lands in San Bernardino County in those general areas for Delhi fly conservation.

Delhi fly Conservation Objective 2 states that successful reproduction shall be documented at all Core Areas once a year for the first 5 years after permit issuance and then as appropriate, but not less frequently than every 8 years thereafter (Dudek & Associates 2003). Reproductive success is defined in the MSHCP as the presence of pupal cases (exuviae) or newly-emerged (teneral) individuals. Because Delhi fly is an endangered species with an extremely limited distribution within the Plan Area, Monitoring Program biologists have surveyed for Delhi fly within the lone accessible Core Area annually since 2005. We describe here the procedure and results of the MSHCP Biological Monitoring Program's 2016 effort to monitor Delhi fly in the Jurupa Hills.

Delhi Sands flower-loving fly has distinctive biological and habitat requirements and faces a number of threats (USFWS 1997). The life cycle of the fly includes egg, larval, pupal, and adult stages. Only the adult stage occurs above-ground, when adults emerge to breed during the summer months. The species is restricted to fine, sandy Delhi series soils, usually with wholly- or partly-stabilized sand dunes and sparse native vegetation. Areas with suitable fly habitat have been highly affected by anthropogenic activities, including conversion to agriculture, residential and commercial development, surface mining for sand, dumping of trash and cow manure, and damage by off-road vehicles. Invasive exotic plants are also thought to degrade fly habitat by increasing vegetation cover or by altering soil conditions through dune stabilization and changes in soil moisture.

The MSHCP Management Program began management actions on-site in 2010 to increase habitat suitability by controlling the spread of non-native vegetation within occupied habitat and opening up more suitable habitat at the edges of the recently occupied area. To assess the effectiveness of these actions we conducted habitat surveys in 2015 and 2016 and compared those results to habitat surveys conducted before management activities took place.

Survey Goals and Objectives

1. Document successful reproduction by Delhi Sands flower-loving fly at the Teledyne site in the Jurupa Hills Core Area.
    a. Record observations of teneral individuals and/or exuviae.

2. Estimate population density of adult Delhi fly during flight season at Teledyne.
    a. Document occurrence of Delhi fly individuals.
    b. Calculate distance sampling-based estimates of population density that account for animal detectability.

3. Determine vegetation and soil characteristics occurring across the Teledyne site and compare site characteristics between sampling years.

4. Document persistence of the population within appropriate habitat and potential expansion of occupied area as a result of vegetation management.
    a. Record observations of adult individuals to potentially assess trends in distribution in response to management activities or other conditions.

5. Monitor the spread of short-pod mustard (*Hirschfeldia incana*) and non-native grasses (Poaceae) across the dune system at the Teledyne site.
    a. Record digital images annually from three photo-stations to document changes in vegetation structure and composition.

METHODS

Protocol Development

We began surveying for Delhi fly in 2005 following the *Interim General Survey Guidelines for the Delhi Sands Flower-loving Fly* (USFWS 1996). These USFWS guidelines were developed to determine presence/absence of Delhi fly by slowly traversing appropriate habitat. We modified the USFWS protocol in 2005 by establishing line-transects and measuring the perpendicular distance between the transect centerline and individual fly observations, with the goal of estimating population density and detection probability following distance sampling methodology (Buckland et al. 2001). This method was used for surveys conducted from 2005-2010, and 2014 to present. Due to personnel and resource limitations, surveys conducted 2011-2013 were reduced to a general site search to simply document successful reproduction. The survey protocol used in 2016 is described more completely in the *Western Riverside County MSHCP Biological Monitoring Program Protocol for Delhi Sands Flower-loving Fly Surveys*, and is available from the Biological Monitoring Program.

Training

All surveyors studied a Delhi fly-specific training manual prepared by the Biological Monitoring Program, relevant invertebrate field guides, and preserved specimens of co-occurring winged invertebrate species. We placed emphasis on the ability to recognize morphological and behavioral field traits of Delhi fly, and proficiency in identifying all co-occurring winged insects to family. We also trained surveyors to differentiate between adult and teneral individuals in a field setting, and to identify plant species common at the Teledyne site. All surveyors participated in field-based training that involved observing, capturing, and identifying co-occurring insects to family. Prior to conducting line-transect surveys independently, surveyors passed the USFWS Delhi fly practical exam.

Study Site Selection and Transect Placement

The Teledyne site is located in the Jurupa Hills along the Riverside-San Bernardino County border in the vicinity of Pyrite Street. The site encompasses 6.24 ha of Delhi series soils and is primarily composed of coastal sage scrub vegetation (Dudek & Associates 2003). Common plants found at the site include *Eriogonum fasciculatum*, *Ambrosia acanthicarpa*, *Amsinckia menziesii*, *Croton californicus*, *Rhus trilobata*, *Brassica* spp., and various non-native grasses.

We established permanent transects at the Teledyne site in 2005 by first delineating Delhi series soils within the target area as identified by the USFWS (1997). We then distributed 32 parallel transects, at 15-m intervals across the delineated area, randomly orienting them along a 28° bearing. Transects were 44 - 222 m in length for an aggregate length of 5.04 km. However, if a transect traversed dense vegetation that made it logistically impossible to walk the transect without significant damage to vegetation, we eliminated those portions of the transect from the survey. The eliminated portions added up to 114 meters in 2016, therefore the total length of the transects actually surveyed was 4.93 km. We marked the centerline of each transect with wooden stakes every 30 - 40 m and flagged shrubs or grasses between stakes to ensure easy navigation of the transect and accurate distance measurements from the transect centerline to observed Delhi fly.

Survey Methods

Line-transect Surveys

We divided the survey area into three sections (aggregate transect length range: 1,462 - 1,815 m) and surveyed each section once or twice a day depending on available personnel. When 2 observers were available, each observer surveyed whole sections and started from opposite ends of the survey site, usually resulting in at least 1 section being surveyed twice per survey day. When only 1 individual was available, the observer surveyed as many whole sections as possible once. We recorded time, general weather description, temperature (°C) in shade 1 m above-ground, average wind speed (mph), and percent cloud cover (0, 1-20, 21-40, 41-60, 61-80, 81-100) at the start and end of each survey. We walked each transect at approximately 1.2 km/h. When we observed a Delhi fly, we immediately marked the initial location of the individual with large metal washers with attached flagging or a pin flag. We ensured accurate distance-to-detection measurements by clearly marking transect centerlines and carefully recording the perpendicular distance between the transect centerline and Delhi fly markers. Observers then recorded transect ID, UTM coordinates, time, sex, activity, age class (1-3) of the detected Delhi fly and photo numbers if photos were taken. Any flies detected during an active survey were recorded on the datasheets; Delhi fly observed outside of an active survey (e.g., before the start time or after the end time of a survey) were recorded as incidental observations. Non-target winged insects were identified to family but distance to detection was not measured. If possible, we took photos of teneral Delhi fly individuals. Surveyors took care to avoid disturbing any individuals that were detected. When Delhi fly exuviae were detected the surveyors recorded the UTMs of the location then placed their GPS unit next to the exuviae (to make the exuviae location more apparent in a photograph), stepped back 1-2 meters and took a photo to include the exuviae and the surrounding habitat. The surveyors then collected the exuviae to avoid double counting it in future surveys.

Vegetation Sampling

Vegetation sampling plots were first established at Teledyne in 2008. We used ArcGIS v. 9.3.1 software (ESRI 2009) and the Hawth's Tools extension (Beyer 2004) to randomly distribute four hundred 2.25 m^2 plots and fifty 100 m^2 plots across the site using a spatially stratified random sampling design. In 2009, to minimize spatial variation between years and thus allow for better year-to-year comparisons of vegetation and soil structure, we re-sampled all four hundred 2.25 m^2 plots, as well as five 2.25 m^2 plots at locations where perched Delhi fly were observed during surveys. In 2010, based on the results of a paired-sample power analysis, the number of plots sampled was decreased to 300. To characterize locations where Delhi fly had been observed, we sampled one 2.25 m^2 plot at each location where a perched Delhi fly was recorded. It was assumed that these locations better indicated a resource usage decision by a given fly, as opposed to observations made of individuals in flight.

For 2016 vegetation surveys, we resampled the same 300 randomly distributed points surveyed in 2010 and 2015 using one 2.25 m^2 plot per point (Fig. 1) in order to characterize the soil and vegetation characteristics of the site as a whole and compare findings across years. We also sampled an additional 38 points where exuviae were found during the survey season (Fig. 1). In each sampling plot, we estimated ground cover in the categories of litter, rock, sand, hardpan, basal stem, and "other" (e.g., concrete). The percent cover of the tree, shrub, and herbaceous layers, as well as percent cover of individual shrub species that were strongly dominant within each plot were estimated. Additionally, we estimated percent cover for species/families that are believed to be positively associated with Delhi fly occurrence (*Eriogonum fasciculatum*, *Croton californicus*, *Ambrosia acanthicarpa*, *Heterotheca grandiflora*, and *Stephanomeria* sp.) or negatively associated with Delhi fly occurrence (*Brassica/Sisymbrium* sp., and non-native grasses; USFWS 1997). While there is evidence that *E. fasciculatum*, *C. californicus*, and *H. grandiflora* are important resources for Delhi fly (USFWS 2008), the importance of *A. acanthicarpa* and *Stephanomeria* sp. is anecdotal and more research is needed. Finally, we measured compactness (kg/cm^2) of undisturbed soil near the center of each plot and at the center of each quarter of the plot in the 4 cardinal directions using a soil penetrometer (Forestry Suppliers, model 77114). Compaction readings in 2016 were increased to 5 per plot in an effort to increase accuracy.

To monitor the spread of invasive mustard (*Hirschfeldia incana*) and non-native grasses (Poaceae) across the dune system, we established 3 permanent photo stations in 2006. We chose to monitor these species because they may pose a threat to Delhi fly through dune stabilization (USFWS 1997) and are included in vegetation management activities by the Management Program at this site. We revisited photo stations again in 2016, and took digital images in the 4 cardinal directions to qualitatively document vegetative cover and species composition. These images are stored with those from previous years and will be used to qualitatively track vegetation changes through time and to visually complement quantitative changes in vegetation if additional sampling is conducted in the future.

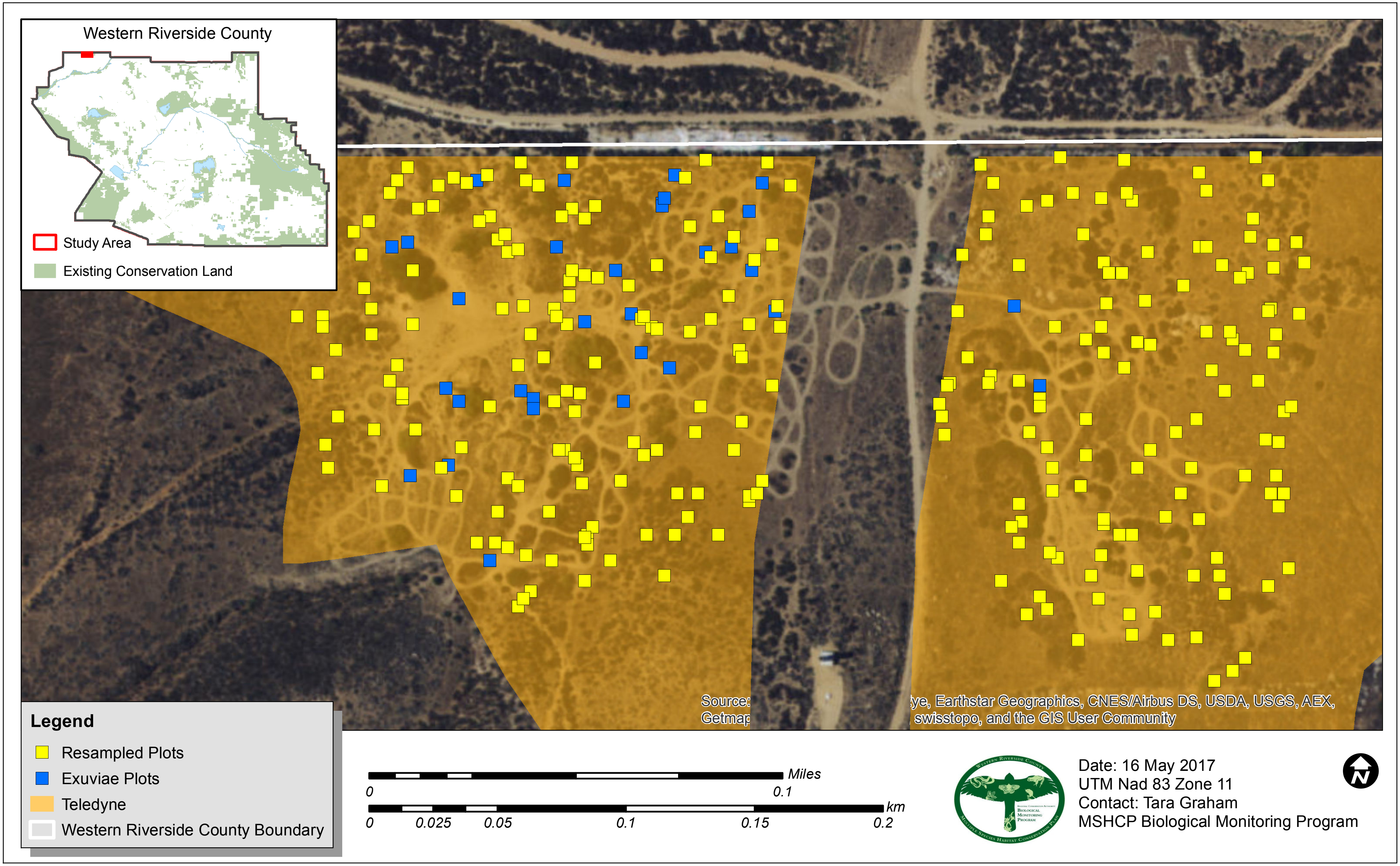

Figure 1. Vegetation sampling plots at Teledyne in 2016.

Data Analysis

Line-transect Surveys

We used distance-sampling methodology and Program DISTANCE to estimate the detection probability and population density of Delhi fly at the Teledyne site in 2016 (Buckland et al. 2001; Thomas et al. 2009). Distance sampling allows for density estimation with incomplete detection of animals (i.e., not all animals present need to be observed to estimate density). The method relies on fitting data to a pre-defined detection function based on the assumption that objects become less detectable with increasing distance from the observer (Buckland et al. 2001). Distance sampling also requires that three assumptions be met: 1) complete detection of subjects on the transect line, 2) subjects are detected at their initial locations, and 3) distances are measured accurately (Buckland et al. 2015). We examined detection histograms (i.e., number of observations per distance category) for the survey period for spikes in the number of observations away from the transect (suggesting violation of assumption 2), and for relatively few observations near the transect centerline in relation to other distance categories (suggesting violations of assumptions 1 and 2).

We pooled data across the entire 2016 survey season to fit a detection function, and derived both stratified (i.e., daily) and pooled (i.e., average daily) estimates of population density. From our dataset, we removed observations beyond 201.4 inches from the transect to avoid fitting detection functions with extended ‘tails’. Lastly, based on recommendations generated by the DISTANCE software pertaining to our dataset, we grouped observations into ten 20-inch distance categories (i.e., 20, 40…200 inches; Buckland et al. 2001).

We evaluated the full combinations of uniform and half normal key functions with cosine, simple-polynomial, and Hermite-polynomial series expansions (Buckland et al. 2001). We did not use the hazard-rate key function because this model function frequently overestimates the unknown parameters unless the detection function curve is tightly matched to the hypothetical curve (Buckland et al. 2001). We assessed model fit by graphical inspection of the detection function and using a chi-square goodness of fit test. We excluded models from the candidate set that demonstrated significant lack of fit based on the above criteria. We ranked competing models using Akaike's Information Criterion adjusted for small sample size (AICc).

Vegetation Sampling

Analysis of 2016 Vegetation Data

We summarized data from the 300 randomly-distributed 2.25-m^2 vegetation plots by mean percent cover and by percent presence (percentage of plots on which plant species were recorded). Although we only recorded the 3 most dominant species in each vegetation class, plus the 7 species/families that were presumed to be associated with Delhi fly occurrence, percent presence still provides a useful measure of the distribution of species with substantial percent cover. Likewise, mean percent cover for species not recorded in each plot may be biased slightly low, but we provide the results to give the reader a general sense of the cover of each species. Furthermore, we surveyed 38 additional vegetation plots centered on coordinates where exuviae were observed to explore whether there were differences in vegetation or ground cover characteristics.

Comparison of 2008-2016 Vegetation Data

Following the 2016 data summarization, we extracted data that were collected on the same 300 plots during 2008-2010 and 2015-2016 Delhi fly vegetation surveys to compare site characteristics between sampling years using paired t-test analyses.

Analysis of Vegetation Characteristics as a Result of Management Activities

The MSHCP Management Program has been actively managing the Teledyne site since 2010 in an effort to increase habitat suitability for Delhi fly (RCA 2014). Management activities have included *E. fasciculatum* transplanting, dead vegetation removal, various intensities of selective weeding, and mechanical sand destabilization. We compared the resampled plots between 2010 (pre-management) and 2016 (post-management) to see if management actions resulted in continued significant changes to relevant habitat characteristics and Delhi fly suitability, using paired sample t-tests. The plot data collected during the two post-management years (2015 and 2016) was also summarized and compared using paired sample t-tests. We expected vegetation characteristics in pre-management plots in 2010 to be significantly different from post-management plots in 2016 as a result of the various management actions, with less significance detected between 2015 and 2016.

Analysis of Vegetation Characteristics Surrounding Exuviae Locations

We compared the resampled plots in 2016 to the locations where Delhi fly exuviae were found during our 2016 Delhi fly surveys to see if there were significant differences in habitat characteristics. This data was summarized and compared using Welch's two sample t-tests. We expected the exuviae plots to be significantly different from the resample plots.

RESULTS

Line-transect Surveys

We began 2016 line-transect surveys on 28 June after detecting the first Delhi fly at Teledyne during a scouting survey on 20 June, and ended the surveys on 18 August after no Delhi fly were observed for 4 consecutive survey days. In total, we conducted surveys on 24 days between 09:19 h and 14:30 h. We walked a total of 140 km over the course of the 24 survey days which resulted in 0.65 Delhi fly observations per km surveyed. We observed adult Delhi fly on transects on 91 occasions with observations ranging from 28 June to 9 August (Fig 2; note that the blank strip through the middle of the figure is a Metropolitan Water District parcel not currently included in the MSHCP Conservation Area). Of those observations, 56 were male, 30 were female, and 5 were of indeterminate sex. Additionally, 9 teneral individuals were observed while conducting surveys. We observed 7 adult individuals incidentally, defined as observations occurring before or after an active survey.

A total of 43 exuviae were collected in 2016, with 42 collected during active surveys and 1 collected incidentally (Fig. 2). Exuviae are expected to degrade relatively quickly if not discovered, so their presence in a given survey year is assumed to represent emergence of new individuals in the year of discovery. Any exuviae observed were collected by surveyors to avoid over-counting in subsequent surveys.

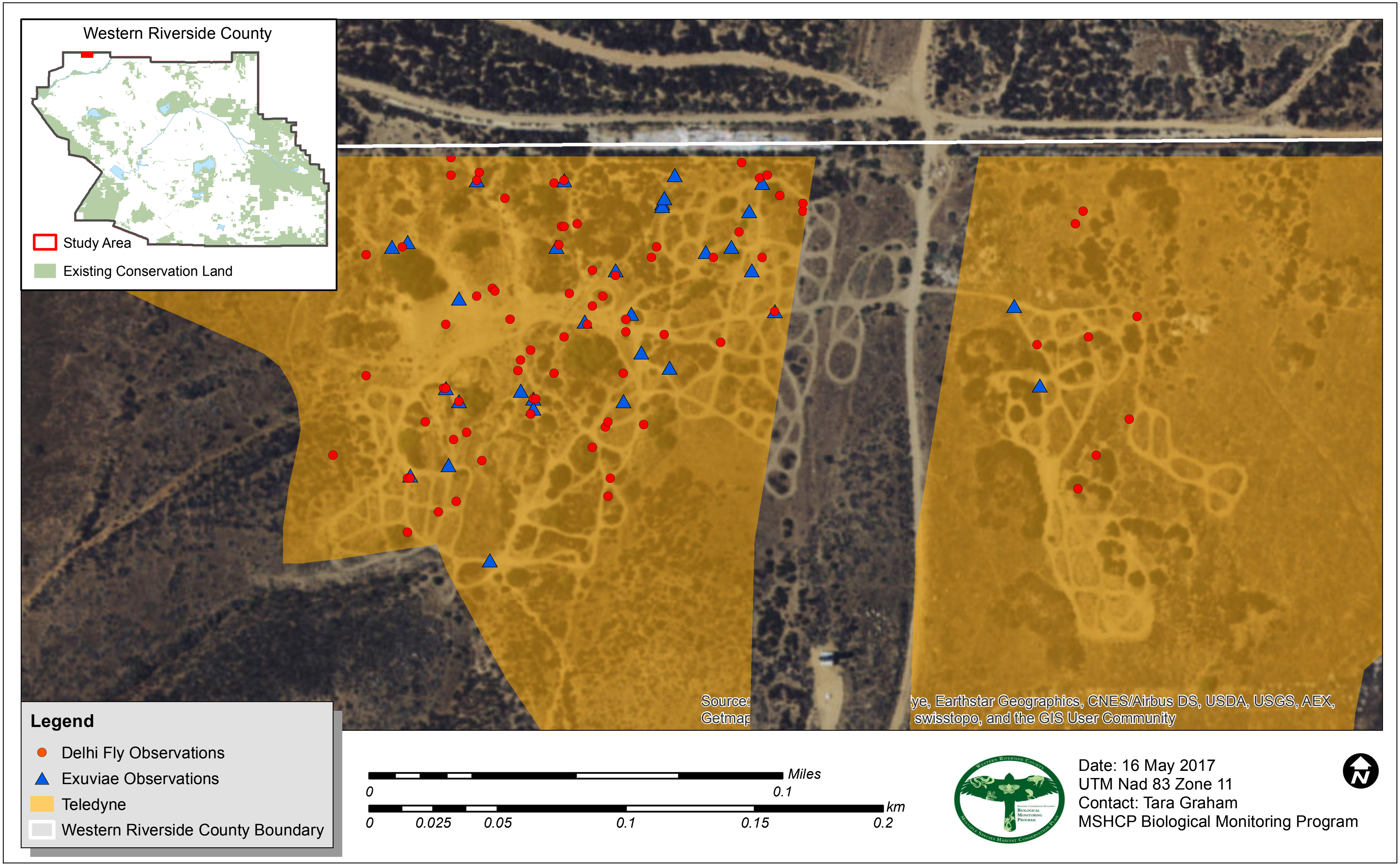

Figure 2. Delhi Sands flower-loving fly detections at Teledyne in 2016.

The distribution of exuviae was fairly even throughout the upper dunes; this is in contrast to concentrations of exuviae northwest of the open dune observed in past years. This shift in exuviae occurrence (i.e., Delhi fly emergence) might be contributed to the management of invasive vegetation and the clearing of vegetation from the paths in this area.

The density estimate for Delhi fly at Teledyne was 1.3 individuals/ha (95% CI: 0.97 - 1.7) and the detection probability was 0.43 (95% CI: 0.37 - 0.51). All 3 of the top performing models (half-normal key function with a cosine, simple polynomial, and hermite polynomial expansion) resulted in the same density estimate and detection probability values. The fourth top ranked distance model (uniform key function with a simple polynomial expansion) was within 1.96 delta AICc of the 3 top performing models, meaning that the half-normal models were somewhat superior to the uniform model in describing the 2016 data. We visually checked the detection function curve shape criterion and confirmed an appropriate detection function curve for each model. The 2016 density estimate is a considerable increase from 2015 (0.86 individuals/ha). Estimated Delhi fly density peaked early in the season (7 - 12 July), and then declined sharply around 28 July to below 1 individual/ha through the remainder of the season.

Vegetation Sampling

Results of 2016 Vegetation Data Analysis

Vegetation sampling took place over 21 days in 2016, beginning 27 September and ending on 18 November. Total mean vegetation cover estimated for the 300 resampled plots had a value of 21.8% (SE ± 1.5). Mean vegetation cover values for the 3 vegetation classes within those plots were: shrubs = 12.9% (SE ± 1.4), forbs/grasses = 6.6% (SE ± 0.4), and trees = 2.3% (SE ± 0.8). Additionally, we recorded 31 species and 2 families in a dominant category at least once (Table 1).

On the 300 resampled plots we found the family group Brassicaceae present on 44% of plots and the family group Poaceae present on 96% of plots. The most common individual species were Poaceae (recorded on 96% of plots), Brassicaceae (44%), *Croton Californicus* (32%), *Amsinckia menziesii* (32%) and *Verbesina encelioides* (31%) (Table 1). The dominant individual species, by mean percent cover, were *E. fasciculatum* (6.8%), Poaceae (3.3%), *Rhus aromatica* (3.2%), *Sambucus nigra ssp. canadensis* (1.4%), and *Verbesina encelioides* (0.84%). Values may be biased high from the true sample statistic as they do not contain plots where the species were absent.

Total mean vegetation cover estimated on the exuviae plots had a mean value of 4.7% (SE ± 0.8). Mean vegetation cover values for the 3 vegetation classes within those plots were: shrubs = 2.6% (SE ± 0.6), forbs/grasses = 2.2% (SE ± 0.4), and trees = 0% (SE ± 0). Additionally, we recorded 11 species in a dominant category at least once (Table 1).

On the 38 exuviae plots, we found the family group Brassicaceae present on 66% of plots and the family group Poaceae present on 97% of plots. The most common individual species were Poaceae (recorded on 97% of plots), Brassicaceae (66%), *Croton Californicus* (42%), *Ambrosia acanthicarpa* (37%) and *E. fasciculatum* (32%) (Table 1). The dominant individual species by mean percent cover were *E. fasciculatum* (1.5%), Poaceae (1.5%), *Croton Californicus* (0.9%), *Ambrosia acanthicarpa* (0.2%) and Brassicaceae (0.2%). Values may be biased high from the true sample statistic as they do not contain plots where the species were absent.

Table 1. Most common plant species and families recorded across 300 resampled vegetation plots and 38 exuviae plots in 2016. Target species/families are listed in bold; all other species/families were recorded as 1 of the 3 dominant species in at least one plot. Species that are underlined are hypothesized as having a positive association with the Delhi fly. Standard error (SE) is only reported for target species/families.

	Percent presence		**Mean percent cover**	
Plant species/family	**Resampled**	**Exuviae**	**Resampled**	**Exuviae**
Poaceae	**96**	**97**	**3.32 (SE ± 0.25)**	**1.48 (SE ± 0.36)**
Brassicaceae	**44**	**66**	**0.49 (SE ± 0.08)**	**0.18 (SE ± 0.05)**
Croton californicus	**32**	**42**	**0.74 (SE ± 0.10)**	**0.91 (SE ± 0.35)**
Amsinckia menziesii	32	29	0.35	0.35
Verbesina encelioides	31	24	0.84	0.84
Eriogonum fasciculatum	**22**	**32**	**6.83 (SE ± 1.20)**	**1.54 (SE ± 0.57)**
Phacelia ramosissima	19	8	0.74	0.74
Rhus aromatica	13	5	3.19	3.19
Ambrosia acanthicarpa	**7**	**37**	**0.16 (SE ± 0.03)**	**0.22 (SE ± 0.12)**
Erodium cicutarium	7	-	0.46	0.46
Acmispon glabrus	7	-	0.01	0.01
Unidentified forb/grass	6	3	0.02	0.02
Encelia farinosa	5	-	0.5	0.5
Lessingia glandulifera	5	5	0.06	0.06
Centaurea melitensis	4	-	0.11	0.11
Keckiella antirrhinoides	3	-	0.83	0.83
Corethrogyne filaginifolia	3	-	0.06	0.06
Sambucus nigra ssp. *canadensis*	3	-	1.41	1.41
Prunus ilicifolia	2	-	0.83	0.83
Marrubium vulgare	2	-	0.08	0.08
***Stephanomeria* sp.**	**2**	**-**	**0.03 (SE ± 0.02)**	**0 (SE ± 0)**
Salvia mellifera	2	-	0.4	0.4
Camissonia sp.	2	-	0.01	0.01
Eriogonum gracile	1	-	0.002	0.002
Adenostoma fasciculatum	1	-	0.2	0.2
Artemisia californica	1	-	0.09	0.09
Ericameria pinifolia	1	-	0.11	0.11
Helianthus annuus	1	-	0.07	0.07
Heterotheca grandiflora	**0.3**	**-**	**0.03 (SE ± 0.03)**	**0 (SE ± 0)**
Rhamnus crocea	0.3	-	0.06	0.06
Cryptantha muricata	0.017	-	0.003	0.003
Crassula connata	0.003	-	0.0007	0.0007
Unidentified shrub	0.003	-	0.01	0.01

Comparison of 2008-2016 Vegetation Data

To compare ground cover and vegetation class cover at the Teledyne site over sampling years, data collected during the 2008, 2009, 2010, 2015, and 2016 sampling efforts were summarized (Table 2). Only plots that were resampled during each survey effort were extracted (n = 300) and data were examined for integrity. Several plots were excluded from the ground cover and vegetation class cover comparison due to data inconsistencies (e.g., missing data, ground cover variables not adding up to 100 ± 1%). Comparisons between years show that the proportion of total sand increased and total vegetation decreased, attributed mostly to a decrease in forbs/grasses. The average soil compactness continued its downward trend; however, this measurement is not directly comparable to previous years due to the increased compaction readings taken within each plot.

Ground cover results for the resampled plots in 2016, in order from highest to lowest percent cover, were sand (58.6%, SE ± 1.9), litter (39.1%, SE ± 1.8), bare ground-other (1.1%, SE ± 0.5), basal stem (0.9%, SE ± 0.06), rock (0.3%, SE ± 0.1), and hardpan (0%) (Table 2). Mean soil compactness was 0.36 kg/cm^2 (SE ± 0.02).

Table 2. Comparisons between average ground cover percentages, average vegetation class cover percentages, and soil compactness across sites sampled during 2008-2016. The summarization only includes plots that were resampled each year that vegetation surveys took place, as well as the 38 exuviae plots. Several plots were excluded from the summarizations due to data inconsistencies, as discussed in the body of the report. Ground compaction measurements were not collected in 2008.

Variable	Exuviae 2016	2016	2015	2010	2009	2008
Ground cover						
Number of plots	38	295	286	298	287	296
Hardpan (%)	-	-	-	0.2	-	0.1
Loose sand (%)	NA	NA	14.3	31.2	40.8	45.3
Stabilized sand (%)	NA	NA	35.5	7.4	7.4	24.2
Total sand (%)	90.6	58.6	49.8	38.6	48.2	69.4
Other bare ground (%)	0.04	1.1	0.7	1.2	1.5	-
Basal stem (%)	0.5	0.9	1.0	0.6	0.9	0.5
Litter (%)	9.0	39.1	47.8	58.9	49.4	28.9
Rock (%)	0.1	0.3	0.8	0.6	0.2	1.1
Soil compactness (Kg/cm^2)	0.12	0.36	0.44	0.57	0.41	NA
Vegetation classes						
Number of plots	38	300	300	298	298	298
Forbs/Grasses (%)	2.2	6.6	17.0	23.6	20.0	13.8
Shrubs (%)	2.6	12.9	18.1	8.2	6.2	4.6
Trees (%)	-	2.3	2.5	1.4	1.4	1.0
Total vegetation (%)	4.7	21.8	36.4	32.0	26.9	19.5

Comparisons between 2010 resampled vegetation plots and 2016 resampled vegetation plots using a paired t-test show a significant decrease for the mean percent cover of *Ambrosia acanthicarpa*, Poaceae and *Stephanomeria*. The mean percent cover of

Eriogonum fasciculatum significantly increased between years (Table 3). Comparisons between 2015 resampled vegetation plots and 2016 resampled vegetation plots using a paired t-test show a significant decrease for the mean percent cover of *Ambrosia acanthicarpa,* Brassicaceae, *Croton californicus, Eriogonum fasiculatum,* Poaceae and *Stephanomeria* 2016 **(**Table 4).

Table 3. Results of paired t-test comparisons between target species/family mean percent coverage across 300 vegetation sampling plots in 2010 and 2016. Species are divided by hypothesized positive and negative associations with Delhi fly, respectively. **Bold** indicates significant differences between sampling years. The number in ( ) indicates the percent presence.

	Mean percent cover (% present)			
Target species/family	**2010**	**2016**	**P-value**	**95% CI**
Ambrosia acanthicarpa	2.79 (48)	0.16 (7)	**< 0.001**	(2.017, 3.401)
Croton californicus	0.99 (26)	0.74 (32)	0.271	(-0.147, 0.521)
Eriogonum fasciculatum	2.92 (11)	6.83 (22)	**0.002**	(-5.877, -1.270)
Heterotheca grandiflora	0.01 (1)	0.03 (0.3)	0.508	(-0.072, 0.036)
Stephanomeria sp.	2.35 (41)	0.03 (2)	**< 0.001**	(0.107, 0.321)
Brassicaceae	0.92 (35)	0.49 (44)	0.071	(-0.043, 1.031)
Poaceae	6.17 (87)	3.32 (96)	**< 0.001**	(2.434, 4.370)

Table 4. Results of paired t-test comparisons between target species/family percent coverage across 300 vegetation sampling plots in 2015 and 2016. Species are divided by hypothesized positive and negative associations with Delhi fly, respectively. **Bold** indicates significant differences between sampling years. The number in ( ) indicates the percent presence.

	Mean percent cover (% present)			
Target species/family	**2015**	**2016**	**P-value**	**95% CI**
Ambrosia acanthicarpa	2.20 (40)	0.16 (7)	**< 0.001**	(1.511, 2.583)
Croton californicus	1.49 (34)	0.74 (32)	**<0.001**	(0.319, 1.103)
Eriogonum fasciculatum	9.52 (29)	6.83 (22)	**0.013**	(0.575, 4.839)
Heterotheca grandiflora	0.02 (1)	0.03 (0.3)	0.937	(-0.069, 0.064)
Stephanomeria sp.	0.24 (13)	0.03 (2)	**< 0.001**	(1.284, 1.581)
Brassicaceae	2.49 (63)	0.49 (44)	**< 0.001**	(1.390, 2.630)
Poaceae	5.02 (94)	3.32 (96)	**< 0.001**	(0.693, 2.701)

Comparisons between 2016 resampled vegetation plots and 2016 exuviae vegetation plots using Welch's two sample t-test show that mean percent cover of *Ambrosia acanthicarpa* was significantly higher on exuviae plots than on the resampled plots **(**Table 5). The mean percent cover of Brassicaceae, *Eriogonum fasciculatum,* Poaceae, *Stephanomeria* and the average soil compactness was significantly lower on the exuviae plots than the resampled plots. Ground cover results for the exuviae plots, in order from highest to lowest percent cover, were sand (90.6%, SE ± 2.5), litter (9.0%, SE

± 2.5), basal stem (0.5%, SE ± 0.1), rock (0.1%, SE ± 0.03), bare ground (0.04%, SE ± 0.01), and hardpan (0%) (Table 2).

Table 5. Results of Welch two sample t-test comparisons between target species/family percent coverage across 300 resampled vegetation sampling plots and 38 exuviae plots in 2016. Species are divided by hypothesized positive and negative associations with Delhi fly, respectively. **Bold** indicates significant differences between the two types of sampling plots. The number in ( ) indicates the percent presence.

	Mean percent cover (% present)			
Target species/family	**Exuviae**	**Resampled**	**P-value**	**95% CI**
Ambrosia acanthicarpa	0.22 (37)	0.16 (7)	< **0.001**	(-0.307, 0.177)
Croton californicus	0.91 (42)	0.74 (32)	0.646	(-0.892, 0.559)
Eriogonum fasciculatum	1.54 (32)	6.83 (21)	< **0.001**	(2.684, 7.907)
Heterotheca grandiflora	0 (0)	0.03 (0.003)	0.318	(-0.026, 0.079)
Stephanomeria sp.	0 (0)	0.03 (2)	**0.040**	(0.001, 0.061)
Brassicaceae	0.18 (66)	0.49 (40)	< **0.001**	(0.128, 0.500)
Poaceae	1.48 (97)	3.32 (95)	< **0.001**	(0.957, 2.715)

DISCUSSION

In 2016, our goals were to document successful reproduction by Delhi fly at Teledyne, estimate population density of adult Delhi fly to compare to previous estimates, and document persistence of the population within appropriate habitat. We also returned to a quantitative evaluation of vegetation and habitat conditions, with particular reference to recent management onsite.

We confirmed successful Delhi fly reproduction again at Teledyne in 2016, documenting 9 teneral individuals and 43 exuviae. Density estimates and observations per km in 2016 increased considerably from 2015 (Fig. 3). The daily density estimate in 2016 was 1.3 individuals/ha as compared to 0.86 in 2015. However, this density estimate is still substantially lower than peak values seen in 2009 (2.76 individuals/ha). As noted above, estimated Delhi fly density peaked from 7 - 12 July, then after a steep decline on 28 July settled at a density below 0.73 individuals/ha until 9 August when the last Delhi fly was seen. The density peak in 2016 occurred only 1 day later than the peak in 2015.

The number of Delhi fly observations per km surveyed was 0.65 in 2016, comparable to the rate increase observed between 2014 (0.21 observations/km) and 2015 (0.45 observations/km). Again, these metrics are lower than peaks seen in 2009 (0.90 observations/km) and 2010 (0.75 observations/km). From 2011-2013 the survey protocol did not include walking the pre-established transects; thus comparable data are unavailable for those years.

As similarly noted in previous years, we detected most Delhi fly individuals in the western section of the site, where soils are generally more sandy and loose and vegetation is less dense. Furthermore, surveyors generally detected Delhi flies on the edges of vegetation, rather than in middle of the open sand dune or in the middle of thicker patches of shrubs or trees.

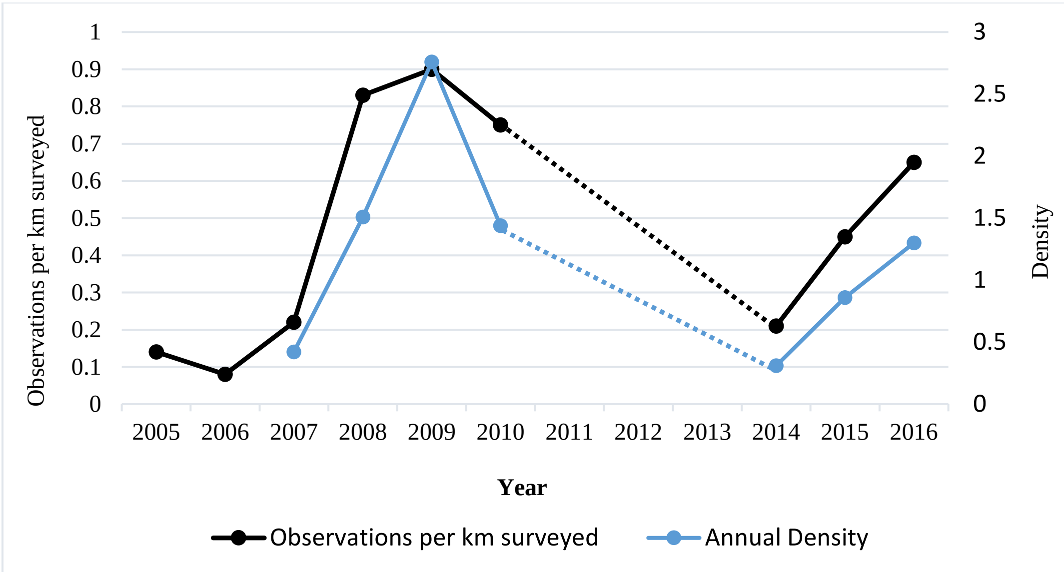

Figure 3. Delhi Sands flower-loving fly observations per km surveyed and annual density estimates (individuals per ha) from 2005-2016. Surveys from 2011-2013 were conducted following a different protocol, therefore those data are excluded. From 2005-2006 and 2011-2013 there were insufficient data to obtain densities, therefore those years are excluded.

We began survey efforts relatively early in the year (28 June) as individuals have been consistently observed in July in recent years. This remains noteworthy as the USFWS Recovery Plan states that the flight season historically did not begin until early August (USFWS 1997). We officially ended surveys on 18 August after four consecutive unsuccessful surveys. The final individual was observed on 9 August.

Recent management activities by the MSHCP Management Program at Teledyne seem to be preliminarily successful at improving site conditions for Delhi fly. Density estimates and observations per km increased considerably from 2015 to 2016. Many of the vegetation metrics tracked from pre- (2010) and post- (2016) management activities show beneficial effects (e.g., a decrease in the percent cover of Poaceae and Brassicaceae as well as average soil compactness, and higher *H. grandiflora and E. fasciculatum* than would have been expected without management). Between the 2 post-management years (2015 and 2016) many of the target species, both the positively and negatively associated with the Delhi fly, declined in percent cover which may be attributed to management goals of increasing total percent cover of sand. Comparisons between the 300 resampled plots and the exuviae plots indicated that there is significantly less mean percent cover of Brassicaceae, Poaceae and *E. fasciculatum* on the exuviae plots than on the plots where exuviae was not located; mean vegetative cover overall was also lower on exuviae plots than the resampled plots. The soil compaction values show the soil is 3 times less compact on the exuviae plots (Table 2). Stabilization of Delhi series soils onsite remains a concern even though data shows that the average soil compactness measurements have gone down and overall percentage of total sand has gone up in the last year. A management concern for future years may be preventing Delhi series sand from shifting or blowing offsite. When comparing the density of the Delhi fly at Teledyne and the percent cover of *Heterotheca grandiflora* across the years, there appears to be no dependency of the Delhi fly on this plant species, as had previously been thought (USFWS 2008).

Recommendations

The species-specific monitoring objective for Delhi Sands flower-loving fly states that successful reproduction shall be documented at all Core Areas once a year for the first 5 years after permit issuance and then as appropriate, but not less frequently than every eight years thereafter. The MSHCP permit was issued in 2004; therefore, further surveys to document successful annual reproduction of Delhi fly are not strictly mandated. However, given the endangered status of the species and the minimal effort required to document successful reproduction at the sole occupied site within the Plan Area, we should continue to monitor the Delhi fly annually so long as personnel are available.

Furthermore, evaluating the efficacy of ongoing efforts by the Management Program to improve habitat conditions for Delhi fly at Teledyne requires the more intensive line-distance transect study design. Density estimates during and post-management can then be compared to earlier measures to track the population status of Delhi fly onsite. Modeling density and detection probability is important as it allows us to regularly estimate the density of individuals and determine whether changes in the number of detections are due to changes in fly abundance or changes in detectability. Line transect sampling allows us to model detection probability and density in order to better describe population changes at occupied sites, especially as active habitat management continues. We plan to conduct the more demanding line-transect study again in 2017 to continue to monitor impacts of management activities and Delhi fly population fluctuations. Vegetation and soil characteristics should continue to be monitored in conjunction with ongoing management actions conducted as described by the Delhi Sands Flower-loving Fly Habitat Management Plan (Marchant 2005) and Delhi Sands Flower-loving Fly Habitat Management Update (RCA 2014).

In addition to the vegetation surveys we recommend performing ground-dwelling arthropod surveys in order to track the impact of Brassicaceae on the relative abundance and richness of the arthropod community. This could additionally serve as a habitat quality indicator of the Delhi sand dunes at Teledyne (Hulton et al. 2013).

Lastly, we recommend installing a weather station onsite to enable the collection of environmental parameters (e.g., air and substrate temperature, precipitation, soil moisture at multiple depths, humidity). Tracking these environmental parameters over time may help us to identify trends that influence Delhi fly emergence and abundance, and contribute to a better understanding of Delhi fly biological requirements.

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