Western Riverside County
Multiple Species Habitat Conservation Plan (MSHCP)
Biological Monitoring Program

Delhi Sands Flower-loving Fly
(*Rhaphiomidas terminatus abdominalis*)
Survey Report 2009

23 April 2010

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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. The Monitoring Program monitors the distribution and status of the 146 Covered Species 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 Game and the U.S. Fish and Wildlife Service). Monitoring Program activities are guided by the MSHCP species objectives for each Covered Species, the information needs identified in MSHCP Section 5.3 or elsewhere in the document, and the information needs of the Permittees.

MSHCP reserve assembly is ongoing and it is expected to take 20 or more years to assemble the final Conservation Area. The Conservation Area includes lands acquired for conservation 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 the Conservation Area as understood by the Monitoring Program at the time the surveys were planned and conducted.

We would like to thank and acknowledge the land managers in the MSHCP Plan Area, who in the interest of conservation and stewardship facilitate Monitoring Program activities on the lands for which they are responsible. A list of the lands where data collection activities were conducted in 2009 is included in Section 7.0 of the Western Riverside County Regional Conservation Authority (RCA) Annual Report to the Wildlife Agencies. Partnering organizations and individuals contributing data to our projects are acknowledged in the text of appropriate reports.

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.

The primary preparer of this report was 2009 Project Lead, Nate Zalik. If there are any questions about the information provided in this report, please contact the Monitoring Program Administrator. If you have questions about the MSHCP, please contact 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*; DSF) 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 currently occur, or to have occurred in the past, within the following 3 Core Areas: Jurupa Hills, Agua Mansa Industrial Center, and Mira Loma (Dudek & Associates 2003). To date, conservation of the species has only occurred within the Jurupa Hills Core Area (Teledyne site, 6.24 ha). Species-specific objective 2 in the MSHCP 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 as the presence of pupal cases or newly emerged (teneral) individuals. We describe here the procedure and results of our 2009 effort to monitor DSF at the Teledyne site in the Jurupa Hills.

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

We began surveying for DSF at the Teledyne site in 2005. The primary goal of our survey was to evaluate if DSF were successfully reproducing, with secondary goals of estimating DSF detectability and density and gathering data on DSF habitat associations. Detectability is important because the federal Recovery Plan for DSF requires information on population density and trends (USFWS 1997), which typically require associated detection probability estimates. Total DSF detections were relatively low from 2005 through 2007 and therefore did not allow us to model detectability. We detected a greater number of DSF in 2008, allowing us to model detectability for the first time. Continuing to model detection probability is important, as it will allow us to determine whether annual changes in the number of detections are due to changes in DSF abundance or changes in detectability. DSF habitat associations have been difficult to determine, either due to few DSF detections (2005-2007) or to measured habitat features being poorly correlated with DSF presence (2008).

In an effort to better estimate fine-scale area use by DSF and DSF habitat associations, we conducted a pilot project in 2009 to map individual DSF movements. Anecdotal observations indicate that male DSF may defend territories. We hoped to better understand DSF territorial behavior, home range size, and habitat preferences by recording DSF movements and habitats utilized. We could use these data to sample vegetation in known DSF home ranges. We therefore tested the feasibility of following individual adult DSF to determine adult DSF territoriality, home range size, and habitat use.

Unanswered questions entering the 2009 field season included: 1) Are annual changes in the number of DSF detections due to changes in abundance or changes in detection?, 2) What measurable habitat features are associated with DSF presence?, 3) Do adult DSF hold territories, and if so, what is their territory size?. Given that detection modeling is the key to reliably documenting population trends important to assessing recovery status and the continued need for quantifiable descriptions of DSF habitat to guide future management efforts towards species recovery, we established the following survey goals and objectives for 2009.

Survey Goals and Objectives:

1) Document successful DSF reproduction at Core Areas currently in conservation.
    a. Record observations of teneral individuals and/or pupal cases (exuviae).

2) Estimate population density of adult DSF during flight season at Core Areas currently in conservation.
    a. Calculate distance-sampling-based estimates of population density that account for animal detectability.

3) Test and refine protocol for surveying adult DSF.
    a. Improve the marking of transect centerlines.
    b. Improve the accuracy of distance-to-detection measurements.

4) Quantify DSF resource selection and identify potentially important habitat characteristics that may drive species distribution.
    a. Model effect of soil compactness and tree, shrub, and herbaceous plant cover on DSF distribution.

5) Monitor the spread of short-pod mustard (*Hirschfeldia incana*) and non-native grasses (Poaceae) across the dune system at the Teledyne site.
    a. Take annual digital images from 3 photo stations to document temporal changes in vegetation structure and composition.

6) Test method of mapping adult DSF territories to refine distribution and habitat use model.
    a. Follow individual adult DSF and map territories with handheld GPS units.

METHODS

Protocol Development

We began conducting surveys for DSF 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 DSF by slowly traversing appropriate habitat. We modified the USFWS protocol 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). We have continued to use this basic protocol, with minor adjustments, to survey for DSF since 2005. Specifically, we have increased our survey frequency from once to twice per day. We also increased our efforts to satisfy the assumptions of distance sampling, including accurately measuring distances and improving the marking of transect centerlines. The 2009 survey protocol is described more completely in the *Western Riverside County MSHCP Biological Monitoring Program Protocol for Delhi Sands Flower-loving Fly Surveys, dated June 2009* (Appendix A).

Personnel and Training

All field observers studied pinned specimens of co-occurring winged invertebrate species, a DSF-specific training manual prepared by the Biological Monitoring Program, and relevant invertebrate field guides. We placed emphasis on the ability to recognize morphological and behavioral field traits of DSF, and proficiency in identifying all co-occurring winged insects to family. We also trained observers to differentiate between adult and teneral individuals, and to identify plant species common at the Teledyne site. All observers participated in field-based training that involved observing, capturing, and identifying co-occurring insects to family. All field observers who conducted line-transect surveys passed the USFWS DSF practical exam and observed adult DSF in the field before participating in 2009 surveys.

Biological Monitoring Program personnel were funded by the California Department of Fish and Game or the Regional Conservation Authority. The following personnel conducted DSF surveys in 2009:

- Nate Zalik (Project Lead, Biological Monitoring Program)
- Masanori Abe (Biological Monitoring Program)
- Kim Freeburn-Marquez (Biological Monitoring Program)
- Ana Hernandez (Biological Monitoring Program)
- Ariana Malone (Biological Monitoring Program)
- Lynn Miller (Biological Monitoring Program)
- Ashley Ragsdale (Biological Monitoring Program)
- Jonathan Reinig (Biological Monitoring Program)
- Liliana Santilli (Biological Monitoring Program)[1]
- Annie Bustamante (Biological Monitoring Program)[2]
- Karyn Drennen (Biological Monitoring Program)[2]
- Jeff Galvin (Biological Monitoring Program)[2]

[1] Did not participate in line transect surveys, only in territory mapping and vegetation surveys
[2] Did not participate in line transect surveys, only in vegetation surveys

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 (Figure 1). 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, Rhus trilobata Brassica spp., Croton californicus,* and various non-native grasses. We noted frequent off-road vehicle use at the Teledyne site in previous survey years, but such use has declined in the past year following fence installation around the site.

We established permanent transects at the Teledyne site in 2005 by first delineating our survey area as Delhi series soils mapped by the USFWS (1997) (Figure 1). We then distributed 32 parallel transects with 15-m spacing across mapped Delhi soils, randomly orienting them along a 28° bearing. Transects ranged between 50 and 220 m in length for a total aggregate length of 5.04 km. We have continued to use these transects annually since 2005. In 2009, we excluded 120 m of transect length (2.4% of the total) because these portions intersected with impenetrable vegetation (e.g., *Prunus ilicifolia* or *Rhus trilobata*), reducing our total transect length to 4.92 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 fly observations. We placed pin flags between stakes to mark the transect centerlines in areas with little vegetation.

Survey Methods

Line-transect Surveys

We began weekly visits to the Teledyne site in mid-June 2009 to determine the beginning of the DSF flight season. We first observed DSF on 1 July, and began conducting line transect surveys on 2 July. We conducted surveys once (n = 11 days) or twice (n = 28 days) daily (i.e., morning and afternoon), depending on personnel availability. When personnel were limited, we did not conduct afternoon surveys because data from previous years indicate that DSF are less detectable in the afternoon (see 2008 DSF report). Morning surveys began between 0930 and 1015 and afternoon surveys began between 1145 and 1230. We conducted surveys on 39 days, ending on 31 August after the number of DSF observations decreased to 2 or fewer per day for 11 consecutive days. We divided Teledyne into 3 sections (total transect length range: 1532-1838 m) and surveyed each concurrently with 1 observer per section. 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, end, and on hourly intervals of each survey (Appendix B). We walked each transect at approximately 1.2 km/h, and recorded the perpendicular distance between the transect centerline and each DSF observation (initial sighting). We marked the initial DSF sighting to facilitate accurate measurement by placing a marker on the ground. We also recorded transect ID, UTM coordinates, time, sex, activity, and age class (1-3) of each DSF detected during a survey (Appendix B). We recorded flies detected while not walking transects as incidental observations. Non-target winged insects were identified to

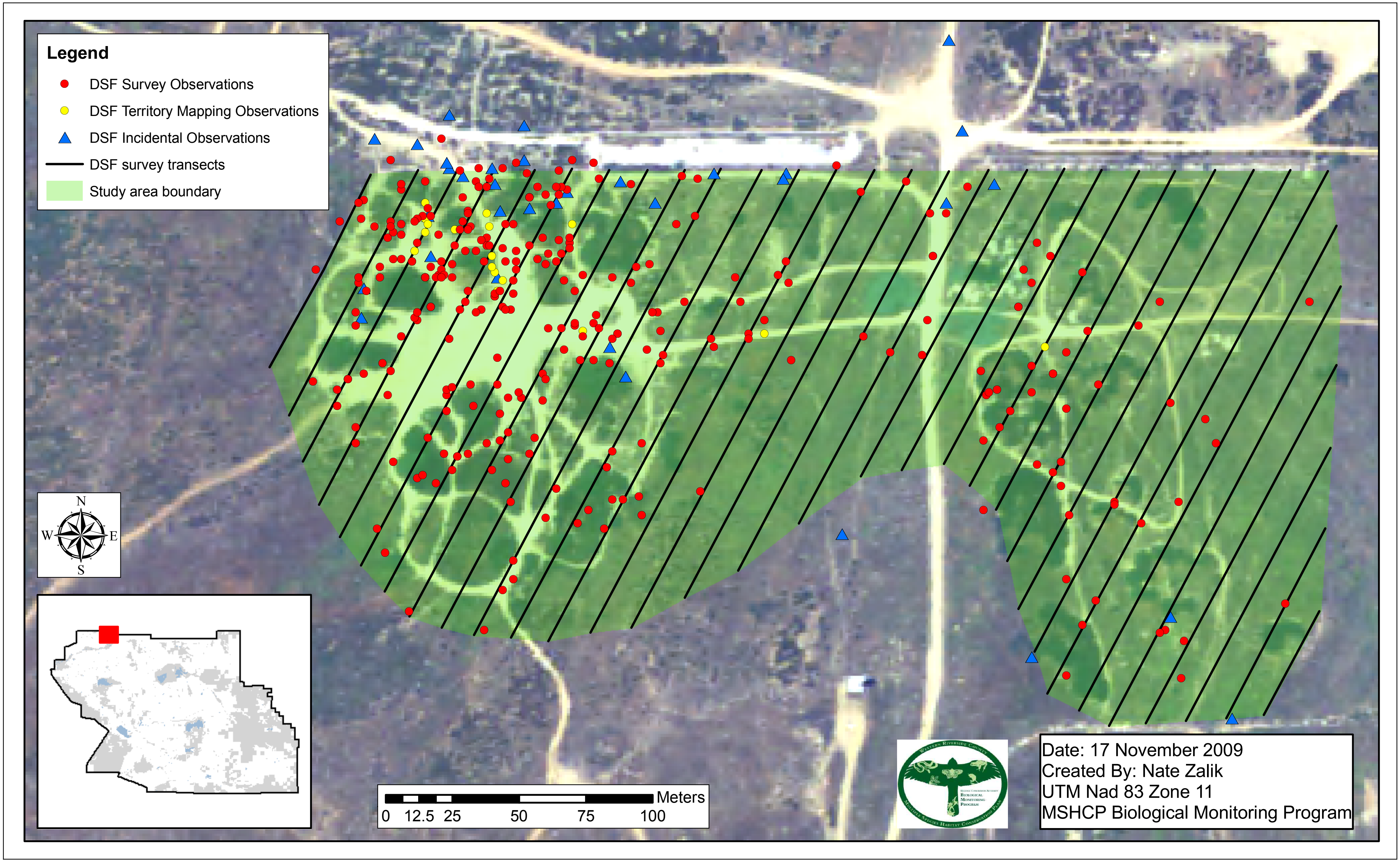

Figure 1. Delhi sands flower-loving fly observations and transect lines in 2009

family, but distance to detection was not measured. If possible, we took photos of teneral DSF individuals.

Territory Mapping

We conducted a pilot effort in 2009 to map territories of individual adult DSF. Our goal was to assess the feasibility of following flies to gather information on adult DSF territoriality, home range, and habitat use. We conducted mapping surveys beginning at 0730 and ending before the daily line-transect surveys began (typically around 1000) to avoid interference between efforts. We searched for DSF in teams of 2 in areas where the species was observed during the previous day's line-transect survey. We then followed DSF for as long as possible, marking the perimeter of the area over which the DSF flew with pin flags. We placed double pin flag markers at locations where DSF had perched, or where any unusual behavior occurred (e.g., interspecific or intraspecific interaction, oviposition, nectaring, etc.). We then mapped the perimeter of the area covered by the observed DSF with a GPS unit (Garmin eTrex Legend HCx) once observers lost sight of the individual. We also took waypoints at each double-flagged location. We recorded the sex and age class (1-3; Appendix B) of each DSF followed, and noted the duration (i.e., start and end times) of each survey.

Vegetation Survey

We sampled vegetation with 401 randomly distributed quadrats (2.25 m^2) to characterize the vegetation and soil structure at the Teledyne site. Quadrats were first established as part of our 2008 vegetation-sampling effort, and were randomly distributed across the survey site using Arc GIS v. 9.3.1 software (ESRI 2009) and the Hawth's Tools extension (Beyer 2004). We estimated percent cover of tree, shrub, and herbaceous vegetation classes in each quadrat, and estimated percent cover of the 3 most dominant species within each class. We also estimated percent cover for the following species/functional groups presumed to be positively or negatively associated with DSF occurrence: *Eriogonum fasciculatum*, *Croton californicus*, *Ambrosia acanthicarpa*, *Heterotheca grandiflora*, *Stephanomeria sp*., *Brassica/Sisymbrium sp.*, and non-native grasses (USFWS 1997). We estimated ground cover in the categories of litter, rock, loose sand, stabilized sand, hardpan, basal stem, and "other" (Appendix C). Finally, we measured soil compactness (kg/cm^2) of undisturbed soil near the center of each quadrat using a soil penetrometer (Forestry Suppliers, model 77114).

We also sampled vegetation and soil at all locations where DSF were observed perched during 2009 transect surveys (*n* = 58) to compare with a sub-sample (*n* = 58) of our 401 randomly distributed locations. Our goal was to investigate habitat characteristics that may drive adult DSF distribution across the Teledyne site at 2 spatial scales (i.e., 2.25 m^2, and 56.25 m^2). We selected a smaller and a larger spatial scale for vegetation and soil sampling because we are unsure of the most relevant scale at which to explore potential correlations between DSF presence/absence and habitat characteristics. We distributed 116 clusters of five 2.25-m^2 plots by centering 1 quadrat at each randomly distributed or DSF perch location, and then placing the remaining 4 quadrats 2.25 m northeast, northwest, southeast, and southwest from the perimeter of those center quadrats. We recorded all quadrat centers using a GPS unit with submeter accuracy (Trimble GeoExplorer). Within each quadrat, we measured the same variables as described above for the 401 randomly-distributed quadrats. A complete description of the 2009 vegetation sampling protocol is provided in *Delhi Sands Flower-Loving Fly Vegetation Protocol 2009* (Appendix D).

We distributed 3 permanent photo stations in 2006 to monitor the spread of short-pod mustard (*Hirschfeldia incana*) and non-native grasses (Poaceae) across the dune system at the Teledyne site with digital images. We chose to monitor these species because they may pose a threat to DSF through dune stabilization (USFWS 1997). Results from previous years indicated that DSF were most abundant in areas that contain a high percentage of native vegetation and more than 60% open-sand substrate (see *Delhi Sands Flower-loving fly Survey Report 2006*). We revisited photo stations in 2009, and took digital images in the 4 cardinal directions. Unauthorized stake removal prevented us from relocating the exact points from 2006, but we were able to relocate approximate locations with GPS units and by aligning the previous year's photos against the landscape.

Data Analysis

2009 Line Transects

We used program DISTANCE and distance-sampling methodology to estimate the detection probability and population density of DSF at the Teledyne site in 2009 (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 data reflect the following 3 assumptions: 1) complete detection of subjects on the transect line, 2) subjects are observed before any movement response to the observer, and 3) distances are measured accurately (Buckland et al. 2001). We examined detection histograms (i.e., number of observations per distance category) during the survey period for spikes in observations away from the transect (suggesting violation of assumption 2), or relatively few observations near the transect centerline in relation to other distance categories (suggesting violations of assumptions 1 and 2). We also ensured accurate distance-to-detection measurements by clearly marking transect centerlines, and using large metal washers with attached flagging to mark initial fly locations as soon as a DSF was observed.

We pooled data across the entire 2009 survey season to fit a detection function, and derived both stratified (i.e., daily) and pooled (i.e., average daily) estimates of population density. We also removed observations beyond 200 inches from our data set to avoid fitting detection functions with extended ‘tails’. Lastly, we manually binned observations into ten 20-inch distance categories (e.g., 0-20, 21-40, ..., 181-200 inches) (Buckland et al. 2001).

We evaluated the full combinations of uniform, half-normal, and hazard-rate key functions with cosine, simple-polynomial, and hermite-polynomial series expansions (Buckland et al. 2001). We assessed model fit by graphical inspection of the detection function (i.e., shape criterion) 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), and constructed a 95% confidence model set by summing the Akaike weights from the highest to lowest ranked models until the weights summed to ≥ 0.95 (Burnham and Anderson 2002). We excluded models that fell outside of this 95% confidence set, recalculated Akaike weights, and derived model-averaged estimates of density and detection.

Reanalysis of 2008 Line Transect Data

We did not stratify density estimates of population density in 2008, but rather pooled data across days and estimated only the average daily DSF density over the entire survey season. We also pooled transect length in the 2008 analysis, resulting in a potentially inaccurate variance estimate that was biased low. We therefore reanalyzed data from the 2008 DSF survey season using the same methods as used to analyze 2009 data, except for different data truncation and binning of observations. Data for 2008 were truncated at 130 inches and manually binned into 9 distance categories (0-10, 11-25, 26-40, 41-55, 56-70, 71-85, 86-100, 101-115, 116-130 inches).

Vegetation Analysis

We summarized data from our 401 randomly distributed 2.25 m^2 vegetation quadrats by mean percent cover and by percent presence (percentage of plots on which plant species were recorded). Although not every plant species was recorded in each plot (we only recorded the 3 most dominant species in each vegetation class, plus the 7 species/families that were presumed to be associated with DSF 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 the statistic is presented to give the reader a general sense of the cover of each species.

We analyzed vegetation and soil data in relation to DSF presence/absence at 2 spatial scales (2.25 m^2 and 56.25 m^2) using generalized linear models (GLMs) with binomial error structures and logistic link functions. We selected 7 vegetation and soil variables hypothesized to impact DSF distribution (Table 1). We first tested a global model including all variables for goodness of fit using a chi-square test. We then ran models comprising all possible subsets of the 7 variables, for a total of 127 models at each spatial scale. We ranked competing models using Akaike's Information Criterion (AIC), and computed Akaike weights (Burnham and Anderson 2002). We weighted parameter estimates by their Akaike weights and averaged over all models. We also estimated relative variable importance by summing the Akaike weights across all models in which each variable appeared (Burnham and Anderson 2002).

RESULTS

2009 Line Transects

We surveyed transects at the Teledyne site on 39 days in 2009, beginning on 2 July and ending on 31 August. We observed adult DSF on transects on 297 occasions, made 34 incidental observations, and recorded 17 observations during territory mapping

Table 1. Variables used in generalized linear models for vegetation analysis. Percent cover variables were arcsine transformed so that they were no longer bounded between 0 and 1. *Stephanomeria* and *Amsinckia* were originally collected as percent cover but were transformed to presence/absence because of high zero inflation.

Variable	Description	Justification
Vegetation cover	Percent cover of all vegetation	Adults do not use areas of dense vegetation (USFWS 1997).
Shrub cover	Percent cover of all shrubs	Oviposition takes place in the shade of shrubs (Rogers and Mattoni 1993).
Bare ground cover	Total percent cover of all bare ground categories	Potential area for oviposition; indicates "openness" of the substrate.
Soil compactness	Soil compactness as measured by a soil penetrometer (kg/cm^2)	Less compact soil may be more suitable for oviposition.
Brassicaceae/Poaceae	Combined percent cover of all plants of the Brassicaceae and Poaceae families	Non-native forbs and grasses that have the potential to stabilize soil and reduce bare ground cover.
Stephanomeria	Presence/absence of *Stephanomeria* sp.	This is 1 of only 2 plants (the other being *Eriogonum fasciculatum*) on which adult DSF have been observed nectaring.
Amsinckia	Presence/absence of *Amsinckia menziesii*	Negative association with DSF in 2008.

for a total of 348 DSF observations in 2009 (Figure 1). We walked a total of 329.8 km during DSF transect surveys. Evidence of successful reproduction was confirmed in 2009. We recorded multiple teneral individuals and observed 3 individuals emerging from their pupal cases (exuviae). Surveyors also collected 8 pupal cases found at the Teledyne site and stored these exuviae at the Monitoring Program office.

We discarded the distance models using the hazard rate key function because they did not meet the shape criterion. Of the remaining models, the 3 top-ranked models (half-normal key function with a cosine expansion, uniform key function with a cosine expansion, and half-normal key function with a simple polynomial expansion) formed the 95% confidence set. The results of these 3 models were averaged, weighted by their Akaike weights (Burnham and Anderson 2002). The model-averaged density estimate was 2.76 individuals/ha (95% CI: 2.16-3.51 individuals/ha) and the detection probability was 0.31 (95% CI: 0.27 - 0.35).

We observed our first DSF of the season on 1 July and our last observation occurred on 27 August. Estimated DSF abundance peaked during the week of 20 - 24 July and gradually declined from then until the end of the season.

Reanalysis of 2008 Line Transects

We walked a total of 317.4 km during DSF surveys in 2008. The distance analysis produced a density estimate of 2.43 individuals/ha (95% CI: 1.80 - 3.28 individuals/ha) and a detection probability estimate of 0.43 (95% CI: 0.36 - 0.49). As with the 2009 dataset, we discarded distance models using the hazard rate function because they did not meet the shape criterion. Of the remaining models, the 4 top-ranked models (half-normal key function with a cosine expansion, uniform key function with a cosine expansion, half-normal key function with a simple polynomial expansion, and uniform key function with a simple polynomial expansion) formed the 95% confidence set. We averaged the results from these 4 models, weighted by their Akaike weights (Burnham and Anderson 2002) to compute the reported density and detection probability estimates.

Territory Mapping

In the territory mapping study, we found DSF on 7 of 15 days. We followed 17 DSF for a total of 273 minutes (median = 6 minutes/observation, mean = 16.1 minutes/observation). The mean area used by DSF individuals during these observations was 59.4 m^2 (range: 4.1 - 160.1 m^2). Because we often lost sight of DSF early in our observations and were generally unable to follow DSF for long periods of time, the reliability of this estimate is low. It should not be interpreted as a valid estimate of DSF home range or territory size.

Vegetation Analysis

Total vegetation cover estimated from our 2.25 m^2 site characterization quadrats (n = 401) was 26.5 ± 1.0% (mean ± SE). Mean vegetative cover values for the 3 vegetation classes were 20.2 ± 0.9% forbs/grasses, 6.1 ± 0.7% shrubs, and 1.3 ± 0.5% trees. Additionally, we recorded 31 plant species and 2 families at the Teledyne site (Table 2). We found the family group Poaceae on 84% of plots (mean percent cover 8.7 ± 0.7%) and the family group Brassicaceae on 47% of plots (mean percent cover 0.7 ± 0.1%). The most common individual species were *Amsinckia menziesii* (recorded on 50% of plots), *Ambrosia acanthicarpa* (48%), *Phacelia ramosissima* (27%), *Croton californicus* (22%), *Stephanomeria* sp. (21%), *Lessingia glandulifera* (16%), and *Rhus trilobata* (15%) (Table 2). The most dominant individual species by mean percent cover were *Amsinckia menziesii* (3.9%), *Phacelia ramosissima* (3.6%), *Rhus trilobata* (3.2%), *Lessingia glandulifera* (1.5%), *Ambrosia acanthicarpa* (1.4%), and *Eriogonum fasciculatum* (1.4%).

Ground cover variables in order from highest to lowest percent cover were litter (49.3 ± 1.7%), bare ground-loose sand (40.7 ± 1.8%), bare ground-stabilized sand (7.5 ± 0.8%), bare ground-other (1.3 ± 0.5%), basal stem (0.9 ± 0.1%), rock (0.2 ± 0.03%), and bare ground-hardpan (0.2 ± 0.2%). Mean soil compactness was 0.42 ± 0.04 kg/cm^2.

We modeled the relationship between fly presence/absence and our vegetation and soil data at 2 spatial scales using generalized linear models. At the 2.25 m^2 scale, the presence of *Amsinckia menziesii* was negatively associated with DSF presence (Table 3). Models that included *Amsinckia* held 99% of model weight and the confidence interval did not include zero. Confidence intervals for all other variables at the 2.25 m^2 scale overlapped zero, as did all variables at the 56.25 m^2 scale. *Amsinckia* was also the most important variable at the large spatial scale but the confidence interval overlapped zero. Point estimates for bare ground cover and shrub cover were positive at both spatial scales, but confidence intervals overlapped zero. Brassicaceae and Poaceae cover, soil compactness, and *Stephanomeria* sp. cover had negative point estimates with confidence intervals that overlapped zero at both spatial scales. The relationship of DSF presence to total vegetation cover was inconsistent across the 2 spatial scales.

Table 2. Mean percent cover and percent of 2.25-m^2 plots (n = 401) that target (bold) and dominant plant species/families were recorded on at Teledyne. Standard errors are reported in parentheses for species/families targeted for their presumed importance to DSF distribution. Non-bolded species were recorded only if 1 of 3 most dominant on any plot, and values are biased high from the true sample statistic as they do not contain plots where the species were absent.

Species or family	Mean percent cover	Percent presence
Poaceae	8.7 (0.7)	84
Amsinckia menziesii	3.9	50
Phacelia ramosissima	3.6	27
Rhus trilobata	3.2	15
Lessingia glandulifera	1.5	16
Ambrosia acanthicarpa	1.4 (0.1)	48
Eriogonum fasciculatum	1.4 (0.4)	9
Croton californicus	0.8 (0.1)	22
Brassicaceae	0.7 (0.1)	47
Stephanomeria sp.	0.6 (0.1)	21
Sambucus nigra ssp. canadensis	0.6	2
Prunus ilicifolia	0.5	1
Cucurbita foetidissima	0.3	1
Keckiella antirrhinoides	0.3	2
Salvia mellifera	0.2	2
Adenostoma fasciculatum	0.1	1
Camissonia sp.	0.1	8
Corethrogyne filaginifolia	0.1	2
Encelia farinosa	0.1	1
Helianthus annuus	0.1	1
Lotus scoparius	0.1	0.2
Marah macrocarpus	0.1	1
Nicotiana glauca	0.1	0.5
Marrubium vulgare	0.04	2
Salsola tragus	0.04	0.5
Artemisia californica	0.02	0.5
Centaurea melitensis	0.02	1
Erodium cicutarium	0.02	0.5
Heterotheca grandiflora	0.01 (0.01)	1
Crassula connata	0.01	0.5
Nicotiana quadrivalvis	< 0.01	0.5
Cryptantha sp.	< 0.01	0.2
Eriogonum gracile	< 0.01	0.2

We recorded digital images from the 3 established photo stations on 16 September 2009. These images were stored at the Monitoring Program office to facilitate long-term comparisons of vegetation conditions at the Teledyne site.

Table 3. Parameter estimates (β), 95% confidence intervals (CI), and summed model weights (Σw_i) for each vegetation and soil predictor variable. Estimates are model-averaged over all possible models weighted by Akaike weights (Burnham and Anderson 2002). Values in bold have confidence intervals that do not overlap zero. Summed model weights indicate the relative importance of each variable.

	Intercept	***Amsinckia***	**Bare ground**	**Brassicaceae/ Poaceae**	**Shrub cover**	**Soil compactness**	***Stephanomeria***	**Total Vegetation**
2.25 m^2 plots								
β	0.02	**-1.72**	0.56	-0.21	0.1	-0.3	-0.06	0.15
95% CI	(-1.83, 1.88)	**(-2.80, -0.65)**	(-0.78, 1.90)	(-1.60, 1.17)	(-0.61, 0.82)	(-1.26, 0.65)	(-0.56, 0.44)	(-0.81, 1.12)
Σw_i	1	**0.99**	0.57	0.33	0.29	0.44	0.28	0.32
56.25 m^2 plots								
β	0.53	-0.51	0.29	-1.16	0.41	-0.01	-0.35	-0.4
95% CI	(-1.44, 2.49)	(-1.58, 0.55)	(-0.91, 1.50)	(-4.35, 2.04)	(-1.07, 1.89)	(-0.34, 0.32)	(-1.30, 0.59)	(-1.99, 1.19)
Σw_i	1	0.63	0.38	0.5	0.38	0.28	0.5	0.37

DISCUSSION

In the fifth year of Delhi Sands flower-loving fly monitoring, we recorded the greatest number of DSF observations to date and confirmed breeding at the only Core Area where conservation has occurred (Teledyne). For the second consecutive year, we observed an increase in DSF observations over 2005-2007 levels and collected vegetation and soil data at over 450 points within the Teledyne site.

Since 2005, we have increased our survey effort each year and have observed DSF on more occasions in each successive year. Additionally, the number of observations per km walked in 2008-2009 (i.e., adjusted per unit effort) has increased significantly from 2005-2007 levels (Figure 2). There are 2 possible explanations for this increase: 1) the DSF population at Teledyne has increased, or 2) our ability to detect DSF has improved. The key to answering this question is in the detection probability as estimated in our distance analysis. However, we were unable to estimate detection probability in 2005 or 2006 because of the small number of DSF observations. In 2007, despite a greater number of observations, the data was distributed in a way that did not allow for a good model fit. Therefore, we have only been able to compute reliable detection probabilities for 2008 and 2009. As a result, we cannot yet determine whether the increase in observations is due to a population increase or a change in detection. Continued surveys will be necessary to assess DSF population changes.

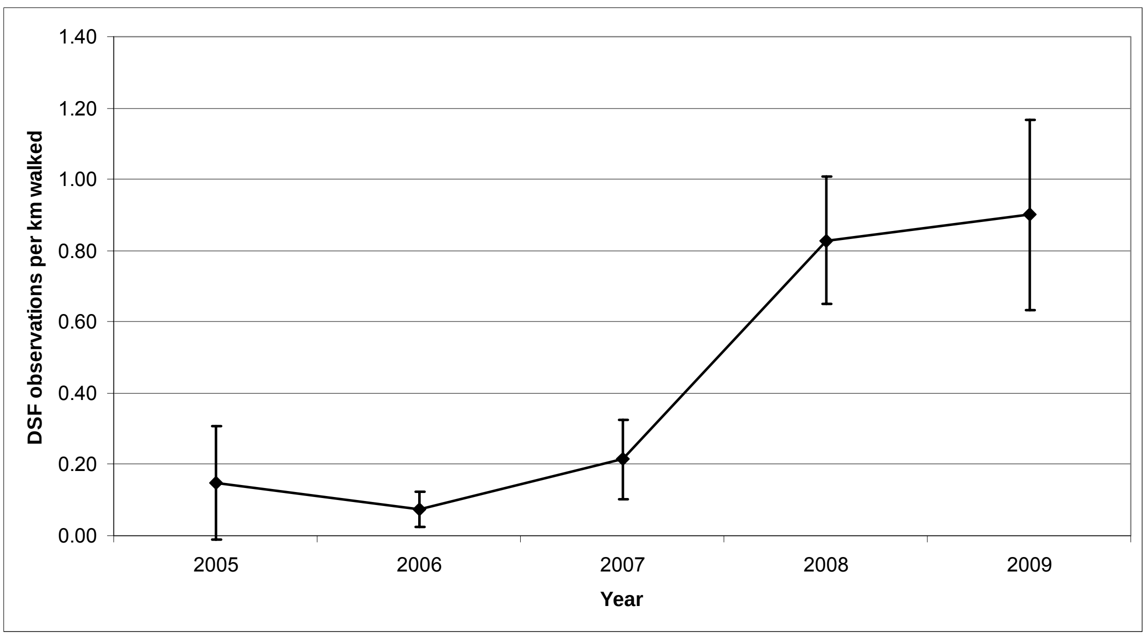

Figure 2. DSF observations per km walked during line-transect surveys. Error bars show 95% confidence limits, estimated by measuring the variation between daily surveys.

Although we estimated daily DSF density at the Teledyne site, using this estimate to determine annual DSF abundance is problematic without data on DSF adult longevity. For example, if we knew that adult DSF lived only 1 day, we could simply sum the daily abundance estimates to estimate the number of DSF that emerged over the course of the year. However, if adult DSF live 1 week, our annual abundance estimate would be substantially lower, as many of our observations may have been repeat observations of the same individuals over several days. Our estimate would be further reduced with increasing adult DSF longevity. Therefore, reliably estimating annual abundance requires information on adult DSF lifespan. Despite the limitations of our daily density estimate in estimating annual abundance, it is useful in assessing changes in DSF density across years. Our survey methods also help to standardize survey effort across different observers and years. Furthermore, if other DSF sites are conserved, we will be able to use our line-transect methods to compare densities across sites.

The territory mapping surveys were an attempt to obtain some of the necessary life history information currently lacking for DSF. Unfortunately, the surveys did not provide the necessary data quality to validly estimate home range size. Adult DSF were difficult to follow for more than a few minutes, even with 2 observers. Observed flies would often fly into vegetation or over the ridge of a sand dune and be lost from sight. Additionally, DSF are extremely difficult to find when they are perched, so if a fly was lost and then perched, it was nearly impossible to find again. Finally, more than 1 DSF could fly over the same area, so we often did not know whether we were continually following 1 individual or multiple flies, especially when we could not maintain constant visual contact with each individual fly. Due to the difficulty of following DSF for extended time periods, we do not recommend continuing these territory mapping surveys.

For the second consecutive year, we found a strong negative association between DSF presence and *Amsinckia menziesii* presence. Two explanations exist for this association. First, DSF may truly avoid areas in which *Amsinckia* is present. The plant does not provide much vegetative cover at the time of the DSF flight season, as it is desiccated and brown by then. However, where it occurs on the site, the vertical stems are generally close together, and may therefore function similar to an area of dense cover and be avoided by flying DSF. Alternatively, DSF may be more difficult to detect in areas dominated by *Amsinckia*. The dense stems may make it difficult to see DSF in those areas, especially if they are perched. A possible method for addressing this question is to estimate detection with *Amsinckia* as a covariate in the distance analysis. This method would require a large sample size to estimate detection, but it may be possible to pool data across years to achieve the necessary sample size.

We found no consistent associations between fly presence and habitat variables other than the negative association with *Amsinckia*. Additionally, no variables were strongly supported as factors influencing DSF presence at the large spatial scale, likely because the vegetation and soil is more heterogeneous at this scale. Reports in previous years have identified stabilized sand and *Hirshfeldia incana* as negatively associated with DSF presence, while bare ground and loose sand have been identified as positively associated, but results have been inconsistent across years. Perhaps the above-ground vegetation is not as important for DSF as subsurface vegetation (root structure) and soil conditions are for larval DSF. The larval stage is by far the longest in the DSF life cycle, as they overwinter as larvae. Another possibility is that the mobility of adult DSF makes it difficult to determine where to place vegetation plots. Our approach was to center plots over areas where DSF were observed perched. Many times, however, a DSF perches for only a few seconds before taking flight again. It is therefore unclear whether perched sites are better indicators of DSF habitat preference than other areas over which DSF are observed in flight. Ultimately, preferred oviposition sites for females may contain the most important habitat characteristics. Finding such sites, however, is extremely difficult.

Recommendations for Future Surveys

We will continue to conduct annual line-transect surveys at the Teledyne site to document changes in DSF reproduction and abundance, unless instructed to do otherwise by the Reserve Management Oversight Committee, as per the DSF species account. We now have 2 years with reliable detection and abundance estimates using distance sampling methods. Continuing to use these methods will allow us to meet the required species objective and to monitor population changes at Teledyne. We can also employ these survey methods at additional sites when they are conserved. We will also continue to take digital images at established photo stations to monitor the spread of invasive grasses and mustards at the site.

We continue to require information on adult DSF life history (particularly adult DSF longevity) to better interpret our DSF abundance estimates. As stated in previous reports, attaching radio transmitters to newly emerged individuals would allow us to estimate DSF lifespan and microhabitat use. However, methods for safely capturing and handling these federally listed, fragile insects would need to be developed and extensively tested before attempting the procedure on such a rare and delicate species as DSF. As described earlier, our territory mapping project did not provide the quality of data we had hoped it would because of the difficulty of observing DSF for long time periods.

Perhaps most important from a management perspective is the need to establish vegetation and soil requirements for DSF. Although our vegetation surveys have produced inconsistent results across years, more associations with DSF presence have been found at small spatial scales than at large scales over the past 2 years, perhaps indicating that we should focus future habitat sampling efforts at the smaller scale. This result could also be an artifact of more variance in vegetation data at larger spatial scales than at smaller scales.

Although the number of DSF observations varies across the site, there are no large areas at Teledyne where DSF are not observed. Therefore, we may need to expand vegetation survey efforts beyond the borders of the DSF survey area to gather data from areas in which DSF do not occur. One strategy would be to sample small quadrats both within and outside of the DSF survey area. Another alternative would be to identify an area with few to no fly observations (within or adjacent to the DSF survey area) in which the vegetation could be manipulated experimentally. For example, *Amsinckia menziesii* could be removed from treatment plots. These plots could then be monitored for DSF and compared to control areas. Given the endangered status of DSF and the small size of the Teledyne site, careful planning would be required to avoid inadvertently damaging DSF habitat.

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Appendix A. Western Riverside County MSHCP Biological Monitoring Program Protocol for Delhi Sands Flower-loving Fly Surveys, June 2009

This protocol was modified from the U.S. Fish and Wildlife Service's (USFWS) Interim General Survey Guidelines for the Delhi Sands Flower-loving Fly (*Rhaphiomidas terminatus abdominalis*, DSF) dated December 1996. Protocol adjustments were made to specifically address the survey goals below, rather than focusing on the USFWS's goal of providing a credible method for determining DSF presence-absence at a given site. The main adjustments include using a line-distance sampling methodology to estimate DSF density and detectability and less emphasis on mapping habitats on-site.

Goals

A) Document successful reproduction of DSF within Core Areas, as measured by the presence/absence of newly emerged (teneral) individuals.

B) Gather data regarding DSF density, detectability, resource selection, and important distribution covariates including co-occurring insect Families within Core Areas.

To achieve the above goals, visual encounter surveys along pre-established transects will be conducted annually in Core Areas accessible to the Monitoring Program. Data resulting from these surveys will be used to verify reproduction within Core Areas and analyzed to provide insight into the ecology of DSF as described in Goal B. Although they are to be recorded if detected, focused surveys for pupae cases (exuviae) will not be conducted using this protocol.

Timing

Surveys for adult DSF will be conducted annually for approximately twelve weeks during the flight season, generally from July through September. The beginning and end of the survey season will be established by biologists from the Monitoring Program. Annual surveys at a given location will not begin until adult DSF have been observed at that location in the year of the survey.

Survey Locations

Surveys will be conducted annually in Core Areas accessible to the Monitoring Program. Accessible lands will be identified by the Project Lead prior to surveys. In 2009, we will survey only the Jurupa Hills Core Area, as the Core Areas in the northwestern corner of the Plan Area (Mira Loma) and in the Agua Mansa Industrial Center area, are currently inaccessible to the Monitoring Program.

METHODS

Transect Setup

Survey transects will be established in suitable habitat within accessible Core Areas. Suitable habitat was previously defined by the presence of Delhi series soils described by a GIS shapefile. Pilot surveys in 2005 indicated that 32 parallel transects spaced approximately 15 m apart, and ranging from approximately 50 to 200 m long provided adequate coverage of the suitable habitat within the Jurupa Hills Core Area (see Delhi Sands Flower-loving Fly (*Rhaphiomidas terminatus abdominalis*) Survey Report

2005). Transects will be marked with wooden stakes approximately every 30 – 40 m and flagging on shrubs or grasses between stakes so that surveyors can easily navigate between stakes and accurately measure the perpendicular distance between any point on the transect and any DSF observation.

During transect establishment, impenetrable vegetation stands (*e.g.*, *Prunus ilicifolia* or *Rhus trilobata*) that prohibit surveyors from walking directly on-transect will be marked with flagging on both sides of the stand. Surveyors will walk around these sections, and the impenetrable section of the transect will be excluded from the transect and subsequent analyses.

Surveying for Adult Delhi Sands Flower-loving Fly

Before surveys begin, surveyors must demonstrate the ability to identify DSF and co-occurring insect Families by passing the USFWS Delhi Sands Flower-loving Fly practical exam, and locating and identifying insects in the field with the Project Lead. Refer to the Field Training Manual for instructions.

After the survey season begins, each transect will be surveyed twice per weekday for a minimum of twelve weeks during the flight season, or until the Project Lead has determined that a sufficient amount of data has been collected. Surveys will be conducted on established transects between 0930 and 1430 hours. Weather conditions should be clear skies and winds less than 5 mph. If wind speeds are sustained at greater than 5 mph, surveyors will delay beginning the survey until they decrease or cancel the survey if winds do not decrease. Infrequent gusts over 5 mph are acceptable. Surveys should not be conducted under extremely cloudy, overcast, or rainy conditions since DSF has not been observed under these conditions (USFWS 1997).

Survey Equipment

- Handheld GPS unit
- Clipboard
- data sheets and pen
- Thermometer
- Measuring tape
- Anemometer
- Binoculars (if desired)
- Camera
- Insect Identification Aids (if desired)

Data collected at the start of a survey include: date, observer, time, general weather condition, temperature in shade at 1 m above ground, average wind speed, and cloud cover category (see Delhi Sands Flower-loving Fly Survey Datasheet). Time, general weather condition, temperature in shade at 1 m above ground, average wind speed, and cloud cover are also recorded one hour after the survey begins, two hours after the survey begins, etc. and at the end of the survey.

Surveying consists of walking previously established parallel transects looking for DSF either flying or perched on vegetation. **Move carefully to avoid trampling DSF adults, larvae or otherwise harming the habitat onsite.** Although, as discussed below, DSF are likely to flush out of the way of a moving observer, it is imperative to avoid harming individuals because this Endangered Species is so rare. Walk slowly and stop occasionally to look around – surveyors standing still are more likely to see an insect already in flight.

While walking a transect, always remain as close to the centerline of the transect as possible. The statistics used to analyze the data collected assume that close to 100% of the DSF that are directly on-transect are observed. DSF **should** take flight if an observer approaches them and a vigilant observer should notice a DSF take flight in front of them nearly 100% of the time. DSF further off-transect will be observed with a decreasing probability as the distance from an observer on transect to the fly increases and this bias is accounted for in the statistical analysis.

Data collected when a DSF is encountered include: the perpendicular distance from the transect to the **original sighting location** (accurate to the inch, data will be converted to metric measurements later), the coordinates of the original sighting, time, sex, activity, whether or not the individual was teneral, and any other relevant notes. Teneral individuals are "covered with golden pelage and have emerald green eyes and no rigid wing venation" (Kingsley 1996). If recording a DSF as teneral, take a digital photo when possible. Otherwise, take photos if time permits or you want to document the location of the fly. Binoculars are not required for surveying, but can aid in identifying behavior and age class of observed individuals.

When approaching a perched DSF for identification purposes, move slowly and keep the movement of your hands, arms, legs, and body to a minimum. If the fly is first seen in flight, follow from 1 – 2 m away until it lands, or you have seen enough to confirm that it is a DSF. Do not make sudden movements. If the fly is circling, stand still and wait for it to land – if it perceives your movement, it is less likely to stop. After the individual has been confirmed or disconfirmed as a DSF, and necessary data have been taken, return to the transect departure point, and continue with the survey.

Surveyors should also record the Families of co-occurring winged insect species encountered as the survey progresses. Counts of co-occurring Families are unnecessary. If an insect is observed that you know is **not DSF,** do not spend time attempting to identify the Family if it isn't immediately apparent.

Also take waypoints and/or photographs of any other MSHCP Covered Species encountered. Record photographs and waypoints of Covered Species on an Incidental Species Sighting Form if the necessary data can not be stored by naming the marked waypoints appropriately (see Incidental Observation Instructions and Instructions for Taking and Storing Digital Photos).

Recording Data

There should be two Delhi Sands Flower-loving Fly datasheets per surveyor for each day of survey activities at each locality surveyed. If there are no observations of DSF on a particular day, that should be noted on the datasheet.

The locations of all adult DSF **incidentally observed** should be recorded with a GPS unit, whether they are observed before, during, or after a survey. DSF observations made during a survey but while walking around an excluded section of a transect are considered incidental and these points are not entered on the survey datasheet. If additional info beyond the date, time, observer, species code, and location coordinates are desired (*e.g.*, substrate, number of individuals, sex, etc.) fill out an Incidental Species Sighting Form. If two or more DSF individuals are observed in the same small area (~10 m diameter circle) these can be recorded with the same waypoint, taken near the center of the cluster. Record the number of DSF observed on the Incidental Species Sighting Form. DSF observations made on-transect during a survey do not need to be marked with a GPS, simply record the coordinates on the survey form, as described above. Data will be recorded in the NAD83 datum; all survey areas are in Zone 11S.

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Appendix B. Delhi Sands Flower-loving Fly Survey Sheet

Date ________________ Section_______ **Delhi Sands Flower-loving Fly** **Teledyne Site** __Data Entered __Data Proofed

Observer(s) ____________________________

Time	Temp ºC	Avg Wind*	Weather**	Cloud Cover***
Start :				
Hour 1:				
Hour 2:				
Hour 3:				
Hour4:				
End:				

* mph

** general description

*** 0, 1-20, 21-40, 41-60, 61-80, 81-100

Activities/Behaviors

Perched: indicate substrate

Interspecific Interaction: describe interaction

Intraspecific Interaction: describe interaction

Nectaring: record plant species, or take sample

Oviposition: *describe site, record soil temp!!!*

Cruising

Mating

Age Code

1: fuzz entirely covers dorsal thorax = teneral (note wing margin wear)

2 : fuzz covers ≥ half dorsal thorax (note wing margin wear)

3 : fuzz covers < half dorsal thorax (note wing margin wear)

Transect #	Distance (in)	UTM East	UTM North	Time	♀ or ♂	Activity	Age Code	Waypoint

Notes:

Appendix C. DSF Vegetation Sampling Sheet

Observers: ____________________ **Date:** ______________

Plot ID: ___ ___ ___ ___-_____

Vegetation		
	Species	**% cover**
Trees		
species 1		
species 2		
species 3		
Shrub		
species 1		
species 2		
species 3		
Eriogonum fasciculatum		
Croton californicus		
Forb/Grass		
species 1		
species 2		
species 3		
Heterotheca grandiflora		
Ambrosia acanthicarpa		
Stephanomeria sp.		
Brassica and *Sisymbrium*		
non-native grass		
Total vegetation cover:		

Ground codes		
Surface substrate	**%**	
Litter		
Rock		
Basal stem		
Bare ground- stabilized sand		
Bare ground- loose sand		
Bare ground- hardpan		
Bare gound- other (describe):		
All ground codes	**100%**	

Soil Compactness	kg/cm^2	Circle One-	(FOOT)	(NO FOOT)

Notes: Disturbance, Site Characteristics, et cetera

Appendix D. Delhi Sands Flower-loving Fly Vegetation Sampling Protocol 2009

The objectives of this vegetation sampling protocol are to characterize the vegetation and soil structure at sites occupied by Delhi Sands flower-loving fly (DSF) and to determine what aspects of the plant community and soil structure correlate with DSF presence. Vegetation sampling locations for DSF in 2009 will be spread evenly throughout the single occupied site (Teledyne) to characterize the study site and will also focus on areas where flies have been observed to compare to the site as a whole. We will monitor plant species diversity, vegetation structure, community composition, and surface soil structure at multiple spatial scales as potential predictors of DSF presence or frequency of observation.

To characterize the study site, we will place four-hundred 2.25 m^2 quadrats throughout the study site using a spatially stratified random sampling design. These 400 vegetation sampling locations were selected in 2008 and the same locations will be used in 2009 to minimize spatial variation between years and thus allow for better year-to-year comparisons of vegetation and soil structure.

To characterize locations where DSF have been observed, we will sample five 2.25 m^2 quadrats at each location where a perched DSF was recorded during surveys (n = 58). Only perched locations will be used as it is assumed that these locations better indicate a resource usage decision by a given fly, as opposed to observations made of individuals in flight. One quadrat will be centered on the fly observation and the remaining 4 will be spaced 1 quadrat-width Northwest, Southwest, Northeast, and Southeast of the central quadrat (Figure 1). In addition, 58 of the 400 randomly distributed quadrats will be more intensively surveyed using the same method as at the perched locations.

Within each quadrat, we will record percent cover of the tree, shrub, and herbaceous layers, as well as percent cover of individual shrub species that are strongly dominant within individual quadrats or are hypothesized to be important to DSF (*Eriogonum fasciculatum* and *Croton californicus*) (U.S. Fish and Wildlife Service 1997). We will also record percent cover of herbaceous species or functional groups, including *Heterotheca grandiflora*, *Ambrosia acanthicarpa*, *Stephanomeria* sp., non-native grasses, and non-native mustards (*Brassica* and *Sisymbrium*).

Data will be analyzed using logistic regression to develop models predicting the probability of occurrence of DSF in relation to vegetation and soil. The location of quadrat centers will be recorded using a submeter accuracy GPS unit to facilitate the use of spatially explicit models.

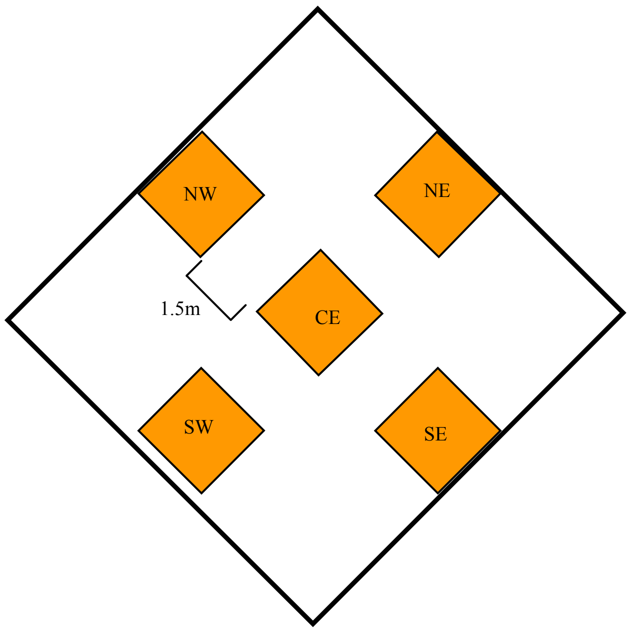
Quadrat Layout Equipment List

- Trimble
- Pin Flags (At least 100)
- Masking Tape
- Sharpie

Surveyor Equipment List

- Quadrat
- Quadrat List
- Point Intercept Quadrat
- Pin Flags (At least 4)
- GPS
- Declinated Compass
-
- Plant Identification Aides
- Datasheets (At least 60)
- 2-way Radio
- Clipboard
- Pocket penetrometer

Figure 1. Example of a vegetation sampling plot with 5 quadrats



Pre-Sampling Calibration

Inherent in any percent-cover estimate is a certain amount of observer variability. To minimize this variability, at the start of the survey period and at the start of each week, surveyors will calibrate to a known percent cover with the aid of a 2.5 m² point-intercept quadrat. The point-intercept quadrat will be strung with fishing line so that 100 points are equally distributed throughout the frame. Each of the 100 points will be sampled using a pin-flag; all species touching the pin and the ground cover it lands on will be recorded. The number of hits for each species and ground cover will be summed to determine the percent cover values. For example, if the pin hits *Ambrosia acanthacarpa* 32 times, that species would have an approximate percent cover of 32 percent. Next, the point-intercept frame will be replaced by a 2.5 m² quadrat and each surveyor will estimate cover within the quadrat following the 2009 DSF Vegetation Sampling Protocol. Surveyors will not share those values until everyone in the group has finished. The percent cover values from the point-intercept quadrat will be compared to the aerial cover estimates. This procedure will be repeated until all of the surveyors aerial cover estimates are within 5 percent of the point intercept values.

In addition to the weekly calibration, on a daily basis surveyors will calibrate to each other by sampling a quadrat as a group. Surveyors will record their own cover estimates and not share those values until everyone is finished. Quadrats will be sampled as a group until all surveyors are recording values within 5 percent of each other.

Quadrat Layout

At the start of each week, a surveyor will place flags at the center points of the 2.5 m^2 quadrats. Using a Trimble submeter accuracy GPS unit, the surveyor will navigate as close as possible to the center point of a quadrat and place a flag directly below the Trimble. To mark each flag, a piece of masking tape labeled with the plot ID will be placed around the pin.

Sampling

Using a handheld GPS, a 2 person survey team will navigate to a flag marking the center point of a plot. A 2.5 m^2 quadrat will be placed on the ground so that the flag is in the center and the corners are oriented in the cardinal directions: North, South, East, and West. A declinated compass should be used so that the orientation is as exact as possible. The quadrat should be on the ground or extremely close; this may mean that it needs to be taken apart and reassembled around and/or through dense vegetation.

For quadrats with a 4-digit plot ID, the surveyor will record the initials of all observers, the date, the plot ID, and the Plot Direction (NE, NW, SE, and SW). The plot direction is recorded in the plot ID field, to the right of the hyphen (see Figure 1). For quadrats with a 3-digit ID, the surveyor will record the initials of all observers, the date, and the plot ID. The direction portion of the plot ID field should be left blank.

Percent cover data collected for vegetation in each quadrat include: percent cover of the tree layer, shrub layer, forb/grass layer, and total vegetation. Except for total vegetation, each layer is estimated independent of all the others. For example, total herb/grass cover is not influenced by the shrub layer, even if the two overlap. For total vegetation cover, overlap between layers is taken into account. Therefore, total vegetation is not simply the sum of the covers from all three vegetation layers. In addition to cover estimate for each vegetation layer, surveyors will estimate percent-cover values for the 3 most dominant species in each vegetation layer and any species/functional group listed on the data sheet: *Eriogonum fasicultum*, *Croton californicus*, *Ambrosia acanthacarpa*, *Heterotheca grandiflora*, *Stephanomeria sp*., *Brassica/Sisymbrium*, and non-native grasses. Any of the listed species/functional groups can be included as one of the 3 dominants.

Under the heading Ground codes, surveyors will record the percent cover for all components of the surface substrates. These will include basal stem (should generally be between 1 and 5%), litter, rock (> 2 cm), and 4 different categories of bare ground. *Stabilized sand* refers to sand whose movement is arrested or whose form is protected from further wind action by growth of vegetation or cementation of sand. *Loose sand* is that on which erosion and deposition can still occur. *Hardpan* is any bare ground that is substantially compacted and is not composed of sand. If the ground is too hard to take a reading with the Pocket Penetrometer, the soil is probably hardpan. There is an *'Other'* category for any bare ground that does not fit into these 3 categories. Include next to

'Other' a description of the soil. All of the ground codes together should add up to 100%. All values must be recorded with a number; it is not acceptable to use 'r' to note that a ground cover is the remainder of the 100%.

After the Aerial cover estimates are recorded, a Pocket Penetrometer will be used to measure the compactness of the soil within the quadrat. One reading will be taken on undisturbed soil at the center of the quadrat. If the center point is not representative of the entire quadrat, a reading will still be taken and the observer will record the discrepancy in the notes section. The surveyor will slowly press the zeroed Penetrometer into the soil to a depth of ¼ in, the height of the foot adapter, and record the compactness in kg/cm^2. The reading should be taken from the top of the white ring and rounded to the nearest ¼ kg/cm^2 increment. If the recorded value is less than .5 kg/cm the foot adapter should be attached to increase the accuracy of the reading.

If the quadrat has a 3-digit plot ID the surveyor will move on to the next Plot. If the quadrat has a 4-digit plot ID, an additional 4 quadrats must be sampled. Surveyors will flag the corners of the central quadrat that was just sampled. The frame will be flipped twice so that it is 1 quadrat width, 1.5 m, northwest of the central quadrat. 'NW' will be recorded with the plot ID on the right side of the hyphen. The 'NW' quadrat will be sampled using the same procedure as the central one. This procedure will be repeated for the 3 remaining quadrats located 1.5 m. Southwest, Northeast, and Southeast of the central one.

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