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

## Delhi Sands Flower-loving Fly
## (*Rhaphiomidas terminatus abdominalis*)
## Survey Report 2010

**23 March 2011**

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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 2010 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 2010 Project Lead, Ashley Ragsdale. 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.

**Contact Information:**

Executive Director
Western Riverside County
Regional Conservation Authority
4080 Lemon Street, 12th Floor
P.O. Box 1667
Riverside, CA 92502-1667
Ph: (951) 955-9700

Western Riverside County MSHCP
Monitoring Program Administrator
c/o Adam Malisch
4500 Glenwood Drive, Bldg. C
Riverside, CA 92501
Ph: (951) 248-2552

# 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 currently known to occur, or to have occurred, within 3 Core Areas defined by the Western Riverside County MSHCP: Jurupa Hills, Agua Mansa Industrial Center, and Mira Loma (USFWS 1997, Dudek & Associates 2003). To date, conservation of the species within the MSHCP Plan Area has only occurred within the Jurupa Hills Core Area (Teledyne site). There are no lands that are currently a part of the Conservation Area within the other 2 Core Areas for this species.

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 in the MSHCP as the presence of pupal cases (exuviae) or newly-emerged (teneral) individuals. We describe here the procedure and results of the MSHCP Biological Monitoring Program's effort to monitor DSF at the Teledyne site in the Jurupa Hills in 2010.

Delhi sands flower-loving flies have distinctive biological and habitat requirements and face a number of threats (USFWS 1997). The life cycle of DSF includes egg, larval, pupal, and adult stages. Only the adult stage occurs above-ground, when adults emerge to breed during the summer months. DSF are restricted to fine, sandy Delhi soils, usually with wholly- or partly-stabilized sand dunes and sparse native vegetation. Areas with suitable DSF 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 DSF habitat by increasing vegetation cover or by altering soil conditions through dune stabilization and changes in soil moisture.

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; secondary goals were to estimate adult DSF detection probability and density and to gather 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 detection probability. We detected a greater number of DSF in 2008 and 2009, allowing us to calculate reliable estimates of detection probability and density. 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, due either to few DSF detections (2005-2007) or to poor correlation between DSF presence and measured habitat features (2008-2009).

Our focus as we entered the 2010 field season was on trying to understand 1) if annual changes in the number of DSF detections are due to changes in abundance or changes in detection and 2) which measurable habitat features are associated with DSF presence. 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 2010.

**Survey Goals and Objectives:**

1) Document successful DSF reproduction at the Teleydne site in the Jurupa Hills Core Area.
    a. Record observations of teneral individuals and/or exuviae.
2) Estimate population density of adult DSF during flight season at Teledyne.
    a. Calculate distance sampling-based estimates of population density that account for animal detectability.
3) 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 presence on DSF distribution.
4) 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 3 photo stations to document changes in vegetation structure and composition.

# METHODS

## Protocol Development

We began surveying 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 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). 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 2010 survey protocol is described more completely in the *Western Riverside County MSHCP Biological Monitoring Program Protocol for Delhi Sands Flower-loving Fly Surveys, June 2010* (Appendix A).

## Personnel and Training

All field observers studied a DSF-specific training manual prepared by Biological Monitoring Program leads, 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 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 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 2010:

- Ashley Ragsdale (Project Lead, Biological Monitoring Program)
- Elise Hinger (Biological Monitoring Program)
- Esperanza Sandoval (Biological Monitoring Program)
- Masanori Abe (Biological Monitoring Program)
- Jeff Galvin (Biological Monitoring Program)
- Joanna Gibson (Biological Monitoring Program)
- Jonathan Reinig (Biological Monitoring Program)
- Joseph Sherrock (Biological Monitoring Program)
- Julie Golla (Biological Monitoring Program)
- Karyn Drennen (Biological Monitoring Program)
- Laura Magee (Biological Monitoring Program)
- Lynn Miller (Biological Monitoring Program)
- Mike Robinson (Biological Monitoring Program)
- Tara Graham (Biological Monitoring Program)

## 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, 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 recently following fence installation around the site.

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 50 - 220 m in length for an aggregate length of 5.04 km. We marked the centerline of each transect with wooden stakes every 30 - 40 m. We also flagged shrubs or grasses between stakes to ensure easy navigation of the transect and accurate distance measurements from the transect centerline to observed DSF. We placed pin flags between stakes to mark the transect centerline in areas with little vegetation.

## Survey Methods

### Line-Transect Surveys

We began 2010 line-transect surveys on 12 July after previously observing adult DSF at Teledyne during transect installation. 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 excluded afternoon surveys because data from previous years indicated that DSF are less detectable in the afternoon (see *Delhi Sands Flower-loving Fly Survey Report 2008*). Morning surveys began between 0930 h and 1015 h and afternoon surveys began between 1145 h and 1230 h. We conducted surveys on 39 days, ending on 10 September 2010.

We divided the survey area into 3 sections (aggregate 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 at hourly intervals of each survey. We walked each transect at approximately 1.2 km/h. When we observed a fly, we immediately marked the initial location of the DSF with large metal washers with attached flagging. We ensured accurate distance-to-detection measurements by clearly marking transect centerlines and carefully recording the perpendicular distance between the transect centerline and DSF markers. Surveyors then recorded transect ID, UTM coordinates, time, sex, activity, and age class (1-3) of the detected DSF. We recorded flies detected while not walking transects 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 DSF individuals.

### Vegetation Sampling

Vegetation sampling quadrats were first established at Teledyne during our 2008 survey effort. We used ArcGIS v. 9.3.1 software (ESRI 2009) and the Hawth's Tools extension (Beyer 2004) to randomly distribute points across the survey site using a stratified random sampling design. We then located all quadrat centers in the field using a GPS unit with submeter accuracy (Trimble GeoExplorer).

In 2010 we sampled vegetation and soil in three-hundred 1.5 m x 1.5 m (2.25 m$^2$) quadrats using a spatially stratified random sampling design to characterize the vegetation and soil structure throughout the Teledyne site. We estimated percent cover of tree, shrub, and herbaceous vegetation classes in each quadrat, and of the 3 dominant species within each class. We also estimated percent cover for the following species/families that are believed to be positively associated with DSF occurrence: *E. fasciculatum*, *C. californicus*, *A. acanthicarpa*, *Heterotheca grandiflora*, *Stephanomeria* sp., or negatively associated with DSF occurrence: *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". 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).

One of our goals was to investigate habitat characteristics that may influence adult DSF distribution across the Teledyne site. We used the same vegetation sampling protocol at all locations where we observed DSF perched ($n$ = 63) to compare with a random sub-sample from our 300 quadrats. A complete description of the 2010 vegetation sampling protocol is provided in *Delhi Sands Flower-Loving Fly Vegetation Protocol 2010* (Appendix B).

We established 3 permanent photo stations in 2006 to monitor the spread of *H. 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 2010, 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

### Line-Transect Surveys

We used distance-sampling methodology and the program DISTANCE to estimate the detection probability and population density of DSF at the Teledyne site in 2010 (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 3 assumptions be met: 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) 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 2010 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 from our dataset observations beyond 180 in from the transect to avoid fitting detection functions with extended ‘tails’. Lastly, we grouped observations into nine 20-in distance categories (e.g., 0-20, 21-40, …, 161-180 in) (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 hazard-rate key function for analysis 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

We summarized data from the 300 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 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 we provide the results to give the reader a general sense of the cover of each species.

We analyzed vegetation and soil data in relation to DSF presence using generalized linear models (GLM) with binomial error structures and logistic link functions. We selected 6 of the 7 vegetation and soil variables hypothesized by USFWS (1997) to impact DSF distribution (Table 1). We ultimately excluded vegetation cover in a set of candidate models because vegetation cover and ground cover were strongly inversely correlated. Percent cover variables were arcsine transformed so that they were no longer bounded between 0 and 1. *Stephanomeria sp.* and *A. menziesii* were originally collected as percent cover but were transformed to presence/absence because of high zero inflation. 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 6 variables, for a total of 63 models. 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 the weighted values 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

Line-Transect Surveys

We surveyed transects at the Teledyne site on 39 days in 2010, beginning on 12 July and ending on 10 September. We walked a total of 337.68 km during 67 surveys. We observed the first DSF during surveys on 12 July 2010 and the last on 8 September 2010. We observed adult DSF on transects on 253 occasions and recorded 22 incidental observations, for a total of 275 DSF observations (Figure 1). We also observed 21 teneral individuals, including 1 next to an exuviae, and 3 additional exuviae. Estimated DSF abundance peaked during the week of 19 - 22 July with a second peak from 30 July to 12 August, then gradually declined until the end of the season.

**Table 1.** Variables explored for use in GLM models of DSF occurrence and habitat condition. Vegetation cover was ultimately excluded because of its strong inverse correlation with bare ground cover.

| **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* sp. | 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 menziesii* | Presence/absence of *Amsinckia . menziesii* | Negative association with DSF in 2008 and 2009. |

The top 4 ranked distance models were within 1.88 delta AIC differences, meaning that none of these models were particularly superior to the others in describing the 2010 data. However, 3 models were violated by the detection function curve shape criterion. Only the uniform key function with a cosine expansion model showed an appropriate detection function curve to be valid by the shape criterion. Therefore, we used this model to estimate unknown parameters. The density estimate using the uniform key function with a cosine expansion was 1.44 individuals/ha (95% CI: 1.21-1.73) and the detection probability was 0.55 (95% CI: 0.52 - 0.59).

## Vegetation Sampling

Total vegetation cover estimated for the study site had a mean value of 31.7% (SE ± 1.3). Mean vegetation cover values for the 3 vegetation classes were: forbs/grasses = 22.7% (SE ± 1.0), shrubs = 7.88% (SE ± 0.9), and trees = 1.4% (SE ± 0.5). Additionally, we recorded 26 species and 2 families in a dominant category at least once (Table 2). We found the family group Poaceae on 87% of plots and the family group Brassicaceae on 35% of plots. The most common individual species were *A. acanthicarpa* (recorded on 48% of plots), *Stephanomeria* sp., *Phacelia ramosissima* (38%), *Amsinckia menziesii* (28%), *Croton californicus* (26%), and *Camissonia* sp. (23%) (Table 2). The dominant individual species by mean percent cover were *P. ramosissima* (8.7%), *Rhus trilobata* (3.0%), *Eriogonum fasciculatum* (2.9%), *A. acanthicarpa* (2.8%), and *Stephanomeria* sp.

(2.4%). Values may be biased high from the true sample statistic as they do not contain plots where the species were absent.

**Table 2**. Most common plant species and families recorded across 363 vegetation sampling quadrats. Target species/families are listed in **bold**; all other species/families were recorded as 1 of the 3 dominant species in at least one quadrat. Standard error (SE) is reported only for target species/families.

| Species or family | Percent presence | Mean percent cover |
|---|---|---|
| ***Poaceae*** | 87 | 6.2 (SE ± 0.4) |
| ***Ambrosia acanthicarpa*** | 48 | 2.8 (SE ± 0.3) |
| ***Stephanomeria* sp.** | 41 | 2.4 (SE ± 0.3) |
| *Phacelia ramosissima* | 38 | 8.7 |
| ***Brassicaceae*** | 35 | 0.9 (SE ± 0.2) |
| *Amsinckia menziesii* | 28 | 0.8 |
| ***Croton californicus*** | 26 | 1.0 (SE ± 0.1) |
| *Camissonia* sp. | 23 | 0.2 |
| *Lessingia glandulifera* | 19 | 1.9 |
| *Rhus trilobata* | 17 | 3 |
| ***Eriogonum fasciculatum*** | 11 | 2.9 (SE ± 0.7) |
| *Corethrogyne filaginifolia* | 4 | 0.1 |
| *Helianthus annuus* | 3 | 0.1 |
| *Marrubium vulgare* | 3 | 0.1 |
| *Sambucus nigra* ssp. *canadensis* | 2 | 0.7 |
| *Encelia farinosa* | 2 | 0.2 |
| ***Heterotheca grandiflora*** | 1 | 0.01 (0.004) |
| *Prunus ilicifolia* | 1 | 0.6 |
| *Cucurbita foetidissima* | 1 | 0.2 |
| *Lotus scoparius* | 1 | 0.2 |
| *Artemisia californica* | 1 | 0.1 |
| *Deinandra paniculata* | 1 | 0.1 |
| *Nicotiana glauca* | 1 | 0.1 |
| *Verbesina encelioides* | 1 | 0.1 |
| *Centaurea melitensis* | 1 | 0.03 |
| *Cryptantha* sp. | 1 | 0.01 |
| *Amaranthus albus* | 0.3 | 0.01 |
| *Eriogonum gracile* | 0.1 | 0.01 |

Ground cover variables in order from highest to lowest percent cover were litter (55.9%, SE ± 1.8), bare ground-loose sand (35.0%, SE ± 1.8), bare ground-stabilized sand (6.9%, SE ± 0.7), bare ground-other (1.0%, SE ± 0.4), basal stem (0.6%, SE ± 0.03), rock (0.5%, SE ± 0.3), and bare ground-hardpan (0.2%, SE ± 0.1). Mean soil compactness was 1.83 $kg/cm^2$ (SE ± 0.06).

We modeled the relation between DSF presence/absence and vegetation and soil data using GLMs (Table 3). Not surprisingly, bare ground showed a stronger positive correlation to DSF presence compared with other variables. Models that included bare ground held 86% of model weight and none of the vegetation variables showed association with DSF presence (Table 3). However, confidence intervals for all variables overlapped zero.

We recorded digital images from the 3 established photo stations on 16 September 2010. These images were stored at the Monitoring Program office to facilitate long-term comparisons of vegetation conditions.

## DISCUSSION

In 2010, the sixth year of DSF monitoring, the recorded number of observations decreased from the previous 2 years, although it remained considerably higher than in surveys from 2005-2007. We confirmed DSF reproduction again at Teledyne, the only conserved Core Area for this species.

From 2005-2009, we increased our survey effort each year and 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) increased significantly from 2005-2007 levels (Figure 2). In 2010 our survey effort decreased slightly due to a lack of available personnel, and number of observations per km walked also decreased slightly from 2009. However, the number of DSF observations per km walked remained substantially higher in 2010 than in 2005-2007.

The 2010 density estimate was lower than the calculated 2.76 individuals/ha (95% CI: 2.16-3.51) in 2009, but the detection probability was higher than it was in 2009 [0.31 (95% CI: 0.27-0.35)]. Although the total number of DSF observations was also lower in 2010 than in 2009, the detection probability was higher, while the accuracy of the estimate was about the same. This suggests that the decrease in estimated density of flies from 2009 to 2010 was real and not a result of poor detection. We are unable to isolate any single factor that might cause this decline although we suspect that the increase in vegetation cover may be a contributing factor. Continued surveys will be necessary to assess DSF population changes.

Although we estimated daily DSF density, using this estimate to determine annual DSF abundance is problematic without information about 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 survey period. However, if adult DSF live 1 week, our annual abundance estimate would be substantially lower, as we may have observed the same individuals repeatedly over several days. 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 the survey effort across different observers and survey years. If other DSF sites are conserved, we will be able to use this line-transect method to compare densities across sites.

**Table 3**. Parameter estimates ($\beta$), 95% confidence intervals (95% CI), and summed model weights ($\Sigma w_i$) for each vegetation and soil predictor variable. Estimates are model-averaged over all possible models weighted by Akaike weights (Burnham and Anderson 2002). Summed model weights indicate the relative importance of each variable. Note that findings are not statistically significant as confidence intervals for all variables overlapped zero.

| | **Intercept** | **Bare ground** | **Shrub cover** | **Soil compactness** | ***Amsinckia menziesii*** | **Brassicaceae/ Poaceae** | ***Stephanomeria* sp.** |
|---|---|---|---|---|---|---|---|
| $\beta$ | -1.85 | 0.69 | -0.01 | -0.06 | 0.04 | -0.66 | -0.01 |
| 95% CI | (-3.05, -0.65) | (-0.23, 1.61) | (-0.36, 0.33) | (-0.26, 0.14) | (-0.21, 0.28) | (-2.60, 1.28) | (-0.21, 0.18) |
| $\Sigma w_i$ | 1 | 0.86 | 0.28 | 0.41 | 0.29 | 0.46 | 0.28 |

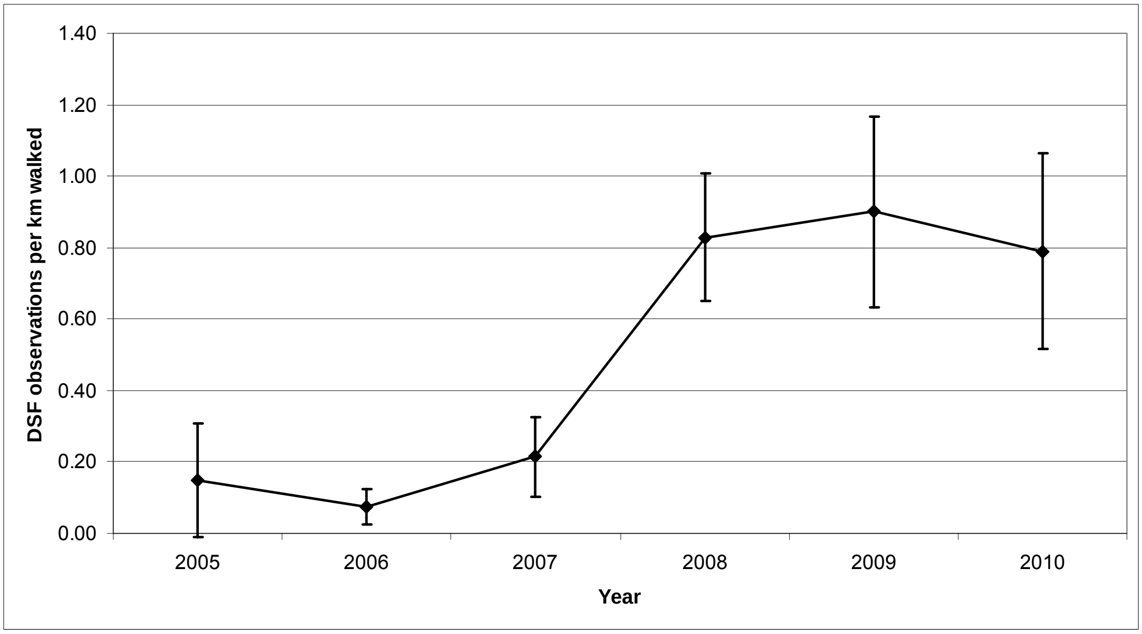


**Figure 2**. DSF observations per km walked during line-transect surveys. Error bars show 95% confidence limits, estimated by measuring the variation between daily surveys.

Two incidental observations about 700 m south of the Teledyne study area were recorded along a dirt road in 2010. Additional surveying was conducted around the exterior of the occupied polygon in an attempt to see if flies were dispersed beyond the study area but none were found.

Of all the variables examined this year, bare ground showed the strongest positive correlation with fly presence/absence, although it was a statistically weak correlation. However, the pattern does support earlier findings that adult DSF prefer open ground (USFWS 1997). Given the absolute decrease in bare ground cover and the corresponding increase in total vegetation cover from 2009 to 2010, the small decline in DSF observations is not unexpected. Another factor influencing the DSF-vegetation association may be the mobility of the adult fly and placement of the vegetation quadrats. Male flies usually perch in one spot for only a few seconds, then move to other locations; females, on the other hand, perch much longer than males. Taking this behavior into consideration, we conducted a pre-analysis using only female presence/absence as a response variable instead of all DSF presence/absence, but the results were similar.

*A. menziesii* showed a negative association with DSF presence in 2008 and 2009; however, in 2010 this variable was very slightly positively correlated with DSF presence. There is no known ecological reason to support a positive correlation between *A. menziesii* presence/absence and DSF presence/absence but this result weakens the hypothesis that presence of *A. menziesii* is negatively correlated with DSF presence.

## Recommendations for Future Surveys

We now have 3 consecutive 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 continue to take digital images at established photo stations to monitor the spread of invasive plants at the site.

Additional information regarding adult DSF life history, particularly adult DSF longevity and determination of the number of reproductive cycles that are typical in a season would allow better interpretation of DSF abundance estimates. Attaching radio transmitters to newly emerged individuals would allow estimation of 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.

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, a methodological lesson which allowed us to streamline habitat sampling in 2010.

Reports in previous years have identified *A. menziesii*, *H. incana*, and stabilized sand 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 above-ground vegetation and habitat conditions are not as important for DSF as subsurface habitat components (root structure, soil conditions, food sources) are for larval DSF. The larval stage is by far the longest in the DSF life cycle, as they overwinter as larvae. Investigating subsurface habitat conditions is likely beyond the feasible scope of Monitoring Program activities as it is not essential in order to meet the listed monitoring objective and involves additional disturbance of habitat for this Endangered Species. Another possibility is that the mobility of adult DSF makes it difficult to properly place vegetation sampling 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.

While 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, *A. 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.

Because vegetation surveys in the past several years have been inconclusive in determining fly presence/absence relative to selected habitat variables, future vegetation sampling efforts will have to carefully consider potential benefits from the effort and the resources that such work entails. Omitting the vegetation surveys in the future may be considered. We will continue to conduct annual line-transect surveys at the Teledyne site to document DSF reproduction and changes in abundance, unless instructed to do otherwise by the Reserve Management Oversight Committee, as per the DSF species account.

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[USFWS] U.S. Fish and Wildlife Service. 1997. Delhi Sands flower-loving fly (*Rhaphiomidas terminatus abdominalis*) Recovery Plan. U.S. Fish and Wildlife Service, Portland, OR. 51 pages.

## **Appendix A.** Western Riverside County MSHCP Biological Monitoring Program Protocol for Delhi Sands Flower-loving Fly Surveys, June 2010.

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 and collected 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 2010, we will survey only the Jurupa Hills Core Area (Teledyne site), as the Core Areas in the northwestern corner of the Plan Area (Mira Loma and the Agua Mansa Industrial Center) are currently inaccessible to the Monitoring Program.

## METHODS:

### Transect Set-up

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 every 30 – 40 m and flagging placed 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.

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 with data sheets and pen
- Thermometer
- Measuring tape
- Anemometer
- Binoculars (if desired)
- Digital 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.

Digital photos taken as data (e.g., photos of potentially teneral DSF or important behaviors) are stored as JPEG images at: S:\Projects\Data_Photos\DSF\2010 and are named according to the following convention: date photo was taken (yyyymmdd), observer initials, JPEG number (e.g., "20100324_AJM_043"). Digital photos that are not official data associated with a given survey (e.g., general survey area photos, surveyors in the field) are stored at: S:\Projects\Invertebrates\DSF\Non-Data_Photos\Photos '10 and should follow the same naming convention. Note that it is critical that the exact name of each photo also appears on the appropriate datasheet.

Also take waypoints and/or photographs of any other MSHCP Covered Species encountered. Record 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).

### 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 A cont. 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 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## **Appendix B.** Delhi Sands Flower-loving Fly Vegetation Sampling Protocol 2010

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 2010 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 as potential predictors of DSF presence or frequency of observation.

To characterize the study site, in 2008 we distributed four-hundred 2.25 $m^2$ quadrats 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 400 quadrats. In 2010, based on the results of a paired-sample power analysis, we decreased the number of quadrats used to characterize the site to 300. Even with the decreased sample size we will still be able to detect significant changes in cover and composition of vegetation across years.

To characterize locations where DSF have been observed, we will sample one 2.25 $m^2$-quadrat at each location where a perched DSF was recorded during surveys. 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.

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*). In addition, we will record percent cover of ground-cover components (litter, rock, basal stem, stabilized sand, loose sand, and hardpan), as well as the compactness of the soil within the quadrat.

### 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, surveyors will calibrate to a known percent cover with the aid of a 2.5 $m^2$ 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 $m^2$ quadrat and each surveyor will estimate cover within the quadrat following the 2010 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% of the point intercept values.

In addition to the point-intercept 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% 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. The surveyors will record the plot ID and the initials of the observers.

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 0.25 $kg/cm^2$ increment. If the recorded value is less than 0.5 $kg/cm^2$, the foot adapter should be attached to increase the accuracy of the reading.

**Quadrat Layout Equipment List:**

- Trimble
- Pin Flags (At least 100)
- Masking Tape
- Sharpie
- List of Quadrats
- Highlighter

**Surveyor Equipment List:**

- Quadrat
- Quadrat List
- GPS
- Declinated Compass
- Plant Identification Aides
- Pocket Penetrometer
- PDA
- Site Map
- Unknown label/envelope

## Data Analysis

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.

## Literature Cited:

U.S. Fish and Wildlife Service. 1997. Delhi Sands flower-loving fly (*Rhaphiomidas terminatus abdominalis*) Recovery Plan. U.S. Fish and Wildlife Service, Portland, OR. 51 pages.