Lower Colorado River
Multi-Species Conservation Program

Balancing Resource Use and Conservation

Monitoring of the MacNeill's Sootywing and its Habitats

2015 Annual Report

Work conducted under LCR MSCP Work Task F6

July 2017

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Lower Colorado River Multi-Species Conservation Program

Monitoring of the MacNeill's Sootywing and its Habitats

2015 Annual Report

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ACRONYMS AND ABBREVIATIONS

BB	Big Bend Conservation Area location code
BL	Beal Lake Conservation Area location code
CN	Cibola National Wildlife Refuge location code
CV	Cibola Valley Conservation Area location code
GPS	Global Positioning System
HH	Hunters Hole location code
HM	Hart Mine Marsh location code
IW	Imperial National Wildlife Refuge location code
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
MEFF	mobile electronic field form
n	sample size
PV	Palo Verde Ecological Reserve location code
RH	relative humidity
SE	standard error

Symbols

>	greater than
%	percent
±	plus or minus

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1 Map of Study Areas

ABSTRACT

Early life stages and an adult MacNeill's sootywing (*Pholisora gracielae* = *Hesperopsis gracielae* [MacNeill]), a small skipper butterfly, were searched for at 10 locations along the Lower Colorado River Valley. Evidence of sootywings was found at nine of the locations. A single location had low numbers of the larval food plant, quailbush (*Atriplex lentiformis*), and this may have resulted in non-detection of the butterfly. Early life stages of sootywings were associated with quailbush that had statistically higher soil moisture at the plant base. Plants where early life stage sootywings were detected (n = 41) averaged 63 $\pm$ standard error (SE) 6.3% soil moisture, while those where sootywings were not detected averaged 37 $\pm$ SE 4% soil moisture. Appropriate densities of quailbush also appeared to be important attributes for support of MacNeill's sootywing populations. The size of quailbush and the presence of nectar in the environment were not statistically important attributes contributing to the presence/abundance of sootywings.

INTRODUCTION

The MacNeill's sootywing (*Pholisora gracielae* = *Hesperopsis gracielae* [MacNeill]) is a small (wingspan 0.79 to 1.25 inches, 20 to 32 millimeters), dark-colored skipper butterfly endemic to the lower Colorado River system (Pratt and Wiesenborn 2011). Larvae of the sootywing can only complete development on the quailbush shrub (*Atriplex lentiformis*) (Wiesenborn 2012). A variety of other plant species are used for nectar by adult sootywings (Wiesenborn and Pratt 2010). Heliotrope (*Heliotropium curassavicum*) and western purslane (*Sesuvium verrucosum*) are considered important nectar sources for sootywing habitat creation (Wiesenborn and Pratt 2010).

This butterfly is the only invertebrate covered by the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is expected to facilitate a balance between the anthropogenic use of river resources and the conservation of native species and their habitats (http://www.lcrmscp.gov/general_program.html). Information contained within this report concerns MacNeill's sootywing presence at quailbush plots in LCR MSCP conservation areas. Quailbush attributes were examined at various locations as well as its associations with early life stage sootywings. Nectar plant presence was also studied because of its assumed importance in maintaining sootywing populations.

METHODS

Potential habitats for MacNeill's sootywings were surveyed for the presence of MacNeill's sootywing eggs, caterpillars, and adults, and habitat conditions were recorded. Selected monitoring sites all contained quailbush and were generally associated with conservation areas. Sites were monitored in April, May, and June 2015.

Five quailbush at each monitoring site were selected. The biologists collected data at the first quailbush near the survey start point. After data collection at that point, they walked for 5 minutes through the site. When 5 minutes passed, the biologists stopped walking and selected the closest quailbush. This was the second monitoring point. This method was repeated until the presence of MacNeill's sootywings and habitat conditions were recorded at five quailbush. The set stopping time allowed for data to be collected throughout the plot. The sampling locations within the plot were not truly random because the route walked through the environment was directed by the density of the quailbush and honey mesquite (*Prosopis glandulosa*), which can be impassible, and the presence of nectar plants. The timing of monitoring was designed so as to avoid the hottest times of the day (approximately 1:00 to 3:00 p.m.). Previous monitoring (e.g., Pratt and Wiesenborn 2009; Nelson et al. 2015) suggest that adult sootywings were difficult to find during the warmest time of day perhaps because they were avoiding activity and seeking shade within quailbush.

Quailbush at each monitoring point were measured for height, width (nearest 0.1 foot), and an estimated percentage of dry or absent leaves (an indicator of plant lushness, visually agreed upon by two observers). Soil moisture at the base of each plant was also measured. Moisture (% saturation relative to field capacity) was measured with a Kelway soil moisture tester, Model HB-2. Estimates of sootywing habitat quality also included floral (nectar) measurements. Floral abundance by plant species in the immediate environment was qualitatively noted, where 0 = none, 1 = scarce (flowers rarely encountered), 3 = common (flowers often observed), and 5 = abundant (floral abundance unlikely to be limiting). The floral index consisted of the sum of the value recorded for each plant species therefore, if 3 separate plant species all had abundant flowers, the plot score would be 15. This index favors both floral abundance and the diversity of flower sources.

Two people spent 5 minutes searching each selected quailbush for sootywing eggs and caterpillars. Any adult sootywings that were encountered were also enumerated. Identification of various life stages of sootywings utilized information in Nelson et al. (2015). Behaviors of detected adult butterflies were recorded as flying, perching, basking (wings open), nectaring (probing of flower with proboscis), puddling, mating, and ovipositing. A sootywing's sex was also recorded when distinguished; females are identified by paler and more mottled forewings and typically have a larger body size compared to males. After quailbush characteristics and sootywing observations were completed, timing for the next monitoring point was initiated. Quailbush were flagged after sampling to avoid resampling on future visits. If, during a survey, eggs or caterpillars were found at additional quailbush, information was also collected at these supplementary plants. Quailbush damage associated with presumptive larval sootywings and invertebrates other than sootywings was also noted (http://www.lcrmscp.gov/images/species/macneills_sootywing/macneills_sootywing_05.jpg). The presence of honey mesquite was documented at the end of each survey.

Windspeed (miles per hour), air temperature (degrees Fahrenheit), relative humidity (RH), and lux were collected at the start and end of each sampling occasion. The windspeed was measured with a Kestral 3000 Wind Anemometer Meter (±3% accuracy). The air temperature and RH were measured with a hand-held Extech Easy View 20 Hydro-Thermometer [RH range 10 to 95% with 0.1% resolution and basic accuracy of ±3% (30 to 95% RH) and ±5% (105 to 30% RH)]. Lux was measured with a hand-held Extech 401025 light probe meter (resolution of 1 lux with 5% accuracy). The temperature and RH were also recorded each time an adult sootywing was detected.

A mobile electronic field form (MEFF) developed by the LCR MSCP was used for data collection. Data were collected on a Trimble Global Positioning System

(GPS) unit running Terrasync software and downloaded and processed using Pathfinder Office Professional. Instructions for utilizing the MEFF is documented in the LCR MSCP Mobile Electronic Field Form Guidebook-Sootywing (LCR MSCP 2015).

Sites/Locations

Monitoring of both adult and immature stages of MacNeill's sootywings occurred at plots containing quailbush in LCR MSCP conservation areas. Sites and location codes (derived from the LCR MSCP Mobile Electronic Field Form Guidebook-Sootywing [LCR MSCP 2015]) are presented in table 1, and a map of site locations is presented in attachment 1.

Table 1.—Sites sampled for adult and immature stages of MacNeill's sootywings
(Sites are arranged upstream to downstream along the Colorado River Valley. Most sites were sampled in April, May, and June 2015. Three locations were sampled at the Palo Verde Ecological Reserve.)

Site	Location code	Global Positioning System		Comments
		Easting	Northing	
Big Bend Conservation Area	BB	714175.127	3887327.004	Few quailbush at this site.
Beal Lake Conservation Area	BL	725505.21	3851154.723	
Palo Verde Ecological Reserve	PV-1	728330.681	3730507.485	Also sampled in 2014 but identified as Blythe NE (NE) in annual report.
	PV-4	730597.745	3731109.796	Also sampled in 2014.
	PV-6	731041.534	3732449.239	Also sampled in 2014
Cibola Valley Conservation Area	CV	714169.985	3698891.325	Sampled in 2014 but identified as CVCA-4-west-north in annual report.
Cibola National Wildlife Refuge	CN	714367.433	3687283.13	Sampled in 2014.
Hart Mine Marsh	HM	717898.281	3686015.794	Previously sampled in 2014.
Imperial National Wildlife Refuge-Betty's Kitchen	IW	735364.375	3634299.612	Sampled in May and June 2015.
Hunters Hole	HH	706561.848	3600219.199	Sampled small-stature quailbush along wetland edge and larger plants that were more upslope.

Statistics

Differences in characteristics of quailbush where early life stages of sootywings were "detected" and "not detected" were tested for with *t*-tests. A Pearson correlation was employed for examination of relationships between variables and total sootywing abundance (all life stages).

Box and whisker plots were used to graphically examine quailbush use by sootywings. Boxes enclose the middle half of the data and are bisected by a line that represents the median value. The "X" within the box is the mean value. Vertical lines at the box top and bottom represent the range of typical data values. Asterisks represent possible outliers, and o's represent probable outliers. Possible outliers are outside the box boundaries by > 1.5 times the box size, and probable outliers are outside the boundaries by more than 3 times box size. The software *Statistix 10* was used for performing analyses.

RESULTS

Mobile Electronic Field Form Method Analysis

The MEFF was modified over the three sampling dates. Data on the presence of butterflies other than sootywings were omitted, as earlier studies (e.g., Pratt and Wiesenborn 2011) indicate confusion of sootywings with other butterflies in the environment was unlikely. The collection of lux data at the base of quailbush were not included in the methods used in 2015, as surveys in 2014 (Nelson et al. 2015) showed that quailbush provided adequate shade and refuge from heat for sootywings.

Operating the MEFF on a Trimble GPS unit makes it easy to inadvertently enter incorrect data. On several occasions it was noted that pressing a number with the stylus would result in a different number appearing. This could be important in cases where the intention was to record one egg, and the entry comes up as a zero (or vice versa). Investigators need to be aware that this may happen.

The screen on a Trimble GPS unit is also an issue, as the sun's reflection can temporarily blind the operator even while wearing sunglasses.

The use of a Trimble GPS unit also requires two people sampling together, as the attention required to operate the device and fill in the MEFF means that one person is needed for operating the unit while the other is fully devoted to searching for sootywings. If one surveyor is used, more time per monitoring point may be required to ensure that 5 minutes are spent searching for sootywings and the data are recorded before moving to the next survey point.

In a single case, data were missing. This occurred at the Imperial National Wildlife Refuge (IW) in May. It seemed that the Trimble GPS unit failed to charge (perhaps because of a faulty outlet) the prior day. Despite being fully charged the following night, there was a failure to obtain satellite readings during the IW survey. Later examination suggested that the Global Navigation Satellite System feature had been automatically turned off during the low-battery period and resulted in the absence of data collection.

General Quailbush Plot Information and Feeding Damage

Most quailbush were generally dispersed in groves; however, some had been planted in rows (table 2). Leaf size and density varied between locations as did feeding damage. Quailbush damage attributed to sootywing caterpillars was deemed as absent to scarce at most locations. Damage associated with other insects was often attributed to feeding by moth caterpillars (table 2).

Table 2.—General quailbush characteristics and observed feeding damage

Location	Quailbush grove typology/irrigation history	Leaf size and density	Larval sootywing damage	Insect damage
BB	Dispersed.	Small leaves of medium to high density.	Absent to scarce	Grasshopper feeding damage noted in June; galls and thrips also present.
BL	Dispersed.	Small to normal leaves of medium density.	Absent to scarce	Insect damage limited to some moth[a] caterpillar feeding.
PV-1	Dispersed.	Small to normal leaf sizes with medium to high density.	Absent to scarce	None.
PV-4	Planted in rows and irrigated.	Mostly normal-sized leaves of low to medium density.	Absent to scarce	None.
PV-6	Planted in rows and irrigated.	Small to normal leaf size with medium to high leaf density.	Absent to light	Damage from moth caterpillars noted in a single instance.
CV	Planted in rows. Irrigated in the past but not at present time.	Normal-sized leaves of medium density.	Light to moderate	Moth damage noted on a single occasion.
CN	Dispersed.	Small to normal leaf size of mostly high density.	Moderate	Moth damage was noted at a single plant.
HM	Dispersed plants. Groundwater appears to be near the surface.	Normal leave sizes of low to high density.	Absent to light	Moth damage noted on a few plants.
IW	Dispersed plants. Tags on some plants indicated plantings within past 2 years. Irrigated in past.	Normal leaf sizes of mostly low density.	Absent to scarce	No insect damage.
HH	Dispersed.	Mostly normal-sized leaves with a wide range of densities.	Absent to scarce	Moth damage was noted at several plants.

[a] In past years, moths associated with quailbush were identified as being *Trichocosmia inornata* in the family Noctuidae (Nelson et al. 2015).

Quailbush Attributes

PV-4 and HM contained relatively large quailbush (table 3), while the smallest stature plants were found at BB, PV-6, and CV. Quailbush plants at PV-1 were exceptionally dry and also had very low soil moisture (table 3). Soil moisture varied widely at locations, with BB and PV-1 having mean values of less than 1%, while other locations were in the 80% range (PV-4, PV-6, and HM). Quailbush at BB were so uncommon (eight plants) that some of the few plants present were resampled over the three months. Therefore, the n value in table 3 represents something other than 16 separate plants.

Table 3.—Quailbush attributes at LCR MSCP conservation locations
(Locations are arranged from upstream to downstream along the Colorado River Valley. Values are mean ± standard error and range [minimum and maximum]).

Location code	Quailbush attributes			
	Height (feet)	**Width (feet)**	**Plant dryness (%)**	**Soil moisture (%)**
BB (n = 16)[a]	5.0 ± 0.4 (1.0 – 7.0)	6.7 ± 0.6 (1.2 – 8.5)	5.3 ± 1.3 (0.0 – 15.0)	0.6 ± 0.4 (0.0 – 5.0)
BL (n = 16)	7.9 ± 0.5 (5.0 – 12.0)	11.9 ± 0.8 (5.0 – 18.0)	6.3 ± 2.0 (0.0 – 25.0)	33.3 ± 9.0 (0.0 – 100.0)
PV–1 (n = 15)	6.8 ± 0.5 (4.0 – 10.0)	8.0 ± 0.7 (5.0 – 15.0)	39.3 ± 8.1 (0.0 – 100.0)	0.4 ± 0.4 (0.0 – 5.0)
PV–4 (n = 16)	9.7 ± 0.8 (5.0 – 15.0)	10.2 ± 0.6 (7.0 – 16.0)	8.7 ± 3.3 (0.0 – 50.0)	86.9 ± 6.0 (10.0 – 100.0)
PV–6 (n = 15)	5.3 ± 0.4 (3.5 – 8.0)	7.6 ± 0.4 (4.5 – 10.0)	15.0 ± 3.3 (0.0 – 40.0)	89.0 ± 5.0 (30.0 – 100.0)
CV (n = 17)	5.5 ± 0.5 (1.5 – 10.0)	6.1 ± 0.7 (1.5 – 15.0)	10.0 ± 2.5 (0.0 – 30.0)	32.9 ± 8.2 (0.0 – 100.0)
CN (n = 16)	6.5 ± 0.4 (4.0 – 9.0)	9.6 ± 0.7 (4.0 – 16.0)	6.6 ± 2.6 (0.0 – 75.0)	59.4 ± 8.5 (0.0 – 100.0)
HM (n = 17)	8.9 ± 0.4 (5.50 – 12.0)	11.6 ± 0.8 (6.5 – 21.0)	6.8 ± 1.6 (0.0 – 20.0)	88.5 ± 5.6 (30.0 – 100.0)
IW (n = 5)[b]	8.4 ± 1.1 (5.0 – 11.0)	11.3 ± 1.6 (6.5 – 15.0)	0.0 ± 0.0 (0.0 – 0.0)	10.0 ± 7.6 (0.0 – 40.0)
HH (n = 18)	6.5 ± 0.6 (4.0 – 14.0)	7.2 ± 0.4 (4.0 – 11.0)	2.2 ± 1.7 (0.0 – 30.0)	16.4 ± 5.5 (0.0 – 65.0)

[a] Quailbush at this location were resampled each month because of a limited number of plants (eight plants).

[b] Low numbers due to data not being collected because of equipment failure.

Note: As there were only eight quailbush plants at BB, the analysis of quailbush attributes for this site was flawed. The correct summary statistics for BB should have been based on the mean of the repeated measures for each plant. The ranges and standard error in the analysis represent temporal variation (including some measurement error) instead of variation among plants. In the future, when this situation occurs, it is recommended to use the plant means for *t*–tests as well (so the total number of plants would be 135 instead of 150).

Sootywing Abundance and Distribution

Sootywings were detected at all locations except for BB (table 4). Adults were most commonly detected, followed by eggs and then caterpillars (table 4). The number of sootywings detected differed among locations, with the highest numbers recorded from HM, CV, and PV-4. Much lower numbers were found at BL, PV-1, and IW (table 4). It did not appear that the level of feeding damage was a good indicator of how frequently sootywings were detected at a location (compare tables 2 and 4).

Table 4.—Numbers of immature and adult stages of MacNeill's sootywings found at LCR MSCP conservation area locations
(Locations are arranged from upstream to downstream along the Colorado River Valley.)

Location code	Month	Number of eggs	Number of caterpillars	Number of adults	Total all stages and months
BB	April	0	0	0	0
	May	0	0	0	
	June	0	0	0	
BL	April	0	0	0	3
	May	0	1	2	
	June	0	0	0	
PV-1	April	0	0	0	3
	May	0	0	0	
	June	1	1	1	
PV-4	April	2	0	6	22
	May	0	1	0	
	June	3	0	10	
PV-6	April	3	0	0	12
	May	0	0	0	
	June	6	0	3	
CV	April	0	0	1	31
	May	4	0	9	
	June	12	5	0	
CN	April	4	1	2	21
	May	1	1	10	
	June	2	0	0	
HM	April	5	1	1	37
	May	2	0	19	
	June	7	2	0	
IW	May*	0	0	0	1
	June	0	0	1	
HH	April	0	0	0	7
	May	0	0	4	
	June	1	0	2	
	Totals	**53**	**13**	**71**	**137**

* May data at IW were not recorded on the MEFF.

Sootywing Behaviors

Adult sootywings were observed at temperatures from 72 to 109 degrees Fahrenheit and at % RH from 0 to 38.2. Windspeeds were recorded on the Beaufort scale (an empirical measure of wind strength ranging from calm [force 0] to hurricane [force 12]), and most windspeeds fell within the Beaufort scale of 0–3 (calm to light air). On three occasions, values were recorded as 4–6, which is a light breeze according to the scale. The highest value was observed at HM in May (Beaufort scale = 6), and it did not seem to inhibit the flight of sootywings, as the highest number of adults were recorded at this location in May (see table 4). Microclimates within quailbush likely decrease wind effects on sootywings.

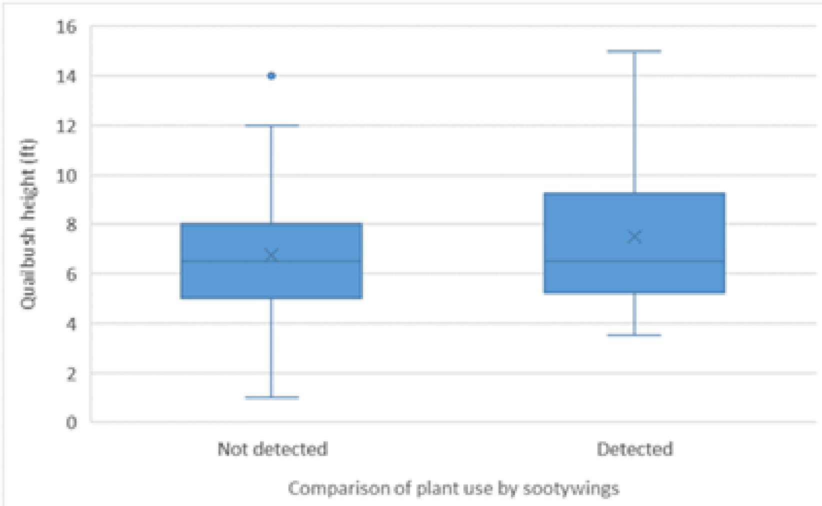
Sixty-nine behaviors were noted. Flying was the numerically dominant behavior (54%), and sootywings were observed flying from approximately 8:00 a.m. to 4:30 p.m. Basking was detected for 16% of sootywing observations. Nectaring was noted as 12% of the behaviors; however, seven out of eight of these observations were on a single day at HM and all of these were at a single species of unidentified nectar plant. Perching was observed 10% of the time. Ovipositing was the least observed behavior, at 9%.

Quailbush Attributes and Associations with Sootywings

The presence of egg and larval stages of sootywings on quailbush were not significantly associated with quailbush height (n = 41 detected sootywings, n = 109 not detected; two sample *t*-test for mean differences, T = 1.41, p = 0.17), width (T = 0.79, p = 0.43), or percent dry quailbush (T = -0.85, p = 0.39) (figures 1 and 2a). Significant differences, however, were detected in soil moisture at the base of selected quailbush where sootywings were detected and not detected (n = 41 detected sootywings, n = 108 not detected; T = 3.38, p = 0.001) (figure 2b). Mean soil moisture at the base of quailbush where sootywings were detected was 62.6 $\pm$ standard error (SE) 6.3 and 37.4 $\pm$ SE 3.9 at plants where sootywings were not detected.

When moisture and sootywing abundance were examined at the level of location, there was also a significant association between soil moisture and total abundance (r = 0.69, p = 0.03; figure 3).

a



b

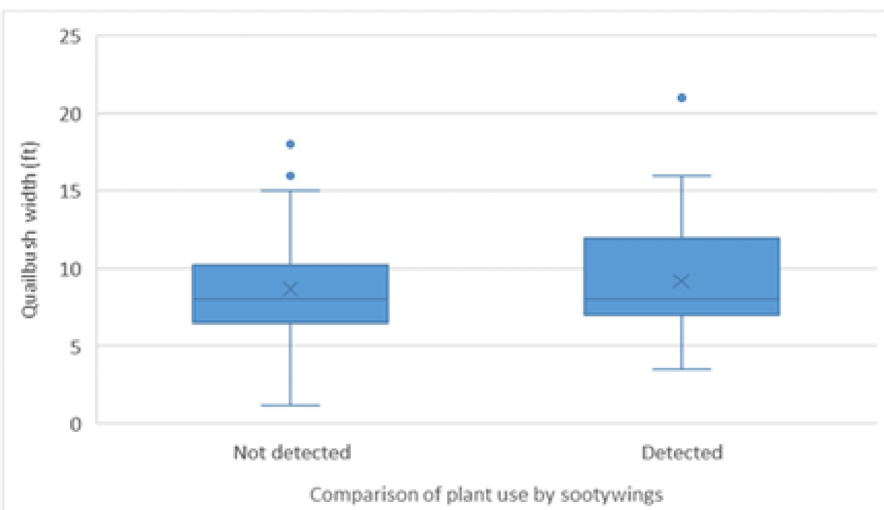
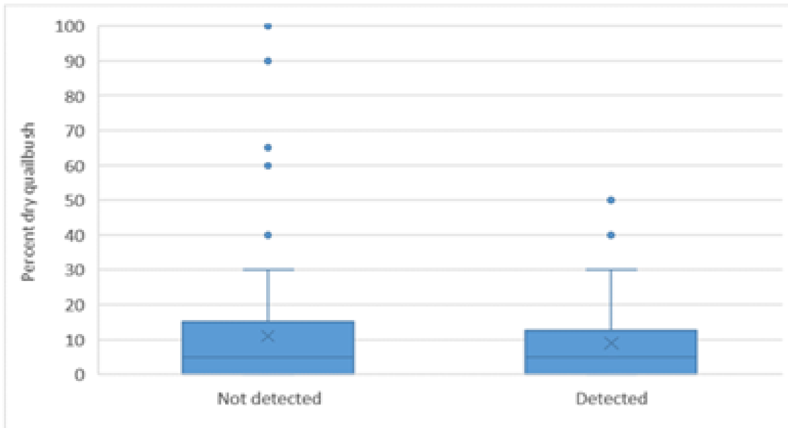


Figure 1.—Quailbush height (a) and width (b) at plants where early stage sootywings were detected and not detected.
No statistical differences were detected.

a



b

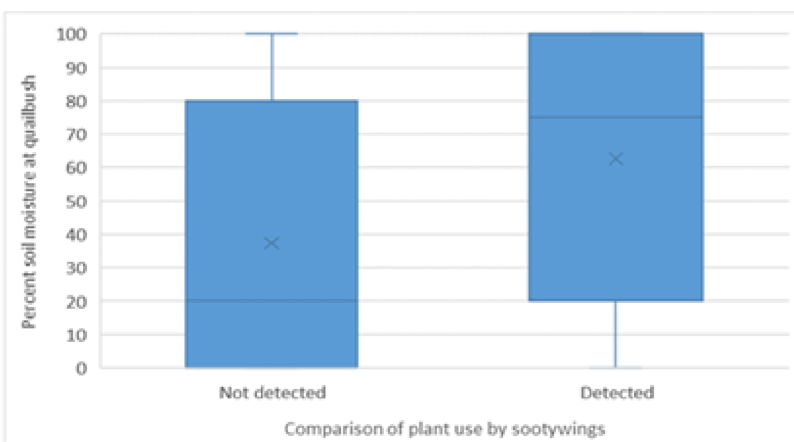


Figure 2.—Percent dry quailbush (a) and soil moisture (b) at plants where early stage sootywings were not detected and where they were detected.
While percent dry quailbush did not differ significantly between the two groups, there were significant differences between soil moisture at plants where sootywings were detected and not detected ($p = 0.001$).

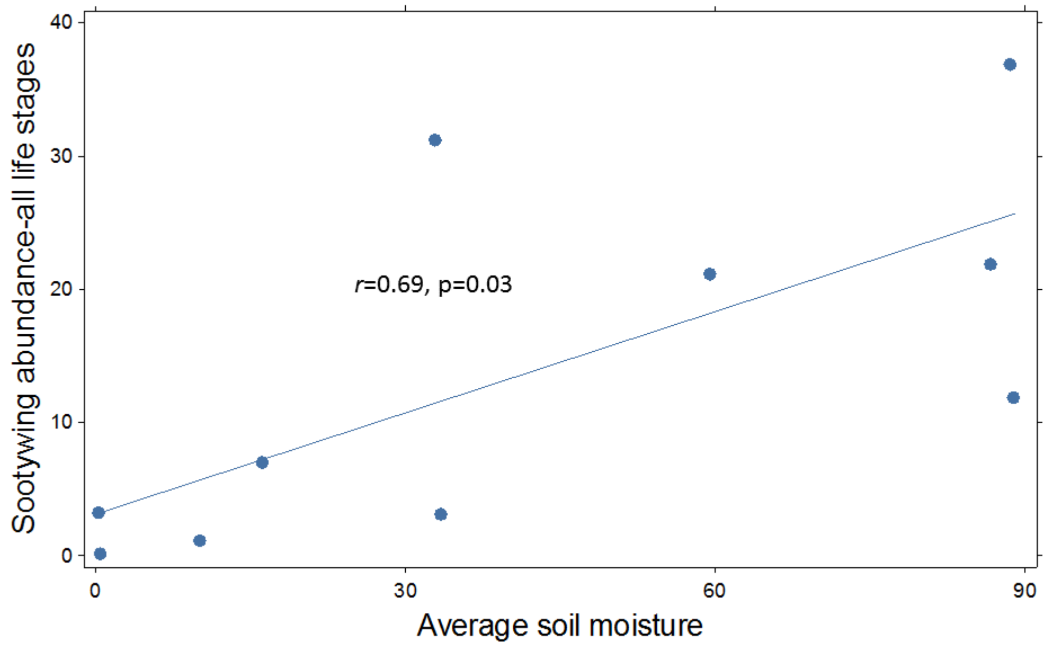


Figure 3.—Relationship between soil moisture at monitoring locations and sootywing abundance.

Floral Index

Floral metrics ranged from 0–8 for all sites and months. Only honey mesquite and arrowweed (*Pluchea sericea*) were ever deemed to have abundant flowers in the environment. Heliotrope, western purslane, and alfalfa (*Medicago sativa*) were uncommon elements that also contributed to the floral index. Mean index values for locations were highest at BB (5.3 $\pm$ SE 2.2) and PV-6 (5.3 $\pm$ SE 1.3). No flowers were detected at PV-1.

The two locations with the highest mean floral metrics differed greatly in the number of detected sootywings (all life stages). No sootywings were detected at BB, which had the highest mean floral index, while 12 were detected at PV-6. The highest number of sootywings (37) were found at HM, and floral metrics there ranged from 1–5 for the three months. It did not appear there was any relationship between the mean floral index and sootywing abundance (r = -0.023, p = 0.94971) at locations.

DISCUSSION

MacNeill's sootywings were detected at 9 of the 10 locations monitored in 2015. Locations were spread over a wide geographic range. Quailbush plots also varied in characteristics and irrigation history, along with differences in plant height, width, and leaf size. Early life history stages of sootywings seemed to be positively associated with environments with greater soil moisture. There was a significant correlation between soil moisture and sootywing abundance. Environmental moisture and quailbush plant moisture have been linked to successful sootywing populations in the past (Pratt and Wiesenborn 2011; Wiesenborn and Pratt 2008). The present information supports these earlier studies.

The absence of any correlation between floral indices and sootywing abundance seems to point to limited importance of nectar to sootywings. Information collected in 2014 (Nelson et al. 2015) also found no association between floral metrics and sootywing abundance. This assumption is also supported by how few adult sootywings were seen nectaring. Nectaring behavior is uncommon in sootywings. Pratt and Wiesenborn (2009) observed a large number of sootywing behaviors (1,620) and noted that only 12% of these behaviors involved landing on flowers (nectaring), which matches what was found in 2015. This is also similar to the 8% nectaring observed in 2014 (Nelson et al. 2015). While Pratt and Wiesenborn (2011) indicate nectar plant abundance was important to increasing fecundity, the information in this report indicates that abundant nectar is not obligatory for sootywing presence at a plot. Butterfly species differ in their use, and perhaps need, of nectar. Loertscher et al. (1995) compared five different butterfly species and found species-specific nectaring behavior varying from 0.2 to 53% of observed behaviors. It seems that sootywings are at the low end of butterfly nectar need.

The single location where sootywings were not detected was at BB, where quailbush were uncommon. Eight individual plants were documented at this location. This location also had very low soil moisture. The combination of dryness with a low density of quailbush may decrease the suitability of the plot for sootywings. As there were only eight quailbush plants at BB, the analysis of quailbush attributes for this site was flawed. The correct summary statistics for BB should have been based on the mean of the repeated measures for each plant. The ranges and SE in the analysis represent temporal variation (including some measurement error) instead of variation among plants. In the future, when this situation occurs, it is recommended to use the plant means for *t*-tests as well (so the total number of plants would be 135 instead of 150).

At some plots quailbush appeared healthier in 2015 compared to recent years. CV was a good example. Quailbush that appeared dead in the past had relatively low percent dry values (plants were lusher) in 2015. In 2014, sootywings were undetected (with one more additional sampling trip compared to 2015), except along the edge of the plot where leaky irrigation gates allowed for growth of some robust quailbush. The entire CV plot in 2015 supported sootywings, especially in June. A maximum of seven eggs was recorded at one particular quailbush at CV in 2015.

Plot moisture (and influence on quailbush moisture) and appropriate densities of quailbush appeared to be the most important attributes for support of MacNeill's sootywing populations. The size of quailbush and the presence of nectar in the environment did not seem to be driving forces in plot suitability for sootywings.

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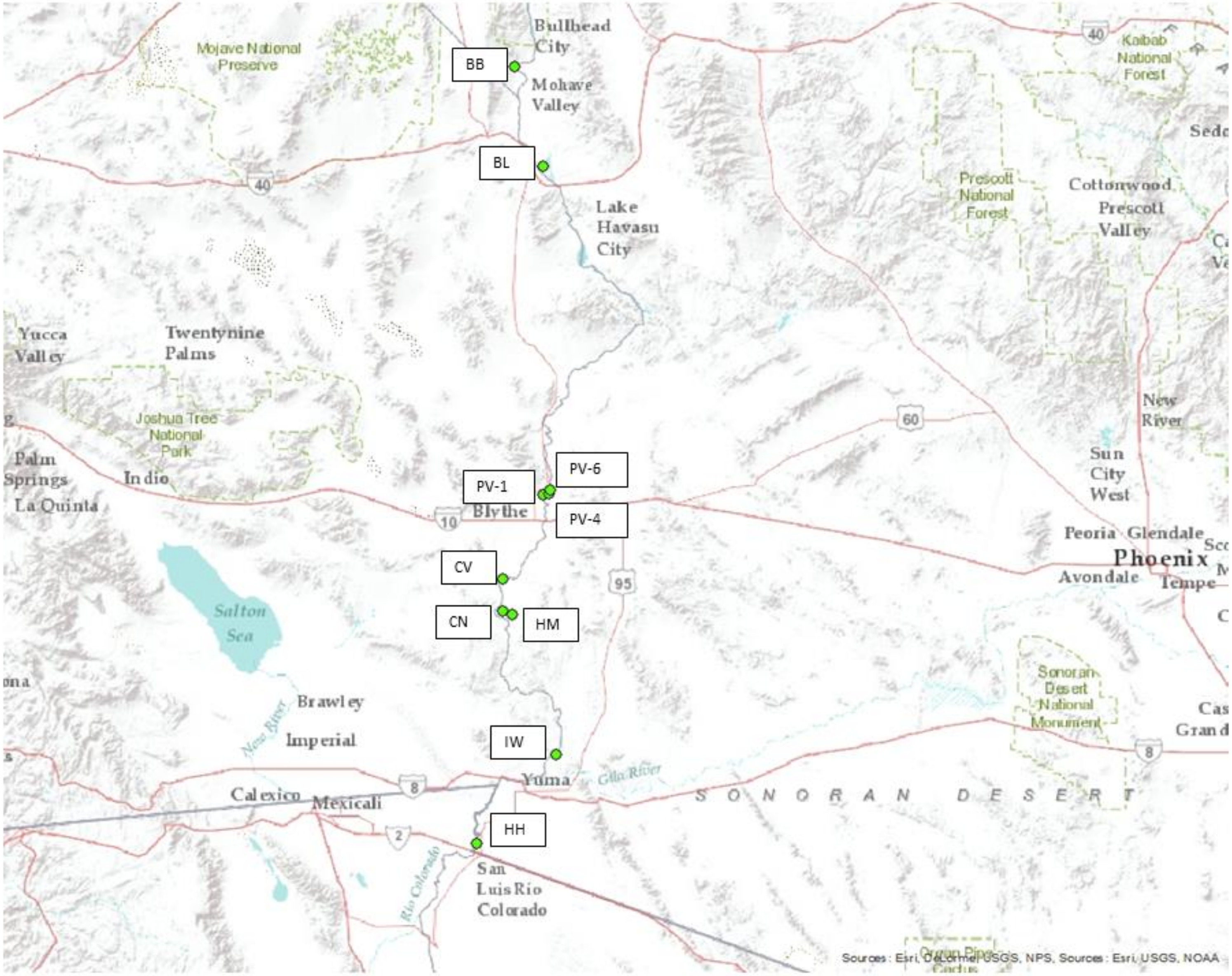
ATTACHMENT 1

Map of Study Areas



BB
BL
PV-6
PV-1
PV-4
CV
CN
HM
IW
HH
Bullhead City
Mohave Valley
Lake Havasu City
Mojave National Preserve
Twentynine Palms
Yucca Valley
Joshua Tree National Park
Palm Springs
Indio
La Quinta
Blythe
Salton Sea
Brawley
Imperial
Calexico
Mexicali
Yuma
San Luis Rio Colorado
Prescott National Forest
Cottonwood
Prescott Valley
Kaibab National Forest
New River
Sun City West
Peoria
Glendale
Phoenix
Avondale
Tempe
Sonoran Desert National Monument
SONORAN DESERT
Gila River
New River
Rio Colorado
Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA