ASSESSING THE STATUS AND EVALUATING HABITAT PREFERENCES OF THE THREATENED SKIPPER, *EUPHYES VESTRIS HARBISONI*, IN SOUTHERN CALIFORNIA

by

Abigail R. Lyons

An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
in the Department of Biological & Clinical Sciences
University of Central Missouri
May, 2023

ABSTRACT

by

Abigail R. Lyons

The dun skipper is found throughout much of the United States; however, the Harbison's dun skipper subspecies is geographically isolated in southern California and northern Mexico. It is only known to feed on the San Diego sedge as a larva and a previous listing as a Category 2 species by the United States Fish and Wildlife Service demonstrates concern for its conservation. I conducted surveys in 2021 and 2022 to update the status of populations, and a mark-recapture study in 2022 to estimate population sizes and compare to visual survey estimates. Habitat preferences were explored by collecting habitat covariates in the field and analyzing GIS available environmental data. Skippers were detected at seven of the 17 sites visited in 2021, but due to the small population sizes and low recapture numbers in 2022, population estimates were able to be calculated for only two locations. Habitat analysis found no significant difference found between used and unused portions of woodlands. Woodlands with San Diego sedge were more likely to be historically occupied at higher elevations with warmer summer temperatures. My results show a more restricted distribution of the skipper, and declining populations at extant sites. Small numbers of individuals and low accuracy population estimates indicate that maximum daily counts are a more useful monitoring method for the Harbison's dun skipper. Habitat analysis determined that the entirety of the woodlands should be considered important habitat, while a large-scale approach highlighted the environmental conditions for areas that may be colonized by the skipper. These data bring into focus areas where conservation and restoration can focus in order to help promote the longevity of the Harbison's dun skipper.

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CHAPTER 1

Introduction

Many ecosystem functions rely on biodiversity to keep them operating at maximum capacity and global biodiversity losses have led to a decline in many of the species that perform these functions (Macdougall et al. 2013; Oliver et al. 2015; Cardoso et al. 2020). In recent decades, insect abundance and diversity have been declining due to a variety of factors including habitat loss and climate change (Hallmann et al. 2017; Montgomery et al. 2019; Seibold et al. 2019; van der Sluijs 2020; Didham et al. 2020; Wilson and Fox 2021). Recent research suggest that these insect declines are widespread, and may be affecting other trophic levels in the ecosystem due to the critical role of insects (Kunin 2019; Seibold et al. 2019; Møller 2019). Climate and population modeling predicts continued declines in population sizes and shifting distributions among many insect groups in the coming decades (Maes et al. 2010; Engelhardt et al. 2022). Due to these declines, there is a call for an increase in species monitoring and planning to preserve and restore habitats in order to maintain populations (Forister et al. 2019).

Europe has a relatively long history of butterfly monitoring and has documented declines in butterfly population sizes, distribution, and dispersal due to habitat loss and climate warming (Saarinen et al. 2003; Stefanescu et al. 2011). These trends are correlated with habitat structure and land use, with species in semi-natural grasslands decreasing but those in open field margins increasing (Kuussaari et al. 2007). The European Grassland Butterfly Indicator reported a 39% decline in the abundance 17 butterfly species from 1990–2017 across 16 countries in the European Union (Van Swaay et al. 2019). Additionally, decreased grazing in woodland areas and increased grazing and spring hay harvest in grassland areas promotes declines in specialist and other butterfly species (Nilsson et al. 2013).

Monitoring efforts in the United States have also documented declines in butterfly populations (Wepprich et al. 2019; Forister et al. 2021). Monitoring from 1996–2016 in Ohio, USA showed an approximate 33% decrease in butterfly abundance over this 20-year period (Wepprich et al. 2019). Long-term survey data from midwestern United States have also shown significant decreasing trends in butterflies and skippers, especially in grassland and specialist species (Schlicht et al. 2009; Swengel and Swengel 2015). Ecological factors such as increased wildfire (Swengel 2001; Schlicht et al. 2009; Swengel et al. 2011) and habitat fragmentation (Summerville and Crist 2001) were correlated to the declining trends in grassland butterflies. Across the western United States, drought conditions over the past 40 years have resulted in a 1.6% annual decline in butterfly population sizes (Forister et al. 2021). Although population trends are not uniform across the United States, population declines in areas with low precipitation rates and warmer temperatures point to the changing climate as a factor (Crossley et al. 2021).

California has a rich history of butterfly research, which has also documented declines in butterfly populations. Species richness varies across locations and habitats, but many sites and species have exhibited declines (Forister et al. 2010, 2011). Effects of a long term drought along an elevation gradient caused decreases in species diversity, population sizes, and species densities, leading to delayed and shortened flight times at higher elevations (Forister et al. 2011, 2018). Additional studies in California suggested that increased neonicotinoid use (Forister et al. 2016), land-use changes (Casner et al. 2014), and wildfires (Marschalek and Klein 2010; Dartnell et al. 2022) are potential causes for the decline in butterfly populations and diversity but there is still a need for long term monitoring.

Within the butterflies (Lepidoptera: Papilionoidea), several skipper species (Hesperiidae) have been listed as threatened or endangered in the United States. The Dakota skipper (*Hesperia dacotae*) and the Poweshiek skipperling (*Oarisma poweshiek*) are at risk of extinction due to prairie habitat loss and associated population declines in both the United States and Canada (Dearborn and Westwood 2014; Pogue et al. 2016; Belitz et al. 2018; US Fish and Wildlife Service 2019). The Pawnee montane skipper (*Hesperia leonardus montana*), is restricted to four counties in Colorado and highly vulnerable due to habitat loss and alteration and fire (US Fish and Wildlife Service 1998). The Ottoe skipper (*Hesperia ottoe*) has also been a focus of conservation in tallgrass prairies in Illinois, Iowa, Minnesota, and Wisconsin, USA, and has experienced population declines since the late 1900s. During surveys conducted from 1998–2011, only 11–33% of the study sites had detectable populations (Swengel and Swengel 2013).

The Harbison's dun skipper (*Euphyes vestris harbisoni*) is another skipper, as well as a habitat specialist, that has declined in population sizes and distribution (Marschalek et al. 2019). At the species level, the dun skipper (*Euphyes vestris*) is known to inhabit much of the United States and parts of southern Canada (Glassberg 2001), with the Harbison's dun skipper subspecies occurring only in southern California and northern Mexico (Brown and McGuire 1983; Marschalek et al. 2019). The larval stage is only known to feed on the leaves of one plant species, San Diego sedge (*Carex spissa*), which is most often found in riparian oak woodland habitats (Brown and McGuire 1983; Marschalek et al. 2019). San Diego sedge has a distribution that is more widespread than skipper, extending as far north as Monterrey County, CA, USA (CalFlora 2023).

Brown and McGuire (1983) described this subspecies as tan to dull brown with a forewing length ranging from 14.7–17.0 mm in females and 15.0–16.1 mm in males (Figure 1).

The species is sexually dimorphic, with males characterized by a black stigma on the forewing that is not present in females (Brown and McGuire 1983). Adults emerge starting in May, are active until mid-July, and can be found nectaring on a variety of floral sources (Brown and McGuire 1983; Marschalek et al. 2019).

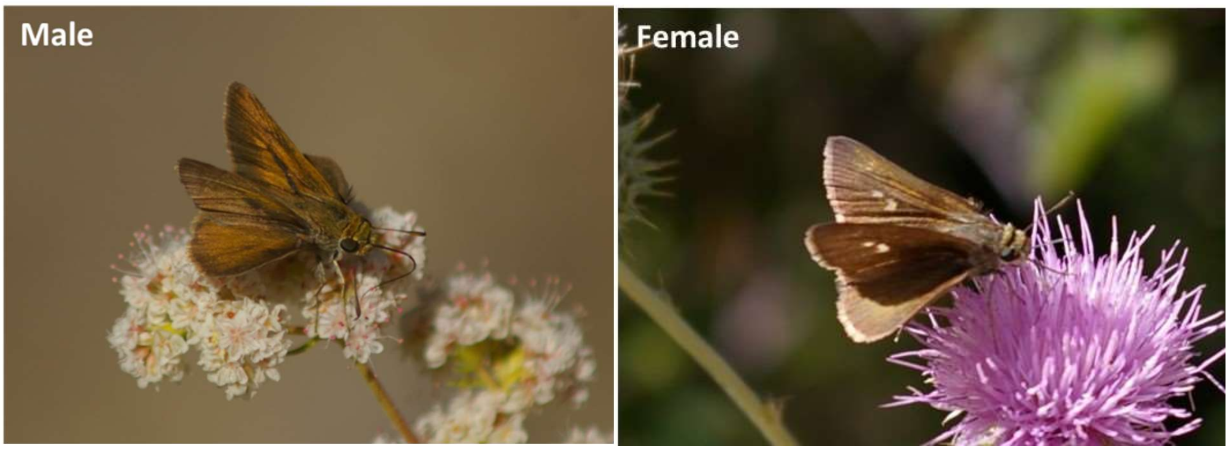

Figure 1. Adult Harbison's dun skippers. Males are characterized by the black stigma on the forewing (photos by D.A. Marschalek).

The Harbison’s dun skipper has been of conservation concern for the last few decades. This skipper was listed as a Category 2 species (a discontinued classification), indicating that listing as threated or endangered may be appropriate, but sufficient data was not available (US Fish and Wildlife Service 1989). In 1991, a petition to list the skipper on the Endangered Species Act was submitted (US Fish and Wildlife Service 1991) but that petition did not contain sufficient data to justify listing (US Fish and Wildlife Service 2006), again requiring more data to properly assess the skipper. Recent surveys yielded numerous locations for possible populations based on the presence of San Diego sedge; however, approximately 66% of locations were occupied and all population sizes were small (Marschalek et al. 2019).

Due to conservation concerns and knowledge (data) gaps, further study is needed to update population trends, distribution, and habitat use by the skipper. Addressing these questions will allow for the development and prioritization of effective management practices to better preserve habitat and increase population sizes. This study aims to address the following objectives:

1. Update the status of the Harbison's dun skipper by describing changes abundance and distribution in 2021 and 2022 on conserved lands in San Diego County.
2. Quantify population sizes by comparing marking estimates with transect counts at a subset of populations in 2022.
3. Describe movement patterns within and between occupied and unoccupied riparian oak woodlands using a subset of populations in 2022.
4. Quantify and compare habitat characteristics (e.g., canopy density, elevation, percent cover bare ground) of areas used and not used by adult skippers, and across occupied and unoccupied riparian oak woodlands to describe preferences of the skipper.

CHAPTER 2

Methods

Study Area

This study was conducted in San Diego County, CA, USA in the foothills to the north and east of the city of San Diego. The surveys focused on the riparian oak woodlands approximately 234 to 974 m in elevation, but much of the surrounding habitat is comprised of coastal sage scrub and chapparal.

Harbison's dun skippers were recorded at a number of locations in San Diego County, California during surveys from 2013-2017. Locations (Figure 2) of previous skipper sightings (Marschalek et al. 2019) and San Diego sedge were visited weekly from mid-May to late June in both 2021 and 2022, weather permitting. Sites surveyed in 2021 included Barrett Lake, Boden Canyon Ecological Reserve, Crestridge Ecological Reserve, Daley Ranch, Hellhole Canyon County Park, Hollenbeck Canyon Wildlife Area, Lake Hodges, Pamo Valley (Cleveland National Forest, CNF), Red Mountain, San Diego National Wildlife Refuge-Las Montanas (South), San Pasqual Academy, Skye Valley Road (Cleveland National Forest, CNF), and Sycuan Peak Ecological Reserve.

Based on the results of weekly surveys in 2021, a subset of sites was selected for a mark-recapture study in 2022. Marking sites (Figure 2) included Barret Lake, San Diego National Wildlife Refuge (SDNWR)-Beaver Hollow, Hollenbeck Canyon Wildlife Area, and Skye Valley Road (CNF). Additional sites were visited in 2022 to survey for adult skippers and conduct vegetation sampling, including Crestridge Ecological Reserve, Hellhole Canyon County Park, Lake Hodges, Pamo Valley (CNF), and Sycuan Peak Ecological Reserve.

Figure 2. Study sites in San Diego County. Visual surveys were conducted at all sites, while mark-recapture studies were conducted at the sites in blue.

Visual Surveys

Surveys, following previously developed protocol (Marschalek et al. 2019), were conducted from May 23 to June 29 in 2021 and May 26 to June 24 in 2022. Surveys began at approximately 8:30 am as long as temperatures were at least 24°C and completed at approximately 2:00 pm when high temperatures result in decreased skipper activity. Each site was surveyed for at least an hour, regardless of if adults were observed or not. Surveys began at areas near San Diego sedge plants and extended outward to include more of the woodland and adjacent flowering plants if skippers were not immediately detected. For each skipper observation, the sex, plant species (if nectaring), and location with a Garmin handheld GPS unit were recorded. Air temperature and wind speed were recorded with a handheld Kestrel weather meter. Sites were visited weekly in 2021.

Mark-recapture Surveys

To further assess local population sizes within habitat patches (oak riparian woodlands), a marking study was conducted from mid-May to late June 2022. Sites were selected based on observations of several Harbison's dun skipper adults in 2021 and visited three times per week. Specific areas within each habitat patch where adult skippers were observed in 2021 were surveyed, beginning with a visual count of adults. Efforts were made to not double count individuals, only counting the number of adult skippers visible at any given time, as they tended to fly in and out of sight. Following the visual count, adults were caught with an aerial net, uniquely marked using felt-tipped markers on the ventral side of the hindwing, and released (Figure 3). Visual surveys, followed by marking and releasing adults, were repeated each time the site was visited. The location of all captures and recaptures were recorded with a Garmin handheld GPS unit. Recaptured individuals were recorded to track individual movements and estimate populations. The straight-line distance (to the nearest meter) between captures was measured in ESRI ArcMAP 10.7, and the minimum lifespan for each individual was determined as the number of days from first to last capture.

Figure 3. Marked Harbison's dun skipper male. Skippers were caught and marked on the hindwing using felt tipped markers. A combination of dots and lines were used to uniquely mark individuals.

Habitat Preferences

Within Oak Woodlands

To quantify habitat characteristics, sampling was conducted in 2022 at study sites that previously had skipper observations in 2021 and 2022, with the exception of Elfin Forest which was last occupied in 2016. Past data indicated that all adult skippers would be found in a relatively small area (possibly as restricted as on a single flowering plant) adjacent to the ravine. Because few skippers were observed nectaring in 2022 and few left the drainage, sampling occurred at occupied and unoccupied San Diego sedge patches within the drainage. Habitat variables were sampled using a one-square meter quadrat at the location of the skippers or sedge, as well as distances of 2.5, 5.0, 7.5, and 10.0 meters from this starting location in each direction in the ravine (Figure 4).

Figure 4: Vegetation sampling. A) An aerial image of a typical riparian oak woodland. The dark green wooded area extends through the landscape, often extending for several kilometers.

At each location, the percent cover of bare ground, leaf litter, herbaceous vegetation, woody vegetation, and canopy cover, as well as height of understory vegetation and temperature were recorded. The ground temperature and air temperature at one meter height were recorded at all locations along the transect as quickly as possible prior to beginning the vegetation sampling. Ground temperatures were recorded using a BTMETER BT-1500 Non-contact Pyrometer 30:1 Industrial Laser Thermometer Gun, and air temperature at 1.0 meters above the ground was recorded using a Kestrel 2500 Handheld Weather Meter. Using the locations of skippers in 2021 and 2022, as well as historic survey data, the distance to the drainage, determined by the nearest flowline (U.S. Geological Survey et al. 2020), was determined using the Near tool in ESRI ArcMAP 10.7.

Among Oak Woodlands

A habitat analysis at a broader geographic scale was conducted using a GIS approach. Locations of San Diego sedge were compiled from field surveys dating back to 2013 (this project and Marschalek unpublished data) (Figure 5A) to create polygons that riparian woodlands with San Diego sedge. A 50 m buffer was created using the buffer tool in ESRI ArcMap 10.7 and merged for overlapping polygons (Figure 5B). A data layer containing flowlines for San Diego County was obtained from the San Diego Association of Governments (U.S. Geological Survey et al. 2020), and a 20 m buffer was created around each flowline and merged (Figure 5C). The San Diego sedge buffer was clipped by the flowline buffer to restrict spatial analysis to the riparian area rather than representing a substantial portion of upland habitats (Figure 5D). Vegetation data (City of San Diego et al. 2022; SANDAG 2015) that included San Diego County was used to determine the vegetation communities that San Diego sedge points were found within (Holland 1986; Oberbauer 1996; Sawyer et al 2009; Sproul et al. 2011).

Logistic regression was used to compare climate variables of the riparian woodlands with San Diego sedge within the skipper's historic range to outside of the historic range. Woodlands that had Harbison's dun skipper observations, regardless of current status, was considered within the historical range. Raster and polygon data for environmental variables were extracted to the San Diego sedge points using the Extract Multi Values to Points and Intersect geoprocessing tools in ESRI ArcMAP 10.7, respectively (Table 1). These data were then averaged according to the woodland groups created in ArcMap 10.7. The environmental variables selected represent longer timeframes rather than a single month or year, more appropriate for assessing long term processes such as historic occupancy. All variables were standardized to have a mean of 0 and standard deviation of 1. This simplified the comparisons across variables with different scales and units. Some variables were transformed prior to standardization. Log transformation was typically used to normalize data by reducing right skew and leptokurtosis.

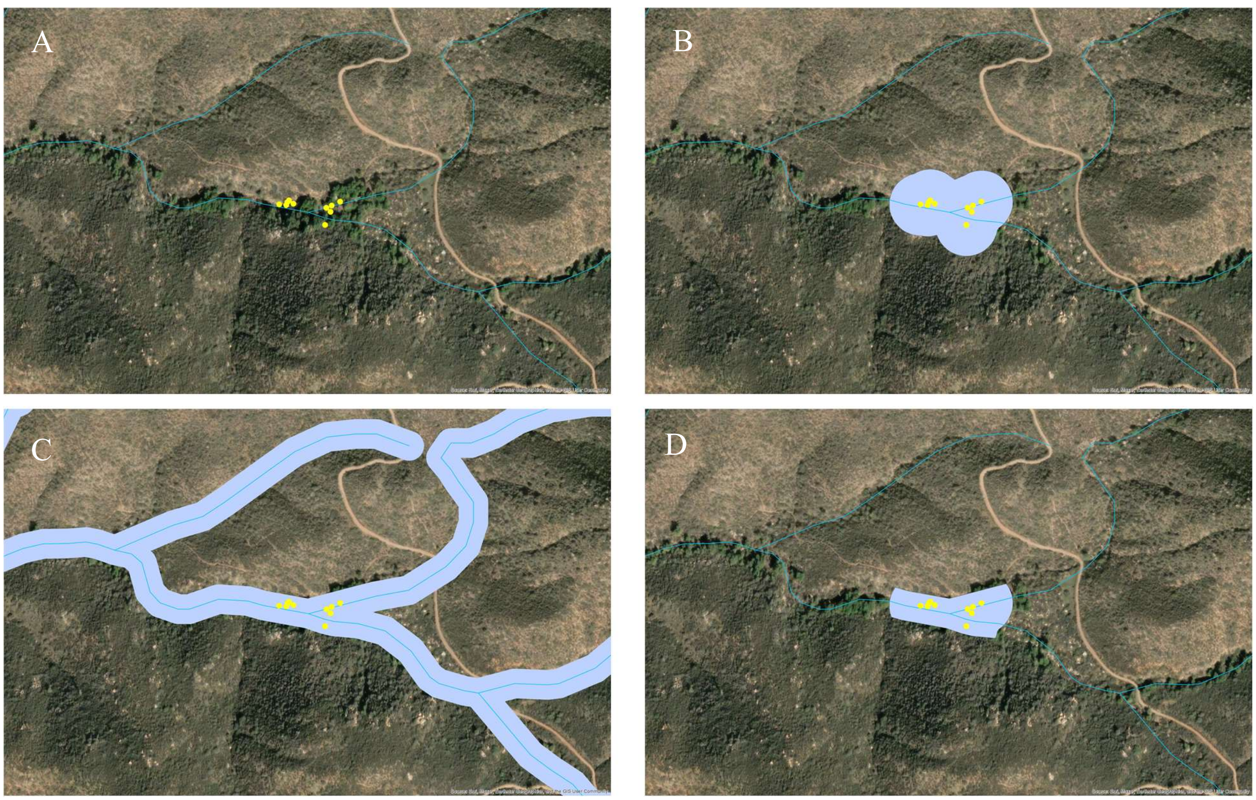

Figure 5. Riparian area and woodland delineation. A. San Diego sedge locations in yellow. B. 50-meter buffers were created around San Diego sedge locations. C. 20-meter buffers were created around the flowlines. D. The San Diego sedge buffers were clipped by the flowline buffers to represent riparian areas.

Table 1. List of variables used in GIS habitat analysis. Several variables included data for each month of the year. Data was a combination of raster and vector layer.

Variable	Description	Resolution	Transformation	Citation
aet	30-year average of monthly actual evapotranspiration in mm (1981-2010)	270m	Log	Flint et al. 2014
ClayPer	percent clay	polygon	Log(x+1)	U.C. Davis
cwd	30-year average of climatic water deficit in mm (1981-2010)	270m	Squared	Flint et al. 2014
DrainArea	Total drainage area (sq km)	line	Log	US Geological Survey 2019
elev30grd0	elevation	30m	Log	US Geological Survey 2015
maxt	30-year average of maximum temperature for each month in C (1981-2010)	270m	Cubed	Flint et al. 2014
mint	30-year average of minimum temperature for each month in C (1981-2010)	270m	N/A	Flint et al. 2014
prec	30-year average of monthly precipitation in mm (1981-2010)	270m	Log	Flint et al. 2014
QEMA	mean annual stream flow of natural conditions (1971-2000)	line	Log	US Geological Survey 2019
S0104	Insolation from January to April for 2021	10m	N/A	US Geological Survey 2015
S0507	Insolation from May to July for 2021	10m	N/A	US Geological Survey 2015
SandPer	percent sand	polygon	N/A	U.C. Davis
SiltPer	percent silt	polygon	N/A	U.C. Davis
SlopeStrm	Slope of Stream Channel	line	Log(x+1)	US Geological Survey 2019
UpStrmImp	Percent Impervious based on 2019 NCLD	line	Log(x+1)	US Geological Survey 2019
UpStrmLen	Cumulative Catchment Stream length (km)	line	Log	US Geological Survey 2019
VEMA	mean annual stream velocity of natural conditions (1971-2000)	line	Log(x+1)	US Geological Survey 2019

Within each group of variables with monthly data (e.g. minimum temperature, precipitation), if several months were correlated, one month was retained for modeling. The others were omitted from further analysis, reducing the total number of variables from 72 to 20. For example, the actual evapotranspiration (AET) for each month was evaluated (Figure 6). A correlation was observed among winter months and summer months, with March, April and May intermediate. January and July were selected for modeling. Additional correlations among the 20 variables retained for modeling are expected considering the climate (cool, wet winters and hot, dry summers) and the influence of elevation on temperatures and precipitation. Correlations were evaluated using a PCA with varimax rotation in SYSTAT 13.1 (SYSTAT Software, Inc.).

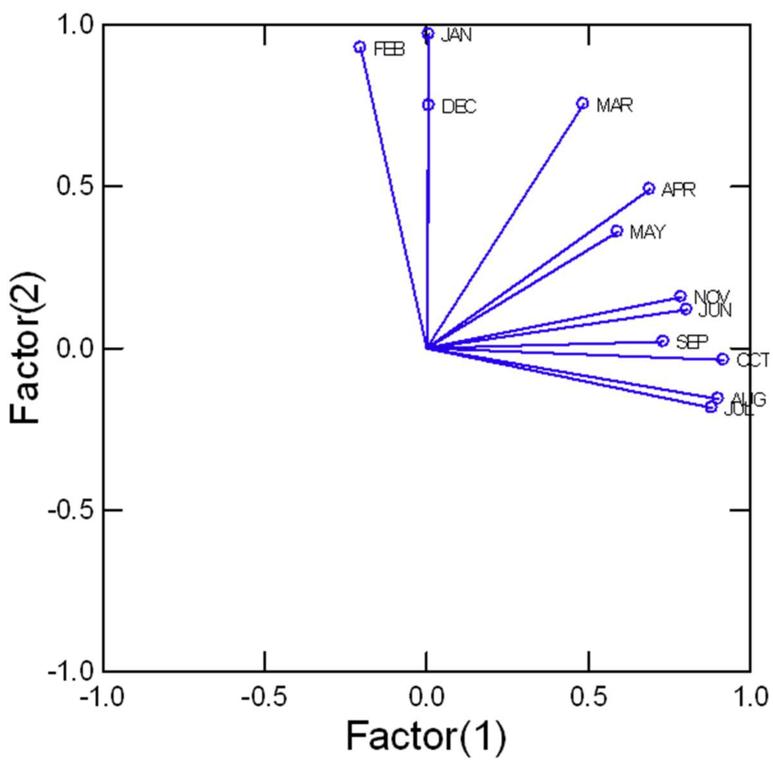

Figure 6. Correlations among monthly actual evapotranspiration (AET) data. PCA analysis of monthly data. January and July were retained for modeling.

Data Analysis

Trends among maximum daily counts for surveys conducted in 2021 and 2022, as well as the previous survey data from 2013, 2014, 2016, and 2017, were analyzed using the sign test in SYSTAT 13.1. Changes in the number of occupied sites over time was evaluated using a Pearson's Chi-squared test with a Fisher Exact Test, due to small sample sizes, in SYSTAT 13.1. Marking data were analyzed using a Jolly-Seber method to estimate population sizes (Jolly 1965, Seber 1965, Krebs 1999). Due to recaptures only occurring at Barrett Lake and Beaver Hollow, population size estimates calculations using the Jolly-Seber method were only possible at these sites. A Pollard index for each site was calculated for each site in 2022 by summing all visual survey counts that were conducted (Pollard 1977). Habitat data were transformed using a z-score to meet the assumptions of normality. Data were displayed using non-metric multidimensional scale (NMDS) plots and analyzed with PERMANOVA tests in PRIMER 7.0.21 (PRIMER-e, Quest Research Limited). A forward stepwise logistic regression was performed in SYSTAT 13.1 to create a habitat model. A $p = 0.15$ cutoff was used to avoid failing to include important variables (Bendel and Afifi 1977).

CHAPTER 3

Results

Visual Surveys

Visual surveys were conducted at 14 sites in 2021 (Table 2), with a total of 22 Harbison's dun skipper observations. Surveys yielded relatively low numbers of adult skippers at all sites, with the highest daily count being four adults at Lake Hodges and at least one observation at five other sites. No skippers were observed at seven sites despite weekly surveys throughout the flight season. No skippers were observed during a single survey on Otay Mountain.

In 2021, 14 of 40 sites were determined to be extant, six sites were classified as probably/likely extant, and two sites were extirpated due to wildfires. Extant sites were determined by direct observations of the skippers, while those sites likely extant had direct observations in previous years but none in 2021 and no substantial disturbance (i.e. wildfire). For the latter, skippers are likely still present at that site, but in an area that was not surveyed. Skippers were recorded by local biologists (RECON Environmental, Inc.) at two locations at Otay Mountain, west of the area I searched. Based on information gathered during surveys in 2022, 15 of 40 sites were determined to be extant, including skippers observed at SDNWR-Beaver Hollow. Pamo Valley (CNF) was updated from extant to probable due to skippers not being observed, but the habitat undergoing no major changes. Skye Valley Road (CNF) was updated from extirpated to extant, with skippers being observed two years post wildfire, bringing the total to 15 probable extant sites and 10 extirpated sites (Figure 7). The current status of each site is based on surveys occurring in 2013 or later. Some sites, such as Sycamore Canyon County Park and Blue Sky Ecological Reserve, were last surveyed in 2013 and are listed as extirpated.

The skippers have been shown to recolonize withing a few years after wildfire, and it is possible that recolonizations have occurred since the most recent surveys.

To compare changes in the number of local populations (occupancy) across time, count data were converted to presence/absence. A comparison of sites that were surveyed in *both* 2013 and 2021 found a decline in the number of sites that are occupied (2013 = 46.4%, 2021 = 32.1%), but it was not statistically significant ($\chi^2 = 3.394$, df = 1, p = 0.165). The sites that were surveyed in 2021 were chosen because they had a high probability of being occupied by adult skippers so this could explain the lack of significance. I also assessed occupancy rates among all sites there were surveyed in *either* 2013 or 2021 and there was a similar decline in the number of sites that were occupied by adult skippers (2013 = 68.42%, 2021 = 46.67%), but not significant ($\chi^2 = 1.638$, df = 1, p = 0.296). Although there was not a significant change in occupied sites, we did see declines in the daily maximum counts. Significant declines were observed from 2013 to 2017 (p = 0.006) and from 2014 to 2017 (p = 0.008), with marginally significant declines from 2013 to 2014 (p = 0.065).

In 2022, the highest daily count was five skippers at Barrett Lake with three surveys per week during the flight season (Table 2). SDNWR-Beaver Hollow and Hollenbeck Canyon Wildlife Area were also surveyed three times per week, and both had daily high counts of two skippers, while Skye Valley Road (CNF) had a maximum of one. Crestridge Ecological Reserve (4 visits), Hellhole Canyon County Park (2 visits), and Lake Hodges (3 visits) were surveyed when time permitted and had daily high counts of three, two, and two, respectively. Skippers were not observed at the other four sites.

Table 2. Comparison of Harbison's dun skipper annual adult population sizes. Counts in bold represent maximum daily count for weekly surveys during the flight season while counts not bolded are the highest count among two to three surveys (one survey at SDNWR-Las Montanas South in 2013, one survey at San Pasqual Academy in 2021, one survey at Elfin Forest and Sycuan Peak Ecological Reserve in 2022). Data from 2013-2017 are from Marschalek et al. (2019).

Location	2013	2014	2016	2017	2021	2022
Barrett Lake	6-8	**4**	**5**	**1**	**3**	**5**
Beaver Hollow						**2**
Boden Canyon Ecological Reserve	5-6	**1**	**1**	1	**0**	-
Blue Sky Ecological Reserve	0	**0**	-	-	-	-
Calavera Nature Preserve	0	-	-	-	-	-
Camp Pendleton	-	-	0 (1 pupa)	-	-	-
Carlsbad Highlands Ecol. Reserve	0	-	-	-	-	-
Crestridge Ecological Reserve	1	**0**	**0**	0	**2**	3
Daley Ranch	1	**2**	**4**	-	**0**	-
El Capitan (west of reservoir)	0	-	-	-	-	-
Elfin Forest	-	-	1	-	**0**	0
Hellhole Canyon County Park	4	**1**	**1**	0	**2**	2
Hollenbeck Canyon Wildlife Area	6-10	**5-6**	**2**	**3-4**	**2**	**2**
Lake Hodges	5-6	**4**	**6**	-	**4**	2
Loveland Reservoir	8	**4-5** or **3-6**	**3**	**2**	-	-
Pamo Valley (CNF)	1-2	**2-3**	**0**	2	**2**	0
Red Mountain	1	**-**	**0**	-	**0**	**-**
SDNWR- Las Montanas (South)	2	**1**	**0**	-	**0**	-
San Pasqual Academy	0-1	**-**	**0**	-	0	-
Skye Valley Road	2	**2**	**4**	1	**0**	**1**
Sycamore Canyon County Park	0	**0**	-	-	-	-
Sycuan Peak Ecological Reserve	5-6	**2**	**4**	-	**0**	0

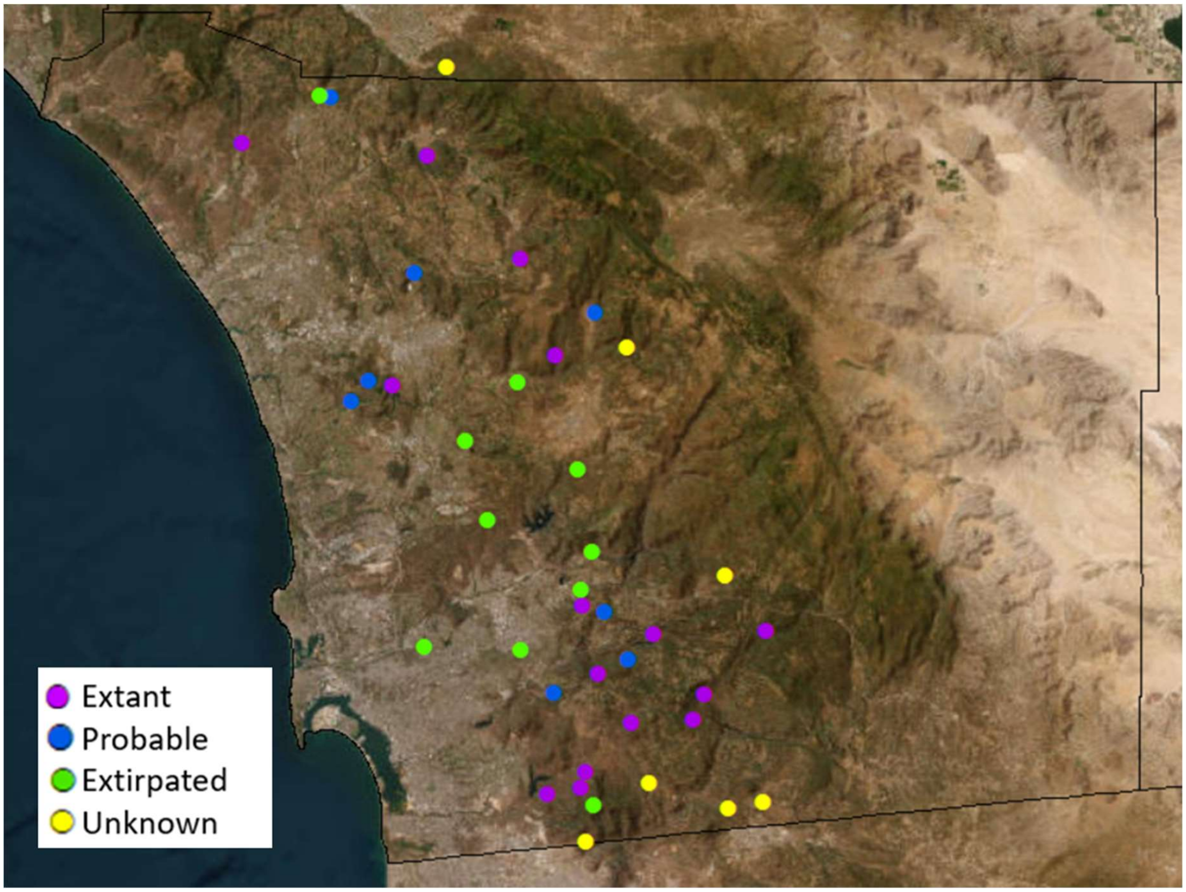

Figure 7. Site status following 2022 visual surveys. Probable (probably extant) sites have signs of larval feeding, but individuals of any life stage were not observed. Unknown sites are unable to be surveyed due to being located on private property, or not a specific location. Status is based on surveys conducted in 2013 or later, but not necessarily every year since 2013.

Mark-recapture

Marking was conducted at Barrett Lake, SDNWR-Beaver Hollow, Hollenbeck Canyon Wildlife Area, and Skye Valley Road (CNF). Skippers were also marked at Crestridge Ecological Reserve and Lake Hodges, although the sites were not visited regularly. A total of 63 skippers were marked, 53 males and ten females (Table 3). Nine skippers were recaptured at Barrett Lake and SDNWR-Beaver Hollow, with nine recaptures occurring at Beaver Hollow. Due to the low numbers of recaptures, Jolly-Seber estimates were only able to be calculated for Barrett Lake and Beaver Hollow. The Jolly-Seber estimates for the two sites were poorly resolved due to the small sample sizes. As a result, the confidence intervals are so wide as to render the estimates meaningless. The Jolly-Seber estimate for Barrett Lake was 36 (7-794, 95% CI) and was Beaver Hollow was 10, (3-203, 95% CI) (Table 4). A Pollard Index representing the total number of adult skippers observed at a site was calculated for all sites where skippers were observed. Barrett Lake (44) had the highest Pollard Index, as well as the highest maximum count (eight) in one day.

Of the nine recaptured individuals, three were captured for a third time (Table 5). The minimum lifespan based on time between captures ranged from 2 to 10 days, with an average lifespan of 7.3 days. Recapture rates were 22% and 20% at Barrett Lake and Beaver Hollow, respectively (Table 3). The peak abundance for all sites where adult skippers were observed occurred between June 1 and June 10, except for Hellhole Canyon on June 18. The average straight-line distance between each capture was 36 ± 76 m and the distance traveled ranged from 1 to 273 m (Table 5).

Table 3. Harbison's dun skipper marking data. Counts and proportions of male and female adult skippers captured and recaptured at each site.

Site	Males	Females	Total	Males Recaptured	Females Recaptured	Total Recaptures	Male Proportion Recaptured	Female Proportion Recaptured	Total Proportion Recapture
Barrett Lake	26	6	32	6	1	7	0.23	0.17	0.22
Beaver Hollow	9	1	10	2	0	2	0.22	0.00	0.20
HCWA	6	2	8	0	0	0	-	-	-
Skye Valley	4	0	4	0	0	0	-	-	-
Crestridge	6	1	7	0	0	0	-	-	-
Lake Hodges	2	0	2	0	0	0	-	-	-
Total	53	10	63	8	1	9	0.15	0.10	0.14

Table 4. Summary data for 2022 surveys. Comparison of population size estimates and indices for Harbison's dun skipper populations. Jolly-Seber estimates were only calculated for those sites with recaptures.

Site	Barrett Lake	HCWA	Beaver Hollow	Skye Valley	Crestridge	Lake Hodges	Hellhole Canyon
Peak Abundance	1-Jun-22	6-Jun-22	10-Jun-22	6-Jun-22	3-Jun-22	7-Jun-22	18-Jun-22
Pollard Index	44	10	15	6	13	6	2
Max Count	5	3	4	2	3	3	2
Total Marked	32	8	10	4	7	2	-
Jolly-Seber Estimate	36	-	10	-	-	-	-
Lower 95% CI	7	-	3	-	-	-	-
Upper 95% CI	794	-	203	-	-	-	-
Recapture Rate	0.22	0	0.20	0	0	0	-

Table 5. Harbison's dun skipper recaptures. The dates of captures, minimum lifespan, and the minimum distances traveled for the nine adult skippers that were recaptured.

Skipper ID	First Capture	Second Capture	Third Capture	Minimum lifespan (days)	Distance between consecutive captures (m)	Minimum Distance Traveled (m)
3	31-May-22	3-Jun-22	-	4	51	51
10	1-Jun-22	10-Jun-22	-	10	12	12
16	3-Jun-22	9-Jun-22	-	7	25	25
18	3-Jun-22	10-Jun-22	-	7	273	273
26	6-Jun-22	10-Jun-22	-	5	29	29
35	8-Jun-22	15-Jun-22	17-Jun-22	10	1, 2	3
42	9-Jun-22	10-Jun-22	-	2	7	7
43	10-Jun-22	17-Jun-22	20-Jun-22	11	11, 12	23
48	13-Jun-22	20-Jun-22	22-Jun-22	10	2, 3	5
Average				7.3	35.7	47.6

Habitat Assessment

Habitat sampling was conducted at nine field sites during the 2022 field season where adult skippers were observed in 2021 or 2022. One sampling location at Crestridge Ecological Reserve was removed from analysis due to a low amount of canopy cover (zero percent) resulting in an outlier. A PERMANOVA test demonstrated that there was no significant difference between areas of woodland that were used and not used ($F = 0.937$, $df = 1$, $p = 0.481$). There were inverse relationships between canopy cover and bare ground cover, canopy cover and 1m temperature, shrub cover and herbaceous cover, and positive correlations between 1m temperature and bare ground cover (Figure 8).

A second analysis was conducted, removing the temperature data because of its natural potential for variability both across time and space. This provides a specific assessment of vegetation and interspersed bare ground. The PERMANOVA test demonstrated that there was no significant difference between areas of the woodland that were used and not used ($F = 1.164$, df

= 16, p = 0.355). The relationship among habitat variables was similar to when temperatures were included (Figure 9). A PERMANOVA test detected a significant difference among sites (F = 2.128, df = 8, p = 0.017), and a pairwise comparison using Monte Carlo tests detected a significant difference between only the Elfin Forest and Skye Valley Road (CNF) sites (p = 0.043). With only two sampling locations for each site, statistical power is low. Based on the locations of all skipper records, the average distance skippers were observed from the drainages was 11 ± 10 m with a median of 9 m.

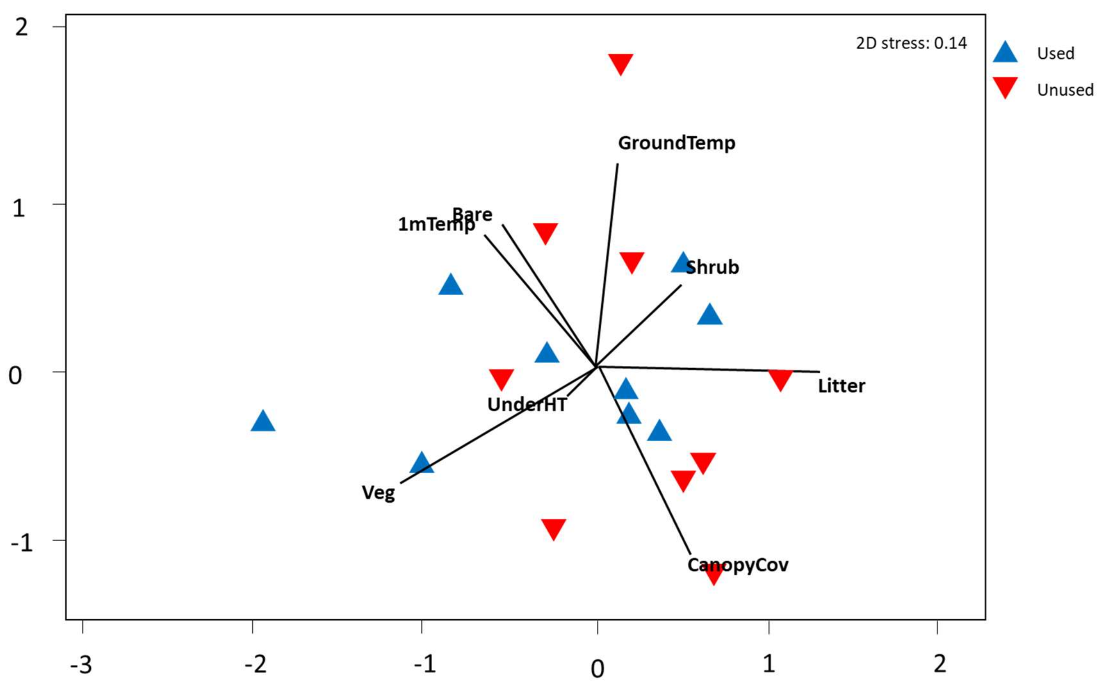

Figure 8. NMDS of habitat characteristics. NMDS of areas within woodlands that were used and not used by Harbison's dun skippers in 2022. Abiotic variables are overlayed and fitted as vectors.

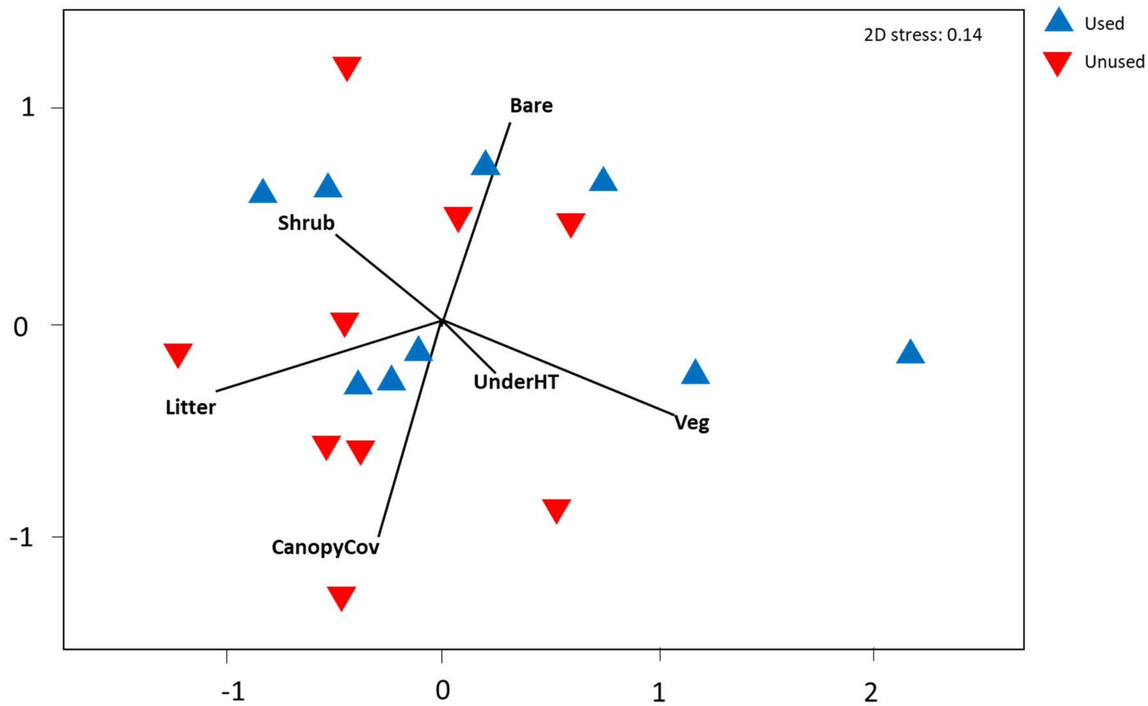

Figure 9. NMDS of vegetation characteristics (and percent cover bare ground). NMDS of areas within woodlands that were used and not used by Harbison's dun skippers in 2022. Abiotic variables are overlayed and fitted as vectors.

GIS Analysis

A total of 404 San Diego sedge records from surveys conducted in San Diego County between 2013 and 2022 were compiled. Using the 1995 Holland classification code for vegetation (City of San Diego, SANDAG, County of San Diego, Planning and Development Services, LUEG-GIS Service, 2014) 163 (40.3%) occurred within the Southern Coast Live Oak Riparian Forest vegetation community and a total of 292 (72.3%) occurred in vegetation communities containing oaks (Table 6). Of the 404 San Diego sedge records, 312 records were located within conserved lands in San Diego County. Using a more recent vegetation map, only for conserved lands of western San Diego County (SANDAG, 2015), the most common vegetation groups were Riparian Forest and Forest/Woodland, with 129 (31.9%) and 126 (31.2%) locations, respectively (Table 7). Approximately 74% of the San Diego sedge records within conserved lands fell within an alliance or association containing oaks. The two most common vegetation associations with records of San Diego sedge included *Platanus racemose-Quercus agrifolia* and *Quercus agrifolia*/*Salix lasiolepis*, both containing 53 locations.

Table 6. San Diego sedge and Holland code classification. The number of San Diego sedge records that occur within each vegetation community based on the 1995 Holland code classification (City of San Diego, SANDAG, County of San Diego, Planning and Development Services, LUEG-GIS Service, 2014).

Holland Code Categorization	Count
11200 Disturbed Wetland	3
11300 Disturbed Habitat	2
12000 Urban/Developed	2
18000 General Agriculture	1
32500 Diegan Coastal Sage Scrub	12
37000 Chaparral	15
37120 Southern Mixed Chaparral	6
37132 Mafic Northern Mixed Chaparral	1
37200 Chamise Chaparral	2
37830 *Ceanothus crassifolius* Chaparral	1
37G00 Coastal Sage-Chaparral Transition	5
42000 Valley and Foothill Grassland	7
42200 Non-Native Grassland	1
52410 Coastal and Valley Freshwater Marsh	6
61300 Southern Riparian Forest	3
61310 Southern Coast Live Oak Riparian Forest	163
61320 Southern Arroyo Willow Riparian Forest	1
61330 Southern Cottonwood-Willow Riparian Forest	11
62400 Southern Sycamore-Alder Riparian Woodland	17
63300 Southern Riparian Scrub	7
63320 Southern Willow Scrub	7
71100 Oak Woodland	2
71120 Black Oak Woodland	30
71160 Coast Live Oak Woodland	39
71161 Open Coast Live Oak Woodland	2
71162 Dense Coast Live Oak Woodland	19
71181 Open Engelmann Oak Woodland	37
83230 Southern Interior Cypress Forest	2
Grand Total	**404**

Table 7. San Diego sedge and vegetation community association. The number of San Diego sedge records that occur within the vegetation GROUPS (bold, all caps), Alliance (bold), and Associations.

Vegetation Classification	Count	
CHAPARRAL	**24**	
***Adenostoma fasciculatum* Alliance**	**6**	
Adenostoma fasciculatum-(Eriogonum fasciculatum, Artemisia californica, Salvia mellifera) Association		6
***Adenostoma fasciculatum-Xylococcus bicolor* Alliance**	**16**	
Adenostoma fasciculatum-Xylococcus bicolor-Ceanothus crassifolius Association		4
Adenostoma fasciculatum-Xylococcus bicolor-Ceanothus tomentosus Association		9
Adenostoma fasciculatum-Xylococcus bicolor-Ceanothus verrucosus Association		2
Adenostoma fasciculatum-Xylococcus bicolor-Quercus (berberidifolia, ×acutidens) Association		1
***Arctostaphylos glandulosa* Alliance**	**1**	
Arctostaphylos glandulosa-Adenostoma fasciculatum/Chamaebatia australis Association		1
***Quercus (berberidifolia, ×acutidens)-Adenostoma fasciculatum* Alliance**	**1**	
Quercus (berberidifolia, ×acutidens)-Adenostoma fasciculatum Association		1
DEVELOPED	**2**	
FOREST/WOODLAND	**126**	
***Callitropsis forbesii* Alliance**	**2**	
Callitropsis forbesii Provisional Association		2
***Eucalyptus (globulus, camaldulensis)* Semi-Natural Stands**	**1**	
Eucalyptus (globulus, camaldulensis) Semi-Natural Stands		1
***Quercus agrifolia* Alliance**	**119**	
Alliance only		27
Quercus agrifolia/Artemisia californica Association		4
Quercus agrifolia/Quercus (berberidifolia, ×acutidens) Association		1
*Quercus agrifolia/Toxicodendron diversilobum/*Grass Association		87
***Quercus engelmannii* Alliance**	**4**	
*Quercus engelmannii-Quercus agrifolia/Toxicodendron diversilobum/*Grass Association		4
GRASS/HERB	**2**	
***Bromus rubens-Schismus (arabicus, barbatus)* Semi-Natural Stands**	**1**	
Bromus rubens-Schismus (arabicus, barbatus) Semi-Natural Stands		1

Mediterranean California Naturalized Annual and Perennial Grassland Semi-Natural Stands	**1**	
Mediterranean California Naturalized Annual and Perennial Grassland Semi-Natural Stands		1
RIPARIAN FOREST	**129**	
***Platanus racemosa* Alliance**	**73**	
Platanus racemosa/Baccharis salicifolia Association		4
Platanus racemosa-Populus spp./Salix lasiolepis Association		16
Platanus racemosa-Quercus agrifolia Association		53
***Populus fremontii* Alliance**	**2**	
Alliance only		2
***Quercus agrifolia* Alliance**	**53**	
Quercus agrifolia/Salix lasiolepis Association		53
***Salix lasiolepis* Alliance**	**1**	
Salix lasiolepis Association		1
RIPARIAN SCRUB	**7**	
***Baccharis salicifolia* Alliance**	**7**	
Baccharis salicifolia Association		7
SCRUB	**22**	
***Artemisia californica-Eriogonum fasciculatum* Alliance**	**21**	
Artemisia californica-Eriogonum fasciculatum-Malosma laurina Association		21
***Artemisia californica-Salvia mellifera* Alliance**	**1**	
Alliance only		1
Grand Total	**312**	

Using all 404 San Diego sedge records, data were extracted from the raster and vector data for the full set of climate variables for each record and narrowed down to 20 variables after evaluating the correlations (Table 8). A total of 148 separate woodlands with San Diego sedge were delineated in ArcMap, with environmental variables averaged within each woodland if there were multiple sedge locations. A final forward stepwise logistic regression model (Naglekerke's $R^2 = 0.587$) included three variables that are important for determining suitability of riparian woodlands: maximum temperature in June ($Z = -3.761$, $p < 0.001$), actual evapotranspiration of July ($Z = 2.515$, $p = 0.012$), and elevation ($Z = -2.067$, $p = 0.039$). The odds of Harbison's dun skipper presence is 7.6 (2.7-22.2 95% CI) times higher for approximately every 2.2°C increase. Given the temperature regime, the odds of skipper presence is 5.4 (1.4-19.9 95% CI) less likely for approximately every 1.8 millimeter increase of actual evapotranspiration in July, and 3.7 (1.1-12.5 95% CI) more likely for approximately every 851 meter increase in elevation.

Table 8. Variables selected for GIS analysis. The data was a combination of raster and vector layers.

Variable	Description
aet01	30-year average of actual evapotranspiration for January in mm (1981–2010)
aet07	30-year average of actual evapotranspiration for July in mm (1981–2010)
ClayPer	percent clay
cwd01	30-year average of climatic water deficit for January in mm (1981–2010)
cwd04	30-year average of climatic water deficit for April in mm (1981–2010)
DrainArea	Total drainage area (sq km)
elev30grd0	elevation
maxt06	30-year average of maximum temperature for January in C (1981–2010)
mint09	30-year average of minimum temperature for September in C (1981–2010)
prec01	30-year average of January precipitation in mm (1981–2010)
prec08	30-year average of August precipitation in mm (1981–2010)
prec12	30-year average of December precipitation in mm (1981–2010)
QEMA	mean annual stream flow of natural conditions (1971–2000)
S0507	Insolation from May to July for 2021
SandPer	percent sand
SiltPer	percent silt
SlopeStrm	Slope of Stream Channel
UpStrmImp	Percent Impervious based on 2019 NCLD
UpStrmLen	Cumulative Catchment Stream length (km)
VEMA	mean annual stream velocity of natural conditions (1971–2000)

Correlations exist among the final 20 variables selected for the model, which may mask the importance of some environmental variables. The following variables had a Pearson correlation coefficient greater than 0.7, equivalent to an R-squared value of 0.49 and explaining 49% of the variation (approximately half). All Pearson correlation coefficients were calculated using the pairwise deletion to account for missing data. Actual evapotranspiration in July was highly correlated with elevation ($r = 0.828$, $df = 142$, $p < 0.001$), precipitation in August ($r = 0.928$, $df = 142$, $p < 0.001$), precipitation in December ($r = 0.723$, $df = 142$, $p < 0.001$), and negatively correlated with minimum temperature in September ($r = -0.862$, $df = 142$, $p < 0.001$). Elevation was correlated with maximum temperature in June ($r = 0.757$, $df = 146$, $p < 0.001$), precipitation in August ($r = 0.867$, $df = 146$, $p < 0.001$), December ($r = 0.766$, $df = 146$, $p < 0.001$), and negatively correlated with minimum temperature in September ($r = -0.810$, $df = 146$, $p < 0.001$). Maximum temperature in June was also negatively correlated with minimum temperature in September ($r = -0.701$, $df = 146$, $p < 0.001$).

In San Diego County, summer temperatures are typically higher at high elevations, and these areas in the summer have higher evapotranspiration rates and lower overall precipitation rates. It appears that skippers are more often found in areas of higher elevation and higher temperatures, but there is a maximum threshold of tolerance when elevation or temperature become too high, and occupancy decreases (Figure 10). The same relationship can be seen in maximum temperature in June and the actual evapotranspiration in July (Figure 11). Occupancy was observed more often at sites with higher temperatures and evapotranspiration rates, but there is an upper threshold when it becomes too dry, and occupancy decreased.

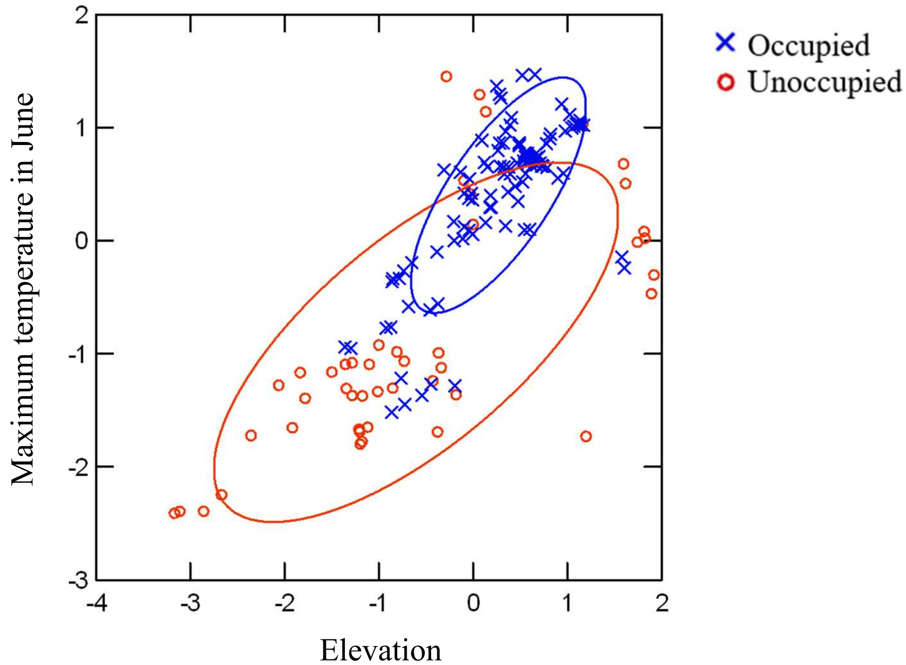

Figure 10. Relationship of maximum temperature in June and elevation with Harbison's dun skipper historic range. Most historically occupied sites occur at locations at higher elevation and with higher temperatures, but there is a maximum threshold when occupancy decreased.

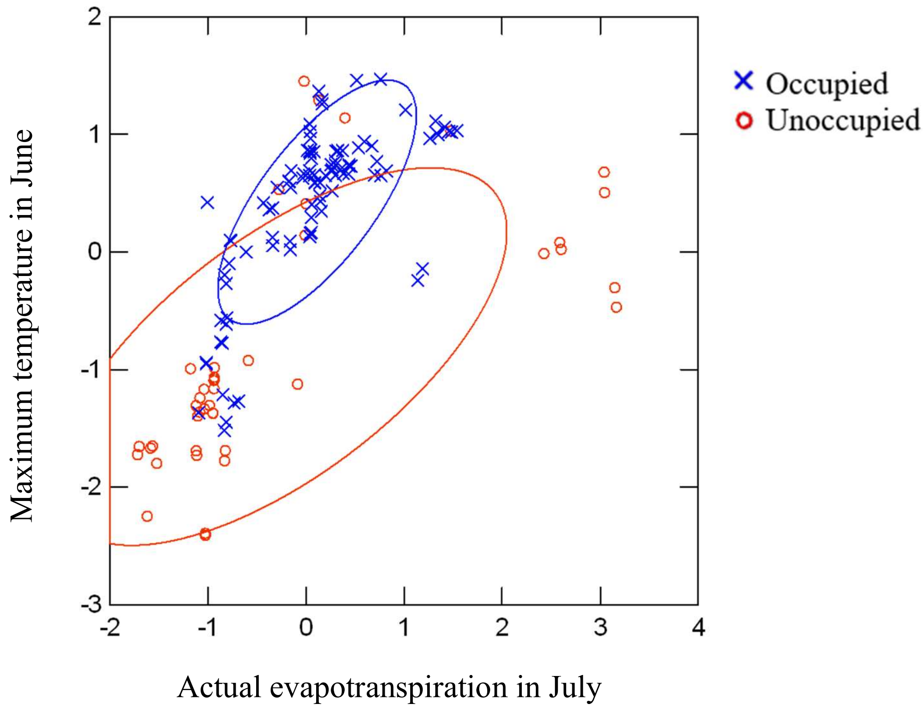

Figure 11. Relationship of maximum temperature in June and actual evapotranspiration in July with Harbison's dun skipper historic range. Most historically occupied sites occur at locations with higher temperatures and higher evapotranspiration rates, therefore being dryer, but there is a maximum threshold when it became too dry.

CHAPTER 4

Discussion

This study focused on updating the status of historically occupied habitat patches, comparing population estimates to population indices, and habitat preferences of the Harbison's dun skipper. I detected skippers at fewer locations, although not statistically significant, and fewer skippers (statistically significant) at those sites compared to surveys in 2013, likely due to drought conditions over the last decade. These low population sizes resulted in population estimates with low accuracy of the estimates suggesting that population indices, such as the daily maximum count, should be used. The habitat assessment found no significant difference in used an unused areas within woodlands, while a county wide assessment determined the environmental variables that are most important in describing the historic range of the Harbison's dun skippers.

These surveys were conducted based on modified Pollard transects, by searching riparian oak woodlands with San Diego sedge and areas where adult Harbison's dun skippers were previously observed. Pollard walks were originally developed (Pollard 1977) as a way to standardize survey methods by establishing a transect through the habitat that is walked within set time and weather parameters, recording all butterflies observed within a certain area in front and to the side of the surveyor. The fixed transect through the habitat allows for easy replication by other surveyors as well as across years, while also allowing other vegetation and habitat variables to be measured along the transect (Pollard 1977).

Pollard walks have since been modified in a variety of ways to increase the habitat areas that are surveyed to provide the most accurate snapshot of butterflies present in an area, such as in this study. Modifications include varying widths of survey area along the transect (Swengel 1996; Kral-O'brien et al. 2021) or alterations to the transect path in order to encompass more habitat types or areas of high butterfly use, such as sunny areas or areas populated by flowering plants (Thomas 1983; Beneš et al. 2003; Gottschalk 2020). While other survey methods for butterflies exist, Pollard walks are typically more cost effective, requiring less field time to conduct. Survey methods such as timed or area-searches are more intensive, and while they usually detect higher numbers of individuals they present comparable estimates of species richness (Royer et al. 1998; Kadlec et al. 2012; O'Brien et al. 2022; Barkmann et al. 2023).

This study also estimated population sizes of the Harbison's dun skipper utilizing mark-recapture at several sites. Low numbers of recaptures resulted in only being able to estimate populations at two sites, and the resulting estimates had very large confidence intervals. Mark-recapture studies work to establish an actual population size, rather than a relative population size (index) that are generated from Pollard walks. Pollard indices are useful for trend analyses, and while mark-recapture more accurately represent actual population sizes, they are more likely to fail when working with small populations (Haddad et al. 2008), such as experienced with the Harbison's dun skipper in this study. Others have found a positive a correlation between this method and Pollard walk methods (Collier et al. 2008; Haddad et al. 2008), suggesting that either method can be used to assess changes in population sizes. The efficiency of Pollard walks has increased its popularity in the realm of butterfly monitoring (Haddad et al. 2008; Nowicki et al. 2008). In reality, the most accurate monitoring plans will likely encompass a combination of monitoring methods based on study questions, location, and funding available (Pellet et al. 2012; Montgomery et al. 2021).

While these methods focus on monitoring for adult butterflies, similar methods can also be used to monitor for other stages such as eggs, larvae, or hibernacula (Hinneberg et al. 2022). While these surveys are typically more intensive due to the increased difficulty of finding individuals, these life stages are typically longer, allowing for a prolonged study period. These methods could be useful for future Harbison's dun skipper surveys due to the difficulty of finding adults and relatively conspicuous hibernacula (and associated larva or pupa). Surveys could be conducted for larvae or hibernacula during winter months, when vegetation growth and foliage is minimal, reducing the difficulty of navigating through poison oak and increasing visibility in the woodlands.

Although not statistically significant, the number of occupied woodlands declined. The low number of sites and slow rate of decline could be responsible for low statistical power and a failure to detect a significant trend. However, the daily maximum count did experience a statistically significant decline from 2013 to 2017. In recent decades, the southwestern United States has undergone severe drought, which has been compared to historic megadroughts and enhanced by anthropogenic climate change (Williams et al. 2020, 2022). In San Diego County, 2013 to 2015 showed historically low amounts of (San Diego County Water Authority, 2023), likely resulting in the decline in the observed numbers of skippers. Other studies conducted in the western United States also point to the prolonged drought as a reason for declining butterfly (Forister et al. 2018; Crossley et al. 2021).

Climate change has been linked to changes in insect populations and distributions in a variety of habitats around the world. As climate change alters the suitability of habitats, range distributions are changing and are often linked with phenological changes (Macgregor et al. 2019; Hill et al. 2021). In Britain, an observed ~0.5°C spring temperature increase from 1995 to

2014 has been linked to an advanced emergence date in British Lepidoptera. These earlier emergence dates have led to abundance declines in univoltine habitat specialist species (Macgregor et al. 2019). In contrast, the peak flight activity of the Fender's blue butterfly (*Icaricia icarioides fender*), an endangered butterfly in Oregon, USA, is getting earlier. However, populations are increasing at some sites, indicating that these phenological changes may not always be a concern for butterflies (Bonoan et al. 2021).

Genetic variation within populations may allow for some adaptation or evolutionary responses, but the extent to which species will be able to cope with a changing climate is often unknown due to a lack of long term-monitoring data for many insect groups (Hoffmann and Willi 2008; Hoffmann and Sgró 2011; Hoffmann et al. 2013; Halsch et al. 2021). When considering small or isolated populations, particularly of threatened or endangered species, high genetic variability is often not present. Low genetic variability has been shown to lead to increased extirpation rates (Saccheri et al. 1998; Frankham 2005).

Several woodlands previously occupied by Harbison's dun skippers burned during the Valley wildfire in September 2020. Following the fire, skippers were observed at the northern Barrett Lake site during the 2021 surveys but not at Skye Valley Road (CNF). Skippers were likely present at the north Barrett Lake site due to connectivity of the woodland with the southern portion of the site, approximately 1.65 km away, that did not burn. In 2022, skippers were observed at Skye Valley Road, just under two years following a fire. While it is unknown where these skippers originated from, the recolonization provides some hope for the longevity of the species to persist in a landscape that experiences regular wildfire.

Dispersal rates of butterflies are often linked to the connectivity of habitat patches. In the case of the marsh fritillary, a butterfly with short dispersal distances, extinction probability increased with a reduction in connectivity of the habitat type, and the fast recovery rates following a drought in Europe are due to high habitat connectivity (Pertoldi et al. 2021; Johansson et al. 2022). Marschalek et al. (2016) evaluated populations of Hermes copper (*Tharsalea hermes*) butterflies in southern California and found that recent changes and fragmentation of the habitat resulted in reduced dispersal.

Habitat preferences of the Harbison's dun skippers in San Diego County were assessed at a fine-scale level within woodlands, and at a coarser scale among woodlands. Based on the variables sampled, I was not able to detect differences between areas used and not used by the skipper adults. Together with observations that the placement of the San Diego sedge patches within woodlands changes year to year, suggests that the full woodland represents a habitat patch. This study demonstrated that the maximum temperature in June, elevation, and actual evapotranspiration in July were important in defining the skipper's historic range.

Monitoring and Management Considerations

Data from this study describe the population sizes and ecology of the Harbison's dun skipper and provides important information for monitoring and management of this skipper in San Diego County. Continued monitoring is important due to the low and declining population sizes, and to evaluate how the skipper responds to a changing environment, particularly, if numbers increase following a winter of above average rainfall as just occurred during the 2022–2023 winter. Due to San Diego sedge plants changing locations and no obvious microhabitat preferences of adults, entire woodlands with the sedge should be considered important habitat if within the historic range. At this time, it is unknown how much upland habitat should be conserved or is required to support a population of skippers. It may be that these upland areas are used more often during wet years when riparian vegetation is denser and creates more shade, forcing the skippers to move out to find warmer microhabitats. Additional work during wetter years might be required to address this question.

Several challenges arise when working with the Harbison's dun skipper. Several sites require a substantial hike to reach the areas where San Diego sedge and the skippers are found. The terrain is rugged, and an abundance of poison oak growing in the habitat makes navigating through the riparian areas difficult and slow. Considering a relatively short daily window to survey for the skipper, only one to three sites can be visited in a day, but not fully searched. The changing location of San Diego sedge patches also makes surveys less efficient.

In summary, these results provide important information on the ecology of the Harbison's dun skipper and will provide insight when updating management and monitoring plans. Additional data from more in-depth vegetation surveys encompassing more areas of the habitat to evaluate nectar sources available for adults would be insightful when determining areas of important habitat. Additionally, there may be some bias in these results due to focusing on areas that have historically been occupied but Harbison's dun skippers. Future work could focus on a continuation of monitoring occupancy and populations, while working to expand the knowledge surrounding habitat, dispersal, and genetic variation within the populations. Implementing surveys during other portions of skipper lifecycle may allow for further exploration of woodlands to determine occupied areas, allowing surveys during adult flight seasons to focus on habitat assessments.

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Appendix

Determination of Research

Dear Investigator,

Your project does not require review by IACUC. You may proceed with your project.

If you have questions or would like more information, you can reach me at researchreview@ucmo.edu.

Regards,

Kathy Schnakenberg
Research Compliance Officer/Program Administrator
660-543-8562
researchreview@ucmo.edu

UCM Determination of Research

Changes since 3/31/21 9:05 AM

1 row changed

1 row added or updated (shown in yellow)

Row 810

Instructions	
UCM Email Address	
Last Name	Lyons
First Name	Abigail

Project Title	Conservation of the Harbison's dun skipper
Project Summary	Surveys for Harbison's dun skipper (Euphyes vestris harbisoni) adults are needed to assess population sizes and habitat requirements. Surveys will consist of systematic searches around San Diego sedge patches conducted during periods of appropriate weather (sunny or partly sunny, 24 to 35 degrees C, and modest wind speeds). These surveys will provide an index of population size, evaluate skipper detectability, and describe the adult flight season phenology, behavior, and nectaring sources. If no adult skippers are detected during at least two surveys, we will search the San Diego sedge for the presence of larval hibernacula. This provides a second method of determining occupancy but will not contribute to a population size index. Butterfly and skipper numbers vary due to climatic conditions so having some understanding of year-to-year variation is important. In addition, the number and diversity of flowering plants is also likely to change which is important for assessing habitat use. A marking study will be conducted at two to three sites to estimate population sizes and describe movement patterns. The mark-recapture estimates will be compared to the daily maximum counts to provide information to interpret daily survey data. Each site will be visited a couple times each week through the 4 to 6 week flight season. All Harbison's dun skipper adults will be uniquely marked with a felt-tipped marker during their first capture. The location of every observation will be recorded with a handheld GPS unit. Vegetation will be sampled in and around oak riparian woodlands to describe habitat preferences. No human or vertebrate species are involved.

Changes made by schnakenberg@ucmo.edu