San Diego County Harbison's Dun Skipper (*Euphyes vestris harbisoni*) Habitat Conservation and Management Plan

Prepared for:
San Diego Association of Governments

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Introduction

The Harbison's dun skipper (*Euphyes vestris harbisoni*) is restricted to southern Orange County, extreme western Riverside County, and San Diego County (Brown and McGuire 1983, Marschalek and Deutschman 2015), with one record from Mexico (Marschalek and Deutschman 2015). Entomologists have expressed concern that the skipper is rare and may be negatively impacted by habitat loss and degradation (Brown 1991, Glassberg 2001). In 1989, the United States Fish and Wildlife Service (USFWS) issued a notice of review, on which Harbison's dun skipper was listed as a Category 2 species (USFWS 1989).

Within San Diego County, the Harbison's dun skipper was historically found within the area addressed by the *Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County*: *A Strategic Habitat Conservation Roadmap* ("MSP Roadmap") and is designated a Category SL species within this plan. Category SL refers to species determined to be at risk of loss entirely on conserved lands in the MSP area. The MSP area has been divided into 11 management units (MUs), and the Harbison's dun skipper was historically found in MUs 2, 3, 4, 5, 6, 8, and 11.

Purpose

The *Management and Monitoring Strategic Plan for Conserved Lands in Western San Diego County*: *A Strategic Habitat Conservation Roadmap* ("MSP Roadmap") is an adaptive management and monitoring framework for prioritized species and vegetation communities in western San Diego County (San Diego Monitoring and Management Program and The Nature Conservancy 2017). Large portions of Conserved Lands in western San Diego County are within approved or proposed Natural Community Conservation Planning (NCCPs) Plan areas. These conservation plans recognize that biological monitoring and management should extend beyond plan boundaries to facilitate regional conservation of an interconnected preserve system for the persistence of rare and sensitive wildlife species and vegetation communities. Management and monitoring of these preserve lands is largely the responsibility of plan participants and varies considerably in methods and timing across the preserve system so that it is not possible to determine the regional status and effectiveness of conservation efforts. The purpose of the MSP Roadmap is to provide a scientifically based strategic plan to determine the status of conserved natural resources across the landscape and to guide regional decision-making and funding priorities for managing natural resources on Conserved Lands. The plan prioritizes plant and animal species, vegetation communities, and threats for management and provides adaptive management and monitoring goals, objectives, and actions with implementation timelines. It offers a process for coordinated implementation by land managers, conservation groups, and other stakeholders

The MSP Roadmap does not replace the need for preserve resource management plans, daily maintenance activities at existing preserves, or prior obligations negotiated with the US Fish and Wildlife Service and California Department of Fish and Wildlife. Rather, the MSP Roadmap provides a framework for the efficient use of funds, to leverage existing funding, and to assist with regional conservation efforts. It does not assign responsibilities for specific management and monitoring objectives, although it identifies "what" and "where" management is needed. The "where" in many instances is often preserve specific, although this does not assign responsibility for achieving specific objectives. Implementation and funding for MSP Roadmap objectives may be accomplished using multiple resources and entities as long as the land owner(s) and entities are in agreement. The MSP Roadmap

has objectives to prepare and implement management plans for species, vegetation communities, and threats. These management plans establish priorities, goals, and objectives which are advisory and meant to be consistent with the intent of regional plans. Management plans prepared as part of MSP Roadmap objectives may be used to inform the development and implementation of preserve resource management plans, annual work plans, and/or area specific management directives (ASMDs). Species management plans can be used to help determine whether any significant occurrences of species are known to occur on a preserve, provide goals and objectives for management and monitoring, facilitate collaboration on the implementation of regional management and monitoring objectives, and use the outcome of regional efforts to inform and augment preserve management activities.

This document has been prepared to help establish a management strategy with priority actions for the Harbison's dun skipper in the MSP area (Appendix A).

Goal: This plan identifies and prioritizes management and restoration needs over the next five years (2018-2022) for the Harbison's dun skipper in San Diego County, with the long-term goal of ensuring persistence of this species over the next 100 years.

Specific objectives are included in the Management Strategies section.

Approach and Planning Area

This plan provides a summary of what is known regarding the Harbison's dun skipper, including life history, historic and current distribution, movement patterns, suitable habitat, and threats. A thorough understanding of the species is necessary to make appropriate adaptive management recommendations in an attempt to alleviate the current threats to the species. To develop this plan, we:

1. Reviewed existing data, including historic Harbison's dun skipper locations, recent (2013-2017) survey data, property ownership to identify conserved lands for potential surveys, management, and acquisitions, and
2. Consulted with the wildlife agencies and other stakeholders to ensure that the most current information regarding Harbison's dun skipper biology, management, regulations, conserved lands, and potential acquisitions were included.

Species Description and Life History

Harbison's dun skipper adults are medium-sized skippers with a wingspan of 25-35mm, plain brown to dark brown with golden hairs on the top of their head (Garth and Tilden 1986, Opler et al. 2013). The Harbison's dun skipper is larger than the other western subspecies (Brown and McGuire 1983) so the wingspan of most individuals are likely to be closer to 30-35mm. Males have a black stigma on the upperside of the forewings bordered by varying amounts of a rusty to orange color (Figure 1A) while females have two light spots on the forewing and sometimes very light discal band spots on the underside of the hindwing (Figure 1B).

Figure 1. Adult Harbison's dun skipper (*Euphyes vestris harbisoni*). A) male identified by the black stigma on the forewing, B) female identified by the light spots on the forewing.

Brown and McGuire (1983) and Marschalek and Deutschman (2015) provide the most complete description of the Harbison's dun skipper biology. Additional notes are included in Marschalek and Deutschman (2016, 2017a, 2017b). Adult Harbison's dun skippers emerge in the late spring/early summer, with specimens recorded from 15 May to 16 July. They often remain close to their only known larval food plant San Diego sedge (*Carex spissa*) (Figure 2) and will often visit nearby nectar sources (Table 1). Opler et al. (2013) indicate that dun skippers nectar on white, pink, and purple flowers. Adults in San Diego County have been observed also obtaining nectar from flowers yellow in color, but these occurrences are rare (e.g. a single observation for each plant species).

Figure 2. San Diego sedge (*Carex spissa*). A) Several San Diego sedge plants in riparian oak woodland, B) close up of San Diego sedge flowers.

Table 1. Observed nectar sources for adult Harbison's dun skippers (Brown and McGuire 1983; Marschalek and Deutschman 2015, 2016).

Common Name	Scientific Name	Flower Color
California Buckwheat	*Erigonum fasciculatum*	White
Black Sage	*Salvia mellifera*	Purple
Narrow-leaf Milkweed	*Asclepias fascicularis*	White
Indian Milkweed	*Asclepias eriocarpa*	White
Slender Sunflower	*Helianthus gracilentus*	Yellow
Bull Thistle	*Cirsium vulgare*	Pink
California Thistle	*Cirsium occidentale*	Pink/Purple
Italian Thistle	*Carduus pycnocephalus*	Pink
Fleabane Daisy	*Erigeron foliosus*	Purple
Coastal Bushmallow	*Malacothamnus fasciculatus*	Purple
Salt Heliotrope	*Heliotropium curassavicum*	White
Hedge Nettle	*Stachys rigida*	Purple
California Loosestrife	*Lythrum californicum*	Purple
Hedge Nettle	Stachys rigida	Purple
Sacapellote	*Acourtia microcephala*	Purple
California Rose	*Rosa californica*	Pink/White
Morning Glory	*Calystegia macrostegia*	White
Watercress	*Nasturtium officinale*	White
Golden Yarrow	*Eriophyllum confertiflorum*	Yellow
Short-pod Mustard	*Hirschfeldia incana*	Yellow
Black Mustard	*Brassica nigra*	Yellow
Slender Sunflower	*Helianthus gracilentus*	Yellow

Females deposit pale yellow-green eggs with a red ring and red dot singly on the underside of host plant leaves. Shortly after, larvae emerge and feed near the base of the plant. Second and third instar larvae construct a shelter (hibernaculum) by attaching two to four leaves together (Figure 3) where they can be found when not foraging. The head will be oriented away from the base of the leaves (Figure 4). Fourth, but occasionally third, instar larvae overwinter in these hibernacula. Pupation also occurs in these hibernacula, although larvae will construct more than one shelter. Immediately prior to pupation, the upper end is filled with a white, cotton-like substance (Figure 5), with pupation lasting 18-21 days. Brown and McGuire (1983) collected a larva, pupa, and adult at one location on the same day indicating that development is not tightly synchronized among individuals at a single site.

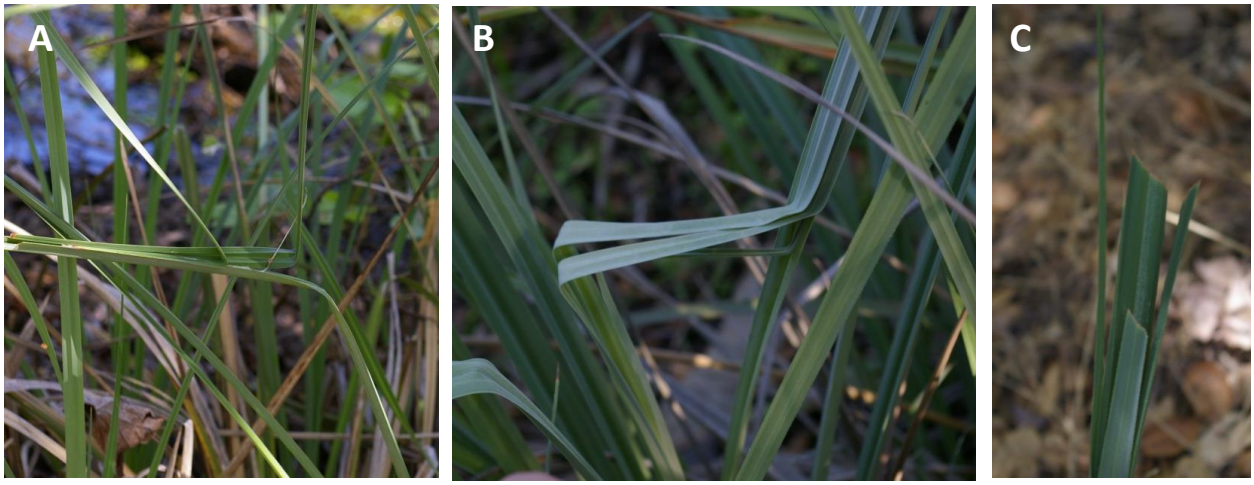

Figure 3. Harbison's dun skipper larval hibernacula. A) Horizontal orientation, B) vertical orientation, C) vertical orientation low in plant with leaf ends chewed off.

Figure 4. Harbison's dun skipper larva. A) Fourth instar larva after opening hibernaculum, B) head of fourth instar larva evident when looking into hibernaculum.

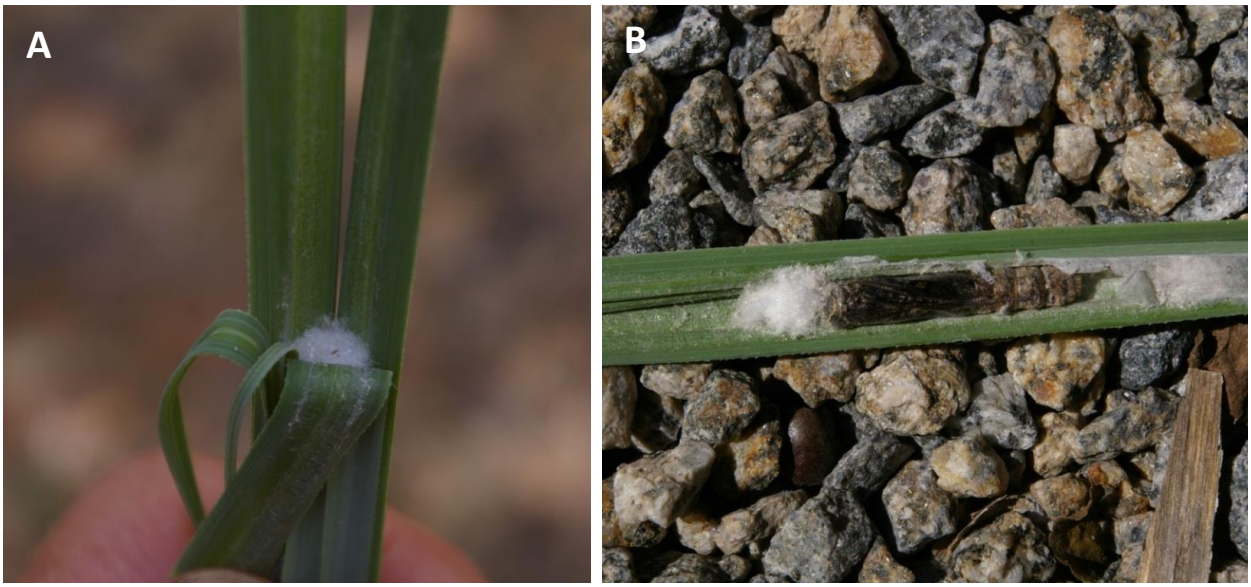

Figure 5. Harbison's dun skipper pupa. A) White, cotton-like substance superior to the pupa (two of four leaves pulled down for visibility), B) full hibernaculum during pupation exposed by removing one leaf.

Historical and Current Distribution and Abundance

Methods

The historical distribution of the Harbison's dun skipper was reconstructed using museum specimens, published journal articles, unpublished reports, and personal communications with local biologists. The current distribution has been determined by surveys for Harbison's dun skipper larvae and adults, starting with Marschalek and Deutschman (2015). This included surveys at historical Harbison's dun skipper locations, Harbison's dun skipper locations reported by local biologists, and databased San Diego sedge locations. Areas not included in these efforts were private property.

Three sources of information were used to identify areas that might have potential habitat.

1) San Diego sedge locations as reported in the San Diego Natural History Museum (SDNHM) Plant Atlas (www.sdplantatlas.org), Calflora (http://www.calflora.org/), and the California Consortium of Herbaria (http://ucjeps.berkeley.edu/consortium/).

2) Locations of San Diego sedge and oak riparian woodlands as reported by other biologists.

3) Historical Harbison's dun skipper locations.

San Diego sedge is not restricted to oak woodlands. However, it was quickly evident that searching for oak woodlands in low-lying areas was an efficient way to locate the sedge compared to searching all ravines and riparian areas. Brown (1991) also observed this subspecies typically inhabiting partially shaded riparian oak woodlands.

San Diego Sedge and Larval Surveys

We conducted surveys for Harbison's dun skipper's larval food plant, San Diego sedge, by searching for riparian woodlands, and primarily riparian oak woodlands. Using aerial imagery, these oak woodlands are characterized by dark, linear patterns of vegetation across the landscape. Other riparian habitats (e.g. willow riparian) were searched adjacent to the oak woodlands. The location of San Diego sedge plants and/or patches were recorded with a GPS unit. The sedges were searched for signs of Harbison's dun skipper foraging, larval hibernacula (shelters), and larvae themselves. The distinctive hibernacula are relatively easy to find.

Adult Surveys

Surveys consisted of systematic searches around San Diego sedge patches and focused on potential nectar sources. We conducted surveys between 8:30-14:00 and during periods of appropriate weather (sunny or partly sunny, 24-35°C and modest wind speeds of less than 15mph). Previous work identified these conditions as optimal for adult activity and detection (Marschalek and Deutschman 2015). Data from these surveys provide an index of population size, evaluate skipper detectability, and describe the adult flight season phenology, behavior, and nectaring sources.

Results

Based on records contained in the SDNHM Plant Atlas, Calflora, and the California Consortium of Herbaria, San Diego sedge has a relatively restricted distribution but not as limited as the Harbison's dun skipper. San Diego sedge records extend from the United States-Mexico border north into extreme southern Monterey County. Most of these localities are in coastal San Diego and southern Orange County, extreme northern Los Angeles basin, and coastal San Luis Obispo County. These three regions are widely separated from one another.

All sedge plants were found in or immediately adjacent to riparian oak woodlands except for two small patches (Crestridge Ecological Reserve, Otay Mountain). However, both of these locations also had oak woodlands containing San Diego sedge. In many cases, oak woodlands were patchily distributed along a creek and the sedge was only found in those patches of woodlands (not in the openings between woodlands). Occasionally willows and sycamores were mixed in with these oaks. We did not find San Diego sedge in or along pools of still/standing water, only in areas with moving water or a dry ravine that has moving water when present. It appears that *Arundo* and *Typha* are able to out compete the sedge, utilize a different niche, or both as the sedge was not present in close proximity to these other species. Published reports for San Diego sedge indicate a distribution up to 600 meters in elevation (Hickman 1993, Calflora 2013); however, the plants on Otay Mountain were at 950 meters in elevation.

McGuire and Brown (1983) initially compiled the Harbison's dun skipper distribution. Recent contributions include surveys conducted as part of a project funded by a CDFW Local Assistance Grant (Marschalek and Deutschman 2015) and a previous SANDAG contract (Marschalek and Deutschman 2016, 2017a, 2017b). Based on these surveys for larvae and adults in 2013-2017, the current Harbison's dun skipper distribution includes the foothills in the northern and southern parts of San Diego County, extreme western Riverside County, southern Orange County, and one observation in Mexico (Figure 6). This Mexico observation occurred on 13 June 2009 and was reported by K. Radamaker and D. Powell. MacNeill (1962) and Hoffmann (1941) suspected that the skipper would be found in the northern boreal regions of Baja California, Mexico but there was no confirmation. It is unclear whether the skipper

currently occupies Silverado Canyon, its northernmost location. Extirpation from Silverado Canyon would represent a substantial range contraction.

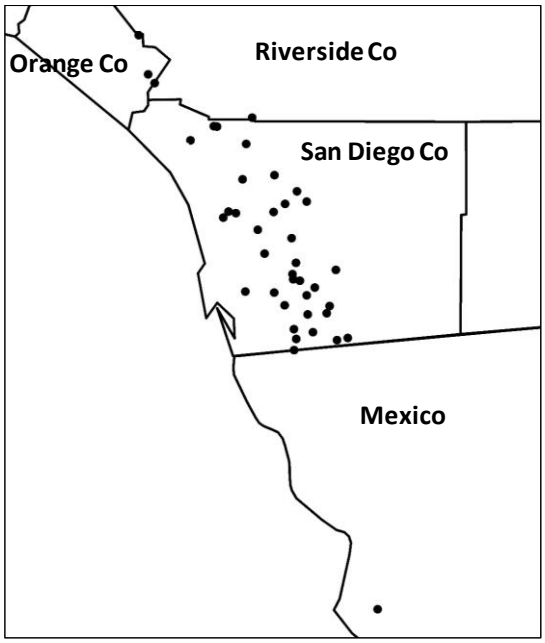

Figure 6. Distribution of the Harbison's dun skipper.

A total of 32 historic and current Harbison's dun skipper localities have been documented on public lands (29 in San Diego County, 2 in Orange County, 1 in Riverside County). Most often, historical locality data provided a general description rather than a specific point. Therefore, it was difficult to know if we were revisiting the same location. In San Diego County, there appears to be a significant gap around the Poway area due to local extirpations likely resulting from wildfires (Figure 7). Specific historic and current Harbison's dun skipper locations on conserved lands are listed in Appendix A.

Determining the actual number of adults present at a site was very difficult due to their flight patterns. Adult skippers are so fast that observers were unable to track individuals for more than several meters. In addition, they would often move through and around tall, dense vegetation which would eventually obstruct the view of the skipper. Most adults were observed nectaring on one or a few flowers which assisted counting. Separately tracking the number of males and females was also helpful. However, adults would often come and go from a flower or flower patch and it was not always possible to determine if it was the same skipper returning. In one case, a preliminary marking study resulted in the capture of three different males from the same perch within a ten-minute span at Barrett Lake. On June 19, 2016 at Lake Hodges, a survey yielded a count of 5-6 skippers flying around an area. However, skippers were captured to obtain genetic samples and at least 14 unique individuals were in the area. These observations suggest a lack of true territoriality (although males will frequently chase other males) and use of the same area by multiple individuals.

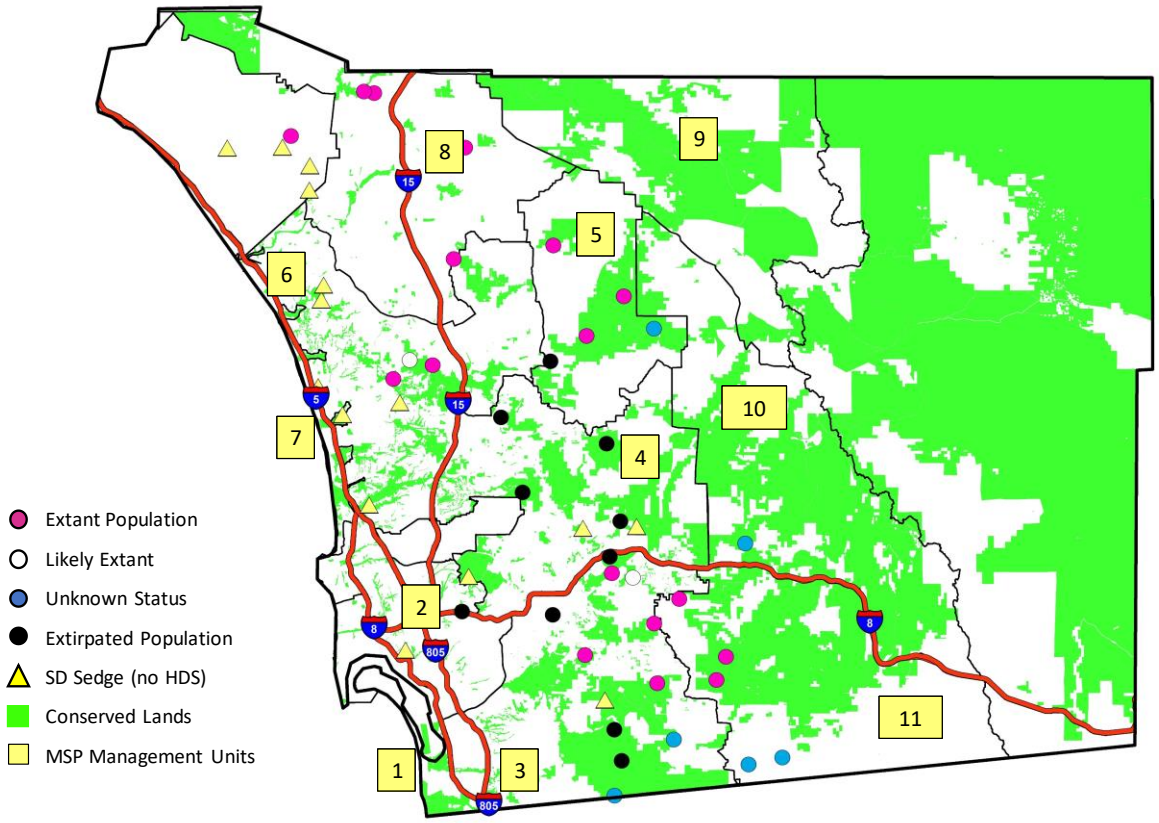

Figure 7. Distribution of the Harbison's dun skipper in San Diego County. MSP Management Units are outlined in black and numbered. Only those locations with detailed geographic information are shown as this information is required to assess the status of each population.

The maximum number of Harbison's dun skipper adults observed at a single time were recorded at several sites in 2013, 2014, 2016, and 2017 (Table 2). Some sites during certain years were not surveyed on a regular basis. This precludes a confident assessment of the number of skipper adults present during the peak of the flight season. In Table 2, these data (count) are in regular font without an associated date. Repeated sampling ensures sampling during the peak of the flight season and a more confident assessment. These data are in bold with the associated date (Table 2).

Non-lethal genetic samples were collected from adults in preparation for a future landscape genetics project. This involved capturing adults, removing a middle (mesothoracic) leg and placing the leg in ethanol, and marking the skipper prior to release. Marked individuals were not recaptured to avoid duplicate sampling and reduce further damage. From the 2013, 2014, 2016, and 2017 flight seasons, we have been able to obtain 181 genetic samples.

Table 2. Daily maximum counts of Harbison's dun skipper adults. Maximum counts from repeated surveys with a high probability of occurring during the peak flight season are in bold (associated date or dates provided- month represented by Roman numeral), while maximum counts from less frequent surveys are also provided (not bolded and without associated date).

Location	2013	2014	2016	2017
Barrett Lake	6-8	**4**: VI-6	**11**: VI-6	**1:** VI-22
Boden Canyon Ecological Reserve	5-6	**1**: V-27, VI-6	**1**: VI-21	1
Blue Sky Ecological Reserve	0	**0:** N/A	-	-
Calavera Nature Preserve	0	-	-	-
Camp Pendleton	-	-	**0:** N/A	0
Carlsbad Highlands Ecol. Reserve	0	-	-	-
Crestridge Ecological Reserve	1	**0:** N/A	**0:** N/A	0
Daley Ranch	1	**2**: VI-6	**4**: VI-17	0
El Capitan (west of reservoir)	0	-	-	-
Elfin Forest	-	-	-	0
Fox Springs (CNF)	-	1	-	0
Hellhole Canyon County Park	4	**1**: VI-6,13	**1**: VI-10	0
Hollenbeck Canyon Wildlife Area	6-10	**5-6**: VI-11	**2**: VI-9	**3-4:** VI-19
Hot Springs (CNF)	-	1	-	0
Lake Hodges	5-6	**4**: V-28	**15-20**: VI-19	-
Loveland Reservoir	8	**4-5**: V-27 or **3-6**: V-29	**3**: VI-14	**2:** VI-15, VI-27
Pamo Valley (CNF)	1-2	**2-3**: V-28, VI-2	**0:** N/A	2
Red Mountain	1	-	**0:** N/A	-
SDNWR- Las Montanas (South)	2	**1**: V-29	**0:** N/A	-
San Pasqual Academy	0-1	-	**0:** N/A	-
Santa Margarita Trail	-	-	-	1
Silverado Canyon (CNF)	-	0	-	0
Skye Valley Road	2	**2**: VI-2	**15-17**: VI-14	1
Sycamore Canyon County Park	0	0	-	-
Sycuan Peak Ecological Reserve	5-6	**2**: V-19,27	**8-12**: VI-16	-

Summary of Historical and Current Distribution and Abundance

The historic distribution of the Harbison's dun skipper is restricted to southern California and one observation in northern Mexico, all records in the coastal foothills. The current range of the Harbison's dun skipper is reduced compared to the historic range, primarily due to habitat loss (urbanization and vegetation clearing), wildfires, and drought. The skipper may be extirpated from MUs 2 and 4, creating a gap through the central portion of San Diego County and the skipper's distribution.

Historically, small local populations were reported. However, recent surveys have illustrated that determining an absolute population size or population size index may be difficult. Marking of skipper adults suggests that the populations may be at least slightly larger than previously thought. In addition, skippers may use different areas in different years, which alters detection probabilities. Regardless, data still suggests that local population sizes tend to be small and vary annually. This annual variation is not consistent across all sites.

Habitat Description

Methods

Habitat data was collected on woodland tree composition, condition of the San Diego sedge, surface water availability, and potential threats at all locations where we conducted surveys for adults (Table 3) (Marschalek and Deutschman 2016). The site assessments were designed to be rapid and detect large differences/changes.

Table 3. Habitat assessment variables.

Category	Measurements
Tree species	% composition of canopy, % healthy, % thin canopy, % dead, % with fire damage
San Diego sedge	Leaves green, leaves with brown tips, leaves mostly brown
Flowing or standing water	Present/absent
Threats	Grazing, dumping/trash, encampments, feral pig activity, illegal trail use, goldspotted oak borer, Kuroshio/polyphagous shot hole borer, non-native vegetation (e.g. *Arundo*, *Tamarix*)

Results

Habitat was assessed at 23 locations with recent Harbison's dun skipper observations just after the flight season (27 July – 9 August 2016). Oak species dominated the woodlands, with lesser amounts of sycamore and willow trees (Table 4). The condition of the San Diego sedge plants ranged from nearly all very healthy (green) to all dead. Most of the plants had green leaves with brown tips, suggesting some water stress although this may be typical during the late summer and early fall. The most common potential threat was the presence of the goldspotted oak borer. Evidence of this beetle was observed at 8 of the 23 sites (35%) and it is close to 5 other sites (an additional 22%). At least 15 non-native plant species were detected in the riparian area.

Table 4. Composition of woodlands occupied by Harbison's dun skippers.

Tree Species	% Composition
Oaks	71.6
Sycamores	13.0
Willows	12.0
Other species	3.4

One site had no trees and is excluded from this table.

Summary of Habitat Description

Harbison's dun skipper habitat generally consists of a riparian oak woodland vegetation community, although other tree species may occur among the oaks. Larvae only feed on San Diego sedge so this is a strict requirement. However, adults have more opportunistic and flexible foraging behaviors and will feed on nectar from a number of plant species. The San Diego sedge is most often found within the shade of the oak canopy while the flowers used as nectar sources are generally in the sun, outside of the oak canopy shade.

Threats

Fire

We were unable to detect the presence of the Harbison's dun skipper in the Poway area at Sycamore Canyon Ecological Reserve and Blue Sky Ecological Reserve. It appears that the 2003 Cedar Fire and 2007 Witch Fire, respectively, extirpated these historic populations. The skipper was observed as recently as 1999 at Sycamore Canyon (G. Pratt pers. comm.). Fire does not always result in extirpation as recent (2013-2017) surveys detected the skipper at Crestridge Ecological Reserve (2003 Cedar Fire), Hollenbeck Canyon Wildlife Area (2007 Harris Fire), and near the San Pasqual Academy (2007 Witch Fire). The impact of fires can be direct or indirect. Fire can destroy skipper populations, or erosion following a fire can result in the removal of San Diego sedge during scouring of the creek bed. This was observed at one location at Crestridge Ecological Reserve. A second indirect impact of fires may be related to increased grazing on San Diego sedge. Deer grazing may occur following fire where the sedge is often one of very few green plants (D. Faulkner pers. comm.).

Habitat loss or degradation

Adobe Falls is the only extirpation previously reported (Brown and McGuire 1983). Based on an initial assessment of the skipper, Brown (1982) concluded that it is easily extirpated by habitat modifications. Our observations support Brown's assertion. We documented local extirpations as the result of habitat alterations in parks and residential areas. This included bank stabilization/channelization via concrete-lined stream channels accompanied by clearing all vegetation down to the water's edge. This appears to have occurred at Flinn Springs County Park, as Brown and McGuire (1983) reported a relatively large population. Brown (1991) described the population as declining while the park was being constructed, and we were unable to locate San Diego sedge. At other sites, what appeared to be appropriate habitat (oak woodland with a small stream) was found but all of the vegetation along the stream bank had been removed. At these sites, we did not have information on the historic conditions to use as a reference.

Although several sites have experienced habitat modifications, restoration of the habitat is possible. In areas where the vegetation has been cleared, plantings of San Diego sedge can be successful. At Crestridge Ecological Reserve, we found skipper larvae within a year or two of planting. Restoration should also include potential nectar sources for the adults in an area that receives full sunlight and at a similar elevation as the stream bank.

Small populations or lack of connectivity

In general, small populations and restricted distributions increase the susceptibility of a species to decline and extinction. This pattern may be typical for the Harbison's dun skipper, but recent extirpations have been documented which results in a further reduced distribution. Further isolation of populations reduces or possibly prevents movement of individuals among these populations which can be a key factor in site occupancy (WallisDeVries 2004). Isolation can also impact the evolutionary pathway of populations and the species by reducing gene flow and subsequently increasing inbreeding (Couvet 2002). Deleterious effects of inbreeding, including reduced survival and fecundity, have been documented in other butterflies (Saccheri et al. 1998; Crnokrak and Roff 1999; Frankham 2005; Vandewoestijne et al. 2008). A restricted range and relatively isolated populations inhibits species from recovering from stochastic events such as wildfires, as seen with the Hermes copper in San Diego County (USFWS 2011).

Climate change

Drought appears to be a significant threat to the skipper by negatively impacting its larval food plant. San Diego sedge inhabits drainages and canyons where water availability is greater than adjacent uplands. It also appears that the sedge benefits from the woodland canopy. In 2014, those sedge plants which were not directly under the riparian woodland canopy appeared stressed which made them unusable (dry, brown leaves) by dun skipper larvae (Figure 10). When all sedge plants exhibited heavy drought stress, we were unable to detect Harbison's dun skipper larvae or adults. A reduction in San Diego County precipitation, as predicted with climate change (Li et al. 2014), will likely lead to a reduction in already small annual adult population sizes. This is commonly observed in other butterfly species (Pollard 1988). Climate change has been linked to declines and extinctions in other butterfly species (Forister et al. 2010, Casner et al. 2014, Oliver et al. 2015, Tack et al. 2015).

Goldspotted Oak Borer

The goldspotted oak borer (*Agrilus auroguttatus*) is an invasive, exotic beetle that is responsible for killing oak trees in San Diego County. This beetle appears to have killed trees in a riparian oak woodland at Crestridge Ecological Reserve, which is occupied by the Harbison's dun skipper. Oak tree mortality results in the thinning or loss of the canopy, reducing the amount of shade cast on sedge plants. In turn, this increases the water-stress of these sedge plants and will likely have detrimental impact as described above (Threats: Climate Change).

Grazing

Cattle grazing of San Diego sedges represents another threat to the skipper. At Pamo Valley (City of San Diego), a patch of sedge was found but nearly all leaves were grazed to about 25cm in height. This is at or below the level of where larger larvae would be found. The grazing would result in inadvertent consumption of the larvae and/or competition for the food source. It is unknown if the cattle were

responsible for an extirpation of the population, but it is likely since the skipper was recorded nearby (Cleveland National Forest).

Management Strategies

Harbison's dun skipper conceptual model

To assist with identifying stressors to the Harbison's dun skipper, a conceptual model (Table 5, Figure 8) was created and involved the development of a management goal: Ensure Harbison's dun skipper persistence throughout the historic range in San Diego County.

Table 5. Model elements for the Harbison's dun skipper conceptual model.

Anthropogenic Drivers	Species Variables	Natural Drivers
Development/Fragmentation	Eggs	Temperature
Fire	Larvae	Precipitation
Invasive Plants	Pupae	Drought
Vegetation Clearing	Adults	Flooding
Grazing	Female Behavior	Habitat
	Male Behavior	Riparian Oak Woodland
	Reproduction	Nectar Sources
	Oviposition	San Diego Sedge
	Dispersal	Predators/Parasitoids
	Gene Flow	Oak Mortality
	Population Structure	Goldspotted Oak Borer
		Shot Hole Borers
		Pathogens

Narrative for the Harbison's dun skipper conceptual model:

Anthropogenic Threats:		
Development Fragmentation	Development associated with urbanization as well as creation of parks and species relatively free of vegetation for human use has resulted in habitat loss and extirpations. Habitat fragmentation may exacerbate problems associated with dispersal limited species.	Brown and McGuire (1983), Marschalek and Deutschman (2015)
Fire	Wildfires cause direct mortality of Harbison's dun skippers.	Marschalek and Deutschman (2015)
Invasive Plants	Invasive plants such as *Arundo* can outcompete the San Diego sedge and alter the vegetation community.	Brown and McGuire (1983)
Grazing	Cattle have been observed feeding on San Diego sedge that would preclude skipper larval feeding and development.	Marschalek and Deutschman (2015)

Species Variables:		
Reproduction	Most of the Harbison's dun skipper life cycle is achieved on San Diego sedge, including oviposition, larval feeding, and pupation.	Brown and McGuire (1983), Marschalek and Deutschman (2015)
Dispersal	Harbison's dun skipper adults are able to move throughout oak woodlands and adjacent habitat relatively easily. It appears that individuals will frequently move in and out of different areas.	Marschalek and Deutschman (2015, 2016)

Natural Drivers:		
Vegetation Community	The Harbison's dun skipper occur in riparian oak woodlands, although other tree species may be mixed in. The skipper utilizes San Diego sedge (*Carex spissa*) for oviposition, larval food, and pupation. Adults require nectar from flowering plants but are more generalists.	Brown and McGuire (1983), Marschalek and Deutschman (2015)
Predators Parasitoids	Predators and parasitoids of the Harbison's dun skipper are unknown, but are important factors for other Lepidoptera.	Marschalek pers. comm.
Precipitation	A minimum amount of precipitation is required to maintain San Diego sedge populations, flowering plants used by adults for nectar sources, and oaks. Drought conditions have resulted in extirpation of several local Harbison's dun skipper populations. A high amount of precipitation and flooding may result in mortality of larvae on San Diego sedge.	Marschalek and Deutschman (2015, 2017a, 2017b)
Temperature	The timing of emergence and the single annual flight season of the Harbison's dun skipper appears to be influenced by weather conditions, although the specifics of this relationship are as yet unknown. In addition, activity on a given day in the flight season is strongly influenced by temperature and cloud cover, with adults remaining inactive and generally unseen until a temperature of 75°F and sunny conditions.	Marschalek and Deutschman (2015, 2017a, 2017b)
Oak Mortality	A number of factors have led to the mortality of oak trees within the Harbison's dun skipper range including the goldspotted oak borer (*Agrilus auroguttatus*), shot hole borers (*Euwallacea* sp.), and various pathogens.	Coleman & Seybold (2011), USDA Forest Service (2015), UCR (2017)

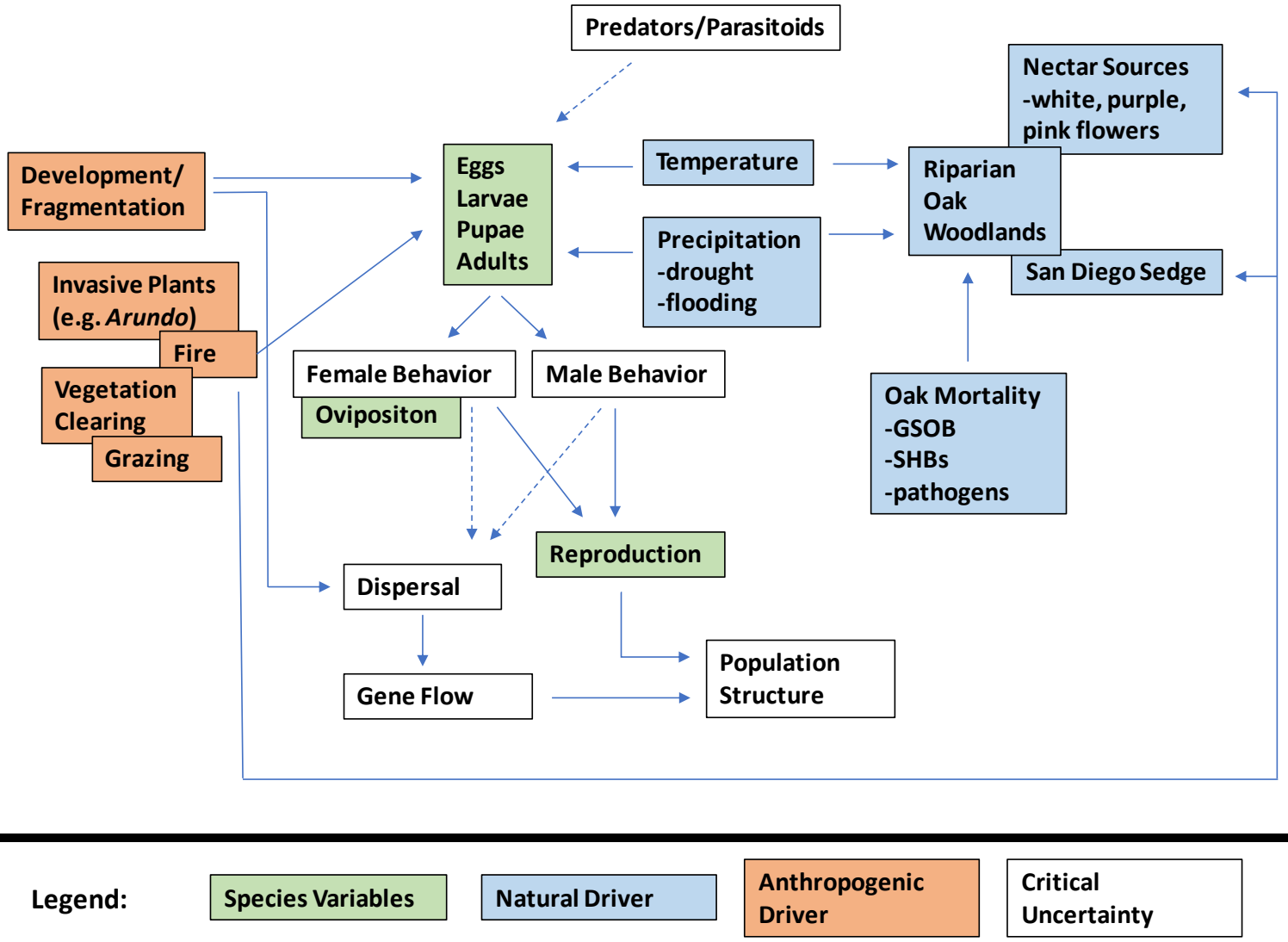

Figure 8. Harbison's dun skipper conceptual model. The model includes anthropogenic drivers (red), natural drivers (blue), and the measurable response variables (Harbison's dun skipper, green). Arrows indicate the relationship between drivers and the response variables.

The conceptual model focuses on the habitat components directly used by the Harbison's dun skipper and the factors that are most important to those components. This primarily includes factors influencing the distribution and health of the San Diego sedge.

The goal of ensuring Harbison's dun skipper persistence throughout the historic range in San Diego County can be accomplished by:

1) Protecting current populations from wildfires
2) Enhancing existing populations, particularly those that have the smallest population sizes
3) Expanding the current distribution of populations
4) Protecting habitat

Protect current populations from wildfires

Pre-fire

Objective: Protect current Harbison's dun skipper populations from fire.

Because fire has resulted in the extirpation of populations, action should be taken to reduce this threat. This could include reducing the number of fires and/or limiting the size of fires. The San Diego Monitoring and Management Program is developing a wildfire plan that will address this topic.

Post-fire

Objective: Ensure recovery of San Diego sedge and oaks following wildfires. This may not always be required following a fire.

Without the shade from the oak canopy, San Diego sedge plants may die during drier years. Immediately following severe fires, oak trees have a reduce canopy, subjecting the sedges to a warmer and drier microhabitat. Supplemental water and/or shade could enhance survival of the sedges until the oak canopy recovers. In addition, San Diego sedge are often quick to grow following a fire and experience heavy herbivory pressure. Temporary fencing may assist with protecting any larvae that survived the fire.

Sites dependent on local site characteristics and severity of fires.

Enhance existing populations, particularly those that have the smallest population sizes

Objective: Increase the number of San Diego sedge plants at sites with fewer than five Harbison's dun skipper adults at peak abundance during a year with average winter precipitation.

The distribution of the Harbison's dun skipper is geographically limited, so each population is important for their long-term persistence. Having numerous, robust populations spread out across the landscape is important considering the regular occurrence of wildfires. Increasing the number of San Diego sedge plants and expanding the extent of these plants should increase the local Harbison's dun skipper population size. This increases larval resources and expands suitable habitat. If potential nectar sources

are not present, they should accompany the new sedge plants. The small populations that warrant enhancing include (Figure 9):

Camp Pendleton
Canada de San Vicente
Crestridge Ecological Reserve
Elfin Forest
Hollenbeck Canyon Wildlife Area
Loveland Reservoir
Pamo Valley
Santa Margarita Trail
USFWS- Las Montanas

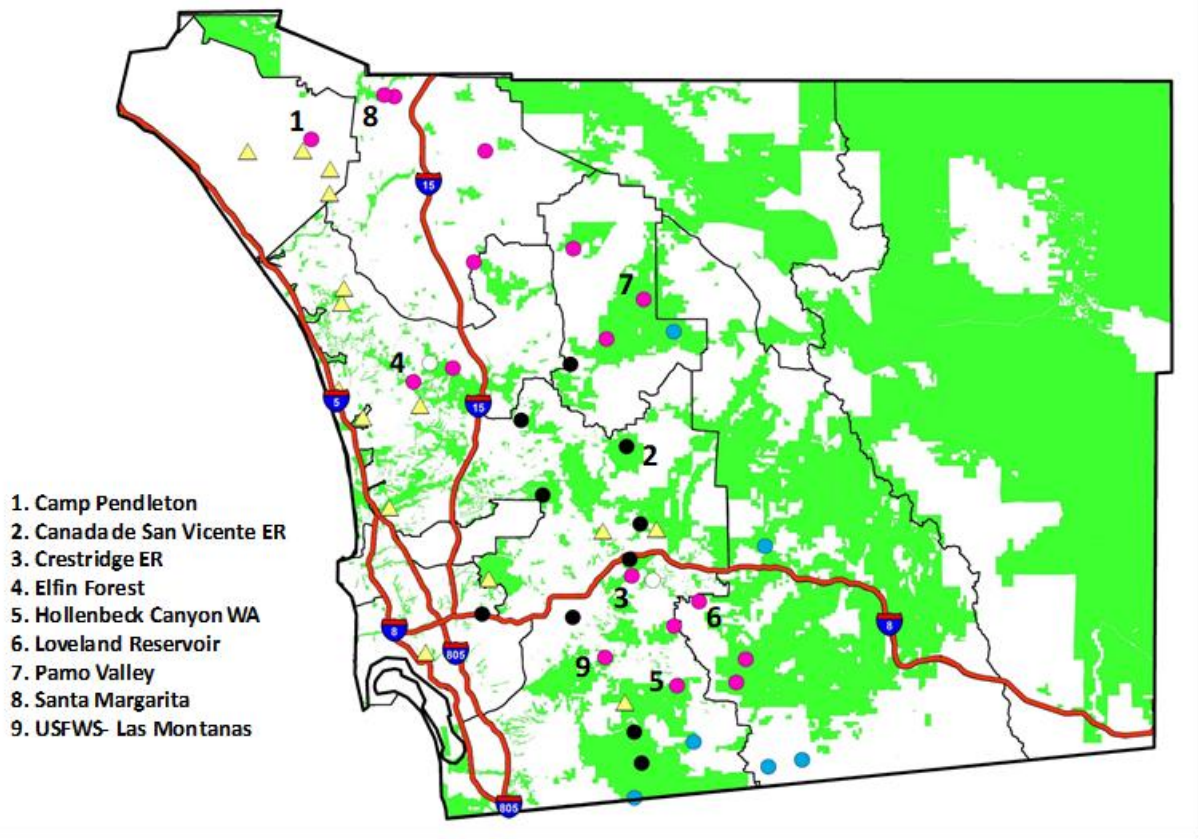

Figure 9. Sites with small populations that should be enhanced.

San Diego sedge plants have been successfully transplanted and used by skipper larvae at Crestridge Ecological Reserve. Placement in or adjacent to creeks and ravines, while under the shade of the oak canopy, would increase the skipper's larval resources. If rare, plants to provide nectar for adult skippers should be planted in partly to full sun areas adjacent to sedges and/or in or adjacent to creeks and ravines. Appropriate plant species are listed in Table 1.

Establishment of oak trees may be appropriate to either restore or enhance woodlands, which should facilitate sedge growth. For sites that suffered high oak mortality follow fire or GSOB infestation, reestablishment of oaks and their associated shade may be essential for San Diego sedge survival if water flow is low.

Increasing the number of San Diego sedge plants and expanding the extent of these plants should increase the local Harbison's dun skipper population size. This increases larval resources and expands suitable habitat. Sites that experience relatively consistent water flow should be prioritized as it is expected that they will be most resistant to drought and fire.

Expand the distribution of populations

Objective: Restore vegetation within and adjacent to riparian oak woodlands, and translocate Harbison's dun skippers to reestablish or create populations if natural recolonization does not occur, so that the skipper is as widely distributed as historic conditions.

Habitat loss, wildfires, and drought have reduced the number of Harbison's dun skipper populations as well as the spatial extent to which this species is reliable found. Habitat loss in regards to the previous alterations of the vegetation under the oak trees represents potential restoration opportunities. Many degraded oak woodlands in San Diego County have high non-native vegetation cover under the oak canopy. In riparian woodlands, San Diego sedge should be planted in or adjacent to drainages and potential nectar sources planted in sunny areas adjacent to the sedge. Sites where restoration and possibly reintroduction efforts should occur are (Figure 10):

Adobe Falls
Blue Sky Ecological Reserve
El Monte Oaks
Flinn Springs County Park
Old Ironsides County Park
Otay Mountain
San Pasqual
Sycamore Canyon County Park

Creation of habitat in suitable locations and subsequent colonization will expand the distribution of the Harbison's dun skipper. Sites should have relatively consistent water flow through the winter/spring but not sandy soils. Trees (ideally oaks) may need to be established to provide shade for the San Diego sedge. Research to identify appropriate conditions for San Diego sedge growth may be required prior to large scale efforts. As with enhancing small populations, sites that experience relatively consistent water flow should be prioritized as it is expected that they will be most resistant to drought and fire. These could include urban areas that experience constant runoff ("urban drool") throughout much of the year.

If natural colonization to a restored or created habitat does not occur, translocation of larvae could be considered. Larvae are relatively easy to locate due to their larger size, which should also facilitate survival while handling during the translocation process.

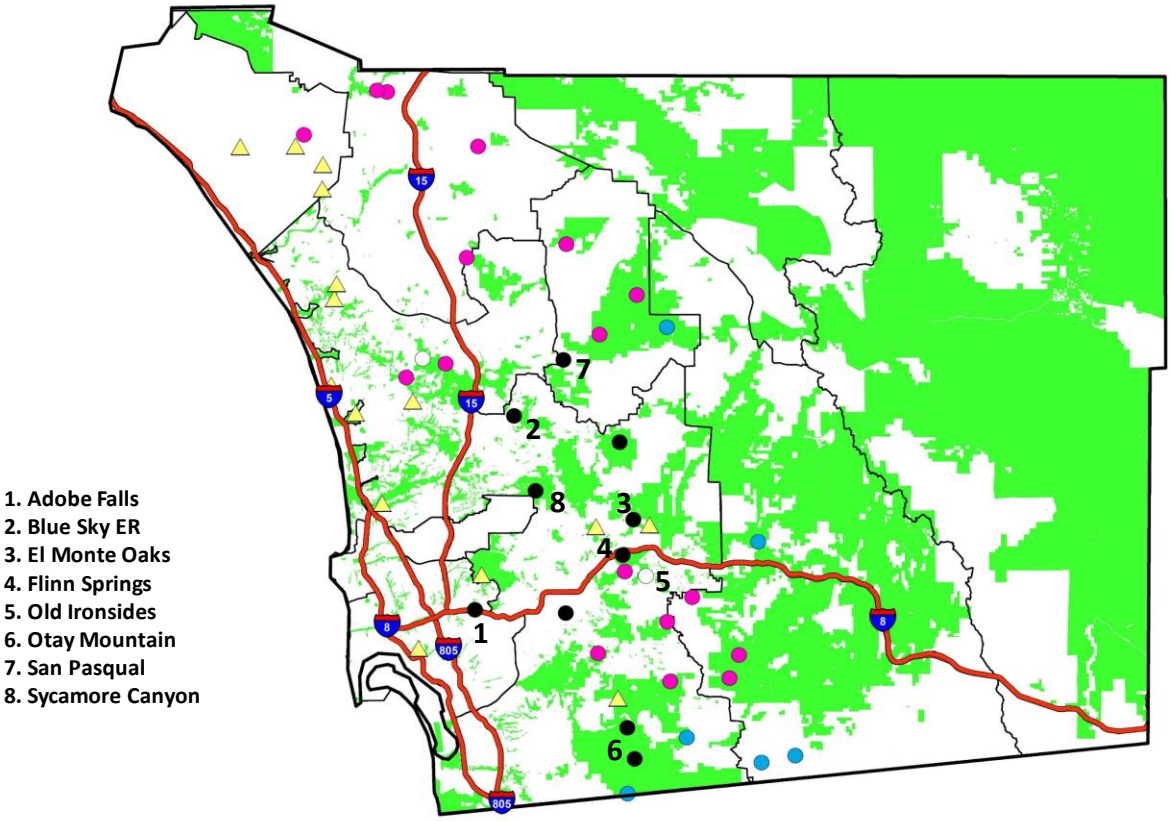

Figure 10. Potential sites for habitat restoration and subsequent translocations to expand the Harbison's dun skipper distribution by reestablishing populations.

Protect Habitat

Objective 1: Protect habitat from future development or alteration through land acquisitions and incorporated in the San Diego County preserve system.

Objective 2: Protect, maintain, and restore riparian oak woodland vegetation communities in the San Diego County preserve system.

Due to the naturally restricted distribution of Harbison's dun skipper and the increasingly fragmented San Diego County landscape, protecting current habitat is important for the long-term persistence of this species. This should include protecting occupied or suspected occupied habitats, but also maintaining or restoring connectivity of riparian oak woodlands. Any oak woodlands within the historic range of the Harbison's dun skipper should be considered for acquisition to protect skipper populations, habitats, and connectivity.

For those riparian oak woodland communities already in the San Diego County preserve system, the condition of the San Diego sedge and flowering plants should be maintained or enhanced. Clearing of oak woodland understory vegetation, whether it is by humans for human use, livestock grazing, or any other action, should be avoided. Harbison's dun skippers utilize the entire sedge plant throughout their

lifecycle (eggs, larvae, and pupae) and are found on the sedge plant the entire year. For this reason, any impact to the plant during any time of year will likely have detrimental impacts to at least one life stage of the skipper.

Research Needs

The current conceptual model includes biological uncertainties. These uncertainties as well as future research topics are listed below:

Biological Uncertainties
How maximum counts relate to actual population size
Habitat use of Harbison's dun skipper adults
Major predators and parasitoids
Mortality factors including predators, parasitoids, and others
Overall species dispersal behavior and ability, including impacts on gene flow

Future Research Topics
Causes of mortality including predation and parasitoidism
Habitat preferences- habitat use, including annual variation in areas used
Annual variation in population sizes
Landscape genetics study to assess:
- Genetic structure
- Population size
- Dispersal ability

Translocation methods for reintroductions

Causes of Mortality

Causes of mortality for the Harbison's dun skipper are poorly described or understood. Due to the quickly flight of the adults and relatively short duration of the flight season, mortality is likely greatest in the larval stage. Predation events have not been observed, but several dead larvae were found that suggest parasitoid induced mortality. Braconid wasps and tachinid flies are likely parasitoids, as they are often associated with Lepidoptera (Pierce and Mead 1981, Ohsaki and Sato 1994). Harbison's dun skipper larvae (at least late instar) are relatively easy to find so that parasitoid rates could be calculated and parasitoid species identified. If non-native predators or parasitoids are identified, efforts to reduce or remove those species could enhance skipper population sizes. It is known that Argentine ants are a common predator in the southern California riparian habitats.

Habitat Preferences

For prioritized and effective landscape conservation planning and habitat restoration, a better understanding of habitat is necessary. This relates to characteristics that drive population sizes and connectivity of San Diego sedge patches. The number and spatial arrangement of San Diego sedge,

topography, and possibly other variables could be influential. Increasing connectivity between habitat patches is important for natural dispersal. However, little is known about how most insect species move across complex landscapes so more work is needed before species-specific management can be implemented for the Harbison's dun skipper.

Annual Variation in Population Sizes

Developing a better understanding of the annul variation in local Harbison's dun skipper population sizes will allow for the assessment of the skipper's ability to survive drought and recolonize following fire. Monitoring of Harbison's dun skipper adults at regularly surveyed sites should continue so that we can assess the ability of the species to recover following multiple years of drought. Populations that are less sensitive to drought are more likely to survive and increasingly important considering climate change projections for less precipitation (Li et al. 2014). Monitoring of Harbison's dun skipper adults at historically occupied sites which were extirpated by recent wildfires will inform about natural recolonization ability. Conditions of both the post-wildfire habitats and dispersal corridors are likely to influence recolonization rates. If recolonization events are rare, the importance of translocations and captive populations will be elevated. Likewise, if future fires result in loss of additional population, the importance of these activities will be elevated.

Landscape Genetics

Detecting movements of small animals (particularly insects) is very difficult using traditional direct methods. Even then, detecting a long-distance dispersal event does not ensure that the individual successfully reproduced. Genetic techniques offer an ability to assess dispersal and connectivity but assessing population structure and other genetic characteristics.

During the 2013, 2014, 2016, and 2017 flight seasons, non-lethal (legs) genetic samples were collected, with relatively more focused efforts in 2016. With a goal of at least 10 samples from each site, a total of 181 samples have been collected. Due to the small number of Harbison's dun skipper adults encountered, many sites are represented by fewer than 10 individuals but this generally represents greater than 50% of adult skippers encountered.

Translocation Methods for Reintroductions

Translocating individuals may be an important management tool if natural colonization to a restored or created habitat does not occur. A comparison of techniques will provide information regarding the most efficient and effective protocol. Both the larval and adult life stages appear appropriate for translocations. The translocation of a gravid female could result in the introduction of many skipper individuals (in the egg stage), but there is no guarantee that the female will remain in the release area. Larvae are relatively easy to locate due to their larger size, which should also facilitate survival while handling during the translocation process. The larvae would remain in the area until at least the adult emerges, when they may or may not remain in the release woodland.

Table 6. Number of non-lethal genetic samples obtained from Harbison's dun skipper adults, 2013-2017.

Location	2013	2014	2016	2017	Total
Barrett Lake	4	4	18	1	27
Boden Canyon Ecological Reserve	3	0	1	1	5
Crestridge Ecological Reserve	1	0	0	0	1
Daley Ranch	1	1	5	0	7
Elfin Forest	-	-	2	0	2
Fox Springs (Riverside County)	0	1	0	1	2
Hellhole County Park	5	0	1	0	6
Hollenbeck Canyon Wildlife Area	8	2	5	4	19
Hot Springs (Orange County)	-	1	-	0	1
Lake Hodges	9	0	24	-	33
Loveland Reservoir	7	11	2	6	26
Pamo Valley	0	2	0	2	4
San Diego National Wildlife Refuge	2	0	0	-	2
Santa Margarita Trail	0	0	0	1	1
Sky Valley Road	1	1	25	-	27
Sycuan Peak Ecological Reserve	5	4	10	-	19
	46	**26**	**93**	**16**	**181**

Prioritization of activities

All activities listed in this document are expected to benefit the Harbison's dun skipper and help ensure the persistence of this species over the next 100 years in San Diego County. Due to the restricted distribution and relatively small population sizes, protecting the few large populations and working towards reestablishing additional populations (particularly large populations) are most important. Activities of highest priority are assigned a rank of 1, followed by 2 and 3.

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Appendix A: Site assessments and prioritized management actions

Site Name*	Manager	MU	Dun Skipper Status	Summary of Habitat Conditions	Management Options**	Priority
Adobe Falls	SDSU	2	Extirpated	Degraded and non-native plant species common.	Expand distribution (restoration)	3
Barrett Lake	City of San Diego	11	Extant	Oak woodland with non-native grasses common, San Diego sedge plants scattered throughout drainages. GSOB present.	Protect from fire	1
Blue Sky Ecological Reserve	CDFW	4	Extirpated	Oak woodland with abundant San Diego sedge. Burned in 2003.	Expand distribution	3
Boden Canyon Ecological Reserve	CDFW	5	Extant	Oak woodland with abundant San Diego sedge in spots.	Protect from fire	1
Camp Pendleton- India Training Area	US Marine Corps	N/A	Extant	Recently burned in 2014, with willows, oaks, and San Diego sedge recovering.	Enhance population	1
Canada de San Vicente	CDFW	4	Likely Extirpated	Oak woodland with non-native grasses common.	Enhance population	3
Cleveland National Forest- Lake Sutherland Area	USFS	5	Extant	Specific location not located yet.	N/A	N/A
Cleveland National Forest- Pamo Valley	USFS	5	Extant	Oak woodland with native plants in the upper portion and more non-native grasses in the lower portion.	Protect from fire	2
Cleveland National Forest- Sky Valley Road	USFS	11	Extant	Oak woodland with many native plants but some non-native plants between the road and creek. GSOB present.	Protect from fire	1
Crestridge Ecological Reserve	EHL	3	Likely Extant	Oak woodland in process of restoration. San Diego sedge plantings a couple years ago were used by skipper larvae. GSOB present.	Enhance population	2
Daley Ranch	City of Escondido	6	Likely Extant	Oak woodland with mostly native plants. GSOB present.	Protect from fire	2
El Monte Oaks	County of San Diego	4	Extirpated	Oak woodland with non-native grasses common.	Expand distribution (restoration)	3
Elfin Forest	ECC	6	Extant	Oak woodland with mostly native plants but Arundo present.	Protect from fire, enhance population	1, 1
Flinn Springs County Park	County of San Diego	3	Extirpated	Oak woodland with non-native grasses common. Creek is channelized.	Expand distribution (restoration)	1
Hellhole Canyon	County of San Diego	5	Unknown	Oak woodland with mostly native plants.	Protect from fire	2
Hollenbeck Canyon Wildlife Area	CDFW	3	Extant	Three oak woodlands with mostly non-native plants. Full exent of skipper population may not be realized due to dense poison oak and steep topography.	Protect from fire, enhance population	1, 2
Lake Hodges	City of San Diego	6	Extant	Oak woodland with mix of native and non-native plants. Some off-trail use (plant and sedge damage). Additional flowering plants could be benificial.	Protect from fire	2, 1
Loveland Reservoir	Sweetwater Authority	11	Extant	Oaks and willows present. Most of the oaks are dying. GSOB present.	Protect from fire, enhance population	3, 1
Old Ironsides	County of San Diego	3	Unknown	Few trees and some vegetation removal for the park. Some vegetation in the wet areas growing taller.	Expand distribution (restoration)	3
Otay Moutain- near Pio Pico	BLM	3	Likely Extirpated	Few trees and too dry to support San Diego sedge in recent years.	Expand distribution	3
Otay Moutain- near peak	BLM	3	Extirpated	No trees and too dry to support San Diego sedge in recent years.	Expand distribution	3
Otay Moutain- near Mexico border	BLM	3	Unknown	Exact location not located yet.	N/A	N/A
Pala Reservation	Pala	8	Extant	Oak woodland with mix of native and non-native plants. Some off-trail use (plant and sedge damage).	Protect from fire	1
Pamo Valley	City of San Diego	5	Extant	Oak woodland with mix of native and non-native plants. Cattle grazing on the San Diego sedge.	Enhance population	2
Red Mountain		8	Extant	Oak woodland with mostly native plants.	Protect from fire	2
San Pasqual	County of San Diego	5	Extirpated	Oak woodland burned in 2007 and oaks slow to regrow crowns. Too dry to support San Diego sedge in recent years.	Expand distribution	3
Santa Margarita Trail		8	Extant	Oak woodland with mostly dense native vegetation.	Protect from fire, enhance population	1, 1
Sky Valley Road	City of San Diego	11	Extant	Oak woodland with many native plants but some non-native plants between the road and creek. GSOB present.	Protect from fire	1
Sycamore Canyon County Park	County of San Diego	4	Extirpated	Oak woodland with non-native grasses common, San Diego sedge plants scattered throughout drainages. Burned in 2003.	Expand distribution	3
Sycuan Peak Ecological Reserve	CDFW (private)	3	Extant	Oak woodland with mix of native and non-native plants.	Protect from fire	1
USFWS- Las Montanas	USFWS	3	Extant	Oak woodland with mix of native and non-native plants including Arundo.	Enhance population	1

Appendix A: Site assessments and prioritized management actions, continued.

Site Name*	Manager	MU	Dun Skipper Status	Summary of Habitat Conditions	Management Options**	Priority
Riverside County						
Cleveland National Forest- Fox Springs	USFS	N/A	Extant	Oak woodland with mostly native species.	Protect from fire	1
Orange County						
Cleveland National Forest- Silverado Canyon	USFS	N/A	Extant	Oak woodland with mostly native species.	Protect from fire	1
Cleveland National Forest- Hot Springs Canyon	USFS	N/A	Extant	Oak woodland with mostly native species.	Protect from fire	1

Appendix B: Research needs prioritization

Research Needs	Priority
Causes of mortality	3
Habitat preferences	1
Annual population size variation	2
Landscape genetics	1
Translocation Methods for Reintroductions	2