RARE BUTTERFLY MANAGEMENT STUDIES ON CONSERVED LANDS IN SAN DIEGO COUNTY: HERMES COPPER (*LYCAENA HERMES*)

Hermes Copper Survey and Rearing Final Report

Prepared for: San Diego Association of Governments
Contract: #5004388
Contract Manager: Keith Greer

Prepared by: Dr. Daniel Marschalek and Dr. Douglas Deutschman, PI
Department of Biology, San Diego State University

SAN DIEGO STATE UNIVERSITY

31 August 2015

Executive Summary

The Hermes copper butterfly, *Lycaena hermes*, is a rare butterfly endemic to San Diego County, which is threatened by recent urbanization and wildfires. In 2011 the United States Fish and Wildlife Service placed Hermes copper on its candidate species list. This SANDAG funded project began in 2010, focusing on collecting population data for the first two years. In 2012 the emphasis shifted to resolving critical biological uncertainties which will deepen our understanding of the species for improved planning and management of Hermes copper. The focus for 2014-2015 remained on resolving these uncertainties, primarily regarding immature stages. In this report we summarize our work over the last three years including results from surveys in 2013 which were not part of this funded project.

In 2013 the number of Hermes copper adults observed at sentinel sites was higher than counts in 2010-2012, but counts decreased in 2014 and even more in 2015. Rainfall was very low in 2014 and 2015 and these drought conditions are likely the reason for the low Hermes copper counts. In 2013 and 2015, the flight season started very early, with the first observed adult on the 15th and 1st of May, respectively. The May 1st date is the earlier recorded date for a Hermes copper adult, preceding the previous earliest known adult by 11 days. Over the last 13 years, the flight season tends to start early during years with warmer spring temperatures. The flight season at Roberts Ranch was consistently delayed compared to the other sites. Surveys conducted in 2013 at historic Hermes copper populations that were extirpated by the 2003 or 2007 wildfires did not result in the detection of recolonization events. In fact, adults were not detected at Wildwood Glen although they had been in the past. This was one of two sites to experience recolonization following these recent wildfires.

In 2013, egg searches resulted in a (relatively) larger number of eggs (10 eggs from searching 149 spiny redberry shrubs) compared to 2012 (6 eggs from searching 297 shrubs). Most are on the lower branches, on the underside of the branch, and on the side of the shrub closest to a dirt road. Monitoring these eggs through the spring yielded observation of two larvae in the field. Initial foraging occurred on the smallest and newest leaves. In addition to the larvae moving frequently, their small size and cryptic coloration likely resulted in not being able to relocate the larvae just prior to pupation.

Additional egg surveys yielded 8 eggs after searching 132 spiny redberry shrubs in 2014 and 2 eggs (both on the same plant) after searching 76 shrubs in 2015. Monitoring of these eggs demonstrated three important things. The first is that larvae emerged from the eggs earlier than previously observed. Second, eggs can remain on the spiny redberry shrub for more than one year after larval emergence. This means that if an egg is found with an exit hole, the year of larval emergence cannot be determined with certainty. Third, larvae can diapause in the egg for at least one year. This is likely an adaptation to deal with periodic years with very unfavorable conditions (e.g. drought).

Laboratory rearing yielded mixed results. In 2013, 10 of the 36 eggs showed signs of larval activity and four larvae left the egg. Three of these larvae died within a couple days; however one larva was alive for about 50 days and reached the fourth and final larval instar before dying. We contribute the success of the fourth larvae to offering clippings with very small and new leaves as was observed in the field. This is a major milestone given issues other researchers have had when attempting to rear Hermes copper. In

2014 and 2015, we attempted to tightly regulate rearing conditions (temperature and humidity) but were unable to obtain larvae from 25 eggs in 2014 and 9 eggs in 2015. These efforts included use of a bird egg incubator and a rearing chamber at the San Diego Zoo.

We recommend that surveys at four sentinel sites continue to record the annual Hermes copper adult population size. Because climatic conditions greatly impact butterfly densities, these data provide an important context to future management and monitoring efforts. Surveys for spiny redberry and Hermes copper should also occur in the northern portion of their range. This area appears to have small local populations, but is an important region as most individuals are found in a small portion of San Diego County. As it stands today, Hermes copper is one large fire away from being so rare that conservation efforts would be very difficult or impossible. These surveys would be a first step to increase these population sizes.

Continuing the work to successfully rear Hermes copper from egg to adult in captivity is also important. We have had some success breaking winter diapause and started to test different temperatures and levels of humidity during the spring. Altering humidity levels during the overwintering period (cold treatment) should be explored.

Table of Contents

List of Figures

List of Tables

Introduction

The Hermes copper, *Lycaena hermes*, is a rare butterfly endemic to San Diego County and northern Baja California. This species is threatened by recent urbanization and wildfires throughout its range in the United States. In April of 2011 the United States Fish and Wildlife Service (USFWS) issued a 12-month finding which concluded that listing the Hermes copper butterfly as threatened or endangered was warranted, and is currently on the USFWS list of candidate species (USFWS 2011). A proposed rule, including designated critical habitat, will be developed.

In anticipation of this ruling, SANDAG started contracting San Diego State University in 2010 to conduct Hermes copper research with an emphasis on describing its distribution and resolving critical biological uncertainties. In 2010, this project focused on identifying previously unknown populations. This work continued in 2011, providing a multi-year comparison. In 2012 the project shifted to resolving critical uncertainties about the species biology, while also evaluating population size trends at several large "sentinel" sites.

Biology and Life History of Hermes Copper

In the United States, Hermes copper is only found within San Diego County, west of the Cuyamaca Mountains (Thorne 1963; Brown 1991; Faulkner and Klein 2004; Marschalek 2004; Marschalek and Klein 2010; see Figure 1). The species also occurs in northern Baja California, Mexico; however very little is known about the status of the butterfly south of the United States-Mexico border (Thorne 1963; Emmel and Emmel 1973; Marschalek and Klein 2010). Hermes copper has been recorded as far north as near the community of Fallbrook, in San Diego County and as far south as Ensenada in Mexico. They have never been recorded immediately along the Pacific coast, and have not been found above 1300 meters in elevation (Marschalek and Klein 2010).

Hermes copper larvae emerge in the late spring after overwintering as eggs (Thorne 1963; Faulkner and Klein 2004) while the duration of the larval and pupal stages are unknown. Adult emergence is fairly consistent, generally beginning in mid to late May, with the flight period extending to late June or mid-July (Faulkner and Klein 2004; Marschalek and Deutschman 2008; Marschalek and Klein 2010). Emergence appears to be influenced by climatic conditions; however our understanding of this relationship is incomplete.

Hermes copper larvae use only spiny redberry, *Rhamnus crocea*, as a host plant (Thorne 1963; Brown 1991; Faulkner and Klein 2004). Oviposition typically occurs at the intersection of branches on new growth (Marschalek and Deutschman 2009). Although adults gather nectar almost exclusively on California buckwheat, *Eriogonum fasciculatum*, they are rarely found far from spiny redberry plants (Thorne 1963; Brown 1991; Faulkner and Klein 2004; Marschalek 2004). A more detailed understanding of suitable habitat is lacking. For example, it is not clear how many spiny redberry and/or California buckwheat plants are necessary to support a Hermes copper population in a given area. It is also unknown why Hermes copper has a restricted distribution considering spiny redberry and California buckwheat are found hundreds of miles north of San Diego County.

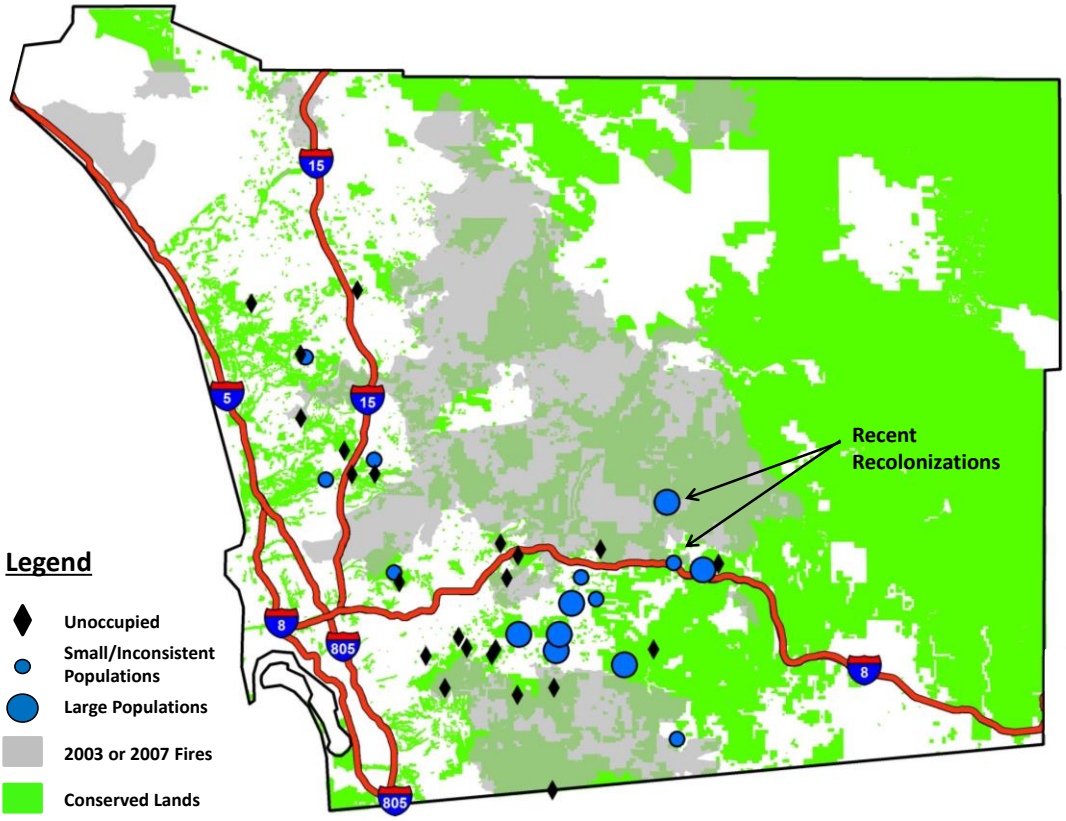

Figure 1. Detection of Hermes copper butterflies on conserved lands, 2010-2013. Fire data from CalFire and Conserved Lands data from SANDAG.

During the flight season, Hermes copper adults become active at around 22°C (72°F) (Marschalek 2004; Marschalek and Deutschman 2008). Adult males have a strong preference for openings in the vegetation, including roads and trails, specifically for the north and west sides of openings (Marschalek 2004; Marschalek and Deutschman 2008). This results in a preference to perch on the south and east sides of plants (Marschalek 2004; Marschalek and Deutschman 2008). They tend to remain inactive or sluggish under conditions of heavy cloud cover and cooler weather (Marschalek 2004; Marschalek and Deutschman 2008).

Hermes copper males typically exhibit short movements with the majority of their displacements well under 50 meters (Marschalek 2004; Marschalek and Klein 2010). This behavior is the result of territoriality in males who generally return to an area after being spooked. In addition, the majority of individuals encountered are males. Hermes copper females display remarkably different behavior, exhibiting no territoriality. After being spooked, females do not return to the area. For all individuals, movements rarely exceeded 100 meters, and the longest movement documented for a Hermes copper is just over 1 kilometer (Marschalek and Klein 2010).

Previous Results

In 2010-2012 we made a total of nearly 400 visits to approximately 40 sites (Deutschman et al. 2010, 2011). Surveys confirm that the species' range is limited to a very small area. In addition, we counted very few individuals at most of the occupied sites. We showed that the relative size of individual populations was very similar across all three years (high degree of concordance). As a result, if the objective is to track annual changes, it is not cost effective to monitor all populations every year. Wildfires continue to greatly influence the distribution of Hermes copper, as Wildwood Glen Lane and Boulder Creek Road are the only documented recolonizations following the large wildfires of 2003 and 2007.

A landscape genetic study (Strahm et al. 2012) complemented the previous marking studies (Marschalek and Deutschman 2008, Marschalek and Klein 2010) by evaluating the dispersal ability of Hermes copper across the landscape of San Diego County. In addition, development and confirmation of a non-lethal genetic sampling protocol allowed for widespread sampling without harming local populations (Strahm et al. 2012, Marschalek et al. 2013). Our analyses indicated very little genetic differentiation among individuals. However, some peripheral populations (Boulder Creek Road, Meadowbrook Ecological Reserve, and Mission Trails Regional Park) exhibited greater increased genetic differentiation when compared to the core area of the Hermes copper distribution. These patterns likely reflect historical processes rather than contemporary influences (e.g., habitat fragmentation) as genetic differences reaching detectable levels would probably require more time to accumulate. Hermes copper was likely able to move across the landscape (as lack of strong differentiation demonstrates), but dispersal may be more limited now (supported by few post-wildfire recolonizations and slight genetic differentiation of certain peripheral populations).

Recent work has also provided new information regarding Hermes copper immature stages. This is particularly important because working with the immature stages has been very difficult in the past. Prior to the 2012 flight season, six eggs were found during searches of 297 spiny redberry shrubs. Five of the six were on the east side of the shrub. It appears that a larva emerged from two of the six prior to 16 April (circular hole in center of egg), one may have experienced predation/parasitoidism (irregular hole on side of egg), and we were unable to detect any changes from the remaining two eggs prior to the 2012 flight season. This provides an initial assessment of oviposition site preference and provides information important for additional research involving the poorly understood immature stages of Hermes copper.

Adult Surveys

We continued to monitor four Hermes copper populations designated as sentinel sites to develop a long-term data set. Unfunded surveys conducted during 2013 are reported with results from the 2014-2015 surveys as part of this funded project. These surveys provide the ability to measure annual variation in adult densities which can later be analyzed with environmental factors to determine parameters important in determining adult densities.

In 2013, we also conducted surveys at historic Hermes copper populations which were extirpated by the 2003 and/or 2007 wildfires. Wildfires have been identified as a major threat to the species (Marschalek and Klein 2010, USFWS 2011) and recolonization is critical to the existence of Hermes copper. Detecting recolonization events can provide information about dispersal ability across the current San Diego County landscape. Being the 10th flight season since the 2003 wildfires, we felt it was appropriate to redirect efforts back to these locations as this information is critical for conservation management and planning of Hermes copper.

Methods

We monitored four sentinel sites during the 2013-2015 flight seasons with the goal of recording the maximum number of Hermes copper adults present on a single day at each site (***maximum count***). Because our previous work showed that Hermes copper populations are concordant in terms of relative abundance from year to year, we focused sampling at four locations we have designated as sentinel sites: Boulder Creek Road, Lawson Peak, Roberts Ranch North, and Sycuan Peak Ecological Reserve. In addition, the 2013 surveys included historic populations to determine if recolonization had occurred. These surveys occurred along transects established and sampled in previous years (2003-2012).

We monitored daily adult numbers (predominately males) at sentinel sites to obtain an indication of relative population size at discrete spiny redberry patches. Survey intensity was low during the start of the flight season (1-2 times per week), more frequent when adults were most abundant (2-3 times per week), and stopped surveying as soon as adult numbers declined. This strategy provided an efficient and cost-effective way to obtain annual maximum counts for each site.

In 2013 and 2014, initial surveys started on 15 May at Sycuan Peak Ecological Reserve and occurred about one time per week. This site was chosen because past survey efforts have shown this area to regularly produce the first adults of the season. Once Hermes copper adults were found, we started surveys at the other three sentinel sites. Sampling occurred at shorter intervals (weather dependent) as counts increased. Once counts started to decline markedly, we stopped surveys at that site.

In 2015, initial surveys at Sycuan Peak Ecological Reserve and Skyline Truck Trail started on 17 April due to warm weather and advanced phenology of other butterfly and plant species earlier in the year. We followed the 2013-2014 sampling protocol in 2015.

In 2013, we also conducted surveys at locations where Hermes copper was extirpated by recent wildfires of 2003 and/or 2007 in attempts to detect recolonization events. Adult survey protocol followed the methods outlined in Marschalek (2004) and Marschalek and Deutschman (2008). Surveys were conducted during periods of appropriate weather (sunny or partly sunny, 22 to 35 degrees C, and modest wind speeds).

Additional surveys occurred at the Skyline Truck Trail site in 2014 and 2015 to search for gravid females to be used in a translocation project. The primary objective was to capture females and as a result, these counts are not identical to our standardized Pollard transect sampling. For this reason, counts from the Skyline Truck Trail site should only be used to make qualitative, rather than quantitative, comparisons.

Results

Sentinel Sites

In 2013, the first Hermes copper adults were observed on 15 May, with six individuals at Sycuan Peak Ecological Reserve and one at Skyline Truck Trail. Typically the flight season starts with just a couple adults. Despite the relatively high count on this date, we feel that the first adults were present no earlier than 13 May. This is based on the wear pattern of adults (bright orange) and that 13-14 May were extremely hot (near 100°F/38°C). This represented the second earliest known emergence (12 May 2004, Marschalek and Deutschman 2008). Adults (eight) were also seen at Lawson Peak on 16 May, but Hermes copper did not start flying at Roberts Ranch North until sometime between 25-27 May. Of these sites, Hermes copper adults have appeared earliest at Sycuan Peak Ecological Reserve during this project (2010-2013). Roberts Ranch North has consistently had the latest start to the adult flight season during these same years, with adults emerging about one to two weeks later than those at Sycuan Peak Ecological Reserve.

In 2013, the local Hermes copper population sizes were higher than what was observed in recent years (Table 1). At times, a relatively large number of adults would be seen in close proximity to each other. On consecutive days, we observed 5-6 adults within a 30 centimeter diameter on an inflorescence of a single California buckwheat plant. This was the first time since 2003 that we have witnessed more than three adults in such close proximity to each other. Although Roberts Ranch North did not exceed the 2011 count, this may be a result of making only two visits to the site when adults were flying and missing the peak activity in 2013. We sampled the other three sites at an adequate frequency to provide a high level of confidence that sampling occurred during maximum adult activity.

Table 1. Maximum counts of Hermes copper adults at four sentinel sites and an additional site that received frequent visits, 2010-2015. Sampling at sentinel sites consisted of repeated transects to obtain an accurate maximum count. Sampling at the Skyline Truck Trail site was focused on locating females and did not follow a strict protocol for determining the number of Hermes copper present.

Sentinel Sites	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Sycuan Peak	12	27	14	41	11	1
Lawson Peak	2	15	5	17	5	4
Roberts Ranch North	4	9	6	8	4	5
Boulder Creek	---	---	18	29	17	6
Other Visited Site	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Skyline Truck Trail 1	9	---	7	6	7	1
Skyline Truck Trail 2	---	---	12	27	9	2

" --- " indicates no survey

In 2014, the first Hermes copper adults were observed at Sycuan Peak Ecological Reserve (three) and Lawson Peak (four) on 29 May. Emergence occurred at Boulder Creek Road a couple days later and at Roberts Ranch North a couple days after that. Hermes copper counts at all four sentinel sites were lower than those in 2013 (Table 1). Counts quickly dropped after reaching a peak, resulting in a flight season of about two weeks at each site and about three to four weeks overall.

In 2015, the first Hermes copper adults (two) were observed on 1 May at the Skyline Truck Trail site (four weeks earlier than 2014!). One of the two individuals was faded orange in color which is typical of an individual at least 3-4 days post-pupal emergence. Additional adults were observed at Lawson Peak and Boulder Creek Road on 2 May, and adults emerged about one month later at Roberts Ranch North. The counts of Hermes copper adults were lower than those of 2014. The flight season at Sycuan Peak Ecological Reserve may have been incredibly short as only one single male was observed. In the previous five years, no fewer than 11 adults had been documented at Sycuan Peak Ecological Reserve (Table 1). Adults were also only observed on a single day at the two Skyline Truck Trail subsite locations, but on different days (two on 1 May at Skyline Truck Trail 2, one on 10 May at Skyline Truck Trail 1). In contrast, adults were known to be present at Boulder Creek for at least 45 days.

While Hermes copper adults were observed at all four sentinel sites in 2015, counts were substantially lower than in previous years (Table 1), likely due to the continued drought. The shrubs at Boulder Creek, Lawson Peak, and Roberts Ranch North were relatively green in late May/early June; however, the shrubs at Sycuan Peak Ecological Reserve were generally brown in color (due to brown leaves, lack of leaves or both). Nearly all of the spiny redberry shrubs at Sycuan Peak Ecological Reserve had few leaves and no new growth in 2015 (Figure 2). The poor condition of the vegetation likely reflects local precipitation patterns. Vegetation and climatic conditions also influence Hermes copper adult densities and phenology.

Figure 2. Spiny redberry shrub at Sycuan Peak Ecological Reserve with no new growth in 2015 and few leaves.

Climate Analysis

While drought conditions generally result in fewer adult butterflies regardless of species, we were unable to find a correlation between maximum counts of Hermes copper and precipitation (Table 2). This may be a result of a small dataset, as just one observation has the potential to greatly influence the trend or lack of a trend. This may be the case in terms of early spring (February and March) precipitation where there is an outlier that has substantial impact on the overall analysis (Figure 3). Additional years are needed to expand this dataset which will decrease sensitivity to unusual events and increase the statistical power to detect relationships. The correlation among maximum counts of the four sentinel sites further supports the necessity to survey only a few sites each year to know if there are below average, average, or above average adults present in a particular year. We also see an expected correlation of wet and cool years and warm and dry years.

Table 2. Correlation of Hermes copper annual maximum counts, monthly precipitation, and monthly average temperatures. Weather data are from the Western Regional Climate Center (http://www.raws.dri.edu/index.html) for the Alpine weather station.

		Hermes Copper				Precipitation				Temperature		
		Boulder Creek	Lawson Peak	Roberts Ranch	Sycuan Peak	Oct-Apr (in)	Feb-Apr (in)	Mar-Apr (in)	Feb-Mar (in)	Oct-Apr (°C)	Jan-Apr (°C)	Feb-Apr (°C)
Hermes Copper	Boulder Creek											
	Lawson Peak	0.857										
	Roberts Ranch	0.737	0.92									
	Sycuan Peak	0.957	0.91	0.782								
Precip.	Oct-Apr (in)	0.084	0.113	0.362	0.136							
	Feb-Apr (in)	0.07	-0.119	0.145	0.01	0.887						
	Mar-Apr (in)	0.01	-0.361	-0.122	-0.206	0.361	0.733					
	Feb-Mar (in)	0.258	0.242	0.485	0.242	0.916	0.915	0.53				
Temp.	Oct-Apr (°C)	-0.918	-0.542	-0.606	-0.713	-0.749	-0.648	-0.224	-0.748			
	Jan-Apr (°C)	0.91	-0.568	-0.624	-0.732	-0.714	-0.547	-0.095	-0.651	0.98		
	Feb-Apr (°C)	-0.9	-0.354	-0.384	-0.617	-0.693	-0.678	-0.327	-0.682	0.963	0.927	

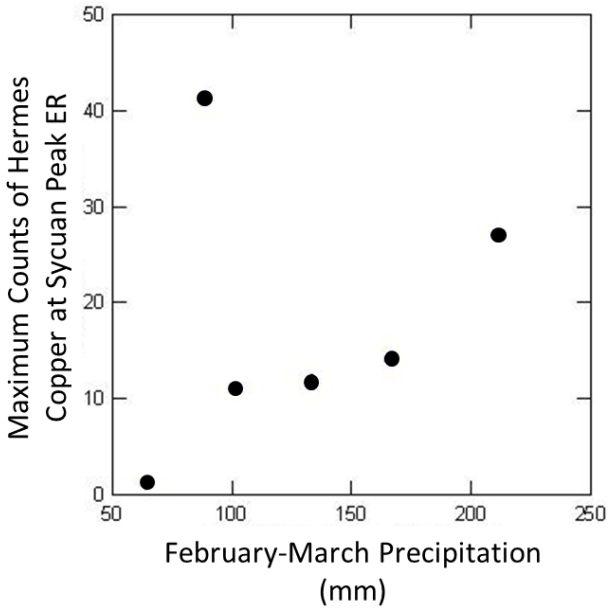

Figure 3. The annual maximum counts of Hermes copper adults at Sycuan Peak Ecological Reserve in relation to the amount of precipitation in February and March. Weather data are from the Western Regional Climate Center (http://www.raws.dri.edu/index.html) for the Alpine weather station.

January through April 2015 was warmer and drier than average and this resulted in a shift in phenology of flowering for many plants (e.g. San Diego Thorn Mint, *Acanthomintha ilicifolia*, and Otay Tarplant, *Deinandra conjugens*) and adult life-stages for other insects (e.g. Callippe Fritillary, *Speyeria callippe*, and the blister beetle *Lytta nitidicollis*). For this reason, we started monitoring for adult Hermes copper earlier than usual. The month of May was cool with several rainstorms which resulted in most days being unsuitable for surveys.

Butterfly development, like other insects, is often heavily influenced by the ambient temperature. We have 13 years of data on the start of the Hermes copper flight season (Marschalek 2004, Marschalek and Klein 2010, Deutschman et al. 2010 and 2011, Strahm et al. 2012). The data support the idea that earlier emergence is associated with warmer weather and vice versa. The highest correlation was between the average February-April temperature and date of emergence (r = -0.39), rather than the average temperature for January-April (r = -0.32) or January-May (r = -0.19). The February to April time period is the same time as the larval stage.

Two years stood out in these data, as 2003 was an exceptionally cool spring (compared to the other years in the dataset) and 2015 was an exceptionally warm spring (again, compared to the other years in the dataset). These two years also followed a year of extreme drought and few Hermes copper adults were observed. It appears that Hermes copper diapaused to avoid emerging during these unfavorable years. These organisms would have essentially two years for development and may respond differently. If these years are removed, a stronger correlation between February-April temperature (Pearson = -0.510) exists (Figure 4).

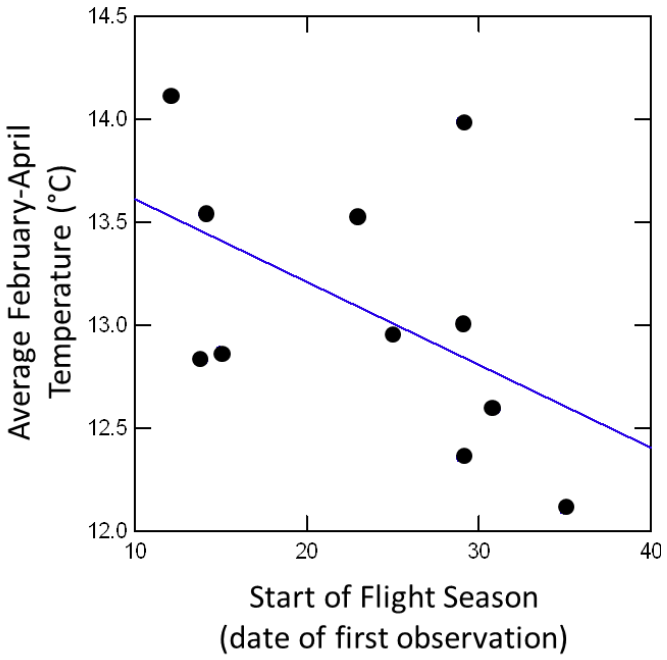

Figure 4. Correlation of first Hermes copper adult emergence with annual temperature.

Post-wildfire Sites

We allocated a relatively large portion of our effort during the 2013 flight season to survey for recolonization events at historic Hermes copper populations. In addition to repeating transects established prior to the 2003 and/or 2007 wildfires, adjacent spiny redberry patches were searched for more complete coverage. No Hermes copper adults were observed in areas impacted by the 2003 and/or 2007 wildfires, and surprisingly we were not able to detect adults at Wildwood Glen Lane which had apparently been recolonized following a 2003 fire (Figure 1, Table 3).

Table 3. Hermes copper survey data from sites that experienced wildfires in 2003 and/or 2007.

Sites	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Crestridge ER	49	---	0 (1)	---	0 (1)	0	0	0	0	0	0
Anderson Road	73	---	---	---	0	0	0	0	0	0	0
Wildwood Glen Lane	13	---	---	---	1	1 (3)	0 (2)	1	2	0 (3)	0
Hollenbeck Canyon WA	---	---	90	13+	45	0	---	0	0	---	0
Rancho Jamul ER (2003)	42	---	---	---	0	0	0	0	0	---	0
Rancho Jamul ER (2004)	---	10	20	5	4	0	0	0	0	---	0
Sycamore Canyon Co Park	7	---	---	---	---	0	---	---	---	---	0
San Diego National Wildlife Refuge*	---	present	present	present	present	---	---	0	---	---	0

Notes:
"---" indicates no survey
(#) Numbers in parentheses include those observed, but not on the historical transect.
* data from John Martin (USFWS)
Survey efforts were similar from 2003-2012 at each site if sampled (see note below)
but efforts (transect length) increased at some sites in 2013.
At Hollenbeck Canyon WA, survey efforts were similar in 2005 and 2007, but not in 2006.

Other Notes

In 2013, we documented a natural enemy of Hermes copper, the ambush bug *Phymata pacifica* (Figure 5). This immature individual was on a California buckwheat inflorescence, with a similar color pattern to the flowers and was feeding on a Hermes copper adult.

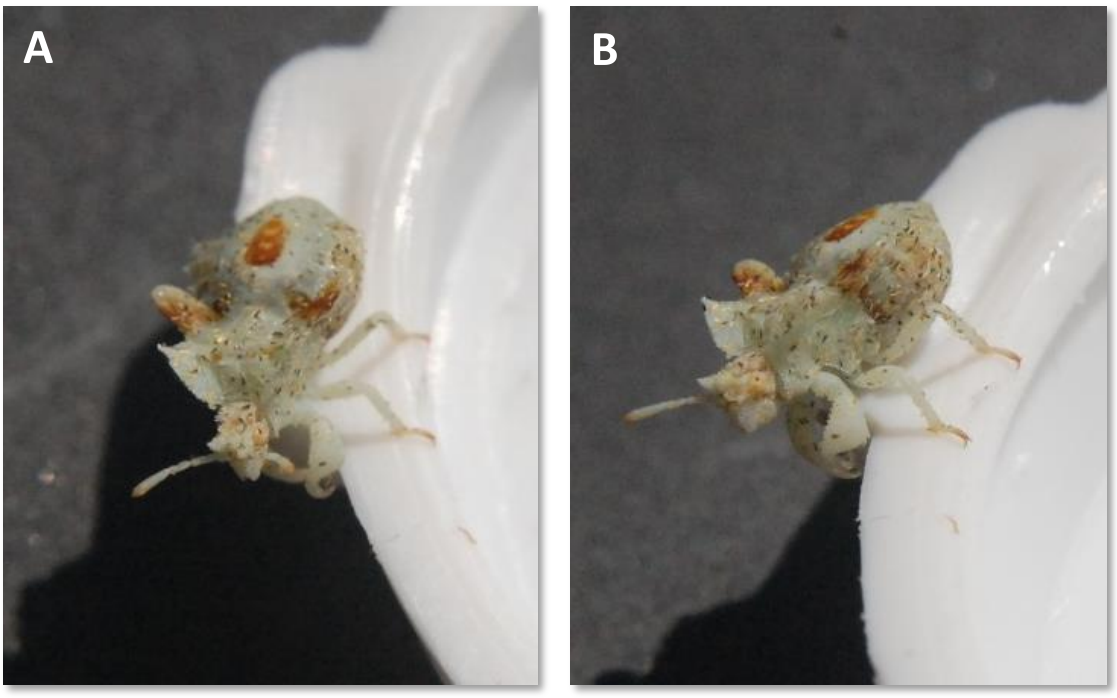

Figure 5. The ambush bug, *Phymata pacifica* observed feeding on an adult Hermes copper. A) dorsal view, B) lateral view.

In 2014, there were few flowering plants due to drought conditions. Specifically at the Boulder Creek Road site, few buckwheat plants flowered but those plants that flowered had several nectaring hedgerow hairstreaks. No Hermes copper adults were observed on these flowers, but at least one was observed repeatedly nectaring on common snakeweed (*Gutierrezia sarothrae*).

Discussion

The 1 May observations in 2015 were 11 days earlier than the previous record on 12 May (Marschalek and Deutschman 2008). Fortunately, we were in the field on other conservation monitoring projects and we anticipated an early start to the flight season. Routine tracking the flowering phenology of multiple plant species in the county and making this data available in real time may be beneficial for a number of researchers and managers. This is particularly relevant in light of climate change so that monitoring and management activities are conducted at the appropriate time.

Reduced adult population sizes are commonly observed with insects during drought years. This was clearly the case with Hermes copper. Similarly small populations and short flight seasons were observed with Hermes copper in 2002 (Klein pers. com.). This includes five Hermes copper adults observed at Anderson Road, with all five individuals observed on the same survey date and no adults observed on three other dates. Also, one Hermes copper adult was observed at Crestridge Ecological Reserve, and it was seen on only one of five survey dates. In 2003, repeated transects were sampled at both locations and yielded maximum counts of 73 and 49 for Anderson Road and Crestridge Ecological Reserve, respectively (Marschalek 2004, Marschalek and Deutschman 2008). While sampling efforts may have varied, this suggests that Hermes copper is able to diapause for at least one year until favorable conditions return. Monitoring the expected rebound in numbers following the next good rainfall year is important to confirm that the population will recover. It is likely that prolonged periods of severe drought increase the probability that local populations will go extinct.

There is little published information available concerning recolonization following fires. Thorne (1963) indicated that Hermes copper are found in areas that frequently burn but did not provide specifics about frequency, size, or pattern of these fires. Faulkner and Klein (2004) reported that Mission Gorge recolonized by 2000 following a 1982 fire.

Eggs and Larvae

We continued several field and laboratory projects aimed at improving our understanding of the eggs and larvae of this species, as well as evaluating key threats and potential management tools. Searches prior to the 2013 flight season yielded 10 eggs while searching 149 spiny redberry shrubs (eggs found on 6.7% of searched spiny redberry shrubs). The 2013 efforts provided increased sample sizes to help us determine important characteristics of egg placement. It also provided increased opportunity for larval detection. We also obtained 36 eggs on spiny redberry clippings from females in captivity for laboratory rearing.

Field Observations

Methods

We searched for and recorded the position of Hermes copper eggs to help understand oviposition sites as well as larval biology and habitat requirements. Located eggs were revisited closer to the flight season, noting their condition, in an attempt to locate and observe larvae. In addition this qualitative data will be important in developing a captive rearing program and in refining the conceptual model.

Hermes copper butterflies deposit small, white, semi-spherical eggs on spiny redberry. Eggs are approximately one millimeter in diameter. The sphere of the egg is finely reticulated, with the texture smoothing toward the center where a central pore or dot is located. Captive females generally oviposit on the underside of branches, at the intersection of branches, under leaf nodes or other sheltering structures on the host plant (Marschalek and Deutschman 2009).

Egg searches began in January and continued into April, occurring at Sycuan Peak Ecological Reserve because it is a densely populated site. Redberry shrubs were also searched at a property along Skyline Truck Trail in 2014 and 2015. In early 2013, the field crew was instructed to search entire spiny redberry shrubs, paying special attention to the underside of branches, leaf nodes and branch intersections. Due to the large number of divisions of branches on spiny redberry, each shrub takes some time to search (15 to 20 minutes on average). Field days were limited to four to six hour increments due to the tedious nature of these searches. During this time, each person can completely survey 10 to 20 shrubs. Each searched spiny redberry was recorded with a GPS unit to avoid resampling. Based on results of 2012 and 2013, searches in 2014 and 2015 focused on the underside of the lower branches in an effort to be more efficient.

We regularly monitored previously located eggs without emergence holes to track development of the immature Hermes copper stages. Surveys started earlier in the season compared to past years because larvae had emerged prior to mid-April in 2012.

Results

We found ten eggs at Sycuan Peak Ecological Reserve between the 2012 and 2013 flight season after searching 149 redberry shrubs. Five had an emergence hole at the time of discovery, four did not, and one had a hole not consistent with normal larval emergence (possible predation/parasitism) (Table 4). It is unclear if larvae recently emerged from the five eggs containing an emergence hole, or if the eggs remain on the spiny redberry for over a year. Of the four eggs without evidence of eclosion, a larva emerged from three of the eggs by 16 April. Based on the typical emergence hole, it appears that larvae emerged from these eggs between 27 February - 6 March, 4-11 March, and 11-18 March, respectively. We were able to locate larvae near two of these eggs and successfully relocated these larvae a few weeks following eclosion. However, later larval stages and pupa were not found.

The two larvae located in the field both initially fed on very small leaves at the tip of a branch, scraping the surface rather than consuming the entire leaf or a section of that leaf (Figure 6). These leaves were very new, still slightly folded, and bright green in color. Specific details are found in Table 5.

Table 4. Results of egg searches and subsequent larval monitoring at Sycuan Peak Ecological Reserve in 2013. Red represents the presences of a larva.

Egg #	30-Jan-13	1-Feb-13	11-Feb-13	13-Feb-13	14-Feb-13	18-Feb-13	27-Feb-13	4-Mar-13	6-Mar-13	11-Mar-13	18-Mar-13	21-Mar-13	25-Mar-13	16-Apr-13	1-May-13
1	H	H					H			H			H		
2			NH		NH	NH	NH	NH		H			H		
3			H				H	H		H			H		
4			H				H	H		H			H		
5				NH		NH	NH		H	H	H	H	Unk		
6					H		H		H	H			H		
7							P			P	P		P		
8									NH	NH	NH	NH	NH		
9										NH	H	H	H	H	Unk
10											H		H		

NH: Not Hatched H: Hatched P: Predation/Parasitism Unk: Unknown Location

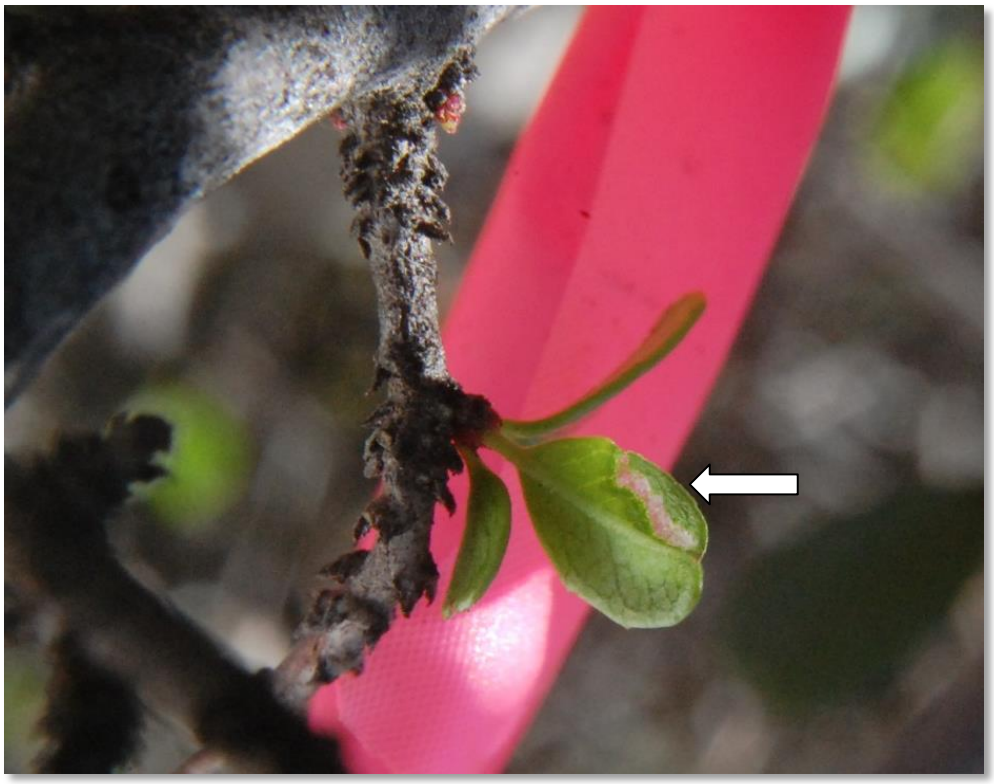

Figure 6. Signs of foraging on a spiny redberry leaf near a Hermes copper egg. This foraging damage is consistent with what was observed with Hermes copper larvae in captivity.

Table 5. Observations of two Hermes copper larvae in the field.

Date	Notes for Larva from Egg #5		Date	Notes for Larva from Egg #9
6 March	Larva on very tip of branch, 14cm from egg on same branch. About 1.5mm in length with hairs.		18 March	Larva located 4cm from egg, at tip of fresh leaves. About two times longer than the egg is wide (1.5-2.0mm) and bright yellow in color.
11 March	No obvious size change compared to previous observation (about 1.5mm in length). Yellowish with hairs. About 10cm from egg.		21 March	Trail of foraging damage observed from original branch to another branch. Yellowish in color and about 1.5 to 2.0mm in length.
14 March	Larva is greener in color compared to previous observation. It is on a bright green leaf about 2mm long which is about 16mm from the egg. Larva is about 2mm in length and appears longer than previous observation.		25 March	Larva still has hairs, apple green in color, about 2.5mm in length.
18 March	Unable to locate larva.		16 April	Larva 5mm in length.
21 March	Fell off of branch, found and returned to branch.		1 May	Unable to locate larva but evidence of leaf damage similar to that seen with laboratory rearing.
25 March	Unable to locate larva.			

Two (and likely all three) of the eggs exhibited signs of larval emergence occurring before a previously published date for eclosion of 16 March (Thorne 1963). For a second consecutive year, larvae did not emerge from all of the eggs and it is unknown if they remain viable. This appears to be the first time Hermes copper larvae have been observed in the field without beating them out of a spiny redberry shrub.

In 2014, a total of 132 spiny redberry shrubs were searched and eight eggs were found (Table 6). This includes four eggs on 109 shrubs at Sycuan Peak Ecological Reserve and four eggs on 23 shrubs at a property along Skyline Truck Trail. Eggs #3 and #5 are believed to be from the previous year because of the early date which they were found and already possessed an emergence hole. This suggests that the eggs remained on the branches for an entire year after larvae emerged. Egg #2 became brown in color and was assumed to be non-viable.

In 2015, 76 shrubs were searched and two eggs were found (Table 7). This includes no eggs on 46 shrubs at Sycuan Peak Ecological Reserve and two eggs on 30 shrubs at the Skyline Truck Trail site. These two eggs were found on the same spiny redberry shrub, something not observed in previous years. This was one of only a few shrubs which had new growth of branches and leaves (Figure 7). One of the two eggs was no longer on the branch as of the 20 February survey. It is believed to have been knocked off as a wildlife trail was immediately adjacent to the shrub and branch with the egg.

Table 6. Results of egg searches and subsequent larval monitoring in 2014.

Egg #	7-Jan-14	15-Jan-14	23-Jan-14	29-Jan-14	5-Feb-14	17-Feb-14	25-Feb-14	4-Mar-14	13-Mar-14	19-Mar-14	28-Mar-14	8-Apr-14	22-Apr-14
1	NH	NH	NH	NH	NH	NH	NH	NH	NH	NH	NH	**H**	**H**
2	NH	NH	NH	NH	NH		NH						
3		**H**	**H**	**H**	**H**	**H**	**H**						
4			NH	NH	NH	NH	NH	NH	NH	**H**	**H**	**H**	**H**
5				**H**									
6				NH	NH	NH	**H**	**H**	**H**	**H**	**H**	**H**	**H**
7				NH	NH	NH	NH	NH	NH	NH	NH	NH	NH*
8						NH	NH	NH	NH	**H**	**H**	**H**	**H**

NH: Not Hatched H: Hatched *continued in 2015

Table 7. Results of egg searches and subsequent larval monitoring in 2015.

Egg #	20-Jan-15	26-Jan-15	4-Feb-15	11-Feb-15	20-Feb-15	12-Mar-15
1	NH	NH	NH	NH	**H**	**H**
2	NH	NH	NH	NH	Unk	Unk
2014-7	NH	NH	NH	NH	**H**	**H**

NH: Not Hatched H: Hatched
Unk: Unknown Location

An egg discovered in January 2014 that did not eclose was also monitored in 2015. In mid-February 2015 an exit hole consistent with Hermes copper larvae was observed, providing evidence that the species is able to diapause in the egg stage for at least two winters.

We also revisited a couple of the 2014 eggs that that had larva emerge that spring and found that they were still attached to the spiny redberry branches (Figure 8). This supports our conclusions that 2014 Eggs #3 and #5 were from a previous year rather than larvae emerging very early in the season.

Figure 7. New growth on a spiny redberry shrub, represented by small leaves that are light green in color and shiny, as well as reddish bark on the branches.

Figure 8. Egg that had a larva emerge in spring 2014 at Sycuan Peak Ecological Reserve. The egg remained on the branch at least one year after larval emergence. Photo taken on 15 January 2015.

Dates of larval eclosion were staggered in 2014 and similar to what we have observed in previous years. The first larva emerged as early as 17 February and the last as late as 8 April. In 2015, the two larvae emerged earlier than those in 2014, both sometime between 11-20 February.

When considering all of the eggs collected in both 2014 and 2015, there does not appear to be a preference regarding side of the spiny redberry shrub (Table 8). The size of the specific shrub also varied a good deal. However, there did appear to be more consistency in egg location in terms of height above the ground (30-58 cm).

Table 8. Hermes copper egg location descriptions.

2014	Site	Egg location (Side of RB)	Egg above ground (cm)	Egg to branch tip (cm)	RB width (cm)	RB height (cm)
Egg 1	Sycuan Peak	W	58	13.5	169	95
Egg 2	Sycuan Peak	N	33	12	171	136
Egg 3	Sycuan Peak	N	30	13	170	86
Egg 4	Sycuan Peak	S	40	3	190	86
Egg 5*	Skyline Truck Trail	E			271	206
Egg 6	Skyline Truck Trail	SW	42	13	102	66
Egg 7	Skyline Truck Trail	W	41	31	323	257
Egg 8	Skyline Truck Trail	W	34	12	164	139

* An empty egg was located but it fell off of the branch before measurements

2015	Site	Egg location (Side of RB)	Egg above ground (cm)	Egg to branch tip (cm)	RB width (cm)	RB height (cm)
Egg 1	Skyline Truck Trail	S	37	3	154	123
Egg 2	Skyline Truck Trail	S	58	16	154	123

We were unable to locate larvae, although signs of foraging were present and consistent with what was observed during laboratory rearing experiments (Figure 6).

In January-March 2014, spiny redberry shrubs had at least some new growth (small branches with reddish-brown bark and new leaves) despite the dry winter. Late growth was observed immediately following a rainstorm which occurred during the last couple days of February 2014. However, there was little to no new growth on spiny redberry shrubs at Sycuan Peak Ecological Reserve in 2015. Some shrubs at the Skyline Truck Trail property had more new growth than others, including the shrub on which both eggs were found. A full list of locations of searched spiny redberry shrubs can be found in Appendix 4.

Discussion

Our efforts to study the egg and larval stages of Hermes copper in 2013-2015 yielded some important results despite the low samples sizes. We confirmed that larvae can diapause in the egg stage and larvae can eclose after two years. We also confirmed that eggs can remain on the branch for a year or more after eclosion. Dates of larval emergence were generally earlier than Thorne (1963) observed. In addition, we continue to refine our understanding of oviposition. Eggs are found on a diverse array of spiny redberry plants ranging in height from about 2 to 6 feet tall. Eggs are found in a fairly narrow range between 1 and 2 feet above ground. Finally, we documented that feeding damage on spiny redberry plants in the field match what was observed in the laboratory rearing experiments.

Laboratory Rearing

Rearing of Hermes copper from egg to adult in the laboratory will provide insight into the specific habitat requirements for the immature stages. It may also serve as valuable information if a captive breeding program is determined necessary to avoid extinction.

Methods

Hermes copper eggs obtained from three captive females during the 2012 flight season were used for this captive rearing experiment in the spring of 2013. Spiny redberry clippings containing eggs were allowed to dry under normal room conditions until being placed in 4°C. Roughly half of the eggs for each female were subjected to the cold treatment on 1 November and the other half on 29 November. Roughly half of each group of eggs was removed on 6 February and half on 27 February for four treatments. Following eclosion from the egg, we transferred larvae to fresh spiny redberry clippings or placed the old clipping (with egg and larva) on a fresh spiny redberry clipping. Eggs and larvae were then closely monitored daily and provided fresh spiny redberry clippings when determined necessary. All eggs and larvae were subjected to conditions of the room, although water dishes and lids were used to maintain a higher humidity for the eggs. Larvae and eggs were moved using a damp camel-hair paint brush, or the entire clipping was moved.

Due to the rarity of Hermes copper, we did not attempt to capture and obtain eggs from all females observed in the field. For this reason, sample sizes for each treatment are limited.

Rearing efforts in the spring of 2014 utilized approximately 25 eggs from females captured in 2013. Spiny redberry clippings with eggs were cut to keep only the short sections with the eggs and kept in petri dishes (Figure 9). All eggs were subjected to room temperature in the laboratory until 1 November when they were place in a refrigerator at 4°C. Thirteen eggs were removed from the refrigerator on 17 February and placed into petri dished and then into a Brinsea Octagon 20 Advance (bird) egg incubator (Figure 10) with the relative humidity setting at 60%. This incubator is designed for bird eggs but has some ability to control the temperature and humidity at a relatively low cost.

Figure 9. Petri dish with spiny redberry clippings containing Hermes copper eggs (arrows pointing at each egg).

Figure 10. Brinsea Octagon 20 Advance egg incubator and humidity pump.

The remaining 12 eggs were removed from the refrigerator on 5 March and placed into the incubator with the original 13 eggs and the relatively humidity setting was increased to 70%. On 13 March, the relative humidity was increased to 80%, the highest setting on the incubator.

The incubator's temperature range is 20.0-40.0°C and the relative humidity range is 20-80%; however the incubator cannot maintain a temperature or humidity below ambient conditions. The temperature of the laboratory varied due to heating and cooling of the day and air conditioning use. The relative humidity of the laboratory was typically around 45% but on rainy days the laboratory (and incubator) relative humidity would increase to about 70%.

Nine eggs were obtained from females captured in 2014 for rearing efforts in the spring of 2015 and kept at room conditions. On 30 October, the eggs were placed in the refrigerator at 4°C. Three eggs were selected in an attempt to replicate conditions in 2013 in hopes of obtaining larvae, including the timing of the 4°C cool treatment. These eggs were placed in an aquarium at room temperature with an open container of water and cover in an attempt subject the eggs to at least 90% relative humidity. The short spiny redberry clippings with eggs were positioned on a fresh redberry clipping so that if a larva emerges, it immediately has access to fresh food (Figure 11).

Figure 11. Hermes copper egg on a spiny redberry twig, place on a fresh spiny redberry clipping.

Construction of the San Diego Zoo's rearing facility continued into the spring of 2015, with 3 March being the first day available for use (Figure 12). The remaining six eggs were removed from the 4°C cool treatment on this date and placed into a rearing chamber (Geneva Scientific, LLC Model GI-36VL) on fresh spiny redberry clippings. The specifications for the rearing chamber limited the relative humidity level so a humidifier was placed in the rearing chamber 5-13 March to maintain a relative humidity greater than 80%. On 14 March the built-in humidifier was used as a water supply was hooked up, but the settings had to be limited to 80% relative humidity. The temperature was kept at 26-27°C in the rearing chamber for the entire time.

Figure 12. Rearing facility at the San Diego Zoo.

Results

In 2013, ten eggs showed signs that larvae were attempting to exit the eggs (Table 9). During eclosion, the larva could be seen moving back and forth when closely inspecting the egg. It appeared that layers were slowly removed from the inside out, first creating a hole in the center and holes where the egg surface projected inward, then eventually a larger hole (Figure 13A). Of the 36 eggs, larvae (Figure 13B) emerged from six eggs and four other larvae created a small hole in the center of the egg but did not emerge.

Table 9. Outcome of 36 Hermes copper eggs during laboratory rearing in the spring of 2013.

Female ID	Start Date (4°C)	End Date (4°C)	Outcome
1	1 November	6 February	0/4 eggs hatched.
		27 February	1/1 egg hatched, died (see details below).
2	1 November	6 February	3/4 eggs hatched, all died.
		27 February	No eggs for this treatment from this female.
3	1 November	6 February	1/4 eggs hatched, died.
		27 February	3/4 eggs had partial hatches (larva ate hole in egg) but larvae did not leave egg. All three larvae eventually died.
Unknown*	1 November	6 February	One egg hatched and larva died. Other egg partially hatched (larva ate hole in egg) but larva did not leave egg and eventually died.
1	29 November	6 February	0/3 eggs hatched.
		27 February	0/2 eggs hatched.
2	29 November	6 February	One egg developed mold and was discarded. Other egg did not hatch.
		27 February	0/2 eggs hatched.
3	29 November	6 February	0/4 eggs hatched, two of the eggs developed some mold.
		27 February	0/3 eggs hatched.

* Two eggs were found in the cage not attached to spiny redberry clippings. They were found after removal of all females and clippings so the exact female could not be positively identified.

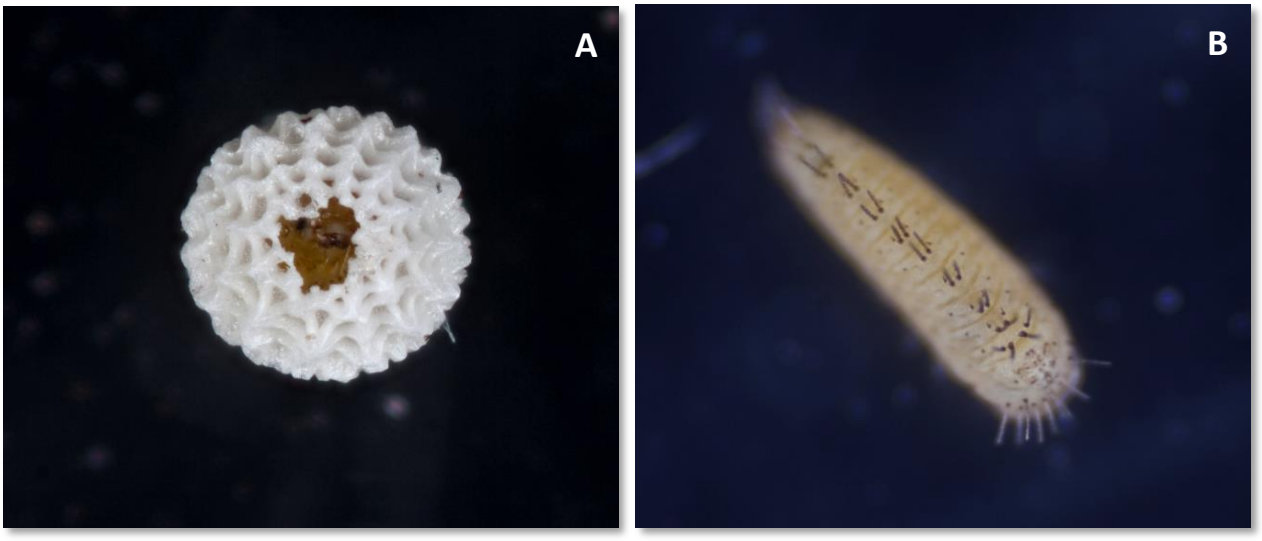

Figure 13. Hermes copper eclosion. A) larva during the process of eclosion, B) a first instar larva just a few hours after leaving the egg.

All larvae were about 1mm in length at the time they left the egg (Figure 13B), being about as long as the egg is wide. The last larva to emerge was the only individual to develop beyond the first instar (Table 8). Based on information from field observations, we provided spiny redberry clippings that contained extremely small leaves (less than 3mm in length). It appears that initial foraging occurs on these leaves and that leaf tissue is eaten from one surface rather than a section or entire leaf (Figure 14, also see Figure 6). Later foraging behavior included eating portions of a leaf as well as the spiny redberry flowers (Figure 15B). We also minimized handling with this individual by allowing it to travel to new clippings by itself rather than physically moving it. This individual traveled frequently, seemingly found on opposite sides of a clipping each day (roughly a 5cm distance). This also includes one time it nearly escaped as it was found on the outside of the cage's lid on 9 April (a minimum total distance traveled of 30cm away from the spiny redberry clipping). The larva remained alive for 49 days, reached a length of 8mm, and eventually developed into a fourth instar before apparently ceasing to feed and dying. A chronology of important events is listed in Table 9. Larvae have been reported as large as 13mm in length (Comstock and Dammers 1935) and 15mm in length with a 1.31mm head width (Ballmer and Pratt 1988).

The remaining 26 eggs did not have any detectible larval activity; however we did observe mold growing directly on three of these eggs. All eggs with larval emergence or partial emergence were subjected to 4°C on 1 November and no eggs subjected to 4°C on 29 November had detectable larval activity. This could be a result of the temperature cycle but the increased humidity and mold may have impacted the 29 November group.

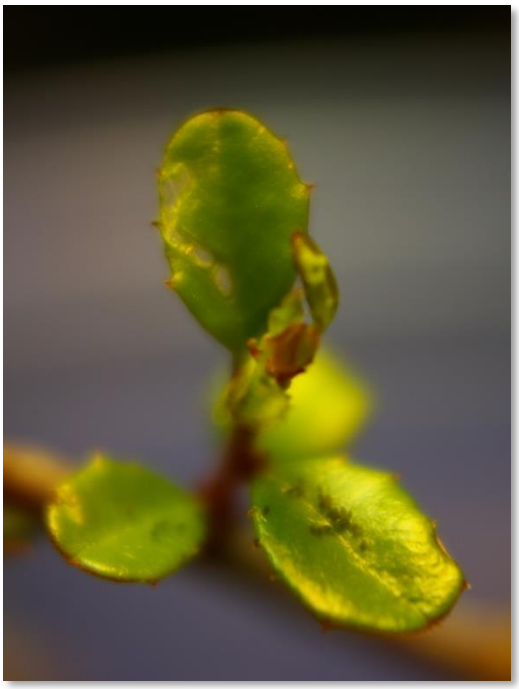

Figure 14. Foraging damage from a first instar Hermes copper larva. The upper spiny redberry leaf has a skeletonized path where the larva chewed tissue off of one side of the leaf, and a lower leaf contains frass on its upper surface.

Figure 15. Hermes copper larva. A) 4th instar larva, B) 2nd instar larva feeding on a spiny redberry flower, C) 2nd instar larva feeding on a spiny redberry leaf.

Table 10. Important dates in the development of the captive Hermes copper larva which developed past the first instar.

Date	Observations
18 March	Hatched, about 1mm in length
25 March	About 2mm in length
26 March	About 3mm in length
28 March	Molting
31 March	About 4mm in length
5-6 April	Molting
8 April	About 5mm in length
12 April	About 6mm in length
19 April	Lots of frass under larva
21 April	Less frass under larva than seen on 19 April (perhaps indicating lower foraging rate), about 7mm in length
22 April	Molting
23 April	Still less frass than seen on 19 April
1 May	About 8mm in length
6 May	Dead

In 2014, no larvae emerged from the first set of eggs (13 eggs) that were exposed to 60% relative humidity from 17 February - 5 March, 70% humidity from 5-13 March, and 80% humidity from 13 March - 8 April. No larvae emerged from the second set of eggs (12 eggs) that were exposed to 70% relative humidity from 5-13 March and 80% humidity from 13 March - 8 April. All eggs were returned to room conditions on 8 April. (Note, we have observed multi-year diapause of Hermes copper eggs in the field).

On 25 April, five of the eggs were opened. Two eggs had what appeared to be a living larva that occupied the entire internal space of the egg. Three other eggs had dead and desiccated larvae. Mold was generally not a problem at these humidity levels, but some mold did eventually develop on four of the spiny redberry twigs by 25 April (e.g. Figure 16).

Figure 16. Hermes copper egg with mold starting to grow at the base of the leaf.

In 2015, from 9-20 February while trying to maintain relative humidity greater than 90% in an aquarium, mold started to develop on the spiny redberry twigs. No larvae emerged from these three eggs.

The use of a humidifier in the rearing chamber at the San Diego Zoo was able to achieve relative humidity levels between 82-92% and the built-in humidifier produced humidity levels around 78-82%. No larvae emerged from these six eggs by 14 April so the eggs were removed from the rearing chamber. Mold started growing on 11 March near two eggs and one egg was discarded on 13 March due to mold covering the egg.

Discussion

Hermes copper larvae are extremely difficult to rear in captivity. This was noted as early as the 1930s (Comstock and Dammers 1935, Thorne 1963) and continues to be problematic today. To our knowledge, no one has successfully reared a Hermes copper from egg to adult. This is a critical barrier to several management approaches that are available for other butterfly species, which can be cultured under controlled conditions for study or for reintroduction projects.

We had hoped that a systematic approach would lead to identifying acceptable conditions for breaking winter egg diapause and larval development in Hermes copper. Using several levels of relative humidity greater than ambient conditions did not result in obtaining larvae. Efforts to replicate the conditions that successfully broke winter diapause in 2013 were also unsuccessful, illustrating the importance for

equipment that can regulate and measure temperature and humidity. Although the results of these efforts were disappointing, collaborating with the San Diego Zoo and using their new (now running) facility gives some measure of hope that we can develop a reliable method for rearing Hermes copper. Overwintering humidity is a particular factor that warrants attention in future rearing efforts.

Previous literature pertaining to Hermes copper larval stages include Comstock and Dammer (1935) description of a larva "raised to maturity", Thorne (1963) observation of a larva emerging from an egg and beating "mature" larvae from a spiny redberry shrub, and Balmer and Pratt (1988) describing the last larval instar biology and morphology with a photo. Although apparently short-lived (based on the single captive larva reaching the second instar), it does not appear that the first larval instar has been described. Despite observation of a first instar larva, Thorne (1963) does not mention any distinction from the later instars Comstock and Dammers (1935) describe.

During the last three years we have regularly observed eggs found in the cage and not on the spiny redberry clippings. Others (e.g. Johnson et al. 2010) have reported the same behavior in several butterfly and skipper species in captivity. Based on these additional observations of oviposition and egg attachment strength, it is likely that we (Marschalek 2004) were not correct that some eggs fell off of the spiny redberry clippings during inspection of the spiny redberry clippings. Rather the female deposited eggs loosely in the cage.

Conclusions

This project continues to advance our knowledge of Hermes copper which provides important information for the management and long-term conservation of the species. We are starting to have a better understanding of how climate impacts annual population sizes, microhabitat requirements, and how to rear Hermes copper in captivity. However, additional work is required.

Reduced winter/spring precipitation appears to result smaller adult population sizes and warmer winter/spring temperatures result in earlier starts to the adult flight season. However, there may be more complicated interactions between these two climatic variables in relation to population size and phenology. Monitoring of sentinel populations has demonstrated to be critical to all work involving Hermes copper adults as it is necessary to carefully track the flight season. This ensures surveys are conducted at the appropriate time as well as providing context to survey counts (e.g. "good" or "bad" year).

Historically, working with immature stages of Hermes copper has been problematic. We have made significant gains in regards to learning more about these stages as well as captive rearing. Unfortunately most of our work has occurred during years of below average rainfall or drought condition. This has substantially limited sample sizes, both in the lab and field. We've had to proceed slowly as to not jeopardize local populations.

Monitoring of sentinel sites should continue to contribute to a long-term data set which will provide the ability measure annual variation in adult densities. This can later be analyzed with environmental factors to determine parameters important in determining adult densities. Required efforts are minimal. It is

only necessary to obtain an annual maximum adult count. Because climatic conditions greatly impact butterfly densities, these data provide an important context to future management and monitoring efforts, as well as influences of climate change

Even ten years after some fires and what appears to be recovery of suitable habitat, Hermes has not recolonized most of its historic localities. Consideration should be given to exploring translocations as a management tool to re-establish populations. As it stands today, Hermes copper is one large fire away from being so rare that translocation efforts would be very difficult or impossible.

Because most Hermes copper adults are found in a small portion of their historic range, surveys should be conducted in the northern portion of their range. It appears that the northern local populations are small, but are important because a fire is unlikely to impact this area as well as the core region. Surveys are needed to better describe the distribution on Hermes copper and spiny redberry in this area to guide restoration efforts with the goal of increasing population sizes of those peripheral sites.

Now that we have some success breaking winter diapause of eggs, additional efforts are warranted to further describe larval biology and develop a rearing protocol. Proper humidity and temperature are two factors that are likely very influential in the success of rearing attempts and overwintering humidity in particular should be addressed.

Acknowledgements

We would like to thank many people for assistance with this project (2013-2015 and previous years), including sharing their knowledge of the Hermes copper, permits, and access to reserves. These include, but are not limited to (alphabetically): Bureau of Land Management (Joyce Schlachter), California Department of Fish & Wildlife (Richard Burg, Esther Burkett, Tracie Nelson, Jason Price, Warren Wong), City of San Diego (Nicole McGinnis, Betsy Miller, Kim Roeland, Matt Sanford), Cleveland National Forest (Megan Jennings, Kirsten Winter), County of San Diego (Maureen Abare-Laudy, Jennifer Miller, Jennifer Price, Nick Sloan, Ron Strahm), Earth Discovery Institute (Cathy Chadwick), Endangered Habitats League (Michael Beck), David Faulkner, Michael Klein, Laura Packer, Sweetwater Authority (Pete Famolaro, Katherine Vittum), and United States Fish and Wildlife Service (John Martin, Jill Terp).

We would also like to thank Beth Jamie, Julia Jesu, Kalee Koeslag, Heather Llanas, Benito Lo, Hannah Sadowski, Andrew Smith, and Spring Strahm for their hard work in the field, helping us collect this data.

Literature Cited

Ballmer GR and GF Pratt. 1988. A survey of the last instar larvae of the Lycaenidae Lepidoptera of California USA. Journal of Research on the Lepidoptera 27:1-81.

Brown J. 1991. Sensitive and declining butterfly species (Insecta: Lepidoptera) in San Diego County, California. Draft report prepared for Dudek and Associates. 27 pages.

Comstock JA and CM Dammers. 1935. Notes on the early stages of three butterflies and six moths from California. Bulletin of the Southern California Academy of Science 34:124-126.

Deutschman DH, ME Berres, DA Marschalek and SL Strahm. 2010. Initial evaluation of the status of Hermes copper (*Lycaena hermes*) on conserved lands in San Diego County. Final Report for San Diego Association of Governments Contract: MOU # 5001442. 41 pages.

Deutschman DH, ME Berres, DA Marschalek and SL Strahm. 2011. Two-year evaluation of Hermes copper (*Lycaena hermes*) on conserved lands in San Diego County. Final Report for San Diego Association of Governments Contract: MOU # 5001442. 53 pages.

Emmel TC and JF Emmel. 1973. The butterflies of southern California. Natural History Museum of Los Angeles County, Science Series. 26:1-148.

Faulkner D and M Klein. 2004. San Diego's sensitive butterflies: a workshop focusing on 10 local species, San Diego, CA.

Johnson J, T Longcore, A Clause, A Lansing, D Renner, A Romero, B Messerschmidt, B Pickett, P Kores, K Courtney. 2010. Captive rearing of Laguna Mountain skipper (*Pyrgus ruralis lagunae*). Cooperative Agreement No. 814307J024. The Urban Wildlands Group, Inc.

Marschalek DA. 2004. Factors influencing population viability of Hermes copper (*Lycaena hermes*). Master's Thesis. San Diego State University. 58 pages.

Marschalek DA and DH Deutschman. 2008. Hermes copper (*Lycaena* [*Hermelycaena*] *hermes*: Lycaenidae): life history and population estimation of a rare butterfly. Journal of Insect Conservation 12(2): 97-105.

Marschalek DA and DH Deutschman. 2009. Larvae and Oviposition of Hermes Copper (Lepidoptera: Lycaenidae). Journal of Entomological Science 44(4): 400-401.

Marschalek, D.A., J.A. Jesu and M.E. Berres. 2013. Impact of non-lethal genetic sampling on the survival, longevity and behavior of the Hermes copper (*Lycaena hermes*) butterfly. Insect Conservation and Diversity. 6:658-662. (online 20 February 2013)

Marschalek DA and MW Klein. 2010. Distribution, ecology, and conservation of Hermes copper (Lycaenidae: *Lycaena* [*Hermelycaena*] *hermes*). Journal of Insect Conservation 14:721-730.

Strahm S.L., D.A. Marschalek, D.H. Deutschman and M.E. Berres. 2012. Monitoring the status of Hermes copper (*Lycaena hermes*) on conserved lands in San Diego County. Final Report for San Diego Association of Governments Contract: MOU # 5001442. 61 pages.

Thorne F. 1963. The distribution of an endemic butterfly *Lycaena hermes*. Journal of Research on the Lepidoptera 2:143-150.

United States Fish and Wildlife Service. 2011. Endangered and threatened wildlife and plants; 12-Month finding on a petition to list Hermes copper butterfly as endangered or threatened. Federal Register 50 CFR(17): 20918-20939. http://federalregister.gov/a/2011-9028.

Appendix 1: 2013 Adult Hermes Copper Observations.

Date	Site	Latitude	Longitude
15-May-2013	Sycuan Peak	32.74860766	-116.8007052
15-May-2013	Sycuan Peak	32.74891108	-116.8001152
15-May-2013	Sycuan Peak	32.75038068	-116.800399
15-May-2013	Sycuan Peak	32.7518108	-116.8010838
15-May-2013	Sycuan Peak	32.75405413	-116.8054242
15-May-2013	Skyline Truck Trail	32.73168518	-116.8053177
15-May-2013	Skyline Truck Trail	32.73200906	-116.8070498
16-May-2013	Lawson Peak	32.71352688	-116.7057979
16-May-2013	Lawson Peak	32.7145866	-116.705642
16-May-2013	Lawson Peak	32.7159899	-116.7072835
16-May-2013	Lawson Peak	32.71560014	-116.7088121
16-May-2013	Lawson Peak	32.7146068	-116.7101067
16-May-2013	Lawson Peak	32.71468107	-116.7103306
16-May-2013	Lawson Peak	32.71647412	-116.7118507
16-May-2013	Lawson Peak	32.7171383	-116.7123845
20-May-2013	Lawson Peak	32.71383877	-116.7056859
20-May-2013	Lawson Peak	32.71391002	-116.7056234
20-May-2013	Lawson Peak	32.71447261	-116.7056421
20-May-2013	Lawson Peak	32.71497728	-116.7060782
20-May-2013	Lawson Peak	32.71519136	-116.7061683
20-May-2013	Lawson Peak	32.71562076	-116.707091
20-May-2013	Lawson Peak	32.71617103	-116.7074867
20-May-2013	Lawson Peak	32.71463999	-116.7098146
20-May-2013	Lawson Peak	32.71475324	-116.7102855
20-May-2013	Lawson Peak	32.71541926	-116.7104801
20-May-2013	Lawson Peak	32.7164608	-116.7118087
20-May-2013	Lawson Peak	32.71663464	-116.7120188
20-May-2013	Lawson Peak	32.71727988	-116.7125139
20-May-2013	Lawson Peak	32.7173927	-116.7124847
20-May-2013	Sycuan Peak	32.74705432	-116.7998708
20-May-2013	Sycuan Peak	32.74782437	-116.7998769
20-May-2013	Sycuan Peak	32.74842703	-116.8000416
20-May-2013	Sycuan Peak	32.7486007	-116.8006702
20-May-2013	Sycuan Peak	32.74862861	-116.8006798
20-May-2013	Sycuan Peak	32.74875518	-116.8001815
20-May-2013	Sycuan Peak	32.74886607	-116.8000917
20-May-2013	Sycuan Peak	32.74886624	-116.8000908
20-May-2013	Sycuan Peak	32.74886641	-116.8000904
20-May-2013	Sycuan Peak	32.74886641	-116.8000905

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
20-May-2013	Sycuan Peak	32.74909758	-116.8001415
20-May-2013	Sycuan Peak	32.7493109	-116.8002493
20-May-2013	Sycuan Peak	32.74930897	-116.8002624
20-May-2013	Sycuan Peak	32.74960016	-116.8003545
20-May-2013	Sycuan Peak	32.74959815	-116.8003551
20-May-2013	Sycuan Peak	32.75041857	-116.8003596
20-May-2013	Sycuan Peak	32.75152649	-116.8000427
20-May-2013	Sycuan Peak	32.75217768	-116.8018603
20-May-2013	Sycuan Peak	32.74993854	-116.8003074
20-May-2013	Sycuan Peak	32.74993854	-116.8003076
20-May-2013	Skyline Truck Trail	32.73205373	-116.8072165
22-May-2013	Boulder Creek	32.926174	-116.631151
22-May-2013	Boulder Creek	32.926972	-116.631512
22-May-2013	Boulder Creek	32.927073	-116.631615
22-May-2013	Boulder Creek	32.927824	-116.631364
22-May-2013	Boulder Creek	32.928851	-116.631074
22-May-2013	Boulder Creek	32.929549	-116.634432
22-May-2013	Boulder Creek	32.925472	-116.633046
22-May-2013	Sycuan Peak	32.74692566	-116.7994956
22-May-2013	Sycuan Peak	32.74709011	-116.7998548
22-May-2013	Sycuan Peak	32.74822477	-116.800002
22-May-2013	Sycuan Peak	32.74839744	-116.800028
22-May-2013	Sycuan Peak	32.74854328	-116.8003736
22-May-2013	Sycuan Peak	32.74863322	-116.8006799
22-May-2013	Sycuan Peak	32.74864403	-116.8007229
22-May-2013	Sycuan Peak	32.74875602	-116.8003181
22-May-2013	Sycuan Peak	32.74889675	-116.8001012
22-May-2013	Sycuan Peak	32.7490151	-116.800101
22-May-2013	Sycuan Peak	32.7491389	-116.8001595
22-May-2013	Sycuan Peak	32.74913312	-116.8001626
22-May-2013	Sycuan Peak	32.74932029	-116.8002643
22-May-2013	Sycuan Peak	32.74954476	-116.8003774
22-May-2013	Sycuan Peak	32.74959287	-116.8003234
22-May-2013	Sycuan Peak	32.74961567	-116.8003568
22-May-2013	Sycuan Peak	32.74965297	-116.800374
22-May-2013	Sycuan Peak	32.74977601	-116.8004897
22-May-2013	Sycuan Peak	32.74987827	-116.800493
22-May-2013	Sycuan Peak	32.75010768	-116.8004603
22-May-2013	Sycuan Peak	32.75016175	-116.8004495

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
22-May-2013	Sycuan Peak	32.75037951	-116.800408
22-May-2013	Sycuan Peak	32.75147595	-116.7991976
22-May-2013	Sycuan Peak	32.75154149	-116.799991
22-May-2013	Sycuan Peak	32.75149405	-116.8004251
22-May-2013	Sycuan Peak	32.75228865	-116.8019641
22-May-2013	Sycuan Peak	32.75266366	-116.8020088
22-May-2013	Sycuan Peak	32.75285318	-116.8023056
22-May-2013	Sycuan Peak	32.75300992	-116.8038539
22-May-2013	Sycuan Peak	32.75330748	-116.8045193
22-May-2013	Sycuan Peak	32.75326313	-116.8045987
22-May-2013	Sycuan Peak	32.75325065	-116.8047776
22-May-2013	Sycuan Peak	32.75325601	-116.8048396
22-May-2013	Sycuan Peak	32.75325383	-116.8048397
22-May-2013	Sycuan Peak	32.75335031	-116.8050533
22-May-2013	Sycuan Peak	32.7537109	-116.8052242
22-May-2013	Sycuan Peak	32.75402245	-116.8054313
22-May-2013	Sycuan Peak	32.75429511	-116.8056775
22-May-2013	Sycuan Peak	32.75433426	-116.8058715
22-May-2013	Sycuan Peak	32.75442378	-116.805956
22-May-2013	Sycuan Peak	32.75201373	-116.8015014
22-May-2013	Skyline Truck Trail	32.72517513	-116.7927387
22-May-2013	Skyline Truck Trail	32.72550856	-116.7930579
22-May-2013	Skyline Truck Trail	32.72571073	-116.7933428
22-May-2013	Skyline Truck Trail	32.73085035	-116.7970932
22-May-2013	Skyline Truck Trail	32.73085252	-116.7970921
22-May-2013	Lawson Peak	32.713527	-116.705751
22-May-2013	Lawson Peak	32.713875	-116.705607
22-May-2013	Lawson Peak	32.714238	-116.705507
22-May-2013	Lawson Peak	32.714914	-116.706057
22-May-2013	Lawson Peak	32.715255	-116.706178
22-May-2013	Lawson Peak	32.714538	-116.709922
22-May-2013	Lawson Peak	32.714664	-116.71031
22-May-2013	Lawson Peak	32.714663	-116.710306
22-May-2013	Lawson Peak	32.715322	-116.710497
22-May-2013	Lawson Peak	32.716219	-116.710943
22-May-2013	Lawson Peak	32.71637	-116.711791
22-May-2013	Lawson Peak	32.716575	-116.712012
22-May-2013	Lawson Peak	32.716557	-116.71193
22-May-2013	Lawson Peak	32.717361	-116.71251

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
22-May-2013	Lawson Peak	32.714744	-116.710241
24-May-2013	Lawson Peak	32.71368873	-116.7057575
24-May-2013	Lawson Peak	32.71431394	-116.7055048
24-May-2013	Lawson Peak	32.7151922	-116.7061615
24-May-2013	Lawson Peak	32.71548254	-116.7063298
24-May-2013	Lawson Peak	32.71583953	-116.7071427
24-May-2013	Lawson Peak	32.71463748	-116.7091887
24-May-2013	Lawson Peak	32.71467059	-116.7097523
24-May-2013	Lawson Peak	32.71459046	-116.710027
24-May-2013	Lawson Peak	32.71477637	-116.7102824
24-May-2013	Lawson Peak	32.7147752	-116.7102245
24-May-2013	Lawson Peak	32.71478567	-116.7102289
24-May-2013	Lawson Peak	32.71470957	-116.7102974
24-May-2013	Lawson Peak	32.71623071	-116.7108481
24-May-2013	Lawson Peak	32.7164328	-116.7117905
24-May-2013	Lawson Peak	32.7166001	-116.7119097
24-May-2013	Lawson Peak	32.71685701	-116.7121627
24-May-2013	Lawson Peak	32.71740485	-116.7125065
24-May-2013	Boulder Creek	32.92616445	-116.6311413
24-May-2013	Boulder Creek	32.92914069	-116.6309683
24-May-2013	Boulder Creek	32.92734252	-116.6314796
24-May-2013	Boulder Creek	32.92965048	-116.634379
24-May-2013	Boulder Creek	32.92971837	-116.6342946
24-May-2013	Boulder Creek	32.92982021	-116.6341893
24-May-2013	Sycuan Peak	32.74708224	-116.7998629
24-May-2013	Sycuan Peak	32.74824841	-116.7999876
24-May-2013	Sycuan Peak	32.7482863	-116.7999879
24-May-2013	Sycuan Peak	32.74841974	-116.8000313
24-May-2013	Sycuan Peak	32.74845133	-116.8000536
24-May-2013	Sycuan Peak	32.7486002	-116.8006642
24-May-2013	Sycuan Peak	32.74867119	-116.8007088
24-May-2013	Sycuan Peak	32.7487758	-116.8002996
24-May-2013	Sycuan Peak	32.74879944	-116.8002517
24-May-2013	Sycuan Peak	32.74893908	-116.8000928
24-May-2013	Sycuan Peak	32.74915307	-116.8001848
24-May-2013	Sycuan Peak	32.74917771	-116.8001921
24-May-2013	Sycuan Peak	32.74929464	-116.8002363
24-May-2013	Sycuan Peak	32.74933445	-116.8002639
24-May-2013	Sycuan Peak	32.74932884	-116.8002944

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
24-May-2013	Sycuan Peak	32.74933646	-116.8003002
24-May-2013	Sycuan Peak	32.74956739	-116.8003835
24-May-2013	Sycuan Peak	32.74961298	-116.8003491
24-May-2013	Sycuan Peak	32.74966369	-116.800405
24-May-2013	Sycuan Peak	32.74968691	-116.8003828
24-May-2013	Sycuan Peak	32.74974098	-116.8004746
24-May-2013	Sycuan Peak	32.74979143	-116.8005142
24-May-2013	Sycuan Peak	32.74990191	-116.8005003
24-May-2013	Sycuan Peak	32.74985002	-116.8004861
24-May-2013	Sycuan Peak	32.7501081	-116.8004767
24-May-2013	Sycuan Peak	32.75041387	-116.8004147
24-May-2013	Sycuan Peak	32.75150553	-116.8004217
24-May-2013	Sycuan Peak	32.75221095	-116.8019392
24-May-2013	Sycuan Peak	32.7522843	-116.8019654
24-May-2013	Sycuan Peak	32.75247431	-116.8019921
24-May-2013	Sycuan Peak	32.75290204	-116.8021876
24-May-2013	Sycuan Peak	32.75290104	-116.8021912
24-May-2013	Sycuan Peak	32.7530131	-116.8038642
24-May-2013	Sycuan Peak	32.75325811	-116.8047751
24-May-2013	Sycuan Peak	32.75370453	-116.8051958
24-May-2013	Sycuan Peak	32.75443568	-116.8059885
24-May-2013	Sycuan Peak	32.7540284	-116.8054086
24-May-2013	Sycuan Peak	32.75001615	-116.8003934
24-May-2013	Sycuan Peak	32.74714694	-116.7999956
24-May-2013	Sycuan Peak	32.74690974	-116.799506
27-May-2013	Lawson Peak	32.71342839	-116.7058788
27-May-2013	Lawson Peak	32.71353526	-116.7057912
27-May-2013	Lawson Peak	32.714296	-116.7055012
27-May-2013	Lawson Peak	32.71460421	-116.7098563
27-May-2013	Lawson Peak	32.7147622	-116.7102834
27-May-2013	Lawson Peak	32.71520787	-116.7103669
27-May-2013	Lawson Peak	32.71521122	-116.7103611
27-May-2013	Lawson Peak	32.71539923	-116.7104427
27-May-2013	Lawson Peak	32.71539914	-116.7104429
27-May-2013	Lawson Peak	32.71619459	-116.7107436
27-May-2013	Lawson Peak	32.71645392	-116.7117766
27-May-2013	Lawson Peak	32.71745087	-116.7125005
27-May-2013	Sycuan Peak	32.74688769	-116.7995418
27-May-2013	Sycuan Peak	32.74704041	-116.7998731

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
27-May-2013	Sycuan Peak	32.74721961	-116.8000256
27-May-2013	Sycuan Peak	32.74820558	-116.7999889
27-May-2013	Sycuan Peak	32.74839216	-116.8000675
27-May-2013	Sycuan Peak	32.74842938	-116.8000574
27-May-2013	Sycuan Peak	32.74855385	-116.800687
27-May-2013	Sycuan Peak	32.74871185	-116.8003392
27-May-2013	Sycuan Peak	32.74875266	-116.8002729
27-May-2013	Sycuan Peak	32.74886758	-116.8001216
27-May-2013	Sycuan Peak	32.74886775	-116.8001221
27-May-2013	Sycuan Peak	32.74929472	-116.8002702
27-May-2013	Sycuan Peak	32.74928651	-116.8002874
27-May-2013	Sycuan Peak	32.74952598	-116.8003576
27-May-2013	Sycuan Peak	32.74962639	-116.8003632
27-May-2013	Sycuan Peak	32.74977543	-116.8004912
27-May-2013	Sycuan Peak	32.74989319	-116.800471
27-May-2013	Sycuan Peak	32.75030558	-116.8004709
27-May-2013	Sycuan Peak	32.75025982	-116.8004594
27-May-2013	Sycuan Peak	32.75036777	-116.8003807
27-May-2013	Sycuan Peak	32.75217273	-116.8018677
27-May-2013	Sycuan Peak	32.7522195	-116.8019088
27-May-2013	Sycuan Peak	32.75302249	-116.8038527
27-May-2013	Sycuan Peak	32.75335601	-116.805046
27-May-2013	Sycuan Peak	32.75404592	-116.8054294
27-May-2013	Sycuan Peak	32.75432831	-116.8056366
27-May-2013	Sycuan Peak	32.75434499	-116.8058681
27-May-2013	Sycuan Peak	32.75440902	-116.8059339
29-May-2013	Boulder Creek	32.926707	-116.631434
29-May-2013	Boulder Creek	32.92689	-116.631502
29-May-2013	Boulder Creek	32.926877	-116.631508
29-May-2013	Boulder Creek	32.927018	-116.631579
29-May-2013	Boulder Creek	32.927115	-116.631587
29-May-2013	Boulder Creek	32.927124	-116.631611
29-May-2013	Boulder Creek	32.927149	-116.631642
29-May-2013	Boulder Creek	32.927241	-116.631527
29-May-2013	Boulder Creek	32.927322	-116.631493
29-May-2013	Boulder Creek	32.927553	-116.631355
29-May-2013	Boulder Creek	32.927673	-116.631349
29-May-2013	Boulder Creek	32.927693	-116.631332
29-May-2013	Boulder Creek	32.927815	-116.631375

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
29-May-2013	Boulder Creek	32.927862	-116.631331
29-May-2013	Boulder Creek	32.927765	-116.631334
29-May-2013	Boulder Creek	32.92799	-116.631402
29-May-2013	Boulder Creek	32.928135	-116.631284
29-May-2013	Boulder Creek	32.928496	-116.631082
29-May-2013	Boulder Creek	32.929005	-116.631
29-May-2013	Boulder Creek	32.929231	-116.631119
29-May-2013	Boulder Creek	32.930255	-116.631227
29-May-2013	Boulder Creek	32.925805	-116.632351
29-May-2013	Boulder Creek	32.929147	-116.634734
29-May-2013	Boulder Creek	32.929473	-116.634716
29-May-2013	Boulder Creek	32.929527	-116.634473
29-May-2013	Boulder Creek	32.929571	-116.634428
29-May-2013	Boulder Creek	32.929801	-116.634255
29-May-2013	Boulder Creek	32.929789	-116.634251
29-May-2013	Boulder Creek	32.929845	-116.634188
29-May-2013	Boulder Creek	32.929991	-116.634037
29-May-2013	Boulder Creek	32.929981	-116.634035
29-May-2013	Boulder Creek	32.9288	-116.634816
29-May-2013	Boulder Creek	32.928382	-116.634854
29-May-2013	Boulder Creek	32.928118	-116.634907
29-May-2013	Boulder Creek	32.926305	-116.631338
29-May-2013	Boulder Creek	32.926294	-116.631308
29-May-2013	Boulder Creek	32.926216	-116.631172
29-May-2013	Boulder Creek	32.926212	-116.631169
31-May-2013	Roberts Ranch North	32.82711407	-116.6155675
31-May-2013	Roberts Ranch North	32.82763182	-116.6149929
31-May-2013	Roberts Ranch North	32.82749486	-116.6147975
31-May-2013	Roberts Ranch North	32.82747592	-116.6148081
31-May-2013	Roberts Ranch North	32.82747198	-116.6148116
31-May-2013	Roberts Ranch North	32.82788504	-116.6143766
31-May-2013	Roberts Ranch North	32.82790935	-116.6142584
31-May-2013	Roberts Ranch North	32.8279246	-116.6142511
31-May-2013	Skyline Truck Trail	32.73172835	-116.7963253
31-May-2013	Skyline Truck Trail	32.73142451	-116.7965478
31-May-2013	Skyline Truck Trail	32.73144244	-116.7964889
31-May-2013	Skyline Truck Trail	32.73109627	-116.7966254
31-May-2013	Skyline Truck Trail	32.7310495	-116.7966236
31-May-2013	Skyline Truck Trail	32.73091606	-116.7970802

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
31-May-2013	Skyline Truck Trail	32.73091841	-116.7970825
31-May-2013	Skyline Truck Trail	32.73094665	-116.7970711
31-May-2013	Skyline Truck Trail	32.73096149	-116.7970846
31-May-2013	Skyline Truck Trail	32.73096107	-116.797081
31-May-2013	Skyline Truck Trail	32.72924655	-116.7969432
31-May-2013	Skyline Truck Trail	32.72925795	-116.7968933
31-May-2013	Skyline Truck Trail	32.73078723	-116.7971589
31-May-2013	Skyline Truck Trail	32.73070307	-116.7974613
31-May-2013	Skyline Truck Trail	32.7307615	-116.7974822
31-May-2013	Skyline Truck Trail	32.73070945	-116.7977427
31-May-2013	Skyline Truck Trail	32.73068002	-116.7976112
3-Jun-2013	Boulder Creek	32.926185	-116.631188
3-Jun-2013	Boulder Creek	32.926309	-116.631323
3-Jun-2013	Boulder Creek	32.926262	-116.631644
3-Jun-2013	Boulder Creek	32.926173	-116.631918
3-Jun-2013	Boulder Creek	32.92596	-116.632156
3-Jun-2013	Boulder Creek	32.927832	-116.634985
3-Jun-2013	Boulder Creek	32.927846	-116.634848
3-Jun-2013	Boulder Creek	32.927953	-116.634927
3-Jun-2013	Boulder Creek	32.927953	-116.634927
3-Jun-2013	Boulder Creek	32.927953	-116.634927
3-Jun-2013	Boulder Creek	32.928095	-116.634918
3-Jun-2013	Boulder Creek	32.928095	-116.634918
3-Jun-2013	Boulder Creek	32.928229	-116.634854
3-Jun-2013	Boulder Creek	32.928233	-116.63486
3-Jun-2013	Boulder Creek	32.928392	-116.634826
3-Jun-2013	Boulder Creek	32.928393	-116.634827
3-Jun-2013	Boulder Creek	32.928402	-116.634817
3-Jun-2013	Boulder Creek	32.928808	-116.634815
3-Jun-2013	Boulder Creek	32.929418	-116.634756
3-Jun-2013	Boulder Creek	32.929543	-116.634461
3-Jun-2013	Boulder Creek	32.929593	-116.634384
3-Jun-2013	Boulder Creek	32.929886	-116.634203
3-Jun-2013	Boulder Creek	32.929906	-116.634104
3-Jun-2013	Boulder Creek	32.929931	-116.634076
3-Jun-2013	Boulder Creek	32.929932	-116.634066
3-Jun-2013	Boulder Creek	32.929977	-116.634012
3-Jun-2013	Boulder Creek	32.926402	-116.631257
3-Jun-2013	Boulder Creek	32.926672	-116.63143

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
3-Jun-2013	Boulder Creek	32.926898	-116.631489
3-Jun-2013	Boulder Creek	32.927032	-116.631595
3-Jun-2013	Boulder Creek	32.927186	-116.631555
3-Jun-2013	Boulder Creek	32.927237	-116.631521
3-Jun-2013	Boulder Creek	32.927343	-116.631457
3-Jun-2013	Boulder Creek	32.92737	-116.631439
3-Jun-2013	Boulder Creek	32.927606	-116.631341
3-Jun-2013	Boulder Creek	32.92778	-116.631288
3-Jun-2013	Boulder Creek	32.927837	-116.631314
3-Jun-2013	Boulder Creek	32.927952	-116.631292
3-Jun-2013	Boulder Creek	32.928107	-116.631291
3-Jun-2013	Boulder Creek	32.928214	-116.63138
3-Jun-2013	Boulder Creek	32.928284	-116.631232
3-Jun-2013	Boulder Creek	32.929224	-116.630992
3-Jun-2013	Roberts Ranch North	32.827892	-116.614254
3-Jun-2013	Roberts Ranch North	32.827864	-116.61431
6-Jun-2013	Skyline Truck Trail	32.73214191	-116.8076999
6-Jun-2013	Skyline Truck Trail	32.73200327	-116.8059807
6-Jun-2013	Skyline Truck Trail	32.7321171	-116.8061306
6-Jun-2013	Skyline Truck Trail	32.7318001	-116.8059065
6-Jun-2013	Skyline Truck Trail	32.73117372	-116.8052849
6-Jun-2013	Skyline Truck Trail	32.73207771	-116.8065348
6-Jun-2013	Skyline Truck Trail	32.73169977	-116.7963333
6-Jun-2013	Skyline Truck Trail	32.73137732	-116.7965947
6-Jun-2013	Skyline Truck Trail	32.73126542	-116.7966561
6-Jun-2013	Skyline Truck Trail	32.73109074	-116.7966418
6-Jun-2013	Skyline Truck Trail	32.73111354	-116.796564
6-Jun-2013	Skyline Truck Trail	32.73107129	-116.7966367
6-Jun-2013	Skyline Truck Trail	32.73088178	-116.796801
6-Jun-2013	Skyline Truck Trail	32.73085202	-116.796795
6-Jun-2013	Skyline Truck Trail	32.73088563	-116.7970587
6-Jun-2013	Skyline Truck Trail	32.73084263	-116.7971003
6-Jun-2013	Skyline Truck Trail	32.73076368	-116.7971665
6-Jun-2013	Skyline Truck Trail	32.73064398	-116.7973795
6-Jun-2013	Skyline Truck Trail	32.73065538	-116.7974901
6-Jun-2013	Skyline Truck Trail	32.73067583	-116.7977648
6-Jun-2013	Skyline Truck Trail	32.7306765	-116.7977656
6-Jun-2013	Skyline Truck Trail	32.73048414	-116.7974214
6-Jun-2013	Skyline Truck Trail	32.73084138	-116.7970831

Appendix 1: 2013 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
6-Jun-2013	Skyline Truck Trail	32.7303652	-116.7968504
6-Jun-2013	Skyline Truck Trail	32.73003529	-116.796682
6-Jun-2013	Skyline Truck Trail	32.72980529	-116.796733
6-Jun-2013	Skyline Truck Trail	32.72972071	-116.7967388
6-Jun-2013	Skyline Truck Trail	32.72928519	-116.796817
11-Jun-2013	Skyline Truck Trail	32.7311194	-116.7965688
11-Jun-2013	Skyline Truck Trail	32.7311013	-116.7966328
11-Jun-2013	Skyline Truck Trail	32.73096409	-116.7966986
11-Jun-2013	Skyline Truck Trail	32.73090089	-116.7968251
11-Jun-2013	Skyline Truck Trail	32.73076904	-116.7968517
11-Jun-2013	Skyline Truck Trail	32.73084666	-116.7970787
11-Jun-2013	Skyline Truck Trail	32.73085143	-116.7970798
11-Jun-2013	Skyline Truck Trail	32.73085604	-116.7970809
11-Jun-2013	Skyline Truck Trail	32.73091966	-116.7970107
11-Jun-2013	Skyline Truck Trail	32.73093852	-116.7971572
11-Jun-2013	Skyline Truck Trail	32.7307734	-116.7971801
11-Jun-2013	Skyline Truck Trail	32.73071246	-116.7971666
11-Jun-2013	Skyline Truck Trail	32.73073803	-116.7972214
11-Jun-2013	Skyline Truck Trail	32.73064625	-116.7972873
11-Jun-2013	Skyline Truck Trail	32.73064683	-116.7972862
11-Jun-2013	Skyline Truck Trail	32.73054918	-116.7974532
11-Jun-2013	Skyline Truck Trail	32.73054835	-116.7974539
11-Jun-2013	Skyline Truck Trail	32.73056419	-116.7975583
11-Jun-2013	Skyline Truck Trail	32.73056536	-116.7975633
11-Jun-2013	Skyline Truck Trail	32.73056008	-116.7975615
11-Jun-2013	Skyline Truck Trail	32.73063568	-116.7976322
11-Jun-2013	Skyline Truck Trail	32.73065371	-116.7974557
11-Jun-2013	Skyline Truck Trail	32.73064767	-116.7973644
11-Jun-2013	Skyline Truck Trail	32.73061859	-116.7973898
11-Jun-2013	Skyline Truck Trail	32.73073074	-116.7968876
11-Jun-2013	Skyline Truck Trail	32.73123164	-116.7966503
11-Jun-2013	Skyline Truck Trail	32.73195466	-116.7961162
11-Jun-2013	Sycuan Peak	32.74858645	-116.8006707

Appendix 2: 2014 Adult Hermes Copper Observations.

Date	Site	Latitude	Longitude
29-May-14	Lawson Peak	32.71466623	-116.7097109
29-May-14	Lawson Peak	32.71466916	-116.7097853
29-May-14	Lawson Peak	32.7163924	-116.7117979
29-May-14	Lawson Peak	32.71720176	-116.7124969
29-May-14	Sycuan Peak	32.74692457	-116.7994712
29-May-14	Sycuan Peak	32.7518077	-116.8010927
29-May-14	Sycuan Peak	32.75228396	-116.8019784
3-Jun-14	Boulder Creek Road	32.92639	-116.631258
3-Jun-14	Boulder Creek Road	32.92684	-116.631443
3-Jun-14	Boulder Creek Road	32.926922	-116.631393
3-Jun-14	Boulder Creek Road	32.927045	-116.631577
3-Jun-14	Boulder Creek Road	32.927297	-116.631493
3-Jun-14	Boulder Creek Road	32.927538	-116.631389
3-Jun-14	Boulder Creek Road	32.927613	-116.631334
3-Jun-14	Boulder Creek Road	32.927854	-116.631317
3-Jun-14	Boulder Creek Road	32.927862	-116.631313
3-Jun-14	Boulder Creek Road	32.92964	-116.634354
3-Jun-14	Boulder Creek Road	32.92966	-116.634343
3-Jun-14	Lawson Peak	32.714515	-116.709925
3-Jun-14	Lawson Peak	32.71458	-116.710076
3-Jun-14	Lawson Peak	32.714663	-116.710302
3-Jun-14	Lawson Peak	32.714689	-116.710322
3-Jun-14	Lawson Peak	32.717126	-116.712418
3-Jun-14	Skyline Truck Trail	32.73064759	-116.7975006
3-Jun-14	Skyline Truck Trail	32.73082059	-116.7970858
3-Jun-14	Skyline Truck Trail	32.7308216	-116.7968847
3-Jun-14	Skyline Truck Trail	32.73086552	-116.7970107
3-Jun-14	Skyline Truck Trail	32.73104615	-116.7966733
3-Jun-14	Sycuan Peak	32.74688493	-116.7995042
3-Jun-14	Sycuan Peak	32.74833273	-116.8000229
3-Jun-14	Sycuan Peak	32.74843088	-116.8000798
3-Jun-14	Sycuan Peak	32.74848587	-116.8006603
3-Jun-14	Sycuan Peak	32.74853331	-116.8006783
3-Jun-14	Sycuan Peak	32.74885576	-116.8001234
3-Jun-14	Sycuan Peak	32.74887227	-116.800033
3-Jun-14	Sycuan Peak	32.7490602	-116.8001488
3-Jun-14	Sycuan Peak	32.74959379	-116.8003608
3-Jun-14	Sycuan Peak	32.75038965	-116.8004096

Appendix 2: 2014 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
3-Jun-14	Sycuan Peak	32.75227206	-116.8019591
4-Jun-14	Skyline Truck Trail	32.72940204	-116.79689
4-Jun-14	Skyline Truck Trail	32.73066133	-116.7975634
4-Jun-14	Skyline Truck Trail	32.73076133	-116.7972024
4-Jun-14	Skyline Truck Trail	32.73080458	-116.7969881
4-Jun-14	Skyline Truck Trail	32.73178518	-116.8058641
4-Jun-14	Skyline Truck Trail	32.73205901	-116.8072037
4-Jun-14	Skyline Truck Trail	32.73207461	-116.8067885
4-Jun-14	Skyline Truck Trail	32.73209196	-116.8064836
4-Jun-14	Skyline Truck Trail	32.73209481	-116.8064608
4-Jun-14	Skyline Truck Trail	32.73212741	-116.8061359
4-Jun-14	Skyline Truck Trail	32.73213169	-116.8062783
5-Jun-14	Boulder Creek Road	32.92639461	-116.6312323
5-Jun-14	Boulder Creek Road	32.92682569	-116.6314877
5-Jun-14	Boulder Creek Road	32.9268459	-116.6315002
5-Jun-14	Boulder Creek Road	32.92703658	-116.6315655
5-Jun-14	Boulder Creek Road	32.92710389	-116.6315783
5-Jun-14	Boulder Creek Road	32.92725099	-116.6314816
5-Jun-14	Boulder Creek Road	32.92731168	-116.6314517
5-Jun-14	Boulder Creek Road	32.92785164	-116.6312793
5-Jun-14	Boulder Creek Road	32.92928168	-116.6346326
5-Jun-14	Boulder Creek Road	32.9295328	-116.6343865
5-Jun-14	Boulder Creek Road	32.92965031	-116.6342343
5-Jun-14	Lawson Peak	32.71463262	-116.7098509
5-Jun-14	Lawson Peak	32.71717418	-116.7124619
5-Jun-14	Roberts Ranch North	32.82753862	-116.6149561
5-Jun-14	Roberts Ranch North	32.82778429	-116.6143566
5-Jun-14	Sycuan Peak	32.74726077	-116.7997086
5-Jun-14	Sycuan Peak	32.74834639	-116.8000271
5-Jun-14	Sycuan Peak	32.7484173	-116.8000689
5-Jun-14	Sycuan Peak	32.74855267	-116.8006564
5-Jun-14	Sycuan Peak	32.74905316	-116.8001431
5-Jun-14	Sycuan Peak	32.74957577	-116.8003391
5-Jun-14	Sycuan Peak	32.74975715	-116.8004897
5-Jun-14	Sycuan Peak	32.75036744	-116.8003962
5-Jun-14	Sycuan Peak	32.75370729	-116.8052622
6-Jun-14	Skyline Truck Trail	32.73069955	-116.797138
8-Jun-14	Sycuan Peak	32.7483821	-116.8000607

Appendix 2: 2014 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
8-Jun-14	Sycuan Peak	32.74854312	-116.8006482
8-Jun-14	Sycuan Peak	32.74886431	-116.8000756
8-Jun-14	Sycuan Peak	32.74909037	-116.8001684
8-Jun-14	Sycuan Peak	32.74960376	-116.8003378
8-Jun-14	Sycuan Peak	32.75037867	-116.8003884
8-Jun-14	Sycuan Peak	32.75047976	-116.8002708
9-Jun-14	Boulder Creek Road	32.925724	-116.633557
9-Jun-14	Boulder Creek Road	32.926341	-116.631149
9-Jun-14	Boulder Creek Road	32.9264	-116.63145
9-Jun-14	Boulder Creek Road	32.926403	-116.631266
9-Jun-14	Boulder Creek Road	32.926451	-116.631273
9-Jun-14	Boulder Creek Road	32.926786	-116.631542
9-Jun-14	Boulder Creek Road	32.926958	-116.63152
9-Jun-14	Boulder Creek Road	32.926958	-116.63152
9-Jun-14	Boulder Creek Road	32.927055	-116.631579
9-Jun-14	Boulder Creek Road	32.927129	-116.631624
9-Jun-14	Boulder Creek Road	32.927195	-116.631559
9-Jun-14	Boulder Creek Road	32.927309	-116.631481
9-Jun-14	Boulder Creek Road	32.9274	-116.631436
9-Jun-14	Boulder Creek Road	32.927558	-116.631351
9-Jun-14	Boulder Creek Road	32.92786	-116.631305
9-Jun-14	Boulder Creek Road	32.928089	-116.631274
9-Jun-14	Boulder Creek Road	32.92922	-116.630992
9-Jun-14	Boulder Creek Road	32.929569	-116.634395
9-Jun-14	Boulder Creek Road	32.930207	-116.631184
9-Jun-14	Roberts Ranch North	32.827518	-116.614946
9-Jun-14	Skyline Truck Trail	32.73061003	-116.7975783
9-Jun-14	Skyline Truck Trail	32.73065396	-116.7975846
9-Jun-14	Skyline Truck Trail	32.73067198	-116.7974778
9-Jun-14	Skyline Truck Trail	32.7307796	-116.7970165
9-Jun-14	Skyline Truck Trail	32.73077977	-116.7969787
9-Jun-14	Skyline Truck Trail	32.73078547	-116.7969872
9-Jun-14	Skyline Truck Trail	32.73087046	-116.7970957
9-Jun-14	Skyline Truck Trail	32.73090215	-116.7970626
9-Jun-14	Skyline Truck Trail	32.73172282	-116.7962893
9-Jun-14	Skyline Truck Trail	32.73173648	-116.8058666
10-Jun-14	McGinty Mountain	32.75772532	-116.8656234
10-Jun-14	McGinty Mountain	32.7688927	-116.8697543

Appendix 2: 2014 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
11-Jun-14	Boulder Creek Road	32.925737	-116.632385
11-Jun-14	Boulder Creek Road	32.926788	-116.631541
11-Jun-14	Boulder Creek Road	32.927066	-116.63158
11-Jun-14	Boulder Creek Road	32.9271	-116.631577
11-Jun-14	Boulder Creek Road	32.927235	-116.631504
11-Jun-14	Boulder Creek Road	32.927333	-116.631449
11-Jun-14	Boulder Creek Road	32.929803	-116.634252
11-Jun-14	Roberts Ranch North	32.827584	-116.614466
11-Jun-14	Skyline Truck Trail	32.73067592	-116.797622
11-Jun-14	Skyline Truck Trail	32.73082017	-116.7970571
11-Jun-14	Skyline Truck Trail	32.7308371	-116.7967988
12-Jun-14	Boulder Creek Road	32.9275141	-116.6313957
13-Jun-14	Roberts Ranch North	32.82723636	-116.616457
13-Jun-14	Roberts Ranch North	32.82764867	-116.61446
13-Jun-14	Roberts Ranch North	32.82777691	-116.6143696
13-Jun-14	Roberts Ranch North	32.82784279	-116.6143619
16-Jun-14	Roberts Ranch North	32.82756728	-116.6150985
16-Jun-14	Roberts Ranch North	32.82786207	-116.6143689

Appendix 3: 2015 Adult Hermes Copper Observations.

Date	Site	Latitude	Longitude
1-May-15	Skyline Truck Trail	32.73073	-116.796963
1-May-15	Skyline Truck Trail	32.73089	-116.797005
2-May-15	Boulder Creek Road	32.926872	-116.63152
2-May-15	Boulder Creek Road	32.927308	-116.631479
2-May-15	Boulder Creek Road	32.92795	-116.631292
2-May-15	Boulder Creek Road	32.928103	-116.631291
2-May-15	Boulder Creek Road	32.929835	-116.634112
2-May-15	Lawson Peak	32.713396	-116.705882
2-May-15	Lawson Peak	32.714636	-116.710356
2-May-15	Lawson Peak	32.71743	-116.712536
10-May-15	Skyline Truck Trail	32.731781	-116.805864
11-May-15	Boulder Creek Road	32.925742	-116.632414
11-May-15	Boulder Creek Road	32.925869	-116.632247
11-May-15	Boulder Creek Road	32.926294	-116.631706
11-May-15	Boulder Creek Road	32.926864	-116.631484
11-May-15	Boulder Creek Road	32.926865	-116.631484
11-May-15	Boulder Creek Road	32.926865	-116.631484
11-May-15	Boulder Creek Road	32.926922	-116.631488
11-May-15	Boulder Creek Road	32.927637	-116.631308
11-May-15	Lawson Peak	32.714679	-116.710294
11-May-15	Lawson Peak	32.715341	-116.710446
11-May-15	Lawson Peak	32.715343	-116.710459
11-May-15	Lawson Peak	32.717418	-116.712488
17-May-15	Lawson Peak	32.714692	-116.710291
17-May-15	Lawson Peak	32.714741	-116.710213
17-May-15	Lawson Peak	32.717335	-116.712509
20-May-15	Boulder Creek Road	32.926248	-116.63178
20-May-15	Boulder Creek Road	32.927149	-116.631594
20-May-15	Lawson Peak	32.714626	-116.710312
26-May-15	Boulder Creek Road	32.927035	-116.631594
28-May-15	Boulder Creek Road	32.926724	-116.631431
28-May-15	Boulder Creek Road	32.929255	-116.634715
28-May-15	Lawson Peak	32.714801	-116.710249
30-May-15	Lawson Peak	32.714745	-116.710232

Appendix 3: 2015 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
1-Jun-15	Boulder Creek Road	32.926254	-116.631779
1-Jun-15	Boulder Creek Road	32.926701	-116.631446
1-Jun-15	Boulder Creek Road	32.927118	-116.631629
1-Jun-15	Boulder Creek Road	32.927304	-116.631508
1-Jun-15	Boulder Creek Road	32.927329	-116.631487
1-Jun-15	Boulder Creek Road	32.928088	-116.634945
1-Jun-15	Boulder Creek Road	32.928254	-116.634894
1-Jun-15	Boulder Creek Road	32.928729	-116.631032
1-Jun-15	Boulder Creek Road	32.928842	-116.634836
1-Jun-15	Lawson Peak	32.714725	-116.710456
1-Jun-15	Roberts Ranch North	32.827551	-116.615001
3-Jun-15	Boulder Creek Road	32.926787	-116.631479
3-Jun-15	Boulder Creek Road	32.926866	-116.631514
3-Jun-15	Boulder Creek Road	32.927122	-116.631604
3-Jun-15	Boulder Creek Road	32.927289	-116.631504
3-Jun-15	Boulder Creek Road	32.927812	-116.631359
3-Jun-15	Boulder Creek Road	32.928784	-116.634826
3-Jun-15	Boulder Creek Road	32.929713	-116.634219
3-Jun-15	Roberts Ranch North	32.827454	-116.614631
3-Jun-15	Roberts Ranch North	32.828526	-116.617873
7-Jun-15	Boulder Creek Road	32.926226	-116.631786
7-Jun-15	Boulder Creek Road	32.926247	-116.631777
7-Jun-15	Boulder Creek Road	32.926271	-116.634368
7-Jun-15	Boulder Creek Road	32.926876	-116.631441
7-Jun-15	Boulder Creek Road	32.92694	-116.631469
7-Jun-15	Boulder Creek Road	32.927125	-116.631564
7-Jun-15	Boulder Creek Road	32.92732	-116.631466
7-Jun-15	Boulder Creek Road	32.928074	-116.634883
7-Jun-15	Boulder Creek Road	32.928304	-116.634833
7-Jun-15	Boulder Creek Road	32.92855	-116.634776
7-Jun-15	Roberts Ranch North	32.827265	-116.61638
7-Jun-15	Roberts Ranch North	32.827491	-116.614612
7-Jun-15	Roberts Ranch North	32.827593	-116.61496
7-Jun-15	Roberts Ranch North	32.827889	-116.614364
7-Jun-15	Roberts Ranch North	32.828548	-116.617781

Appendix 3: 2015 adult Hermes copper observations (continued).

Date	Site	Latitude	Longitude
8-Jun-15	Sycuan Peak	32.748879	-116.80011
9-Jun-15	Boulder Creek Road	32.926793	-116.631501
9-Jun-15	Boulder Creek Road	32.926833	-116.631519
9-Jun-15	Boulder Creek Road	32.928584	-116.634823
9-Jun-15	Roberts Ranch North	32.827488	-116.614886
10-Jun-15	Lawson Peak	32.714903	-116.710699
11-Jun-15	Boulder Creek Road	32.925911	-116.632237
11-Jun-15	Boulder Creek Road	32.926128	-116.631093
11-Jun-15	Boulder Creek Road	32.926289	-116.631791
11-Jun-15	Boulder Creek Road	32.927146	-116.631577
11-Jun-15	Boulder Creek Road	32.927375	-116.631439
11-Jun-15	Boulder Creek Road	32.927939	-116.634975
11-Jun-15	Boulder Creek Road	32.928289	-116.634884
11-Jun-15	Boulder Creek Road	32.929608	-116.63438
11-Jun-15	Boulder Creek Road	32.92995	-116.633963
11-Jun-15	Roberts Ranch North	32.826918	-116.615716
11-Jun-15	Roberts Ranch North	32.827845	-116.614384
15-Jun-15	Boulder Creek Road	32.926255	-116.63129
15-Jun-15	Boulder Creek Road	32.926267	-116.631234
15-Jun-15	Boulder Creek Road	32.92694	-116.631523
15-Jun-15	Boulder Creek Road	32.927059	-116.631607
15-Jun-15	Boulder Creek Road	32.927142	-116.63163

Appendix 4. GPS coordinates of spiny redberry shrubs (*Rhamnus crocea*) searched at Sycuan Peak Ecological Reserve and Skyline Truck Trail in 2013-2015.

Site	Year	Latitude	Longitude
Sycuan Peak ER	2013	32.75459326	-116.8059344
Sycuan Peak ER	2013	32.75328292	-116.8044663
Sycuan Peak ER	2013	32.74787659	-116.7998463
Sycuan Peak ER	2013	32.74767039	-116.7998622
Sycuan Peak ER	2013	32.7477543	-116.7997762
Sycuan Peak ER	2013	32.75457071	-116.8062623
Sycuan Peak ER	2013	32.75451112	-116.8063312
Sycuan Peak ER	2013	32.75437131	-116.8061368
Sycuan Peak ER	2013	32.75443719	-116.8061324
Sycuan Peak ER	2013	32.75440441	-116.8061716
Sycuan Peak ER	2013	32.75445269	-116.8062563
Sycuan Peak ER	2013	32.75445906	-116.8058044
Sycuan Peak ER	2013	32.75428372	-116.8057793
Sycuan Peak ER	2013	32.75449486	-116.8058206
Sycuan Peak ER	2013	32.75448849	-116.8058696
Sycuan Peak ER	2013	32.75457029	-116.8058657
Sycuan Peak ER	2013	32.75455579	-116.8058826
Sycuan Peak ER	2013	32.75444951	-116.8059811
Sycuan Peak ER	2013	32.7544542	-116.8059677
Sycuan Peak ER	2013	32.75445093	-116.8059513
Sycuan Peak ER	2013	32.75458396	-116.805938
Sycuan Peak ER	2013	32.75440601	-116.8057856
Sycuan Peak ER	2013	32.75458857	-116.8059219
Sycuan Peak ER	2013	32.75449804	-116.8059349
Sycuan Peak ER	2013	32.75452344	-116.8059038
Sycuan Peak ER	2013	32.75450768	-116.8059056
Sycuan Peak ER	2013	32.7544941	-116.8058821
Sycuan Peak ER	2013	32.75449343	-116.8059043
Sycuan Peak ER	2013	32.75449083	-116.8059217
Sycuan Peak ER	2013	32.75177049	-116.8010387
Sycuan Peak ER	2013	32.75174744	-116.8009654
Sycuan Peak ER	2013	32.75433878	-116.805642
Sycuan Peak ER	2013	32.75173469	-116.8006849
Sycuan Peak ER	2013	32.75171718	-116.8007294
Sycuan Peak ER	2013	32.75161492	-116.8006429
Sycuan Peak ER	2013	32.75168994	-116.8009188
Sycuan Peak ER	2013	32.7515404	-116.8006799
Sycuan Peak ER	2013	32.75156069	-116.8005551

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2013	32.75137729	-116.8007113
Sycuan Peak ER	2013	32.75134066	-116.8006829
Sycuan Peak ER	2013	32.75128668	-116.8005668
Sycuan Peak ER	2013	32.75128534	-116.8005712
Sycuan Peak ER	2013	32.75440492	-116.8056987
Sycuan Peak ER	2013	32.75128936	-116.8005715
Sycuan Peak ER	2013	32.7513524	-116.8006005
Sycuan Peak ER	2013	32.75134913	-116.8005666
Sycuan Peak ER	2013	32.75143647	-116.8005612
Sycuan Peak ER	2013	32.751456	-116.8005499
Sycuan Peak ER	2013	32.75137989	-116.8004362
Sycuan Peak ER	2013	32.75152003	-116.800525
Sycuan Peak ER	2013	32.75139749	-116.8004601
Sycuan Peak ER	2013	32.75146463	-116.8003588
Sycuan Peak ER	2013	32.75161031	-116.8001316
Sycuan Peak ER	2013	32.75424901	-116.8056122
Sycuan Peak ER	2013	32.75164685	-116.7999751
Sycuan Peak ER	2013	32.75154786	-116.8000706
Sycuan Peak ER	2013	32.75148206	-116.8001968
Sycuan Peak ER	2013	32.75159346	-116.7999902
Sycuan Peak ER	2013	32.75150235	-116.7999823
Sycuan Peak ER	2013	32.75158709	-116.7996996
Sycuan Peak ER	2013	32.75157795	-116.7996817
Sycuan Peak ER	2013	32.75161634	-116.7996378
Sycuan Peak ER	2013	32.75160863	-116.799557
Sycuan Peak ER	2013	32.75160134	-116.7994045
Sycuan Peak ER	2013	32.75427559	-116.8056834
Sycuan Peak ER	2013	32.75161852	-116.7993675
Sycuan Peak ER	2013	32.75145533	-116.7990537
Sycuan Peak ER	2013	32.75140495	-116.7990781
Sycuan Peak ER	2013	32.75147611	-116.7992069
Sycuan Peak ER	2013	32.75122206	-116.7992173
Sycuan Peak ER	2013	32.75126078	-116.7992217
Sycuan Peak ER	2013	32.75117587	-116.7995198
Sycuan Peak ER	2013	32.75112717	-116.7994386
Sycuan Peak ER	2013	32.75110102	-116.7995147
Sycuan Peak ER	2013	32.75111569	-116.7994735
Sycuan Peak ER	2013	32.75432143	-116.8057335

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2013	32.75090849	-116.7996422
Sycuan Peak ER	2013	32.7506831	-116.7997173
Sycuan Peak ER	2013	32.75083934	-116.7996148
Sycuan Peak ER	2013	32.75060984	-116.7999343
Sycuan Peak ER	2013	32.75050214	-116.8001354
Sycuan Peak ER	2013	32.75038077	-116.8003644
Sycuan Peak ER	2013	32.75026015	-116.8002377
Sycuan Peak ER	2013	32.75012177	-116.8002477
Sycuan Peak ER	2013	32.75001012	-116.8002716
Sycuan Peak ER	2013	32.74990384	-116.8002825
Sycuan Peak ER	2013	32.7543071	-116.8057123
Sycuan Peak ER	2013	32.74996997	-116.8002761
Sycuan Peak ER	2013	32.75002219	-116.8004806
Sycuan Peak ER	2013	32.75007877	-116.8003693
Sycuan Peak ER	2013	32.750047	-116.8004047
Sycuan Peak ER	2013	32.75370972	-116.8044412
Sycuan Peak ER	2013	32.7497331	-116.8004876
Sycuan Peak ER	2013	32.75371685	-116.8044504
Sycuan Peak ER	2013	32.7536057	-116.8043616
Sycuan Peak ER	2013	32.75358332	-116.804355
Sycuan Peak ER	2013	32.75347545	-116.8043146
Sycuan Peak ER	2013	32.7533783	-116.8042766
Sycuan Peak ER	2013	32.75347553	-116.804296
Sycuan Peak ER	2013	32.75344611	-116.8042737
Sycuan Peak ER	2013	32.7532203	-116.8044333
Sycuan Peak ER	2013	32.75344561	-116.8042641
Sycuan Peak ER	2013	32.75344318	-116.8042967
Sycuan Peak ER	2013	32.74971625	-116.8003107
Sycuan Peak ER	2013	32.75342709	-116.8042984
Sycuan Peak ER	2013	32.75335819	-116.8043623
Sycuan Peak ER	2013	32.75331963	-116.8043927
Sycuan Peak ER	2013	32.75326649	-116.8044426
Sycuan Peak ER	2013	32.75333631	-116.8045664
Sycuan Peak ER	2013	32.75335081	-116.80453
Sycuan Peak ER	2013	32.75334008	-116.8045043
Sycuan Peak ER	2013	32.75330756	-116.8044869
Sycuan Peak ER	2013	32.74959044	-116.8004094
Sycuan Peak ER	2013	32.75338031	-116.8046139

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2013	32.75329934	-116.8046727
Sycuan Peak ER	2013	32.75324939	-116.804713
Sycuan Peak ER	2013	32.75325568	-116.8047507
Sycuan Peak ER	2013	32.75323095	-116.804727
Sycuan Peak ER	2013	32.75406319	-116.8055924
Sycuan Peak ER	2013	32.75402346	-116.8055765
Sycuan Peak ER	2013	32.75403695	-116.8055727
Sycuan Peak ER	2013	32.75404047	-116.805583
Sycuan Peak ER	2013	32.75405271	-116.8055543
Sycuan Peak ER	2013	32.74960645	-116.8003986
Sycuan Peak ER	2013	32.7541294	-116.805588
Sycuan Peak ER	2013	32.75261982	-116.8021312
Sycuan Peak ER	2013	32.75259091	-116.8021979
Sycuan Peak ER	2013	32.75281797	-116.8021111
Sycuan Peak ER	2013	32.75279325	-116.802151
Sycuan Peak ER	2013	32.75273298	-116.8020867
Sycuan Peak ER	2013	32.75261521	-116.8021691
Sycuan Peak ER	2013	32.75273223	-116.8021374
Sycuan Peak ER	2013	32.75270482	-116.8021203
Sycuan Peak ER	2013	32.75266551	-116.8021395
Sycuan Peak ER	2013	32.74913882	-116.8002304
Sycuan Peak ER	2013	32.75269694	-116.80205
Sycuan Peak ER	2013	32.7495321	-116.8004084
Sycuan Peak ER	2013	32.74952011	-116.8003552
Sycuan Peak ER	2013	32.7493192	-116.8004446
Sycuan Peak ER	2013	32.74908702	-116.8000916
Sycuan Peak ER	2013	32.74871159	-116.8000915
Sycuan Peak ER	2013	32.74873431	-116.8002995
Sycuan Peak ER	2013	32.74869114	-116.8003908
Sycuan Peak ER	2013	32.74863549	-116.8005899
Sycuan Peak ER	2013	32.74799787	-116.7997996
Sycuan Peak ER	2013	32.7542144	-116.8056363
Sycuan Peak ER	2013	32.75432546	-116.8057068
Sycuan Peak ER	2013	32.75454783	-116.8058795
Sycuan Peak ER	2013	32.75448798	-116.8059041
Skyline Truck Trail	2014	32.731707	-116.796352
Skyline Truck Trail	2014	32.731516	-116.79648
Skyline Truck Trail	2014	32.730749	-116.796827

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Skyline Truck Trail	2014	32.730804	-116.796804
Skyline Truck Trail	2014	32.730616	-116.797307
Skyline Truck Trail	2014	32.730599	-116.797222
Skyline Truck Trail	2014	32.730589	-116.797309
Skyline Truck Trail	2014	32.730563	-116.797352
Skyline Truck Trail	2014	32.730549	-116.797527
Skyline Truck Trail	2014	32.73053	-116.797571
Skyline Truck Trail	2014	32.73054	-116.797625
Skyline Truck Trail	2014	32.730593	-116.797744
Skyline Truck Trail	2014	32.730692	-116.797798
Skyline Truck Trail	2014	32.730522	-116.797852
Skyline Truck Trail	2014	32.730466	-116.797851
Skyline Truck Trail	2014	32.730573	-116.797896
Skyline Truck Trail	2014	32.73057	-116.797896
Skyline Truck Trail	2014	32.730692	-116.797527
Skyline Truck Trail	2014	32.730616	-116.797354
Skyline Truck Trail	2014	32.730695	-116.797168
Skyline Truck Trail	2014	32.730785	-116.797147
Skyline Truck Trail	2014	32.730135	-116.796499
Skyline Truck Trail	2014	32.729716	-116.796767
Sycuan Peak ER	2014	32.74775	-116.799782
Sycuan Peak ER	2014	32.748005	-116.799814
Sycuan Peak ER	2014	32.748645	-116.800612
Sycuan Peak ER	2014	32.748748	-116.800304
Sycuan Peak ER	2014	32.748748	-116.800305
Sycuan Peak ER	2014	32.748771	-116.800287
Sycuan Peak ER	2014	32.749107	-116.800187
Sycuan Peak ER	2014	32.749101	-116.800213
Sycuan Peak ER	2014	32.749232	-116.800329
Sycuan Peak ER	2014	32.749325	-116.800471
Sycuan Peak ER	2014	32.749278	-116.800562
Sycuan Peak ER	2014	32.749315	-116.800635
Sycuan Peak ER	2014	32.749454	-116.800701
Sycuan Peak ER	2014	32.749552	-116.800352
Sycuan Peak ER	2014	32.749584	-116.80041
Sycuan Peak ER	2014	32.749598	-116.800283
Sycuan Peak ER	2014	32.749595	-116.800186
Sycuan Peak ER	2014	32.749812	-116.800403

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2014	32.749867	-116.800419
Sycuan Peak ER	2014	32.749909	-116.800413
Sycuan Peak ER	2014	32.749973	-116.800489
Sycuan Peak ER	2014	32.7501	-116.800402
Sycuan Peak ER	2014	32.750003	-116.800312
Sycuan Peak ER	2014	32.750023	-116.800284
Sycuan Peak ER	2014	32.750365	-116.800432
Sycuan Peak ER	2014	32.750426	-116.800386
Sycuan Peak ER	2014	32.750549	-116.80013
Sycuan Peak ER	2014	32.750571	-116.800018
Sycuan Peak ER	2014	32.750946	-116.799643
Sycuan Peak ER	2014	32.751134	-116.799502
Sycuan Peak ER	2014	32.751135	-116.79945
Sycuan Peak ER	2014	32.75114	-116.799454
Sycuan Peak ER	2014	32.751187	-116.799503
Sycuan Peak ER	2014	32.75146	-116.799179
Sycuan Peak ER	2014	32.751611	-116.799366
Sycuan Peak ER	2014	32.751608	-116.799398
Sycuan Peak ER	2014	32.7516	-116.799555
Sycuan Peak ER	2014	32.751606	-116.799624
Sycuan Peak ER	2014	32.751668	-116.799649
Sycuan Peak ER	2014	32.751633	-116.799602
Sycuan Peak ER	2014	32.75018	-116.800256
Sycuan Peak ER	2014	32.749771	-116.800345
Sycuan Peak ER	2014	32.749799	-116.800349
Sycuan Peak ER	2014	32.749751	-116.800373
Sycuan Peak ER	2014	32.750316	-116.800227
Sycuan Peak ER	2014	32.751499	-116.800231
Sycuan Peak ER	2014	32.751498	-116.800357
Sycuan Peak ER	2014	32.751585	-116.800401
Sycuan Peak ER	2014	32.751582	-116.800402
Sycuan Peak ER	2014	32.751589	-116.800399
Sycuan Peak ER	2014	32.751924	-116.801432
Sycuan Peak ER	2014	32.751969	-116.801409
Sycuan Peak ER	2014	32.752149	-116.801896
Sycuan Peak ER	2014	32.752194	-116.801973
Sycuan Peak ER	2014	32.752478	-116.801992
Sycuan Peak ER	2014	32.752449	-116.802008

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2014	32.752898	-116.802103
Sycuan Peak ER	2014	32.752789	-116.80216
Sycuan Peak ER	2014	32.752804	-116.802305
Sycuan Peak ER	2014	32.752704	-116.803122
Sycuan Peak ER	2014	32.752692	-116.803415
Sycuan Peak ER	2014	32.752963	-116.803765
Sycuan Peak ER	2014	32.753359	-116.804314
Sycuan Peak ER	2014	32.753317	-116.80438
Sycuan Peak ER	2014	32.753262	-116.804406
Sycuan Peak ER	2014	32.753307	-116.804458
Sycuan Peak ER	2014	32.753246	-116.804733
Sycuan Peak ER	2014	32.753344	-116.804911
Sycuan Peak ER	2014	32.753496	-116.805031
Sycuan Peak ER	2014	32.753482	-116.804974
Sycuan Peak ER	2014	32.75363	-116.804874
Sycuan Peak ER	2014	32.754402	-116.806054
Sycuan Peak ER	2014	32.754422	-116.806165
Sycuan Peak ER	2014	32.754479	-116.805898
Sycuan Peak ER	2014	32.747218	-116.799804
Sycuan Peak ER	2014	32.747367	-116.799529
Sycuan Peak ER	2014	32.747653	-116.799885
Sycuan Peak ER	2014	32.747875	-116.79985
Sycuan Peak ER	2014	32.749916	-116.800355
Sycuan Peak ER	2014	32.751242	-116.799227
Sycuan Peak ER	2014	32.751258	-116.799211
Sycuan Peak ER	2014	32.751617	-116.798917
Sycuan Peak ER	2014	32.751626	-116.798953
Sycuan Peak ER	2014	32.751669	-116.798898
Sycuan Peak ER	2014	32.751671	-116.798906
Sycuan Peak ER	2014	32.751666	-116.798897
Sycuan Peak ER	2014	32.751648	-116.798887
Sycuan Peak ER	2014	32.751666	-116.798822
Sycuan Peak ER	2014	32.751719	-116.798815
Sycuan Peak ER	2014	32.751679	-116.799053
Sycuan Peak ER	2014	32.751435	-116.799907
Sycuan Peak ER	2014	32.751416	-116.799898
Sycuan Peak ER	2014	32.751442	-116.79997
Sycuan Peak ER	2014	32.752419	-116.802062

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2014	32.752591	-116.802138
Sycuan Peak ER	2014	32.7526	-116.802112
Sycuan Peak ER	2014	32.75266	-116.80215
Sycuan Peak ER	2014	32.75259	-116.802189
Sycuan Peak ER	2014	32.752689	-116.802259
Sycuan Peak ER	2014	32.752626	-116.802309
Sycuan Peak ER	2014	32.751701	-116.801272
Sycuan Peak ER	2014	32.751686	-116.80118
Sycuan Peak ER	2014	32.751796	-116.801305
Sycuan Peak ER	2014	32.751775	-116.801359
Sycuan Peak ER	2014	32.751771	-116.801164
Sycuan Peak ER	2014	32.751809	-116.801115
Sycuan Peak ER	2014	32.751772	-116.801027
Sycuan Peak ER	2014	32.751744	-116.800942
Sycuan Peak ER	2014	32.751734	-116.800917
Skyline Truck Trail	2015	32.731532	-116.796489
Skyline Truck Trail	2015	32.731437	-116.796532
Skyline Truck Trail	2015	32.731478	-116.796602
Skyline Truck Trail	2015	32.73076	-116.796796
Skyline Truck Trail	2015	32.730561	-116.797234
Skyline Truck Trail	2015	32.730563	-116.797329
Skyline Truck Trail	2015	32.730536	-116.797364
Skyline Truck Trail	2015	32.730534	-116.797523
Skyline Truck Trail	2015	32.730533	-116.797561
Skyline Truck Trail	2015	32.730539	-116.797606
Skyline Truck Trail	2015	32.730449	-116.797651
Skyline Truck Trail	2015	32.73046	-116.797701
Skyline Truck Trail	2015	32.730609	-116.797346
Skyline Truck Trail	2015	32.731742	-116.796314
Skyline Truck Trail	2015	32.731641	-116.796438
Skyline Truck Trail	2015	32.73063	-116.79733
Skyline Truck Trail	2015	32.730717	-116.797822
Skyline Truck Trail	2015	32.73071	-116.797776
Skyline Truck Trail	2015	32.730572	-116.797925
Skyline Truck Trail	2015	32.730498	-116.797874
Skyline Truck Trail	2015	32.730453	-116.797937
Skyline Truck Trail	2015	32.730722	-116.797162
Skyline Truck Trail	2015	32.730786	-116.797164

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Skyline Truck Trail	2015	32.730378	-116.796847
Skyline Truck Trail	2015	32.730312	-116.796701
Skyline Truck Trail	2015	32.730062	-116.796698
Skyline Truck Trail	2015	32.730529	-116.796909
Skyline Truck Trail	2015	32.730169	-116.796629
Skyline Truck Trail	2015	32.729734	-116.796777
Skyline Truck Trail	2015	32.729255	-116.796415
Sycuan Peak ER	2015	32.74784	-116.799852
Sycuan Peak ER	2015	32.749093	-116.800224
Sycuan Peak ER	2015	32.749244	-116.800311
Sycuan Peak ER	2015	32.749599	-116.800397
Sycuan Peak ER	2015	32.749795	-116.800414
Sycuan Peak ER	2015	32.750054	-116.800423
Sycuan Peak ER	2015	32.750091	-116.800386
Sycuan Peak ER	2015	32.75018	-116.800402
Sycuan Peak ER	2015	32.750344	-116.800422
Sycuan Peak ER	2015	32.750402	-116.800378
Sycuan Peak ER	2015	32.750533	-116.800145
Sycuan Peak ER	2015	32.750584	-116.800049
Sycuan Peak ER	2015	32.750612	-116.799943
Sycuan Peak ER	2015	32.750619	-116.799522
Sycuan Peak ER	2015	32.750616	-116.799525
Sycuan Peak ER	2015	32.750627	-116.799519
Sycuan Peak ER	2015	32.750632	-116.799513
Sycuan Peak ER	2015	32.750512	-116.799482
Sycuan Peak ER	2015	32.750414	-116.799533
Sycuan Peak ER	2015	32.750337	-116.799479
Sycuan Peak ER	2015	32.750324	-116.799558
Sycuan Peak ER	2015	32.750298	-116.799471
Sycuan Peak ER	2015	32.750307	-116.79944
Sycuan Peak ER	2015	32.750251	-116.799436
Sycuan Peak ER	2015	32.750245	-116.799511
Sycuan Peak ER	2015	32.751697	-116.798802
Sycuan Peak ER	2015	32.751651	-116.798824
Sycuan Peak ER	2015	32.751657	-116.79881
Sycuan Peak ER	2015	32.751638	-116.798902
Sycuan Peak ER	2015	32.751456	-116.799978
Sycuan Peak ER	2015	32.75147	-116.800207

Spiny redberry shrubs searched in 2013-2015 (continued).

Site	Year	Latitude	Longitude
Sycuan Peak ER	2015	32.751466	-116.800347
Sycuan Peak ER	2015	32.751571	-116.800389
Sycuan Peak ER	2015	32.751505	-116.800584
Sycuan Peak ER	2015	32.751694	-116.80074
Sycuan Peak ER	2015	32.751696	-116.80093
Sycuan Peak ER	2015	32.751622	-116.801055
Sycuan Peak ER	2015	32.751725	-116.801036
Sycuan Peak ER	2015	32.751729	-116.801078
Sycuan Peak ER	2015	32.751723	-116.80107
Sycuan Peak ER	2015	32.751701	-116.801082
Sycuan Peak ER	2015	32.751691	-116.801067
Sycuan Peak ER	2015	32.751683	-116.801102
Sycuan Peak ER	2015	32.751586	-116.80112
Sycuan Peak ER	2015	32.749755	-116.800355
Sycuan Peak ER	2015	32.749743	-116.800357