Monitoring the Status of Hermes Copper *(Lycaena hermes)* on Conserved Lands in San Diego County: 2010 - 2012

Photo: Spring L. Strahm

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Executive Summary

The Hermes copper butterfly, *Lycaena* [*Hermelycaena*] *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.

This report is structured around a conceptual model developed collaboratively during a workshop on conceptual models for monitoring and management. We addressed a number of model aspects, including population sizes and locations, dispersal and genetics, egg biology and reproductive behavior.

In 2012 the number of Hermes copper adults observed was moderate when compared to totals of 2010 and 2011, however we had few detections at sparsely populated sites in the northern portion of its distribution. We also added two additional sites at Boulder Creek Road (near Cuyamaca Peak) and Potrero Peak (near Potrero). Boulder Creek Road was densely populated, Potrero Peak was moderate.

Landscape genetics suggest that individuals from peripheral populations in the northern and western portion of the Hermes copper distribution generally exhibit increased differentiation compared to populations in the central region of their range (McGinty Mountain, Sycuan Peak, and Lawson Peak areas). The southeastern peripheral populations near Potrero appear to have adequate dispersal with the central region to prevent genetic differentiation. The overall genetic patterns likely reflect historic processes and it is possible that recent impacts, such as habitat fragmentation resulting in increased isolation, have yet to appear in the genetic composition.

Research of Hermes copper reproductive behavior and eggs yielded new information about the species. Eggs seem to hatch much earlier than reported in the literature, however, Hermes copper eggs do not always hatch the spring immediately following oviposition, suggesting the potential for diapause. Captive rearing from eggs was initiated, but results will not be available until 2013 due the annual lifecycle of the species.

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Introduction

The Hermes copper butterfly, *Lycaena* [*Hermelycaena*] *hermes*, is a rare butterfly endemic to San Diego County and northern Baja California. Hermes copper 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 stated 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 throughout the county.

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 Map 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 elevation (Marschalek and Klein 2010).

Hermes copper emerges in the late spring after overwintering as eggs and spend a short period of time as caterpillars (Thorne 1963; Faulkner and Klein 2004). Adult emergence is fairly consistent, generally beginning in mid to late May, with the flight period extending from late June and 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.

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 only rarely exceed 100 meters, and the longest movement reported for a Hermes copper is just over 1 kilometer (Marschalek and Klein 2010).

Previous Results

This SANDAG funded project began in 2010 with the primary goal of identifying and quantifying new populations of Hermes copper butterflies prior to a potential listing. In 2011 the project continued with these same goals, but added a temporal component. We discovered that the relative density of Hermes copper adults generally remains the same at occupied sites, but that the exact number of individuals can vary widely on an annual basis.

In both years we found that the majority of Hermes copper observations occurred in a small section of San Diego County from Jamul to Descanso, an area that did not burn in 2003 or 2007. This section represents about 2.7% (Figure 1) of the land area in the county. It appears the butterfly's range in San Diego County has been greatly reduced by fire and development (Figure 1, Marschalek and Klein 2010).

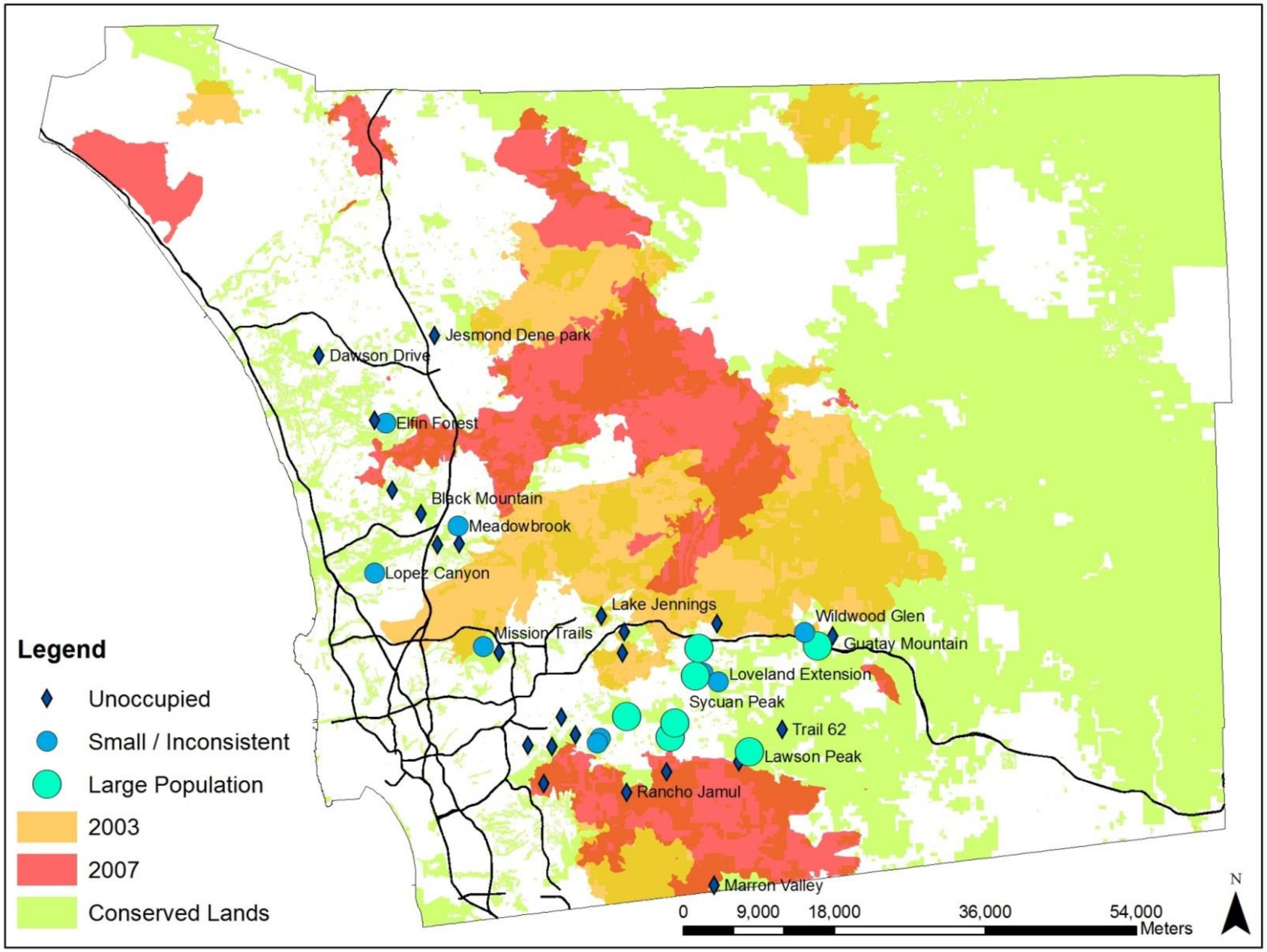

Figure 1: Map of locations surveyed for Hermes copper in 2010 and 2011.

Conceptual Model for Hermes Copper

In February 2012 the Institute for Ecological Monitoring and Management (IEMM) convened a workshop to help local managers and experts develop conceptual models for five topics of regional importance, including the Hermes copper.

Participants included:

- Allison Anderson, Entomologist, United States Fish and Wildlife Service
- Douglas Deutschman, Professor of Biology, IEMM, San Diego State University
- Mark Dodero, Restoration Biologist, RECON
- David Faulkner, Entomologist, Forensic Entomology Service
- Keith Greer, Senior Regional Planner, San Diego Association of Governments
- Daniel Marschalek, Entomologist, California Department of Fish and Game
- John Martin, Refuge Biologist, United States Fish and Wildlife Service
- Dave Mayer, Senior Environmental Scientist, California Department of Fish and Game
- Eric Porter, Biologist, United States Fish and Wildlife Service
- Jennifer Price, Land Use/Environmental Planner, San Diego County Department of Parks and Recreation
- Joyce Schlachter, Wildlife Biologist, Bureau of Land Management
- Susan Wynn, Biologist, United States Fish and Wildlife Service

The conceptual model presented here is the result of their collaboration (Figure 2). This 2012 Hermes copper research was designed to specifically address biological uncertainties that are critical for conservation and management efforts. The conceptual model is presented here in order to provide a context for on-going Hermes copper research.

Conceptual Model Narrative

The working group set a management goal and a monitoring goal to guide their construction of the model.

- **Management:** *Ensure Hermes copper persistence throughout the historic range.*

- **Monitoring:** *Address critical biological uncertainties identified in the model.*

Model Elements

The working group identified a number of anthropogenic threats, natural drivers and aspects of the species biology that have implications for these goals (Table 1).

Table 1: Elements under consideration in the Hermes copper conceptual model.

Anthropogenic Drivers	Species Variables	Natural Drivers
Development/Fragmentation Fire Road kill Invasive Plants Recreation Argentine Ants	Population Structure Female Behavior Reproduction/Oviposition Dispersal/Gene Flow Male Behavior Eggs Larvae Pupae Adults	Habitat/Vegetation Community Predators/Parasitoids Climactic Conditions

Anthropogenic Drivers

Development/Fragmentation

A large portion of the historical Hermes copper range is now developed, diminishing available habitat and increasing fragmentation (USFWS 2011). Hermes copper males do not disperse long distances, and generally do not cross large patches of unsuitable habitat. Although females may have the capacity for long distance dispersal, habitat fragmentation may limit dispersal (including fragmentation caused by conversion of shrub lands into grasslands) (Marschalek and Klein 2010; Marschalek and Deutschman 2008; Deutschman et al. 2010).

Fire

Wildfires cause direct mortality of Hermes copper. Frequent “megafires” (fires of unusually large extent, Figure 1) are especially problematic due to Hermes copper dispersal limitation and the low rate at which the species recolonizes areas (USFWS 2011; Marschalek and Klein 2010).

Road Kill

It is unclear if road kill is a substantial issue for Hermes copper. Given their short dispersal distances and relatively low-flying habit it could potentially be a problem. Marschalek (2004) has observed at least one individual that appeared to have been killed in a collision; however the relative importance of this threat is unknown and at this time seems to be far less important than that of fire (Marschalek and Klein 2010).

Invasive Plants

Invasive plants, particularly non-native grasses, add significant flash fuel to the environment and increase the probability of accidental fires. As a result, these plants may alter the fire regime which can influence Hermes copper distribution by causing local extirpations and change the population structure.

Recreation

Recreation involving motorized equipment increases the number of possible ignition sources in Hermes copper habitat, and as a result could impact populations by altering the fire regime.

Argentine Ants

Argentine ants (*Linepithema humile*) could potentially prey on immature stages of Hermes copper, and as a result could represent an artificially high predator population.

Natural Drivers

Habitat/Vegetation Community

Hermes copper occurs in coastal sage scrub and southern mixed chaparral, utilizing spiny redberry as a host plant for oviposition, larvae, and pupation. Adult Hermes copper show a strong preference for nectaring on California buckwheat, however may utilize other plants occasionally, including chamise (*Adenostoma fasciculatum*) and tarplants (*Deinandra* sp.) (Marschalek and Deutschman 2009; Marschalek and Deutschman 2008; Klein pers. com.; USFWS 2011; Thorne 1963; Marschalek pers. obs.).

Predators/Parasitoids

It is unclear if predators or parasitoids on adult butterflies play a significant role in Hermes copper population dynamics. A single observation of a jumping spider feeding on an adult was made by Marschalek in 2010. Other potential predators or parasitoids are unknown.

Climatic Conditions

Timing of emergence (beginning of the flight season) of Hermes copper appears to be influenced by temperature, precipitation, and elevation, although the specifics of this relationship are unknown. In addition, activity on a given day in the flight season is strongly influenced by temperature and cloud cover, with Hermes copper remaining inactive and generally unseen until a temperature of 22°C. Furthermore, Hermes copper tends to prefer the north and west sides of roads and trails for what seem to be purposes of thermoregulation (Marschalek and Deutschman 2008; Marschalek and Klein 2010; Deutschman et al. 2010).

Species Variables

Population Structure

Genetic analysis indicates that Hermes copper dispersal is complex. Individuals at the same site do not always poses the most similar genetic composition. At this time genetic analysis suggests that populations at the center of the distribution in the southeast part of the county may be mixing at higher rates, but that there is genetic differentiation of small peripheral sites (Deutschman et al. 2010, 2011).

Female Behavior

Hermes copper females may be found in the same open spaces occupied by males, however, upon flushing they fly quickly away and do not generally return. Based on genetic information some long distance dispersal events do occur, however field studies suggest that Hermes copper males typically do not exhibit such movements. Other *Lycaena* show different behavior between the sexes with females dispersing longer distances than males (Deutschman et al. 2010; USFWS 2011).

Reproduction and Oviposition

Most of the Hermes copper life cycle is achieved on spiny redberry, including oviposition, larval feeding, and pupation. Eggs are approximately one millimeter in diameter, generally positioned on the underside of relatively new growth, often near an intersection with another branch or leaf. It is unclear what degree of habitat selection is occurring by females, prior to oviposition (Thorne 1963; Marschalek and Deutschman 2009).

Dispersal and Gene Flow

Hermes copper males appear to move only short distances (Marschalek and Deutschman 2008; Marschalek and Klein 2010), but females may engage in long-distance dispersal (Deutschman et al. 2010, 2011). Evidence suggests that long-distance dispersal occurs within the central region of their distribution in the southeastern portion of San Diego County, but that peripheral populations are more isolated (Deutschman et al. 2010, 2011).

Male Behavior

Hermes copper males only make small movements in the process of defending territory. Even when spooked they usually return to the same area after a few minutes. Males are much more frequently encountered compared to females (Thorne 1963).

Eggs

The location that females choose to oviposit could be crucial for understanding what constitutes high quality habitat. This information could be used to determine if unoccupied sites with spiny redberry are simply unoccupied, or if there is some crucial factor that makes them unsuitable. In addition reproductive success is critical for maintaining the species. It is unclear if eggs are subject to predation or other stressors.

Larvae

Very little is known about the biology of Hermes copper larvae. This stage could be sensitive to a number of environmental stressors, predation and parasitism. The transition from egg to larvae is the part of the lifecycle limiting our ability to rear Hermes copper in a laboratory setting.

Pupae

Very little is known about the placement and phenology of Hermes copper pupae other than that pupation occurs on spiny redberry plants.

Adults

Hermes copper adults are small, but boldly colored butterflies. Although they are easy to spot much remains unknown about their biology.

Biological Uncertainties

Rather than identify monitoring targets, the group identified six uncertainties important to the persistence of Hermes copper. The factors could not be labeled “critical” as lack of information prohibits the determination of their importance. This list was not prioritized.

A. **Sex Dependent Habitat Use and Dispersal**
Male and female Hermes copper adults seem to use habitat differently and contribute differently to dispersal, which has implications for reproduction and connectivity. It is unclear what triggers dispersal and if dispersal is wind-aided or directed flight. Genetics work suggests that landscape features have the potential to impede movement, but that occasional long distance dispersal occurs within the central portion of their range.

B. **Larval Biology and Secondary Diapause**
Very little is known about larval biology, physiology, habitat requirements, and behavior. We have no information on the potential for a secondary diapause, but given wild annual fluctuations in adult population size it seems possible. In addition, if ex-situ rearing is to be used as a protective measure, a better understanding of larval physiological requirements is needed.

C. **Predators, Parasitoids, and Other Sources of Mortality**
We have little information on predators and parasitoids of Hermes copper, in part because larvae and eggs are difficult to locate in the field. Two observations of adult mortality have been made in the field: one of a jumping spider and one through road kill, but there is no data regarding the relative importance of these threats.

D. **Vegetation Community Structure**
In spiny redberry patches it is not clear what determines when and where Hermes copper will occur. Many seemingly suitable sites are not occupied. These sites may simply be unoccupied as an accident of history, but the possibility that other factors are at work cannot be eliminated. It is also not clear if the distribution of California buckwheat and other nectar sources impact behavior.

E. **Climatic Conditions**
Spring rainfall, temperature regimes, and other factors seem to influence annual population sizes and emergence. They may also represent important factors when considering the potential influence of climate change on the species.

F. **Undiscovered Populations and Corridors**
Undiscovered populations of Hermes copper likely exist, especially on private property. In addition, what constitutes a movement corridor in not yet understood. Defining potential corridors can be based on genetics work and the study of dispersal behavior.

Management Actions

The working group also suggested exploring the following management actions. Some of these are contingent upon biological uncertainties being resolved prior to implementation.

G. **Fire Management**
Fuel breaks, fire suppression, fuel manipulation, weed abatement, and other measures to protect occupied spiny redberry stands (such as reducing the risk of ignitions due to recreation) from fire in the short term.

H. **Habitat and Corridor Enhancement**
Selection of strategic areas and corridors for enhancement in order to facilitate dispersal throughout its range. This could also include prioritizing certain areas for conservation to ensure that suitable habitat is within reach of dispersing individuals.

I. **Assisted Dispersal/Translocation**

Perform controlled reintroduction to previously occupied sites extirpated by wildfire if natural dispersal is inadequate.

J. **In Vitro Rearing**

Rearing of Hermes copper for release and preservation of genetic diversity, similar to the Quino checkerspot (*Euphydryas editha quino*) butterfly program. This may become necessary if the species declines further or if assisted dispersal becomes necessary.

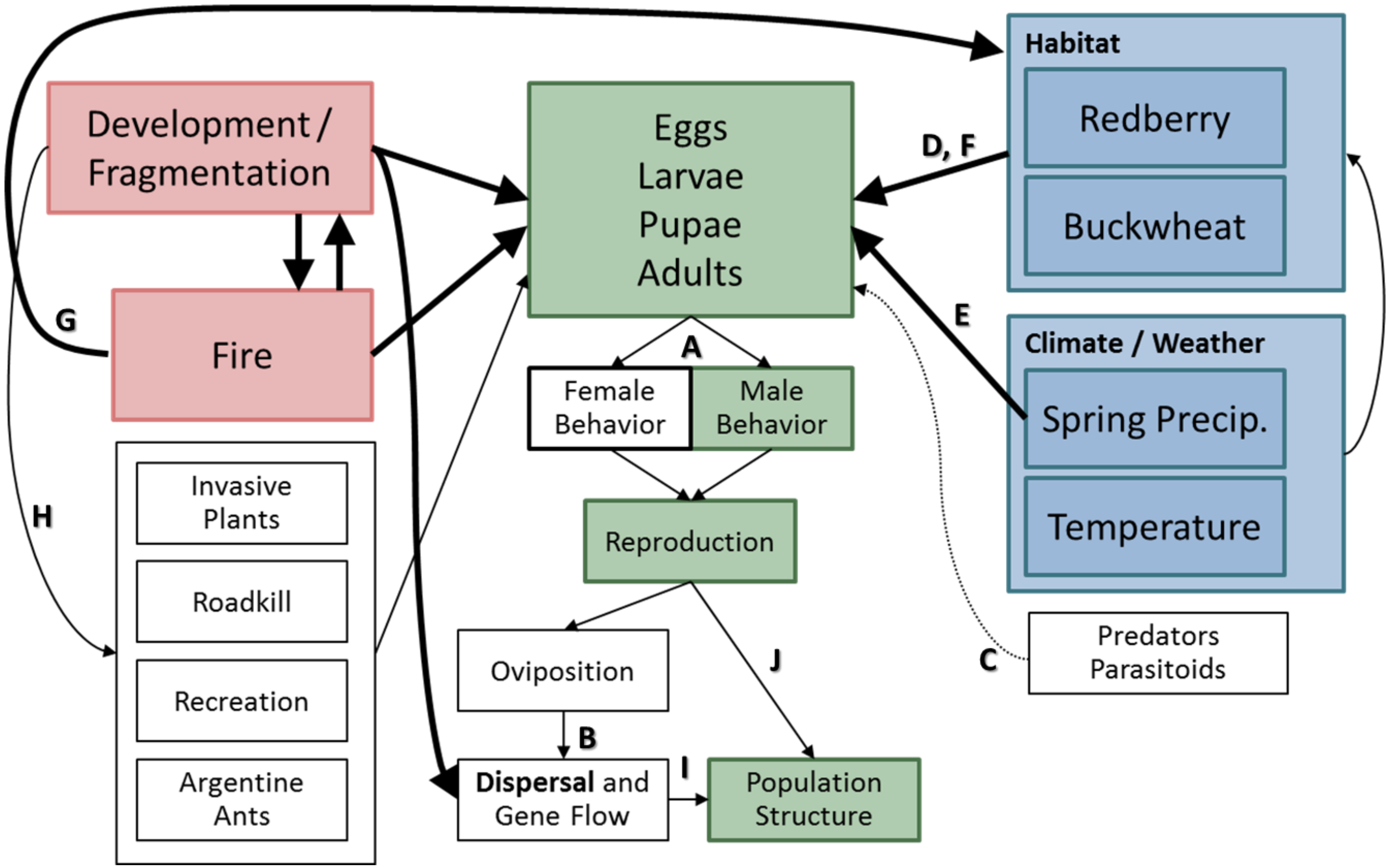

Figure 2: Hermes copper conceptual model.

Adult Surveys

This portion of the project focuses on monitoring daily adult numbers (predominately males) as an indicator of relative population size at discrete spiny redberry patches over time. This technique is also used to assess additional locations for presence of Hermes copper (Conceptual Model Biological Uncertainty F, Figure 2).

Surveys in 2010 and 2011 allowed us to confirm that Hermes copper populations are concordant in terms of relative abundance from year to year. Small populations tend to stay small and large populations tend to stay large, but the absolute population size can fluctuate. However, there are sites with seemingly suitable habitat that are not occupied by Hermes copper. These results have implications for deciding how to allocate efforts concerning Hermes copper monitoring. The probability is low that Hermes copper will appear at sites which have been unoccupied for consecutive years. As a result it is important to evaluate the cost/benefit of revisiting these sites. The same is true with large, robust populations. Since the same relative population size persists year after year, monitoring a subset of those large populations in order to track long-term trends may be adequate, and can be supplemented with occasional range wide checks every few years.

The status of very small populations, with only one or two individuals, is less clear, especially if site occupancy has changed from one year to the next. Data from additional years are required to develop a better understanding of the population dynamics within these smaller populations. It could mean that small populations are hard to detect. This issue relates to several biological uncertainties from the conceptual model (Figure 2) including: (B) Could other individuals be present, but in diapause? (D) What causes similar sites to support vastly different numbers of Hermes copper? (E) What role do environmental and climactic conditions play on emergence?

In order to address these questions we took a two-pronged approach to field surveys this year. We designated three long-term sentinel sites (Lawson Peak, Roberts Ranch North, Sycuan Peak) which have reliably large populations, are located in different regions of the Hermes copper distribution, and can be surveyed efficiently (Table 2, Figure 5). In addition, these sites are widely separated within the Hermes copper distribution to reflect any differences in microhabitat conditions as well as to minimize the chances that all three local populations are extirpated by a single wildfire. These sentinel sites were surveyed once a week from the beginning to end of the flight season, in order to provide trend data. We also identified small sites whose status was unclear and sampled those twice a week (Elfin Forest, Lopez Canyon, Meadowbrook, Mission Trails). All other previously occupied sites as well as new sites were sampled as frequently as possible to obtain genetic samples for the landscape genetic portion of the project. Finally, we did not survey at sites that were unoccupied in both 2010 and 2011 to allocate time to focus on other questions (Table 2).

In 2012, the flight season began on 29 May, with three individuals at Lawson Peak. The flight season was relatively short, peaking during the week of 11 June. County wide the number of Hermes copper adults started low, increased rapidly, and began to decline in the fourth week (Figure 3). Once populations began to decline we discontinued our surveys at the sites with the small populations and focused on reproduction and rearing objectives at larger sites.

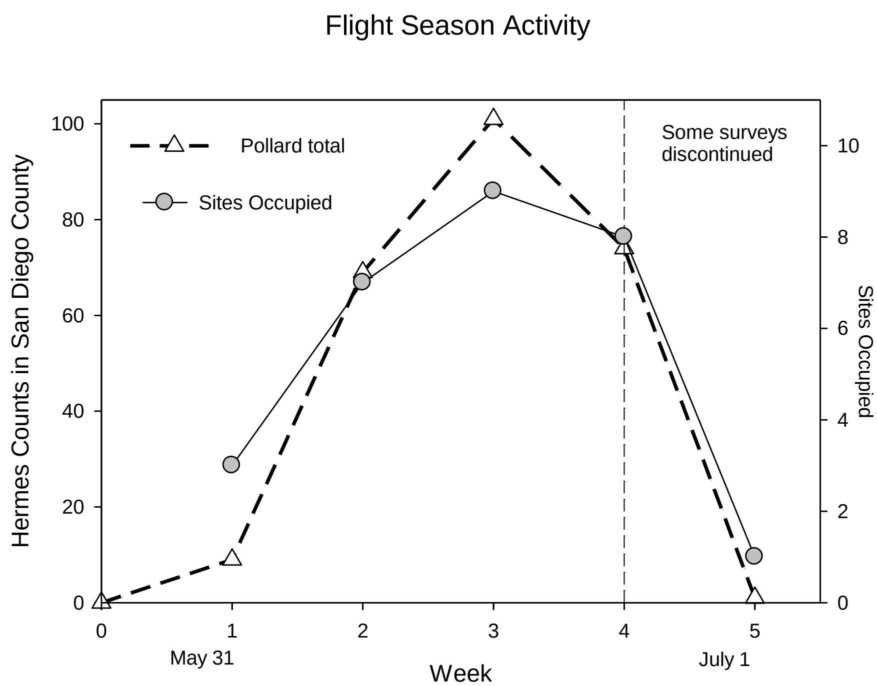

Figure 3: Number of Hermes copper adults observed during the 2012 flight season at all monitored sites.

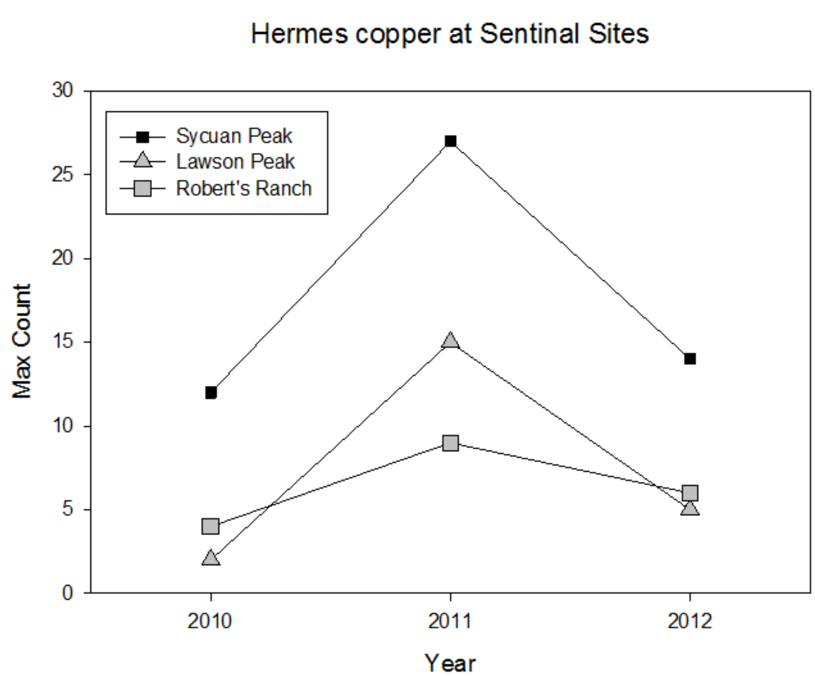

Figure 4: Temporal variability of Hermes copper at sentinel sites.

Table 2: Number of visits and maximum counts for three years of Hermes copper surveys.

Sites with at least one Hermes copper adult detected	2010 Visits	2010 Max	2011 Visits	2011 Max	**2012** Visits	**2012** Max
Skyline Truck Trail Total	15	9	.	.	**7**	**21**
Skyline Truck Trail 1	15	9	.	.	**7**	**7**
Skyline Truck Trail 2	.	.	.	.	**2**	**12**
Skyline Truck Trail 3	.	.	.	.	**2**	**10**
Boulder Creek	.	.	.	.	**7**	**18**
Sycuan Peak **(sentinal)**	9	12	5	27	**8**	**14**
Sycaun Peak extra routes	.	.	17	27	**.**	**.**
McGinty Mountain ***	7	26	10	27	**10**	**8**
Roberts Ranch North **(sentinal)**	4	4	7	9	**4**	**6**
Potrero Peak	.	.	.	.	**2**	**6**
Lawson Peak **(sentinal)**	4	2	5	15	**6**	**5**
Loveland Reservior	5	3	5	10	**4**	**4**
California Riding & Hiking Trail	4	2	5	2	**3**	**1**
Los Montanas South	4	1	4	3	**2**	**0**
Elfin Forest	3	0	3	1	**6**	**0**
Lopez Canyon	.	.	2	5	**7**	**0**
Wildwood Glen	5	1	6	2	**3**	**0**
Los Montanas North	4	3	4	1	**3**	**0**
Meadowbrook	3	0	4	1	**6**	**0**
Mission Trails	4	1	3	0	**7**	**0**
Wrights Field	3	4	5	3	**1**	**0**
Loveland Extension	4	1	5	1	**5**	**0**
Sites with no Hermes copper adults detected	2010 Visits	Max	Visits	Max	Visits	Max
Anderson Truck Trail	2	0	2	0	**1**	**0**
Barrett Lake	3	0	3	0	**.**	**.**
Bette Bendixen Park	3	0	3	0	**.**	**.**
Black Mountain	7	0	3	0	**.**	**.**
Cowels Mountain	4	0	3	0	**.**	**.**
Crestridge	4	0	5	0	**1**	**0**
Damon Lane	3	0	2	0	**.**	**.**
Dawson Drive	4	0	3	0	**.**	**.**
Dictionary Hill	.	.	2	0	**.**	**.**
Flynn Springs	2	0	2	0	**.**	**.**
Guatay Mountain	2	0	1	0	**.**	**.**
Hollenbeck Canyon	2	0	2	0	**.**	**.**
Jesmond Dene park	3	0	3	0	**.**	**.**
La Jolla Canyon	2	0	.	.	**.**	**.**
Lake Jennings	.	.	1	0	**.**	**.**
Marron Valley	1	0	1	0	**.**	**.**
Mendocino	.	.	3	0	**5**	**0**
Rancho Jamul	1	0	2	0	**.**	**.**
Rancho San Diego	3	0	2	0	**.**	**.**
Saber Springs Parkway	3	0	3	0	**.**	**.**
Steele Canyon	5	0	3	0	**.**	**.**
Trail 62	1	0	.	.	**.**	**.**
Totals:	148 Visits	78 Max HC	139 Visits	134 Max HC	**98 Visits**	**83 Max HC**

*** McGinty Mountain has several different survey transects that have been surveyed at different intervals. For this reason, comparisons at this site should not be made across years.

Sentinel Sites

We designated Sycuan Peak, Roberts Ranch North, and Lawson Peak as sentinel sites and for identifying the peak of the flight season (Figure 4). Sycuan Peak was chosen because it contains the highest density, if not largest population of Hermes copper in the county, and is positioned in the central region of their distribution. Another advantage is that it can be surveyed effectively in half a day. Lawson Peak and Roberts Ranch North, both represent large, consistent populations on the southeast and northeast edges of the species range, respectively.

We have surveyed these three sentinel sites for the last three years, allowing for year-to-year comparisons using maximum count as an index of population size (Table 2). The population of Hermes copper fluctuates year to year, but there appears to be a high level of concordance across all sights. As a result using a few sentinel sites to monitor trends in Hermes copper population size is a cost effective approach to understanding the relative number of adults present in a given year. Thus far 2011 seems to have been the most favorable of the three years in this study. We are emphasizing the use of maximum counts because this index is less sensitive to sampling effort compared to summed counts (Pollard Index).

Smaller Populations

Over the last three years, several populations on the northern portion of the Hermes copper distribution have shown a single butterfly on one or two occasions in the same year, but no butterflies in another year (Table 3). It is unclear whether adults do not emerge in these populations every flight season, or if the small population size results in low detection rates. This was particularly surprising at Lopez Canyon which had a maximum count of five in 2011 but none in 2012.

We cannot conclude that Hermes copper has been extirpated from small sites given only a few years of data. Further study at these sites is warranted as they could represent important refugia outside of the region with the larger populations.

Table 3: Annual coherence at sites with small populations.

		Max Count		
Sites	Visits	2010	2011	2012
Elfin Forest	6	0	1	0
Lopez Canyon	7	.	5	0
Meadowbrook	6	0	1	0
Mission Trails	7	1	0	0

New Sites

We conducted surveys for spiny redberry and Hermes copper at several additional sites in 2012 (Conceptual Model Biological Uncertainty F, Figure 2). The two sites (Potrero Peak and Boulder Creek

Road) that had spiny redberry present both had Hermes copper. The Boulder Creek Road location burned in 2003 and there were reports of Hermes copper present in 2011 (Jennings pers. com.).

Table 4: New sites checked for spiny redberry and Hermes copper.

Location	Hermes habitat present
Kit Carson Park	NO: California buckwheat, but no spiny redberry
Double Peak Regional Park	NO: *Ceanothus* chaparral, no spiny redberry
Guajome County Park	NO: Limited native habitat, no spiny redberry
Brengle Terrace Park	NO: Highly developed, no native habitat
Potrero Peak	YES: Spiny redberry present
Boulder Creek Road	YES: Spiny redberry present and Hermes copper reported

Potrero Peak is located near the intersection of State Routes 94 and 188, near the town of Potrero. Over the course of two visits we identified six individual Hermes copper butterflies, on the north side of the mountain. It is relatively isolated from other Hermes copper populations in San Diego.

Boulder Creek Road north of Descanso was occupied prior to a wildfire in 2003. Since then biological consultants have reported a few individuals in the area. In 2012 we added Boulder Creek Road to our survey routes and had 54 Hermes copper observations—representing one of the largest populations. Boulder Creek Road could also be used as a sentinel site due to its relatively large population size and position in the landscape (well separated geographically from other populations). Several individuals were observed nectaring on *Helianthus gracilentus*.

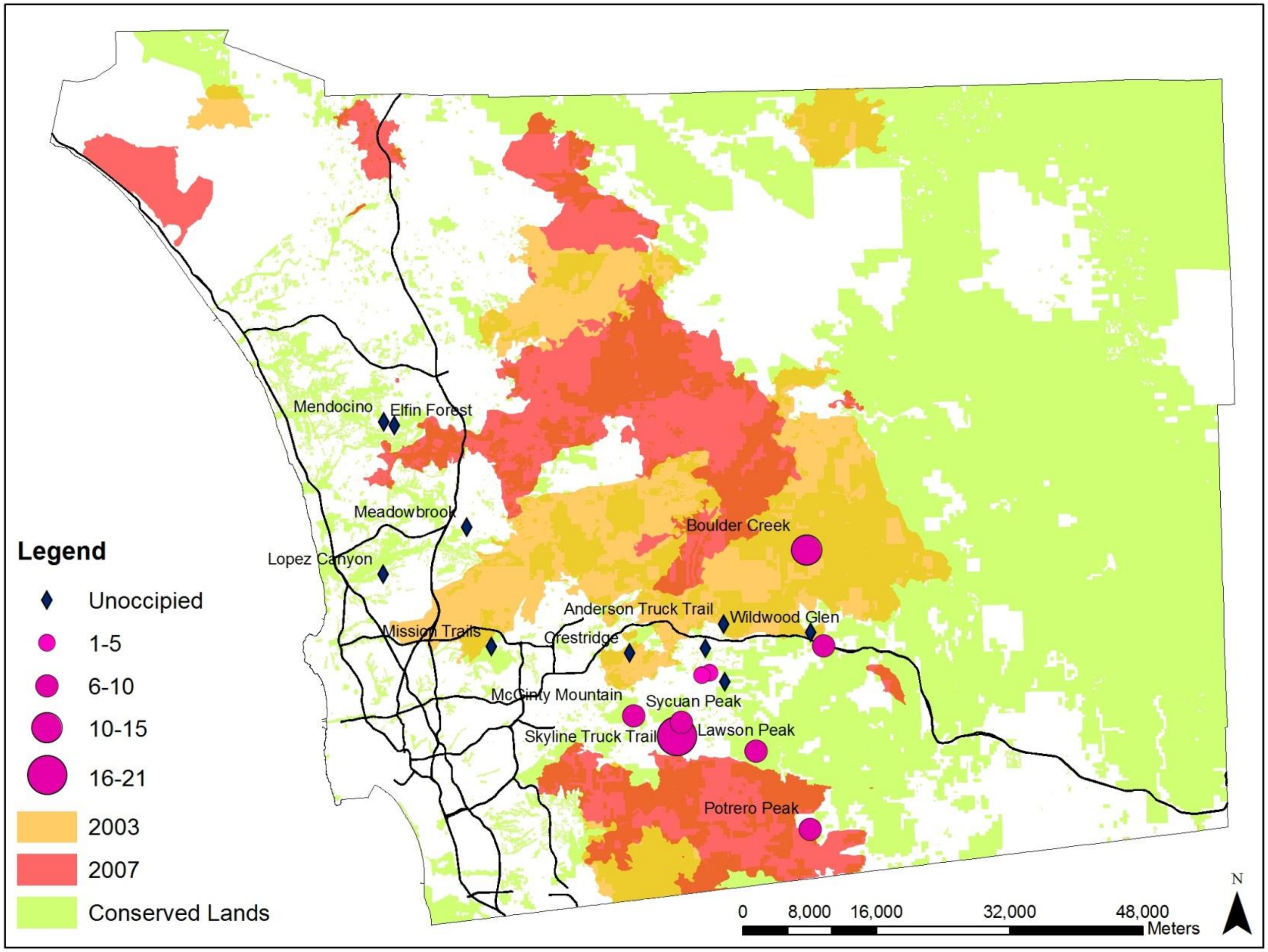

Figure 5: Map of locations surveyed for Hermes copper in 2012, with maximum count of adults observed.

Landscape Genetics

Landscape genetics allows us to evaluate gene flow, and therefore connectivity among local populations/habitat patches (Conceptual Model Biological Uncertainty A, Figure 2). It also provides baseline data so that future work can investigate any changes in genetic variation, potentially due to Allee effect, inbreeding, or genetic bottleneck, or genetic composition potentially due to changes in dispersal patterns (Conceptual Model Management Action I). Integrating the genetic data with natural history and landscape features will identify factors important for the persistence of the species and development of informed conservation and management planning (Conceptual Model Management Action H and I).

Earlier work on landscape genetics were limited in sample size due to low populations of Hermes copper (Deutschman et al. 2010, 2011; Marschalek and Klein 2010) and concern over lethal sampling. However, our recent work has shown no measurable impact of removing a single leg from adult butterflies to obtain a non-lethal genetic sample (Deutschman et al. 2011). This technique allowed us to increase sampling across San Diego in 2012. As a result, the increased sampling allows for a more complete description of the Hermes copper genetic population structure, with the goal of making inferences about dispersal (gene flow).

Methods

We obtained a total of 321 specimens over the course of 2003-2012. Of these, 200 specimens were collected in 2011 or 2012 and were not included in previous analyses (Deutschman et al. 2010, 2011). To evaluate genetic variation and assign individuals to genetic clusters, 204 amplified fragment length polymorphism (AFLP) markers were used.

AFLP has the ability to detect genetic variation at the level of individuals for this population-based study (Vos et al. 1995). We used the trace analysis program DAx 8.0 to visualize the allelic data; AFLP-SURV (Vekemans 2002, Vekemans et al. 2002) to calculate expected polymorphic loci and heterozygosity; and Geneland (Guillot et al. 2005) to investigate spatial genetic structure. We utilized DAx 8.0 to automatically determine the presence or absence of AFLP markers using a threshold value for the trace signal versus noise level of 4.0.

We used GENELAND 4.0.2 (Guillot et al. 2005) to determine clusters of related genotypes using both a non-spatial and spatial model. The non-spatial model only uses genetic information to cluster individuals. The spatial model incorporates both genotypic and spatial data by spatially correlating genotypes and is more biologically realistic (assumes individuals in close proximity tend to be more similar genetically). In comparison to traditional F_{ST} analyses, GENELAND identifies genetic clusters of individuals using genotypes without predefining groups, eliminating potential biases. Moreover, sites where only one individual was sampled can be used in GENELAND.

Results

We calculated basic genetic statistics for the species (all samples). Of the 204 AFLP markers, 90 (44.1%) were polymorphic. The expected heterozygosity calculated from these markers was 0.1299 (SE =

0.0106). While these values are difficult to interpret by themselves, they can be used as a baseline to investigate changes over time.

The non-spatial analysis assigned all individuals to the same cluster for all ten variable K runs. For this reason, we did not run models with a fixed number of genetic clusters. The spatial model identified nine genetic clusters (Figure 6). The dendrogram provided the ability to evaluate substructure (subclusters) within each genetic cluster (Figure 7-13). There were two cases when all individuals from a particular sampling location were more often clustered with each other than with any individual from other locations. These individuals were from Meadowbrook Ecological Reserve and Mission Trails Regional Park (Figures 8 and 9, respectively). Individuals from Boulder Creek Road (Figure 13) showed the greatest genetic differentiation from all others with the exception of one individual (Figure 10). This individual tended to cluster with individuals from several sampling locations.

Besides individuals from these three locations, all other individuals were more frequently assigned to the same genetic cluster with those from different sampling locations. This resulted in individuals from several different sampling locations consistently clustering together. It also includes cases when a subset of individuals from a particular location clustered together frequently, but others from the same location were more often assigned to a separate cluster. For example, of seven individuals from Loveland Reservoir, three always clustered together (Figure 10) and four others nearly always clustered together (Figure 12). However, instances of assignment to the same genetic cluster were relatively infrequent, indicating genetic differences exist between these two groups. This is also seen with individuals collected from Skyline Truck Trail, Roberts Ranch North, and Sycuan Peak.

There were two cases when individuals collected from a single location over two or more years were placed in two different groups, and each group contained individuals from different years. Individuals from Wildwood Glen in 2003-2010 (Figure 9) were more differentiated from to those collected in 2011 (Figure 10) and individuals collected from Skyline Truck Trail in 2008-2010 (Figure 9) were differentiated from those collected in 2012 (Figure 10-11).

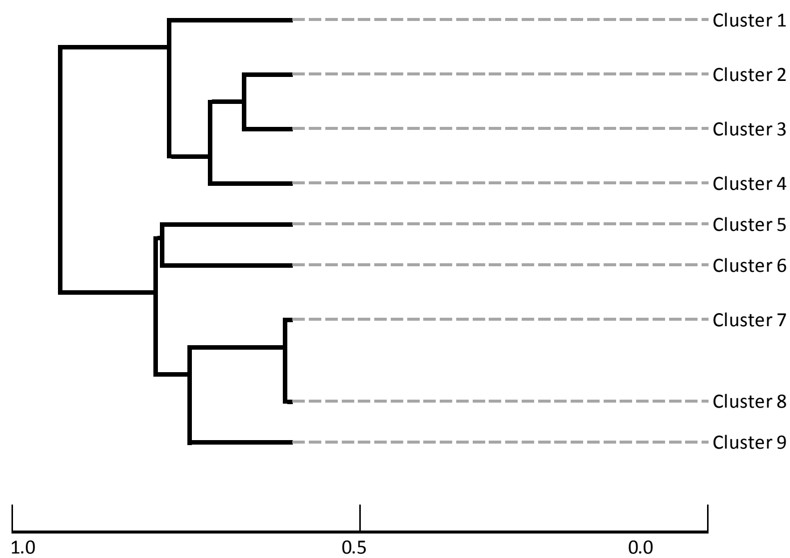

Figure 6: Dendrogram showing relative difference of GENELAND genetic cluster assignments among Hermes copper individuals. Branching at 1.0 would represent individuals never assigned to the same genetic cluster while individuals sharing a branch at 0.0 were always assigned to the same genetic cluster. The dashed lines represent collapsed branches.

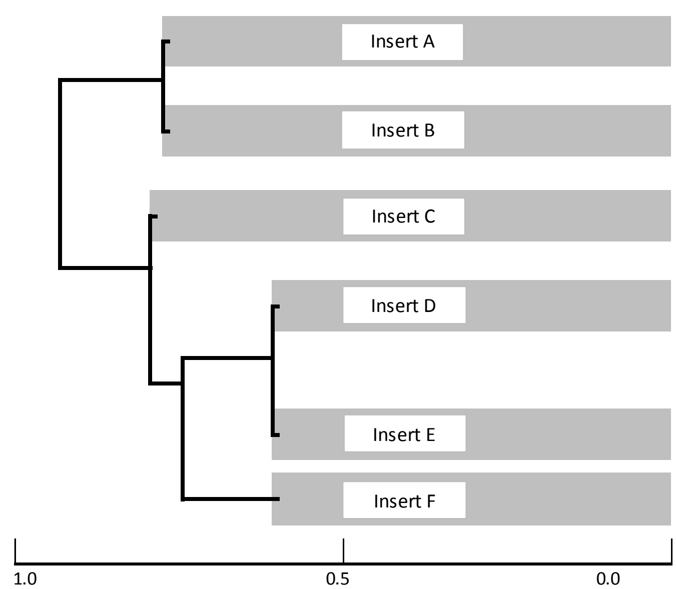

Figure 7: Dendrogram showing relative difference of GENELAND genetic cluster assignments among Hermes copper individuals. Branching at 1.0 would represent individuals never assigned to the same genetic cluster while individuals sharing a branch at 0.0 were always assigned to the same genetic cluster. Within the inserts, the sampling location name is provided along with the specimen numbers at that location. This is the same dendrogram as Figure 1, but showing the hierarchical relationship among all Hermes copper samples.

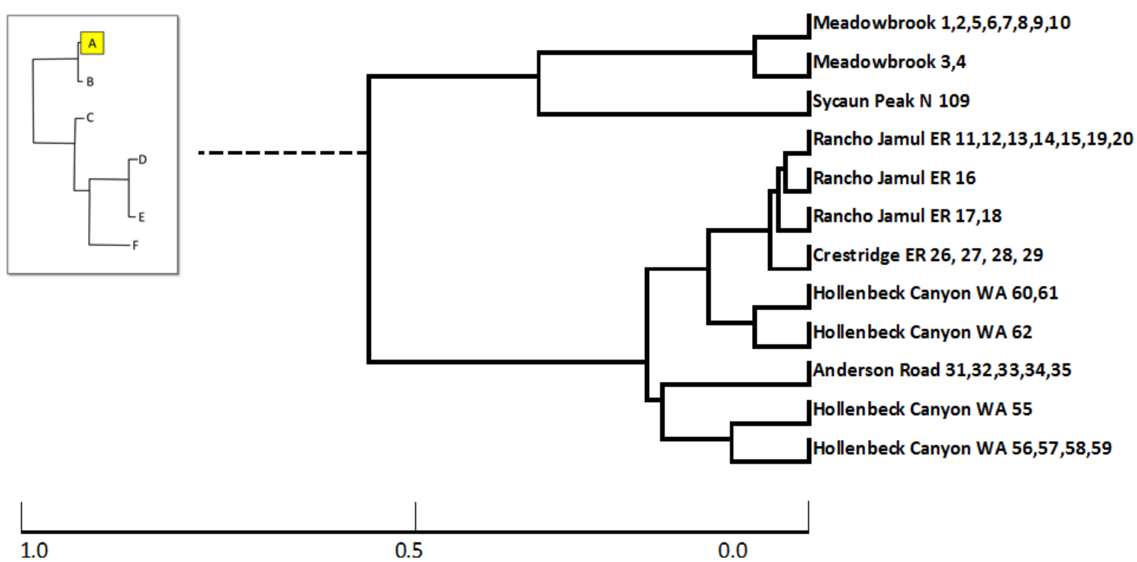

Figure 8: Group A detail. Note the tight cluster of all individuals from Meadowbrook Ecological Reserve.

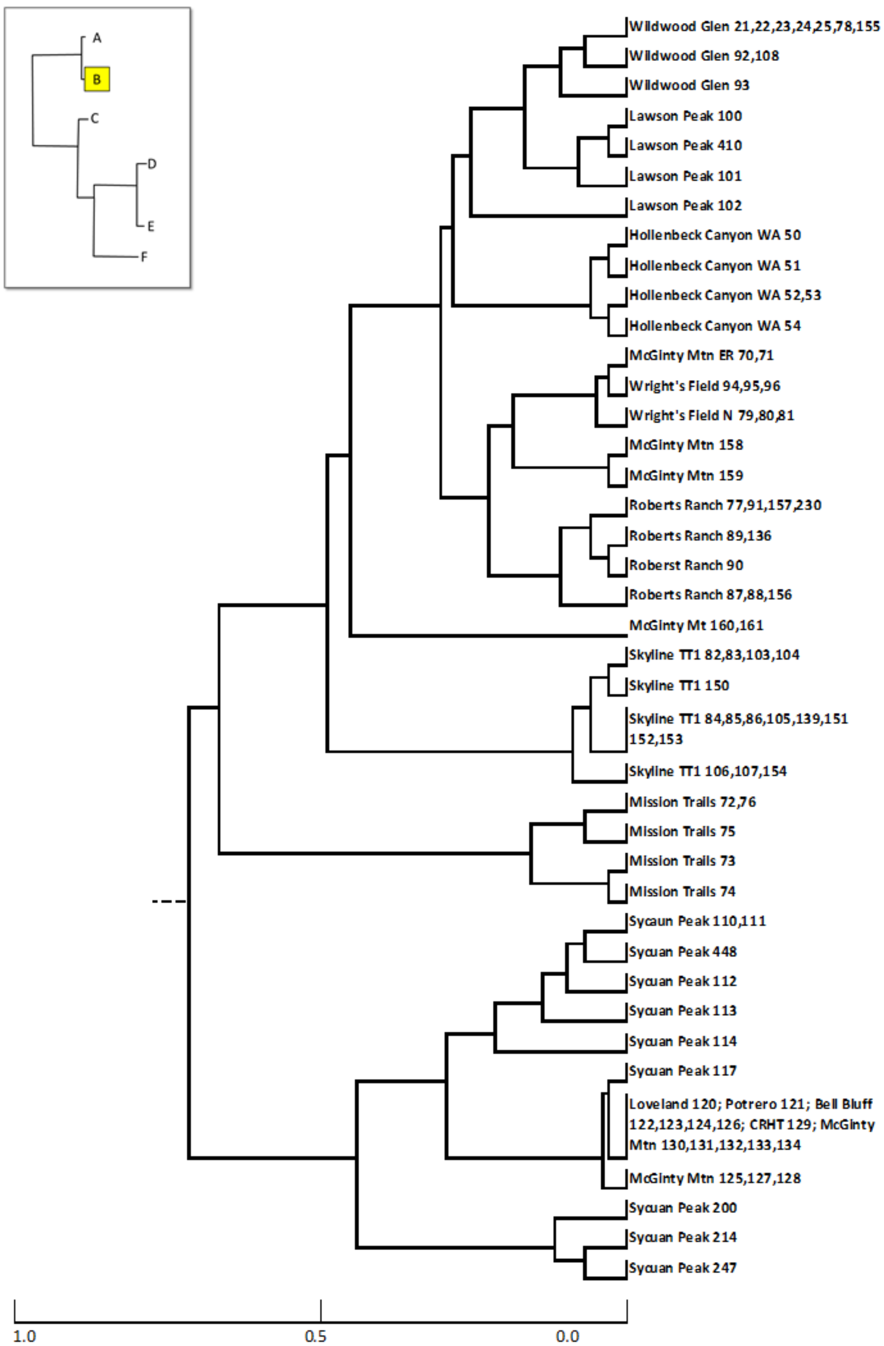

Figure 9: Group B detail. Note the clustering of all individuals collected at Mission Trails Regional Park. The grouping from Wildwood Glen is from 2003 and clustered separately from individuals collected from Wildwood Glen in 2011 (depicted in Figure 10).

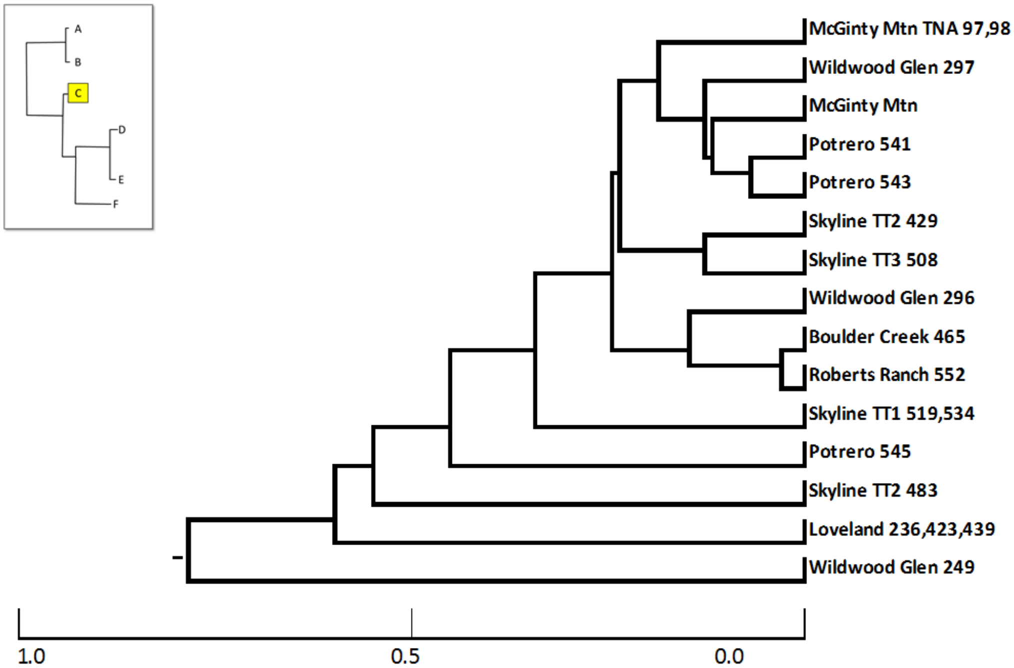

Figure 10: Group C detail. The single individual from Boulder Creek Road shown here is the only individual that did not cluster with the others from that site (Figure 13). Individuals from Loveland Reservoir are clustered here and in Figure 12. The individuals from Wildwood Glen depicted here were collected in 2011 and clustered differently from those collected in 2003-2010 (Figure 9). Likewise the individuals from Skyline Truck Trail shown here were collected in 2008-2010 and clustered differently than those collected in 2012 (Figure 11).

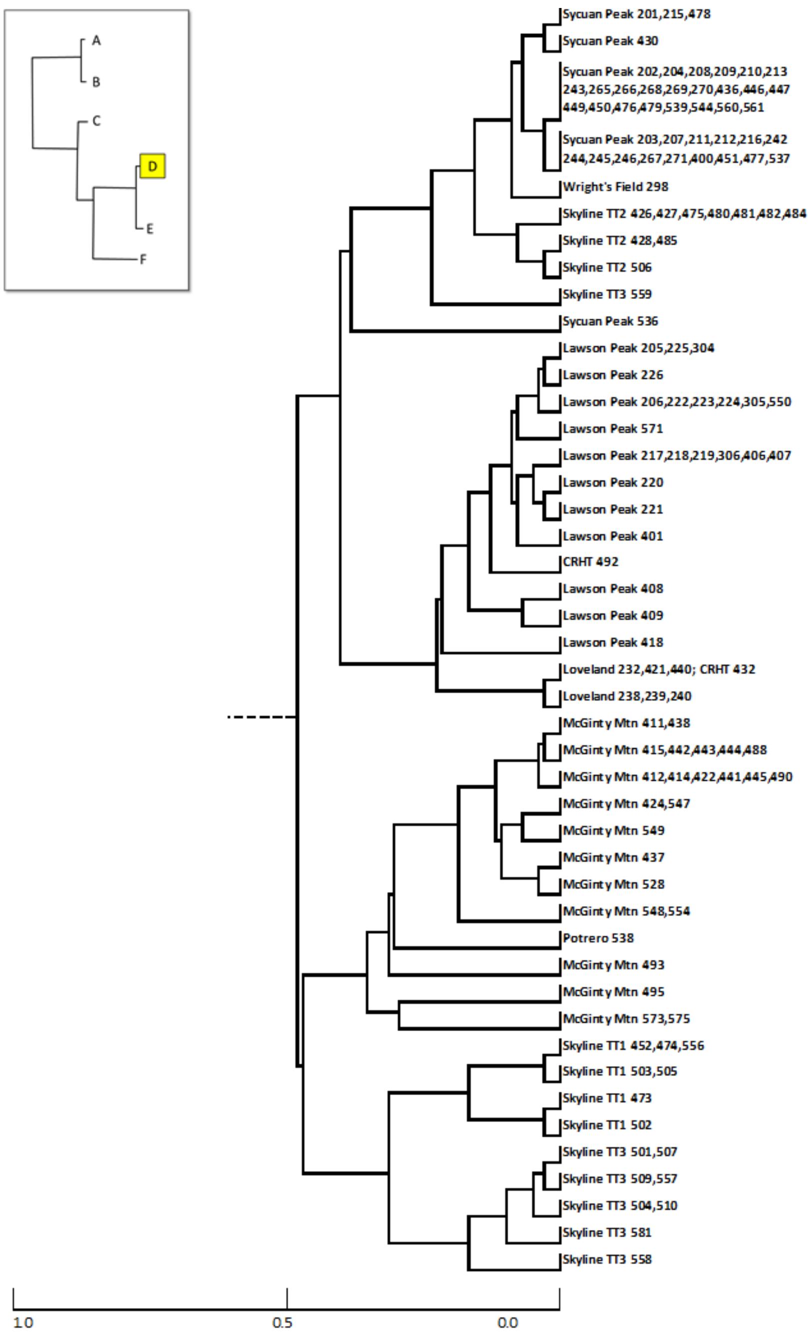

Figure 11: Group D detail. Individuals from Skyline Truck Trail collected in 2012 clustered differently from those collected in 2008-2010 (Figure 10).

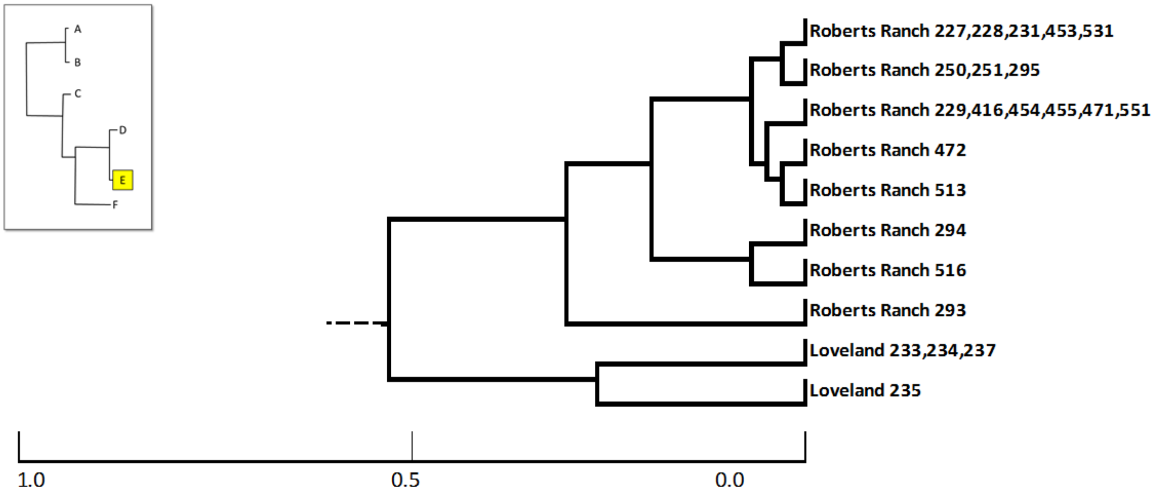

Figure 12: Group E detail. Individuals from Loveland Reservoir cluster here and in Figure 10.

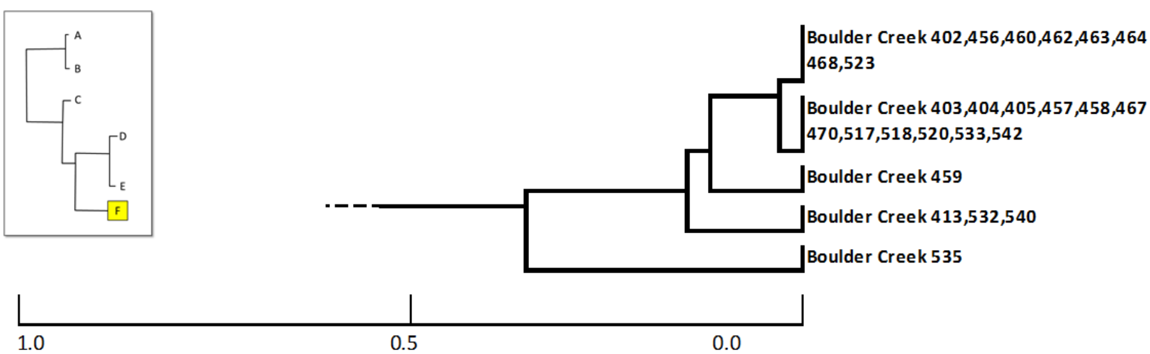

Figure 13: Group F detail. Most individuals from Boulder Creek Road segregated into this cluster. Only one individual belongs to a separate genetic cluster shown in Figure 10.

Discussion

Lack of genetic differentiation as shown by the non-spatial model is not surprising due to the small geographic scale of the Hermes copper distribution in the United States. Genotypes alone, even with 204 AFLP markers, did not provide enough information to establish statistical power needed for multiple genetic cluster assignments in the absence of spatial information.

In contrast, the GENELAND spatial model can detect weak population structure by including spatial information (Guillot et al. 2005; Coulon et al. 2006) and was able to identify genetic discontinuities in Hermes copper. Differences between the two models indicate that most Hermes copper individuals were very similar genetically. These results produced similar patterns of genetic clustering as was seen in previous years with a smaller sample size (Deutschman et al. 2010, 2011).

The peripheral sampling locations of Boulder Creek Road, Meadowbrook Ecological Reserve, and Mission Trails Regional Park exhibited greater genetic differences compared to the other individuals. Peripheral populations often exhibit increased genetic differentiation when compared to the core area of a species, but not always (Eckert et al. 2008). For example, this pattern was not present when considering individuals collected in the Potrero area, as they were most similar to individuals from several areas such as Wildwood Glen, Skyline Truck Trail, and McGinty Mountain.

Individuals from the same sampling location being assigned to different genetic clusters provide evidence for the ability of Hermes copper to disperse between these locations. This was observed for individuals collected in a relatively undisturbed portion of the landscape from McGinty Mountain east to Sycuan Peak and Lawson Peak. The lack of geographic correlation with genetic clusters, and the first post-fire recolonization event (Wildwood Glen) detected in this area, suggests that Hermes copper is able to move around this part of the landscape at a higher rate than other areas.

The only other post-wildfire recolonization event observed was at Boulder Creek Road, about 5,800 meters to the fire perimeter and 11.3 kilometers to the nearest known Hermes copper population (Roberts Ranch North). We are less familiar with this area, particularly in regards to the impact of the recent wildfires. The distance from the fire perimeter suggests that Hermes copper is able to move around this part of the landscape at a higher rate than other areas. However, it is possible that a refuge from the wildfire allowed a local population to survive. This hypothesis is supported by the higher level of genetic differentiation observed with individuals from this sampling location, and would tend to support that recolonizing individuals originated from locations outside the central area. In addition, our genetic analyses indicated there are not high dispersal rates between Boulder Creek Road and these locations.

Increasing sampling locations appears to have increased the incidences of isolation-by-distance patterns, resulting in a hierarchical pattern of genetic differences compared to Deutschman et al. (2011). This resulted in more individuals showing variation in cluster assignment, contrasting with longer branches representing higher levels of genetic differentiation. The identification of well-defined genetic clusters is less apparent. Instead we recommend interpretation be based on the hierarchical relationships. We are attempting to develop a technique to assess the variability associated with dendrogram branching as the computing power of GENELAND runs is intensive and can be limiting. This includes recent updates to GENELAND that may assist with cluster assignment consistency (Guillot 2008) and running many more model replicates.

There is some evidence for temporal separation between individuals, however this may be a result of sampling in different areas in different years. Most of the samples collected in 2003 were more frequently clustered with each other than with those collected in subsequent years. We are unable to resample at these locations because Hermes copper was extirpated by wildfires (Marschalek and Klein 2010). Individuals from Wildwood Glen and Skyline Truck Trail exhibited changes in genetic composition among individuals over eight and three years, respectively. The Wildwood Glen change is likely due to recolonization after wildfires extirpated the local population. More surprising is that the genetic composition of those butterflies from Skyline Truck Trail also demonstrated a change but without an evident explanation. Relatively small sample sizes limit conclusions we can make from these sites.

Conclusion

By adding nearly 200 additional samples to our previous analyses (Deutschman et al. 2010, 2011), we were able to develop a more comprehensive perspective of the genetic characteristics of Hermes copper in San Diego County, while clarifying a number of critical uncertainties as defined by the conceptual model. Individuals were genetically similar to each other, with peripheral portions of the distribution containing most of the differences. This provides evidence that Hermes copper can disperse across much of the landscape, which was not suggested by Thorne (1963) or detected by small-scale marking studies (Marschalek and Deutschman 2008; Marschalek and Klein 2010).

These genetic 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. Much of San Diego's development in the north and east sections of the county is recent. Understanding the historic genetic structure and underlying processes within the species provides important information for guidance of future conservation management and planning. Equally important is to understand how these processes are currently shaping the species. Without massive marking efforts to describe movements across the landscape, recolonization following wildfires provides a means to assess contemporary movement patterns. However, this is limited to areas impacted by fires and the potential source populations for dispersers. For example, reintroductions at previously occupied sites in the central area may be a viable option (Conceptual Model Management Action I) without risk of introducing inappropriate genetic stock, whereas the same action near peripheral populations may require more research.

Our genetic analyses indicate that historical dispersal patterns allowed Hermes copper to move among spiny redberry patches throughout much of its San Diego County range, otherwise wildfires would have eventually led to enough local extirpations to cause extinction of the species. However, recolonization events following the 2003 and 2007 wildfires are rare, suggesting that dispersal is limited. We suggest a comparison of historic versus contemporary ecological factors to help explain this apparent discrepancy. We have observed recolonization within five years of a wildfire (Marschalek and Klein 2010) and historic wildfire regimes included large fires (Keeley and Zedler 2009), suggesting that habitat conditions within spiny redberry patches or the nature of wildfires are not substantially different than in the past. However, the San Diego County landscape has experienced recent fragmentation associated with urbanization and may be limiting dispersal. Unfortunately, historical dispersal data does not exist so the expected length of time for recolonization is unknown.

Egg Biology

We searched for and recorded the position of Hermes copper eggs to help understand oviposition sites as well as larval biology and habitat requirements (Conceptual Model Biological Uncertainties B and D, Figure 2). 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 (Conceptual Model Management Action I and J) and in refining the conceptual model.

Hermes copper butterflies lay 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). Hermes copper overwinter as eggs, with larvae thought to emerge in late spring, and adults generally flying in late May to June.

Methods

Egg searches began in January and continued into February. The field crew was instructed to search entire spiny redberry shrubs, paying special attention to the underside of branches, leaf nodes and branch intersections (Figure 14). 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.

We began follow-up visits in early April to track development of the immature Hermes copper stages. Timing was based on previous research about the life-cycle of Hermes copper (Thorne 1963; Faulkner and Klein 2004). The species is thought to emerge from eggs in late spring, feed for about 10 to 14 days, then 10 to 14 days as a pupa.

Figure 14: Hermes copper egg searches.

Results

Over the course of two months we checked 297 shrubs which resulted in the discovery of six eggs (Table 5), three at Sycuan Peak (Figure 15), two at Lawson Peak (Figure 16), and one at McGinty Mountain (Figure 17). Only two percent of the shrubs were found to contain eggs, providing important information on the level of effort that will be required to perform egg-based research in the future. During our follow-up visits to track the developing immature stages, we found that three of six eggs were empty at the beginning of April. We continued follow up visits on the remaining three eggs once or twice a week until the first adults of the season were spotted.

Table 5: Hermes copper egg location descriptions.

Egg	Shrub Diameter (cm)	Shrub Height (cm)	Height above ground (cm)	Side of Bush	Latitude	Longitude
SYP-1	160	80	31.5	East	32.75439	-116.80572
SYP-2	85	45	20	South	32.7543	-116.80569
SYP-3	117	96	46	East	32.75423	-116.80557
LAW-1	160	133	57	East	32.71375	-116.70577
LAW-2	121	180	39	East	32.71564	-116.70711
MGM-1	305	180	32	West	32.76639	-116.86289
Avg.(stdev)	**158.0 (71)**	**119.0 (47)**	**37.6 (11)**	**--**	**--**	**--**

Sycuan Peak

On 11 January three Hermes copper eggs were found clustered at the top of Sycuan Peak, with each egg on a different shrub and separated by at least 10 meters (Figure 15, Table 5). All other shrubs in the area were searched on the same day with no additional eggs located. Egg A was on the east side of the shrub, egg B on the south side and egg C on the east (Figure 5). All of the eggs were near a branch intersection or (in the case of egg C) a plant node which created a small raised feature. All of the eggs were on the side or downward facing part of the branch.

When these eggs were checked again on 16 April, one was empty with a circular hole in the center of the egg (Figure 15A), one was still intact (Figure 15B), and one had been perforated on the side (Figure 15C). Egg B was checked weekly until 29 May when the flight season began, but never hatched or showed signs of change.

Figure 15: Images of Sycaun Peak eggs.

Lawson Peak

Two eggs were found at Lawson Peak on separate dates (Figure 16). Unlike Sycuan Peak, these eggs were not especially close together, separated by approximately 250 meters. Both were on the uphill (west) side of the dirt road, and on the east side of the shrub (Table 5). The first egg (A) was discovered on 13 January. It was located near on the underside of a branch intersection (Figure 16). By the 12 April it too had a circular hole in the center of the egg. The second egg (B) on Lawson Peak was found on the 19 January, under a leaf node. This egg was smaller than the other eggs which were found. The egg was visited weekly or biweekly until the beginning to the flight season and did not appear to change throughout this period.

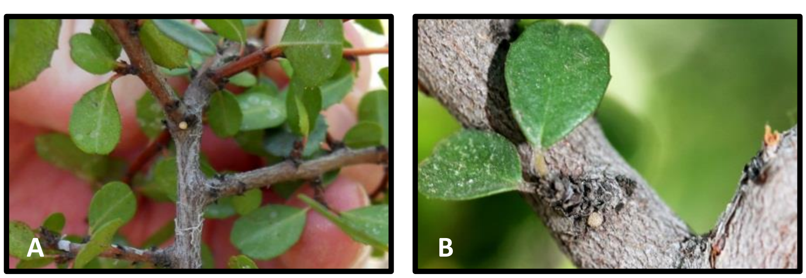

Figure 16: Images of Lawson Peak eggs.

McGinty Mountain

The last egg was found on the northwest plateau of McGinty Mountain on 6 February (Figure 17). It was located on the west side of the shrub, and unlike the other eggs it was not located against a branching point or other structure (Figure 17). In addition it was placed on a vertical branch, which therefore has no underside. At the time of the first observation it had a dark patch on the west facing side of the egg. Our first follow-up visit was on 17 April. We continued weekly and bi-weekly visits until the start of the flight season and the egg never appeared to change.

Figure 17: Image of McGinty Mountain egg.

Summary

Three of the six eggs located were empty by mid-April, two with a strikingly similar hole in the center of the egg. When referenced against pictures of hatched Hermes copper eggs, this appears to be a characteristic pattern for hatching. The damage to the side of one egg at Sycuan Peak could be due to predation or parasitoids, but further studies are required, especially parasitoid species. The other three eggs did not change noticeably in appearance and remain un-hatched. These eggs may be in diapause, waiting to hatching when conditions are optimal. Alternatively, they may be infertile. Continued monitoring of the three un-hatched eggs may offer support for one of these hypotheses. We recommend continuing egg searched in 2013 to increase the sample size and further investigate potential parasitoids/predators and larval requirements.

Information relevant for the future study of Hermes copper eggs includes:

- Oviposition sites tend to be on the underside or sides of branches.
- Oviposition sites are generally close to the ground.
- Eggs are generally on small sized branches, a few years of age without thick, fully grey bark.
- Eggs are often positioned against small protrusions or intersections on branches.

Eggs were rarely encountered during our searches. Not all eggs hatched. This may indicate that Hermes eggs may be capable of multiyear diapause. Importantly these data suggest that, larvae emerge earlier than previously thought.

Female Behavior

Hermes copper females are not easily distinguishable from males, but with close inspection the swollen abdomen of females can be observed. This detail requires the observer to be in close proximity to the butterfly, but care must be taken to not spook the butterfly as this will influence its behavior. In addition, females will generally leave the immediate area after being spooked. Following Hermes copper females is known to be difficult (Marschalek 2004). We were able to observe basking behavior which seems to be fairly consistent for most individuals regardless of sex.

Mating/Courtship

On 19 June at Sycuan Peak we were able to observe a mating event as well as what appeared to be the preceding courtship. A very orange individual flew at a height of about two to three meters on occasion and would leave the road and circle over the adjacent vegetation, repeating this flight pattern several times. A second, less orange individual was observed a couple times when the first individual was circling over the vegetation. This was in a location of a territorial male. Eventually the first orange individual flew down the road past the typical perch location of a male. The second less orange individual flew out towards the orange individual and they commenced to fly in a tight circle (about 20 centimeter diameter) from the trail and through a generally open area in the vegetation. In a couple seconds after catching up to the pair, both were fluttering their wings and landed on a shrub. Within 10 seconds of landing on the shrub they were mating. The pair remained attached by the tips of their abdomens for the entire 25 minutes of observation (observations ended before butterflies separated). During the mating, the pair remained basically motionless with the exception of after 10 minutes the male walked up to be nearly side-to-side with the female (Figure 18). This also put the male in more sunlight. The female had a very swollen abdomen.

A similar event earlier was observed during the same survey. A very orange individual flew extremely fast down the road past a perched male. Returning to the location where the male was just seen (about 20-30 meters away), the male was not present. About an hour later, presumably the same male was back at this location.

General Behavior

Other observations of females were possible for a short time. One female we observed perched on several different species of plants (Table 6) without nectaring. After about 40 minutes of observation it moved to *Eriogonum fasciculatum* and began nectaring in earnest, ignoring bees and other flying insects competing for the blooms. Informal field observations of other Hermes copper suggest that most butterflies feed after this initial basking period. The female repeatedly opened and closed her wings while feeding. Within 10 minutes of initiating feeding the female made a longer flight over the denser vegetation and could not be followed (Table 6).

A second attempt was made to observe a female, however it immediately made a flight up hill at one of the steepest points on the peak and could not be relocated. Another female was encountered in this area but it also flew too far for continued observations.

Figure 18: Hermes copper mating after observed courtship (female on left, male on right).

Table 6: Record of female behavior prior to longer flight.

Time	Temperature	Dist to trail	Plant Perch	Behavior
9:47	77.5	0m	Dead *Pseudognaphalium californica*	Basking
9:50		0m	*Eriogonum fasciculatum*	Basking
9:52	75.2	5m	*Malosma laurina*	Basking, wings facing north
10:26		10m	*Eriogonum fasciculatum*	Nectaring, hopping from flower to flower
10:28		11m	*Malosma laurina*	Basking
10:29	81.9	12m	*Eriogonum fasciculatum*	Nectaring, wings closed
10:35		12m	*Eriogonum fasciculatum*	Nectaring, wings pulsing open and closed
10:38	80.0	30+m		Flying away

Reproduction

Captive Rearing

Developing a better understanding of larval biology is one research target set forward in the Hermes copper conceptual model (Conceptual Model Biological Uncertainty B, Figure 2). If successful, captive rearing may allow for preservation of genetic diversity (Conceptual Model Management Action J) and production of individuals necessary for release into extirpated habitat (Conceptual Model Management Action I). Due to the annual life-cycle of Hermes copper, this experiment will require a full year so results will not be available until June, 2013.

Methods

To obtain eggs, we collected gravid females from the field and placed them in laboratory cages with clippings of spiny redberry branches and California buckwheat flowers. The selected spiny redberry branches consisted of several branches with growth from earlier in the year, as indicated by greener leaves and reddish bark. These locations of the shrubs appear to be preferred for oviposition (Marschalek and Duetschman 2009). The flowers were included to provide a food source for the female. Cut ends of all clippings were placed into a container of water to prevent desiccation of the plants. These containers were covered with the exception of holes just large enough for the clippings to pass through to prevent the butterflies coming into contact with the water, which would likely result in death. Heat sources were used to maintain the ambient temperature around 27°C which was high enough to easily observe the females being active. Lower temperatures would result in females spending nearly all of the time basking rather than walking on the spiny redberry clippings or feeding on the California buckwheat.

The steps to successfully rear Hermes copper from eggs to adults are based on advice provided by a local lepidopterists (K. Shiraiwa). Because time requirements are not known for each developmental stage, we are employing several treatments. Eggs and spiny redberry clippings were kept at room temperature and humidity until 1 November or 29 November, when roughly half of the eggs from each female on each date were placed into an airtight container and kept at 4°C. We are planning to expose the eggs to room temperatures on three different dates in an effort to induce larval emergence from the egg. These dates will occur on roughly 1 February and 1 March.

Results

We obtained a total of 25 eggs from three females, comprised of 11 eggs from a female from Boulder Creek Road on 14 June, 9 eggs from a female from Roberts Ranch North on 12 June, and 5 eggs from a female from Skyline Truck Trail on 18 June. The eggs are currently stored at 4°C but attempts to break winter diapause will not occur until after the contract period. Results will be reported in the final report for the 2013 field season. Eggs from each female will not be able to address all treatments (6 groups) as one female only oviposited five eggs and we are not separating those eggs which are directly adjacent to each other.

Field Cage Experiment

In order to learn more about potential parasitoids and predators of eggs and larvae (Conceptual Model Biological Uncertainty C, Figure 2) we attempted to obtain several eggs of a known location that would be exposed to natural conditions. This consisted of introducing gravid females to a cage which was constructed around a spiny redberry shrub. If nectar sources were not already rooted in the cage, California buckwheat flowers were placed inside for food. This experiment was conducted at Sycuan Peak and Boulder Creek Road because they are larger populations and should be able to better tolerate capturing of a couple individuals.

Hermes copper butterflies seem to tolerate this treatment, but we were unable to obtain eggs. It is possible that the screening provided too much shade and reduced female activity and future attempts will utilize netting with thinner material. A self-imposed limitation was that females were only kept in cages 24 hours and then released so that they might still oviposit during the following days. This was intended to lessen our impacts on the population.

Conclusion

We based this year's efforts on the Hermes copper conceptual model constructed by experts and professional scientists at an IEMM workshop earlier in the year (Figure 2). We addressed 8 of 10 uncertainties and management actions identified in the conceptual model this year. Although these uncertainties are not fully resolved we have made strides in improving our ability to understand and manage Hermes copper.

- Sex dependent habitat use and dispersal
- Larval biology and secondary diapause
- Predators, parasitoids and other sources of mortality
- Vegetation community structure
- Undiscovered populations and corridors
- Habitat and corridor enhancement
- Assisted dispersal
- In vitro rearing

Adult populations were monitored at three sentinel sites (Sycuan Peak, Roberts Ranch North, and Lawson Peak) to investigate year to year variation. Population numbers (maximum count) were generally moderate when compared to those of 2010 and 2011. As in previous years there was a high degree of concordance in terms of relative abundance at these sites, which continues to validate the use of sentinel sites to monitor the Hermes copper population. We did not detect any adults at smaller populations in the northern portion of the species' distribution, however, and cannot draw conclusions about their status. We also monitored two new sites: Potrero Peak and Boulder Creek Road. Both sites had Hermes copper, and the population at Boulder Creek Road was large compared to the other sites. We suggest adding Boulder Creek Road to the sentinel sites being monitored each year.

In addition to monitoring sentinel sites, we also visited all known populations at least once in order to collect genetic material (Figure 20). Landscape genetics shows that Hermes copper has been able to disperse, at least to some degree, in the core area between Jamul and Descanso in the recent past. Outside of this area with most of the observations, dispersal seems to be reduced, as indicated by genetic differentiation of individuals from peripheral sites. The genetic structure described in this report is likely a reflection of historic processes. However recent changes (e.g. habitat fragmentation) may be altering dispersal and it will require more time for the genetic composition to reflect these changes. Without a large-scale marking study, one way to make inferences about current dispersal is to look at post-fire recolonization, as the slow recolonization process suggests limited dispersal.

Because all Hermes copper individuals are very similar genetically, flexibility exists if translocation projects are initiated. Several sources of individuals exist for reintroductions into previously occupied sites for the central region of the species' distribution. More consideration would have to be given to peripheral populations because of their increased genetic differentiation. A better understanding of habitat requirements is required for translocation of immature stages; however, translocations including gravid females may be less strict as biologists could rely on the butterfly finding the correct microhabitat chose for oviposition. Regardless, initial efforts should be well studied as it is unclear if unpopulated areas are suitable habitat and simply not occupied or if there is something fundamentally different about them that could lead to failure of translocations.

Uncertainty remains concerning female behavior (oviposition) and the requirements for immature stages. Preliminary results indicate that the preferred oviposition site is on the underside of the lower spiny redberry branches on the east side of the shrub. However, we have a small sample size and not all egg placements fit this description. It is important to note that it appears that larvae emerge earlier than previously thought and this will help guide future work.

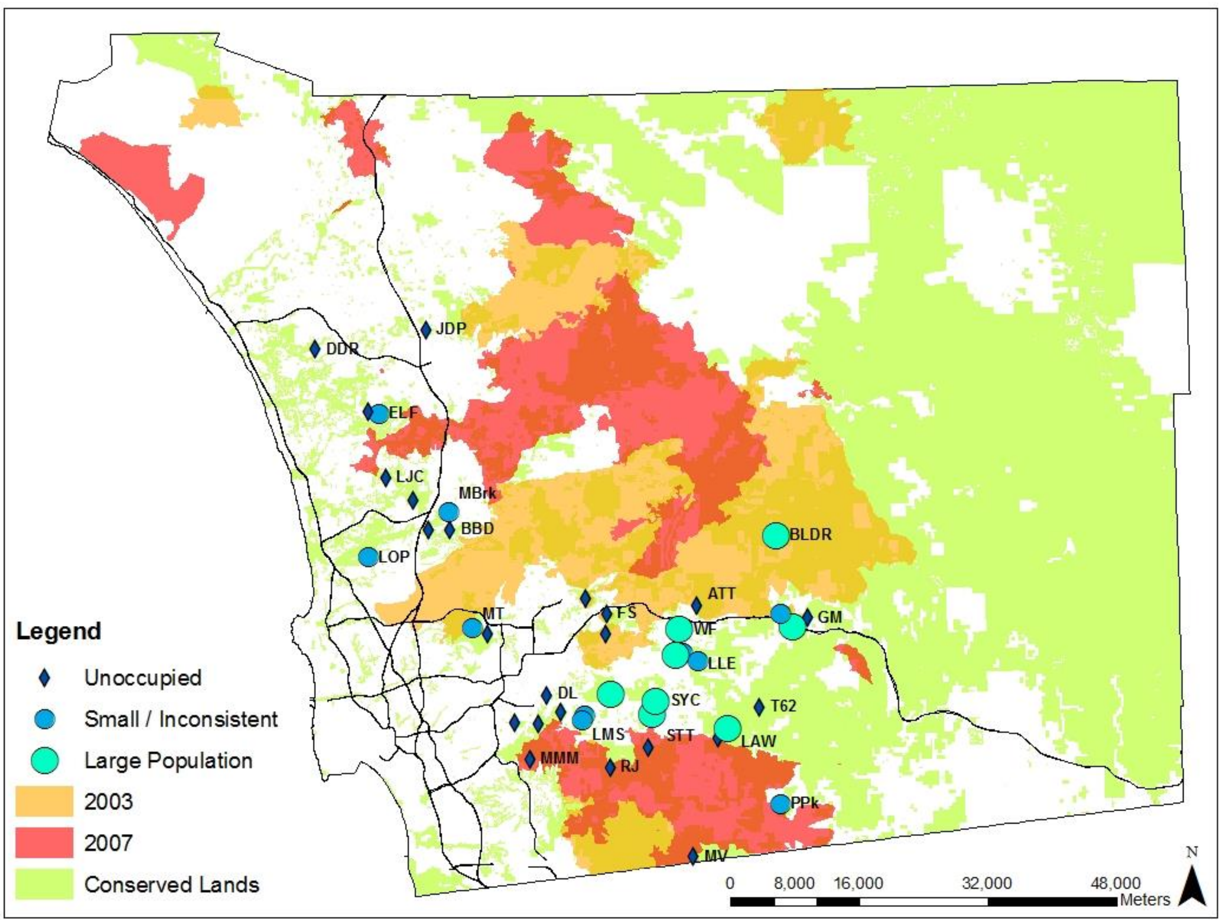

Figure 19: Hermes copper sites searched from 2010-2012 and relative abundance.

Recommendations

Additional work still needs to be conducted as in-situ observations of immature Hermes copper are difficult and occur in low numbers. In addition female behavior remains difficult to study. We recommend the following efforts to continue enhancing our understanding of Hermes copper for development of effective management and conservation practices:

- Continue monitoring for adult Hermes copper butterflies at sentinel sites, including Boulder Creek Road, to identify environmental variables important for annual densities of adults.
- Continue monitoring for adult Hermes copper butterflies at the small populations in the northern portion of the distribution to determine detection rates.
- Monitor sites which experience recent wildfires and local extirpations to detect recolonization events, allowing inferences about dispersal.
- Continue egg searches and track larval development to estimate the rate of hatching, depredation, and diapause as well as better understand habitat requirements.

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Appendix 1: 2012 Hermes copper observations.

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
790	6/12/2012	2012	SYP	32.7527	-116.80316	799
789	6/12/2012	2012	SYP	32.753	-116.80385	808
788	6/12/2012	2012	SYP	32.75322	-116.80475	822
787	6/12/2012	2012	SYP	32.7528	-116.80229	786
786	6/12/2012	2012	SYP	32.75222	-116.80193	771
785	6/12/2012	2012	SYP	32.74985	-116.80046	698
784	6/12/2012	2012	SYP	32.74973	-116.80046	694
783	6/12/2012	2012	SYP	32.74955	-116.8003	690
782	6/12/2012	2012	SYP	32.7485	-116.80065	664
781	6/12/2012	2012	SYP	32.74761	-116.79948	637
780	6/11/2012	2012	LLR	32.78852	-116.79116	426
779	6/11/2012	2012	LLR	32.78841	-116.79123	427
778	6/20/2012	2012	MGM	32.75568	-116.86088	601
777	6/20/2012	2012	MGM	32.75315	-116.85810	569
776	6/6/2012	2012	MGM	32.75719	-116.86443	485
775	6/6/2012	2012	MGM	32.75568	-116.86091	601
774	6/15/2012	2012	MGM	32.76759	-116.86426	319
773	6/13/2012	2012	MGM	32.76409	-116.87441	254
772	6/13/2012	2012	MGM	32.75684	-116.86415	499
771	6/13/2012	2012	MGM	32.75672	-116.86283	536
770	6/13/2012	2012	MGM	32.75530	-116.86137	593
769	6/13/2012	2012	MGM	32.75273	-116.85678	523
768	6/6/2012	2012	MGM	32.75296	-116.85673	518
767	6/12/2012	2012	RRN	32.82702	-116.61553	1075
766	6/12/2012	2012	RRN	32.82786	-116.61439	1091
765	6/12/2012	2012	RRN	32.82782	-116.61433	1091
764	6/12/2012	2012	RRN	32.82778	-116.61441	1091
763	6/12/2012	2012	LAW	32.71342	-116.70582	659
762	6/12/2012	2012	LAW	32.71771	-116.71254	820
761	6/12/2012	2012	LAW	32.71467	-116.71031	763
760	6/11/2012	2012	CRHT	32.79978	-116.76220	461
759	6/11/2012	2012	LLR	32.79142	-116.78328	438
758	6/11/2012	2012	LLR	32.79111	-116.78311	437
757	6/6/2012	2012	MGM	32.75526	-116.85627	479
756		2012	MGM	32.75740	-116.86445	478
755		2012	MGM	32.75679	-116.86269	523
754		2012	MGM	32.75638	-116.86315	530

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
753	6/19/2012	2012	BLDR	32.92957	-116.63434	1187
752	5/31/2012	2012	BLDR	32.92745	-116.63142	1145
751	6/19/2012	2012	BLDR	32.92996	-116.63410	1193
750	6/19/2012	2012	BLDR	32.92986	-116.63426	1190
749	6/19/2012	2012	BLDR	32.92716	-116.63159	1128
748	6/15/2012	2012	SYP	32.74961	-116.80031	692
747	6/15/2012	2012	SYP	32.74960	-116.80031	691
746	6/15/2012	2012	BLDR	32.92997	-116.63393	1200
745	6/15/2012	2012	BLDR	32.92982	-116.63414	1193
744	6/15/2012	2012	BLDR	32.92958	-116.63441	1185
743	6/15/2012	2012	BLDR	32.92604	-116.63104	1133
742	6/15/2012	2012	BLDR	32.92780	-116.63122	1175
741	6/14/2012	2012	BLDR	32.92960	-116.63440	1191
740	6/14/2012	2012	BLDR	32.92948	-116.63472	1186
739	6/14/2012	2012	BLDR	32.92693	-116.63147	1153
738	6/7/2012	2012	BLDR	32.92957	-116.63436	1183
737	6/7/2012	2012	BLDR	32.92712	-116.63162	1146
736	6/7/2012	2012	BLDR	32.92711	-116.63162	1141
735	6/7/2012	2012	BLDR	32.92774	-116.63134	1168
734	6/7/2012	2012	BLDR	32.92857	-116.63107	1187
733	6/7/2012	2012	BLDR	32.92829	-116.63121	1173
732	6/7/2012	2012	BLDR	32.92736	-116.63150	1139
731	6/4/2012	2012	BLDR	32.92853	-116.63101	1203
730	6/4/2012	2012	BLDR	32.92941	-116.63102	1213
729	6/4/2012	2012	BLDR	32.92734	-116.63151	1153
728	6/4/2012	2012	BLDR	32.92695	-116.63149	1146
727	6/4/2012	2012	BLDR	32.92694	-116.63150	1136
726	5/31/2012	2012	BLDR	32.93110	-116.63175	1259
725	5/30/2012	2012	LAW	32.71414	-116.70544	675
724	6/13/2012	2012	RRN	32.82752	-116.61538	1074
723	6/13/2012	2012	RRN	32.82707	-116.61551	1071
722	6/12/2012	2012	STT	32.75270	-116.80316	799
721	6/12/2012	2012	STT	32.75300	-116.80385	808
720	6/12/2012	2012	STT	32.75322	-116.80475	822
719	6/12/2012	2012	STT	32.75280	-116.80229	786
718	6/12/2012	2012	STT	32.75222	-116.80193	771
717	6/12/2012	2012	STT	32.74985	-116.80046	698
716	6/12/2012	2012	STT	32.74973	-116.80046	694
715	6/12/2012	2012	STT	32.74955	-116.80030	690

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
714	6/4/2012	2012	LAW	32.71406	-116.70551	668
713	6/12/2012	2012	STT	32.74850	-116.80065	664
712	6/12/2012	2012	STT	32.74761	-116.79948	637
711	6/12/2012	2012	PPK	32.62831	-116.63642	818
710	6/12/2012	2012	PPK	32.62859	-116.63685	815
709	6/12/2012	2012	PPK	32.62882	-116.63735	808
708	6/12/2012	2012	PPK	32.62882	-116.63735	808
707	6/12/2012	2012	PPN	32.62677	-116.62998	773
706	6/12/2012	2012	PPN	32.62615	-116.62955	762
705	6/11/2012	2012	STT	32.72511	-116.79273	785
704	6/4/2012	2012	LAW	32.71352	-116.70581	663
703	6/11/2012	2012	STT	32.72564	-116.79330	803
702	6/11/2012	2012	STT	32.72542	-116.79302	792
701	6/11/2012	2012	STT	32.72516	-116.79280	785
700	6/11/2012	2012	STT	32.72497	-116.79256	779
699	6/11/2012	2012	STT	32.72496	-116.79242	777
698	6/11/2012	2012	STT	32.72930	-116.79682	734
697	6/11/2012	2012	STT	32.72940	-116.79692	733
696	6/11/2012	2012	STT	32.72940	-116.79691	733
695	6/1/2012	2012	LAW	32.71347	-116.70582	657
694	6/11/2012	2012	STT	32.72981	-116.79672	734
693	6/11/2012	2012	STT	32.73042	-116.79691	732
692	6/11/2012	2012	STT	32.73085	-116.79711	730
691	6/11/2012	2012	STT	32.73085	-116.79711	731
690	6/11/2012	2012	STT	32.73085	-116.79713	730
689	6/11/2012	2012	STT	32.73085	-116.79713	731
688	6/11/2012	2012	STT	32.73111	-116.79666	734
687	6/11/2012	2012	STT	32.73124	-116.79667	734
686	6/11/2012	2012	STT	32.73132	-116.79668	735
685	6/11/2012	2012	STT	32.73176	-116.80555	619
684	6/1/2012	2012	BLDR	32.92695	-116.63150	1141
683	6/11/2012	2012	STT	32.73179	-116.80584	615
682	6/11/2012	2012	STT	32.73209	-116.80719	627
681	6/1/2012	2012	BLDR	32.92946	-116.63102	1204
680	6/8/2012	2012	SYP	32.75353	-116.80502	835
679	6/8/2012	2012	SYP	32.75323	-116.80476	828
678	6/8/2012	2012	SYP	32.75272	-116.80199	781
677	6/8/2012	2012	SYP	32.75228	-116.80197	773
676	6/8/2012	2012	SYP	32.75201	-116.80153	763

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
675	6/8/2012	2012	SYP	32.75153	-116.79998	751
674	6/8/2012	2012	SYP	32.75132	-116.79923	733
673	6/8/2012	2012	SYP	32.75040	-116.80039	716
672	6/8/2012	2012	SYP	32.74990	-116.80048	699
671	6/8/2012	2012	SYP	32.74983	-116.80045	696
670	6/1/2012	2012	BLDR	32.92713	-116.63157	1136
669	6/8/2012	2012	SYP	32.74963	-116.80031	690
668	6/8/2012	2012	SYP	32.74819	-116.79993	656
667	6/8/2012	2012	SYP	32.74768	-116.79952	637
666	6/8/2012	2012	SYP	32.74699	-116.79963	615
665	6/7/2012	2012	RRN	32.82786	-116.61430	1083
664	6/7/2012	2012	RRN	32.82789	-116.61435	1084
663	6/7/2012	2012	RRN	32.82785	-116.61437	1084
662	6/7/2012	2012	RRN	32.82785	-116.61437	1084
661	6/7/2012	2012	RRN	32.82785	-116.61437	1084
660	6/7/2012	2012	RRN	32.82759	-116.61494	1077
659	6/1/2012	2012	BLDR	32.92709	-116.63154	1135
658	6/6/2012	2012	SYP	32.75330	-116.80487	827
657	6/6/2012	2012	SYP	32.75285	-116.80226	788
656	6/6/2012	2012	SYP	32.75225	-116.80193	772
655	6/6/2012	2012	SYP	32.75041	-116.80037	718
654	6/6/2012	2012	SYP	32.75032	-116.80046	715
653	6/6/2012	2012	SYP	32.75010	-116.80040	707
652	6/6/2012	2012	SYP	32.74821	-116.79996	656
651	6/6/2012	2012	SYP	32.74780	-116.79982	645
650	6/6/2012	2012	SYP	32.74763	-116.79949	639
649	6/6/2012	2012	SYP	32.74755	-116.79920	631
648	6/1/2012	2012	BLDR	32.92691	-116.63147	1131
647	6/6/2012	2012	SYP	32.74726	-116.79971	626
646	6/6/2012	2012	STT	32.73131	-116.79662	738
645	6/6/2012	2012	STT	32.73085	-116.79709	732
644	6/19/2012	2012	SYP	32.75292	-116.80236	795
643	6/19/2012	2012	SYP	32.75281	-116.80231	790
642	6/19/2012	2012	SYP	32.75210	-116.80174	768
641	6/19/2012	2012	SYP	32.75202	-116.80154	764
640	6/19/2012	2012	SYP	32.75038	-116.80041	714
639	6/19/2012	2012	SYP	32.75010	-116.80046	702
638	6/19/2012	2012	SYP	32.74958	-116.80033	686
637	6/6/2012	2012	STT	32.72932	-116.79700	740

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
636	6/19/2012	2012	SYP	32.74932	-116.80026	679
635	6/19/2012	2012	SYP	32.74766	-116.79954	635
634	6/18/2012	2012	SYP	32.75281	-116.80227	788
633	6/18/2012	2012	SYP	32.75022	-116.80041	716
632	6/18/2012	2012	SYP	32.75022	-116.80041	715
631	6/18/2012	2012	SYP	32.74903	-116.80011	685
630	6/18/2012	2012	SYP	32.74884	-116.80008	679
629	6/18/2012	2012	SYP	32.74884	-116.80003	679
628	6/18/2012	2012	SYP	32.74860	-116.80070	675
627	6/18/2012	2012	SYP	32.74764	-116.79952	646
626	6/6/2012	2012	STT	32.72982	-116.79671	740
625	6/18/2012	2012	STT	32.72477	-116.78946	735
624	6/18/2012	2012	STT	32.72482	-116.78979	740
623	6/18/2012	2012	STT	32.72473	-116.79046	748
622	6/18/2012	2012	STT	32.72499	-116.79259	772
621	6/18/2012	2012	STT	32.72570	-116.79340	797
620	6/18/2012	2012	STT	32.72579	-116.79359	800
619	6/18/2012	2012	STT	32.72527	-116.79375	814
618	6/18/2012	2012	STT	32.72578	-116.79365	798
617	6/18/2012	2012	STT	32.72570	-116.79334	791
616	6/18/2012	2012	STT	32.72543	-116.79303	781
615	6/6/2012	2012	STT	32.73103	-116.79669	740
614	6/18/2012	2012	STT	32.72528	-116.79291	775
613	6/18/2012	2012	STT	32.72517	-116.79279	772
612	6/18/2012	2012	STT	32.72496	-116.79241	762
611	6/18/2012	2012	STT	32.73239	-116.80851	631
610	6/18/2012	2012	STT	32.73185	-116.80591	610
609	6/18/2012	2012	STT	32.73205	-116.80600	609
608	6/18/2012	2012	STT	32.73213	-116.80639	612
607	6/18/2012	2012	STT	32.73208	-116.80691	613
606	6/18/2012	2012	STT	32.73206	-116.80718	617
605	6/18/2012	2012	STT	32.73220	-116.80787	621
604	6/6/2012	2012	STT	32.73174	-116.80556	623
603	6/18/2012	2012	STT	32.73220	-116.80787	621
602	6/15/2012	2012	SYP	32.75326	-116.80475	824
601	6/15/2012	2012	SYP	32.75283	-116.80227	790
600	6/15/2012	2012	SYP	32.75228	-116.80193	774
599	6/15/2012	2012	SYP	32.75204	-116.80151	764
598	6/15/2012	2012	SYP	32.75038	-116.80038	719

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
597	6/15/2012	2012	SYP	32.75010	-116.80041	708
596	6/15/2012	2012	SYP	32.74979	-116.80047	697
595	6/15/2012	2012	BLDR	32.92685	-116.63153	1148
594	6/15/2012	2012	BLDR	32.92706	-116.63160	1153
593	6/4/2012	2012	LAW	32.71998	-116.71514	877
592	6/15/2012	2012	BLDR	32.92711	-116.63159	1154
591	6/15/2012	2012	BLDR	32.92748	-116.63164	1164
590	6/15/2012	2012	BLDR	32.92757	-116.63193	1165
589	6/15/2012	2012	BLDR	32.92801	-116.63147	1180
588	6/14/2012	2012	RRN	32.82727	-116.61639	1066
587	6/14/2012	2012	BLDR	32.92812	-116.63179	1178
586	6/14/2012	2012	BLDR	32.92792	-116.63130	1175
585	6/14/2012	2012	BLDR	32.92794	-116.63131	1177
584	6/14/2012	2012	BLDR	32.92794	-116.63131	1175
583	6/14/2012	2012	BLDR	32.92806	-116.63146	1173
582	6/4/2012	2012	LAW	32.71989	-116.71311	849
581	6/14/2012	2012	BLDR	32.92781	-116.63142	1169
580	6/14/2012	2012	BLDR	32.92779	-116.63143	1168
579	6/14/2012	2012	BLDR	32.92744	-116.63141	1151
578	6/14/2012	2012	BLDR	32.92716	-116.63154	1148
577	6/14/2012	2012	BLDR	32.92720	-116.63155	1150
576	6/14/2012	2012	BLDR	32.92721	-116.63158	1150
575	6/14/2012	2012	BLDR	32.92708	-116.63155	1147
574	6/14/2012	2012	BLDR	32.92691	-116.63152	1143
573	6/14/2012	2012	BLDR	32.92691	-116.63151	1144
572	6/13/2012	2012	RRN	32.82791	-116.61437	1088
571	6/4/2012	2012	LAW	32.71924	-116.71256	834
570	5/29/2012	2012	SYP	32.75315	-116.80396	818
569	6/20/2012	2012	MGM	32.75191	-116.85710	539
568	6/20/2012	2012	MGM	32.75645	-116.85546	461
567	6/20/2012	2012	MGM	32.75669	-116.85536	449
566	6/19/2012	2012	CRHT	32.79977	-116.76218	469
565	6/19/2012	2012	LLR	32.78845	-116.79117	435
564	6/19/2012	2012	LLR	32.79157	-116.78330	446
563	6/19/2012	2012	LLR	32.79157	-116.78330	446
562	6/19/2012	2012	LLR	32.78845	-116.79121	434
561	6/13/2012	2012	MGM	32.73423	-116.87108	356
560	6/7/2012	2012	CRHT	32.79983	-116.76226	467
559	6/7/2012	2012	LAW	32.71769	-116.71248	816

Case	Date	Year	Site	Latitude	Longitude	Elevation (m)
558	6/7/2012	2012	LAW	32.71982	-116.71706	901
557	6/7/2012	2012	LAW	32.71555	-116.70879	735
556	6/6/2012	2012	MGM	32.76763	-116.86469	318
555	6/27/2012	2012	LLR	32.78850	-116.79114	438
554	6/21/2012	2012	MGM	32.73933	-116.86165	380
553	6/21/2012	2012	MGM	32.73999	-116.86189	368
552	6/6/2012	2012	MGM	32.76786	-116.86619	308
551	6/20/2012	2012	SYP	32.75281	-116.80228	782
550	6/20/2012	2012	SYP	32.75193	-116.80134	755
549	6/20/2012	2012	SYP	32.75084	-116.79959	728
548	6/20/2012	2012	SYP	32.74952	-116.80030	688
547	6/20/2012	2012	STT	32.73208	-116.80725	628
546	6/20/2012	2012	STT	32.73239	-116.80855	639
545	6/19/2012	2012	RRN	32.82748	-116.61548	1063
544	6/19/2012	2012	RRN	32.82722	-116.61638	1051
543	6/19/2012	2012	LAW	32.71656	-116.71201	801
542	6/18/2012	2012	MGM	32.76542	-116.86029	336
541	6/6/2012	2012	MGM	32.76407	-116.87440	253
540	6/18/2012	2012	MGM	32.76789	-116.86617	307
539	6/18/2012	2012	MGM	32.76834	-116.86785	294
538	6/18/2012	2012	MGM	32.76808	-116.86883	289
537	6/18/2012	2012	MGM	32.76879	-116.86953	277
536	6/18/2012	2012	MGM	32.76562	-116.87374	262
535	6/18/2012	2012	MGM	32.76406	-116.87436	248
534	6/18/2012	2012	MGM	32.76505	-116.87442	240
533	6/15/2012	2012	MGM	32.74318	-116.86347	465
532	6/13/2012	2012	MGM	32.76253	-116.88376	147
531	6/13/2012	2012	MGM	32.76846	-116.87792	149
530	6/6/2012	2012	MGM	32.76380	-116.87411	260

Appendix 2: Hermes copper specimens used in landscape genetics study.

Specimen #	Collection Date	Collection Site	Latitude	Longitude
1	17-Jun-03	MBrk	32.96312	-117.06643
2	17-Jun-03	MBrk	32.96311	-117.06661
3	17-Jun-03	MBrk	32.96287	-117.06756
4	17-Jun-03	MBrk	32.96285	-117.06762
5	17-Jun-03	MBrk	32.96314	-117.06656
6	17-Jun-03	MBrk	32.96275	-117.06622
7	17-Jun-03	MBrk	32.96241	-117.06593
8	17-Jun-03	MBrk	32.9628	-117.06326
9	17-Jun-03	MBrk	32.96296	-117.06392
10	17-Jun-03	MBrk	32.96305	-117.06586
11	17-Jun-03	RJ	32.67863	-116.86131
12	17-Jun-03	RJ	32.6787	-116.86132
13	17-Jun-03	RJ	32.67877	-116.86106
14	17-Jun-03	RJ	32.6781	-116.86214
15	17-Jun-03	RJ	32.67894	-116.86124
16	18-Jun-03	RJ	32.67844	-116.86195
17	18-Jun-03	RJ	32.67149	-116.86773
18	18-Jun-03	RJ	32.6714	-116.86724
19	25-Jun-03	RJ	32.67882	-116.86144
20	26-Jun-03	RJ	32.66427	-116.86556
21	19-Jun-03	WWG	32.8419	-116.63905
22	19-Jun-03	WWG	32.84189	-116.63897
23	19-Jun-03	WWG	32.84187	-116.63898
24	19-Jun-03	WWG	32.84188	-116.63927
25	24-Jun-03	WWG	32.84182	-116.63889
26	24-Jun-03	CR	32.82275	-116.86286
27	24-Jun-03	CR	32.82266	-116.86302
28	27-Jun-03	CR	32.82326	-116.86315
29	27-Jun-03	CR	32.82285	-116.86256
31	24-Jun-03	ATT	32.8568	-116.74127
32	24-Jun-03	ATT	32.85683	-116.7412
33	24-Jun-03	ATT	32.85678	-116.74113
34	24-Jun-03	ATT	32.85677	-116.7411
35	24-Jun-03	ATT	32.85701	-116.74098
50	22-Jun-06	HC	32.6941	-116.81511
51	22-Jun-06	HC	32.69463	-116.81406
52	22-Jun-06	HC	32.69504	-116.81379
53	28-Jun-06	HC	32.69517	-116.81267
54	28-Jun-06	HC	32.69539	-116.81183
55	28-Jun-06	HC	32.69137	-116.8063
56	28-Jun-06	HC	32.69081	-116.8065

Specimen #	Collection Date	Collection Site	Latitude	Longitude
57	28-Jun-06	HC	32.6908	-116.80646
58	28-Jun-06	HC	32.69088	-116.80656
59	28-Jun-06	HC	32.69074	-116.80652
60	30-Jun-06	HC	32.68666	-116.80772
61	7-Jul-06	HC	32.68643	-116.80807
62	7-Jul-06	HC	32.68637	-116.802
70	20-May-08	MGM	32.75569	-116.89627
71	20-May-08	MGM	32.75596	-116.89528
72	30-May-08	MT	32.83528	-117.04066
73	30-May-08	MT	32.83492	-117.04015
74	30-May-08	MT	32.83495	-117.03976
75	30-May-08	MT	32.83389	-117.04023
76	30-May-08	MT	32.8355	-117.04073
77	1-Jun-08	RRN	32.82786	-116.614427
78	1-Jun-08	WWG	32.84193	-116.63985
79	1-Jun-08	WF	32.826564	-116.770404
80	1-Jun-08	WF	32.826764	-116.771021
81	1-Jun-08	WF	32.828012	-116.769731
82	3-Jun-08	STT	32.73203	-116.80724
83	3-Jun-08	STT	32.73203	-116.8069
84	3-Jun-08	STT	32.73207	-116.8066
85	3-Jun-08	STT	32.73206	-116.80655
86	3-Jun-08	STT	32.73208	-116.80645
87	6-Jun-08	RRN	32.82699	-116.61593
88	6-Jun-08	RRN	32.82707	-116.6156
89	6-Jun-08	RRN	32.82756	-116.61502
90	6-Jun-08	RRN	32.82769	-116.61448
91	6-Jun-08	RRN	32.82786	-116.61444
92	12-Jun-08	WWG	32.84092	-116.63472
93	12-Jun-08	WWG	32.84182	-116.64397
94	3-Jun-08	WF	32.8221	-116.7706
95	3-Jun-08	WF	32.8221	-116.7706
96	3-Jun-08	WF	32.8221	-116.7706
97	2-Jun-08	MGM	32.74397012	-116.8628866
98	2-Jun-08	MGM	32.74397012	-116.8628866
100	2-Jun-09	LAW	32.71711	-116.71239
101	2-Jun-09	LAW	32.71771	-116.7125
102	2-Jun-09	LAW	32.71658	-116.71198
103	2-Jun-09	STT	32.73204	-116.80727
104	2-Jun-09	STT	32.73205	-116.80724
105	2-Jun-09	STT	32.73201	-116.80599
106	2-Jun-09	STT	32.73178	-116.80587
107	2-Jun-09	STT	32.73174	-116.80562

Specimen #	Collection Date	Collection Site	Latitude	Longitude
108	2-Jun-09	WWG	32.84086	-116.63483
109	3-Jun-09	SYC	32.77293	-116.80503
110	2-Jun-10	SYC	32.74731	-116.79979
111	2-Jun-10	SYC	32.74768	-116.79984
112	2-Jun-10	SYC	32.74868	-116.80035
113	2-Jun-10	SYC	32.74884	-116.80013
114	2-Jun-10	SYC	32.74977	-116.80045
117	15-Jun-10	LMN	32.73124	-116.88149
120	17-Jun-10	LLR	32.79136	-116.78326
121	18-Jun-10	POT	32.647882	-116.623611
122	18-Jun-10	BBTT	32.81421	-116.66257
123	18-Jun-10	BBTT	32.81365	-116.66472
124	18-Jun-10	BBTT	32.81365	-116.66472
125	9-Jun-10	MGM	32.756688	-116.855332
126	18-Jun-10	BBTT	32.81177	-116.67435
127	9-Jun-10	MGM	32.756106	-116.855602
128	9-Jun-10	MGM	32.75454	-116.856639
129	14-Jun-10	CRHT	32.80033	-116.76336
130	9-Jun-10	MGM	32.76408	-116.87439
131	9-Jun-10	MGM	32.76406	-116.87435
132	9-Jun-10	MGM	32.76447	-116.87437
133	9-Jun-10	MGM	32.76446	-116.87424
134	9-Jun-10	MGM	32.7645	-116.87403
136	2010	RRN	32.82759	-116.615
139	2010	STT	32.73201	-116.80599
150	11-Jun-10	STT	32.73221	-116.80659
151	11-Jun-10	STT	32.73212	-116.8064
152	11-Jun-10	STT	32.73211	-116.80626
153	11-Jun-10	STT	32.73188	-116.80615
154	11-Jun-10	STT	32.73178	-116.80589
155	16-Jun-10	WWG	32.842239	-116.641753
156	16-Jun-10	RRN	32.827009	-116.615549
157	16-Jun-10	RRN	32.827846	-116.614447
158	18-Jun-10	MGM	32.76884	-116.87017
159	18-Jun-10	MGM	32.76843	-116.86932
160	18-Jun-10	MGM	32.76785	-116.86611
161	18-Jun-10	MGM	32.76319	-116.8577
200	4-Jun-11	SYC	32.74955874	-116.80030201
201	4-Jun-11	SYC	32.75152488	-116.80006740
202	6-Jun-11	SYC	32.74954533	-116.80032908
203	6-Jun-11	SYC	32.75272433	-116.80200169
204	6-Jun-11	SYC	32.74957358	-116.80033822
205	8-Jun-11	LAW	32.71569376	-116.71056420

Specimen #	Collection Date	Collection Site	Latitude	Longitude
206	8-Jun-11	LAW	32.71473596	-116.71024518
207	9-Jun-11	SYC	32.75322498	-116.80475464
208	9-Jun-11	SYC	32.75035904	-116.80039815
209	13-Jun-11	SYC	32.74849826	-116.80063217
210	13-Jun-11	SYC	32.75040498	-116.80044140
211	13-Jun-11	SYC	32.75162337	-116.80068925
212	13-Jun-11	SYC	32.75272249	-116.80326023
213	13-Jun-11	SYC	32.74723100	-116.79997176
214	13-Jun-11	SYC	32.74908684	-116.80012020
215	13-Jun-11	SYC	32.75087881	-116.79960153
216	13-Jun-11	SYC	32.75272743	-116.80333399
217	16-Jun-11	LAW	32.713418	-116.705816
218	16-Jun-11	LAW	32.713824	-116.705678
219	16-Jun-11	LAW	32.714644	-116.705896
220	16-Jun-11	LAW	32.715653	-116.707092
221	16-Jun-11	LAW	32.714659	-116.709808
222	16-Jun-11	LAW	32.714545	-116.709873
223	16-Jun-11	LAW	32.714649	-116.710298
224	16-Jun-11	LAW	32.714651	-116.710295
225	16-Jun-11	LAW	32.715714	-116.710465
226	16-Jun-11	LAW	32.717328	-116.712527
227	16-Jun-11	RRN	32.82745513	-116.61545201
228	16-Jun-11	RRN	32.82759519	-116.61503116
229	16-Jun-11	RRN	32.82785612	-116.61440344
230	16-Jun-11	RRN	32.82785671	-116.61440721
231	16-Jun-11	RRN	32.82747248	-116.61491356
232	17-Jun-11	LLR	32.79176063	-116.78325143
233	17-Jun-11	LLR	32.79022808	-116.78731238
234	17-Jun-11	LLR	32.78977102	-116.78779358
235	17-Jun-11	LLR	32.78965786	-116.79010405
236	17-Jun-11	LLR	32.78847442	-116.79115967
237	17-Jun-11	LLR	32.79024032	-116.78730592
238	17-Jun-11	LLR	32.78971972	-116.78618300
239	17-Jun-11	LLR	32.78972383	-116.78617688
240	17-Jun-11	LLR	32.78943012	-116.78495874
242	17-Jun-11	SYC	32.75374123	-116.80526393
243	20-Jun-11	SYC	32.74760551	-116.79947832
244	20-Jun-11	SYC	32.75281218	-116.80230050
245	20-Jun-11	SYC	32.75297487	-116.80383582
246	20-Jun-11	SYC	32.75265502	-116.80201451
247	20-Jun-11	SYC	32.74885391	-116.80010277
249	21-Jun-11	WWG	32.84196680	-116.63997604
250	21-Jun-11	RRN	32.82770734	-116.61441023

Specimen #	Collection Date	Collection Site	Latitude	Longitude
251	21-Jun-11	RRN	32.82767901	-116.61442883
265	22-Jun-11	SYC	32.74858284	-116.80067131
266	22-Jun-11	SYC	32.75032292	-116.80038951
267	22-Jun-11	SYC	32.75440641	-116.80599156
268	22-Jun-11	SYC	32.74960635	-116.80036445
269	24-Jun-11	SYC	32.747719	-116.799832
270	24-Jun-11	SYC	32.746881	-116.799431
271	27-Jun-11	SYC	32.753329	-116.804469
293	29-Jun-11	RRN	32.828437	-116.617708
294	29-Jun-11	RRN	32.827249	-116.616346
295	29-Jun-11	RRN	32.827772	-116.614394
296	29-Jun-11	WWG	32.84093	-116.65095
297	29-Jun-11	WWG	32.84081	-116.65106
298	29-Jun-11	WF	32.82108	-116.7711
304	23-Jun-11	LAW	32.71539546	-116.71043356
305	23-Jun-11	LAW	32.71468534	-116.71024287
306	23-Jun-11	LAW	32.71393156	-116.70559293
400	29-May-12	SYC	32.75315	-116.80396
401	30-May-12	LAW	32.71414	-116.70544
402	1-Jun-12	BLDR	32.92691	-116.63147
403	1-Jun-12	BLDR	32.92709	-116.63154
404	1-Jun-12	BLDR	32.92713	-116.63157
405	1-Jun-12	BLDR	32.92695	-116.6315
406	1-Jun-12	LAW	32.71347	-116.70582
407	4-Jun-12	LAW	32.71352	-116.70581
408	4-Jun-12	LAW	32.71924	-116.71256
409	4-Jun-12	LAW	32.71989	-116.71311
410	4-Jun-12	LAW	32.71998	-116.71514
411	6-Jun-12	MGM	32.76763	-116.86469
412	13-Jun-12	MGM	32.76846	-116.87792
413	14-Jun-12	BLDR	32.9296	-116.6344
414	6-Jun-12	MGM	32.7638	-116.87411
415	6-Jun-12	MGM	32.76786	-116.86619
416	12-Jun-12	RRN	32.82786	-116.61439
418	7-Jun-12	LAW	32.71982	-116.71706
421	11-Jun-12	LLR	32.79111	-116.78311
422	13-Jun-12	MGM	32.76409	-116.87441
423	11-Jun-12	LLR	32.78841	-116.79123
424	6-Jun-12	MGM	32.75296	-116.85673
425	6-Jun-12	MGM	32.75568	-116.86091
426	6-Jun-12	STT	32.73103	-116.79669
427	6-Jun-12	STT	32.73085	-116.79709
428	6-Jun-12	STT	32.72982	-116.79671

Specimen #	Collection Date	Collection Site	Latitude	Longitude
429	6-Jun-12	STT	32.72932	-116.797
430	6-Jun-12	SYC	32.74755	-116.7992
432	15-Jun-12	CRHT	32.79157	-116.7833
435	13-Jun-12	MGM	32.75672	-116.86283
436	8-Jun-12	SYC	32.74699	-116.79963
437	13-Jun-12	MGM	32.75684	-116.86415
438	15-Jun-12	MGM	32.76759	-116.86426
439	11-Jun-12	LLR	32.78852	-116.79116
440	11-Jun-12	LLR	32.79142	-116.78328
441	18-Jun-12	MGM	32.76505	-116.87442
442	18-Jun-12	MGM	32.76879	-116.86953
443	18-Jun-12	MGM	32.76834	-116.86785
444	18-Jun-12	MGM	32.76808	-116.86883
445	18-Jun-12	MGM	32.76406	-116.87436
446	6-Jun-12	SYC	32.74763	-116.79949
447	6-Jun-12	SYC	32.7478	-116.79982
448	6-Jun-12	SYC	32.74821	-116.79996
449	6-Jun-12	SYC	32.75032	-116.80046
450	6-Jun-12	SYC	32.75041	-116.80037
451	6-Jun-12	SYC	32.75285	-116.80226
452	6-Jun-12	STT	32.73174	-116.80556
453	7-Jun-12	RRN	32.82759	-116.61494
454	7-Jun-12	RRN	32.82785	-116.61437
455	7-Jun-12	RRN	32.82785	-116.61437
456	4-Jun-12	BLDR	32.92853	-116.63101
457	4-Jun-12	BLDR	32.92695	-116.63149
458	4-Jun-12	BLDR	32.92694	-116.6315
459	4-Jun-12	BLDR	32.92941	-116.63102
460	4-Jun-12	BLDR	32.92734	-116.63151
462	7-Jun-12	BLDR	32.92736	-116.6315
463	7-Jun-12	BLDR	32.92774	-116.63134
464	7-Jun-12	BLDR	32.92829	-116.63121
465	7-Jun-12	BLDR	32.92857	-116.63107
467	7-Jun-12	BLDR	32.92711	-116.63162
468	7-Jun-12	BLDR	32.92736	-116.6315
470	7-Jun-12	BLDR	32.92712	-116.63162
471	7-Jun-12	RRN	32.82785	-116.61437
472	7-Jun-12	RRN	32.82789	-116.61435
473	11-Jun-12	STT	32.73209	-116.80719
474	11-Jun-12	STT	32.73176	-116.80555
475	11-Jun-12	STT	32.73132	-116.79668
476	8-Jun-12	SYC	32.7499	-116.80048
477	8-Jun-12	SYC	32.75228	-116.80197

Specimen #	Collection Date	Collection Site	Latitude	Longitude
478	8-Jun-12	SYC	32.75132	-116.79923
479	8-Jun-12	SYC	32.74819	-116.79993
480	11-Jun-12	STT	32.73111	-116.79666
481	11-Jun-12	STT	32.73085	-116.79713
482	11-Jun-12	STT	32.73085	-116.79713
483	11-Jun-12	STT	32.73085	-116.79711
484	11-Jun-12	STT	32.73085	-116.79711
485	11-Jun-12	STT	32.7294	-116.79692
486	13-Jun-12	MGM	32.73423	-116.87108
488	18-Jun-12	MGM	32.76789	-116.86617
490	18-Jun-12	MGM	32.76562	-116.87374
492	7-Jun-12	CRHT	32.79983	-116.76226
493	8-Jun-12	MGM	32.76542	-116.86029
495	13-Jun-12	MGM	32.74318	-116.86347
501	11-Jun-12	STT	32.72511	-116.79273
502	18-Jun-12	STT	32.73208	-116.80691
503	18-Jun-12	STT	32.73213	-116.80639
504	18-Jun-12	STT	32.7257	-116.7934
505	18-Jun-12	STT	32.73205	-116.806
506	11-Jun-12	STT	32.7293	-116.79682
507	11-Jun-12	STT	32.72497	-116.79256
508	11-Jun-12	STT	32.72516	-116.7928
509	11-Jun-12	STT	32.72542	-116.79302
510	11-Jun-12	STT	32.72564	-116.7933
513	7-Jun-12	RRN	32.82786	-116.6143
516	13-Jun-12	RRN	32.82707	-116.61551
517	14-Jun-12	BLDR	32.92691	-116.63151
518	14-Jun-12	BLDR	32.92691	-116.63152
519	18-Jun-12	STT	32.7322	-116.80787
520	14-Jun-12	BLDR	32.92708	-116.63155
523	14-Jun-12	BLDR	32.92744	-116.63141
528	20-Jun-12	MGM	32.7574	-116.86445
531	14-Jun-12	RRN	32.82727	-116.61639
532	14-Jun-12	BLDR	32.9296	-116.6344
533	14-Jun-12	BLDR	32.9272	-116.63155
534	18-Jun-12	STT	32.7322	-116.80787
535	15-Jun-12	BLDR	32.92982	-116.63414
536	12-Jun-12	SYC	32.753	-116.80385
537	12-Jun-12	SYC	32.7528	-116.80229
538	12-Jun-12	PPk	32.62677	-116.62998
539	15-Jun-12	SYC	32.74979	-116.80047
540	15-Jun-12	BLDR	32.92958	-116.63441
541	12-Jun-12	PPk	32.62859	-116.63685

Specimen #	Collection Date	Collection Site	Latitude	Longitude
542	14-Jun-12	BLDR	32.92716	-116.63154
543	12-Jun-12	PPk	32.62882	-116.63735
544	15-Jun-12	SYC	32.75038	-116.80038
545	12-Jun-12	PPk	32.62831	-116.63642
546	20-Jun-12	MGM	32.75679	-116.86269
547	20-Jun-12	MGM	32.75191	-116.8571
548	20-Jun-12	MGM	32.75669	-116.85536
549	20-Jun-12	MGM	32.75568	-116.86088
550	12-Jun-12	LAW	32.71467	-116.71031
551	12-Jun-12	RRN	32.82782	-116.61433
552	12-Jun-12	RRN	32.71342	-116.70582
554	20-Jun-12	MGM	32.75645	-116.85546
556	18-Jun-12	STT	32.73185	-116.80591
557	18-Jun-12	STT	32.72528	-116.79291
558	18-Jun-12	STT	32.72527	-116.79375
559	18-Jun-12	STT	32.72473	-116.79046
560	18-Jun-12	SYC	32.74884	-116.80003
561	18-Jun-12	SYC	32.75022	-116.80041
571	19-Jun-12	LAW	32.71656	-116.71201
573	21-Jun-12	MGM	32.73999	-116.86189
575	21-Jun-12	MGM	32.73933	-116.86165
581	18-Jun-12	STT	32.72579	-116.79359