Survey of the endangered Mission blue butterfly in the Marin Headlands

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SUMMARY

2008 Field Season

In the spring of 2008, seventeen permanent transects distributed among five monitoring regions in the Marin Headlands (north of San Francisco) were monitored for Mission blue butterflies. Weather permitting, surveys were performed every 7 to 10 days from February 25, 2008 through June 6, 2008. Thirteen surveys were completed during this time frame, and Mission blue butterflies were seen on six of the thirteen surveys. During the surveys, 40 Mission blues were observed on transects and 107 were seen off transect. Locations of butterflies seen off transect were recorded using a handheld GPS device whenever possible. The first adult Mission blue observed during these surveys was seen on March 26, 2008 and the last observed butterfly was seen on May 16, resulting in a 52 day flight season. Most butterflies were observed early in the flight season, with a peak of 22 butterflies seen on transect (88 on and off transect) observed in a single day (on and off transect) on April 11. Males comprised 72% of the transect observations and 64% of off transect observations. Several pairs of butterflies were observed interacting, including four instances of male-male interactions, two instances of apparent courting between males and females, and one observation of a male and a female mating. Mission blue butterflies were observed at four of the five monitoring regions. No butterflies were seen at Battery Duncan and only one butterfly was seen at Wolfback Ridge.

Multi-Year Comparisons 1994-2007

Numbers of Mission blue butterflies have now been monitored at the same sites in the Marin Headlands over a period of 15 years (sequentially from 1994-2005 and 2007; in 2006 monitoring of the transects was not feasible due to logistical constraints, but butterfly monitoring was conducting using different methods at other sites), providing a rare opportunity to examine fluctuations in the abundance of a population of an endangered butterfly. The early survey years - 1994 through 1997 - represent four years of relatively robust populations of butterflies. Total numbers of adults recorded over the duration of the flight season exceeded 100 in three of the four years, and peak numbers observed on a single day ranged from 26 to 52. A precipitous decline in butterfly abundance followed from 1998 to 2002. Daily counts of adults at the peak of the season dropped to between eight and 15, with seasonal totals of less than 30 butterflies in four of the five years. Between 2003 and 2005, there was a moderate increase in Mission blue abundance. Within this time frame, numbers of adult butterflies at the peak of the season ranged from 15 to 23, with seasonal totals climbing to between 40 and 67, representing an apparent recovery from the alarming lows encountered prior to 2003. During the time these counts were

collected, there was not a standardized effort to collect data regarding off-transect butterflies. In 2008, 40 butterflies were seen on these standardized transects; however, incidental sightings between transects were numerous—one-hundred and seven Mission blues in 2008. Thus, only 27% of the Mission blues within the immediate vicinity of the transects were actually observed on transect and were accounted for using the existing monitoring protocol. A similar trend occurred in 2007, when 18% of butterflies seen in these areas surrounding the transects were actually located within the constraints of the transects and were, therefore, included in the current standardized monitoring routine. The high number of butterflies seen off-transect indicate that the butterflies still populate the general areas where the 1994 transects were delineated, even if they have migrated away from the specific monitoring corridor.

Recommendations for future research

Based on last year's recommendation, a vegetation assessment was completed on the transects to compare the current vegetative composition to the groundcover present when the transects were originally established in 1994/1995. For details, see associated report (Bennett 2008). Based on these findings and the extensive observations of Mission blues eluding the current monitoring techniques (high numbers of off-transect butterflies), the current methodology should be revised. For several years there have been park-wide Mission blue management discussions and there is a general consensus that the protocol needs to be reviewed and revised. Special funding should be allocated to this cause, as the current protocol is showing results which, I believe, do not accurately reflect the populations' status.

INTRODUCTION

The Marin Headlands, located immediately north of San Francisco, support one of the few remaining populations of the Mission blue butterfly, *Plebejus (Icaricia) icarioides missionensis*. In 1976, the Mission blue subspecies was federally listed under the Endangered Species Act and has since become the target of a recovery plan to protect, maintain and enhance existing populations (U.S. Fish and Wildlife Service, 1984). Since 1994, annual surveys have been conducted in the Marin Headlands in the Golden Gate National Recreation Area (GGNRA) in order to assess and track the abundance of this endangered subspecies. This report describes the methods and results for the 2008 spring census and looks at patterns of Mission blue abundance over the past 15 years.

OBJECTIVES

The primary aims of this continual monitoring effort are to provide information regarding general Mission blue ecology, including climatic influence and other potential variables. The monitoring regime provides an index of Mission blue abundance in the Marin Headlands, thereby allowing observers to track population changes over time. Observers also work to capture the spatial distribution of the species throughout the Marin Headlands and predict habitat expansion. These inferences will help guide much of the land management activities being implemented by the Park and support the persistence of this fragile species.

NATURAL HISTORY

The Mission blue is a member of the family Lycaenidae, a large and diverse group of butterflies that includes the blues, coppers, hairstreaks, and metalmarks. The Mission blue is univoltine (one generation per year) and has a flight period varying from late March to mid June on San Bruno Mountain (Arnold 1983), and mid March to mid May in the Marin Headlands (Rashbrook & Cushman 1994-2000, Rashbrook 2000-2004). Adults live for about one week and are thought to feed on floral nectar from a variety of plants, including *Eriogonum* sp. (Polygonaceae) and several asters (Arnold 1983). Females oviposit on three lupine species – *Lupinus albifrons*, *L. variicolor* and *L. formosus* (Fabaceae) – that commonly occur in grasslands on thin, rocky soils (Reid & Murphy 1986). These grasslands are susceptible to invasion by non-native, woody plant species such as gorse (*Ulex europeaus*), blue gum (*Eucalyptus globulus*), broom (*Cytisus* spp.), and Monterey pine (*Pinus radiata*). The shade they create is in part responsible for the decreased abundance of lupines (Cushman 1993).

Eggs are usually laid singly on the dorsal surface of young leaves of the larval host plant and hatch in 6-10 days (Downey 1957). Some locally collected data showed that females appear to favor younger leaves for egg deposition, as the mean number of eggs on smaller leaves was significantly higher than that found on larger leaves (Lindzey unpublished data). About three weeks after hatching, the second instar larvae enter an obligate diapause, and spend the remaining summer and winter in the litter at the base of *Lupinus* host plants. Larvae break diapause the following spring and continue feeding on lupine. Post-diapause larvae (third or fourth instars) have been observed both on leaflets and on unopened and opened inflorescences (Rashbrook & Cushman 1996). Arnold (1983) found that pupation occurred in the duff around the base of lupine and other plants.

As is common in many lycaenid butterflies, ants may tend the later-instar larvae of the Mission blue. *Prenolepis imparis* and *Formica lasioides* have been observed collecting the sugary secretions produced by the larger larvae (Downey 1957; Arnold 1983), and these ants may protect the larvae from their natural enemies (see studies discussed in Cushman et al. 1994). Non-native Argentine ants, *Linepithema humile*, were investigating two of the four post-diapause larvae observed at the Marin Headlands in 1996. This is a disturbing sign given that this highly invasive ant species is known to out-compete native ant species in South Africa (Bond & Slingsby 1984).

The Mission blue is attacked by a variety of natural enemies throughout its life cycle. Eggs are attacked by three hymenopteran parasitoids: a trichogrammatid, a scelionid and an encyritid species. The larger instar larvae are parasitized by a tachinid fly and a braconid wasp. Both larvae and pupae are probably preyed upon by rodents, and the second instar caterpillars are subject to desiccation and disease during their diapause (Arnold 1983).

METHODS

TRANSECT MONITORING:

During 1993 and 1994, the Golden Gate National Recreation Area established 17 permanent transects, with transects clustered in five areas (or monitoring regions), in the Marin Headlands (Map 1). Two of these transects are 50 meters in length; the remaining fifteen are 100 meters long. The transects cover areas of undisturbed or restored habitat where Mission blue butterflies had been previously sighted (Maps 2-6). Descriptions of each monitoring region are listed in the appendix.

Mission blue abundance

To estimate Mission blue abundance, butterflies were censused using a low-impact observational technique (Pollard 1977, Pollard & Yates 1993). Each transect was walked on 13 occasions between February 25 and June 7, 2008. When possible, all transects were surveyed on a single day. If transect completion was not possible, a follow-up survey was completed on any remaining transects on the next good weather day. (This occurred on four occasions in 2008: surveys labeled: 3/26, 4/19, 5/16, and 6/7 in the following charts and tables.) Surveys were conducted between 0900 and 1400 hours as wind speeds are typically lower during this period and generally increase throughout the day. As much as possible, given the steep and uneven terrain, each transect was covered at a constant pace of 100 meters per five minutes. When a butterfly was observed and positively identified in front of the monitor or within five meters on either side of the transect, it was recorded on a standard data sheet (see Appendix). Individual butterflies were counted once only. The sex of all individuals was noted and their behavior categorized as either flying, perching on floral structures (and potentially nectaring), perching on the ground or vegetation, courting, inter-male interaction, mating or oviposition. In addition to these transect observations, the sex, behavior and location of any incidental, off-transect sightings of Mission blues were recorded using a Trimble GeoXT GPS unit (see Appendix for off-transect data sheet) when possible. The numbers of other lycaenid butterfly species observed on the transects or on trails between transects were also noted.

Throughout the survey period, sites were visited in semi-systematic rotation, such that a site sampled first on one date was sampled later in the rotation the next week This procedure was adopted in order to minimize any bias due to repeatedly sampling the same site at the same time of day throughout the monitoring season. A Kestrel 3000 Pocket Weather Meter was used to determine conditions (air temperature, humidity, and wind speed) on all sampling days. The wind direction was also noted, and an estimate made of the extent of fog and percent cloud cover at each site. Surveys were not conducted if the fog was judged to be too dense, the temperature was below 53.0˚F, and/or the wind was consistently above 15 mph.

COROLLARY MONITORING

Boisduval's blue, *Plebejus icaroides*, occurs as several subspecies among different regions along the west . The Marin Headlands marks the northern most boundary for the Mission blue butterfly, *Plebejus icariodes missionensis*. The distinctions that differentiate the Mission blue subspecies are subtle, and along the geographic boundaries of the subspecies, a detailed examination of the population is necessary to formally confirm that any Boisduval blue population is, in fact, a Mission blue population. This was the case for a population of blues occurring along the Miwok

Trail north of the Tennessee Valley trailhead (Map 7). This particular area was being considered for a trail alignment modification to reduce erosion potential and improve trail tread surface. I visited the area around the trail re-route for a habitat assessment in mid-February and returned to the site during the Mission blue flight season to assess adult butterflies. I visited the site on one excellent weather day and one slightly overcast day over a two week period in April and took photos of 10 individual butterflies, including one ovipositing female. In the field, special attention was paid to host plant choice and adult flight window. The field photos were used in side-by-side comparisons of photographs used by Dick Arnold and Summer Lindzey in a more thorough assessment of Oakwood Valley's blue butterflies. During photo-comparisons, dot arrangement/structure on the ventral wings, female dorsal wing color, and the width of the black borders on the dorsal wings of the male butterflies were examined.

DATA ANALYSIS

All data were entered into the Golden Gate National Recreation Area's Mission blue butterfly database. Data analysis was conducted using Microsoft Excel. Seasonal weather data was calculated using data collected from a new permanent weather station at Fort Baker. (This information was received by contacting Joe Huang at Joe_Huang@nps.gov or Stephen Kasierski at Stephen_Kazierski@nps.gov.)

RESULTS and DISCUSSION

Weather Conditions

Rains ended considerably earlier in 2008 than in previous years; no major precipitation fell after February. These dry conditions were matched with cooler weather in general. It is interesting to note that the monitoring day that yielded the highest number of butterfly sightings (April 11) was also the warmest monitoring day (76º F). Butterfly emergence in 2008 was sharply peaked and declined quickly after the peak day, as opposed to a smoother transition in previous years (Figures 1 and 5). This could have been an artifact of overcast and cooler weather conditions for the week that followed the peak butterfly abundance week. Rain peaked in January and minimally returned for the rest of the year (see Appendix). Average temperatures for January through May were slightly low, but not atypical (National Weather Service via Western Regional Climate Center, see Appendix). Temperature and wind speeds recorded at the study sites and averaged over each survey date were within the range of acceptable weather conditions during each survey(Table 1).

Mission Blue Abundance

Of the 147 butterflies observed in the monitoring regions, only 40 were found on the transects (Table 2a, 2b; Figure 1). One-hundred seven were found on the trails between transects or nearby transects but outside of the transect monitoring boundary. On- and off- transect butterflies displayed the same overall adult emergence and senescence times (Figure 1). Butterflies were observed on transects on 6 of the 13 survey days. To more completely represent Mission blue population trends for the purpose of analysis, on and off transect butterfly numbers were aggregated in figures and graphs as noted. Of the 82 butterflies seen at the Rifle Range, only seven were seen on-transect. A similar but less striking trend appeared at Slacker Ridge, where 19 of 39 butterflies observed were seen on-transect.

Sex ratios in on transect butterflies (29 males: 11 female, n=40) and off transect butterflies (69 males: 38 female, n=107) indicate that approximately 70% of the butterflies observed were males. This could be explained by the fact that males are actively pursuing females and are more likely to catch the eye of the butterfly monitor than a female depositing eggs or resting. (Table 2a, Figure 2). Males first emerged about a week before females, thought both sexes had peak abundance numbers on the same day (Figure 2).

Butterflies were found at four of the five monitoring regions (Figure 3, Figure 4). When controlled for linear area surveyed (the sum of transect lengths per monitoring region), Battery Cavallo (as historically) appears to have a very dense population, at 13 on-transect butterflies seen per 100-meter transect surveyed (Figure 4). The other, larger sites, specifically Rifle Range and Slacker Ridge had considerably lower abundance when measured in this way (2.3 and 1.4 respectively); however this might simply be due to the fact that the available host plants at Battery Cavallo are more limited in their potential range due to thick scrub/trees bordering the grassy areas preventing the lupines from migrating away from the transects. Casual observation indicates that the majority of lupines in the general area are within 5 m (on either side of the transects) because the site's "good habitat" is so small, resulting in less space for the lupines to naturally "wander" away from the transects, with butterflies obligately following the host plants away from the static transects. No butterflies were seen on transects at Wolfback Ridge and Battery Duncan. The single Mission blue seen at Wolfback Ridge was observed on a windy day in an area dominated by thistles and French broom. Further inspection revealed no *Lupinus albifrons* in the immediate area, which leads me to believe that this butterfly may have blown into the area and did not represent a resident population. A photograph of this individual butterfly was reviewed by local Mission blue experts Summer Lindzey, Vanessa Rashbrook, and John Hafernik for confirmation of this surprising observation (Photo 1).

Behavioral Observations in Monitoring Regions

On- and off-transect butterfly behavioral observations were pooled for this comparison to more completely reflect the Mission Blue population. The majority of butterflies (83% of males and 73% of females) seen were observed flying. "Flying" includes both courting actions (male and females chasing one another) (2% of all males, 4% of all females) and male-male interactions (8% of all males.) The remaining butterflies were seen perched, either on the ground or on vegetation. Only 2 butterflies were seen on the ground; both were females (4% of all females). Eight male butterflies (8% of the male population) were observed interacting as pairs. One pair of butterflies was seen mating, at the stage when the male transfers the spermataphore to the female. Several photos and two videos were taken to capture this interaction.

Other Lycaenid Species

A total of 18 Acmon blues (*Icaricia acmon*) were observed throughout the surveys. These blues appeared in March, disappeared in April, and returned in May. This pattern is apparently not atypical during drier years such as this (Liam O'Brien, personal communication). Half of the Acmons seen were at Wolfback Ridge and 6 were seen at the Rifle Range. Three were observed at Slacker Ridge and the remaining 1 was seen at Battery Duncan.

Eleven Green hairstreaks (*Callophrys viridis*) were seen during this year's survey of the Marin Headlands, between April 11 and May 11. Eight were seen on Slacker (on or between Transects 113, 114, 115, and 116) and three were seen at the Rifle Range (on Transects 109, 100, and 111).

Corollary Monitoring

Field observations—adult flight window and host plant choice—of the butterflies observed in the area along the Miwok Trail in April 2008 suggest that this population falls within the Mission blue subspecies phenotype. This identification is confirmed by following phenotypic markings: blue appearing on the dorsal side of the wings in females, a thin black stripe between the blue and white on the ventral wing, and the maculations being more pronounced on the ventral hind wing than the ventral forewing. Although this particular population did not have especially wide white haloes ringing the black spots on the ventral wings that are typical of Mission blues, the other suite of characteristics allow us to draw the conclusion that these individuals are Mission blues (See e-mail in appendix). The majority of these butterflies were located on an open grassy slope, and casual observations of the *L. albifrons* population indicate a large number of first or second year plants. Up to 20% of these younger plants showed signs of Mission blue larval feeding

damage. While leaving the site, I followed the scrub-lined trail and saw another Mission blue flying among the lupines in a small grass patch (approximately 30 ft^2) surrounded by scrub and bisected by the trail (Map 7). The dust-covered lupines presented larval feeding damage. Only one adult was seen in the vicinity.

MULTI-YEAR COMPARISONS (1994-2008)

When comparing the accumulated data collected since 1994 (Figures 5a, 5b and Table 3), three distinct periods emerge; the four years from 1994-1997 (blue color shades in Figure 5) represent the highest numbers of butterflies recorded in the surveys. In contrast, five years of data from 1998 to 2002 (red/yellow shades) indicate a comparatively severe population decline. Butterfly abundance temporarily increased in 2003, but the trend appears to be downward from that point (green shades in Figure 5a and 5b).

Direct annual comparisons of the total number of butterflies recorded over the survey period (Table 4) is problematic, since varying weather conditions makes it impossible to standardize the monitoring frequency across years, leading to different numbers of surveys taken over different of periods of the flight season, depending on the year. Furthermore, naturally occurring fluctuations in butterfly phenology (presumably due to seasonal weather conditions) annually alter the required monitoring window. Nevertheless, comparing total numbers of butterflies over time clearly illustrates the major changes encountered over the past 15 years (Figure 6). The peak number of butterflies observed is highly correlated with the total number of Mission blues recorded (Bennett 2007). Therefore a comparison of peak numbers of adults observed in a single day during a survey year can be used as an indicator of the overall number of butterfly appearances for a given season. In the four earliest survey years, peak numbers ranged from 26-52, while in the following five years the range fell to 8-15. This compares with a range of 6-23 in 2003-2007, signifying an initial increase and subsequent reduction in butterflies on transects. When using only-on transect data in 2008, the 22 butterflies observed on transect on April 11 clearly fall within this range. The 2008 flight season was the 6^{th} (of 14) longest recorded adult flight window (Figures 5a, 5b, Table 3).

The rich data set collected over the past 15 years allows us to track the status of each Mission blue subpopulation inhabiting a given transect. Every year each transect provides a certain proportion of the season's overall number of butterflies observed. If the habitat quality were consistent among each site over the years, than the relative contribution of each transect would stay constant through time. A comparison of this percent contribution shows that this is not the

case (Figure 7). There are some clear shifts in overall butterfly distribution among the transects. Clearly, Battery Duncan and Wolfback Ridge have shown a more evident decline than the other sites and Battery Cavallo's relative importance has increased considerably from previous years. This could be interpreted to mean that either Battery Cavallo's resources have dramatically improved and allowed for increases in the Mission blue population numbers or it could mean that overall, the other sites are less productive. I suggest, however, that the increase in importance of Battery Cavallo's transects is not an indicator of population health, but a lack of micro-migration among the site. The manner in which spatial distribution data has been collected over time has made it very difficult to tease out distinctions in abundance shifts. A change in numbers might represent a decline in the overall butterfly population occurring in a region (such as Slacker Ridge) or it might represent a geographic shift from one area (such as transect 113) within a region to another area (such as below Transect 113). Specifically, transect 113 showed a steep decline in butterfly proportions (Figure 7); however, several off-transect butterflies were consistently observed at the base of the transect just beyond the monitoring corridor. With the current information available, it is impossible to know whether these off-transect butterflies have always occurred in that location or if those off-transect butterflies of today are the progeny of yesterday's transect 113 butterflies who followed a geographically shifting lupine population. At Battery Cavallo, the transects are located within a flat, open grassland surrounded by scrub or a cliff. The area is completely closed off to park users and, from casual observations, it appears that there is little room for the *Lupinus albifrons* to truly spread away from the area falling within the 100 m x 10 m monitoring corridor that each transect covers. In a larger, steeper area still accessible to park users, there is a higher probability of disturbance, which triggers natural Lupine recruitment. This recruitment essentially allows a population of *L. albifrons* to wander away from the static transect and into another part of the open grassland that doesn't fall within the 100 m x 10 m monitoring corridor. This possibility is being further explored in the associated Mission blue butterfly Monitoring Transect Vegetation Assessment currently being written.

Butterfly Phenology

In the Marin Headlands, the start of the Mission blue flight season has ranged from as early as March 8 (1997) to as late as April 9 (2000, see Table 4). However, in nine of 15 monitored years, butterflies emerged in the second half of March (March 16-31). The end of the flight season has also spanned as much as a month, from April 20 (1995) to May 21 (1999), with butterfly activity in the majority of years (77%) ending in the first half of May (May 1-15). The length of the flight season is correspondingly variable, and ranges from as short as 21 days (2000) to as long as 59 days (2005), with a mean of 47 days or approximately 7 weeks. Similarly, the date of peak abundance has varied between March 29 (1997 and 2003) and April 26 (1998). The

adult flight season for 2008 started early and ended late (March 24 through May 17), resulting in a relatively long season (52 days).

RECOMMENDATIONS and AREAS FOR FUTURE RESEARCH

Based on these observations, conversations with lepidologists, and a literature review, I offer the following recommendations to improve future data collection techniques and to enhance the current body of knowledge on Mission blue butterflies.

1) *Allow for more time to be spent surveying areas that support butterflies.* Either by eliminating certain transects which have never supported a large number of butterflies or by providing funding for more field exploration, a larger proportion of the butterfly monitor's time should be spent tracking existing butterflies. Extra time should be allocated to better understanding their distribution both adjacent to transects and in other areas.

2) *Reevaluate current transects for quality of habitat.* Vegetation type should be evaluated along each transect. Scrub versus grassland should be evaluated, as well as abundance of Mission blue host plants. Lupine size (an age metric) should be recorded, as well as species of lupine. This lupine assessment could augment work completed this year categorizing vegetation type along transects and described in associated report.

3) *Develop more appropriate transect shapes.* The linear transects currently used for this monitoring process no longer reflect the current shape of available Mission blue habitat. As lupine patches change in shape, size, and density, the transects should be modified to allow for adequate surveying. I recommend a wandering transect to meander the majority of each lupine patch for a specific amount of time. The amount of time should correlate directly with the size of the lupines patch to control for inherent differences in resource availability. This would standardize what were formerly off-transect butterfly sightings, as recommended by Vanessa Rashbrook in previous years.

4) *Extend the observation window by monitoring lupines for caterpillars and feeding damage.* Because the Mission blue's flight season is so short and adult butterflies tend to fly under such limited climatic conditions, I recommend incorporating a larval and feeding damage survey component into the current monitoring regime. Areas that support large populations of lupine habitat and adjacent to transects that formerly supported large

Mission blue populations (but no longer do) should be assessed for the presence of Mission blue larvae. This information will help determine the appropriateness of potentially new transects locations. Lindzey's unpublished research at Oakwood Valley shows direct correlations between feeding damage surface area on lupine leaflets and density of Mission blue larvae.

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