Microclimate parameters associated with three overwintering monarch butterfly habitats in central California: a four year study

Project Report 2006

Winters
2002-03
2003-04
2004-05
2005-06

Study Sites:
Andrew Molera State Park (Stands A and B)
Point Lobos State Reserve

Ventana Wildlife Society
Conservation Ecology Program

By:

Jessica L. Griffiths[1]

[1] E-mail: jessicagriffiths@ventanaws.org; Phone: (831) 624-1202

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INTRODUCTION

The western population of monarch butterflies (*Danaus plexippus)* migrates to specific overwintering habitats along the Pacific coast of California and Mexico each fall. Suitable overwintering habitat is comprised of a relatively dense grove of trees with understory, located near water and nectar sources and protected from the wind by topographic landforms or trees (Sakai and Calvert 1991). An overwintering grove acts as a protective "humidity lens" to ameliorate climatic extremes of temperature and moisture occurring outside the grove (Sakai and Calvert 1991).

Managing overwintering monarch butterfly habitat requires an understanding of microclimate conditions needed by butterflies. Microclimate conditions of habitats supporting monarch butterfly populations along the central coast of California are not well documented. Past studies reported that monarch butterflies seek trees with exposure to filtered sunlight and shelter from gusty intermittent winds (Leong 1990, Leong et al. 1991, Sakai and Calvert 1991). Monarch butterflies appear to orient themselves to different aspects relative to the trunk of their roost trees during the winter months in response to the direction of winds through the grove (Leong 1990, Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004, Frey et al. 2005).

Two groves at Andrew Molera State Park and one grove at Point Lobos State Reserve have been recognized as historic monarch butterfly overwintering habitats in Monterey County in the California Natural Diversity Database maintained by the California Department of Fish and Game. Prior to the surveys conducted by Hamilton et al. (2002) beginning in winter 2001-02, monarch butterfly population estimates at these locations had been intermittent and anecdotal.

At Andrew Molera State Park, the earliest monarch butterfly population estimates date back to John Lane's field notes from 1982, when he observed butterflies clustered over the trail adjacent to the Cooper Cabin (hereafter referred to as Stand A) (Appendix A). Whether or not the butterflies were roosting at that time in the western grove across the small drainage (hereafter referred to as Stand B) is not known. In winter 1990-91, Sakai and Calvert (1991) observed the majority of butterflies roosting in Stand B. More recent reports have described monarch butterflies roosting primarily in Stand A (Sakai 2001, Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004, Frey et al. 2005).

At Point Lobos State Reserve, the earliest recorded observations of overwintering monarch butterflies date back to the establishment of the reserve when docents began keeping log books of natural history observations. The majority of observations to-date document the butterflies using the warmer protected areas on the southeast side of Whaler's Knoll (Appendix B) (Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004, Frey et al. 2005).

During the winter seasons in 2002 - 2006 we collected data on microclimate variables in the overwintering habitats at Andrew Molera State Park (Stands A and B) and Point Lobos State Reserve in Monterey County. Our objectives were to establish a long-term monitoring study for 1) comparing microclimate characteristics among monarch butterfly overwintering groves and 2) investigating the relationship between microclimate and relative numbers of overwintering monarch butterflies within the groves.

METHODS

Study sites.—Beginning in 2002, we installed data-loggers and weather equipment each winter at two locations in Andrew Molera State Park (Appendix A) and at one location in Point Lobos State Reserve (Appendix B). Andrew Molera State Park (Molera) is located 34 km south of the Carmel River, Monterey County. Blue gum eucalyptus (*Eucalyptus globulus*) is the predominant tree species at both Stand A and Stand B and was the only tree species used by monarch butterflies. Point Lobos State Reserve (Point Lobos) is located 7 km south of the Carmel River, Monterey County. Monterey pine (*Pinus radiata*) is the predominant tree species at the grove and was the primary tree species used by monarch butterflies.

At each location, we placed a weather station on the northwestern fringe of the "amphitheatre" opening where a significant number of butterflies had clustered in the winter of 2001-02 (Hamilton et al. 2002). However these locations did not exactly match the butterfly roosting sites established in 2003-04 (Frey et al. 2004), 2004-05 (Frey et al. 2005), or 2005-06. In 2003-04 and 2004-05, butterflies clustered near the Molera Stand A weather station, but in 2005-06, the butterflies clustered to the south and west of the weather station. In none of those years did the butterflies cluster near the Stand B weather station. At Point Lobos in 2003-04, the majority of clustering butterflies were about 75 meters west of the weather station (Frey at al. 2004), but in 2004-05 and 2005-06 the majority of butterflies clustered in the vicinity of the weather station (Frey et al. 2005). Each station was elevated

off the ground approximately 0.5 to 1.5 m. This report presents analyses from microclimate parameters collected from 9 November 2005 to 8 March 2006, the period of time when large numbers of monarch butterflies overwintered on the central coast during the 2005-06 overwintering season.

Data management.—Using a HOBO shuttle and cable, we routinely transferred weather data from the data loggers to our office desktop computer using Boxcar Pro 4.0 software. From Boxcar, we imported the data into an Excel spread sheet we designed specifically for managing microclimate data. On a regular basis we monitored equipment, downloaded weather data, maintained the database, and ensured that all equipment functioned properly. After March 2006 we removed and safely stored all weather equipment to prevent vandalism.

Sunlight intensity.—We measured light intensity using the HOBO Light Intensity Logger. Every 30 min the HOBO logged light intensity in lumens per square meter.

Temperature, relative humidity, and dew point.—We measured temperature, relative humidity, and dew point using a HOBO Pro Series Weatherproof Logger protected by a rain shield. Temperature was logged every 30 min in degrees Celsius, relative humidity was logged every 30 min in percent, and dew point was logged every 30 min in degrees Celsius.

Precipitation.—We measured precipitation using a Rainwise III Rain Gauge connected to a HOBO Event Rainfall Logger. The rain gauge collected precipitation using a funnel that dripped water into a "tipping bucket". Each time the bucket tipped, an "event" that equated to 0.02710 cm precipitation was logged.

Monarch butterfly censusing.—In addition to recording microclimate data, we also conducted a weekly census of overwintering monarch butterflies at each of the three locations throughout the overwintering period (9 November 2005 to 8 March 2006) in cooperation with Project Monarch Alert at California Polytechnic University. For the purposes of this report, we documented the presence or absence of clustered monarch butterflies.

Statistical analyses.—We used one-way ANOVA (Ott 1993) to investigate differences in sunlight intensity, temperature, relative humidity, and dew point at each of the three study sites. Statistical significance was assumed at a level of $P < 0.05$.

RESULTS

Light intensity differed significantly between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 120.8$, $P < 0.001$). Stand A at Molera received the least amount of light, Stand B slightly more light, and the Stand at Point Lobos received the most light (Table 1).

There was a technical problem with the data logger that recorded temperature, dew point, and relative humidity at Stand B at Molera, which resulted in the logger ceasing to function after 5 January 2006. Because of this, we compared temperature, dew point, and relative humidity among the stations only during the period when all three stations were recording data, from 9 November 2005 to 5 January 2006.

Temperature differed significantly between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 18.82$, $P < 0.001$). Stands A and B at Molera had nearly identical mean temperatures although Stand B had a slightly higher mean temperature, and the stand at Point Lobos had the highest recorded temperatures (Table 1).

Relative humidity differed significantly between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 366.71$, $P < 0.001$). Stand B at Molera and Point Lobos had nearly identical mean relative humidities although Point Lobos had a slightly higher mean, and Stand A at Molera had the lowest mean relative humidity. (Table 1).

Dew point significantly differed between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 359.59$, $P < 0.0001$). Stand A at Molera had the lowest mean dew point by far, followed by greater mean dew points at Stand B and Point Lobos, respectively (Table 1).

Precipitation data for the overwintering period was not collected properly due to technical difficulties, and therefore cannot be analyzed. Two of the rain gauges and event loggers did not collect viable data at all. In January, the Point Lobos event logger lost all the rain data it had collected up to that point, and an assessment of the equipment revealed that the problem was irreparable. The Molera Stand B rain gauge was physically damaged, and unable to collect data. It was not possible to complete repairs before the end of the winter season. The only station that gathered precipitation data was Molera Stand A, and this data was only from January to March. From 5 January to 8 March 2006, Stand A recorded 2.5 cm of rainfall.

During the overwintering period from 9 November 2005 to 8 March 2006, numbers of overwintering butterflies varied greatly among the three study sites. We regularly observed clusters of overwintering butterflies at Molera Stand A and Point Lobos; weekly population estimates ranged from 16 to 12,455 butterflies at Molera Stand A and 0 to 107 butterflies at Point Lobos. We never observed butterflies at Molera Stand B. The population counts at Molera Stand A were higher than the previous winter, while the counts at Point Lobos were much lower than last year (Frey et al. 2005; Figure 1).

DISCUSSION

Microclimate parameters measured from 9 November 2005 to 8 March 2006 varied significantly among the three study sites. Point Lobos averaged the highest light intensity, temperature, relative humidity, and dew point (Table 1). In contrast, Stand A at Molera averaged the lowest light intensity, temperature, relative humidity, and dew point (Table 1). These different microclimate conditions likely affected the number of overwintering butterflies observed at each of the sites. However, continued long-term monitoring of microclimate parameters and overwintering butterflies is needed to clearly understand relationships between microclimate conditions and their effect on overwintering butterflies.

Monarch butterflies clustered in the greatest aggregations in Stand A at Molera, in lower numbers at Point Lobos, and were completely absent from Stand B at Molera this winter. Preliminary results suggest that microclimate conditions that support overwintering monarch butterflies are more favorable in Stand A at Molera and in Point Lobos compared to conditions in Stand B at Molera. Over the last four years, light intensity has decreased at Stand B (Table 2). Stand B is much more structurally dense and lacks the "amphitheatre" opening where butterfly clusters are most commonly located. Opening up Stand B with management practices (e.g., felling large branches in the center) would likely allow for more sunlight to enter the grove and could potentially create conditions favorable for overwintering butterflies. It is interesting to note that light intensity has also declined steadily over the last four years at Molera Stand A (Table 2). However, the yearly overwintering monarch butterfly population totals at Molera Stand A do not appear to correspond to the declining sunlight intensity (Figure 1). Further monitoring will determine if this decrease in light intensity has any long-term effect on overwintering butterflies, and will dictate whether or not Stand A needs to be managed to increase light intensity.

In contrast to the Molera sites, there has been an overall increase in light intensity at Point Lobos and an increase in average temperature and dew point over the last three years (Table 2; Table 3). Overwintering monarch butterfly populations at Point Lobos have been declining over the last three years, which may correspond with these changes in microclimate (Figure 1).

Last winter (2005-2006) at population peak which occurred during the week of 9 November 2005, we estimated 43,643 butterflies present at nine[2] overwintering sites in Monterey County. This population peak is a 23% decrease from the previous winter's (2004-05) peak of 56,847 butterflies, and a 39% decrease from the 2003-04 peak of 71,566 butterflies, but it is twice as high as the 2002-03 peak of 13,083 butterflies (Figure 1). While the variation among years in the overall number of overwintering butterflies may be a result of the cyclical nature of insect populations, it is likely that such differences among and between years are also a function of annual macroclimate variation. The population dip in winter 2002-03 may be attributed to unseasonably drier and milder conditions in the preceding summer and fall, which may have reduced the availability of milkweed (*Asclepias* spp.), the host plant of the monarch butterfly (Sakai *pers. comm*). When comparing annual fluctuations of butterflies in conjunction with overwintering microclimate parameters, it is important to take macroclimate fluctuations into account. Microclimate fluctuations may be useful in measuring local effects of macroclimate.

Past studies reported that overwintering butterflies did not cluster on trees subjected to sun exposure and bright illumination (Brower et al. 1998, Leong 1990, Leong et al. 1991). Frey et al. (1992) found that on any given day, approximately 80% of the clusters were found in the shaded or indirectly lighted parts of a tree. Chaplin and Wells (1982) surmised that because metabolic rate in butterflies is a function of body temperature, prolonged exposure to direct light could result in suboptimal rate of body fat utilization. However, clustering butterflies were consistently found on southern exposures of trees throughout the overwintering period (Frey et al. 1992, Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004). Frey et al. (1992) suggested that roosting on the southern exposure of trees represents a compromise solution, whereby the butterflies are situated in a portion of the grove that is shaded and protected by wind, but also are provided brief opportunities for

[2] Monarch Grove Sanctuary, George Washington Park, Point Lobos State Reserve, Palo Colorado Canyon, Andrew Molera State Park, Sycamore Canyon, Private Property Site, Prewitt Creek, Plaskett Creek Campground.

radiant thermoregulation, allowing for movement on days near or below the flight threshold (13.8 °C). Given the results of these past studies and our preliminary results suggesting that greater sunlight exposure in Stand B at Molera could be advantageous to overwintering Monarchs, we suggest continuing this microclimate study for a period of at least 10 years, in conjunction with continued butterfly surveys and any habitat management or improvement that is undertaken.

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Table 1. Microclimate parameters compared during winter 2005-06 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

Stand	Light intensity (Lumens/sq. m)		Temperature[c] (°C)		Relative humidity[c] (%)		Dew point[c] (°C)	
	μ[a]	SE[b]	μ	SE	μ	SE	μ	SE
Molera A	-0.29	0.03	11.89	0.07	70.42	0.54	3.93	0.22
Molera B	0.01	0.03	11.93	0.06	85.51	0.45	8.42	0.12
Point Lobos	0.38	0.03	12.43	0.08	86.77	0.43	9.36	0.08

[a] Mean

[b] Standard error of the mean

[c] Data from 9 November 2005 to 5 January 2006 only

Table 2. Sunlight intensity (lumens/sq. m) compared over four winters from 2002 to 2006 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

Stand	2002-03	2003-04	2004-05	2005-06
Molera A	0.41 ± 0.03[a]	0.32 ± 0.03	0.22 ± 0.04	-0.29 ± 0.03
Molera B	0.16 ± 0.03	0.19 ± 0.03	0.10 ± 0.03	0.01 ± 0.03
Point Lobos	0.24 ± 0.03	0.45 ± 0.03	0.33 ± 0.04	0.38 ± 0.03

[a] Measurements are mean ± standard error.

Table 3. Temperature (°C) compared over four winters from 2002 to 2006 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

Stand	2002-03	2003-04	2004-05	2005-6[b]
Molera A	11.80 ± 0.05[a]	10.64 ± 0.04	10.91 ± 0.04	11.89 ± 0.07
Molera B	11.93 ± 0.05	10.72 ± 0.04	10.95 ± 0.04	11.93 ± 0.06
Point Lobos	12.70 ± 0.06	11.18 ± 0.05	11.77 ± 0.05	12.43 ± 0.08

[a] Measurements are mean ± standard error.

[b] Data from 9 November 2005 to 5 January 2006 only

Table 4. Relative humidity (%) compared over four winters from 2002 to 2006 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

Stand	2002-03	2003-04	2004-05	2005-06[b]
Molera A	82.83 ± 0.25[a]	74.49 ± 0.34	80.97 ± 0.30	70.42 ± 0.54
Molera B	81.44 ± 0.22	86.12 ± 0.21	91.48 ± 0.21	85.51 ± 0.45
Point Lobos	79.86 ± 0.26	85.71 ± 0.21	85.06 ± 0.24	86.77 ± 0.43

[a] Measurements are mean ± standard error.
[b] Data from 9 November 2005 to 5 January 2006 only

Table 5. Dew point (°C) compared over four winters from 2002 to 2006 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

Stand	2002-03	2003-04	2004-05	2005-06[b]
Molera A	8.50 ± 0.06[a]	4.75 ± 0.11	6.58 ± 0.10	3.93 ± 0.22
Molera B	8.51 ± 0.05	8.14 ± 0.05	9.10 ± 0.06	8.42 ± 0.12
Point Lobos	8.67 ± 0.05	8.49 ± 0.04	8.81 ± 0.05	9.36 ± 0.08

[a] Measurements are mean ± standard error.
[b] Data from 9 November 2005 to 5 January 2006 only

Figure 1. Peak Monarch Butterfly population counts during the overwintering period at two different overwintering sites in Monterey County, California from the winter of 2002-03 to the winter of 2005-06.

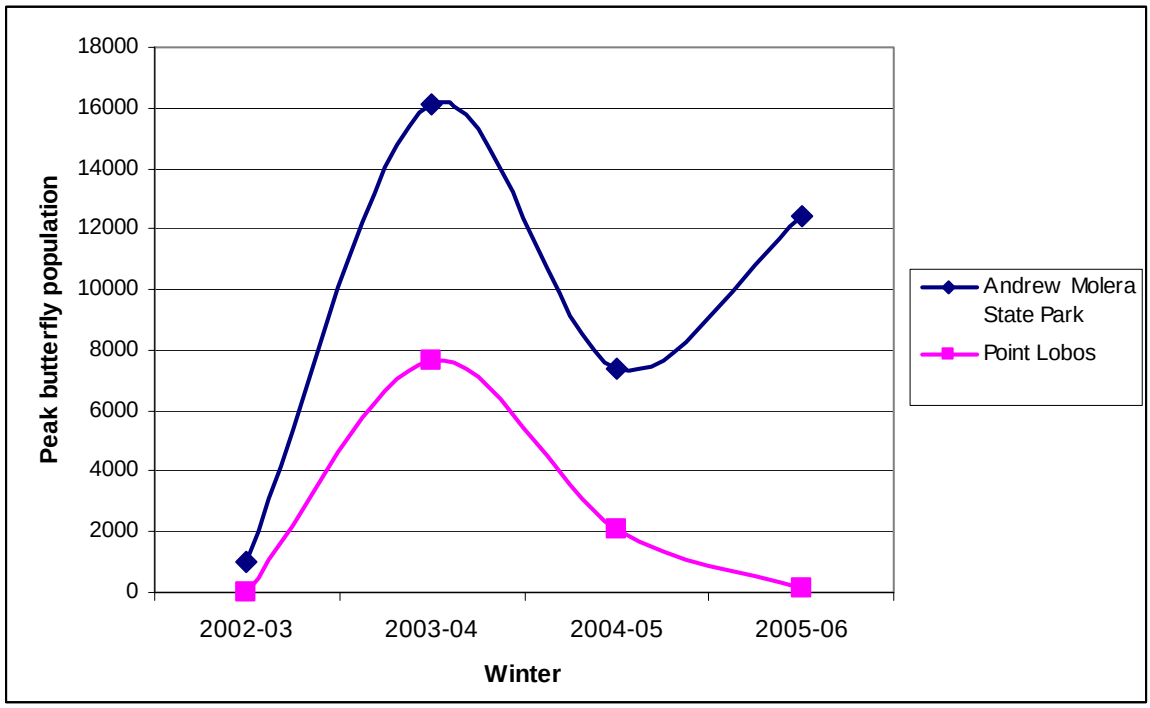
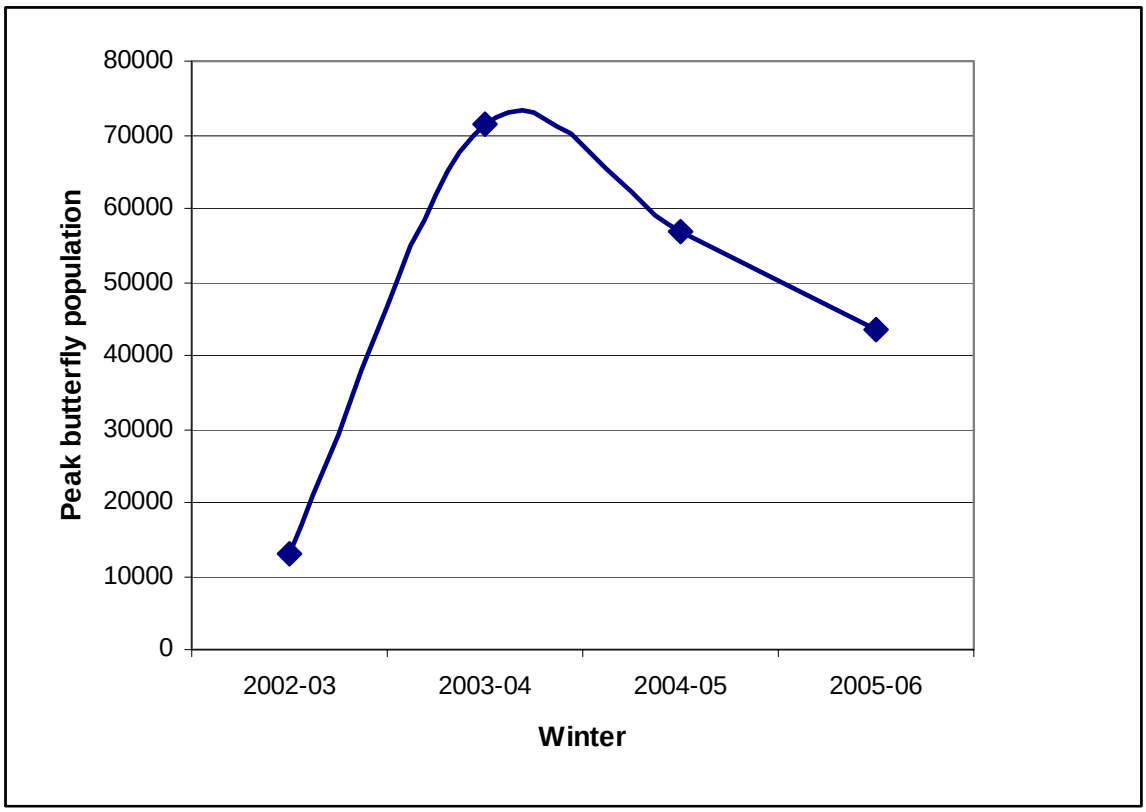
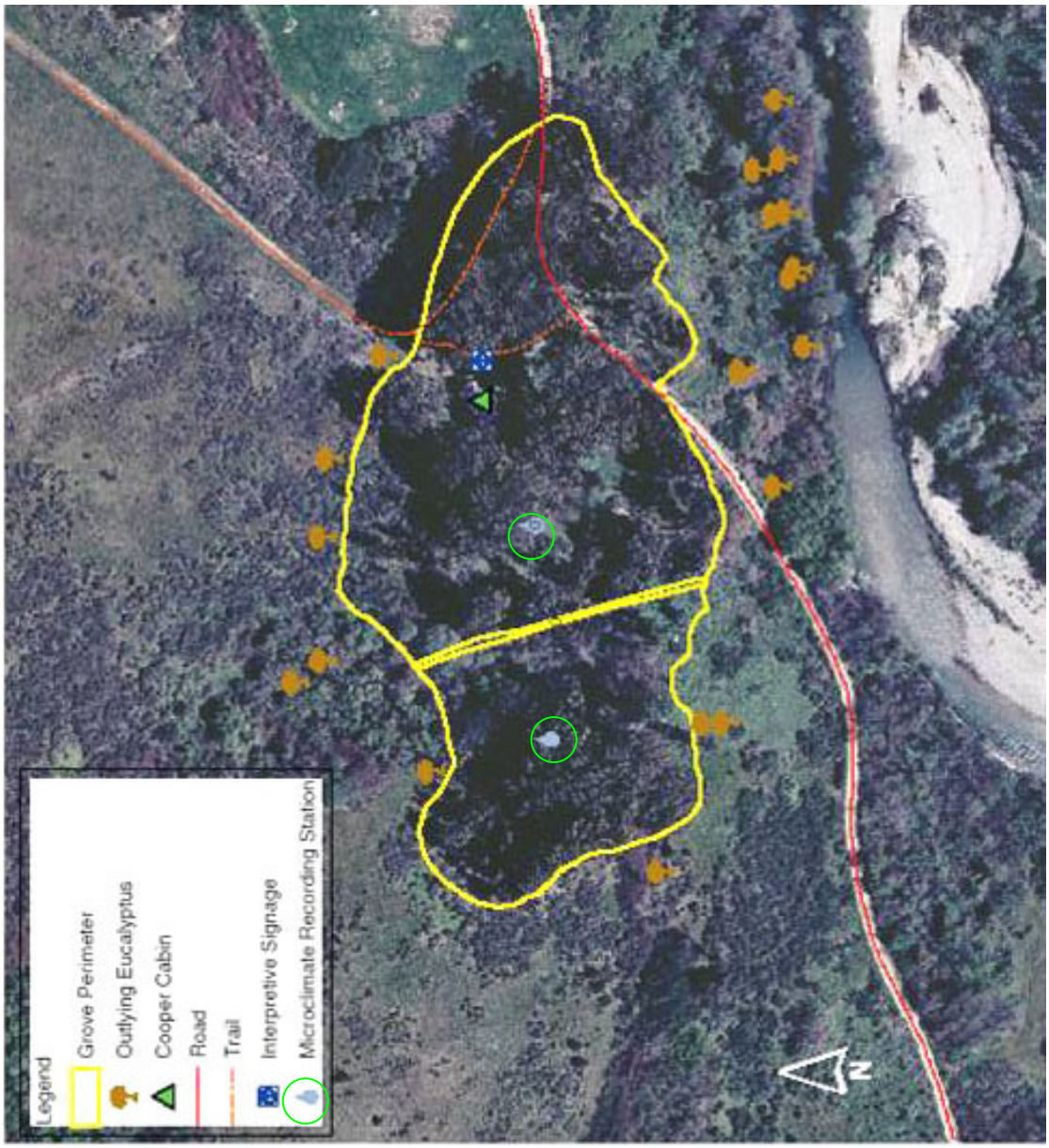


Figure 2. Peak Monarch Butterfly population counts during the overwintering period at nine overwintering sites in Monterey County, California combined from the winter of 2002-03 to the winter of 2005-06.



Appendix A. Study sites: Stand A and Stand B at Andrew Molera State Park, Monterey County, California.



Appendix B. Study Site: Point Lobos State Reserve, Monterey County, California.