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

Project Report 2005

Winters
2002-03
2003-04
2004-05

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

Ventana Wilderness Society's
Big Sur Ornithology Lab

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

INTRODUCTION

The western population of monarch butterflies (*Danaus plexippus)* migrates to specific overwintering habitats along the Pacific coasts of California and Mexico each fall. A suitable overwintering habitat comprises 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 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 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).

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 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 reports of 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).

In the winters of 2002-03, 2003-04, and 2004-05 we conducted a pilot study to gather baseline 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 main 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.—In 2002, 2003, and 2004 we installed data-loggers and weather equipment 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 only 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 areas where the butterflies clustered in the winter of 2003-04 (Frey et al. 2004) or 2004-05 (Frey et al. 2005). In 2003-04 and 2004-05, butterflies clustered near the Molera Stand A weather station, but not 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 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. For the purposes of this monitoring report, we included analyses from microclimate parameters collected from 4 November 2004 to 4 March 2005, the period of time when large numbers of monarch butterflies overwintered on the central coast.

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 30 March 2005 we removed and safely stored all weather equipment to prevent further 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 (4 November 2004 to 4 March 2005) (Frey et al. 2005). 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, $F = 11.11$, $P < 0.0001$). Unfortunately, the logger recording data at Molera Stand A was vandalized near the end of the overwintering period, and as a result, light intensity data was not recorded at Stand A for the entire 120-day period. Because of this, we compared sunlight intensity among the stations only during the 84-day period when all three stations were recording data, from 4 November 2004 to 27 January 2005. Stand B at Molera received the least amount of light, Stand A received a medium amount of light, and the Stand at Point Lobos received the most light (Table 1).

Temperature differed significantly between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 116.35$, $P < 0.0001$). 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; Figure 1).

Relative humidity differed significantly between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 432.12$, $P < 0.0001$). Stand A at Molera had the lowest relative humidity, followed by greater relative humidity at Point Lobos and Stand B, respectively (Table 1; Figure 2).

Dew point significantly differed between the two groves at Molera and the grove at Point Lobos (df = 2, $F = 361.48$, $P < 0.0001$). Stand A at Molera had the lowest mean dew point, followed by greater mean dew points at Point Lobos and Stand B, respectively (Table 1; Figure 3).

Precipitation also differed among the study sites. However, due to several critical technical difficulties, the rain gauges at two of the weather stations did not record precipitation for the entire 120-day overwintering period from 4 November 2004 to 4 March 2005. The rain gauge at Molera Stand B malfunctioned repeatedly throughout the winter, and did not in fact collect any data at all. This station was eliminated from our precipitation analysis. The rain gauge at Molera Stand A also malfunctioned several times, and collected viable data for only 46 days. Because of this, we compared precipitation among the two functional stations when both stations recorded data simultaneously, 22 November 2004 to 6 January 2005. During this time period, Point Lobos received more precipitation (5.75 cm) than Molera Stand A (3.55 cm).

During the overwintering period, 4 November, 2004 to 4 March 2005, numbers of overwintering butterflies varied greatly among the three study sites. We consistently observed clusters of overwintering butterflies at Molera Stand A and Point Lobos; weekly population estimates ranged from 99 to 7,399 butterflies at Molera Stand A and 11 to 2,176 butterflies at Point Lobos. We never observed butterflies at Molera Stand B. The population counts at Point Lobos and Molera Stand A were lower than the previous winter, but higher than the winters of 2001-02 and 2002-03 (Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004, Frey et al. 2005).

DISCUSSION

Microclimate parameters measured from 4 November 2004 to 4 March 2005 varied significantly among the three study sites. Point Lobos averaged the highest light intensity and temperature (Table 1) and the most precipitation. In contrast, Stand A at Molera averaged the lowest temperature, relative humidity, and dew point (Table 1) and the least amount of precipiation. Stand B at Molera averaged the highest relative humidity and dew point, and the lowest light intensity (Table 1). These different microclimate conditions likely affected the number of overwintering butterflies observed at each of the three sites. However, 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 (Frey et al. 2005). 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. Comparatively, Stand B averaged lower light intensity than the other sites. Over the last three years, light intensity has decreased and relative humidity has steadily increased at Stand B (Table 2; Table 4). 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 three years at Molera Stand A (Table 2). Further monitoring will determine if this decrease has any effect on overwintering butterflies, and will dictate whether or not Stand A needs to be managed to increase light intensity.

Last winter (2004-2005) at population peak which occurred during the week of 20 December 2004, we estimated 56,847 butterflies present at eight[2] overwintering sites in Monterey County (Frey et al. 2005). This population peak is a 21% decrease from the previous winter's (2003-04) peak of 71,566 butterflies, but it is more than four times greater

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

than the peak of 13,083 butterflies in 2002-03 and is 25% greater than the peak of 45,362 butterflies present in 2001-02. Such differences among years in the overall number of overwintering butterflies is probably 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. In the fall and winter of 2002-03, average temperature at each overwintering grove was higher than in following years (Table 3) and relative humidity was lower (Table 4).

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 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 greater sunlight exposure in Stand B at Molera could be advantageous, we suggest continuing this microclimate study over several years, in conjunction with butterfly surveys and any habitat management or improvement that is undertaken.

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Table 1. Microclimate parameters compared during winter 2004-05 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[a] (Lumens/sq. m)		Temperature (°C)		Relative humidity (%)		Dew point (°C)	
	μ[b]	SE[c]	μ	SE	μ	SE	μ	SE
Molera A	0.22	0.04	10.91	0.04	80.97	0.30	6.58	0.10
Molera B	0.10	0.03	10.95	0.04	91.48	0.21	9.10	0.06
Point Lobos	0.33	0.04	11.77	0.05	85.06	0.24	8.81	0.05

[a] Data from 4 November 2004 to 27 January 2005 only

[b] Mean

[c] Standard error of the mean

Table 2. Sunlight intensity (lumens/sq. m) compared over three winters from 2002 to 2005 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
Molera A	0.41 ± 0.03[a]	0.32 ± 0.03	0.22 ± 0.04
Molera B	0.16 ± 0.03	0.19 ± 0.03	0.10 ± 0.03
Point Lobos	0.24 ± 0.03	0.45 ± 0.03	0.33 ± 0.04

[a] Measurements are mean ± standard error.

Table 3. Temperature (˚C) compared over three winters from 2002 to 2005 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
Molera A	11.80 ± 0.05[a]	10.64 ± 0.04	10.91 ± 0.04
Molera B	11.93 ± 0.05	10.72 ± 0.04	10.95 ± 0.04
Point Lobos	12.70 ± 0.06	11.18 ± 0.05	11.77 ± 0.05

[a] Measurements are mean ± standard error.

Table 4. Relative humidity (%) compared over three winters from 2002 to 2005 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
Molera A	82.83 ± 0.25[a]	74.49 ± 0.34	80.97 ± 0.30
Molera B	81.44 ± 0.22	86.12 ± 0.21	91.48 ± 0.21
Point Lobos	79.86 ± 0.26	85.71 ± 0.21	85.06 ± 0.24

[a] Measurements are mean ± standard error.

Table 5. Dew point (°C) compared over three winters from 2002 to 2005 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
Molera A	8.50 ± 0.06[a]	4.75 ± 0.11	6.58 ± 0.10
Molera B	8.51 ± 0.05	8.14 ± 0.05	9.10 ± 0.06
Point Lobos	8.67 ± 0.05	8.49 ± 0.04	8.81 ± 0.05

[a] Measurements are mean ± standard error.

Figure 1. Temperature compared during the winter 2004-05 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.

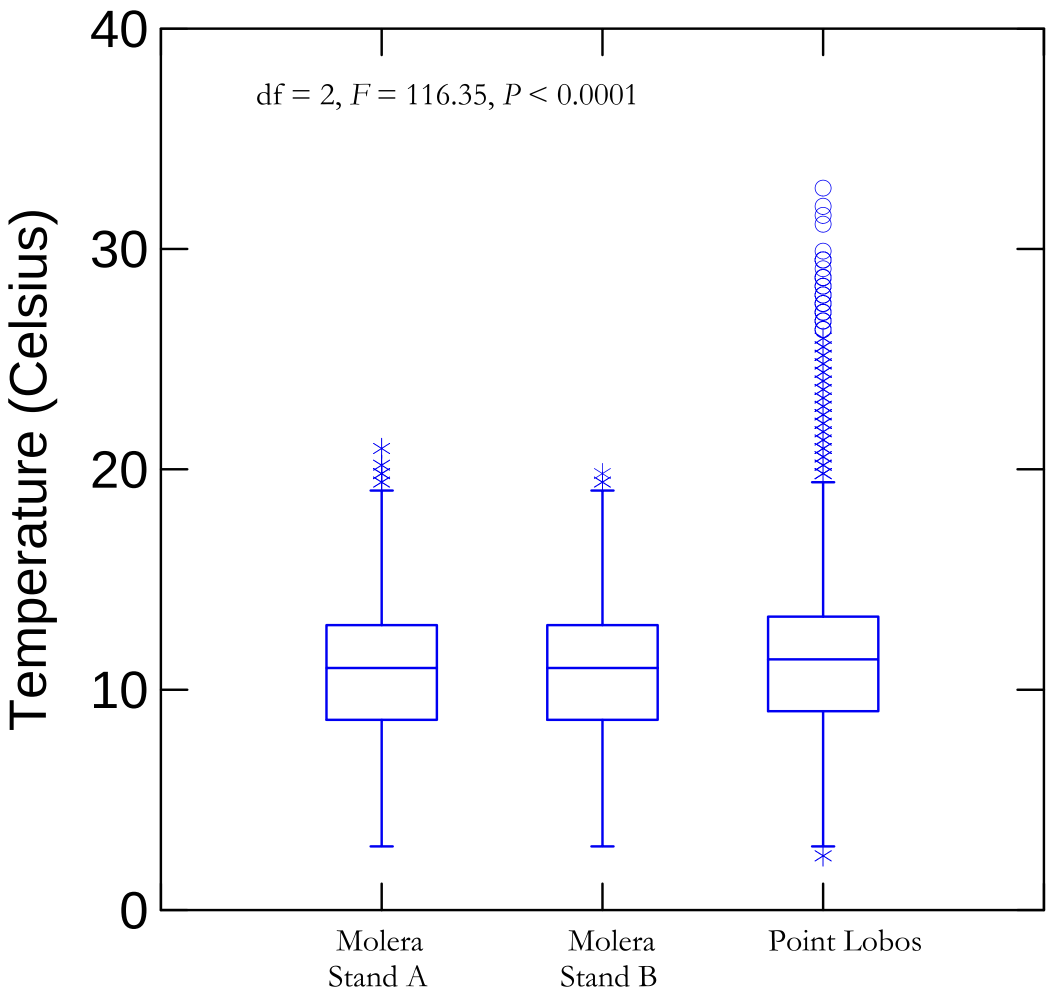


Figure 2. Relative humidity compared during the winter 2004-05 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.

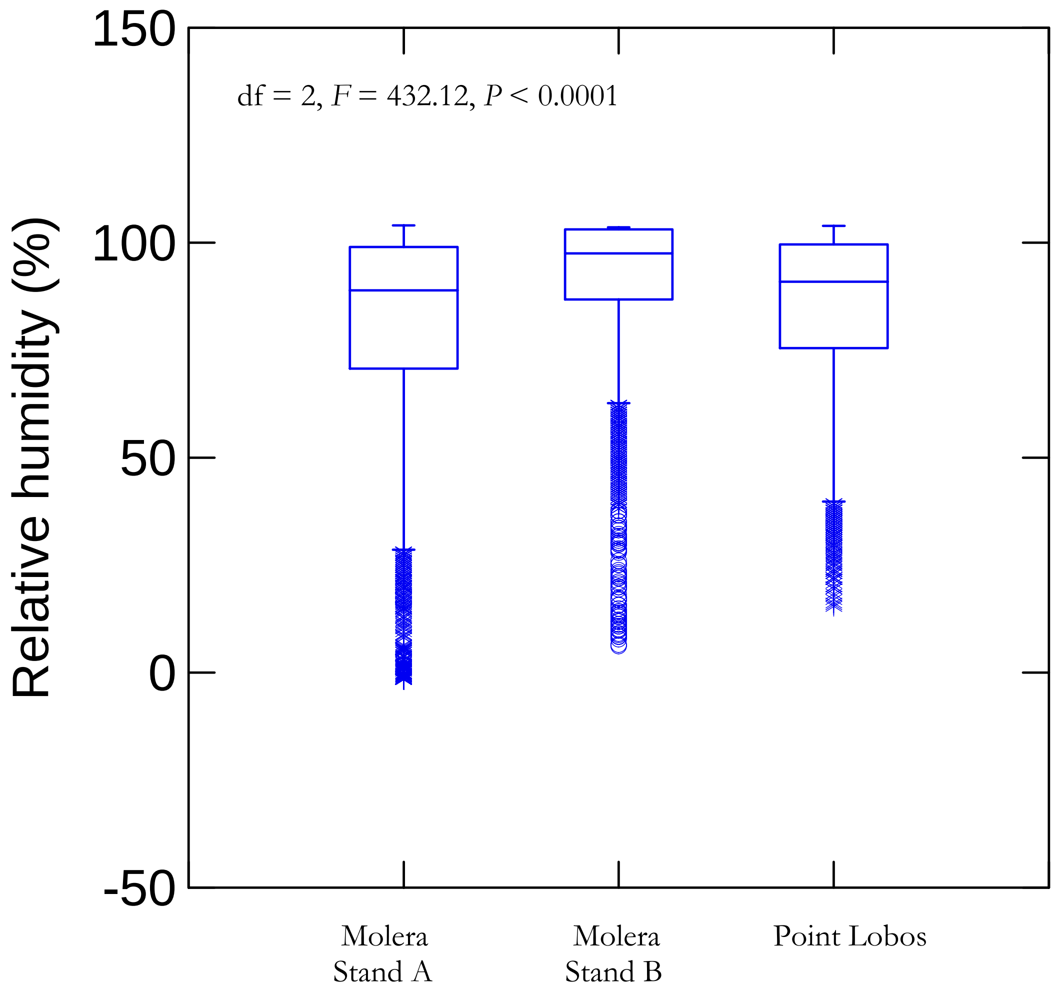
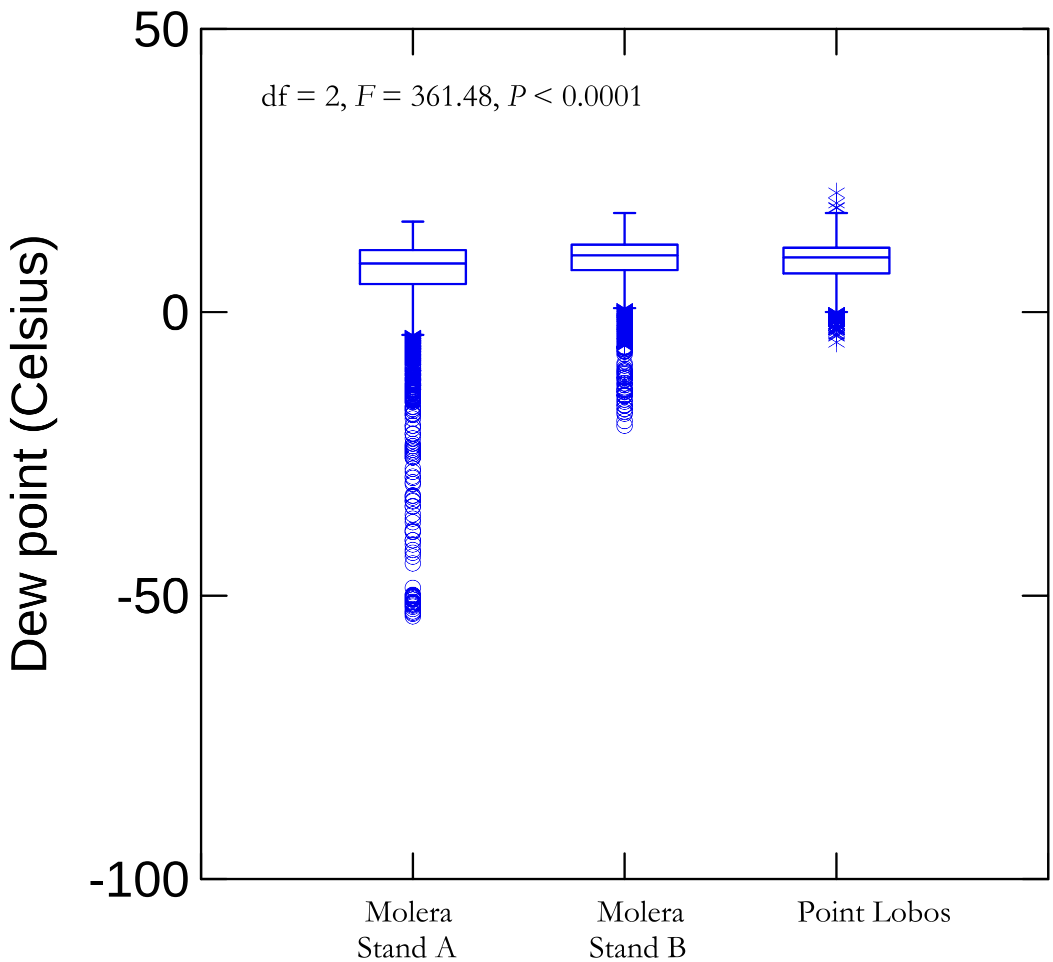
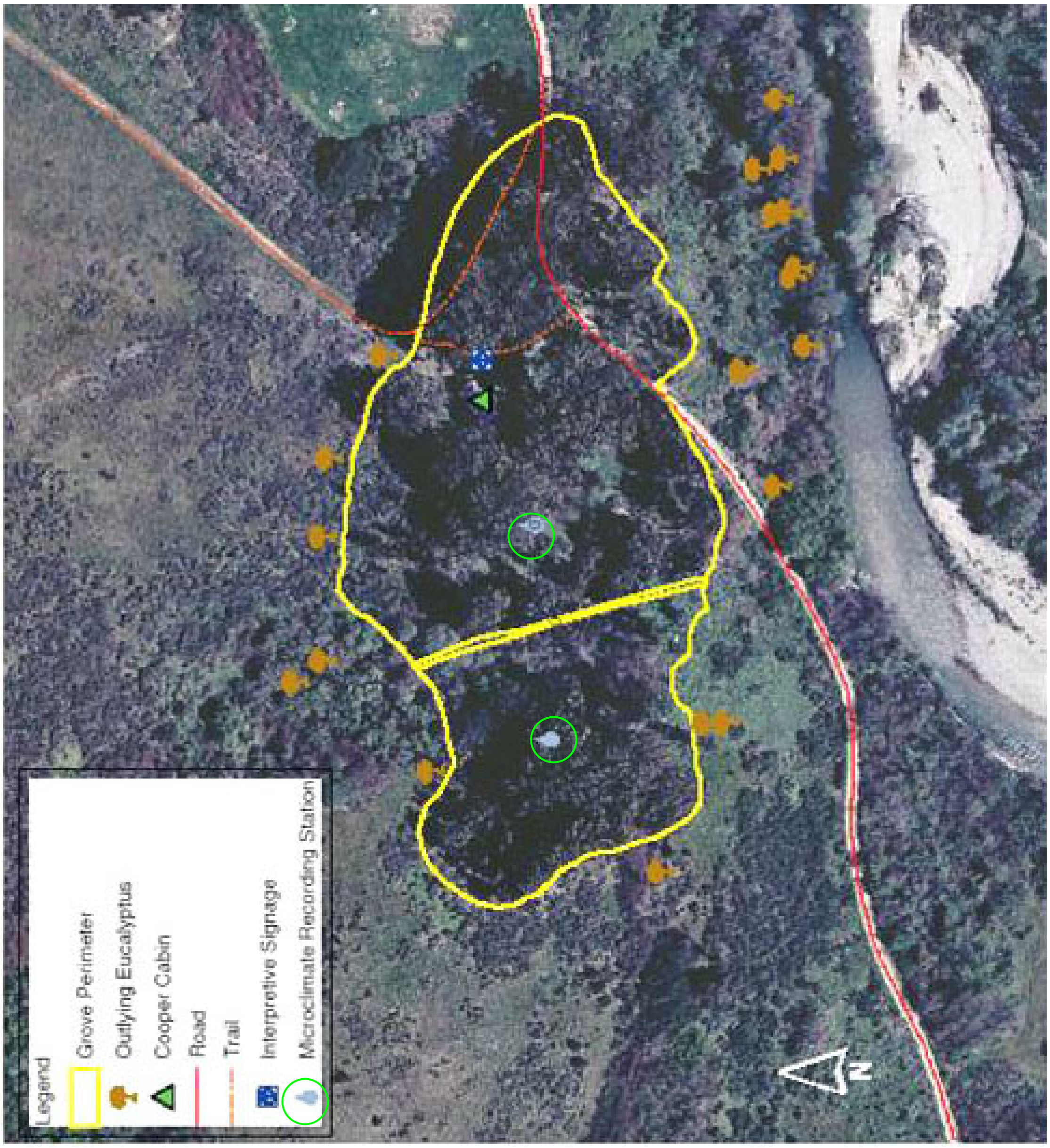


Figure 3. Dew point compared during the winter 2004-05 between the two groves at Andrew Molera State Park (Stand A and Stand B) and the grove at Point Lobos State Reserve, Monterey County, California.



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.

Legend

X Microclimate Recording Station