

Microclimate conditions at the Pacific Grove Monarch Sanctuary  
between September, 2020 - February, 2021

Dominick Sinicropi, Ph.D.

March 10, 2021

## Summary

This report provides a summary of microclimate conditions in the Pacific Grove Monarch Sanctuary during the overwintering period from September, 2020 through February, 2021. The objectives of the study were to provide a rational basis for management planning of the Sanctuary and a baseline for monitoring effectiveness of management activities in the future. Weather data recorded at the Sanctuary were compared with results from previous studies carried out at the Sanctuary, comparison with a nearby regional weather monitoring station, and microclimate conditions known to be critical at other monarch overwintering sites elsewhere in California. The results indicate that the microclimate conditions within the Monarch Sanctuary have degraded over the last couple of decades relative to previous years when substantially greater numbers of monarchs utilized the site for overwintering. Measures suggested to restore the habitat in the Monarch Sanctuary are presented in the discussion.

## Introduction

The Pacific Grove Monarch Butterfly Ecological Preserve (the Monarch Sanctuary) was purchased by the City of Pacific Grove in 1992 with the intention of maintaining it as an overwintering habitat for monarch butterflies (Conservation Easement, 1992). Residents were so determined in their stewardship responsibility that the City adopted the tagline "Butterfly Town USA". Since then the number of monarch butterflies overwintering at the Sanctuary has declined precipitously (Xerces Society, 2021). There are many factors that are likely to have contributed to the decline in the number of monarchs overwintering in Pacific Grove. One factor that we, as residents of Pacific Grove, have as our responsibility is to preserve the habitat for the monarchs to overwinter in our special microenvironment. Survival of the Western Monarch is dependent on several factors but they must have a suitable habitat for overwintering if they are to prevail.

In December, 2019, I proposed to the Beautification and Natural Resources Commission (BNRC) that we establish a weather station to monitor the current microclimate at the Monarch Sanctuary at no cost to the City. Their approval of the project was delayed by the onset of the COVID-19 pandemic. The weather station was eventually installed in late August, 2020. Since then it has been continuously operational and recording weather conditions in the Monarch Sanctuary for more than six months.

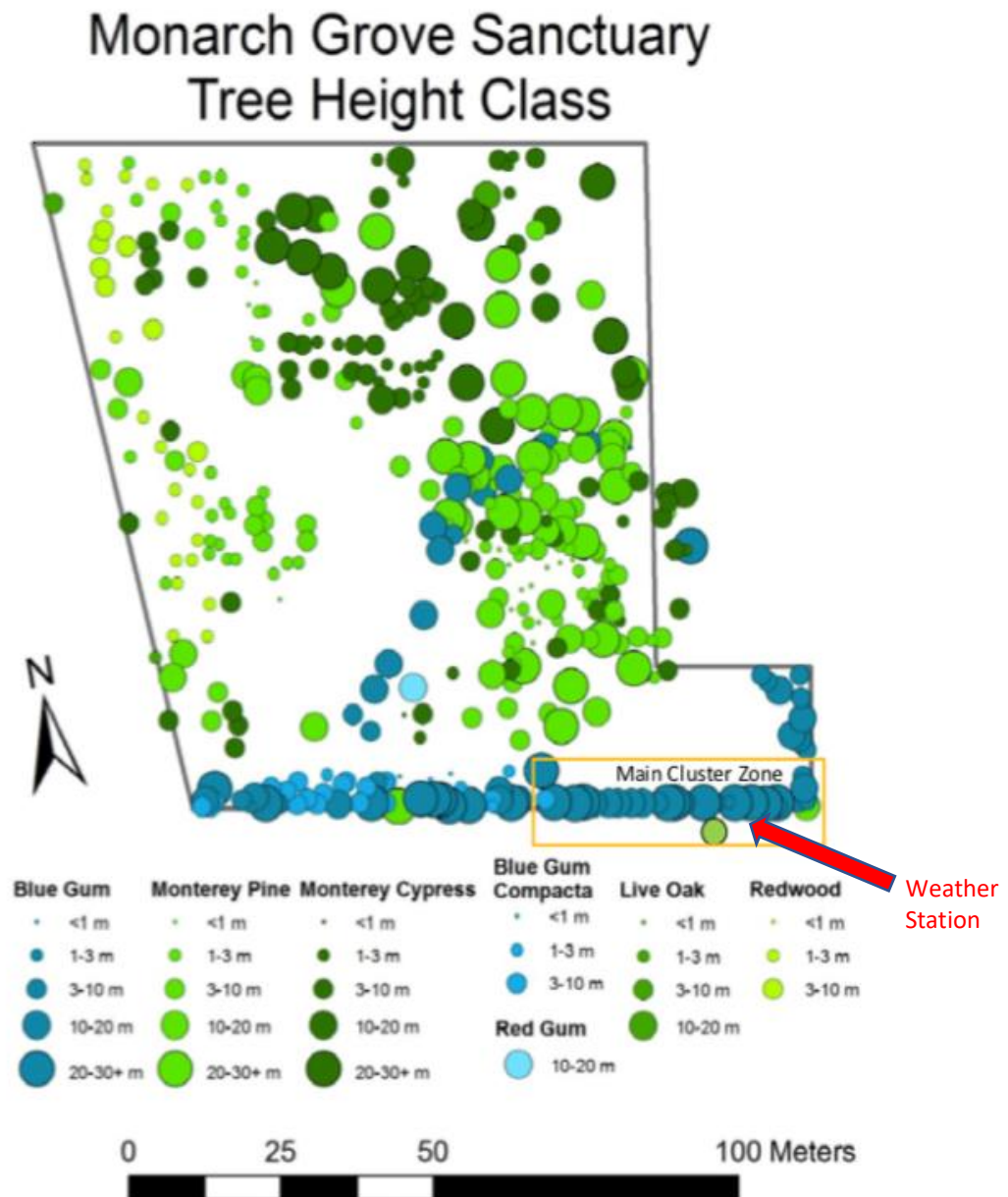
The purpose of this report is to document the data we have recorded from the Sanctuary weather station over the past six months. The data will be discussed in relation to previous microclimate conditions within the Sanctuary, recording of current baseline measurements, and goals for future habitat management in the future.

Stuart Weiss, a consultant that provides a report to the City of Pacific Grove with recommendations for management of the Monarch Sanctuary, has asserted several times that weather data recorded at the Monterey Airport located approximately 10 miles east of the Monarch Sanctuary are representative of the microclimate at the Sanctuary (Weiss, 2016). Local residents are well aware that microclimate conditions at the Monarch Sanctuary and the Monterey Airport are very different, despite their proximity, due to local geography. Nevertheless, Stuart Weiss and his corporation, Creekside Science for Earth Observation, assert with no evidence that weather data from the Monterey Airport can be used to computationally predict microclimate conditions at the Monarch Sanctuary. A goal of this report will be to test this assertion using weather data recorded at both locations.

## Methods

An Ambient Weather 2902A weather station was installed and began operating on August 25, 2020 in the Monarch Sanctuary. It is located between the row of eucalyptus and the fence along the south border of the Sanctuary where indicated by the arrow in Figure 1 at a height of about 10 feet above the ground. This area was chosen because monarchs reliably cluster in this row of trees.

Figure 1



## Data

from the weather station is uploaded every 5 minutes to two online servers: ambientweather.net and wunderground.com. Current weather conditions The name of the

weather station on ambientweather.net is "Monarch Sanctuary, Pacific Grove" and "Pacific Grove Acres (KCAPACIF218)" on wunderground.com. Standard data uploaded to those servers includes temperature, windspeed, wind direction, humidity, atmospheric pressure, rainfall, solar radiation, and UV radiation. Throughout this report data recorded at the Monarch Sanctuary weather station were compared with data recorded at the National Oceanic and Atmospheric Administration (NOAA) weather station at the Monterey Airport; however, fewer weather parameters are reported from this weather station and the data is updated every hour. Archived data from both weather stations can be downloaded from the friendsofthemonarchs.org website at <https://friendsofthemonarchs.org/monarch-sanctuary-weather-page/>.

Weather data recorded from both weather stations were analyzed and graphically summarized using Microsoft Excel.

## Results

### Wind Direction Data:

The weather station has been operating almost continuously for more than six-months. Data reported here cover the period from September, 2020 through February, 2021. The direction of winds coming into the Sanctuary during that period is summarized in Figure 2A. Bars in the figure represent the percentage of the time wind was coming from the indicated direction in each month. In September and October, the predominant wind direction, 45 to 53 percent of the time, was coming from the southwest. During the months of November through February wind direction was more evenly distributed from the east, southeast, south, and southwest with the notable exception of February during which winds from the west predominated.

The pattern of wind direction at the Monterey Airport is shown in Figure 2B. In most months the predominant wind direction was from the north and southeast. During the same six-month period the pattern of wind direction at the Monterey Airport was striking different from that at the Monarch Sanctuary.

Figure 2

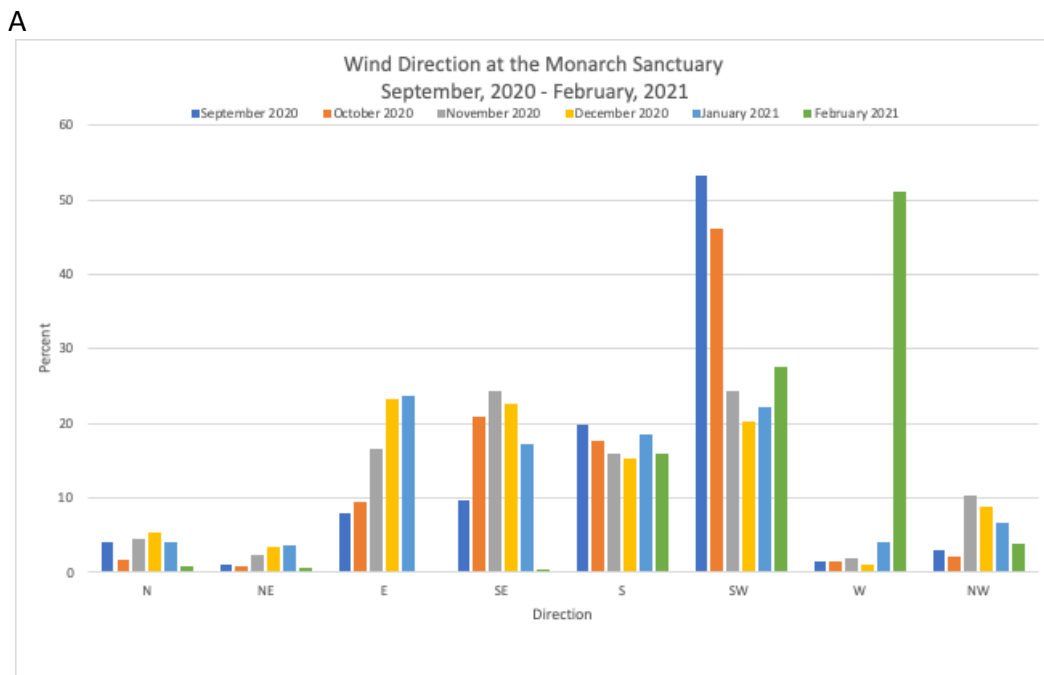
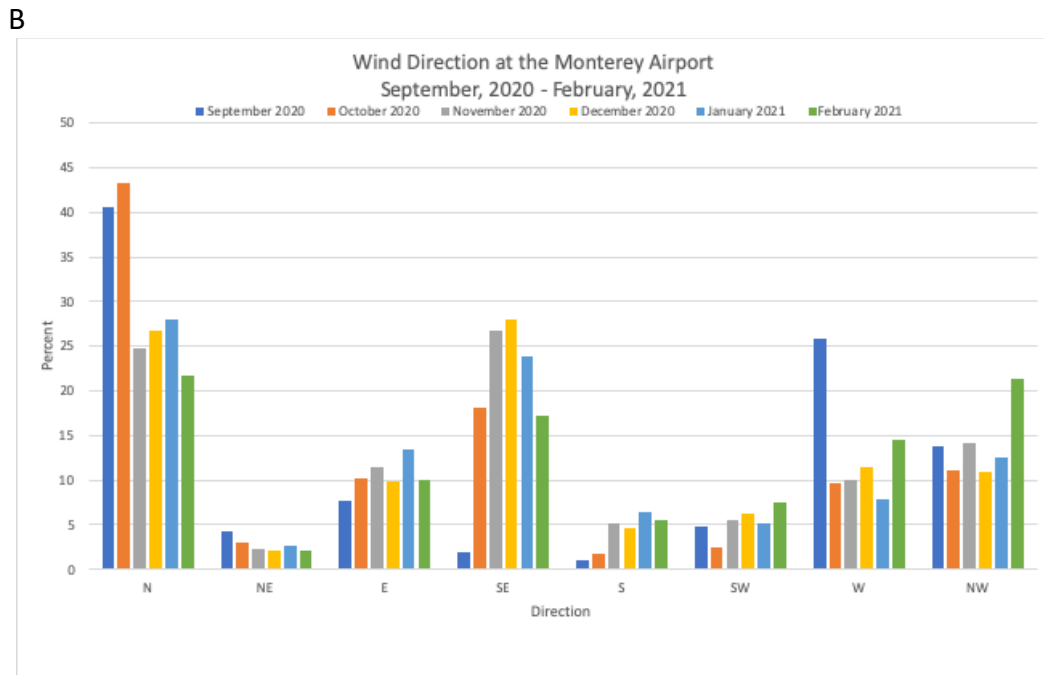


Figure 2 (continued)



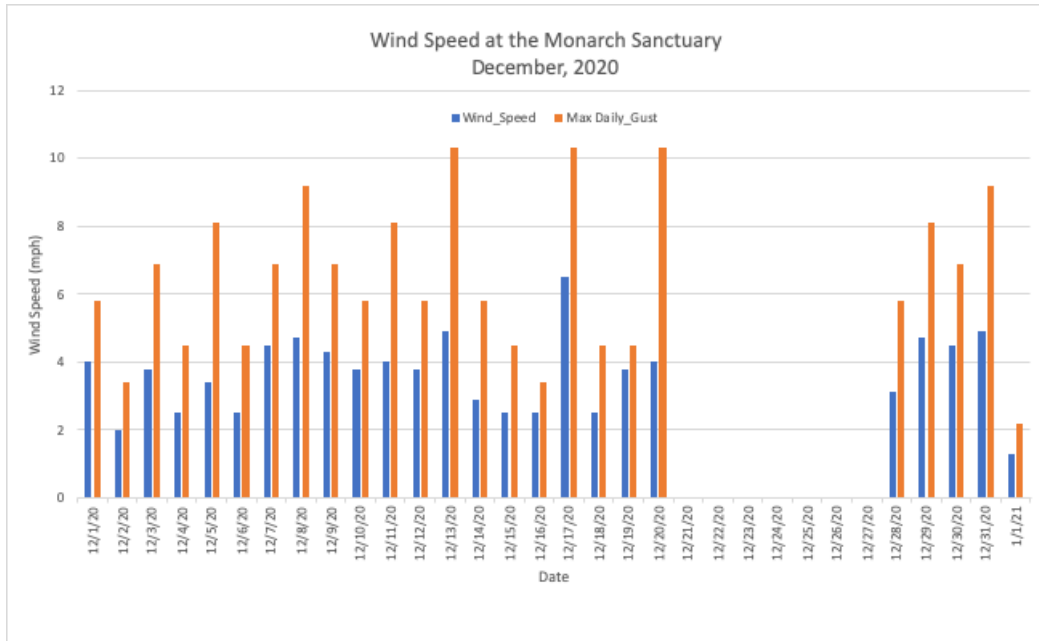
Wind Speed Data:

Wind speeds recorded at the Monarch Sanctuary and the Monterey Airport during the months of December, 2020 and January, 2021 are summarized in Figure 3. The weather was unusually mild for most of the six-month period of data collection but the most severe weather events were reported in December and January. It should be noted that the blue bars in these graphs represent the highest average wind speed recorded on each day. In the Monarch Sanctuary the average windspeed is calculated every five minutes and the blue bars represent the highest wind speed recorded for each day. At the Monterey Airport the average wind speed is calculated every hour and the blue bars represent the highest wind speed recorded for each day. Thus, the blue bars do not represent the maximum wind speed recorded. Instead, the orange bars represent the maximum wind gust recorded each day.

For most of the two-month period average wind speed in the Monarch Sanctuary ranged between 2 - 5 miles per hour (mph) with the exceptions of December 17, 2020 when the average was just over 6 mph and January 25 - 27, 2021 when the average wind speed was 6 -8 mph (Figure 3A and 3C). During those wind events maximum wind gusts reached 10 - 14 mph. In contrast, the average wind speed at the Monterey Airport was between 5 - 17 mph for the two-month period with the exceptions of December 17, 2020 when the average wind speed was 18 mph and January 24 - 27, 2021 when the average wind speed was 28 - 41 mph (Figure 3B and 3D). As anticipated due to the geographical and forestry differences between the sites, wind speeds were dramatically and consistently different between the Monarch Sanctuary and the Monterey Airport.

Figure 3: Wind Speed Graphs

A



B

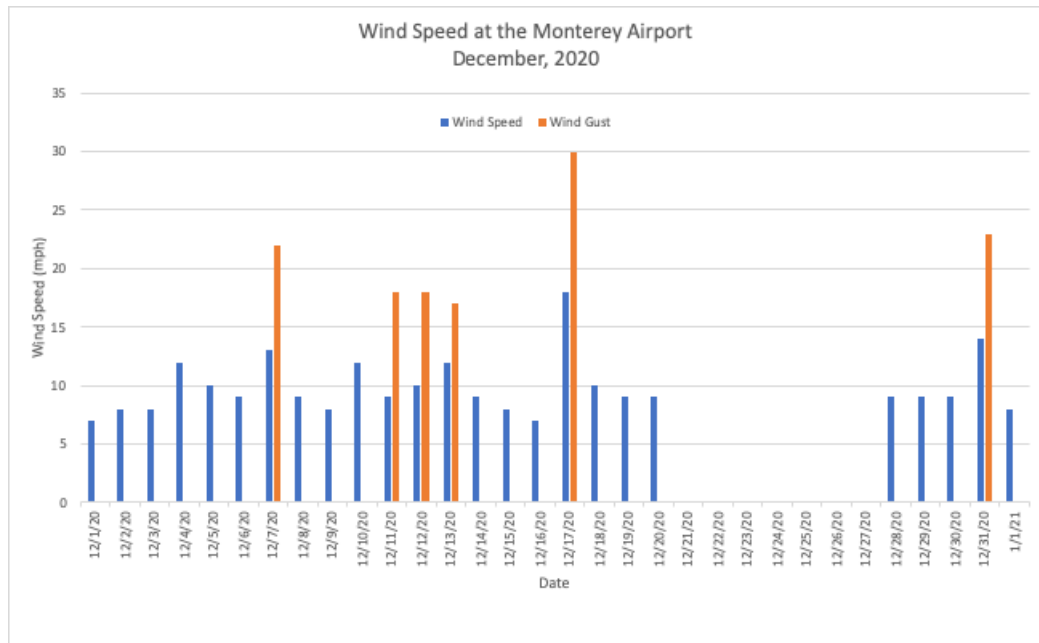
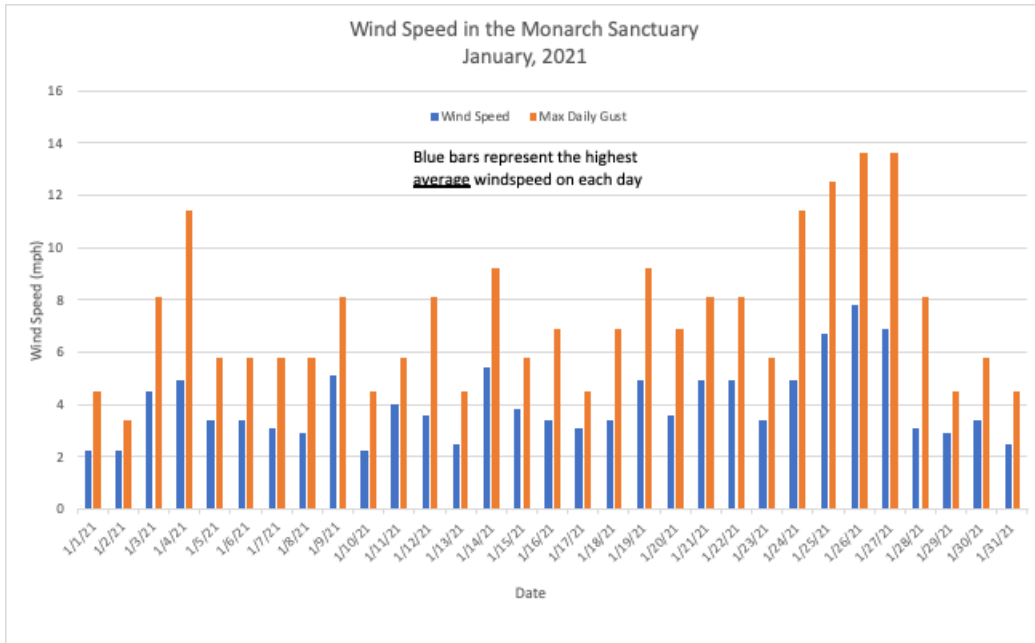


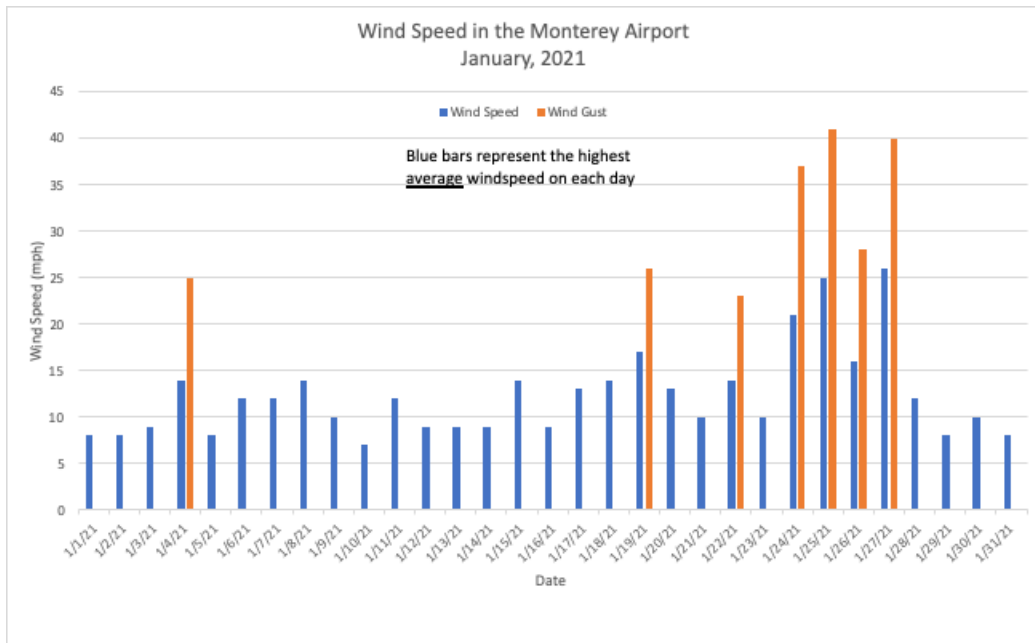


Figure 3: Wind Speed Graphs (continued)

C



D



## Rain Data:

Rain data recorded from the Monarch Sanctuary and the Monterey Airport are summarized in Figure 4. Note that the magnitude of the data cannot be compared directly because the NOAA weather station at the Monterey Airport only reports "hourly rain" and not "daily rain" which is reported from the weather station at the Monarch Sanctuary. Nevertheless, the pattern of daily rainfall at the two sites can be compared. In the month of December rain was recorded on six days at the Monarch Sanctuary whereas rain was detected on only 3 days at the Monterey Airport (Figure 4A and 4B). In the month of January rain was recorded on 10 days at both locations but differences were noted in the pattern of rainfall at the two locations. These data provide further evidence that microclimate conditions at the Monarch Sanctuary differ greatly from those at the Monterey Airport.

Figure 4: Rain Graphs

A

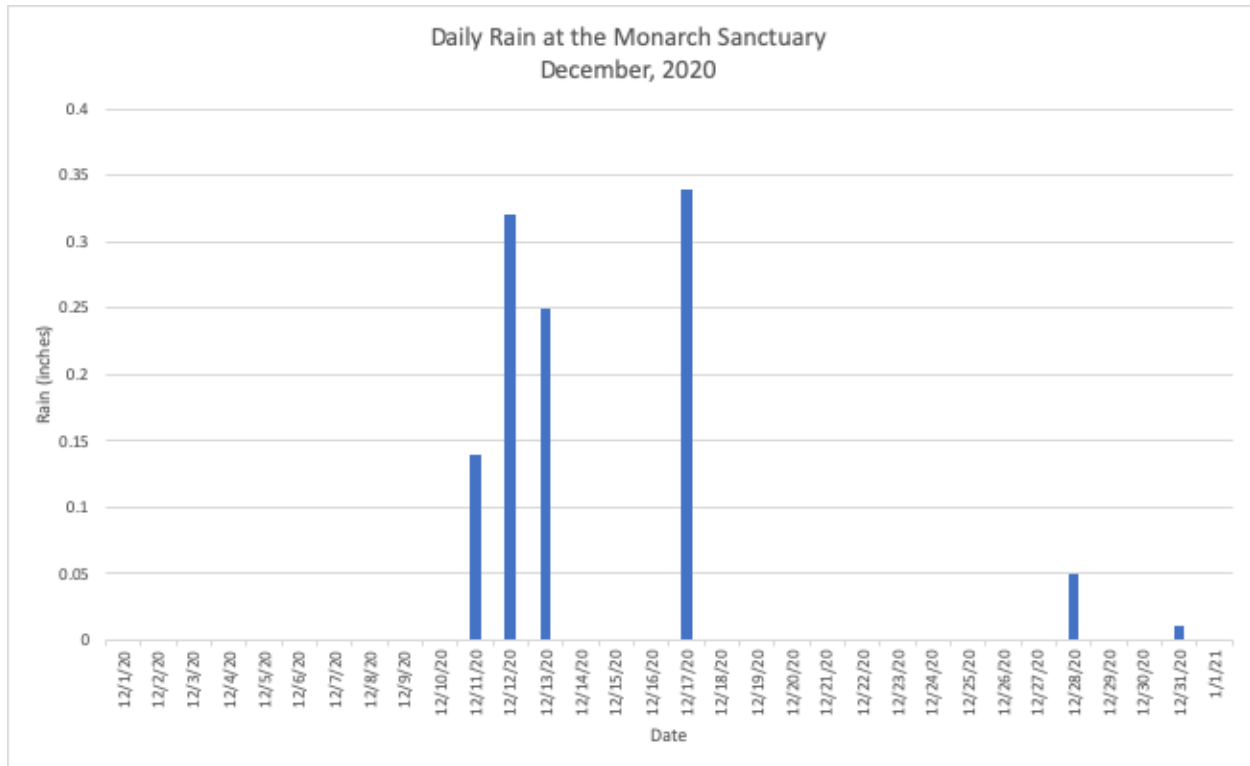
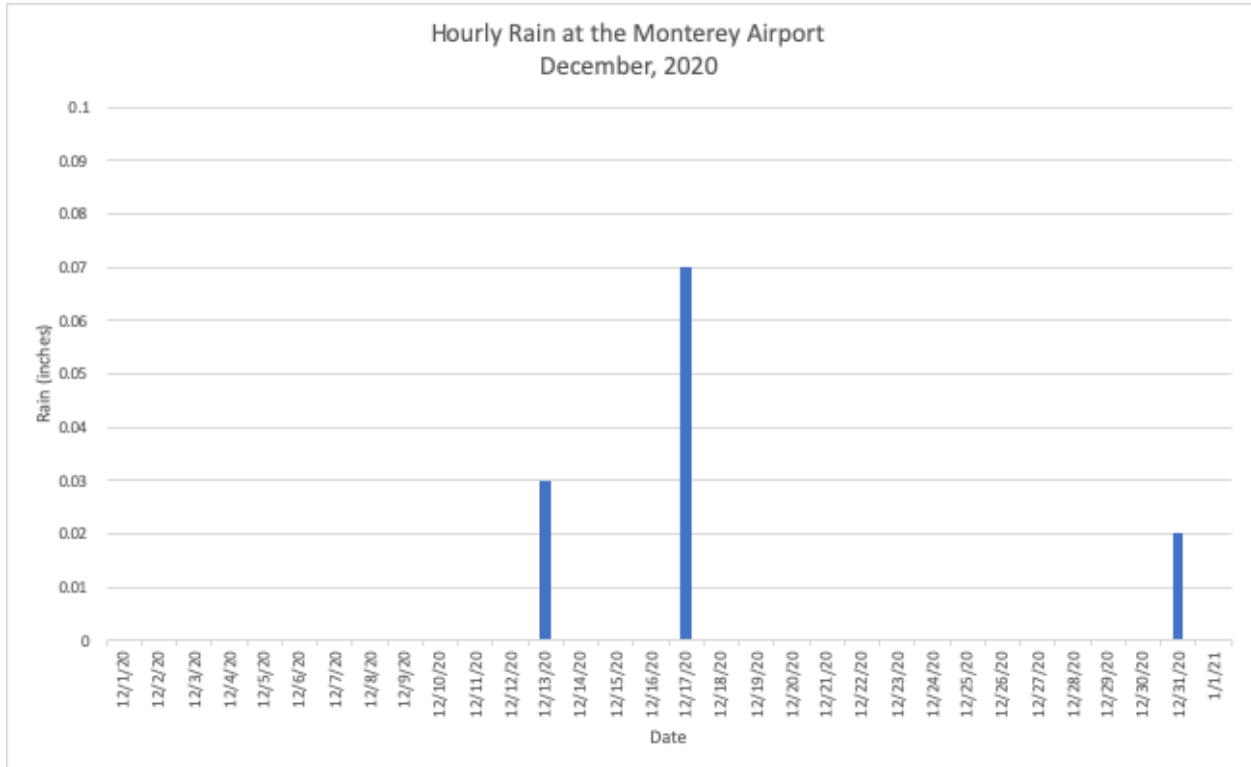


Figure 4: Rain Graphs (continued)

B



C

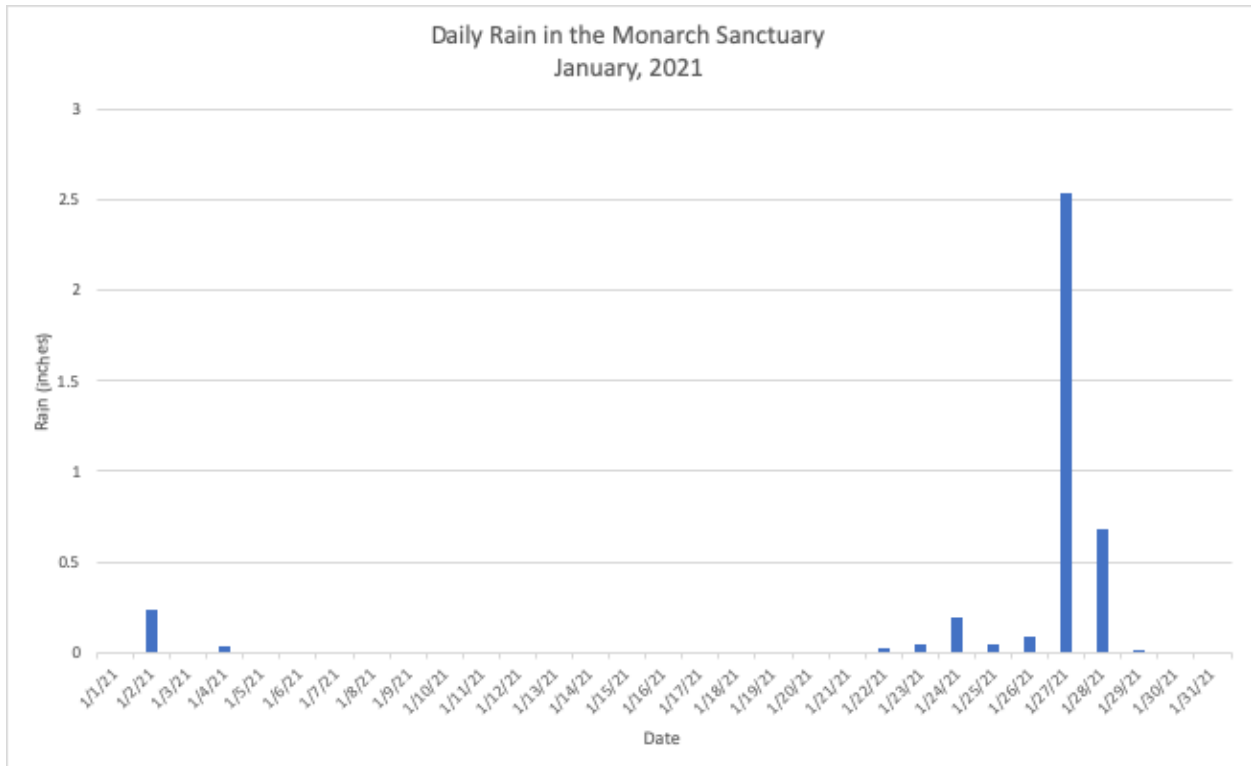
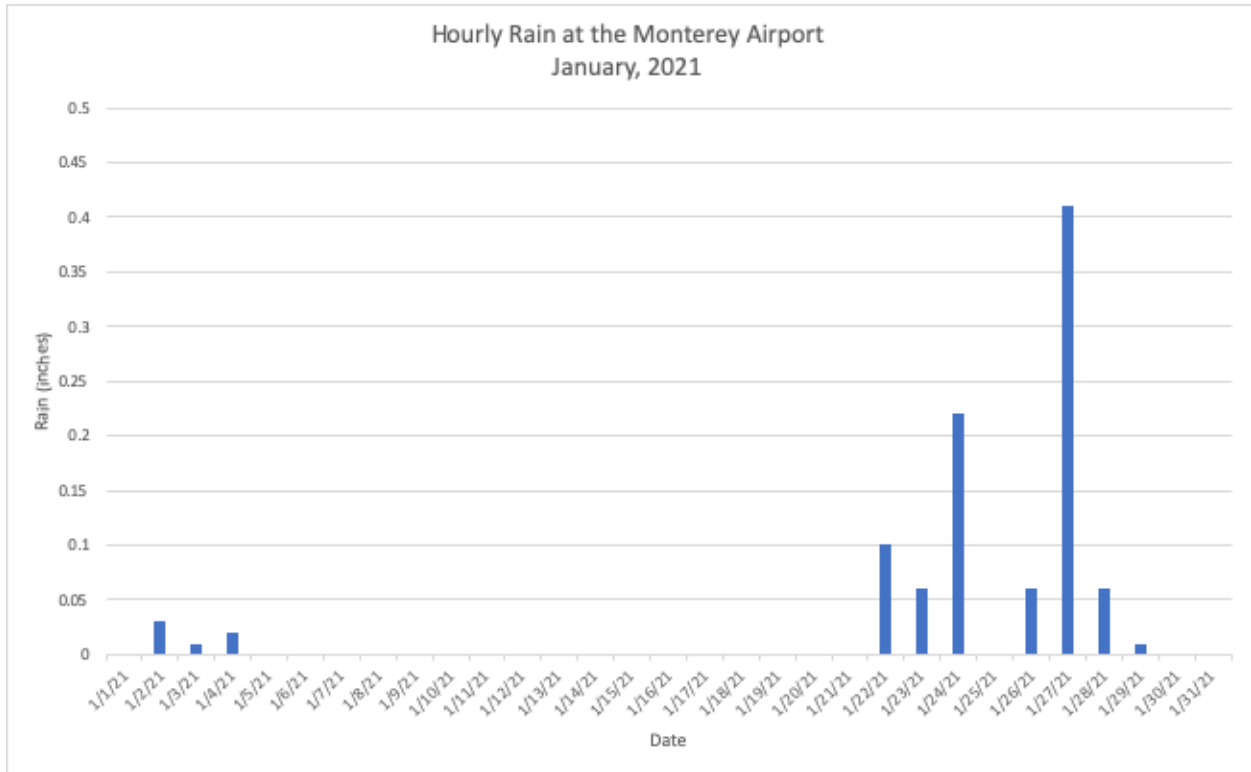


Figure 4: Rain Graphs (continued)

D

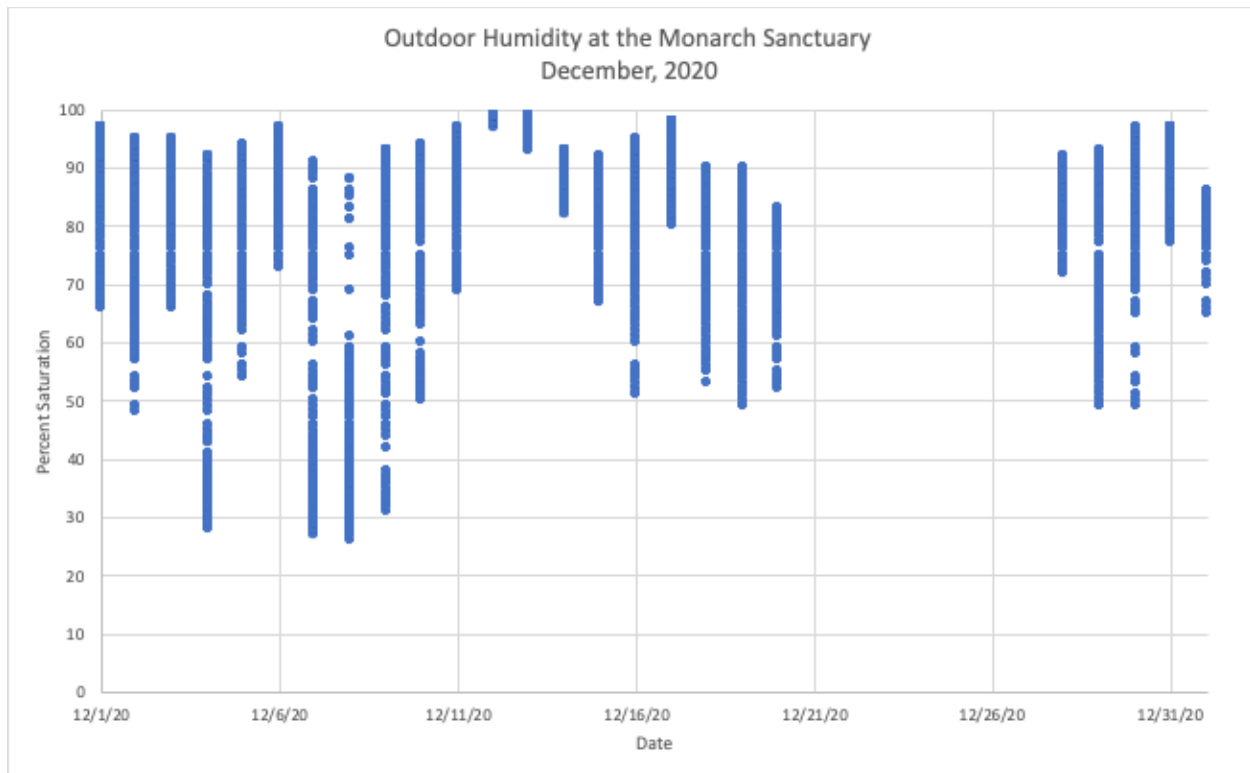


## Humidity Data:

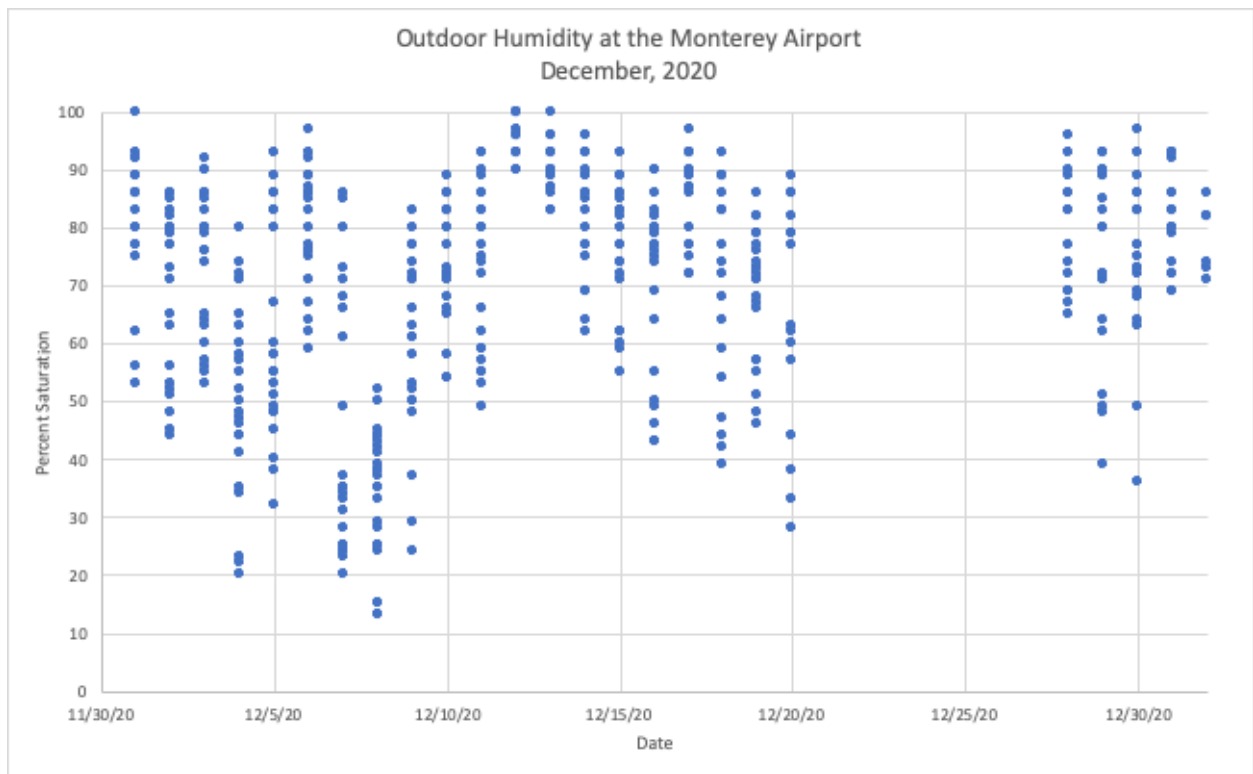
Humidity data recorded from the Monarch Sanctuary and the Monterey Airport for the months of December and January are summarized in Figure 5. Data were not available for December 22 - 27 due to server failure at ambientweather.net. Overall, the pattern of changes in humidity was similar at both locations in December (Figure 5A and 5B). The absolute values, however, tended to differ between the sites. For example, on December 8 the absolute range of values was approximately 25 - 90 percent humidity at the Monarch Sanctuary compared with approximately 12 - 53 percent humidity at the Monterey Airport. Similar observations were made in January at both sites (Figure 5C and 5D). The pattern was similar but the absolute range of humidity was consistently higher at the Monarch Sanctuary.

Figure 5: Humidity Graphs

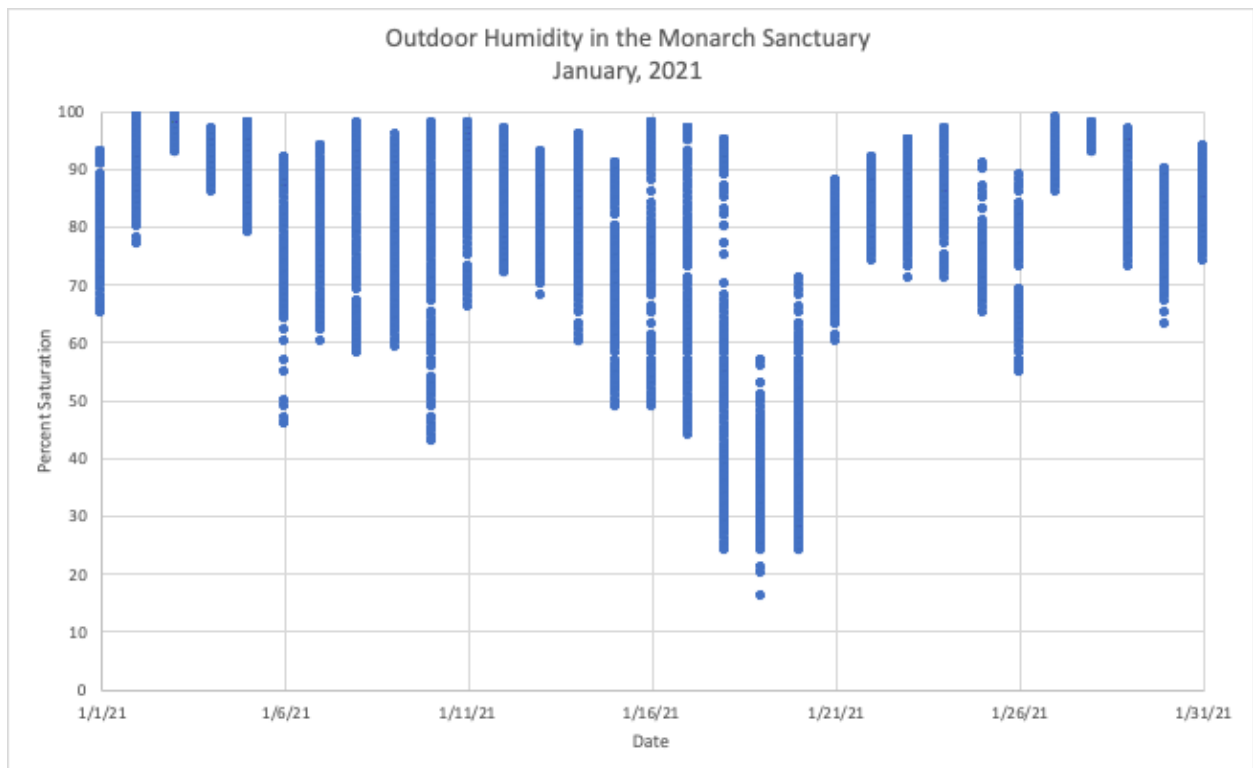
A



B

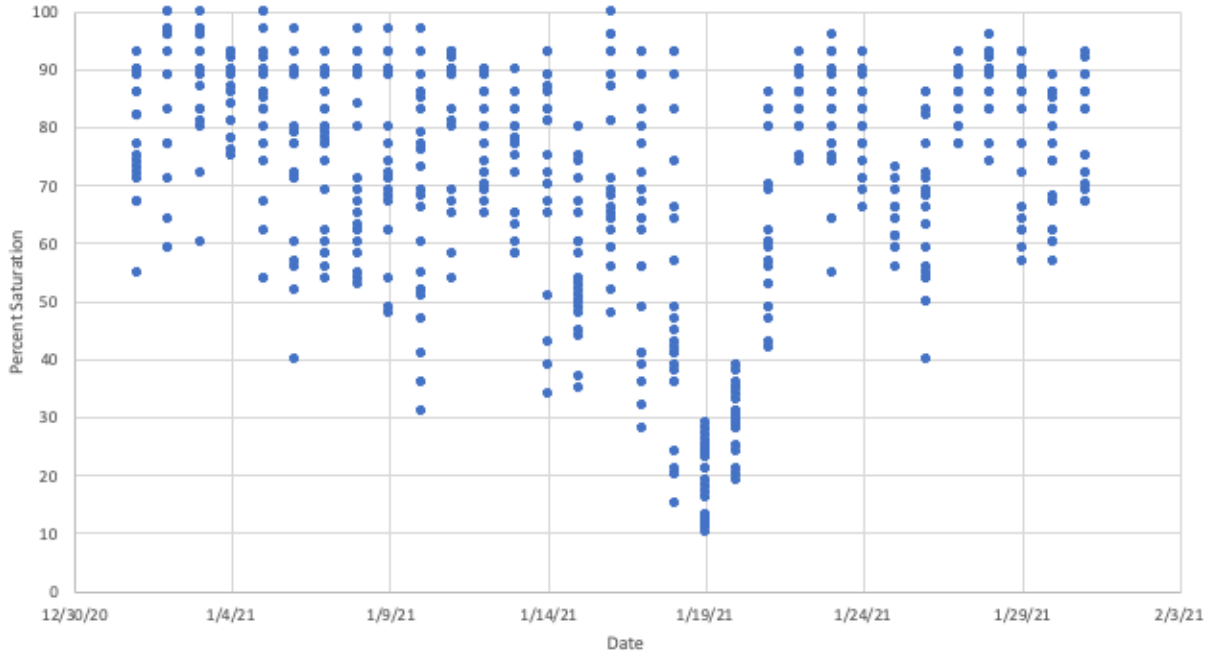


C



D

Outdoor Humidity at the Monterey Airport  
January, 2021



## Discussion

Weather data recorded directly within the Monarch Sanctuary are valuable for developing maintenance plans for the butterfly habitat. Within the community of monarch scientists there is a consensus on the microclimate conditions needed in an overwintering site. For example, as stated by the Xerces Society (2017) "Routine monitoring of microclimatic variables, such as temperature, wind speed and direction, solar radiation, and nectar plant availability, both before and after implementing management actions, will allow you to evaluate the effectiveness of your activities in creating an overwintering habitat that is suitable for monarchs." Although we only have data from the past six months we can compare the measured weather variables with microclimate conditions known from previous studies at other sites that are suitable or adverse for a monarch overwintering site on the West Coast. We can also compare the current microclimate conditions to historical measurements at the Monarch Sanctuary to determine if conditions have improved or worsened over the past several decades. Lastly, the data summarized in this report will provide a new baseline for developing management plans and assessing their effectiveness in the future.

In his 1994 restoration plan for the Monarch Sanctuary, Kingston Leong stated that the "habitat is basically, shady, very moist and windy" (Leong, 1994). This was at a time when the Monarch Sanctuary hosted tens of thousands of butterflies throughout the overwintering period. Leong (2016) defined two terms to describe different types of overwintering sites: Transitional and Climax. Climax sites "...are groves that provide suitable conditions for winter aggregation the entire winter season..." whereas transitional sites "...can provide suitable conditions for winter aggregations for only a few weeks." Sites can progress from transitional to climax and vice versa depending on several factors. For example, "...if not managed, climax grove conditions will transform into a transitional state due to normal grove maturation or tree losses due to winter storms, diseases such as pine pitch canker, or indiscriminate tree thinning by property managers."

Wind speed is a critical factor determining the type of an overwintering site. Wind speeds greater than 4.5 mph, characteristic of a transitional site, will disrupt monarch clusters and they will try to find a more wind-sheltered area for overwintering. The data reported in Figure 2 demonstrate that the average wind speed in the Monarch Sanctuary frequently exceeds 4.5 mph with maximum wind gusts up to 14 mph. We can compare these data to measurements made by Leong (1994) in the Monarch Sanctuary. Our current weather station was located most closely to "weather station #2" in the report by Leong (1994). At that location during the winter of 1993-1994 the maximum wind speed recorded was 4 mph. These results suggest that winds speeds in the Sanctuary have increased dramatically over the past 26 years. Although we can't conclusively attribute the change to a single factor it is highly likely that documented cases of excessive tree trimming and removal over several years have contributed to degradation of the habitat for monarchs.

Winds in the Sanctuary during the six-month data collection period originated predominantly from the east, southeast, south, and southwest. This pattern is similar but somewhat different



from the predominant wind direction reported in 1994 by Kingston Leong when the strongest winds originated from the northeast, east, and southeast. Whether the current pattern of wind direction represents a consistent change will require monitoring for several years. The current pattern of wind direction suggests that planting a U-shaped line of trees as suggested by Kingston Leong would eventually provide an alternative clustering area that is more protected from easterly and southerly winds (Leong, 1994). In addition, increasing the density of trees on the west side of the U-shape would provide an improved barrier to winds originating from that direction.

Humidity measurements in the Monarch Sanctuary were, as expected, higher on average than at the Monterey Airport. However, Leong reported in 1994 that average humidity was in the range 79 - 85 percent saturation compared with the range 20 - 100 percent saturation we observed in the Sanctuary. This may be an important reason for the decline in numbers of overwintering monarchs because they require a moist environment to remain hydrated. Excessive clearing of trees and undergrowth are likely factors contributing to the current dryer microenvironment.

Rainfall was not a parameter measured in the 1994 Leong study but we do know that the current 2020-2021 season has been dryer than average. Moreover, differences in rainfall at the Monarch Sanctuary compared with the Monterey Airport, taken together with the wind direction, wind speeds, and humidity results reported here, conclusively illustrate that measurements from the Monterey Airport cannot be used to assess the microenvironment at the Monarch Sanctuary.

## References

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Xerces Society (2021) Blog post at <https://xerces.org/blog/fifth-annual-western-monarch-new-years-count-confirms-continued-decline-in-western-monarch>