Monarch Butterflies and Microclimate

STAT 414 - Final Report

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Introduction

Every fall, monarch butterflies (*Danaus plexippus*) undergo an annual mass migration from their summer breeding grounds across western North America to overwintering groves along the Pacific Coast (Tuskes and Brower 1978; Urquhart and Urquhart 1978). During winter months, these butterflies "cluster" by the thousands on trees within the groves, often in the same location year after year, despite being those butterflies being generations apart. Scientists hypothesize that monarchs seek out these locations within the groves because they provide ideal weather conditions, including mild temperatures, high humidity, and variable light (Leong et al. 1991; Chaplin and Wells 1982; Weiss et al. 1991). They predict that monarchs will select habitat that meet all of these climatic conditions and will not be found in areas where those conditions are not met, both at the landscape and site levels.

This study investigates how microclimate conditions (temperature, humidity, and light) differ between monarch butterfly aggregation sites and non-aggregation areas within the same grove, seeking to identify whether specific environmental characteristics distinguish the locations where monarchs choose to cluster.

Materials and Methods

Our dataset comes from research conducted by Saniee and Dr. Villablanca (Saniee and Villablanca 2022). They directly investigated the "microclimate hypothesis" by taking temperature, humidity, and light measurements at various locations within monarch overwintering habitat. Within each grove, they placed a weather station (array) at a known aggregation site, where monarch butterflies are thought to be selecting favorable weather conditions. From that aggregation site, they placed four additional arrays in a repeated manner to capture variation within the grove (see Figure 1). This arrangement of weather arrays was repeated across nine

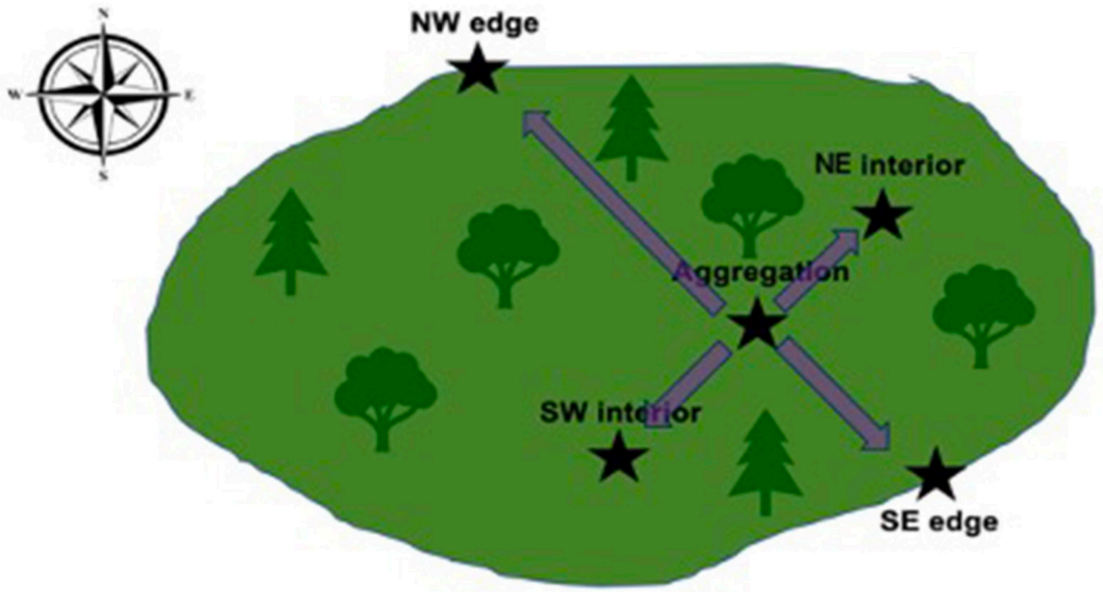

Figure 1: Sampling design relative to the aggregation's location in the groves. The first sample location was placed in the location of an aggregation (Aggregation). Two more sample locations were placed on the SE and NW edges of each grove relative to the aggregation's location to capture morning light and prevailing wind (SE edge and NW edge, respectively). Two interior sample locations were placed halfway between the aggregation's location and the grove's edge in the NE and SW directions (NE interior and SW interior, respectively).

groves in San Luis Obispo, Santa Barbara, and Ventura County (see Figure 2). Climate measurements were taken every 5 minutes, and derivative summary measures were generated for each day (e.g., minimum, maximum, and average temperature).

Point Conception, the westernmost point of California, represents a significant biogeographical boundary that influences numerous ecological systems along the Pacific coast. To examine potential latitudinal patterns in monarch butterfly habitat selection, we classified our study sites into two distinct regions, those located north and those located south of Point Conception (see Figure 2). This classification enabled us to investigate whether the geographical divide corresponds to meaningful differences in monarch butterfly aggregation patterns and associated microclimate conditions.

Figure 2: Groves where weather station arrays were placed in this study. Sites north of yellow dashed line were categorized as north, others were categorized as south.

To more directly investigate the microclimate hypothesis, we reclassified the array stations (aggregation, NE, NW, SE, SW) into a binary variable representing monarch butterfly presence or absence (1,0). We attempted several logistic regression models using this presence/absence classification as our response variable, with various microclimate measurements as predictors. However, these models proved statistically inappropriate due to complete separation in our dataset - monarch presence was perfectly consistent at aggregation sites and perfectly absent at all other array locations throughout the study period. This perfect separation prevented meaningful model convergence and parameter estimation, as there was no variation in presence/absence at any given location. Consequently, none of our attempted models provided better explanatory power than the null model, suggesting that alternative analytical approaches were needed to understand the relationship between microclimate conditions and monarch site selection.

In our alternative approach, we developed a series of linear mixed-effects models to predict each microclimate variable (temperature, humidity, and light) independently. Our base models incorporated grove as a random effect to account for site-specific variation, and included seasonDay (days since the start of the season) as a fixed effect to control for temporal trends. We then compared these base models to expanded versions that included monarch presence as an additional predictor. This approach allowed us to evaluate whether monarch presence significantly improved our ability to predict microclimate conditions, while accounting for both the temporal nature of our data and the nested structure of our sampling design within different groves.

Our dataset has two levels: arrays (weather stations) are Level 1, and grove is Level 2. Below is summary table of the variables used in our study:

Results

Discussion

References

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