Habitat Suitability, Restoration, and Vegetation Management at Monarch Grove Sanctuary, Pacific Grove California

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INTRODUCTION

The Monarch Grove Sanctuary (MGS) in Pacific Grove, California supports thousands of overwintering monarch butterflies in a typical year. However, the continued suitability of MGS is at risk from a number of factors. The major threat to habitat suitability at the site is changes in the forest canopy structure from both natural tree senescence and pitch canker disease in the Monterey Pines. This study reviews previous work at the site, presents the results of new studies of canopy structure, assesses tree health, and makes recommendations for short-term and longer- term vegetation management at the site with the primary goal of improving conditions for monarch butterflies.

The study is comprised of two separate reports. This report by Dr. Stuart Weiss covers the aspects of the site that are relevant for monarch butterfly habitat, including meteorological conditions, forest canopy structure, an analysis of hemispherical photography, a restoration plan that suggests options for the composition and configuration of additional tree plantings, suggestions for continued monitoring at the site, and several other issues. The second report, by Steve Scott, assesses the present health of the trees on site, identifies hazards, and presents management guidelines for pitch canker disease.

The two reports are separate because they each deal with the field of expertise of the principle authors. In some cases, the standard management practices for urban forests described in the Scott report may not be appropriate because of adverse impacts on habitat suitability for monarchs. These cases are noted in the Weiss report.

PRESENT SITE SUITABILITY FOR OVERWINTERING MONARCH BUTTERFLIES

The continued use of MGS by thousands of monarch butterflies indicates that at present the site often contains the essential habitat features required by monarch butterflies. Here we will review previous studies (Leong 1994), examine relevant weather data, quantify canopy structure with hemispherical photography, and make a general assessment of overall habitat suitability within MGS. The major focus is on the micrometeorological factors, and the canopy structure that regulates those factors, that determine the use of habitats by monarch butterflies.

Previous studies

Environmental Impact Report (EIR)

The original EIR for the Diveley property identifies it as a major overwintering site for monarch butterflies. The site is the only largely undeveloped parcel of forest habitat in the area, except for Washington Park (which has also supported monarch butterflies). Considerable controversy over the fate of the site is evident in the comments before, during, and after the EIR process. The property was divided into a small developed area (eastern extension) and a larger monarch reserve that was purchased by the city of Pacific Grove through a bond measure. The division of the property maintained the key habitat features and continued use of the site indicates that the suitability of the site for monarchs was not overly compromised. A detailed site map with tree locations, species, size, and other features of the site was made in 1993, and provides a key data source for future vegetation management.

Leong Report

The 1994 report by Kingston Leong provides detailed micrometeorological data on a 30 meter grid across MGS for 10 sampling dates through the 1993-94 overwintering season. The techniques closely follow those implemented at several other sites in California (Leong 1990, Leong et al. 1991). The measurements indicate that monarchs at the Sanctuary are seeking the same set of conditions that they seek elsewhere in California, with the key variables being wind speed and solar radiation/light. Monarch butterflies do not stay at sites where windspeeds exceed 2 meters/second (m/s), and seek filtered light for thermoregulation.

Monarchs clustered at heights of 25-35 ft in Monterey Pines and *Eucalyptus* in the southeast corner of the site. A Monterey Pine (tree #27 in the Leong 1994) on adjacent private property often supported the largest clusters, and was occupied 75% of the time. Monterey Pines within the row of *Eucalyptus* were also frequently used (38% of the time). Movements of butterflies were associated with changes in wind direction, as butterflies moved from the windward to the leeward sides of the trees. When the wind is from the northwest, monarch butterflies tend to cluster on trees south of the row of *Eucalyptus*, off the Sanctuary property. When the wind is from southerly directions, the butterflies cluster north of the row of *Eucalyptus*.

Leong is optimistic about the potential for habitat restoration at the site, because of its long-term use by monarchs (since the late 1800's), occupancy through most of the winter months in most years, and high ambient moisture. He presents a habitat restoration design that includes a mix of open and forested areas that provides wind shelter and access to moisture and mating sites. That restoration design provides a firm

conceptual basis for enhancing MGS as monarch habitat, and is incorporated into proposed restoration plans.

Weather station data

A weather station was installed at the site in spring 1995, on the north side of the row of *Eucalyptus* at an height of approximately 35 ft. The location of the station is in the middle of the typical monarch aggregation area. Weather measurements taken include temperature, relative humidity, solar radiation, wind speed, and wind azimuth. A whole overwintering season was recorded from October 1995 to March 1996, and data collected provides information on temporal variability of temperature and wind.

Temperature and relative humidity

The location of MGS close to the ocean minimizes the danger of freezing temperatures that are deadly to monarch butterflies. The weather station data collected from November 1995 through February 1996 provide quantitative evidence of the mild winter climate at the site (Fig. 1a). Air temperatures never dropped below 40° F during that time period. The winter of 1995-96 was particularly warm in Central California, and does not represent the full range of winter cold. Occasional outbreaks of arctic air reach Pacific Grove -- the "50 year" freeze in December 1990 brought temperatures in the 20's for several days. This extreme weather event caused substantial (30-40%) mortality of monarchs at Ardenwood Regional Park (on the east shore of San Francisco Bay), and caused severe damage to *Eucalyptus* trees. Coastal sites in southern California, where temperatures were more mild, did not suffer high mortality nor extensive damage to *Eucalyptus*.. However, little can be done to specifically ameliorate such rare freeze events.

Minimum temperatures likely vary through the site and tree canopy. High canopy cover can reduce radiative heat losses at night, and cluster sites higher in the canopy can avoid colder temperatures close to ground level. The site slopes away from the main cluster area, and cold air will tend to drain away downslope. The open area below Brokaw Hall may accumulate colder air. Given the mild macroclimate of Pacific Grove, these temperature variations may take on significance only at night during unusual freeze events.

The relative humidity was generally high, but there were several periods when humidity dropped below 50% (Fig. 1b). However, these are very mild conditions relative to other monarch sites in southern California, where humidity levels can drop below 30% during Santa Ana winds in the autumn. Relative humidity within MGS is not a major concern compared with other meteorological factors.

Wind

The record of maximal hourly wind speeds from November 1995 to February 1996 shows that the weather station site could be exposed to substantial winds during the winter (Fig. 1c). High winds (> 5 m/s) were observed intermittently through the winter, usually, but not always associated with strong winter storms. This period included an extreme windstorm from December 11-12, 1995. The strong southerly storm winds penetrated into the grove and wind speeds at the weather station exceeded 10 m/s

The combination of wind direction and speed is especially important in determining habitat quality. The strongest winds (>10 m/s) come from southerly directions, but strong northwest winds are common (Fig. 2a). Maximum hourly winds exceeded 2 m/s about 25% of the time (Fig. 2b). Of the times when winds exceeded 2 m/s, the most common wind direction was northwest (50% of the time), followed by southwest (20%) and south (10%) (Fig. 2c).

Monarchs do not stay in a site when maximum wind speeds exceed about 2 m/s near the ground (Leong 1990, 1994, Leong et al. 1991, Frey et al. 1992). The monarchs abandoned this site following the December 1995 windstorm; however, other monarch aggregations in northern California (i.e. Ardenwood) were also abandoned following that event. Mitigating the effects of wind is a major component of forest canopy assessment and habitat restoration plans.

Solar Radiation

The solar radiation measurements showed anomalous behavior that suggests that the sensor was obstructed by fallen material, so the data have not been used.

Summary

MGS has a mild maritime climate during the winter, with freezing temperatures rare and high relative humidity the norm. Winds can be very strong from southerly and northwesterly directions during and following storms. Wind exposure appear to a primary micrometeorological factor reducing habitat suitability at MGS.

Forest Canopy Structure

The forest canopy structure at a monarch overwintering site is the prime determinant of its suitability. The canopy regulate the microclimate within a forested site; it reduces nighttime heat losses, provides a mixture of shade and sunlight, and provides wind protection. Importantly, the branches and trunks of the trees provide cluster locations at varying heights in the canopy. The ability of a forest to provide all of the factors required by monarchs goes far beyond the immediate cluster trees -

nearby trees contribute to local canopy cover and wind protection, and trees that are 100 or more meters away can provide important wind breaks. Vertical foliage profiles are also important for windbreak purposes -- a dense canopy with little or no mid-story and understory provides poor protection from wind within the canopy.

The exact tree species present are of lesser importance than the structure. *Eucalyptus globulus* forests are the favored sites in California, because of their widespread distribution along the coast, dense foliage, and provision of wintertime nectar. The rapid growth response to available light means that along forest edges, foliage can be nearly continuous from ground-level to canopy top. Such a structure tends to seal the edges of forest groves against wind. While *Eucalyptus* can often grow extremely dense in the middle of groves, it tends to form heterogeneous canopies that provide a variety of light conditions for monarch butterflies.

Sites in Monterey Pine forests (i.e. Washington Park and Cambria) have supported monarchs in past years. Monterey Pines, however, lose low foliage and branches as the trees grow, leaving open understory. Lower growing Coast Live Oaks (*Quercus agrifolia*) at Washington Park provide dense understory and middlestory. Clustering monarchs are also sometimes found in riparian forests (near Santa Barbara and Malibu) in deep canyons that provide the right microclimatic regime.

In this section, the current forest canopy structure at MGS is assessed using a map of the existing trees, recent aerial photography, and hemispherical photography. All three approaches provide important information, and features identified on one map/photograph can be identified on the other two data sources.

Site Vegetation and Tree map

A map of trees on and adjacent to MGS was created in 1993 as part of the planning process (Fig. 3). Further data were taken from the 1994 Master Plan map. Those maps were updated by Thomas Reid Associates in February 1997, as many trees had been removed, and others planted in the interim. The map shows the position, species, and identification number of each tree on MGS. The identification numbers on each tree are keyed to the table that contains DBH, health assessment, and notes about each tree (Table 1). In this section, discussion will focus on current forest structure as it relates to monarch habitat suitability-- the assessment of tree health and management guidelines are presented in a separate report (Tree Assessment by Steven Scott).

The most important feature of the forest structure on MGS is the "L"-shaped grove of *Eucalyptus globulus* on the south and far eastern boundary of the site. These trees provide the densest forest canopy, the best wind protection, and it is not surprising that the vast majority of monarch butterfly clusters are found on and near these trees. Several Monterey Pines are interspersed in the *Eucalyptus*. Foliage is

relatively dense at all heights, and the trees appear to act as an effective wind barrier to the south.

The large number of Monterey Pines north of the kiosk and viewing area are a mix of young trees and declining older trees. The canopy is quite open, with no significant understory at present. Several Monterey Cypress, as well as one *Eucalyptus*, are present in the stand just east of the MGS boundary. These trees, although they are not in the MGS property, are an important component of the monarch habitat.

Toward the north, a number of large Monterey Cypress are interspersed with large Monterey Pines. These trees screen MGS from the north. There are few trees where an old roadbed parallels the north boundary.

More Monterey Pines form the western boundary, interspersed with some *Acacias*. The *Acacias* are relatively low growing. Because the ground slopes towards the west, these trees do not substantially contribute to wind shelter at the cluster sites higher on the slope.

Native Shrubs

A number of native shrubs, including *Ceanothus* and *Heteromeles* (Toyon) have been planted. These shrubs play little role in habitat suitability at MGS, as they do not reach heights effective enough for windbreaks, except where there are openings in windscreen trees. Shrubs have only a minimal effect of the humidity within the site. However, shrubs do not harm anything and are an attractive addition to the site provided they do not form unwanted ladder fuels in inappropriate areas (see Fuel Management, p. 19-20).

Aerial photography

Aerial photography flown in 1996 was obtained from the City of Pacific Grove (Fig. 4). The black and white image provides information on areas surrounding MGS proper. Because wind conditions within MGS are affected by forest structure in surrounding areas, some consideration of the wider area is necessary,

The unique position of MGS as an undeveloped and largely forested area within the larger matrix of suburban development is clear (Fig. 4). The *Eucalyptus* row forms the densest canopy, and the canopy extends south of the Sanctuary boundary. The canopy north of the cluster sites is more broken, but the canopy appears more dense toward the northern boundary of MGS. Large open areas are seen west of Brokaw Hall, with a narrow band of trees running along Grove Acre Ave.

Hemispherical Photography

The methods of hemispherical photography are presented in detail in the "Methods" section of Weiss et al. 1991 (Appendix A). In short, several "Site Factors" are calculated by digital analysis of the photographs. The digital analysis first identifies areas of open sky versus obstructions. "Indirect Site Factor" (ISF) is the overall proportion of sky seen from the photograph point, and is an integrated measurement of overall canopy openness. "Direct Site Factor" (DSF) is the openness along all sunpaths through the year, and measures direct light penetration through the canopy.

"Wind Site Factor" (WSF) is a new measure that estimates canopy cover in the horizontal directions. WSF is calculated for eight directions in 45° azimuth segments centered on N, NW, W, SW, S, SE, E, and NE, and measures canopy openness at elevation angles up to 30° -- the majority of wind penetration is at lower elevation angles parallel to the ground. The calculation of WSF also uses a correction for the sin of the elevation angle - lower angles (i.e. closer to the ground) are weighted more than higher elevation angles. Absolute WSF values are lower than ISF and DSF, because they represent only a small portion of the hemisphere -- maximum WSF values as calculated here are around 0.04. This value would represent a completely open sky from ground-level up to 30° elevation angle in a 45° azimuth interval. As seen below, WSF values of greater than 0.015 represent relatively open conditions in that wind direction.

In early February 1997, 26 hemispherical photographs were taken across MGS in a configuration that captured the major features of canopy structure (Fig. 5). Areas of high and low canopy cover were specifically selected, and important places such as monarch cluster sites, the south boundary, and the weather station site were included. The selection of sites allows for interpolation of Site Factors across MGS for mapping purposes.

Sample Photographs

Sample hemispherical photographs show the important features of the forest canopy at MGS (Fig. 6, fourteen photographs are presented by photo number keyed to Figure 5). Because the photographs are taken looking up, east and west are reversed. Also, although these scanned photographs show a grey scale, in the digital analysis all trees and obstructions are turned black, and only the white areas represent open sky. The calculated ISF, DSF, and eight WSF's for all photos are presented in Table 2, and the 14 photos discussed in some detail below are highlighted by asterisks.

Figures 6.2 and 6.3 (the suffixes refer to the photograph number on Fig. 5) show canopy conditions just north and south of the *Eucalyptus* row along the south boundary of MGS. In photo 6.2, the row of *Eucalyptus* is seen along the south side of the image, with a narrow gap just east of south. To the north, the stand of declining Monterey

Pines with bare trunks and sparse canopies are clearly seen. ISF is 0.20, indicating a moderately closed canopy, and DSF is 0.05, indicating that most direct light from the south is blocked by the trees. The northwest octant is quite open, and WSF_{NW} is very high (0.033). In contrast, WSF_{SW} is low (0.000), indicating nearly complete blockage of the wind from that direction.

In Photo 6.3, the row of *Eucalyptus* is to the north. The Monterey Pine that often has supported monarch clusters off MGS (Leong tree #27) is seen just west of the *Eucalyptus* The south side of the *Eucalyptus* has lower ISF (0.13), indicating a more closed canopy, but higher DSF (0.23) indicating less obstruction of the sunpaths. WSF_{nw} is low (0.004), but WSF_S is moderate (0.015) indicating that the site is somewhat exposed to south winds. The fact that these two photos were taken just 3 meters apart highlights the high degree of spatial heterogeneity in site factors at MGS.

Photo 6.5 was taken directly below the automated weather station. ISF is moderately low (0.17) and DSF is low (0.06). As in Photo 6.2, the site is open to the northwest (WSF_{NW} is 0.27), explaining the high proportion of winds > 2.0 m/s from that direction. WSF from southerly directions is low (0.002, 0.003, 0.002 for SE, S, and SW, respectively), explaining the relative shelter of the weather station from southerly winds. However, when southerly storm winds are high (the December 1995 storm had hurricane force wind gusts outside forests), the position of the weather station high in the canopy leads to relatively high wind speeds (> 10 m/s) in the canopy (substantially lower than winds outside the forest, but still high enough to be unsuitable for monarchs).

Photo 6.7 was taken west of Photo 6.5, on the south side of the *Eucalyptus* row. ISF is moderately low (0.15), but DSF is relatively high (0.24). WSF_{NW} is low (0.006), but WSF_s and WSF_{SW} are relatively high (0.015 and 0.011, respectively). This photo highlights the importance of off-site trees -- the prominent stand of trees just west of south plays an important role in attenuating southerly winds. These trees can be made out on the aerial photograph (Fig. 4). The trees lower on the horizon also play a role in attenuating the wind. The major cluster tree (Leong #27) is seen in the due east position in this photo.

Photo 6.16 was taken at the information kiosk area. The south and east rows of *Eucalyptus* are clearly seen. To the north and northwest is the open Monterey Pine canopy. ISF and DSF are relatively high (0.31 and 0.25, respectively). This site is highly exposed to northwest winds (WSF_{NW} = 0.037), but well protected from southeast, south, and southwest winds (WSF_{SE} = 0.003, WSF_S = 0.004, WSF_{SW} = 0.002). The entrance trail through the trees can be seen in the northeast quadrant of the photograph.

Photo 6.1 was taken at the southeast corner of MGS, just at the junction of the "L" -shaped *Eucalyptus* stand. ISF and DSF are low (0.13 and 0.06, respectively). The site is

well protected from southerly winds (WSF_{SE} = 0.000, WSF_S = 0.000, WSF_{SW} = 0.005), but is very exposed to northwest winds (WSF_{NW} = 0.028). Some trees off the property can be seen between the large *Eucalyptus* trunks towards the southeast. Monarch butterflies have been observed on these offsite trees.

Photo 6.17 was taken along the eastern boundary of MGS. The canopy is dominated by senescent and declining Monterey Pines (the tree due west is dead). The row of *Eucalyptus* is clearly seen along the southern horizon. ISF and DSF are high (0.34 and 0.37, respectively). WSF_{NW} and WSF_W are high (0.027 and 0.030, respectively), while WSF is low from the south winds (WSF_{SE} = 0.009, WSF_S = 0.005, WSF_{SW} = 0.006). A large Monterey cypress (the flattened canopy to the northeast) provides wind break from the northeast (WSF_{NE} is 0.005, but WSF_E is higher at 0.012), and trees to the north provide shelter from northerly winds (WSF_N is 0.006, similar to WSF from the southerly directions. The trees east of the photo site are on adjacent property.

Photo 6.9 was taken at the SE corner of Brokaw Hall. The building can be seen in the northwest quadrant of the photo (note the chimney). There is little canopy (ISF and DSF are 0.42 and 0.47 respectively) The *Eucalyptus* row is seen in the southeast quadrant, but there is a prominent gap just west of south. A number of *Eucalyptus globulus 'compacta'* have been planted in this gap (Fig. 3).

Photo 6.19 was taken toward the northeast corner of MGS. The typical form of mature and declining Monterey Pines, with no lower branches and spreading upper branches with foliage, dominate the canopy. The lack of understory and middlestory in the forest is particularly apparent in this photo. The *Eucalyptus* row can barely be seen on the south horizon. ISF and DSF are high (0.31 and 0.33, respectively). WSF is moderate to high from the critical wind directions (WSF_S = 0.009, WSF_{SW} = 0.017, WSF_{NW} = 0.031).

Photo 6.11 was taken north of Brokaw Hall at the edge of the northern stand of trees. Late-season monarchs were clustering directly above this photograph in February 1997. ISF is moderately high (0.26), and DSF is high (0.47). This site is highly exposed to morning sun (note the lack of obstruction in the southeast sky), which may explain the presence of monarchs here late in the season when morning flight for mating is especially important.

Photo 6.24 was taken near the southwestern corner of MGS. The *Eucalyptus* row is seen toward the east, and the clump of *Eucalyptus* and Monterey Pine in the far southwest corner are clearly seen. The trees low on the southern horizon are on adjacent property, and provide what little wind shelter exists from due south (WSF_S = 0.016). ISF and DSF are high (0.30 and 0.30, respectively).

Photo 6.14 is taken in the northwest corner of MGS, in a relatively dense stand of Monterey Pines. Several Live Oaks off site can be seen in the southwest direction, and the dense stand of trees along the northern boundary can be seen to the east. ISF and DSF are moderately high (0.24 and 0.27), and the site is moderately exposed to southwest winds (WSF_{SW} = 0.01) and highly exposed to west winds (WSF_{W} = 0.022).

Photo 6.20 was taken near the northeastern corner of MGS. The Monterey Pine canopy is clearly seen to the south. Trees rapidly thin towards the north (see also Fig. 3 map). ISF and DSF are relatively high (0.29 and 0.31, respectively). The trees to the east are on adjacent property. While this site is well protected from northwest winds (WSF_{NW} = 0.003) it is relatively exposed to southwest winds (WSF_{sw} = 0.018).

Photo 6.13 was taken in the densest part of the forest along the northern boundary of MGS. ISF and DSF are relatively low (0.13 and 0.18, respectively). This site is well protected from northwest winds (WSF_{NW} = 0.002) and from southwest and south winds (WSF_{SW} = 0.002, WSF_{S} = 0.006). This site is the only area besides the *Eucalyptus* row that provides a proper mix of site factors, but it may be too far from other suitable sites in MGS to attract butterflies.

Site Factors across MGS

Maps of the various site factors (ISF, DSF, and eight WSF) across MGS provide an overall view of canopy structure, and highlight the opportunities and problems for monarch butterflies that overwinter here. It is important to note that the computerized method of drawing contours may create artifacts well away from sample points, but the critical areas have been well sampled and these artifacts do not apply there.

Indirect Site Factor (ISF) within the Sanctuary varies from 0.13 under the *Eucalyptus* on the south boundary, to 0.47 in the large clearing west of Brokaw Hall (Fig. 7a). The lowest ISF values are the eastern half of the south boundary and along the north boundary. The cluster area has ISF values between 0.13 and 0.21; these values fall in the relatively narrow range that was observed at other sites in California (0.10 to 0.25, Weiss et al. 1991, Weiss and Murphy 1993). The only areas that fall within the highly suitable range of ISF (0.10 to 0.20) are the cluster site and the center of the north boundary. Most of the site is too open for monarchs.

Direct Site Factor within the Sanctuary vary from 0.05 just north of the southern row of *Eucalyptus* to 0.73 in the clearing (Fig. 7b). DSF within the cluster areas ranges from 0.24 south of the row of *Eucalyptus*, to 0.05 just north of the *Eucalyptus*. These values fall within those observed at other sites in California (0.05-0.3, Weiss et al. 1991). Because DSF varies substantially with height, ground level measurements do not accurately reflect conditions at canopy heights where monarchs cluster, but sites higher in the canopy generally have higher DSF values..

WSF varies across the site by wind direction (Fig. 8). A relatively high WSF (> 0.02) indicates much open sky up to 30° elevation, and relatively low WSF (< 0.01) indicates little open sky up to 30° elevation. For example, WSF_{NW} is highest in the southeast corner of the sanctuary (maximum 0.037), and WSF_{SW} is highest north of Brokaw Hall (0.026). WSF across the site is highest during northwest and west winds, and lowest during southeast and northeast winds, so that the site is relatively well protected from south and southeast winds, but is highly exposed to northwest and west winds.

Parts of the cluster site have high WSF_{NW} Within the cluster site, WSF_{NW} changes dramatically from the north side of the *Eucalyptus* row (0.025 to 0.032) to the south side (0.005 and 0.006). Conversely, WSF_S is 0.015 on the south side of the *Eucalyptus*, but is 0.004 to 0.012 on the north side of the row. Monarchs frequently move from one side of the *Eucalyptus* to the other when winds shift direction, indicating the butterflies high sensitivity to wind.

Summary of conditions in the cluster area

The cluster area is one of only two areas within MGS that has enough sufficient canopy cover for monarch butterflies. The spreading canopies of the large *Eucalyptus* create a narrow band 15-30 meters wide along the southern boundary that has ISF and DSF within the ranges observed at other monarch butterfly sites in California. The small area of relatively dense canopy north of Brokaw Hall rarely supports clustering monarchs, although several clusters were observed along the southern edge of this stand in February 1995, after most butterflies had already left MGS.

The major problem at the cluster site is highly exposure to northwest winds. Kingston Leong's studies have repeatedly demonstrated that butterflies move within a site, or leave it completely in response to wind speeds greater than 2 m/s. Monarch Grove Sanctuary is no exception. During northwest winds, the butterflies move from the exposed north side of the *Eucalyptus* to the more sheltered south side, often in a Monterey Pine that is off the MGS property. Because the prevailing winds during sunny conditions are northwesterly, and these winds can be quite strong and continuous, for much of the time conditions are not suitable except south of the *Eucalyptus*. Conversely, during southerly winds preceding and during winter storms, butterflies may move to the north of the *Eucalyptus*.

Summary of Habitat Suitability at Monarch Grove Sanctuary

1) MGS does contain areas that meet the requirements of monarch butterflies through many, if not most overwintering seasons, as evidenced by their continued occupancy of the site.

2) The cluster sites often have micrometeorological parameters that fall within the ranges preferred by monarchs at other sites in California. The key parameters appear to be solar radiation/light and wind. Locations within MGS where monarchs do not cluster have those conditions less often (Leong 1994).

3) These cluster sites have the densest canopy cover on MGS, and have ISF and DSF values that fall within the range observed at other heavily used sites in California. Most of MGS currently has too little canopy cover for monarchs.

4) Wind exposure from the northwest is high on the north-side of the row of *Eucalyptus*. Because northwest winds are common and often strong, it is not surprising that butterflies often cluster on trees just south of the MGS border, on private property.

RESTORATION PLAN

Specific Site Enhancements

The proposed tree planting scheme presented in the Leong report contains the general elements of needed habitat enhancements. A combination of dense tree stands and windbreaks in appropriate areas, combined with more open areas will provide roosting sites, wind protection, and proper light conditions for the monarchs. The major conceptual plan is to create an open area around the current viewing area surrounded by dense tree stands that act as windbreaks and provide canopy cover. An open area on the west end of the site will provide areas for mating and collection of dew water by the butterflies.

By creating sufficient wind shelter from northwest winds within MGS, it is hoped that the majority of butterflies will cluster within the site rather than on adjoining properties.

Short-term plantings

The most important site-enhancement is the creation of a windbreak of trees running from the south border to the abandoned house, and from there to the eastern property line. The ideal structure of this windbreak includes tall trees, and sufficient middle story and understory to create a complete barrier to the wind. Because the

windbreak will be on the north side of the monarch aggregation area, light penetration is not an issue and the foliage can be very thick and dense.

The tree species discussed below have been considered for planting, and each has its advantages and disadvantages.

Monterey Pine (*Pinus radiata*)

Monterey Pine is the primary native forest tree on the Monterey Peninsula. For many reasons, it would be the preferred species for restoration. Monarchs continue to use pines as clustering sites at MGS. Few monarch overwintering sites in Monterey Pine Forests remain, and it would be desirable to maintain a substantial proportion of pines at MGS. The tree is well adapted to the climatic conditions in Pacific Grove, and could be expected to grow well under normal weather conditions. When young (<20 years) and into middle age (20-50 years), the trees provide foliage at many heights. When trees mature, however, lower branches are lost and the understory and middlestory open up. The lifespan of Monterey Pines is about 100 years -- many of the trees on the site are approaching that age and are in obvious decline (see Scott report).

The major factor that prevents widespread use of Monterey Pines at MGS is the pitch canker fungus, which has been positively identified on the site (see Scott Report). Since mortality rates from pitch canker are expected to be on the order of 85%, it is impossible to plan an adequate forest structure using Monterey Pines at present. Widespread use of Monterey Pine at MGS will have to wait for a pitch canker resistant strain to be developed. Monterey Pines are also highly flammable, and native forests appear to require fire for successful stand replacement.

Blue gum (*Eucalyptus globulus*)

Eucalyptus globulus is the most commonly used tree in monarch overwintering aggregations in California. Its tall stature, rapid growth, plastic response to light conditions, potentially dense foliage at all heights, and wintertime flowering habit all make for high quality monarch habitat. The canopy structure lets in appropriate amounts of filtered light, provided that the trees are not too densely planted. At MGS, a single row of *Eucalyptus globulus* provides substantial wind shelter, and butterflies often cluster on the pendulous branches and foliage.

The major disadvantage of *Eucalyptus* is that it is not a native tree and has a reputation as an invader into native habitats. In dense stands, it crowds out native plants and can poison the soil for other species when downed branches and foliage are allowed to accumulate. Downed material can also be a major fire hazard, and trees can develop unbalanced branches that can drop at any time and are a major hazard to people and structures. The species is susceptible to the *Eucalyptus* long-horned borer,

and sites elsewhere in California have been severely impacted. However, *Eucalyptus globulus* at MGS does not appear to be threatened by the borer at this time (see Scott Tree Assessment report).

Additional plantings of *Eucalyptus globulus* is recommended at MGS only with reluctance, with an attempt to minimize its use to a single row to create a northwest wind barrier, and for eventual replacement of the row of *Eucalyptus* along the southern boundary (see below). However, widespread use of *Eucalyptus globulus* would be the fastest and surest way to enhance the quality of the site for monarch butterflies, so a *Eucalyptus* oriented plan is also presented as an option.

A variety of *Eucalyptus globulus* (var. *'compacta'*) has been planted in several locations. The only potential use of *'compacta'* is where a dense screen less than 50 ft. tall is desired -- the variety does not let in enough light, nor provide a good branch structure for monarch clusters. The existing plantings are in spots appropriate for this purpose, so no removals are recommended.

Other *Eucalyptus* species may be considered (i.e. a *Eucalyptus filicifolia* has been planted near Brokaw Hall), but *Eucalyptus globulus* has so many known advantages for monarchs that these other species do not appear to have any particular advantage at MGS.

Specific vegetation management guidelines for *Eucalyptus* are presented in the Scott Tree Assessment report.

Monterey Cypress (*Cupressus macrocarpa*)

The third major canopy tree at MGS is Monterey Cypress. The species is native to two small groves, but has been widely planted on the Monterey Peninsula. Monterey Cypress can form a large spreading canopy, but, like Monterey Pine, loses branches and foliage in the understory and middlestory as trees reaches middle age. Monarchs will form clusters in Monterey Cypress at MGS and elsewhere in California.

The disadvantage of Monterey Cypress is that is it relatively slow growing, and will not reach sufficient heights for wind screen purposes as fast as *Eucalyptus globulus*. However, it can be incorporated into the wind screen as an adjunct to *Eucalyptus*, and may be planted within the wind-sheltered area in lieu of Monterey Pine to provide some canopy cover. The tree is also brittle when it gets older, so hazard management is necessary for mature trees.

Coast Live Oak (*Quercus agrifolia*)

Coast Live Oaks are a common element in Monterey Pine forests, and can provide dense understory foliage when the pines lose lower branches. They do not generally grow large enough to provide sufficient high canopy-level wind protection. Live Oaks do not generally serve as cluster trees (but may be used as in Washington Park), and their role is primarily limited to understory and middlestory foliage.

Coast Redwood (*Sequoia sempervirens*)

Coast Redwood was considered as a wind screen tree, because it is capable of rapid growth and provides dense foliage. However, the species does not do well when directly exposed to winds off the ocean, and MGS is not a suitable site for this species.

Douglas Fir (*Pseudotsuga menzesii*)

Several Douglas Fir trees are growing on Ridge Road, just south of the entrance to MGS. These trees appear healthy and have dense crowns, and would form an effective wind block. Unlike Coast Redwood, Douglas Fir does grow in sites exposed to winds directly off the ocean. However, Douglas Fir is susceptible to pitch canker, but experimental plantings may be appropriate within MGS. Douglas fir also forms epicormic branches that can fill in lower canopy levels if sufficient light is available.

California Bay Laurel (*Ubellularia californica)*

Bay laurels can provide dense screens against wind, but are relatively slow growing and are sensitive to salty winds off the ocean (Bay laurel plantings show considerable wind burn at the MGS). No monarchs cluster sites are known from Bay laurel forests.

Planting schemes

Three planting schemes are considered. Each has similarities in that the overall structure will be the same, but the chosen tree species differ. *It is important to note that these three plans are points along a continuum, and elements of each can be chosen to meet restoration goals. Also, the exact placement of individual trees is flexible, so that openings for trails and the sewer easement may be maintained.*

These plans are described below as:

Plan 1) Moderate *Eucalyptus* plan

Plan 2) Full *Eucalyptus* plan

Plan 3) Minimized *Eucalyptus* plan

All three plans include replacement *Eucalyptus globulus* trees for the southern *Eucalyptus* row.

Most of the discussion below will focus on the need to maintain and enhance appropriate wind shelter and canopy cover at the existing cluster sites in the *Eucalyptus* row. The open area west of Brokaw Hall will be maintained as suggested in the Leong (1994) report for nectaring, watering, and mating. Existing plantings will not be disturbed unless specifically noted.

Eucalyptus Row replacement (All Plans)

The eucalyptus along the southern and eastern borders of the site are approximately 80 years old, and have several decades of useful life remaining in the absence of catastrophic fire or windfall. These trees will eventually need to be replaced with a new stand in the same location, so new plantings of *Eucalyptus globulus* will be necessary within a decade. New trees planted about 15 ft. north of the existing trees will begin the replacement process, and as individual older trees are thinned or removed, the increased light will stimulate growth of the replacement trees.

Plan 1: Moderate Eucalyptus plan (Figure 9)

The first planting scheme -- the "moderate *Eucalyptus* plan" -- attempts to balance the needs of the monarchs with a desire to minimize the amount of *Eucalyptus* planted, and maintain options into the future with regard to Monterey Pine plantings. The drawback of this plan is that the windscreen is farther from the cluster site than is optimal for rapid establishment of effective wind protection. This plan also crosses the "*Eucalyptus* Line" along the sewer easement, but is designed to minimize the number of *Eucalyptus* planted and the area affected by those trees.

The structure of the windbreak in this plan is as follows. First, on the outside (north and west sides) a row of *Eucalyptus globulus* will be planted densely enough (about 15' apart) so that the foliage will be continuous when the trees mature. *Eucalyptus globulus* is suggested because it is the fastest growing tree species available, and will provide wind protection relatively quickly. In front of the eucalyptus by about 20', a row of Monterey cypress will fill the gaps between the *Eucalyptus* trunks. The trees in the windbreak will be planted at a relatively high density for two reasons: first, so that trees will grow vertically at the maximal rate; and second, so that some trees may be thinned and others planted to provide a mixed age structure.

This plan reserves a 40' wide zone in front of the Monterey Cypresses for plantings of pitch canker resistant Monterey pine if and when they become available.

The many recent plantings of Monterey Pine in this zone will not be disturbed unless the trees exhibit signs of pitch canker, in the hope that at least some individuals will prove resistant to the fungus. A scattering of Monterey Cypress about 50′ apart is suggested for the area within the ring of *Eucalyptus*, to eventually provide increased canopy cover.

The planted trees should be of the largest possible size (15 gallon is most desirable, but 5 gallon may be necessary from a cost/availability viewpoint), so that they can put on substantial height growth in a relatively short time period. Watering and fertilization during the first two years would help speed establishment and growth (see Scott report for tree planting guidelines). This recommendation applies to all planting schemes.

Plan 2: Full Eucalyptus Plan (Figure 10)

This plan is focused on rapidly establishing wind protection and canopy cover using *Eucalyptus globulus* and assumes that pitch canker resistant Monterey Pine will not be available in the foreseeable future. The windbreak will be closer to the cluster sites, in the area currently planted with Monterey Pine just north of the main path. *Eucalyptus* will be planted at the same 15 ft intervals as in the shelterbelt in the minimized *Eucalyptus* plan. The open area within the site is planted with individual *Eucalyptus* spaced about 50 ft. apart.

Plan 3: Minimized Eucalyptus plan (Figure 11)

In this plan, the area from the shelterbelt to the path will continue to be planted densely with Monterey Pines in the hope that enough pitch canker resistant trees will become established to create effective wind shelter. As trees grow and start to lose lower branches, the understory should be planted with Live Oaks for wind protection at low levels. Monterey Cypress will form the outer edge of the windbreak, in approximately the same position as in Plan 1, and more cypress could be mixed in with the pines as insurance.

This plan is risky for monarchs, because there is no guarantee that Monterey Pines and Cypresses will grow rapidly enough to provide adequate wind shelter. Repeated plantings will be necessary as attrition of pine seedlings is expected to be quite high. A variety of local stock should be used so that the chance of canker resistance is maximized.

Away from the cluster sites

In areas away from the cluster sites -- the areas north of the proposed shelterbelt and in the northwest portion of MGS, it is suggested that replacement trees be planted near older trees so that the current species composition is maintained largely as a Monterey Pine forest. Because these areas are not presently as critical for monarchs as the cluster sites, failure of Monterey Pines from pitch canker is not as pressing, and by planting numerous trees, at least some may survive to form a canopy. These areas also provide the wildlife benefits of a largely native forest.

Eucalyptus Row trimming

As mentioned in the Scott report, several *Eucalyptus* branches along the main row of trees appear to be at risk of failure. Critical immediate hazards obviously need to be removed, but indiscriminate large scale trimming and removal of these trees will result in a loss of habitat suitability for monarchs. It is fortunate that *Eucalyptus globulus* can rapidly form new shoots and branches, so negative impacts of careful trimming may be mitigated after a few years.

Medium term plantings

A second wave of plantings should be considered in 10-20 years -- it is important to avoid even-aged stands of trees over the long-term, so additional eucalyptus and Monterey cypress may be added in appropriate areas of the windbreak and elsewhere on the site. We do not recommend planting *Eucalyptus* outside of the existing *Eucalyptus* area and the proposed windbreak area. Understory Live Oaks may be added in the windbreak areas as the lower branches of the cypresses and eucalyptus open up.

Fuel Management

There is a direct conflict between the needs of monarch butterflies and the ideal vegetation for fire control. The windscreen function of vegetation necessarily requires that a continuous screen of branches and foliage extend from near ground level to the upper canopy. This provides "ladder fuels" that can turn a ground fire into a canopy fire.

The areas that are proposed to serve as an inner wind screen are limited to the existing *Eucalyptus* row and the new shelterbelt plantings. Within these areas, ladder fuels will exist. In the *Eucalyptus* plans, the ladder fuels will be the branches and foliage of the trees themselves. The proposed plantings of fire resistant Live Oaks as an understory in the shelterbelt can partially mitigate this danger. The removal of downed material and cutting of dry grass around the shelterbelt will decrease the chance for a ground fire to reach the ladder fuels. The creation of a bare zone around the

windbreak/shelterbelts may be considered so that a ground fire does not reach the ladder fuels. Elsewhere on the site, the standard fire management protocols described in the Scott report may be implemented.

Outside the MGS `boundaries

Monarch Grove Sanctuary does not exist in a vacuum. Maintenance of forest cover surrounding MGS is an important factor in allowing for MGS to continue to function as monarch habitat. Tall trees within a few hundred yards of the site can provide important windbreak functions. Many of these trees can be seen on the southern horizon of Photos 6.3 and 6.7. Although the restoration plan attempts to create suitable habitat within MGS independent of the surrounding areas, any changes in the forest outside the boundary may have impacts within MGS

Many of the trees to the south of MGS are Monterey pines that are nearing their effective lifespans, and may be infected with pitch canker; it may be difficult to maintain pines in the near future. It is important that the neighbors of MGS, especially those to the south, be encouraged to maintain large trees on their properties, given constraints on safety and tree health. An education program for surrounding property owners is an essential component for long-term planning at MGS.

Review of 1994 Master Landscape Plan

The 1994 Master Plan for the site (Figure 12) has a number of features that do not conform to the recommendations in this report. The features of the 1994 Master Plan that are not compatible with maintaining quality habitat for monarch butterflies are as follows

1) There is no deliberate attempt to provide shelter from NW winds, except for the plantings of Monterey Pines which are at high risk from pitch canker.

2) The restriction of plantings north of the utility easement to only native plants (for deer habitat, according to the notation on the map) eliminates the possibility of using the most effective and fast growing tree species, *Eucalyptus globulus*, to provide wind shelter.

3) There are extensive proposed plantings of *Eucalyptus globulus* var. *compacta* along the southern boundary. The dense foliage and shorter stature of this tree variety does not provide for optimal monarch habitat -- the lack of open branches for clustering, and the lack of light within the crown are major concerns. The extensive use of *compacta* is risky, as no other monarch overwintering sites in California have extensive stands of this tree.

Some features of the 1994 Master Plan are neutral. The plantings of flowering cherries and plums, while attractive, has little bearing on site quality for monarchs, as these winter-deciduous trees provide little wind shelter. Plantings of red gum, *Eucalyptus rostrata*, may provide the correct structure for windbreaks, in addition to providing nectar.

On the positive side, the placement of paths, entrances, viewing areas, and kiosks are appropriate, and provide for a good viewing experience by visitors.

Continued Monitoring at Monarch Grove Sanctuary

Continued monitoring of monarch butterflies and trees will form the basis for adaptive management at MGS. Adaptive management views management activities as experiments from which to learn, and consistently collecting data on a regular basis is a critical activity. The following monitoring activities are suggested:

1) The automated weather station has proven difficult to maintain, and has largely served its purpose in identifying the key climatic elements relevant to monarchs. If the weather station is to continue functioning, regular maintenance will be necessary, as the anemometer and wind vane are vulnerable to fouling by *Eucalyptus* debris, and the solar radiation meter is easily covered by fallen material. However, further weather data of that level of detail may not be necessary until a shelterbelt is well established (10-20 years from now) and wind attenuation needs to be measured.

However, short-term measurements of wind under particular wind conditions (similar to those done by Kingston Leong) can be done with inexpensive hand-held anemometers and can provide more spatial coverage than the fixed weather station. Such measurements can be done by trained docents, and can be correlated with wind conditions measured at local weather stations.

2) Continued monitoring of monarch numbers and spatial distribution will provide the best measure of habitat suitability at MGS. The docents at the site should be trained in a standard protocol for mapping monarchs, and distribution maps should be compiled at least every two weeks, and if possible, immediately following strong wind events. Accurate estimation of absolute numbers is less important than good data on relative numbers and positions (tree number, approximate height, and side of tree) in the grove. In reviewing previous data, the lack of a standardized map has hindered interpretation of the data. The tree maps and numbering system provided in this report should be used a baseline, and the locations of additional cluster trees outside the MGS boundary added as necessary.

3) Continued monitoring of tree health by a qualified forester. Further large tree removals will be necessary as trees age and pitch canker progresses. Removal of canker infected saplings, and monitoring of new plantings on a yearly basis will catch

infections early, and proper sanitation may prevent or slow the spread of the disease in MGS, as well as identifying tree stock that is potentially resistant. Identification of immediate critical hazards in the *Eucalyptus* is important for safety concerns. The tree data base (Table 1) should be updated, and yearly measurements of the heights of new plantings will monitor the progress of restoration efforts.

Implementation Schedule for Management Activities

Tree plantings for the shelterbelt and *Eucalyptus* row replacement should be started as soon as possible.

Management activities need to be planned around the seasonal cycle at the site and avoid direct impacts on the monarchs during the overwintering season. The following guidelines for timing of suggested management actions are arranged in a seasonal progression:

Autumn (Oct-Nov): Tree and shrub plantings should commence following the first heavy rains, but supplemental irrigation should be available if a dry spell threatens new plantings. Numbers and distribution of arriving butterflies should be monitored.

Winter (Dec-Feb): Removal of large limbfalls from the ground following storms. Continued monitoring of number and distribution of butterflies, especially in relation to weather (wind) and site modifications such as new trees and the off-season removal of hazards.

Spring (Mar- May): Following the departure of monarchs from the site, limb hazards should be removed so that a full spring-summer growing season is available for regrowth. Removal of snags and near senescent trees should also be done at this time.

Summer (Jun-Sep): Tall dry grass should be cut (earlier in dry years, later in wet years), and dry fallen material at the base of trees removed for fire control.

Other issues

Control of Exotic Invasive Species

The site has a number of exotic species that are potentially invasive. Because the site is relatively small, and numerous ornamental plantings already exist, identification and control of invasive plants should be relatively straightforward.

Eucalyptus globulus is potentially invasive, and any seedlings that establish outside of designated *Eucalyptus* zones should be pulled in wintertime when the soil is moist and seedlings and saplings are easily removed.

A few individuals of French Broom (*Cytisus monspessulanus*) were noted along the entrance path from Ridge Road. Any individuals of this species found on or near MGS should be removed by hand during the winter months, when the plants are easily pulled up by the roots.

The understory is dominated by introduced annual grasses. Little can be done to eliminate these species. Native perennial grasses could be reestablished in the understory by plantings, but the annual grasses will always be a substantial part of the vegetation at MGS.

There are numerous ornamental plants associated with the former dwelling. Such plants as *Vinca major* (periwinkle), cala lilies, ice plant, and other ornamentals have little bearing on habitat suitability for the monarchs. If desired, these plants may be removed by hand or with spot treatments of appropriate herbicides.

Other Wildlife

MGS is frequented by a herd of deer. Because much of the site will be maintained as pine-cypress forest with a grassy understory, these deer should not be greatly affected by restoration for monarch butterflies. All plantings of deer-edible species will need to be protected by fencing. Similarly, the raccoons and other small mammals on the site that use pine-cypress forest will still have habitat remaining during and after restoration.

The removal of standing snags for safety and sanitation purposes will eliminate habitat for woodpeckers and other cavity nesting birds. Nest boxes may be provided if desired as mitigation for snag removal. If downed logs are deemed as important wildlife habitat, then no Monterey pine logs should be used because of pitch canker control; Monterey Cypress would be appropriate.

ADA Requirements for Trail Access.

We were unable to obtain adequate information on design requirements for ADA trail accessibility. Apparently ADA has not published formal guidelines and the City has not adopted its own trail accessibility guidelines. The contour map (Fig. 3) of the project site can be used to design a future trail system that meets ADA requirements. Should the placement of the ADA trail require the removal or relocation of proposed monarch trees, we could assess how the tree removal/relocation effects the monarch enhancement plan.

Site Fencing

The existing site fencing appears adequate -- the open nature of the site is one of its attractions. Using movable rope to keep visitors on the paths and in approved viewing areas is a flexible and appropriate method. Any changes in the fence on the south boundary would need extensive consultations with the neighbors

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Weiss, S.B., Rich, P.M., Murphy, D.D., Calvert, W.H., and Ehrlich, P.R. 1991. Forest canopy structure at overwintering monarch butterfly sites: measurements with hemispherical photography. Conservation Biology 5:165-175.

Weiss, S.B., and Murphy ,D.D. 1992. Scientific investigations of overwintering monarch butterfly habitat at Ardenwood and Point Pinole. Report to the East Bay Regional Park District, Oakland, CA.

Figure 1

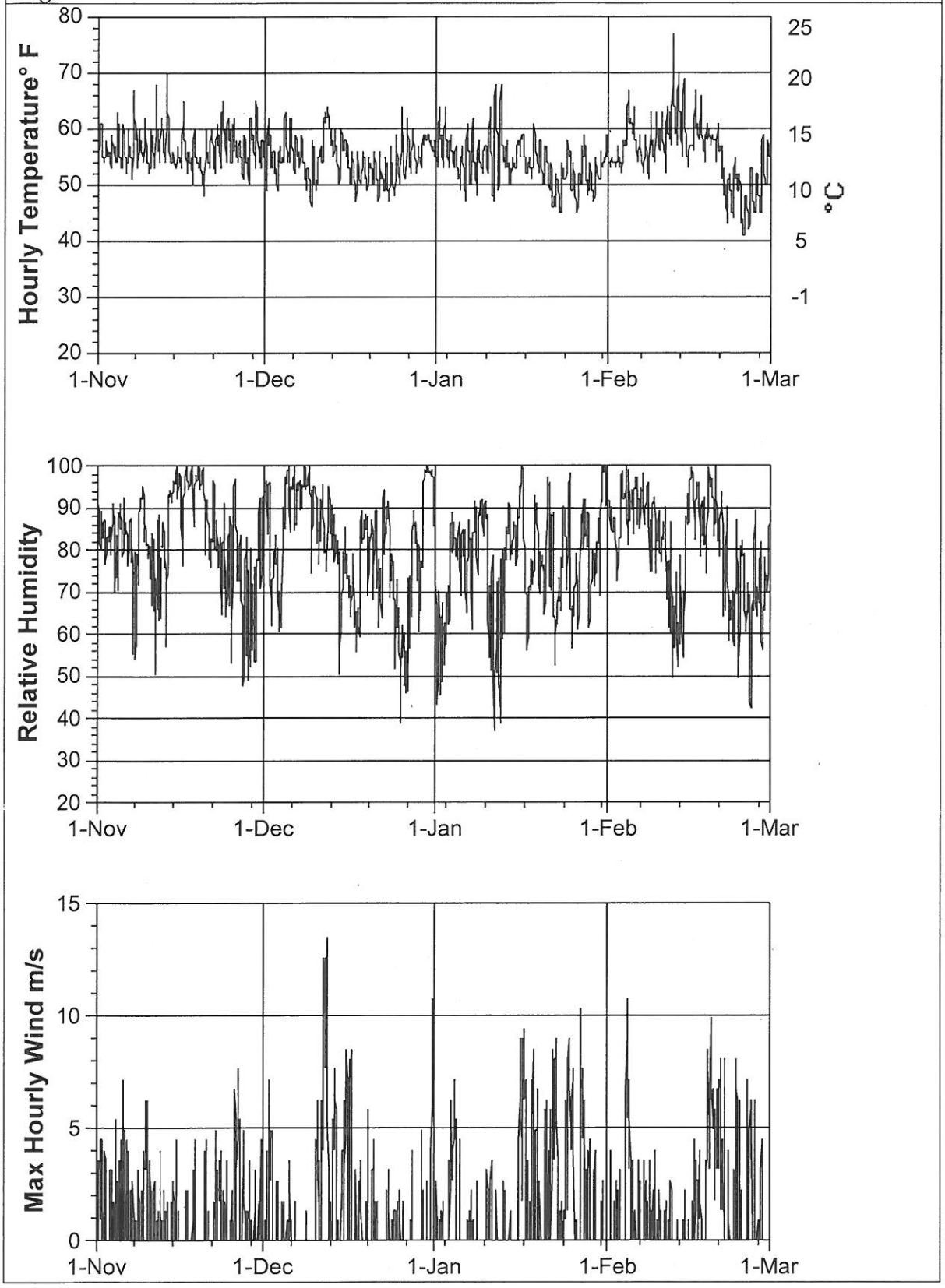
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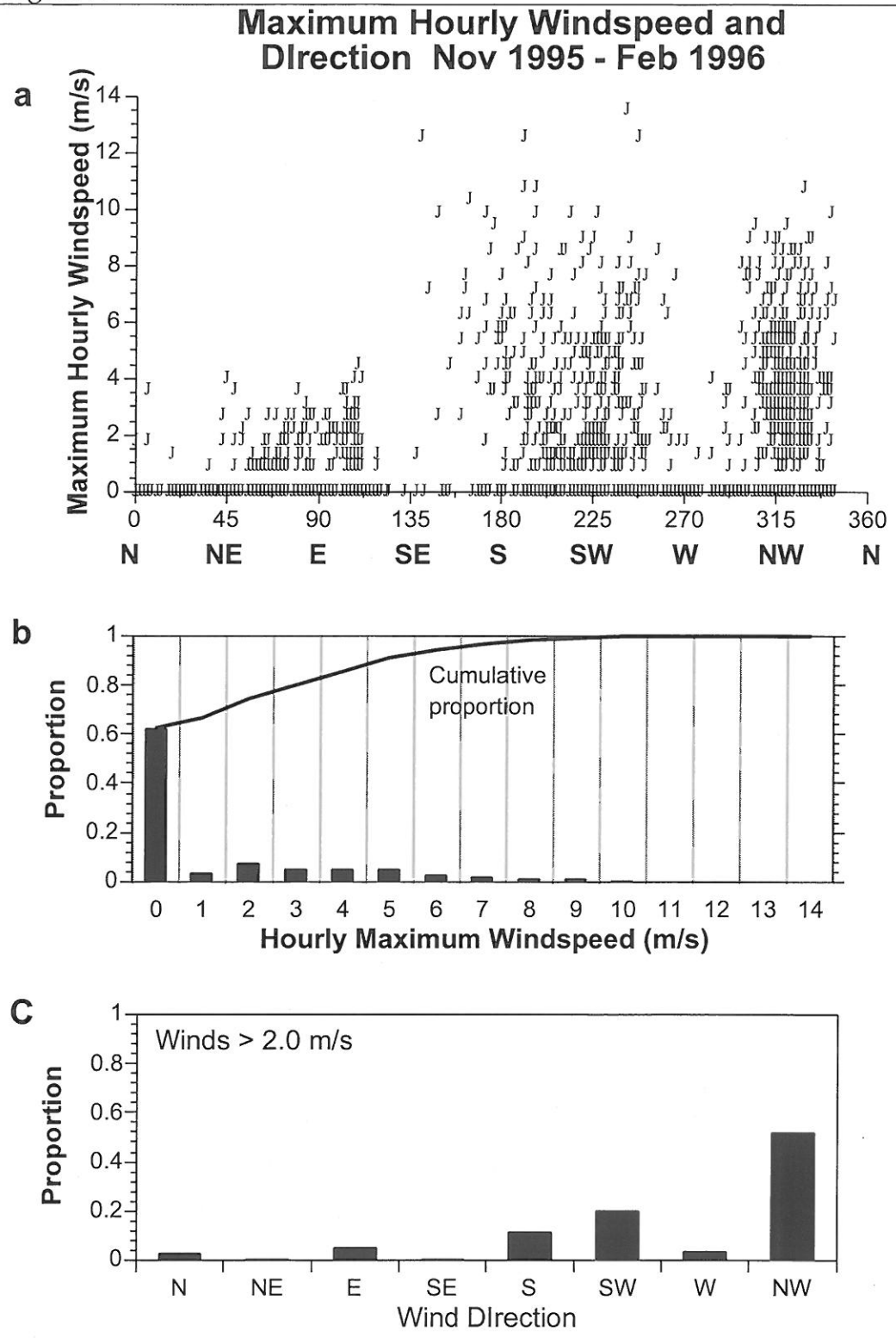
Figure 2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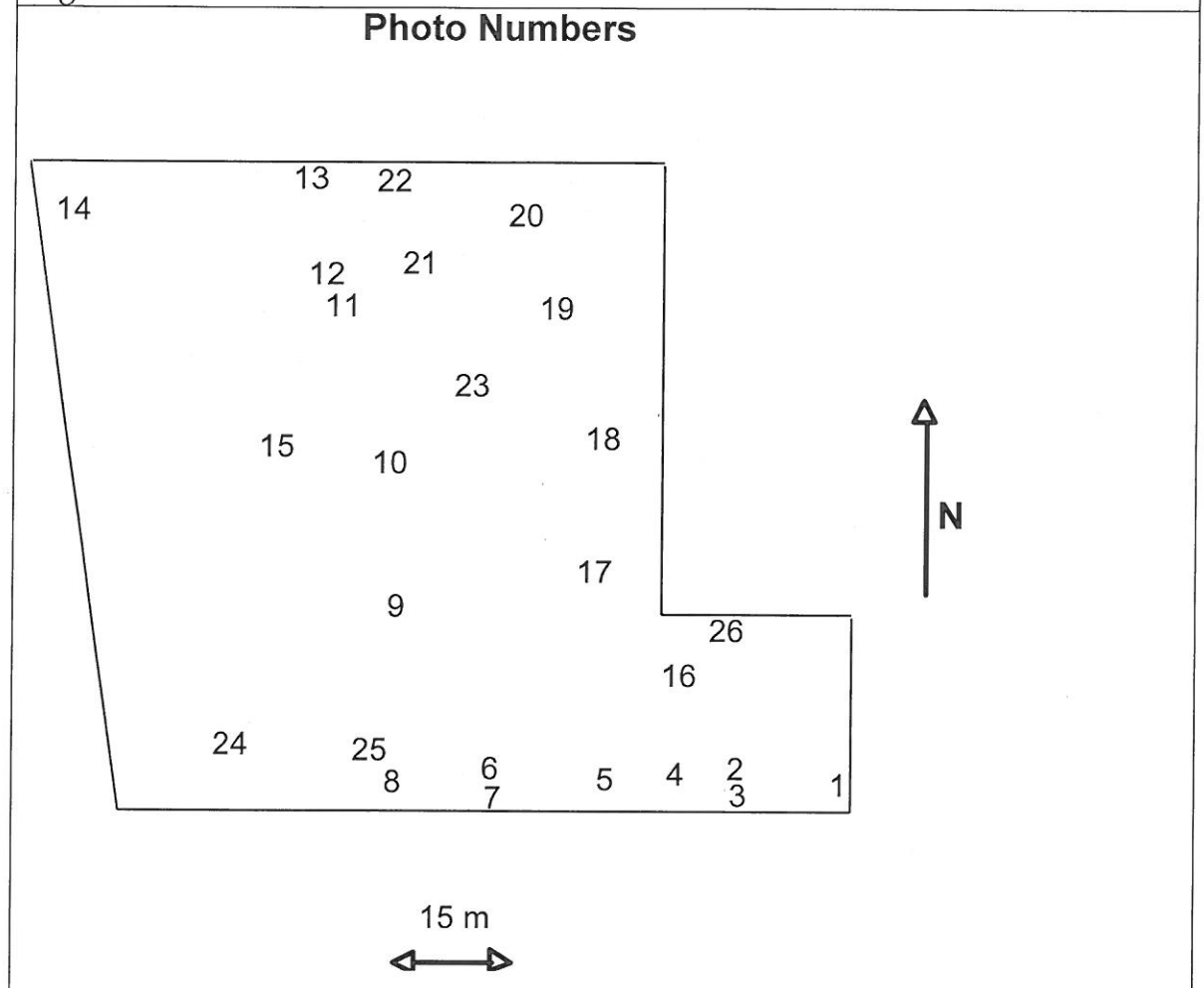
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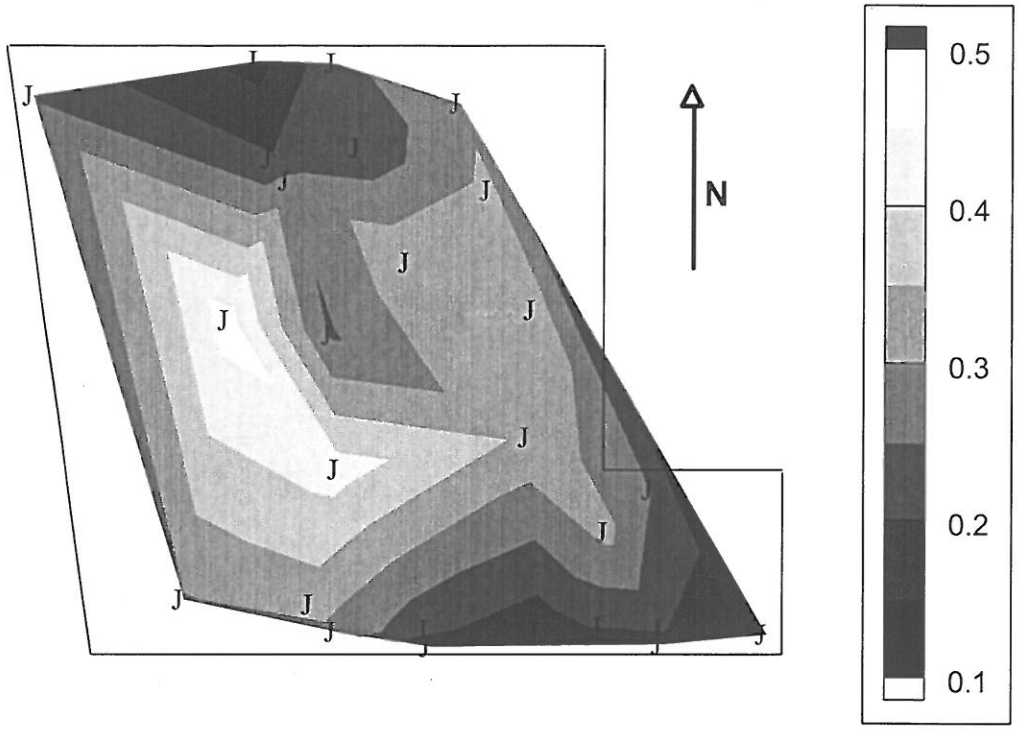

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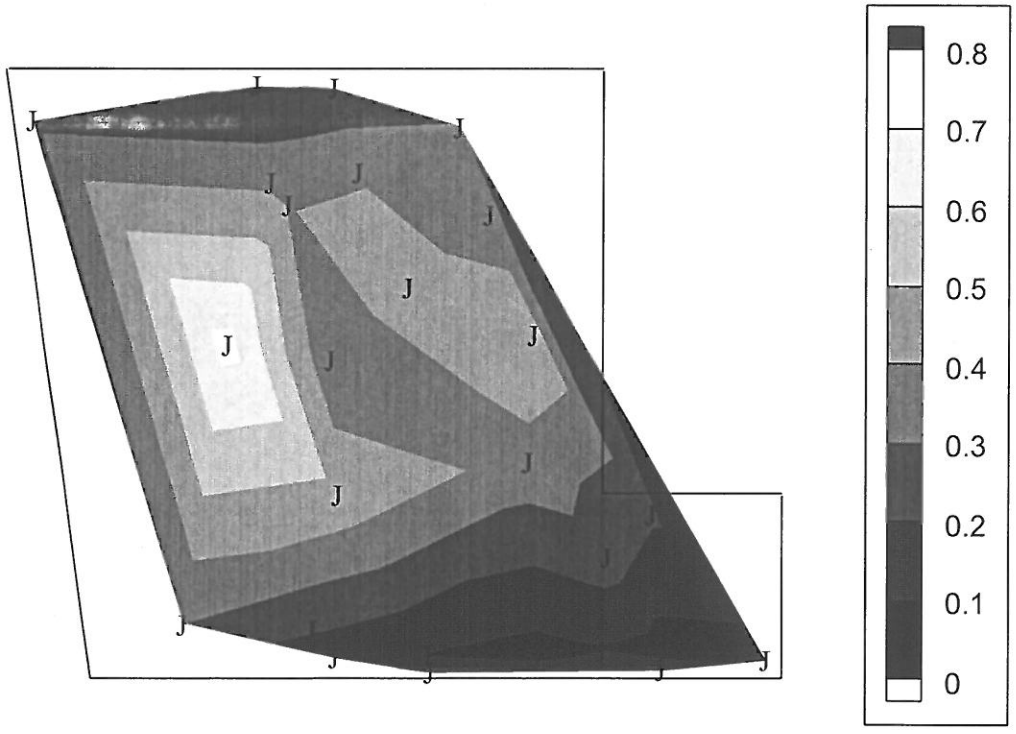
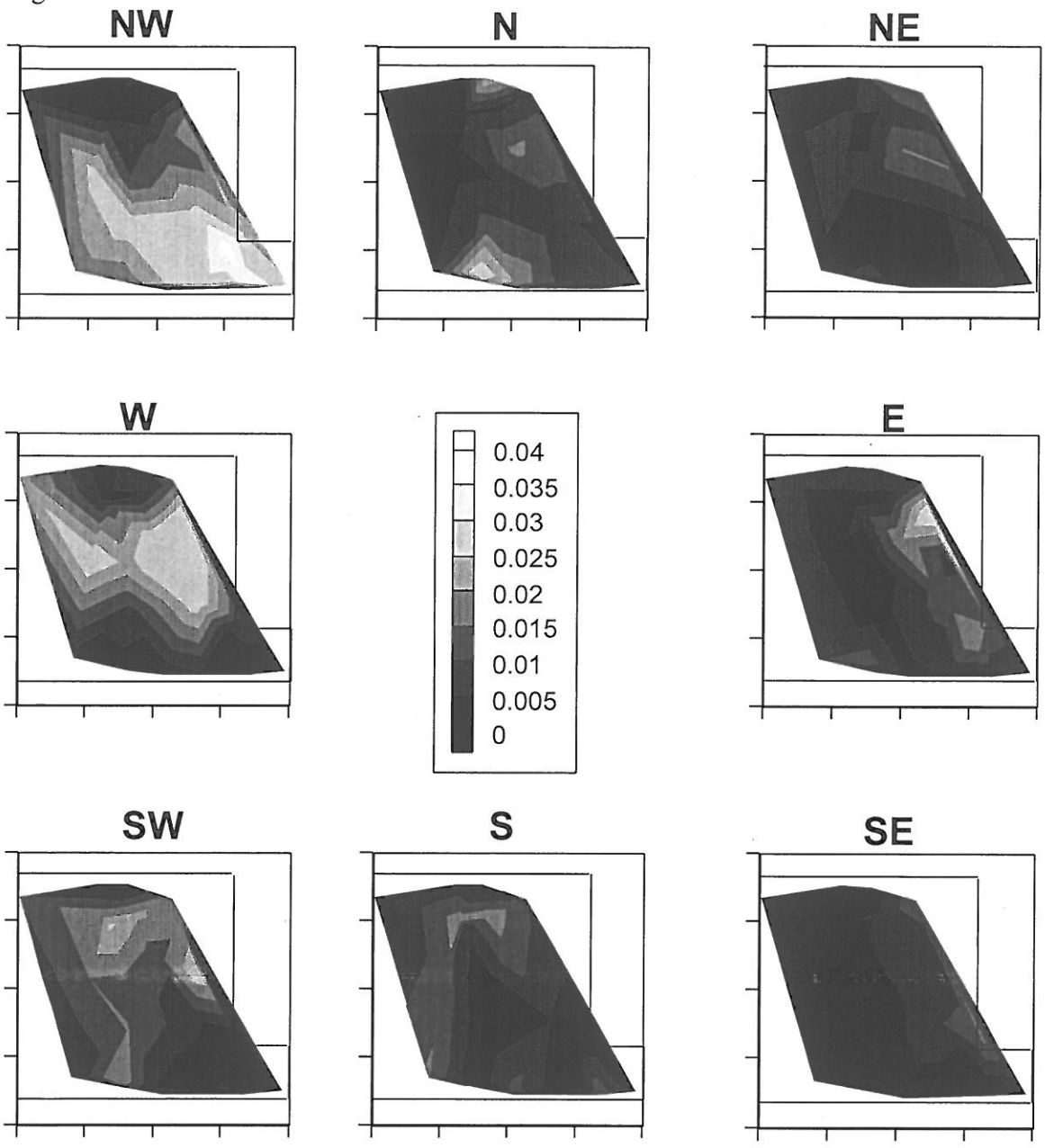
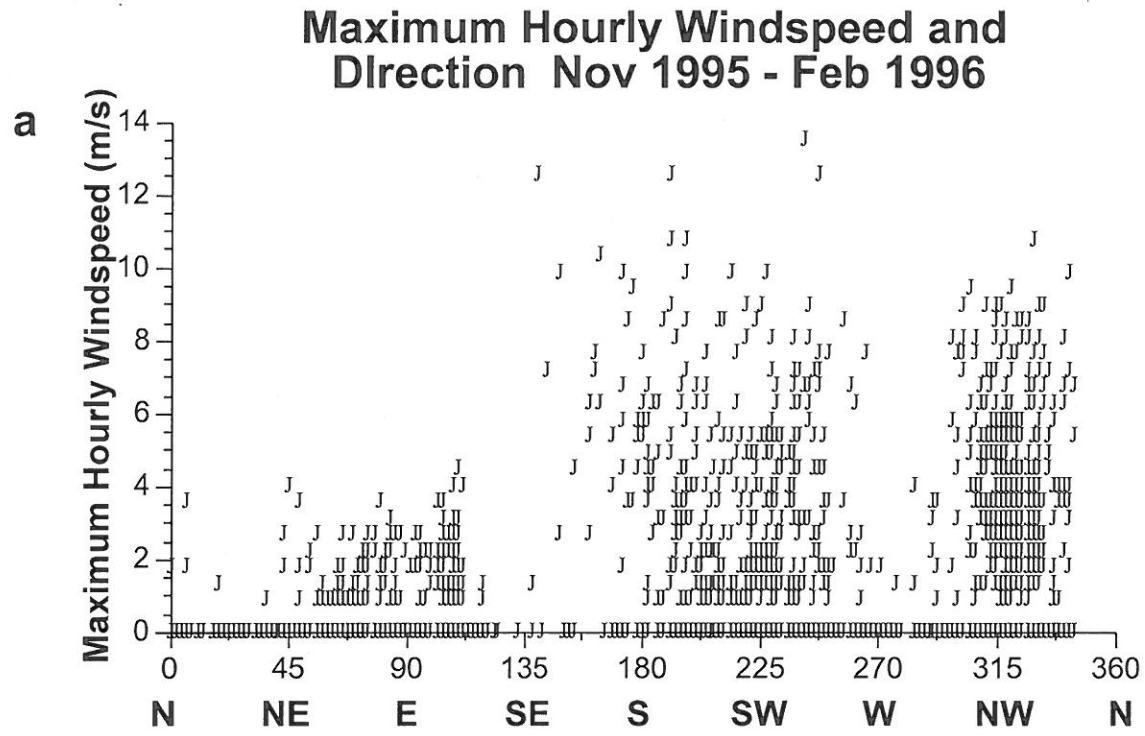


Figure 8



Figures 9, 10, 11 Plan sheets are not present, City of Pacific Grove should have a copy. It will take some doing to get a copy from TRA.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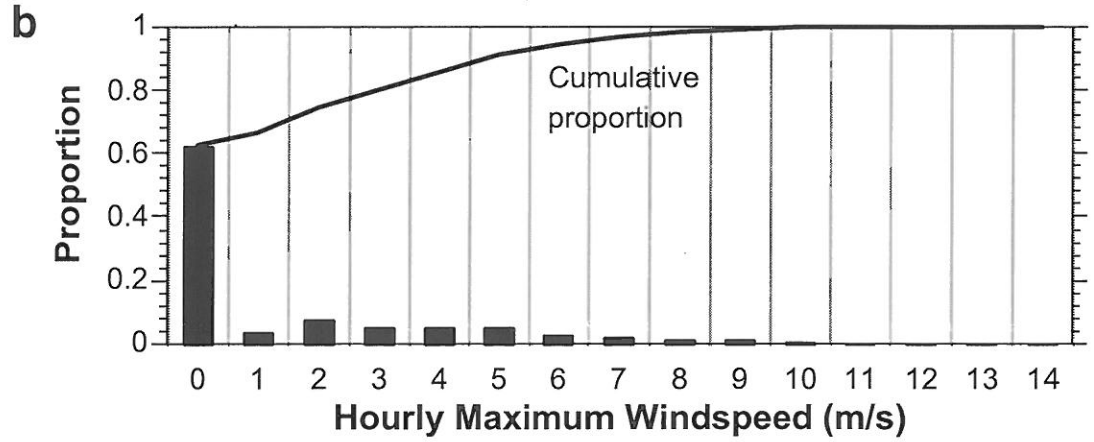
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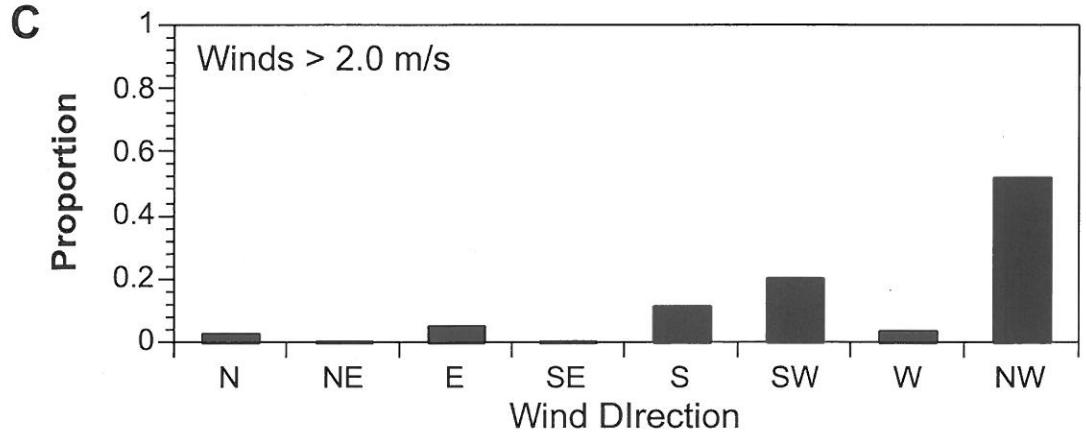
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