Western Wildlife 3:19–26 • 2016
Submitted: 24 March 2016; Accepted: 22 July 2016.

Evaluation and Management of California Monarch Winter Sites

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***Abstract*.—The proposed management system for the California winter sites of Monarch Butterflies (*Danaus plexippus*) is based on environmental and biological variables that govern three central factors: (1) the diurnal field activities of monarchs, (2) their cluster behavior, and (3) their occupancy of winter groves. Key to understanding these variables is the development of a Grove Seasonal Wind Profile (GSWP) that will depict the following: (1) disruptive winds, ≥2 m/s entry and path through the grove; (2) the protectiveness of grove trees against disruptive winds, ≥ 2 m/s; (3) the best area to plant seedlings to buffer strong winds; and (4) the area within the wind protective zone where the butterflies are forming winter aggregations. This information can be used to evaluate and manage the suitability of the grove for winter aggregations and to make informed decisions regarding selective pruning or removal of trees, planting of replacement tree species, planting of grasses and winter flowering plants, and the need to evaluate trees for public safety.**

Key Words.—butterflies; conservation; *Danaus plexippus*; Monarch Butterflies; winter habitat management

Introduction

Each fall North American Monarch Butterflies (*Danaus plexippus*) make their pilgrimage to winter sites in Mexico and California. In California, their winter aggregations are found in selected forested areas generally located along a narrow 1.6 km coastal strip from Mendocino County to Baja California. Their distribution (winter sites and population numbers) displays a bell-shaped curve with the greatest numbers found within the central coast (Santa Cruz, Monterey, San Luis Obispo and Santa Barbara Counties; Leong et al. 2004).

Leong et al. (1991) also showed that overwintering Monarch Butterflies are found only in forest groves that offer a specific set of microclimate conditions. Conditions for winter aggregations are similar for all California winter sites even though such sites may vary in forest structure, density, tree species composition, grove configuration, and topography (Leong 1990; Leong et al. 1991; 2004). These conditions have been created by topography and an ever-changing, fragile, dynamic plant community (forested area as well as the surrounding vegetation) and should be managed by winter habitat mangers or conservationist to maintain their suitability for overwintering butterflies.

Because the winter occupancy of monarchs depends upon the stability of a grove conditions, Leong et al. (2004) proposed two terms to describe winter sites: Transition and Climax. These terms reflect the dynamic nature of overwintering sites and should be the focus of all habitat management. Transitional winter sites can provide suitable conditions for winter aggregations for only a few weeks. They reflect an evolving, interim winter habitat, progressing into (1) those that will provide stable grove conditions to support winter aggregations for the entire season, (2) those that have transformed from stable conditions due to grove-tree senescence or tree losses to diseases and/or storm winds, and (3) those that are non-progressive and will eventually become a non-winter site. Climax sites are groves that provide suitable conditions for winter aggregation the entire winter season and may support overwintering Monarch Butterflies for a few years or for several decades. Eventually, if not managed, climax grove conditions will transform into to 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.

The frequent labeling of winter sites as autumnal and permanent (Nagano and Sakai 1990) should not be used in the context of habitat management, because these terms do not reflect the changing nature of plant communities that support overwintering butterflies. Designating a winter site as permanent, for example, implies that plant communities do not change and that habitat management is unnecessary. Similarly, the term autumnal sites suggest that the butterflies occupy such sites as way stations in the fall as they progress toward permanent sites. Further, labeling winter sites as autumnal or permanent also suggests that they are non-successional sites, which in the majority of instances is not the case. These two terms, in fact, reflect an outmoded philosophy regarding the unchanging nature of winter sites. For example, in 1988, the California Legislature allocated $2 million from a bond issue of $776 million for the acquisition of land where monarchs overwintered along the Pacific coastline (Malcolm 1993), but no monies were allotted to manage the winter sites precisely because they were considered to be either autumnal or permanent sites. A portion of the Escalona Gulch winter site in Santa Cruz County was also purchased under this bond issue, and as time passed, the misleading assumption that the site was permanent resulted in a forested area without overwintering butterflies.

Under the California Tree Culture Act of 1868 (Assembly Bill No. 583), the introduction and planting of eucalyptus trees allowed the State's Monarch Butterflies to expand their winter distribution. However, because there have been no new large tree plantings in recent years in California, the mass winter aggregations of Monarch Butterflies are limited to current discrete and forested areas that are undergoing ecological succession. Unless these sites are managed, grove conditions that presently favor winter aggregations will eventually transform to the point that they will longer support overwintering butterflies. The purpose of the present paper is to propose a management system for California winter sites that is based on the environmental and biological factors governing the monarchs' diurnal field activities, their cluster behavior, and the occupancy levels of their winter groves. This approach facilitates the evaluation of winter groves and ensures informed decisions regarding (1) selecting and replacing trees to buffer disruptive winds or to serve as cluster trees, (2) estimating the need for plantings of winter flowering plants, (3) determining the value of growing milkweeds at the winter groves, and (4) assessing the health of grove trees for public safety.

Materials and Methods

Aerial photographs.—I obtained aerial photographs of the study groves were either from Google Earth or by the agency that requested this study. These photographs give us an overview of the study sites as well as to the pattern of vegetation, topography and/or building associated with the winter sites. I converted some aerial photographs to line drawings to better illustrate the location where the butterflies were aggregating, imbibing on water or nectar, sunning, and mating.

Monarch population estimates.—I observed butterflies from 0730–0830 PST when ambient temperatures were below flight threshold (13° C [55°F]; Masters et al. 1988) and when the butterflies were inactive in their clusters. I visually estimated the population of each cluster using binoculars, counting the number of butterflies in a given area, and multiplying this number by the number of times that area would cover the cluster expanse. I determined the overall population by summing the totals of each cluster.

Field activities.—I surveyed the diurnal activities of Monarch Butterflies (clustering, sunning, foraging for water or nectar, and mating) at Lighthouse Field State Beach winter site, Santa Cruz, California, during the winter season 2001–2002 and at San Simeon winter site, San Simeon, California, during the winter season 2005–2006. I made surveys during sunny winter days at 2-h intervals, starting at 0800 at the cluster arena and terminating at 1400. Each survey was performed at 30 m, 60 m, and 90 m radii distances, starting from the cluster trees and then recorded the type of activity, number of butterflies, and their location.

I took solar radiation measurements using a Kahlsicon radiation balance meter (cal cm^{-2} m^{-1}; Kahl Scientific Instrument Corporation, El Cajon, California) and wind measurements using a Kestrel 4500 Weather Meter (Nielsen-Kellerman Company, Boothwyn, Pennsylvania) in the field where the butterflies were actively foraging for water or nectar or sunning. Additional observations and findings referred to in this paper result from field research conducted by the author at the following locations during the indicated dates: Pismo North Beach, San Luis Obispo County, California, 1990; Los Osos, San Luis Obispo County, California, 1997; Lighthouse Field State Beach, Santa Cruz, California, 2002; Purple Gate, San Rafael, California, 2004; San Simeon, San Luis Obispo, California, 2004; Fort Baker, San Francisco, California, 2006; Woodland Estates, Nipomo, California, 2008; and Sweet Spring Preserve, Los Osos, California, 2013.

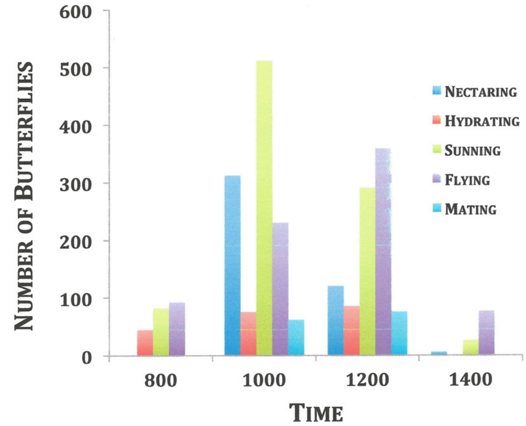
Protectiveness of winter grove against disruptive winds.—The protection from disruptive winds (2 m/s) is an important factor governing the winter occupancy of Monarch Butterflies at California winter sites. To determine the ability of a grove to buffer disruptive winds, I divided the grove into grids 30 m apart (except for Sweet Springs winter site, where the grids were 20 m apart). At each grid intersection (i.e., sample point), I measured wind velocity (m/s) and wind direction (azimuth/heading) using a Kestrel 4500 Weather Meter. At the conclusion of the study, I graphically depicted the winter wind profile of each grove, showing the path and general direction of disruptive winds. I did this by indicating sample stations that recorded at least one wind measurement of ≥ 2 m/s with blue circles and measurements below this threshold with white circles.

Results and Discussion

Field activities.—Because few, if any, flowering plants are available for the millions of overwintering butterflies that descend upon the high mountains of Mexico, the migrating insects primarily survive the winter months by living off their body fat reserves (Brower 1995). In California, Monarch Butterflies have an added survival benefit from the nectar of winter flowering plants. To survive, Monarch Butterflies must, during sunny winter days, warm their body temperatures enough to leave their clusters and drink water or nectar from winter flowering plants. This allows them to metabolize fat reserves for maintenance of their physiological well-being, and by the second week of January for the development of reproductive organs (Leong et al. 2012). After a the activity of a day, butterflies must return to the cooler temperatures of the grove to re-integrate into their winter aggregations and thereby lower their body temperatures and metabolism to conserve their body fat reserve (Chaplin and Wells 1982; Masters et al. 1988; Wells et al. 1992; Frey et al. 1992; Leong et al. 2004).

I observed butterflies flying, sunning, or foraging for water or nectar beginning at 0800, reaching peak activity at 1000, and declining by 1200 (Fig. 1). The number of active butterflies and activity appears to be closely related to the amount of radiant solar energy available (Fig. 1). By 1400, I observed only a few butterflies in the field, while the majority of the butterflies I saw were reforming their winter aggregations in the grove (Fig. 2).

The field activities of overwintering butterflies were limited to a kilometer range of the winter grove and in mainly sunlit areas (Fig. 3). This behavior was documented by my field studies conducted at San Simeon, California and at the Lighthouse Field State Beach, Santa Cruz, California (Fig. 4). Notably, the limits of the foraging distance of butterflies suggest an innate conservation of body energy reserves that is critical for their winter survival. The end of an overwintering season is signaled by intense mating activity. The males capture the females by chasing (Hill et al. 1976) or by capturing them while they bask on the canopy foliage (Leong 1995) and both types of mating activities occur in sunlit open field areas and foliage.



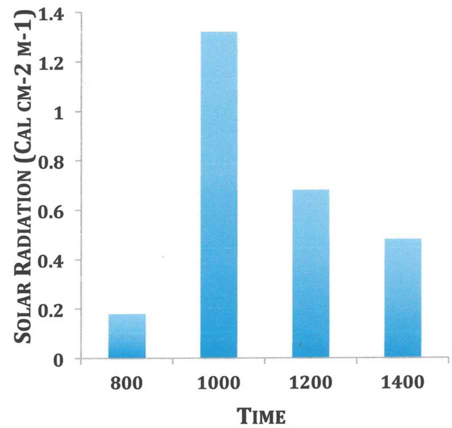


Figure 1. The pattern of the number of Monarch Butterflies (*Danaus plexippus*) active during the day is bell-shaped (A), which corresponds closely with solar radiant energy (B).

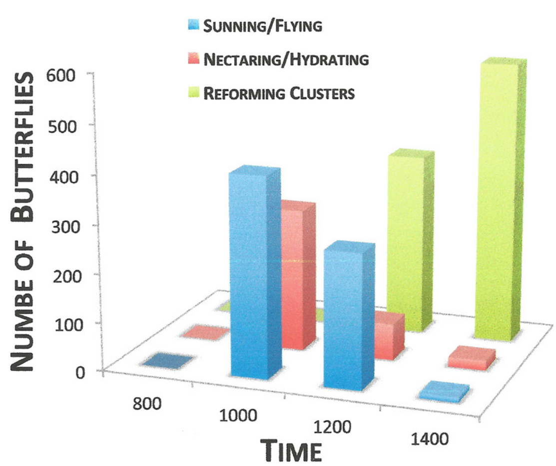


Figure 2. After a day of activities, Monarch Butterflies (*Danaus plexippus*) at San Simeon returned to the cool temperatures of the grove to reform their winter aggregations and to conserve their body energy reserve by lowering their body temperatures and metabolism.

Grove management considerations.—Planting of winter flowing plants and open sunlit areas for sunning, imbibing water and nectar, and mating should be established within a kilometer of the grove and mainly along the southern area of the overwintering colony. Unlike in Mexico, Monarch Butterflies overwintering in California are found in forested areas close to the coastline, where temperatures rarely reach freezing and where relative humidity is high (Leong et al. 2004). The winter occupancy and survival of Monarch Butterflies in California are primarily dependent upon two key environmental variables: wind and the access of butterflies to solar radiant energy, mainly filtered (morning and afternoon) sunlight as it is streamed through the foliage of grove trees.

Monarch Butterflies are very sensitive to winds, forming winter aggregations on trees exposed to minimal winds and on foliage that buffers prevailing winds (Leong 1990). Field studies of butterfly sites I conducted at Los Osos, Purple Gate, Nipomo, and Sweet Springs, in California, have consistently showed that strong winds have a direct negative effect on the winter occupancy of a grove by butterflies (Leong 1990, 1997; Leong et al. 1991, 2004). Winds ≥ 2 m/s are disruptive to the aggregating butterflies by blowing them from their roosting branches or dislodging them by shaking the branches. When the butterflies observed in this study were subjected to winds above flight threshold (about 16° C), they either flew to a more sheltered area of the grove or, if no refuge area was available, abandoned the grove temporarily or for the remainder of the season. If subjected to these winds below flight threshold, they were dislodged from their roost and blown to the ground where they lay like scattered leaves until warmed by ambient temperatures and able to fly to neighboring foliage or to ultimately abandon the grove. I have found that the mortality of the downed butterflies of

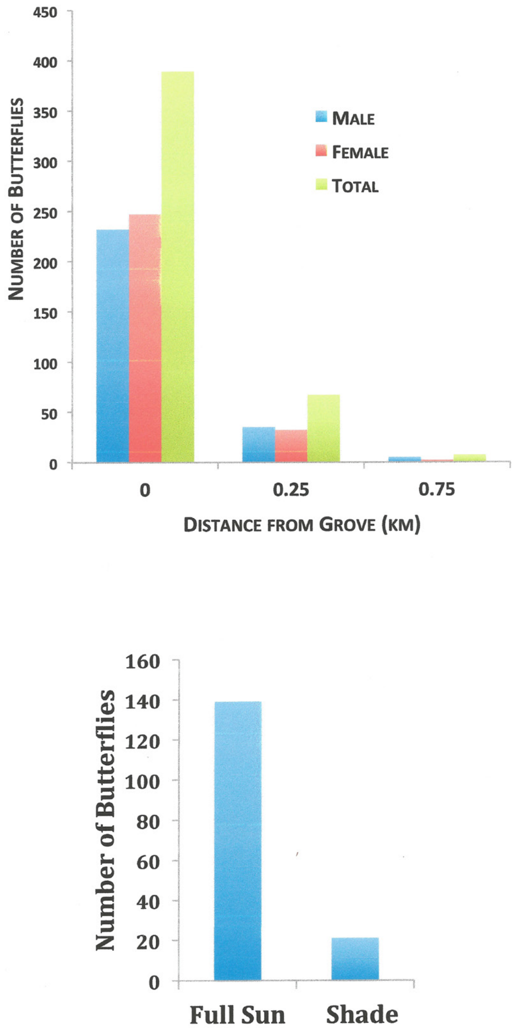


Figure 3. Monarch Butterflies (*Danaus plexippus*) will forage for water or nectar within a kilometer of the grove (A) and mostly in sunlit areas (B).

Figure 4. The seasonal summary of two winter sites of Monarch Butterflies (*Danaus plexippus*) at San Simeon, California (A) and at the Lighthouse Field State Beach, Santa Cruz, California (B). I found that the field activities of the butterflies occurred within 1 km of the grove and in sunlit field and foliage.

Pismo North Beach winter site is < 1% (Kingston Leong, unpubl. data).

The seasonal wind profile of a grove (GSWP) is a valuable management analytical tool to determine protectiveness or the ability of winter groves to buffer disruptive winds. If disruptive winds permeate the cluster arena, the overwintering butterflies will either abandon the grove temporarily or for the rest of the season. The GSWP is also a means to determine the area of the grove that requires wind protection and where planting of seedlings are needed to buffer future disruptive winds. The following scenarios (1, 2, and 3) of winter grove analyses using GSWP are based on my field observations of monarch winter groves in five California locations: Monarch Lane (Leong 1997), Los Osos, Purple Gate, San Simeon, Fort Baker, and Sweet Springs (Kingston Leong, unpubl. data).

Monarch Lane, Los Osos, California.—The GSWP for winter season 1994–1995 showed that strong NW winds (≥ 2 m/s) entered the grove along its western border and permeated to trees supporting winter aggregations of Monarch Butterflies (Fig. 5). When exposed to these winds, 2,000–3,000 butterflies abandoned the grove for the season. Analysis of the perimeter trees of the grove showed that the break in wind protection was attributed to a dead perimeter tree (Leong 1997).

In March 1995, eight 2 m (6 ft) eucalyptus seedlings (*Eucalyptus globulus* var. *compacta* Labill.) were planted in the sunlit area west of the dead perimeter tree to close the gap in wind protection of the remaining perimeter trees. Within two winter seasons, the GSWP of the 1996–1997 winter season revealed that the disruptive winds (blue sample station circles) entered the grove from the NW, NE and SW and were effectively buffered before reaching the trees supporting 3,000 overwintering butterflies (orange circles; Fig. 5). Notably, the butterflies did not form winter aggregations randomly within the protective zone of disruptive wind, but only on trees that provided the best access to filtered morning and afternoon sunlight (Fig. 5). On these trees, the butterflies remained at this locale of the grove the entire winter. Use of GSWP provided graphic analyses of the protectiveness of the grove against disruptive winds for the butterflies and where plantings of new grove trees are needed to buffer such winds.

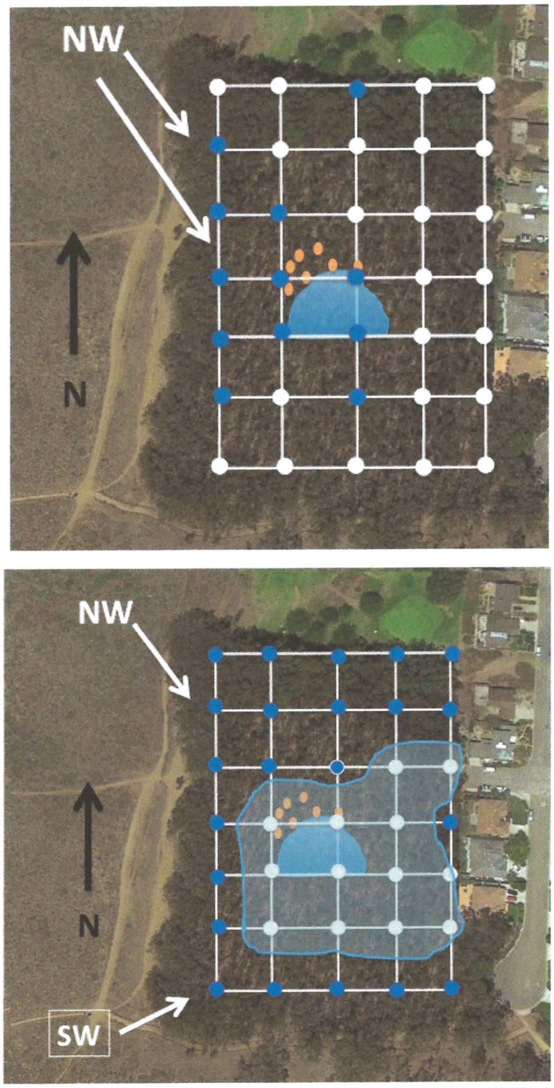


Figure 5. (Top) The seasonal wind profile of the Monarch Lane grove in 1994–95 shows disruptive winds entering the northwest and permeating the cluster arena. (Bottom) The seasonal wind profile of the Monarch Lane grove in 1996–97 shows that the disruptive winds entering from the northwest and southwest. The grove trees effectively buffered the velocities of these winds before they reached the cluster arena, creating a wind buffered zone (shaded light blue).

Purple Gate, San Simeon, California.—The GWSP of the winter site at San Simeon indicated no disruptive wind measurements (Fig. 6), while those at Purple Gate had many readings of disruptive winds ≥ 2 m/s, especially those entering the grove from the northwest (Fig. 7). Notably, the residential home located NW of the trees supporting the winter aggregation of monarchs shielded the butterflies from strong winds and likely accounted for the approximately 2,000 overwintering butterflies at Purple Gate. Although GWSP of San Simeon showed no disruptive wind recordings, there was a winter storm from the southwest a few days prior to the sample on 8 January. The butterflies abandoned the main cluster area, and a small number of butterflies (325 of 6,850) were found clustering on perimeter trees in area A, a refuge location in response to southeastern storm winds. The few butterflies that remained never returned to the main aggregation area, but instead clustered toward the end of the season on perimeter trees in area B. When exposed to storm winds, the butterflies will seek refuge areas within the grove and if none are available will abandon the grove. Refuge areas can be other grove trees or man-made structures as a residential home as was depicted for Purple Gate.

Fort Baker (Duncan Hill) and Sweet Springs, Los Osos, California.—Both winter sites are transitional sites and show similar GSWP where much of the habitat is susceptible to disruptive winds, particularly during winter storms (≥ 2 m/s). These winds permeated the winter site, especially the areas where the butterflies were once or formed (Fort Baker and Sweet Springs, respectively) winter aggregations (Figs. 8 and 9). Both sites share similar characteristics in that they are made up of mature grove trees (at Fort Baker, eucalyptus; at Sweet Springs, Monterey Cypress, *Cupressus macrocarpa*, and Blue Gum eucalyptus, *Eucalyptus globulus globulus*). The groves have heavy canopy foliage with little to no lower foliage to buffer strong horizontal winds, especially during winter storms. The restoration of the two sites is possible with strategic plantings of trees to create a buffer zone against strong winds entering below the canopy foliage. As with most winter sites, however, there is no commitment to manage the site beyond what has been shown in traditional analyses of the habitat. Without proper management, these sites are consequently destined to degrade until they cease serving as overwintering site for the butterflies. Mature grove trees offer minimal protection against storm winds because they lack sufficient lower branches (foliage) to buffer storm winds that enter and permeate horizontally through the grove. When storm winds permeate through the aggregation area, the butterflies will often use these winter sites, at best, as transitional.

The winter aggregations of Monarch Butterflies are not randomly distributed within the wind-protective boundaries of the grove (i.e., light blue shaded area of Fig. 5; Leong et al. 1991; Frey et al. 1992), and I often observed them at Los Osos, Purple Gate, Lighthouse Field State Beach and San Simeon winter sites on trees providing best access to filtered morning and afternoon sunlight. Exposure to morning sunlight, mainly radiant energy, is important for the diurnal activities of butterflies, such as flying, sunning, foraging for water or nectar, and seeking mates.

Afternoon filtered sunlight directs the location within the wind protective zone where the butterflies will form their winter aggregations. Although measurements of actual solar radiant energy were not possible during the present study due to cluster heights, the cluster reforming activities of butterflies could be readily observed beginning at 1200 (Fig. 2). I observed butterflies that were

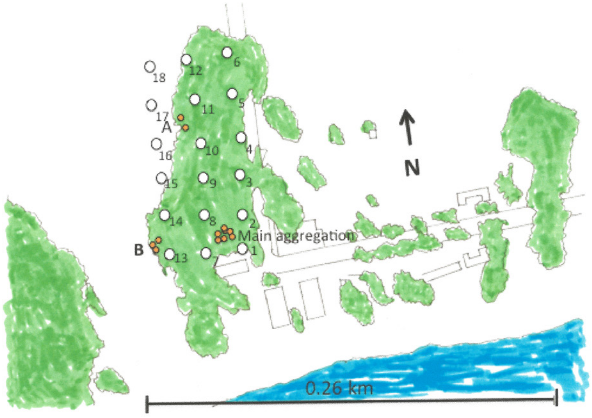


Figure 6. The seasonal wind profile of the San Simeon grove in 2003–2004 shows no recordings of disruptive winds. The butterflies clustered in the main cluster area until they were exposed to a January winter storm from the southeast. The few butterflies that remained move to a refuge area (A) between sample areas 10 and 11.

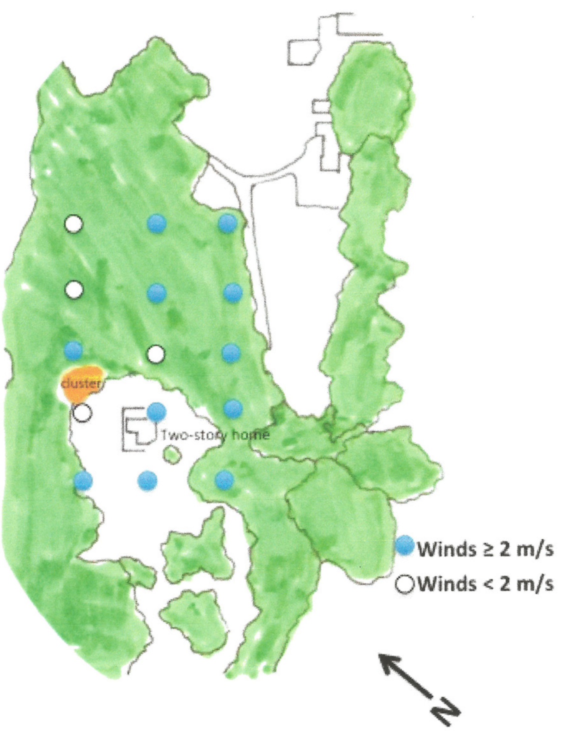


Figure 7. The seasonal wind profile of the Purple Gate grove in 2003–2004 showed disruptive winds entering from the northwest. The butterflies were found behind the wind protective area (shadow) of a two-story residential home.

reforming their winter aggregations fluttering above and settling on branches exposed to filtered sunlight. As the sunlight traverses to other wind-sheltered sunlit branches, the former branches, now shaded, will have roosting butterflies, while the latter will have active butterflies, forming their winter aggregations. Significantly, the formation of winter aggregations of Monarch Butterflies seems to occur only on foliage or branches exposed to afternoon sunlight and seldom on those that are in constant shade or are exposed to direct sunlight.

The influence of filtered sunlight on the winter aggregations of monarchs was demonstrated when I (Leong 1998) selectively topped southern trees prior to the 1996–1997 winter season to allow better morning and afternoon sunlight onto a given area of the Monarch Lane winter site, Los Osos, California. The butterflies clustered on trees within the targeted area and remained on these trees throughout the winter season. I observed a similar response during 2011–2012 winter season at Butterfly Grove, Trilogy, at Nipomo, California. A historical cluster tree was shaded during critical afternoon hours by the new growth of neighboring trees and did not support winter aggregation throughout winter season 2010–2011. Prior to the beginning of the 2011–2012 winter season, I removed trees that were blocking the exposure of historical cluster trees to filtered afternoon sunlight. The butterflies returned to form winter aggregations on the historical tree from the beginning of the season until they abandoned the grove in December. If the access of butterflies to filtered sunlight is the limiting factor for winter aggregations, the butterflies will return to cluster on a targeted tree once southern trees and limbs are removed to permit increased afternoon sunlight exposure.

Other winter habitat management considerations.— To increase adult nutritional resources, plantings of winter flowering plants should be within a kilometer of the grove and in sunlit areas. Overwintering Monarch Butterflies seem to limit their field activities (foraging for water, consuming nectar, sunning, and mating) within a kilometer of the grove, generally in adjacent open, southern areas of the grove. Replacement trees should be planted as soon as possible because they may take 10–20 y to grow to a height and foliage density sufficient enough to effectively buffer disruptive winds or serve as cluster trees. Monterey Cypress, Monterey Pine (*Pinus radiata*), and Blue Gum eucalyptus are fast growing tree species and have supported winter aggregations in mixed or in pure (except Monterey Cypress) stands. The choice of tree replacements should be based on whether a given tree species will serve as a cluster or buffering tree.

Monterey Cypress trees are resistant to pine pitch canker disease and will produce dense foliage ideal for buffering strong winds (State Board of Forester 1908). Planting of Monterey Cypress in the southern region of the grove, however, should be carefully evaluated, because its dense foliage may prevent filtered sunlight from reaching trees supporting winter aggregations. In mixed stands of grove trees, Monterey Cypress trees provide excellent foundations for winter aggregations.

Blue Gum eucalyptus or Monterey Pine may be used as cluster trees or general grove trees, particularly in the southern section because their foliage can effectively buffer gusty and storm-force winds and still allow fil-

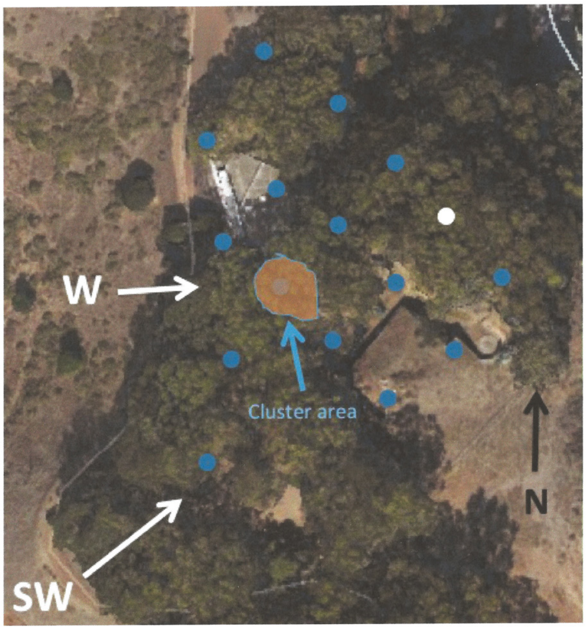


Figure 8. The seasonal wind profile of the Fort Baker grove in 2005–2006 revealed a degraded winter site where disruptive winds permeated through the former aggregation area (shaded orange) and 15 of 16 sample stations.

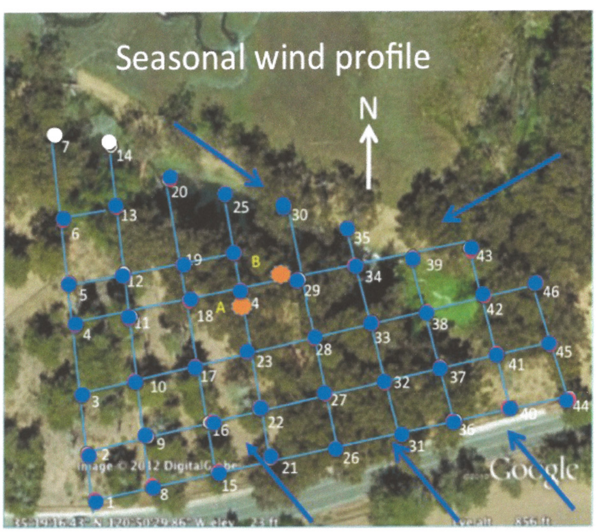


Figure 9. The seasonal wind profile of the Sweet Springs grove in 2013–2014 recorded disruptive winds from 44 of 46 sample stations, indicating a degraded winter site.

tered sunlight into the cluster arena. Although eucalyptus trees, particularly Blue Gum, are considered to be an invasive species, they can be used in a managed grove because volunteer seedlings can be easily eliminated and thereby controlled. Monterey Pine trees should be considered only if a resistant variety to pine pitch canker is developed. Once these trees are planted, their loss due to pine pitch canker will set back the grove recovery several years and will increase the cost of management.

Trees within a managed grove should always be evaluated for public safety as well as for their role in maintaining habitat integrity. The removal of dead or dying trees should be of paramount importance for public safety where they pose a risk to people or property in a monarch grove. No unauthorized visitors should be allowed to enter an overwintering site during winter storms.

The native Narrow-leaf Milkweed, *Asclepias fascicularis*, or Indian or Woollypod Milkweed, *A. eriocarpa*, are the primary larval food sources for Monarch Butterflies and are not available because they die back to their rhizomes during the winter months. Docents at some California winter sites have planted Tropical or Bloodflower Milkweed, *A. curassavica*, during the winter season in an attempt to increase the dwelling numbers of Monarch Butterflies and/or to provide visitors live examples of their life stages. This practice is not advisable and should be discouraged because the majority of the butterflies are in reproductive diapause (Leong et al. 1995). Planting at this time will encourage the few non-diapausing adults to lay eggs, resulting in starving caterpillars or adult butterflies that are not in synchrony with the natural milkweed seasonal cycle.

Acknowledgments.—I am indebted to Lincoln Brower, Robert Dees, and Holly Sletteland for their invaluable editorial comments and suggestions.

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Kingston Leong received his Bachelor's and Master's degree from Unversity of Hawaii and his Ph.D. degree from Oregon State University in Entomology. He has taught at Cal Poly University, San Luis Obispo, in the Biological Science Department since 1970 and retired in 2006. He has worked on various aspects of the biology of Monarch Butterfly biology and for the past 25 y and his research was centered on environmental factors affecting the winter occupancy of overwintering Monarch Butterflies at California winter groves and how these factors can be used to manage winter sites. (Photographed by Carol Leong).