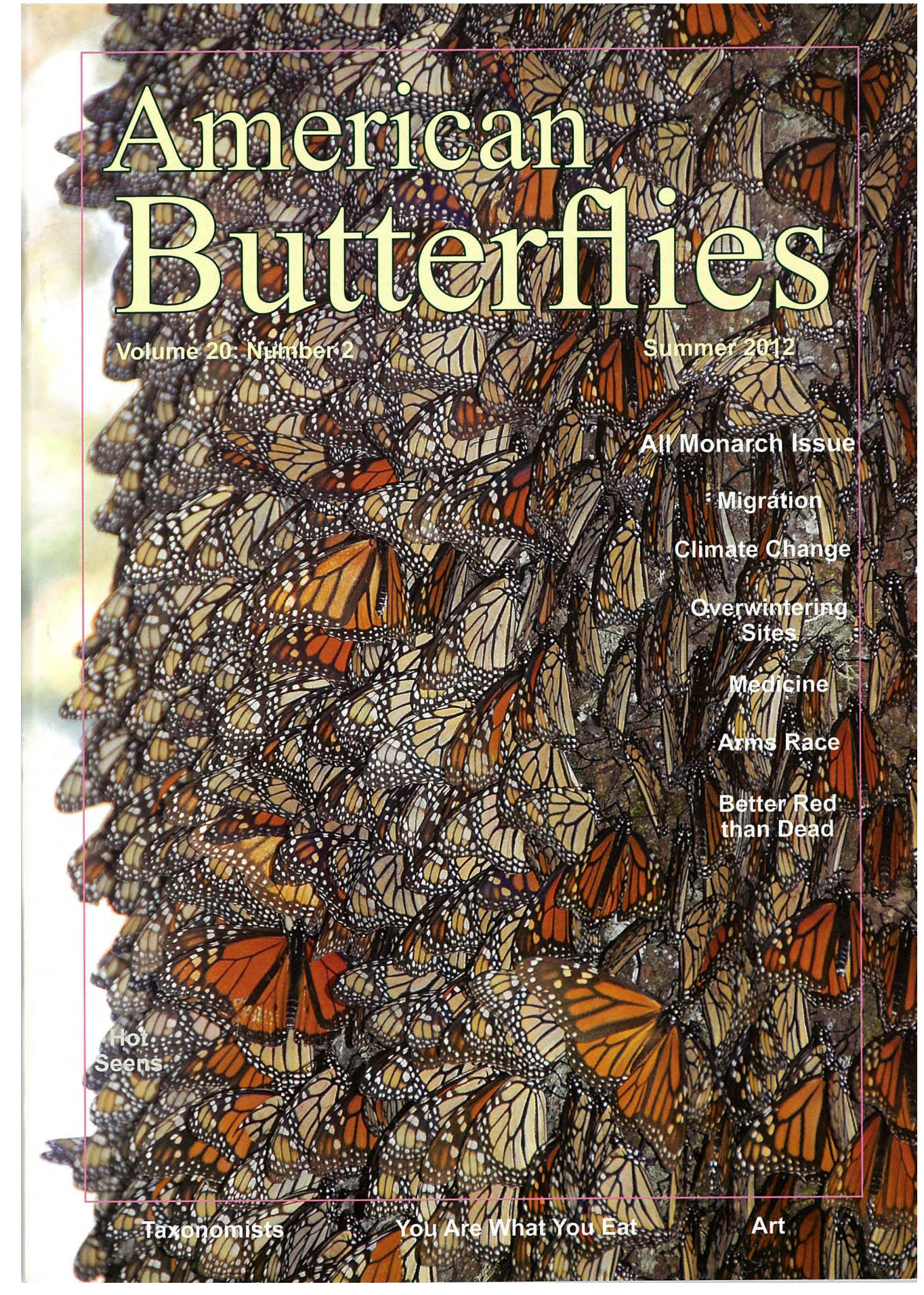

American Butterflies

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Microclimates and the Survival of Overwintering Monarchs

by Ernest Williams

Winter is a difficult time

for most living things. Because of cold and scarce food during this season, most animals get through winter by reducing activity, remaining in a protected stage of their life cycle, storing food in advance, or simply leaving and going somewhere warmer. Few butterfly species can withstand northern winters as adults. Descendants of tropical ancestors, Monarchs cannot survive the freezes that occur in their milkweed-rich summer breeding range, so with the exception of populations in south Florida, all Monarchs from central and eastern North America migrate southward to the subtropical latitudes of central Mexico to pass the winter months. There they aggregate in remarkable densities, estimated at 4 to 20 million per acre, on mountainsides about 100 miles west of Mexico City. These small mountainous sites provide the precise conditions that allow the butterflies to survive the winter.

At the Monarch overwintering sites in Mexico, Monarchs cluster in incredibly high densities.

Right: A view inside the Monarch roost, Feb 6, 2008.

Opposite page: A close-up view of a trunk cluster. Feb 7, 2008.

Southward movement enables Monarchs to avoid freezes, but they have to avoid excessive warmth, too. To do so, they move high up on cool Mexican mountainsides, usually above 10,000 ft. elevation, where they form winter colonies. Like other insects, Monarchs become as warm or as cool as the surrounding air (animals like this are called ectotherms). This fact is important because their metabolic rate — the rate at which they use energy — depends on temperature. The warmer the butterflies are, the faster they burn through the energy reserves (lipids) they have

The large sacred fir trees help the Monarchs stay warm when it is very cold and, conversely, stay cool when the air temperature in the area becomes warm. Jan. 9, 2007

accumulated and stored during the fall. Nectar is very limited on the Mexican mountainsides in winter, so the butterflies are not able to replenish their energy reserves. If they become too warm, they may not have enough energy left to survive the winter or to begin the next spring's migration, so they must remain cool.

A very narrow envelope of climatic conditions is necessary for Monarch survival because of the combination of these two factors: they have to avoid freezes, but they also have to remain very cool. Such locations are rare but, notably, the high elevation fir forests of central Mexico provide a few sites with exactly these necessary conditions. Thus, Monarchs migrate in the fall from throughout their eastern North American breeding range into an area of only a few acres on no more than 13 specific subtropical mountains where they form dense aggregations. Amazingly, they concentrate into an area equal to less than 0.01% of their entire North American summer breeding range.

The wintertime aggregations of Monarchs can be spectacular. The butterflies are so dense on fir trees that one can hardly see the needles and trunks underneath. It's very important that the colonies form under the canopy because the fir forest itself moderates temperature fluctuations. Tree cover blocks the loss of heat energy at night and reduces heat input during the day; this capacity of an undisturbed forest to moderate temperature fluctuations is important for Monarch survival. The canopy also blocks dislodgement by wind and provides umbrella-like coverage that shields the butterflies from rain and snow.

Another critical feature that determines where the colonies form is access to moisture. To avoid drying out, overwintering Monarchs regularly fly out in large numbers, when the sun is shining, to seeps or springs to drink. One of the more astonishing experiences of visitors to the colonies is being surrounded by mid-day flights of tens of thousands of Monarchs. One doesn't think of butterflies being noisy, but a large number of wings fluttering at once creates a gentle whooshing sound. In addition to wet soil, another source of water becomes available to the butterflies

Top: When the sun comes out, Monarchs become exuberant! Jan. 9, 2007.

Bottom: Monarchs obtain water from seeps or, as shown above, from melting frost. Feb. 7, 2008.

when overnight frost melts; thus, in an open meadow one can find lines of Monarchs on the ground drinking where morning sun first shines on the frozen dew.

Under the canopy, most Monarchs cluster densely on boughs of oyamel firs, the most abundant tree at the high elevation overwintering sites. Fir branches and needles provide opportunities for resting and clustering together, and butterflies within the bough clusters may benefit from slightly moderated temperatures and humidity. Although the microclimatic difference between the inside and outside of the bough clusters is little, butterflies on the underside of these clusters are better protected from precipitation.

Monarchs also form dense clusters on the trunks of large trees. Both bough and trunk clusters benefit from microclimatic moderation under the canopy, but tree trunks provide even greater buffering of temperature changes. The inside of a tree trunk is moist wood, so the trunks warm up more slowly and cool down more slowly than the surrounding air. In technical terms, trunks are said to have a much higher specific heat. (Similarly, water has a higher specific heat than land, so lakes and oceans warm up and cool down more slowly than do adjacent land masses, giving less extreme temperatures, for example, in San Francisco than in St. Louis.) Because of the difference in the specific heats of wood and air, trunks in the overwintering Monarch colonies remain up to 5°F warmer during cold nights and up to 4°F cooler during the heat of day. The more extreme the temperature — freezing at night or hot in daytime — the greater the difference between the temperature of the tree trunk and that of the air. This difference keeps Monarchs in trunk clusters well within the narrow microclimatic window they need for surviving the winter.

In addition, larger trees provide even greater moderation of temperature than do smaller trees. For centuries, wood for fuel has been taken from the central Mexican fir forests, so tree size is less than it used to be long ago. Currently, most trees in the overwintering colonies range from 1 to 3 ft. in diameter, but stumps show that in the past they reached more than 6 ft. in diameter. Larger trees provide more space for perching on the trunks as well as greater moderation of fluctuating temperatures. Just by doubling the diameter of a tree, one finds double the surface area for perching and quadruple the trunk volume for temperature moderation. It is likely that in the past, a higher percentage of Monarchs clustered on trunks.

Whether on boughs or tree trunks, Monarchs cluster at intermediate heights between the ground and the canopy. It is obvious to visitors that overwintering Monarchs are densest between 15 and 50 ft. above the ground, a location that keeps them in the vertical part of the forest that is warmest at night. Lower down, the ground itself is a heat sink and remains quite cold. Monarchs on the ground come close to freezing and are more subject to having dew form on them, which can freeze and kill them. The canopy, too, is cold because of its exposure to the sky and radiational cooling. This phenomenon is already familiar to you; our coldest nights occur when there are no clouds to block the escape of heat energy from the ground back to the sky.

While the above description of climatic conditions applies to the eastern migratory population, Monarchs from western North America pass the winter in a series of sites along the Pacific coast, some of which, like Pacific Grove, are well known. Here the climate is different from that in Mexico, but the butterflies find climatic protection similar to that on subtropical mountains; the ocean moderates fluctuations in temperature while keeping the humidity high. Winter aggregations of western Monarchs are much smaller than those in Mexico and they cluster on different species of trees, so the physical features of the clusters differ. Nevertheless, western butterflies also seek climatically protected sites in which to pass the winter.

It is no surprise that the evolution of Monarchs has favored behaviors that increase

survival. To get through the winter, they must avoid freezing but remain cool and find water to drink. It is a remarkable feature of Monarch migration that they are able to accomplish this feat so successfully: Monarchs migrate to precise locations in subtropical high elevation fir forests that provide a narrow microclimatic window of moderated temperatures, and then settle under the canopy in protective bough and trunk clusters at intermediate heights, the part of the vertical profile that is warmest at night. The forest itself serves as an insulating blanket against temperature extremes, as an umbrella shield against precipitation, and as a windbreak against dislodging winds. In addition, the tree trunks provide hot water bottle protection against excessive cold at night and heat in daytime.

These microclimatic features show that a dense and undisturbed forest is critical for the survival of the overwintering butterflies; disruption of the protective microclimatic features by logging and degradation of the forest are continuing serious threats. The high elevation fir forests of central Mexico allow continuance of the Monarch's remarkable migration, a phenomenon that remains astonishing to all of us observers.

A few years ago, Lincoln Brower invited me to join his research in the overwintering colonies, and I want to acknowledge him for the excellent collaborations we've had in studying microclimatic features of the high elevation fir forest.

All photos this article were taken by Ernest Williams at the Sierra Chincua overwintering colony in Michoacán, Mexico.