MONARCH BUTTERFLY PRESS BRIEFING

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The descriptions that follow provide factual details about monarch butterflies that should help explain the monarch migration to the public. I've tried to define the limits of our knowledge. My intention is to summarize what is known but I will leave it to your imaginations and writing skills to add the appropriate adjectives and literary flourishes to describe this extraordinary phenomenon. Although I have covered most of the topics that are of interest to the press and the public in this document, it is quite possible that I haven't answered your specific questions. Should this be the case, please contact me by email or phone.

MIGRATION

Monarch butterflies migrate from the eastern provinces of Canada and the eastern United States each fall to the Transvolcanic Range of central Mexico where they overwinter as clusters in high elevation oyamel fir forests. This migration involves hundreds of millions of butterflies and is one of nature's most intriguing and spectacular displays.

REPRODUCTIVE DIAPAUSE

Migratory monarchs are non-reproductive and generally remain so until mid-February when sexual activity begins as monarchs are about to leave the colonies on their journey northward. This state of suspended reproduction is termed "reproductive diapause". During diapause, juvenile hormone (jh), a necessary hormone for reproduction, is absent or nearly absent from these butterflies, indicative of a major shift in their physiology. In the late summer it is only the newly emerged butterflies that enter reproductive diapause. Butterflies that are already reproductive at the time the migration starts do not enter diapause and do not join the migration. Although there is some evidence that quality of late summer milkweeds eaten by larvae and the temperatures experienced by pupae and adults have a role in diapause, the factors that contribute to the initiation of this non-reproductive condition are not fully understood.

PACE OF MIGRATION

The migration starts slowly in the far North, picks up a bit of speed in middle latitudes of the United States, and then slows again as the butterflies approach the overwintering sites. This detail is relatively unimportant. A more important point is that the migration advances at a rate of 25-30 miles per day on average in the central portion of the continent and is reasonably predictable. In other words, it is possible to predict the date of arrival of the leading edge of the migration to within three days for any latitude from northern Minnesota to the Mexico border.

NAVIGATION

Migrating monarchs in the interior of the continent fly in directions (bearings, headings) that seem to be geographically appropriate, given the need to reach Mexico. For example, monarchs leaving Minnesota fly almost due south while those in eastern Kansas have bearings averaging 210 degrees and those just north of Atlanta fly toward 260 degrees. How the butterfly determines these geographically appropriate directions is the unanswered navigation question. It seems

likely that monarchs integrate locally acquired signals to set direction but the signals used and the manner of integration are unknown. Components of the navigational system that are known involve a time-compensated sun compass linked to the circadian clock, and a protein (Cry1) that is sensitive to blue light and ultraviolet wavelengths. Magnetoreception (the ability to detect a magnetic field) may also be involved in navigation.

SPEED OF FLIGHT

Monarchs have two flight modes - powered flight and gliding. Powered flight can be broken down into short escape flights of greater than 12 mph, directional flight toward another individual or a resource of 10-12 mph or less, and normal flight of less than 10 mph when looking for flowers or host plants in the case of females. Migrating monarchs employ both powered and gliding flights; minimizing the former and maximizing the latter to save energy and reduce wear and tear on the wings and flight muscles on the 1200-2000+ mile continental traverse to Mexico. Gliding flight is composed of soaring (i.e., catching thermals in the manner of hawks and vultures to gain altitude) and then gliding S/SW with the aid of the wind. The glide ratio for monarchs ranges from 3-4 to 1 meaning that they can glide forward 3-4 feet for every foot they drop in altitude. If utilizing favorable tail and quartering winds, they can maintain altitude by flapping the wings once every 20-30 feet.

DISTANCE PER DAY

Although the overall migration advances only 25-30 miles per day, some tagged individual monarchs have covered distances of hundreds of miles in a few days. Most of the long distance records are associated with weather fronts and other favorable wind conditions. One late season monarch averaged 61 miles per day for 2 weeks while flying from Virginia to Texas.

TEMPERATURE AND WINDS

Minimum conditions for flight are full sun, light winds, and temperatures greater than 55F. Headwinds greater than 10 mph and temperatures greater than 88F impede the migration. Unlike many insects, monarchs can migrate at relatively low temperatures (mid 60sF) and with completely overcast skies.

DURATION OF THE MIGRATION

The travel times for individual monarchs from regions of origin to the overwintering sites in Mexico are not known but probably range from 2-2.5 months.

HEIGHT OF THE MIGRATION

Although the monarch migration is visible at ground level, observations by pilots of gliders and commercial aircraft have reported monarchs from the boundary layer (+/-1200ft) to over 10,000 ft under certain conditions. What appear to be monarchs have also been seen on NEXRAD radar. From these observations it is clear that much of the monarch population can pass through an area without being seen by those of us at ground level. How often these high elevation flights occur is not clear.

ARRIVAL AT THE OVERWINTERING SITES

Monarchs begin arriving in the vicinity of the overwintering sites in the last few days of October each year. They are first seen as a high-flying and highly dispersed butterfly-filled sky – not a

mass or a flock, but a loose milling group of butterflies. One might say they are confused or searching but the truth is we don't know how they find the overwintering area and we can't explain this behavior in scientific terms. Coincident with arrival, the monarchs begin to form loose clusters on oyamel fir trees, usually on ridge tops. Over weeks these clusters form and reform and often, but not always, end up clustering in the same general area as in previous years. Presumably, they settle in areas based on microclimate but some scientists speculate that odors from previous clusters might be involved. One would like to think that monarchs always make good choices as to where to cluster but they have been known to select sites with poor protection from the elements and suffer high mortality as a result.

COMPOSITION OF THE COLONIES

Two techniques which identify the geographic origin of each monarch, one using stable isotopes and the other using tagged monarchs, show that the monarchs at each colony come from all portions of the eastern breeding range. For example, more than 2800 monarchs tagged at one Kansas site in a 4-hour period were recovered at three overwintering sites in numbers proportional to all tags recovered from these sites. In other words, if 7% of all tags were recovered from one colony, then roughly 7% of all the tags recovered from that Kansas site were found at that colony. This result shows that the butterflies originating from one location are randomized as they arrive at the overwintering sites and that none of the colonies are representative of a particular region of the northern breeding range.

OVERWINTERING

Monarchs overwinter in dense clusters on oyamel firs in a semi-dormant state. They become active when the conditions allow (sunny with temperatures greater than 55F) and seek water. Water is needed to metabolize the fats stored in the abdomen into sugars that circulate in the blood. These sugars are used to keep the metabolic machinery running (e.g., respiration) during extended cold periods. In effect, the monarchs live off stored fats through the winter months.

WINTER MORTALITY

The biggest threats to overwintering monarchs are winter storms. These storms, though rare, sweep in from the north or the Pacific, bringing moisture-laden warm air. As the moist air rises in the mountains, it cools and rains begin, often wetting the butterflies - a lethal precondition if the skies clear and the temperatures drop into the mid 20sF. A storm that began with 48 hours of rain on the 12th of January in 2002 killed an estimated 80% of the overwintering population and two storms in January-February 2004 killed at least 70% of the monarchs. Although the cardiac glycosides (i.e., toxins) in monarchs give them protection from most birds, two birds - the black-headed grosbeak and black-backed oriole - are able to feed on monarchs in the oyamel forests. Losses to birds are usually less than 10% of the population. Some monarchs die due to broken wings that prevent them from clustering or reaching water sources, others die due to a lack of fat reserves and still others, often quite full of fat, die for unknown reasons. During mild winters the overall mortality is surprisingly low (less than 20%).

POPULATION SIZE

Monarch populations are measured as the number of hectares (1 hectare = 2.47 acres) of trees occupied by clustering butterflies in mid-December of each year. The size of the population has varied from 2.19 to 18.2 hectares over the last two decades; averaging close to 9 hectares in the

90s and between 5-6 hectares in this decade. The population appears to be declining and habitat loss is suspected as having a role in the decline. However, the role of climate, particularly increasing temperatures, cannot be excluded. Estimates of the number of monarchs per hectare has varied from 10-12 to 22 and 75 million; the last two estimates were derived from sampling the dead butterflies on the ground at two colonies after the massive winter kill of 2002. Because of the wide variance in these estimates, we prefer to talk about the population in terms of the numbers of hectares occupied but, if pressed, we might cite 50 million per hectare as our "best guess" at this time. In any case, it seems safe to say that hundreds of million of monarchs spend the winter in oyamel forests in central Mexico.

ANNUAL CYCLE

The monarch's annual cycle can be broken down into two phases, a migratory phase and a reproductive phase. Because the monarch population utilizes much of the North American continent, these phases overlap on the calendar but not by latitude, meaning that at each location only one of these two phases predominates at any given time.

MIGRATORY PHASE At the northern limit of milkweeds (50N = Winnipeg), the migration starts on 15 August and continues until the last of the monarchs arrive at the overwintering sites near the end of the first week of December.

REPRODUCTIVE PHASE Reproduction begins shortly after the overwintering monarchs begin moving north at the end of February and continues until November when the last of the last generation monarchs join the migration in Texas or Mexico.

POPULATION CYCLE

The population is at its maximum size during the middle of the migration (September) but diminishes due to the hazards of the migration (both southward and northward) and losses during the winter. The population of adult monarchs is at its lowest in late March and April.

GENERATION LENGTH

Temperature determines generation length (egg to adult), which can be as short as 25 days or as long as 50 days. Generation length is about 40 days in March-April in much of the South while summer generations in the northern breeding areas are usually 30-36 days.

NUMBER OF GENERATIONS

Most of the monarchs joining the migration each fall are 3-4 generations removed from those that made the journey the previous year. During warm years, a few of the migrants from the mid latitudes of the U.S. are 5th generation butterflies (see below – recolonization).

SIZE AND MASS

With a wingspan of usually more than 3.5 inches (95mm) and an average mass (weight) of 0.5 grams, monarchs are among the largest butterflies in North America. During the migration many monarchs gain in mass by feeding on nectar from fall flowers, often weighing 0.6 -0.7 grams at the start of the overwintering period.

RESOURCES NEEDED BY MONARCHS

All life forms need resources, and the four most important resources needed by monarchs in their annual cycle are food for the larvae (milkweeds) during the breeding phase, nectar from flowers for the adults in both the reproductive and migratory phases, and shelter and water while overwintering.

MILKWEEDS Female monarchs only lay eggs on milkweeds and a few other plants in the same plant family (*Apocyanacae*). While there are over 100 species of milkweeds in North America, many are rare or confined to remote habitats outside of the main monarch breeding areas. Still, monarchs utilize about 30 milkweed species as hosts for their larvae. Predominant among these is the common milkweed (*Asclepias syriaca*), a weedy species that readily invades disturbed sites. Estimates are that 90% of the monarchs that overwinter in Mexico each year have fed on this species as a larva. Please see the section entitled "Protection from Predators" for more information.

NECTAR PLANTS Adult butterflies need sources of carbohydrates, amino acids, and sometimes salts. Monarchs visit both butterfly and bee flowers. Butterfly flowers, those that coevolved with butterflies, e.g., pentas, lantanas, butterfly bushes, have dilute nectars (10-15% dissolved solids, mostly carbohydrates) that contains amino acids. Amino acids are used to sustain bodily functions and aid in egg development. Bee flowers, such as clovers and other legumes, tend to have richer nectars (20-40% dissolved solids) but little in the way of amino acids. These sources of carbohydrates and amino acids are essential for the adult butterflies. Without them the butterflies could neither migrate nor reproduce. Curiously, monarchs, in contrast to many butterflies, seem to have little need for salts.

SHELTER AND WATER Overwintering is all about shelter and water. Without the protection of the canopy provided by intact oyamel fir forests, the monarch migration would collapse. The forest also protects the watershed and provides the sources of water needed by monarchs to metabolize their fats.

OYAMEL FORESTS AND MONARCHS

Oyamel fir trees are the dominant, and often the only, tree species at the sites where monarch colonies form in the mountains of central Mexico. Although monarchs cluster on numerous tree species during their migration southward, the clusters are never as dense as those seen in Mexico. Even though specific colony sites may be chosen for the microclimates they provide, the oyamel, due to its structure, seems to afford a high degree of protection to the monarchs. The very structure of the needles and branches on oyamels seem to allow for the formation of dense clusters and the growth of the forest itself provides a protective canopy that insulates the butterflies from both high and low temperatures. In addition, incident radiation absorbed by the trees during the day is reradiated at night, further moderating the microclimate in the vicinity of the butterflies. Within dense oyamel forests, temperatures seldom exceed 65F during the day or drop below 30F in early morning during the heart of the winter. These dynamics change, and both higher and lower temperatures are reached, as the forests are degraded. Protection of the structural integrity of these oyamel forests is therefore essential for the protection of the monarch migration.

RECOLONIZATION OF BREEDING AREAS

The monarch breeding areas in eastern North America are recolonized by two generations of monarchs; the overwintering butterflies that move north in the spring and their offspring. Monarchs overwintering in Mexico begin moving north at the end of February and continue to arrive in the southern U.S. for 5 weeks or more beginning the first week of March. These butterflies mate and lay eggs as they continue on a path that is generally N/NE, with some females scattering eggs over 1000 miles. Most of these monarchs die before reaching 40N and before 1 May. The first of their offspring reach maturity and begin flying N/NE by the end of April. Due to the wide range of latitudes, and the time span over which the eggs were laid by the returning monarchs, these offspring continue to reach maturity and fly northward over a 6 week period, mating and egg-laying as they do so, thus reestablishing the breeding population to the limits of milkweed (50N). Movement northward appears to cease a week or more before the summer solstice. The number of monarch generations produced at each latitude in the summer is a function of temperature and the length of the period before the migration begins. For example, in Winnipeg, if the monarchs arrive early in June in a warm year, there can be two generations, one in July and another maturing in August in time to begin the migration in the middle of the month. These butterflies would be three generations removed from the previous migration. In cold summers there is only one generation at this latitude and the migrants would be two generations removed from the previous migration. This is the extreme case, as most monarchs that join the migration are produced at lower latitudes and represent generations three or four.

CLUSTERING

The numbers of clustering monarchs can be so dense and weighty that they can bend over small trees and break branches. Clustering is clearly an adaptive behavior but the reasons for clustering are more a matter of speculation than of science. Clearly, clustering can benefit in predator avoidance since the startle effect of disturbed monarchs can make it difficult for a predator to capture a specific butterfly. However, more consequential benefits might come from water conservation; e.g., creating a humid envelope or boundary layer within and around the cluster. The monarchs themselves can serve as sources of water for other monarchs whenever dew forms on the cluster. In addition, the cluster acts as a black body in sunlight, absorbing radiant energy, thus allowing the butterflies on the surface of the cluster to raise their body temperatures in readiness for flight should they be disturbed.

PROTECTION FROM PREDATORS

Milkweeds contain a group of compounds known as cardiac glycosides or cardenolides. As the larvae feed on milkweeds, they acquire some of these compounds and sequester them into the cuticle of the developing adult late in the pupal stage. Cardiac glycosides are toxins that are effective against many vertebrates in that they induce vomiting. A bird needs to only eat a monarch once to get the message that they are not good food items. Most insects that incorporate toxins from noxious plants advertise their own food choice, and thus their inedibility, by being brightly colored; hence, the strongly contrasting black, orange, and white coloration of the monarch adult and the bright black, yellow, and white coloration of the monarch larvae. This form of advertising is known as aposematic (or warning) coloration.

MIMICRY

A color pattern that advertises inedibility seems to invite mimicry among butterflies that live in the same region. The viceroy butterfly (*Limenitis archippus*), whose color and pattern is so similar to that of monarchs that it is frequently represented as a monarch in popular publications, co-occurs with monarchs over much of its range. Viceroys are also distasteful, by virtue of a different set of compounds. Convergence on a common color and pattern by chemically protected butterflies is termed Mullerian mimicry.

LENGTH OF LIFE

Migratory monarchs that survive to reproduce in the United States in the spring are 8-9 months of age and may be the longest lived of all butterflies. In contrast, reproductive monarchs breeding during the summer months only live 2-5 weeks. The difference in longevity is ascribed to the higher metabolic rates and levels of activity of reproductive monarchs as well as the greater hazards faced during reproduction. Continuous use of powered flight during reproduction also contributes to wear and tear on the wings and perhaps the flight muscles.

STREAMING AND CASCADING

Visitors to the monarch overwintering sites in February and March are often astounded by two patterns of flight behavior termed streaming and cascading. Streaming is the rapid descent from the clusters by monarchs seeking water. These butterflies use powered flight and gliding and achieve speeds of 10-12 mph as they fly down the mountain sides to water sources that can be a mile or more distant from the clusters. In some locations one can also see a stream of butterflies returning to the clusters using powered flight as they move back up the mountain. Cascading refers to spontaneous massive bursts of butterflies from clusters. The cascades can involve thousands, perhaps tens of thousands, of butterflies that generally move down-slope for 30 seconds or more before dissipating. Late in the winter cascades are accompanied by bursts of mating behavior. Most of the butterflies from the cascades seem to cluster in new locations although some may go to water and others seek mates. Both of these activities are dependent on temperature and the amount of cloud cover.

MATING BEHAVIOR

Monarch butterflies are notably promiscuous with lifetime mating frequencies approaching 8 for each sex. Since it is usually the sperm from the most recent mating that is used to fertilize eggs, females produce offspring that have been fathered by a series of males through their egg laying history. This high degree of multiple mating may be advantageous in that it increases the genetic variability of a female's offspring in a highly variable (heterogeneous) environment.

BREEDING SYSTEM

Since each colony represents monarchs from all regions of the eastern United States and Canada, multiple mating that begins toward the end of winter, combined with further matings as the butterflies move northward, suggest that monarchs have a panmictic (random) breeding system meaning that all portions of the population have a chance to and probably do mate with each other. In other words, there is complete genetic mixing. This type of breeding structure has the effect of maintaining a high degree of genetic variability while keeping the population from differentiating into geographically distinct sub-populations.

EGG-LAYING

Female monarchs appear to find milkweed plants for egg-laying by sight, olfaction, and taste. Females search visually for plants but will also crawl through vegetation to reach small and inconspicuous plants in the spring, evidently finding these plants through olfaction. Once a female has found a plant, she "tastes" the plant by "drumming" or touching the plant repeatedly with a special set of taste receptors located on the first pair of legs. Females seem to prefer some milkweed species, and individuals within species, to others and show a strong bias by laying eggs on young leaves and flower buds. When flying north in the spring from Mexico, females may scatter their eggs over 1000 miles. The average female is thought to lay around 400 eggs, only a few of which survive to reach the adult stage due to high levels of predation.

DRIVE TO REPLICATE

Life forms strive to replicate themselves, and the drive to survive to reproduce is quite clear in monarchs. From the extraordinary journey south, through the hazards of overwintering, followed by the return northward and egg laying efforts by females to the point of exhaustion and death, this insect gives meaning to the phrase "the struggle for existence".

TAGGING

Tagging was originally used by Dr. Fred Urquhart of the University of Toronto help locate overwintering monarchs and later to determine where monarchs came from that wintered in Mexico. Our long-range tagging program at Monarch Watch has revealed much more. Specifically, tagging has helped define the migration window as well as the timing and pace of the migration as the monarchs move S/SW across the continent in the fall. The tagging also shows that the probability of reaching Mexico is related to geographic location, size of the butterfly, and the date (particularly as this relates to the migration window for a given location).

DISTRIBUTION

Monarchs are a new-world species distributed from at least 50N in Canada to Colombia, Venezuela, and coastal Ecuador and Peru. The intentional and accidental introductions of milkweeds and monarchs due to the activities of colonists, missionaries, and others - along with the development of steamships in the late 1800s - led to the establishment of monarchs in Australia, New Zealand, Hawaii, and numerous islands in the South Pacific as well as a few islands in the eastern Atlantic (the Canaries and Azores).

DISCOVERY OF THE MONARCH COLONIES

Although the existence of overwintering monarch colonies was known to the residents of the mountains in the Mexican states of Mexico and Michoacan, these colonies were not known to science until 1975. Tagging had led Dr. Urquhart to believe monarchs overwintered in Mexico and through an ad he recruited Ken Brugger, an engineer working in Mexico City, to search for overwintering monarchs. Ken and his wife Cathy were led to a monarch colony on Cerro Pelon on 2 January 1975, and subsequently to another colony on Sierra Chincua on 2 February 1975. Further exploration showed that monarch colonies formed most years at elevations of 10,500-12,000 ft on 10 mountains in an area of about 75 sq km at roughly 19.5N.

DAY OF THE DEAD

Monarchs begin to arrive in the vicinity of the overwintering sites each year in the last few days of October. This arrival is close enough to the Day of the Dead (2 November), a holiday to commemorate those that have passed on, that two Indigenous tribes, the Mazahua and P'urhepecha (Tarascans) in the states of Michoacan and Mexico, have come to associate the return of the monarchs with the returning souls of the dead.

THREATS TO THE MONARCH MIGRATION

Resources for monarchs are diminishing. Shelter and water needed by the overwintering butterflies are declining in Mexico and illegal logging has already eliminated a number of former colony sites. Continued thinning of the forests and outright deforestation reduces the availability of water for both the butterflies and the people. In the United States, 6000 acres are converted to development each day, eliminating milkweeds and nectar sources for monarchs. Chemically intensive agriculture that utilizes insecticides and herbicides also eliminates monarchs and their milkweed hosts. The use of Roundup® Ready soybeans, genetically engineered to resist Roundup® (glyphosate, the world's most widely used herbicide), has resulted in the loss of at least 100 million acres of monarch habitat in row crops (corn and soybeans) since 1997. Further, the recent interest in biofuels has brought marginal acres into production often eliminating habitats filled with milkweeds and nectar plants. Land management practices, such as frequent mowing, that favor grasses rather than flowering plants are also a factor. And, there is climate change, which poses threats to monarchs throughout their annual cycle. In spite of their tropical origins, monarchs need moderate temperatures to survive the winter in Mexico, to recolonize the United States and Canada each spring, and to produce large populations for the return migration at the end of the summer. The high temperatures that appear to be in our future seem likely to negatively impact monarchs as well as the milkweeds and nectar plants on which they depend.

WHAT NEEDS TO BE DONE

Sustaining the monarch migration will require the cooperation of all three countries (U.S.A., Canada, Mexico) that are home to monarchs for some portion of the year. A recent development along these lines has been the drafting of a "North American Monarch Conservation Plan". This plan, which is in the early stages of being implemented, advocates control of illegal logging in Mexico and the enhancement, restoration and protection of monarch habitats throughout the continent.

WEB LINKS

Day of the Dead

en.wikipedia.org/wiki/Day_of_the_Dead

Migration maps

monarchwatch.org/tagmig/fallmap.htm

monarchwatch.org/tagmig/spmap.htm

Population size

monarchwatch.org/blog/category/monarch-population-status

monarchwatch.org/blog/2008/02/overwintering-monarch-population-2007-2008

Life cycle

monarchwatch.org/biology/index.htm

monarchwatch.org/biology/cycle1.htm

Two-generation recolonization

monarchwatch.org/tagmig/spmap.htm

Conservation

monarchwatch.org/blog/category/monarch-conservation/

Map of overwintering sites

wwf.org.mx/wwfmex/mapas.php?lugar=mm - The two maps at this site show the outline of the Monarch Butterfly Biosphere Reserve and 98 land parcels within the reserve, nearly all of which are owned and governed by ejidos and Indigenous communities.

Deforestation, reforestation, and habitat loss

monarchwatch.org/blog/2008/03/deforestation-and-monarch-conservation/

Cascading monarchs within a colony on Cerro Pelon (video)

youtube.com/watch?v=x0m_rK_WpjQ

Streaming monarchs headed down-slope for water at Cerro Pelon (video)

youtube.com/watch?v=6N3gjJgAZ5s

Tagging monarchs

monarchwatch.org/tagmig/tag.htm

monarchwatch.org/tagmig/recoveries.htm

Monarch Butterfly Biosphere Reserve/World Heritage Site

whc.unesco.org/en/list/1290/ - A map of the Reserve can be found at this site.

Miscellaneous

Journey North: learner.org/jnorth/monarch

Monarchs in the Classroom: monarchlab.umn.edu

MonarchHealth: monarchparasites.org

View and/or download this document and related materials online at monarchwatch.org/press