PROJECT NATURE NEWSLETTER

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The Monarch Butterfly – I

The majestic monarch butterfly is arguably one of the most recognizable butterflies in the world. It is probably the most recognized insect. Monarch butterfly is also one of the most studied insects. Even beyond insects, the monarch butterfly enjoys a unique iconic status in that it has become a symbol for conservation! The migration of the North American monarch is one of the most fascinating migrations in the animal kingdom. The millions of overwintering monarchs roosting in the oyamel fir trees in the Sierra Madre Mountains of Mexico is a sight to behold!

The bright orange and black color of the monarch not only gives the butterfly a charismatic personality, it is also an evolutionary trait, warning predators that it is unpleasant to eat and hence, they should stay away! The monarch butterfly carries a toxin, called cardiac glycoside, which it acquires from the milkweed plant upon which it fed during its larval stage. Because of this toxin, it is unpalatable to most predators.

It is believed that the butterfly was given the name in honor of King William III of England, perhaps because of his secondary title — Prince of Orange!

The species most abundantly found in North America is *Danaus plexippus* (henceforth referred to as the **North American monarch**). There are 3 known species worldwide of monarch butterflies in the genus *Danaus* — North American monarch, South American monarch, and the Jamaican monarch. Currently, there are 6 subspecies of the North American monarch recognized across the world — in North America and areas outside the Americas, Caribbean and Central America, Virgin Islands, Puerto Rico, and Tobago.

In North America, the monarch butterfly is mainly divided into two distinct populations — the **eastern population** (with breeding grounds east of the Rocky Mountains) and the **western population** (with breeding grounds west of the Rocky Mountains).

The eastern population of the North American monarch overwinters in the mature oyamel fir forests in the mountains of central Mexico. In March, they start their migration up north to the United States and Canada. In the fall, they migrate back to their overwintering grounds in Mexico. This population makes the spectacular migration journey of over 2,000 miles.

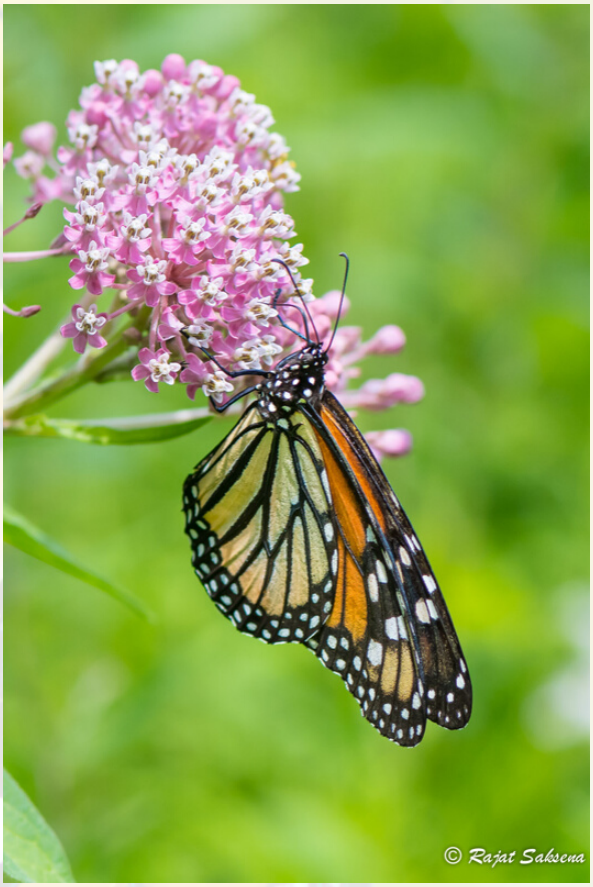
Overwintering

Overwintering is the process by which some organisms pass through or wait out the winter season. It is the adaptation that the organism has developed to pass through the winter conditions, such as cold freezing temperatures and/or scarcity of food. For example, some animals, such as birds, migrate to warmer temperatures and spend their winter (or overwinter) there. Others, such as bears, stay in the cold climate and *hibernate*, which is characterized by reduced metabolic rate as well as slow breathing and heart rate, and lower body temperature, allowing the animal to survive through the winter. Insects react to the winter conditions in similar ways. Similar to hibernation in vertebrates (animals with a vertebral column or backbone), insects and other invertebrates undergo a similar process, called *diapause*, to survive the winter. Diapause is a state of suspended development and reduced metabolic activity. Insects can enter diapause as an adult, egg, larva or pupa. A few insects living in cold climates are able to survive through the winter as adults. Others pass through the winter in egg, larval or pupal form. Yet other insects are migratory and migrate to warmer climates. Even plants have to adapt to the lower water supply and reduced sunlight during the winter months in cold regions and they overwinter by minimizing their growth of vegetative tissues and reproductive structures.

The western population of the North American monarch overwinters on the (native) Monterey pine and Monterey cypress trees, as well as on the non-native blue gum eucalyptus trees, along a 620-mile stretch on the coast of California between Mendocino County and Baja. They overwinter for four months at sites that are cool, but above freezing, and can receive sunlight filtered through the trees while staying protected from heavy winds. The lower slopes of valleys, bays and inlets support the largest numbers of the overwintering butterflies. Recent tagging studies have shown that some western monarchs from the Southwest migrate to central Mexico to mix with the eastern monarch population.

The eastern and western populations of the North American monarch are the same species and scientists have found no significant genetic difference between the two. Both the populations form one genetic population!

Life Cycle



Monarch, like all other butterflies, undergoes a life cycle of ***complete metamorphosis***. In other words, each stage of its life is distinct from the other. For a butterfly, there are 4 stages of metamorphosis — egg, larva, pupa, and adult. The life cycle of a butterfly starts with an egg, which the female lays, usually on a plant leaf. Butterflies are extremely selective about the plant on which they lay their eggs, and each species has its preferred plant(s), which is chemically compatible, on which they will lay their eggs. Such plants are known as the **host plant** of that species. While the adult butterfly will feed on nectar from a wide variety of flowers, its larva has a very specific preference for the plant upon which it will feed and thrive, and hence the female butterfly will lay her eggs on that plant — host plant. For monarchs, the host plant is the **milkweed**. Females find the milkweed plants using a combination of visual and chemical cues. Monarchs usually lay a single egg on a given leaf, often on the bottom of the leaf near the top of the plant. On average, a female might lay 100 to 300 eggs. The egg hatches into a larva in approximately four days. The larva of a butterfly is known as a ***caterpillar***. Caterpillars are voracious eaters and they start right away by eating the shell of the very egg from which they hatched, and then feed on the leaf of their host plant. The caterpillars grow so rapidly that their skin cannot contain them anymore and hence, they have to shed their old skin. This process of shedding the old skin is called ***molting***. The caterpillar often eats the old shed skin as well. The new skin soon hardens and takes the shape of the caterpillar. Caterpillars undergo several molts through the course of their larval stage. Each stage between molts is called an ***instar***. Monarch caterpillars undergo five molts, and after the fifth instar, the caterpillar metamorphoses into its pupal stage. The larval stage lasts about 9 to 15 days. The pupa of a butterfly is known as a ***chrysalis***. During this stage, the tissues transform and reorganize to form the adult butterfly. Once the transformation is complete, the adult butterfly emerges (or ***ecloses***) from the chrysalis. (The emergence of an adult insect from a pupa is referred to as ***eclosion***.) From egg to the eclosion of adult monarch, it takes 4 to 5 weeks. The adult butterfly doesn't grow any further.

From Egg to Adult Butterfly — The Complete Life Cycle of The Monarch Butterfly

Photo Courtesy of the Missouri Department of Conservation

Monarch life-cycle is synchronized with the phenology of milkweed and other nectar sources. Since the caterpillars feed exclusively on milkweed, monarchs must time their reproduction only when the plant has emerged. Similarly they must time their spring and fall migrations to coincide with optimal habitat conditions, such as availability of nectar sources and milkweed for laying eggs.

Phenology

Phenology is the study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life. Phenology is nature's calendar about when flowers bloom, insects emerge, birds build their nest to breed, and animals migrate or hibernate.

Milkweed

The monarch caterpillar feeds exclusively on milkweed. The milkweed plant is in the genus *Asclepias*. Milkweeds get their name from the sticky white sap that oozes from the leaves when they are damaged. The genus name, *Asclepias*, commemorates Asklepios, the Greek god of medicine. Some of the milkweed species have a history of medicinal use. Common milkweed has been used in wart removal and lung diseases, and butterfly weed, also known as pleurisy root, is used for pleurisy and other lung diseases. Common milkweed is one of nature's most popular food source for insects. Over 450 insects are known to feed on some portion of the plant.

There are several species of milkweed plant and depending on the region and monarch species or subspecies, the butterfly will use select species of milkweed for its host plant. In North America, there are over a hundred species of milkweed, but only about a quarter of them are utilized

Eastern Tailed-Blue on Butterfly Weed

Red Milkweed Beetle on Common Milkweed

Brown-belted Bumblebee on Butterfly Weed

Milkweed Bugs on Common Milkweed

Banded Hairstreak on Common Milkweed

Green Sweat Bee on Butterfly Weed

Hummingbird Clearwing Moth on Common Milkweed

Great Spangled Fritillary on Swamp Milkweed

Various insects utilizing milkweed

by monarch butterflies for their host plant. Milkweeds produce cardiac glycoside toxins to deter herbivores (plant-eating animals) from eating them, but monarchs coevolved with the plant and have developed immunity to these toxins. The caterpillar consumes the toxins, which makes it unpleasant to eat, and hence deters predators. These toxins remain in the system even after the caterpillar metamorphoses into chrysalis and then to adult, keeping the butterfly safe from most predators through all its life stages.

Bad Milkweed

In addition to the several native milkweeds in North America, there are a few introduced milkweed plants as well. One of them is in the genus 'swallow-worts'. The two most common species of swallow-worts in the US are black swallow-wort and pale swallow-wort. Swallow-worts are native to Europe and have a similar chemical makeup as some of the native milkweed species that monarchs use for their host plant, and that 'fools' monarchs into laying eggs on them. But swallow-worts are not suitable for the butterfly and the caterpillars feeding on them fail to develop into pupae. Studies have shown that the female monarch would lay eggs on black swallow-wort even when there is common milkweed (a native species and a good host plant for monarch) growing in the same field. Hence, it is strongly discouraged to plant these non-native invasive milkweeds.

Another milkweed plant that is harmful to the North American monarchs is the tropical milkweed. The natural range of tropical milkweed extends as far north as Mexico, but it is not native to the US. The plant is attractive and easy to grow, making it the more commonly available milkweed at commercial nurseries. Since the plant is native to the tropics, it has evolved to grow year-round. When tropical milkweed is planted in the coastal southern United States and California, it continues to bloom and produce new leaves through fall and winter, except during rare freeze events. This year-round growth of tropical milkweed fosters greater transmission of the protozoan parasite *Ophryocystis elektroscirrha* (*OE*), and hence an increased likelihood of infecting the monarchs with the debilitating parasite. Infected monarchs harbor thousands or millions of *OE* spores on their bodies. When the dormant *OE* spores are scattered onto eggs by the infected adults, the caterpillars consume the spores, which then replicate inside the larvae and the pupae. Monarchs might fail to emerge from the pupae severely infected with the *OE* parasites. Monarchs with mild *OE* infection might appear normal but live a shorter life and cannot fly as efficiently as healthy monarchs. Additionally, since tropical milkweed grows year-round, it can encourage monarchs to skip migration and continue to breed throughout the winter. Since monarchs haven't evolved to spend winter in those places,

this poses a potential risk for disease and other complications, which they could have avoided by migrating!

Protozoa

Protozoa are microscopic, one-celled organisms that can be free-living or parasitic in nature.

Dispersal Across the World

Monarch butterflies are originally native to North America in the southern United States and northern Mexico. However, they are now found throughout much of the world. Records indicate that starting in the 1800s, the butterfly spread out across the world. From their original habitat in northern Mexico and southern United States, there have been three dispersions of monarch populations — southwards to Central America, the Caribbean and South America, westwards across the Pacific to Oceania and Australia, and eastwards across the Atlantic to the Iberian Peninsula and northwest Africa. Monarchs were first reported in Hawaii in the 1840s and by the 1860s, they had spread throughout the South Pacific. The first monarchs in Australia and New Zealand were reported in the early 1870s. In Europe, monarchs colonized Portugal and southern Spain along the Iberian Peninsula and then crossed the Strait of Gibraltar and moved into Morocco.

Researchers are still not sure how and why the monarchs made the flight across the oceans. Some have theorized that the overwintering adult monarchs landed on a ship and were then carried across the oceans, or since milkweed is commonly found around shipyards, the caterpillars somehow got on the ships and were transported, and then emerged as adults on another continent. It is also possible that monarchs were deliberately transferred by humans, however, there are no records of such attempts. Lastly, given the fact that monarchs in North America can make a journey of over 2,000 miles during migration, the theory that they were perhaps blown off their migratory pathway and flew across the oceans by themselves, is also

a credible possibility. There have been rare monarch sightings across the coast of the United Kingdom, likely caused by the winds blowing the vagrant monarchs across the sea. Such observations further support the possibility that the monarchs were blown off course and flew across the ocean without any human help.

Colonization across the Atlantic has been linked to the availability of the milkweed host plant — two species of which were well-established in the region of North Africa and the Iberian Peninsula before the first sightings of the butterfly was made there. More recently other species of milkweed have been anthropogenically introduced in southern Spain, where the plant has been thriving and also spreading into the Mediterranean region due to a favorable climate. Hence, it is highly likely that the resident monarchs around the Iberian Peninsula might expand their range in the near future.

Storms and cyclones might have been responsible for blowing monarchs off course across the Pacific all the way to Australia and New Zealand, through intermediate stops along the way. The butterflies perhaps island-hopped from California to Hawaii to Samoa and Fiji, and finally on to New Caledonia, Australia and New Zealand. Since the first record of monarchs in Australia was in the early 1870s, which was coincidentally soon after the California Gold Rush (1848-1855), it is speculated that the ships traveling between California and Oceania could have assisted in the dispersal of the North American monarch to Australia. But in order to colonize the new territory, the butterflies would need their host plant — milkweed. There are native milkweed species in Australia, such as the bush banana, but the butterfly doesn't seem to prefer those. Instead, it predominantly uses two species of the plant that were imported from tropical Africa, the Caribbean and the Bahamas.

While the historical records indicate that the dispersal of the monarchs happened in the 1800s, genetic studies are revealing that the dispersal happened much before that. In the 2014 study published in the journal Nature, researchers from University of Chicago sequenced 101 genomes from different monarch populations across the globe, and their results suggest that monarch populations split from North America about 2,000 - 3,000 years ago!

Migration

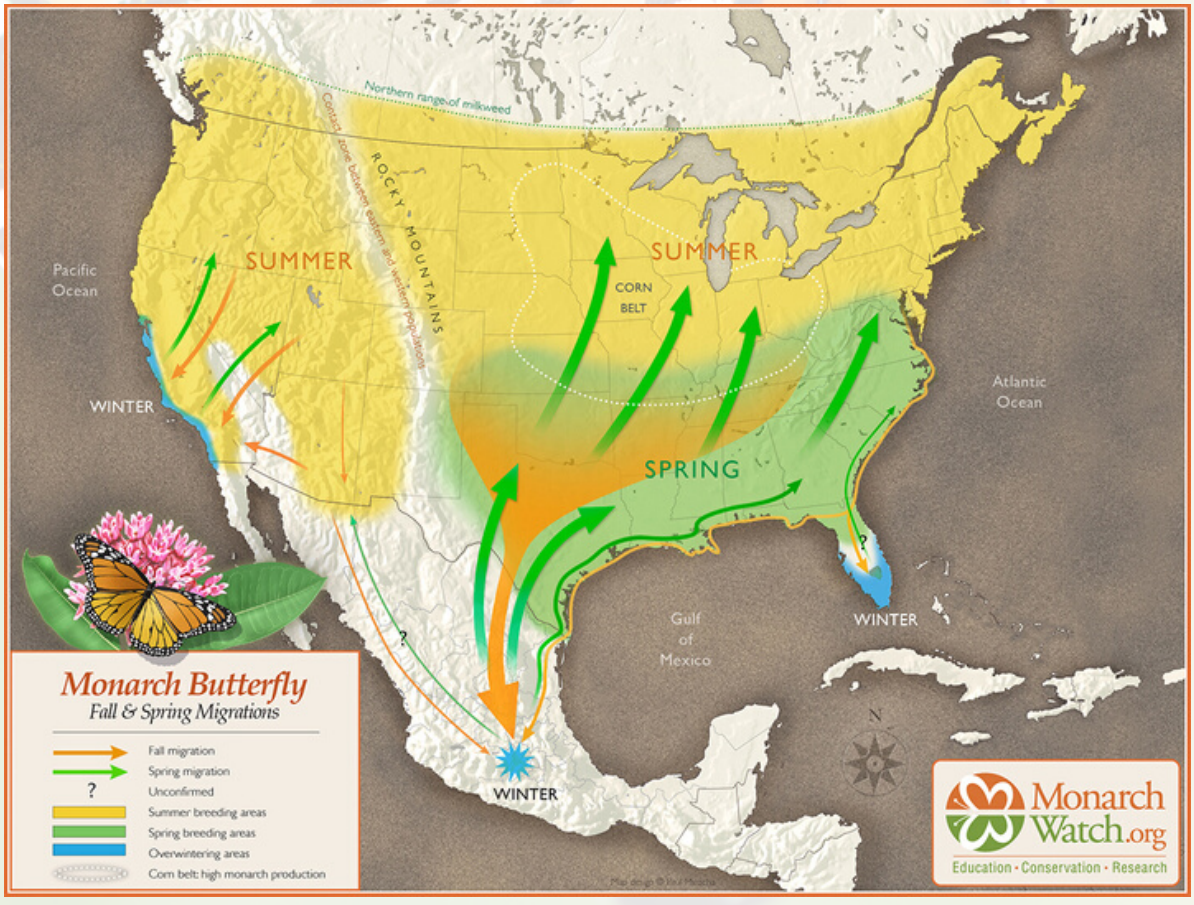
Unlike other butterflies that can survive in cold climates and overwinter as eggs, larvae, pupae or even as adults in some species, monarchs cannot survive the long cold winters of northern climates in any form of their life stage. Hence, the monarchs of these regions must migrate to warmer climates as the winter approaches. Then in spring, they again start their journey north from their wintering grounds in the south for greater opportunities of foraging and breeding. Migration of the North American monarch is one of the world's greatest natural wonders!

The glaciation of the Pleistocene triggered the migration of the monarch butterfly in North America. As the glaciers from the last ice age retreated some 15,000 years ago, the populations of monarchs inhabiting southern United States and northern Mexico began expanding their range by migrating north annually, possibly to exploit the abundance of milkweed that was growing in the newly uncovered habitat by the receding glaciers. [To learn about Pleistocene and Ice Age, reader is referred to the October 2019 issue of Project Nature newsletter.]

The eastern monarchs in North America, with breeding grounds east of the Rocky mountains, start their northward migration from their overwintering sites in Mexico in the spring. They migrate north into Texas and the Southern Plains, and continue through the Northern Plains and the Midwest, and then into the Great Lakes region. This route is termed as the ***central migratory flyway corridor***. Finally, by late summer, the eastern monarchs have reached Canada and spread eastward in the United States from the central migratory flyway corridor throughout the Northeast and Southeast states. The eastern North American monarch completes its migratory journey by traveling up north in the spring and back to their overwintering grounds through 4 to 5 reproductive generations each year. They will cover part of the journey, then reproduce and die. The successive generations will do the same and pass the baton to the next generation and continue the northward migration. Butterflies in the summer generation live 2 to 5 weeks, and start mating when they are 3 to 8 days old. In the fall, the butterflies emerging from the last brood make their journey back to their overwintering grounds. This generation, which makes a stupendous journey of over 2,000 miles, can live up to 9 months, and is often referred to as the 'super generation'. During the southward migration, which takes place from August through September, monarchs fly an average 22 miles a day, but some individuals can fly 50-100 miles in a single day. Often the butterflies will hitch a ride on thermal currents, and can fly as high as a mile. Most monarchs from the Northeast take the

central flyway back, but some fly along the Atlantic coast, and on the way, they concentrate at places, such as the Delmarva Peninsula during their journey, which has become one of the few 'super stops' on the monarch migration trail. The shape of the peninsula 'funnels' the migrating butterflies to a narrow region creating a spectacular sight. At the tip of the peninsula, the monarchs find the shortest distance across open water, and they congregate along the shore to wait for a gentle breeze to assist them across the Chesapeake Bay. Migrating monarchs fly only during the day, and roost on trees at night. For the eastern monarchs, the entire fall migration season is roughly 85 days.

Western monarchs that live to the west of Rocky mountains are a much smaller population and while they also migrate, their migration is for a relatively shorter distance. Instead of making the long journey to Mexico, western monarchs only migrate as far south as coastal areas of central and southern California. The average migration distance for the eastern monarch is almost ten times that of the western monarch. Western monarchs overwinter along California's coast and during summer, they migrate inland to canyons or riparian areas of the West, Southwest, inland California, and the inland Northwest states up to British Columbia. A small number of western monarchs can also be found in the coastal Pacific Northwest during summer.



Not all species of monarch are migratory. Several populations of monarchs found in Mexico, Central and South America and Caribbean islands are sedentary, and do not migrate. Living in the tropics where winters are relatively mild, these monarchs perhaps have no good reason to migrate! In the US, there is a small non-migratory population of monarchs in south Florida. The monarchs found in other parts of the world do not exhibit the same long-distance migration as the North American monarch.

The generation making their migratory journey back to their overwintering grounds have never been there, but somehow they know when they have to leave, where they need to go and what route to follow! Researchers are still investigating and trying to understand how monarchs achieve this remarkable feat. The migrating butterflies supposedly get their cues from circadian rhythms. Factors such as decreasing day length and temperature, as well as aging milkweed, signals the butterflies to head south in the fall. The genes involved in such behavior are found to have subtle differences between the migratory and non-migratory populations. For navigation, monarchs possibly use a combination of directional aids, such as earth's magnetism and position of the sun, among others.

Circadian Rhythm

Circadian rhythms are physical, mental and behavioral changes that follow a daily cycle. They respond primarily to light and darkness in an organism's environment. These are cyclic biological and psychological processes that oscillate in predictable patterns each day, such as telling the body when to sleep, wake, and eat. Biological clocks, which are an organism's innate timing device and found in nearly every tissue and organ, produce circadian rhythms and regulate their timings. Circadian rhythms are found in most living things, including plants, animals and even in many microbes. Natural factors within the body produce circadian rhythms, however, signals from the environment also affect them. The study of circadian rhythms is called ***chronobiology***.

Once the butterflies successfully make their journey to their wintering grounds, they will enter ***diapause*** — a hormonally- and neurally-controlled state of dormancy — that helps them survive the winter while roosting on trees close together in dense clusters that helps them stay

warm. Overwintering monarchs feed very little or not at all. For the eastern monarchs overwintering in Mexico, the mountain hillsides of oyamel forest provide an ideal microclimate. The humidity in the oyamel forest assures the monarchs won't dehydrate, allowing them to conserve their energy.

Right before the onset of spring, they are roused from their diapause and get ready to leave their wintering grounds. The last task of this generation is to mate and reproduce before they say their final goodbye to this world in order to welcome the next generation of monarchs that will once again begin their spring migration to recolonize the north!

Diapause

Diapause in insects is similar to hibernation in vertebrates. During diapause, the insect enters a state of delayed development, in which resource consumption drops drastically and physical development halts.

Evolution of Monarch Migration

Since the tropical populations of monarch do not migrate, it was believed that the primitive monarchs were sedentary and evolved migratory behavior in order to adapt to the changing climate. The 2014 genetic study, published in the journal Nature by the scientists at University of Chicago, found that the original North American monarch that later gave rise to the different populations of modern monarch, have been making their migratory flights in North America for millions of years. The researchers concluded that the primitive North American monarch did migrate annually. However, it was probably only a short-distance migration, and not as extensive as the modern-day monarch. That changed some 15,000 years ago when the last glaciers of the Ice Age receded, and as the climate warmed, the monarch populations as well as their migration expanded!

Solving the Migration Mystery

While it was known that the monarchs in the eastern United States migrated south, no one knew where they went and spent the winter. In 1937, a Canadian couple started to release thousands of individual butterflies in the fall with paper tags glued to their wings, and requested the finders of the butterflies to send it back to them. Frederick Albert Urquhart was a professor in the Zoology Department at the University of Toronto. Together with his wife, Norah Roden Urquhart, and with the help of thousands of volunteer citizen scientists, they tracked the trails of the North American monarch butterflies by tagging the wings of thousands of butterflies. They continued doing so for the next 38 years. Then on January 9, 1975, Kenneth C. Brugger and his wife Catalina Trail finally located the overwintering sites of the butterflies on a mountaintop in Michoacán, Mexico. The Urquharts traveled to Mexico in 1976 to see the site for themselves that they had been trying to find for the past four decades. The discovery was published in the National Geographic magazine with the title "Discovered: The monarch's Mexican haven". A dozen more of such sites are now known in Mexico and the entire region is designated as a World Heritage Site, known as the ***Monarch Butterfly Biosphere Reserve***. The area is protected as ecological preserves by the Mexican government.

Monarch Migration and Genetics

Many migratory populations of animals (of the same species) with different breeding and wintering grounds, may have variations in the genetic structuring between these distinct populations. Divergent migratory pathways and destinations between populations reduces opportunities for genetic mixing, resulting in *speciation* — formation of a new and distinct species in the process of evolution. The eastern and western populations of the monarch butterfly have distinct breeding and wintering grounds from one another. However, no significant genetic difference has been found between the two populations. In the 2012 study published in the journal Molecular Ecology, scientists from Emory University, GA and ETH Zurich, Switzerland, studied the genetic structure of the migratory North American monarch

populations. The authors concluded that both the eastern and western populations of the North American monarch form one *panmictic* population. Tagging studies have shown that some western monarchs do migrate to Mexico and mix with the eastern population. However, researchers found that the eastern and western monarch populations maintain their divergent migrations despite genetic mixing! This is a surprising and fascinating find and suggests that the differences in migratory behavior do not require a substantial genome-wide genetic differentiation. One important implication of these results is with respect to conservation. Since the two populations of monarch form one genetic population, conservation of wintering sites in Mexico may be crucial to protecting both the eastern as well as western monarchs.

Panmixia

Panmixia refers to random mating. A panmictic population is one where all individuals are potential partners with no restriction as regards mating — genetic or behavioral.

Adaptations for Migration

While the colonization of the north by the eastern North American monarch is achieved successively through several generations of the butterfly in a given season, the return migration south to the wintering grounds is made by a single generation. To make this arduous flight, there are several adaptations that this generation of the species has developed. These adaptations are unique to this migrating generation. The generation emerging in late summer or fall, which makes the long-distance migratory journey, has evolved various morphological as well as physiological features, different from the spring and summer generations of the same species.

Wing Morphology — Size and Shape

Among the five generations of the eastern North American monarch in a given season, the forewings of the last generation that makes the long journey south to its wintering grounds are larger than the summer generations. In the 2018 study published in the journal Animal Migration, researchers from University of California, Davis found that the wings of the migrating generation are 4.4% larger than those of the summer generations. Additionally, the researchers found that the wings of the migrating generation are more elongated than the spring and summer generation butterflies, which have more rounder wings. The forewings of the overwintering generation of the eastern monarch were found to be 1.8% larger than their western counterparts, who make a shorter migratory journey, suggesting that migration distance is positively correlated with the wing area. By contrast, scientists found no measurable difference in wing size between the summer breeding populations of the eastern and western monarchs. Additionally, the non-migratory populations of monarchs, such as those of south Florida or Central and South America, have similar wing morphology as the spring and summer generations of the migratory monarchs of North America. These results indicate that change in wing morphology is strongly related to long-distance migration.

Larger and longer wings are thought to aid in gliding for making long-distance flights, whereas smaller, rounder wings facilitate maneuverability, which might be important for the summer populations that need to forage and breed.

Stable isotope data analyses have also shown that butterflies that migrate longer distances have larger forewings, further corroborating the fact that change in wing morphology is strictly a phenomenon related to individuals making the long-distance migration. The results were reported in the 2016 study jointly published by researchers from University of California, Davis, University of Colorado, Denver, and University of Alaska in the journal Ecography.

From evolutionary standpoint, migration acts as a selective force on wing morphology, such that the largest and most capable long-distance fliers disproportionately reach overwintering grounds!

Reproductive Diapause

Evolutionarily, this generation has traded its reproductive ability, temporarily, for the long distance travel. They remain non-reproductive throughout the course of migration to their wintering grounds as well as while they overwinter. They will not regain their reproductive ability until mid-February. This state of suspended reproduction is known as *reproductive diapause*. This physiological adaptation entails a reduction of the ***juvenile hormone*** (jh) — a hormone necessary for reproduction. The reproductive diapause helps monarchs to direct all their resources towards completing their migratory journey. It is only the adults emerging from the last brood in the fall or late summer that enter reproductive diapause; butterflies that emerged earlier and were already reproductive, do not enter reproductive diapause and do not join the migration! As the winter comes to an end at their wintering grounds, the butterflies will break out of their reproductive diapause just before the spring because this generation has to reproduce before they die, and have the next generation start over the journey north in the spring!

A Counterintuitive Adaptation

The 2014 genetic study of monarchs published in the journal Nature found a striking difference between the migratory and non-migratory monarchs in the gene that codes for a protein called ***collagen IV***. The protein is associated with stronger muscles. The researchers found that migratory monarchs didn't produce as much collagen IV in their muscles as the non-migratory populations. Lab tests further showed that non-migratory monarchs were stronger fliers. The migratory monarchs need more energy-efficiency to make the long-distance marathon flights, and so it is believed that they trade strength for endurance!

White (nivosus) Monarch

White 'nivosus' morph of monarch
Photo Courtesy of Monarch Watch (monarchwatch.org)

All species of monarchs carry the bright orange and black "warning" colorations, except the White Monarch, most commonly found in Hawaii. Scientists refer to this morph of monarch as "***nivosus***". Although the white morph of the monarch butterfly is found all across the world, including continental United States, the sightings are extremely rare. The only exception is Hawaii, where they are more abundant. This variation of the monarch butterfly doesn't have any orange; instead it is grayish white in all areas that are normally orange. Usually, this rare morph would only be sighted once in a while. But on the island of Oahu in Hawaii, the sightings of the white monarch became more common in the 1960s, and by the 1990s the population had reached almost 10% of all monarchs in the region. The levels of cardiac glycosides toxin in the tissues of all the monarchs of Hawaii — orange morph as well as white morph — are low. This is due to the low amount of the toxin in the major host plant species of milkweed in the region — crown flower. Consequently, both the white and orange morphs are preyed upon by a bird called *bulbul* (anthropogenically introduced from India), which is able to tolerate the low toxins in the monarchs of Hawaii. However, interestingly the population of white morphs of the butterfly saw a significant increase since the 1960s. Scientists suspect that this might be due to the birds having a hard time spotting the paler morph than the more bright orange one. This theory is supported by the fact that islands with lower bulbul population recorded fewer white morphs of the butterfly. But then by the early 2000s, the population of the white morph had fallen to only 1.7%. Scientists are still not sure as to why! The bulbuls that were once thought to be working to their advantage are no longer helping? There is much to be learned and more studies are needed to understand this unusual white form of monarch.

Threat

Despite the fact that monarchs are one of the most recognizable organisms that enthrall people, they are under a severe threat. The migratory population of the eastern monarch has declined by over 80 percent during the past two decades. The migratory population of the western Monarch has declined by as much as 95 percent within the last thirty years. In the winter of 2013-2014, the overwintering population in Mexico was at its lowest recorded level. The next two lowest recorded levels were within the last decade. There are several reasons for the decline of the species. Habitat loss at both breeding as well as overwintering sites is one of the primary causes, but other factors include disease, overuse of pesticides and insecticides, genetically modified crops, urban development and of course, climate change.

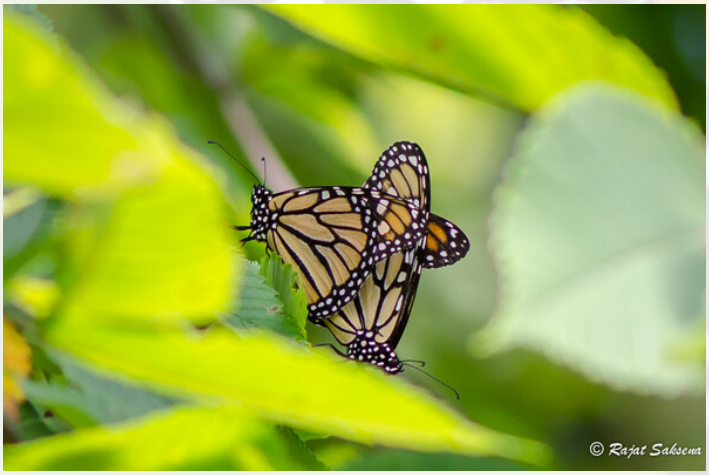
Illegal logging and timbering, infestation of bark beetles as well as poor air quality has been detrimental to the oyamel fir trees, and has consequently reduced the overwintering sites for the eastern monarch. There is a similar habitat loss of the overwintering trees in California for the western monarch, and despite the severe loss in the population of western monarchs, there are only a few overwintering sites that are meaningfully protected and more sites continue to be destroyed. Since 2017, almost a dozen overwintering sites have either been newly destroyed or are threatened due to inappropriate trimming, removal and/or development.

Widespread use of herbicide-resistant corn and soybeans has resulted in the loss of more than 100 million acres of monarch habitat in recent years. These crops are genetically modified to resist the non-selective systemic herbicide glyphosate (Roundup), and allows the growers to spray fields with this herbicide instead of tilling to control weeds. Milkweed is able to survive tilling, but it is defenseless against the repeated use of the chemicals. The drastic loss of milkweed plants in their breeding grounds in the eastern North America is a major factor responsible for the decline of the butterfly. Habitat fragmentation along their migration route

poses a significant threat. Over 90 percent of the grassland ecosystems along the monarch's central migratory flyway corridor has been lost to large-scale industrial agriculture and urban development. Urban development in the United States is increasing at a rate of 6,000 acres (9.4 square miles) a day, which amounts to 2.2 million acres each year. (For a better visualization, this means losing habitat of an area roughly the size of Illinois every 16 years.) All the development effectively consumes the precious habitat for monarchs and other wildlife.

Finally, the increased frequency of untimely weather events due to climate change, such as freezing temperatures, heavy winds and storm events, have further put the species under stress. Additionally, the changing climate disturbs the timing of crucial events, such as the start of migration, putting the butterfly at further risk. A minor disturbance in the phenology of host plants or nectar sources could prove detrimental to the migratory monarchs.

The monarch is currently being considered for federal listing under the Endangered Species Act (ESA). In August 2014, a petition was submitted with the U.S. Fish and Wildlife Service (FWS) to list the monarch butterfly as a federally threatened species. Following the petition submission and an initial 90-day finding that the petition is substantial, per ESA requirement, FWS created the Monarch Conservation Database (MCD). The purpose of the MCD is to help inform the decision whether or not to list the monarch butterfly as threatened or endangered under the Endangered Species Act. Additionally, MCD serves as a data repository for information regarding completed (since 2014), ongoing, and planned conservation plans and efforts implemented to benefit monarch butterflies. The deadline to enter conservation efforts to MCD was May 31, 2020. The decision on listing the monarch butterfly under ESA is pending.



Conservation

The very fact that monarchs are one of the most popular organisms that capture people's imaginations presents an incredible opportunity for everyone — scientists, conservation organizations, governments and most importantly, the general public — to come together and save these amazing creatures. There are continued efforts with on-the-ground action, such as creating more habitat and collecting data, as well as research in the lab to learn more about these fascinating animals so that conservation efforts could be better informed.

Habitat loss is the leading cause of the decline of monarchs. Hence, habitat restoration is the most crucial and the most effective way of helping the butterflies.

Nectar Corridor

While the monarch caterpillar only feeds on the milkweed leaves, the adult butterflies feed on a wide variety of nectar-bearing flowers. Availability of nectar is extremely important to the migrating monarchs. As the monarchs leave their overwintering sites in the spring, they make use of the nectar from early spring wildflowers. Nutrition from these flowers is essential for the butterflies to develop their reproductive organs. The journey up north is continued through three subsequent generations, and the butterflies from each generation require sufficient habitat and energy sources (nectar-bearing flowers). For the last generation that makes the south migration to their overwintering grounds, the food they eat before or during migration not only powers them through the long journey, but must also sustain them throughout the winter, because the overwintering butterflies feed very little or not at all. If the temperatures at their overwintering site drop, they will need to use their fat reserves. Hence, they need to eat a lot in order to build up fat reserves before entering diapause.

Nectar corridor refers to a series of discontinuous habitat patches that contain plants that bloom at appropriate times during the spring and fall migration. These patches of flowering plants act as refueling stations, providing the much-needed energy for the migrating butterflies to continue their journey. These "islands" of nectar sources are extremely crucial in the large areas of urban development and agricultural fields.

Agriculture and Monarchs

While industrial agriculture has negatively impacted monarch habitat across much of North America and with ninety percent of all milkweed habitats occurring within the agricultural landscape, there is a great potential for helping monarch populations with better farm practices. Milkweed not only provides food for monarchs, it also supports other pollinators, such as bees, that are vital to agriculture. Milkweed also supports many beneficial insects that control the spread of insects that are destructive to crops. Farmers and ranchers can make simple tweaks on their working lands to provide quality habitat for monarchs, such as frequency of mowing and a minimum cutting height, limited use of chemicals, using native pollinator-friendly seed mixes, among others. From fallow fields, hedgerows, marginal cropland, and field margins, there are numerous opportunities to improve monarch habitat within the agriculture landscape. Additionally, native prairie or grassland plantings for monarchs can also be incorporated into farm buffer systems (such as filter strips, grassed waterways, roadside embankments, and septic drainage fields).

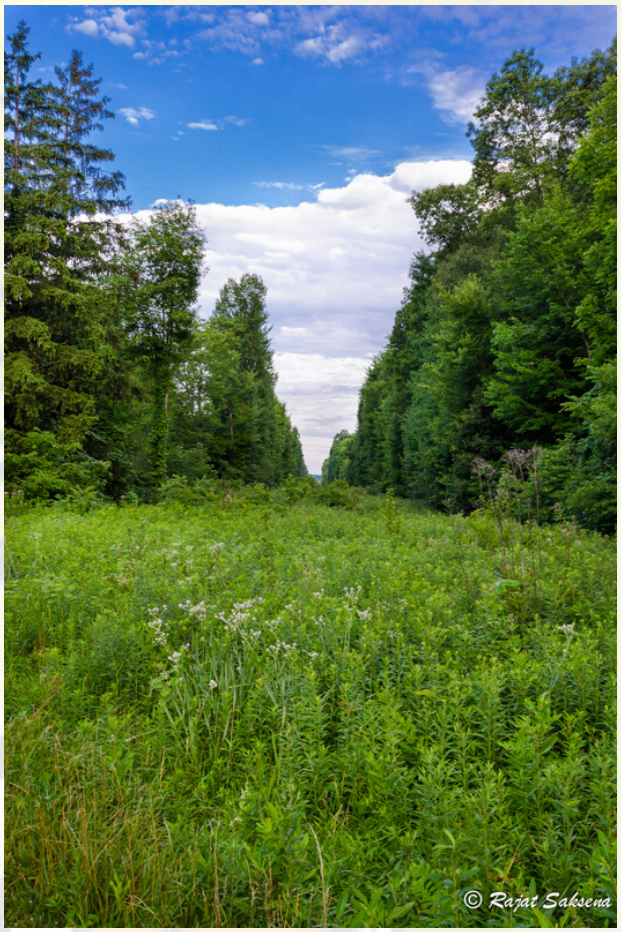
The United States Department of Agriculture's Natural Resources Conservation Service (NRCS) works with agricultural producers in the Midwest and southern Great Plains to combat the decline of monarch butterflies by planting milkweed and other nectar-rich plants on private lands. NRCS conservation practices that benefit monarch butterflies and other insects also help reduce erosion, increase soil health, sequester carbon, control invasive species, provide quality forage for livestock and make agricultural operations more resilient and productive. NRCS provides free technical and also financial assistance to implement these practices, helping producers and landowners manage for monarch habitat on farms, ranches and forests, in order to improve working lands and strengthen rural economies.

Rights-of-Way Habitats

In transportation, Rights-of-Way (ROWs) refers to a type of easement granted or reserved over the land for transport of humans, goods and energy, such as a highway, public footpath, rail transport, canal, as well as electrical transmission lines, oil and gas pipelines.

Paved roadways span approximately 6.6 million kilometers in the continental United States. There is a great potential for creating habitat for pollinators, such as monarch butterflies, along

the roadsides. US roadside habitat is estimated at 10 million acres — an area the size of Maryland. This was first estimated by landscape ecologist Richard Forman. More recent estimates put that number close to 17 million acres. Studies have shown roadsides have conservation potential for insects, especially when other habitat is scarce and if wildlife-friendly management practices are enacted. Several state Departments of Transportation, including Ohio Department of Transportation, plant native plants along the roads and implement Best Management Practices for roadside maintenance, as regards frequency of mowing and use of chemicals. In addition to providing support to the pollinators, such as butterflies, moths and bees, and other insects, roadside habitats can also be beneficial to other animals, such as migratory birds, which could use those as pit stops for resting and feeding.



Gas pipeline Right-of-Way through Blendon Woods Metro Park, OH

Similarly, utility ROWs, such as power lines and gas pipelines, offer an ideal setting for creating and managing habitat for monarchs and other pollinators. Electric and natural gas utility ROW corridors in North America occupy 12 million acres of land. Just like roads, utility lines pass through all types of ecosystems as well as farmlands, offering a great opportunity for creating suitable habitats for pollinators as well as other animals. Utility corridors managed for pollinators provide the ability to comply with FERC (Federal Energy Regulatory Commission) and NERC (North American Electric Reliability Corporation) regulations while providing critical wildlife migratory corridors. Utility lines passing through forests, where trees have been cleared underneath the electrical wires or over the buried gas pipelines, present a great opportunity for creating an *early successional habitat* — a crucial element of the ecosystem. [To learn about early successional habitat, reader is referred to the May 2020 issue of Project Nature newsletter.]

The Nationwide Candidate Conservation Agreement with Assurances for the Monarch Butterfly on Energy and Transportation Lands with an integrated Candidate Conservation Agreement (CCAA/CCA) represents a unique collaboration between the University of Illinois

at Chicago (UIC), the U.S. Fish and Wildlife Service, and more than 30 interested entities from the energy and transportation sectors. Ohio Department of Transportation is a committed member of CCAA.

There is, however, some concern about such ROW habitats becoming an ecological trap. Vehicle strikes are one of the biggest direct sources of mortality for vertebrates along roadsides, and some studies have found that there is an increased mortality of insects too. Studies have also found that insects or other animals are not able to successfully reproduce in some cases of ROW habitats, hence becoming "sink" habitats — habitats in which reproduction is insufficient to balance the loss from mortality, and populations are maintained by immigration from other ("source") habitats. There is ongoing research in understanding the impact of Rights-of-Way habitats on insects and other animals.

But a number conservationists and biologists believe that if done right, rights-of-way provide a tremendous opportunity for a successful creation of quality habitat for not just monarchs and other pollinators but many other species of animals and plants. Hence, the value of research on ROWs as potential habitats cannot be overstated for a careful and responsible implementation of such restoration projects.

International Cooperation

Monarchs do not adhere to borders created by humans, and since the range of the North American monarch spans across several countries, it is imperative that countries come together to conserve this shared and precious wildlife!

Wildlife Without Borders is a program of the US Fish and Wildlife Service (FWS) within the FWS International Affairs program, which coordinates domestic and international efforts to protect, restore, and enhance the world's diverse wildlife and their habitats with a focus on species of international concern. The Wildlife Without Borders program and the International Wildlife Trade program promote conservation across the globe. Additionally, FWS works with private citizens, local communities, farmers, conservation organizations, and foreign governments to ensure effective implementation of conservation efforts.

Citizens and Community

Monarchs being a beloved butterfly for a large number of people, there is a tremendous potential in citizens and communities taking action towards providing the much-needed habitat for their adored creatures. Thousands of homeowners and individual citizens contribute towards helping monarchs and other pollinators by planting milkweed and other native nectar-bearing plants in their backyards, thus creating pocket habitats in the nectar corridor. Community organizations, such as local church groups, schools, clubs and other citizen groups get involved to create pollinator-friendly habitats. Such community-led efforts are not only greater in magnitude compared to an individual's backyard, the larger impact of the community-driven projects is in educating and engaging more people when the projects are implemented on church grounds, schoolyards and other community places. The benefits of creating a pollinator-friendly garden are multifold. In addition to providing precious habitat for pollinators and adding beauty to the landscape with not just the wildflowers but also the beautiful pollinators that visit, they also help mitigate stormwater runoff. [To learn about runoff, reader is referred to the September 2019 issue of Project Nature newsletter]. More importantly, there are several economic benefits that come with creating such gardens with native plants. Native plants do not need any chemicals for management, which saves a significant cost. Since native plants evolved in the area, they are accustomed to the water conditions of the region and do not require much watering. Native plants and trees around a house or a building provide wind breaks as well as cooler temperatures, saving on energy costs. There are numerous citizen science programs that actively engage citizens and communities to participate in creating pollinator habitats in their neighborhoods. [To learn about the citizen science programs to help monarchs and other pollinators, reader is referred to the August, 2020 issue of Project Nature newsletter.]

The Monarch Highway

The "Monarch Highway" is a symbolic branding of the Interstate-35 (I-35) from Laredo, Texas to Duluth, Minnesota, signifying the monarch migration corridor. The Monarch Highway aligns with the central migratory flyway for the eastern population of the North American monarch. The symbolic highway is a partnership effort between State Departments of Transportation (DOTs) with the goal of bringing people together and mobilizing conservation actions throughout the central migratory flyway.

On May 19th, 2015, the White House Pollinator Health Task Force published the National Strategy to Promote the Health of Honey Bees and Other Pollinators. One of the recommendations, among several, that the Strategy called for was investing in habitat for monarch butterflies along the I-35 corridor as well as along rights-of-way, and directed the US Department of Transportation to work with state DOTs to promote pollinator-friendly practices. The idea for a "monarch highway" partnership originated from this federal strategy and in May 2016, the six states along I-35 — Minnesota, Iowa, Missouri, Kansas, Oklahoma, and Texas — signed an agreement establishing I-35 as the "Monarch Highway". The agreement establishes "a cooperative and coordinated effort to establish best practices and promote public awareness of the monarch butterfly and other pollinator conservation." The Monarch Highway partnership extends beyond the states through which I-35 passes. Other states with their respective DOTs committed to the partnership include (in alphabetical order) Alabama, Arizona, Colorado, Connecticut, Delaware, Georgia, Illinois, Louisiana, Maryland, Mississippi, Nebraska, North Carolina, North Dakota, Ohio, Tennessee, Virginia, Washington, and Wisconsin. Each state DOT has a similar commitment on improving pollinator habitat along roadsides and rights-of-way.

Ohio Department of Transportation (ODOT) is a committed partner of the Monarch Highway. ODOT encourages all the counties in Ohio to stop mowing for maintenance or visibility from May 1 through June 30 and then from July 15 through October 15. In June 2016, ODOT prepared the Statewide Roadside Pollinator Habitat Program Restoration Guidelines and Best Management Practices "to serve as a guide for ODOT District managers and maintenance staff to establish and maintain highway pollinator habitat within ODOT rights-of-way (ROWs) throughout the State." ODOT is also a committed member of the CCAA for Rights-of-Way.

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