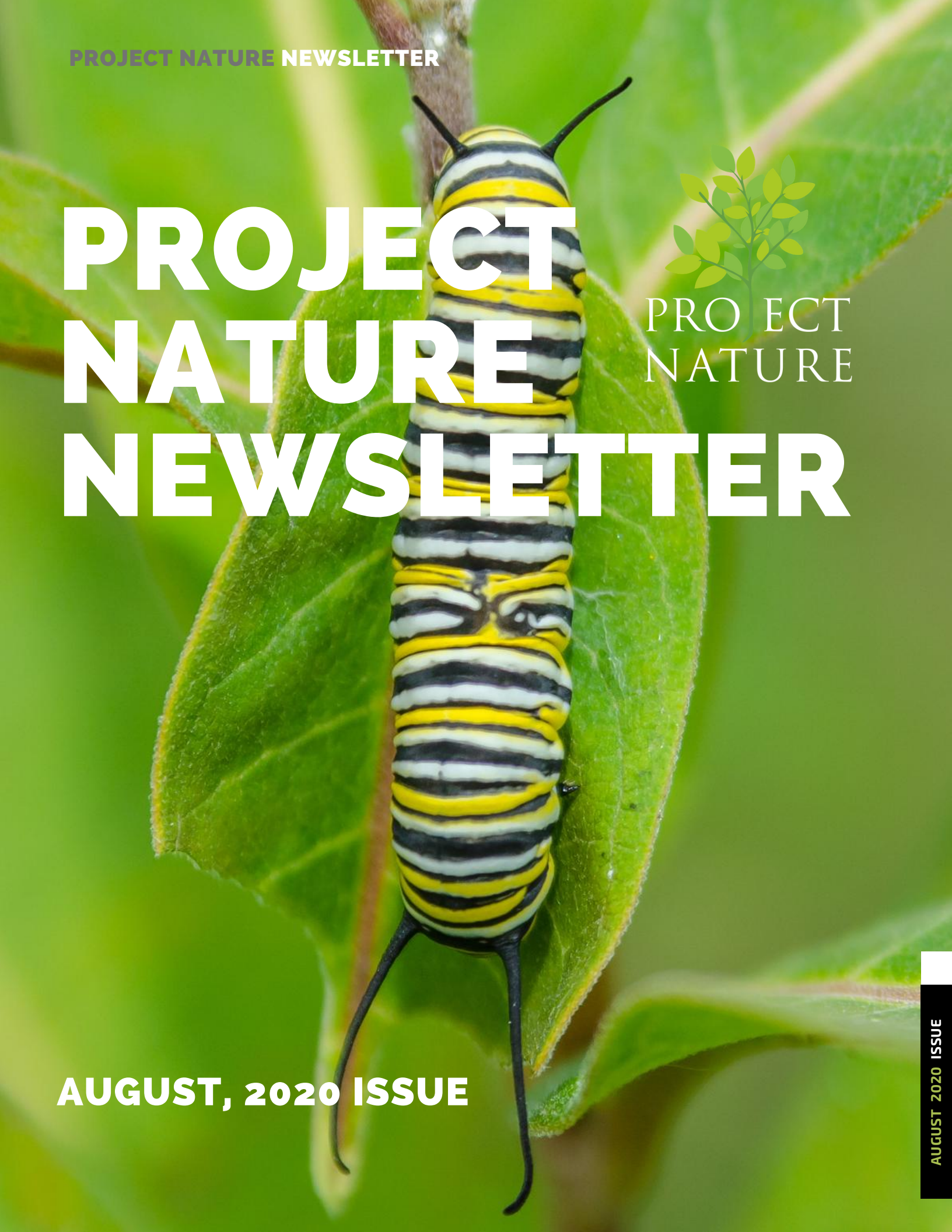

PROJECT NATURE NEWSLETTER

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AUGUST, 2020 ISSUE

The Monarch Butterfly – II

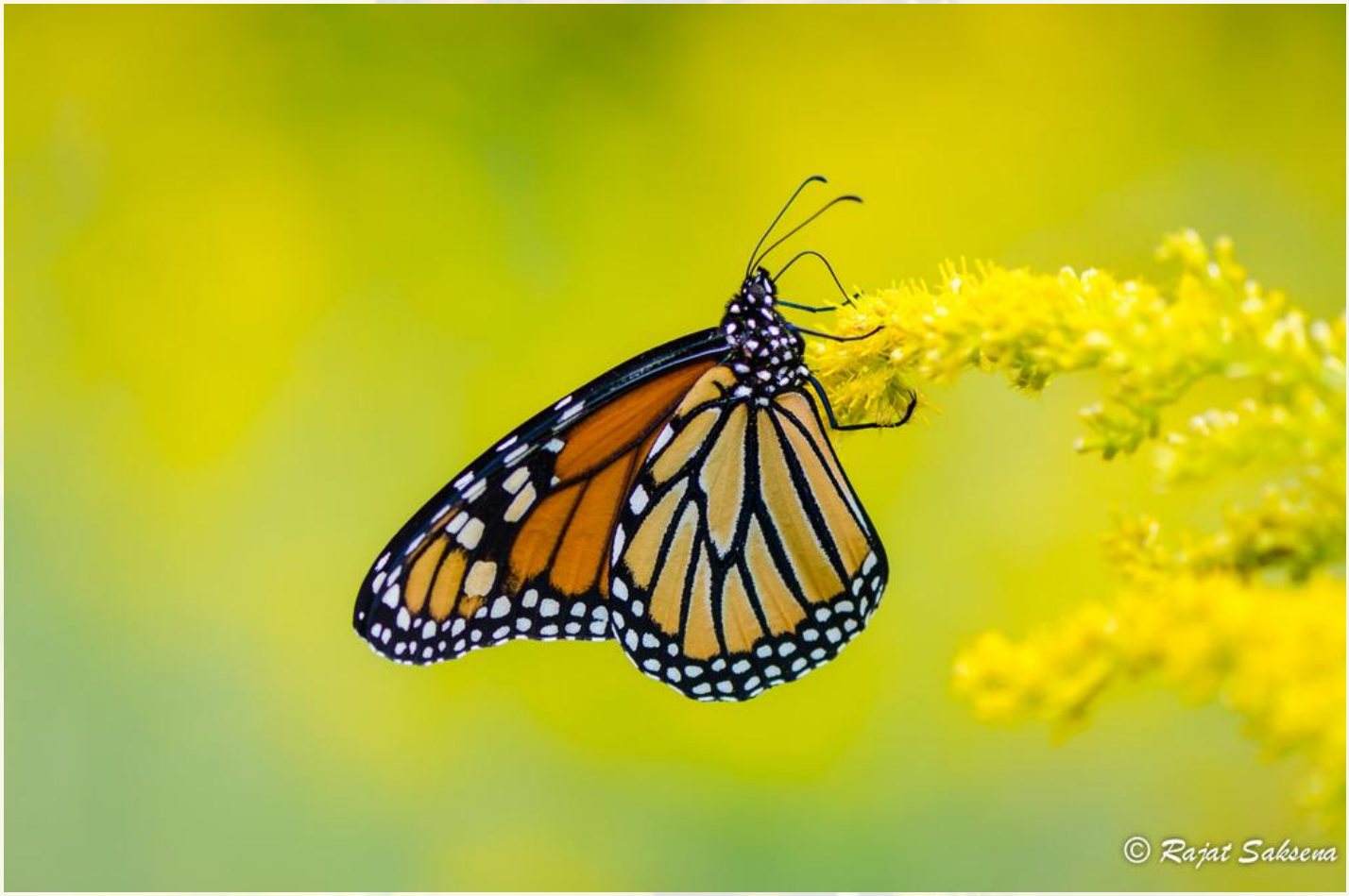
A Cautionary Tale on Conservation!

Monarch butterflies hold an iconic status in the natural heritage of North America. They have the ability to easily capture our imaginations. No other insect, or for that matter a single species of organism, enjoys the level of love and engagement from the general public — kids and adults alike — as the monarchs. But in recent years, monarch populations have declined dramatically. The population of the North American monarchs has declined by over ninety percent within the last two decades. Monarchs still number in millions (10^6), and one might be mistaken to think '*how could a species that exists in such large numbers be threatened with extinction!*' But the numbers need to put into perspective. Just a few decades ago, the monarchs numbered in billions (10^9). Such a steep decline is indicative of the species being threatened with extinction. For this reason, the US Fish and Wildlife Service is currently considering listing the migratory North American monarch butterfly as a threatened species under the US Endangered Species Act (ESA). There are numerous examples of species that were abundant at one point and went extinct within a short span of time. For example, the passenger pigeon was one of the most abundant birds in North America in the late nineteenth century, however, due to habitat loss and overhunting, the bird went extinct within decades in the early twentieth century. With fewer monarchs being reported each year at their wintering grounds, it is feared that the amazing migration phenomenon of these butterflies might be lost forever! A 2016 study by the U.S. Geological Survey concluded that due to continued low population levels of monarchs, there is between an 11% and 57% risk that the eastern monarch migration could collapse within the next 20 years. Scientists estimate that the monarch population needs to reach 225 million butterflies to be considered safe from extinction. A similar threat exists for the western monarchs. In the 2017 study, jointly published by researchers from Washington State University, University of Georgia, Xerces Society, and Tufts University in the journal *Biological Conservation*, it was estimated that at the current rate of decline, the western population of monarchs has a 63% risk of extinction in 20 years and 84% chance of extinction within 50 years.

[To learn about the monarch butterfly — history, biology, and migration — the reader is referred to the July 2020 issue of Project Nature newsletter.]

Monarchs and Citizen Science

Monarch butterflies inspire people. Citizen scientists have been involved with monarchs for decades, and it is the vast amount of data collected by the volunteer citizen scientists across the North American continent that has helped the scientists understand the many aspects of these amazing creatures. Starting in the 1950s, when thousands of citizen scientists volunteered for Dr. Fred Urquhart's Insect Migration Association with the tagging project to track the flights of the individual butterflies and find their, then mysterious, overwintering grounds, citizen scientists have been an integral part of monarch research as well as conservation. With decades of painstaking work done by the thousands of dedicated citizen scientists and the data



collected by them, not only did we finally learn about their overwintering site, we also learned so much more about their incredible migration as well as their biology. Each year, a multitude of citizen scientists help collect data on the different life stages of the butterfly, which involves

reporting sightings, assessing and documenting their habitat, monitoring their larval development, examining the caterpillars and adults for parasites, and tagging the adult butterflies to help study their migration. A 2015 research paper, published in the journal *Bioscience*, made a comprehensive assessment of the contribution made by citizen scientists to the study of monarchs. The study found that 17% of 503 research publications between 1940 and 2014 that focused on monarchs in which new results were presented, had used citizen science data. The authors further argued that the engagement of citizens with monarch conservation and research provides a model system for understanding the impacts of citizen science on scholarship, public engagement, and conservation. [To learn about Citizen Science, the reader is referred to the January 2019 issue of Project Nature newsletter.]

With the increased popularity of monarchs among the general public, many have taken it upon themselves to collect the eggs and caterpillars from the wild and rear them to adulthood inside their homes. While the intention of citizens rearing monarchs in captivity is noble, the outcome might be contrary to the intent of the effort!

Raising Animals in Captivity

Rearing young animals in captivity for release into the wild is sometimes a necessary approach in order to conserve the highly endangered species. The Giant Panda, native to China, is the most famous and well-known example of a captive breeding program to save a species from extinction. As a logo for the World Wildlife Fund (WWF), the Giant Panda is both literally as well as figuratively a symbol of conservation! Ninety nine percent of the Giant Panda's diet consists of bamboo, and due to severe habitat loss, the species came critically close to extinction. For the last several decades the animal has been bred in captivity in several research-based zoos and other facilities. The program has been successful and in 2016, the International Union for Conservation of Nature (IUCN) downgraded the animal from "Endangered" to "Vulnerable" on the global list of species at risk of extinction. The California Condor was once at the brink of extinction, with only 27 left in the wild. A careful breeding program in captivity for the birds, through the dedicated conservation efforts of San Diego Wild Animal Park and the Los Angeles Zoo, was able to help save the birds. The Arabian oryx, a type of antelope native to desert and steppe areas of the Arabian Peninsula, was resurrected from extinction through captive breeding. By 1960, the populations of the oryx had declined drastically due to overhunting. The animal was declared extinct in the wild in 1972. Between 1962 and 1964, the Phoenix Zoo acquired nine oryxes, and with the help of Fauna Preservation Society (now named Fauna and

Flora International) and others, the animal was bred at Phoenix Zoo, located in the northeastern region of the Sonora Desert — a conducive climatic conditions for raising the animals of desert biomes. Conservation efforts helped establish the "World Herd" of the Arabian oryx and saved it from going extinct. In 1981, the animal was reintroduced into the wild in Oman, Jordan, and in 2011, the Arabian oryx was downgraded from "Endangered" to "Vulnerable" by IUCN. Similarly, the Masked Bobwhite Quail was considered endangered with extinction. A successful captive breeding program by the US Fish and Wildlife Service helped re-establish the bird population in the wild.

Such captive rearing and breeding programs require extreme care and precaution to make sure that the reared animals are biologically identical to the ones in the wild. The breeding programs are very carefully managed with a heavy emphasis on research on how rearing in captivity and then releasing into the wild will affect the entire population. Many captive breeding programs are coordinated internationally through organizations, such as the Species Survival Commission (SSC) of the International Union for the Conservation of Nature (IUCN) and the specialist groups of the SSC. The IUCN Captive Breeding Specialist Group plays a coordinating role in captive breeding programs for many species. But even after making every effort to take all the necessary precautions, often there are several challenges to the fitness of the captive-bred or captive-reared animals when introduced into the wild. A few of such challenges include, maintaining genetic diversity, controlling outbreak of infectious diseases, and the animals raised in captivity acquiring the behavior that would help them succeed in the wild, such as the ability to fend for themselves or social skills for animals that are social.

Captive Rearing of Monarchs

Following the news of the sharp decline in the number of overwintering monarchs in recent years, more and more people have started to collect eggs and caterpillars from the wild and rear the butterflies in their homes, sometimes in large numbers, with the goal of supplementing local populations. Monarchs are also often reared in captivity to be used in a wide number of environmental education programs to demonstrate insect life cycle. Additionally, it has become fashionable to release butterflies, including monarchs, at weddings, funerals, and other celebrations. Such releases are usually promoted as helping the butterflies. To meet this growing demand, several commercial businesses breed hundreds of butterflies in captivity. One could argue that by rearing or breeding native butterflies, particularly ones that are experiencing a decline, commercial breeders and individual citizens are helping with the conservation efforts.

However, not only does captive rearing remain unproven in helping the monarch populations, there are several concerns about the fitness of the captive-reared monarchs. Such concerns are especially important with respect to monarchs, since they have a uniquely demanding life stage that involves a long-distance migration. There is still a lot that is needed to be learned about the effect of captive rearing on monarch development and its impact on the wild populations, but an increasing number of studies are indicating that there are significant differences between the monarchs reared in captivity and their wild counterparts. Those differences are of particular consequence when it comes to the fitness of captive-reared monarchs to take on the challenges of migration. Tagging studies have shown that wild monarchs have a greater chance at successfully making it to their overwintering grounds. In the amazing study published in 2015 in the *Annals of Entomological Society of America* by citizen scientist Gayle Steffy, 11,333 fall migrant monarch butterflies were captured, tagged and released over an 18-year period. One of the findings of the study was that captive reared monarchs were 7 times less successful than the wild monarchs at making it to their overwintering grounds. Recent data from Monarch Watch also shows a significantly lower recovery rate for reared monarchs compared to the wild monarchs.

The populations of both the eastern and western North American monarchs have declined sharply in recent years, but thankfully, it has still not reached a point where captive breeding or even captive rearing is absolutely necessitated. There are numerous risks associated with rearing monarchs in captivity. In 2015, several leading research and conservation organizations, such as Xerces Society for Invertebrate Conservation, Journey North, Odum School of Ecology at University of Georgia, Department of Entomology at Washington State University, and others signed a **joint statement** strongly recommending against the large-scale captive rearing of monarchs for release into the wild.

Captive Rearing Vs. Captive Breeding

It is important to make a clear distinction between the two terms.

Captive rearing refers to collecting the eggs or caterpillars from the wild and allowing them to metamorphose in captivity, and then releasing the adults.

Captive breeding refers to the practice of keeping the adult butterflies in captivity, and then breeding them to create a colony of hundreds or thousands of butterflies. Captive breeding is usually practiced by commercial businesses.

Increased Transmission of Disease

In the wild, monarchs develop through each stage of their life cycle far apart from one another. Captive-bred and often captive-reared butterflies are raised in much closer proximity. This increases the risk of diseases and infections from pathogens, such as the protozoan *Ophyrocystis elektroscirrha* (OE) parasite. There is very little awareness about the OE parasite among the general public and while some people might take the necessary precautions of sanitizing the cages in which they rear monarchs and then test the adults to make sure they are healthy before releasing them, a greater number of people rearing monarchs in their homes do not practice such precautionary protocols. In addition to the OE parasite, there are several other pathogens, which haven't been as well-studied as the OE parasite, and can potentially make monarchs sick when raised in close proximity. This poses a serious risk of spreading the disease among the wild populations from the captive-reared butterflies, when released. The risk increases with the number of butterflies being reared or bred. Several studies have found that purchased monarchs from commercial growers were heavily infected with OE.

OE pathogen has been extensively studied, and hence there is a good scientific understanding on how to detect it and control it. But there are several other pathogens, in addition to OE, that often infect monarchs, but little is known about them and how to control or prevent them.

[To learn more about pathogens, the reader is referred to the April 2020 issue of Project Nature newsletter.]

In addition to the increased transmission of disease, breeding or rearing in large numbers in close proximity also allows for more virulent strains of pathogens to quickly mutate and evolve.

Natural Selection and Population Fitness

In the wild, less than 5% of monarch eggs successfully reach adulthood. Most eggs, caterpillars and chrysalises are consumed by predators, such as birds and other insects, or parasitized before they reach adulthood. But monarchs have evolved with such high rates of predation, which essentially results in the 'survival of the fittest'! This process of natural selection ensures population fitness. By rearing the butterflies in captivity and allowing the majority of individuals to survive that wouldn't have otherwise survived in the wild, we are interfering with nature in selecting the most "fit" individuals. The potential implication of this in the long-term is encouraging the "less-fit" genes in the wild monarch populations.

Migration Fitness

Since the North American monarch is a migratory species, its survival is critically dependent on a successful migration to its wintering grounds. A number of studies have shown that among the migratory generation, only the fittest and hardiest individuals are able to make it to the overwintering grounds. From morphological to physiological, the migratory generation of monarchs has developed several adaptations to successfully complete the arduous migratory journey. [To learn about the adaptations for migration, the reader is referred to the July 2020 issue of Project Nature newsletter.] Several tagging studies have shown that monarchs raised in captivity have lower migratory success compared to the wild monarchs.

Wing Morphology

It has been shown that wing-size and wing-elongation are helpful factors for the monarchs successfully making their migratory journey to their wintering grounds. Studies have shown that individuals with larger and more elongated wings are more likely to complete the long migratory journey. In the 2020 study published in the journal *Biology Letters*, the researchers measured the forewing size and aspect ratio (a measure of wing elongation) of three different groups of monarchs — **1.** monarchs caught in the wild during early-October while they were migrating to their overwintering grounds, **2.** monarchs reared indoors in captivity from egg to

adulthood in summer-like conditions (in terms of temperature and day length simulated by overhead lights), and **3.** monarchs reared indoors in captivity from egg to adulthood in late summer-like or fall-like conditions, similar to that experienced by the monarchs of the migratory generation in the wild.

Researchers found that among the three groups that were tested, the wild monarchs were slightly larger than the reared monarchs, and had significantly more elongated forewings than those of the butterflies in both the reared groups. The average aspect ratio (a measure of wing-elongation) of the wild monarchs used in the study was consistent with earlier estimates from the migratory populations in North America, whereas the average aspect ratios of both reared groups of butterflies were similar to those of the sedentary populations of monarchs in Costa Rica and Puerto Rico. Similar results were reported by researchers from University of Chicago in the 2019 study published in *Proceedings of National Academy of Sciences*.

Wing Pigmentation

Wing pigmentation of monarchs is associated with improved flight performance, and hence migration success. Deeper, reddish-orange colors of the wings imply better flight capability. In the same 2020 study published in the journal *Biology Letters*, researchers from University of Georgia found that the reared butterflies from both groups had paler wings than the wild migrants.

Grip Strength

Grip strength is often used as a proxy for assessing the overall strength of insects. Grip strength is considered to be a relevant test for the fitness of migratory monarchs because during migration, they roost on trees and other vegetation at night, and would need to hold fast during storms. Researchers from University of Georgia used the approach to test the strength of monarchs. In the 2020 study published in the journal *Biology Letters*, the researchers tested the strength of the three different groups of monarchs (described above). To measure the grip strength, the butterflies were held above a wooden perch equipped with an electronic force gauge, and allowed to grasp it. The butterfly was then gently pulled until it released the perch. The force gauge recorded the force the butterfly exerted before releasing the perch.

Of the three groups of monarchs tested, the wild group was found to be the strongest. The average strength of both the reared groups of monarchs was found to be 56% lower than that of the wild group.

Directional Orientation

The migratory generation of the eastern population of the North American monarchs emerging in late summer and fall have to make their journey home south to Mexico. They get their cues from circadian rhythms and environmental changes. Consequently, monarchs of this generation tend to orient south in flight. Scientists from Queen's University, Kingston in Canada performed a comprehensive study to reconstruct virtual flight paths of migratory monarch butterflies. To measure flight orientation in the lab, the researchers developed a flight simulator in which the butterflies were allowed to fly tethered through a column of airflow necessary to produce sustained flight behavior. The butterflies were free to orient themselves in any direction. The butterflies tested were the monarchs caught in the wild during their fall migration in September. It was found that the butterflies consistently oriented themselves in the southwest direction while flying in the flight simulator. Even if they were manually turned in another direction, they would immediately return to orient themselves southwest. The results were published in the *Proceedings of National Academy of Sciences* in 2002. (Video clips of the monarchs flying in the flight simulator can be found in the supplementary materials of the publication at pnas.org.)

In another study, also published in the *Proceedings of National Academy of Sciences* (PNAS) in 2019, researchers from University of Chicago studied the flight orientation of two different groups of monarchs — commercially-bred monarchs and wild-caught monarchs. Offspring of both the groups were reared over two successive generations — summer and fall — in outdoor insectaries. When tested in the flight simulator, the offspring of the wild monarchs that emerged in the summer did not have a group direction but the ones that emerged in the fall (October) — the migratory generation — flew directionally south. On the other hand, the offspring of commercial monarchs did not have a directional orientation — either in the summer or the fall generation.

In the same 2019 PNAS study, the researchers from University of Chicago also investigated the effect of indoor rearing. Offspring of wild-caught monarchs were reared indoors in two different conditions — one group in summer-like conditions and another in fall-like conditions. The seasonal conditions were simulated in terms of temperature and day length by controlling the duration of overhead lights. When tested in the flight simulator, neither of the groups exhibited a directional orientation. The researchers did one additional test in which they moved a group of outdoor-reared fall generation pupae from the offspring of the wild monarchs indoors, maintained in fall-like conditions to mimic the same outdoor environment. The adults eclosed about 4-5 days after being brought indoors. Even these individuals that had spent the vast majority of their life cycle outdoors failed to orient south in the flight simulator, highlighting the fragility of migratory behavior where a brief exposure to unnatural conditions, even late in the life cycle, may be enough to disrupt migratory behavior.

These findings strongly indicate that captive breeding as well as indoor captive rearing has the effect of monarchs losing their migratory directional sense.

Reproductive Diapause

Reproductive diapause in monarchs is a crucial adaptation in the migratory generation. A temporary suspension in reproductive ability allows the monarchs to direct all their resources towards making the long migratory journey home. In the 2019 study published in PNAS by researchers from University of Chicago, the female butterflies were tested for whether they entered reproductive diapause. This was achieved by counting the number of mature ***oocytes***. An oocyte is a germ cell in the females involved in reproduction. In simpler words, an oocyte is an immature egg cell. The wild-caught females of the fall generation have their mature oocytes

significantly reduced compared to the ones of the summer generation. The study found that while the outdoor-reared females of the fall generation did have their mature oocytes reduced, however, the majority of butterflies reared indoors in fall-like conditions did not have a lower oocyte count, implying they did not enter reproductive diapause.

Stress of Human Handling

In the 2020 study published in the *Journal of Lepidopterists' Society*, researcher Andrew Davis from University of Georgia investigated the cardiac reactions of monarch butterflies to human handing. When threatened by a predator, an inherent fight-or-flight response is common in all animals, including insects and invertebrates, as a natural defense mechanism. This physiological response is marked by increased respiration and heart-rate, as well as release of stress-related neurochemicals. For the study, the response to human handling was assessed for all three life stages of monarchs — larva, pupa, and adult — by measuring changes in cardiac activity or heart rate. The butterflies were raised in captivity in plastic containers from larvae to adult. The fifth instars of the larvae were tested for their cardiac activity. The caterpillars were physically "handled" for a stipulated amount of time, following a consistent protocol. The caterpillars' heart rate was measured immediately after being handled by placing them under a microscope and visually counting the pulses of the larval dorsal vessel. Similar measurements, but using a different protocol appropriate for pupae, were made during the pupal stage. The heart rate measurement of the pupae was made using an electronic heart meter. To study the adult monarchs, wild butterflies were caught during the fall migration, and the heart rate was measured immediately after handling them under the microscope and visually counting the beating of the dorsal vessel on the abdomen. For each life stage, a careful procedure was followed to establish a baseline that represented the normal heart rate for the butterfly in unstressed conditions.

The caterpillars showed a significant increase (20%) in the heart rate following direct human handling. The pupae exhibited brief bursts of heart contractions at a rate that was three times higher than normal. Adult monarchs only showed a minor increase in heart rate.

These results offer a good insight into the effect of human handling on monarch caterpillars and chrysalises, both of which showed a marked increase in heart rate as a result of it. Such cardiac reactions would typically occur in animals following a predation attempt, implying that human handling is perceived as a predation attempt by monarch larvae and pupae. The long-term implications of the stress of human handling experienced during the immature stages of

the butterfly is not known at this point, but with captive rearing of monarchs becoming increasingly popular, it is important to have the knowledge that we inadvertently put the butterflies under extreme stress when raising them.

Captive Breeding

In addition to all the implications noted above for captive rearing of monarchs, there are other even more serious concerns with captive breeding of monarchs. Usually captive breeding is practiced by a commercial enterprise, where hundreds or thousands of butterflies are bred in captivity.

Lack of Genetic Diversity

Continuous breeding in captivity of related individuals (or inbreeding) over multiple generations can dilute genetic diversity. Many breeders share monarch lineages with each other, which implies that even individuals from different facilities could still be related. Lack of genetic diversity is usually unhelpful for the success of a species' survival. When these captive-bred individuals are released, they may have adverse effects on the wild populations.

Genetics of Commercially-Bred Monarchs

In the 2019 study published in *Proceedings of National Academy of Sciences*, scientists from University of Chicago generated whole genome sequencing (WGS) data from the commercially-bred monarchs to determine their ancestry. Since the dispersal of monarchs out of North America to different parts of the world, four genetically-distinct populations of monarchs have established — North American, Central/South American, Pacific, and Atlantic. Except for the North American monarchs, all other populations are non-migratory. The researchers found that the commercial monarchs represent a distinct and previously unknown population of monarchs. Phylogenetic analyses revealed that the commercial monarch population was originally derived from North America but there has been no appreciable gene flow into the commercial population from the non-migratory populations. The commercial monarchs represent a distinct population of monarchs, different from the wild North American monarchs or monarchs from other parts of the world. The finding implies that commercial breeding seems to have the same effect on population genetics as natural dispersal.

Phylogenetic Analysis

Phylogeny refers to the evolutionary history of a species. Phylogenetics is the study of phylogenies — or the study of the evolutionary relationships of species. Phylogenetic analysis is the means of estimating the evolutionary relationships.

Adaption to Captive Conditions

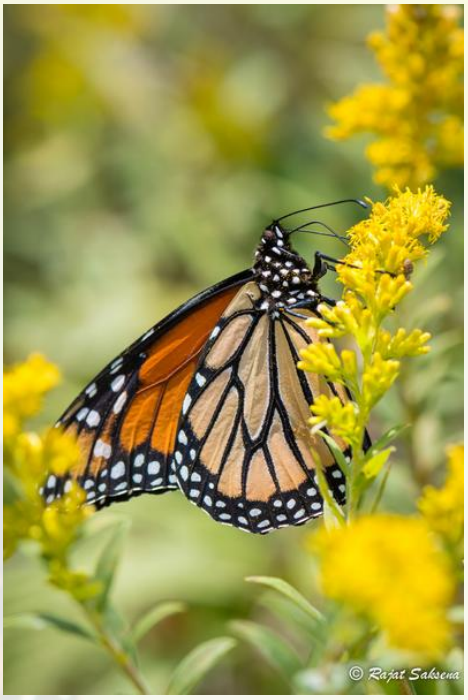
Captive breeding of closely related individuals over successive generations can not only potentially lead to lack in genetic diversity, it also has a far-reaching evolutionary consequence. Studies have shown that animals raised in captivity can genetically adapt to captive conditions. Since the conditions in captivity are greatly different from those in the wild, such animals would have a significantly lower survival rate in the wild, if released. For the monarchs, this could have an additional consequence — a complete loss of the migration phenomenon!

Impact on the Wild

While the impact of butterflies bred or reared in captivity on the wild populations has not been studied extensively, there are credible potential risks. Facilities where the butterflies are bred or reared in large numbers in close proximity can have a high buildup of pathogen levels that could then be transmitted to the butterflies in the wild. When commercial breeders ship the butterflies to different places, there is a risk of introducing novel strains of pathogens to regions where they would not normally occur. Such implications have been shown in other pollinators, such as bumblebees.

Increasing numbers of studies are finding that captive-reared and captive-bred monarchs appear to be functionally and behaviorally different from their wild counterparts. Captive-bred monarchs are often shipped to regions far from where they were bred. When these butterflies are released and they mate with the wild butterflies, it can potentially alter the natural gene flow. Captive-reared and captive-bred monarchs have been found to be less fit for

migration — a fact supported by the lower recovery rates of captive-reared monarchs at overwintering sites. Migratory traits appear to be lost in captive-bred as well as captive-reared monarchs and this could potentially impact their survival. For example, if the fall generation of monarchs reared in captivity are unable to orient in the right direction, they are less likely to successfully reach their overwintering grounds, and hence not contribute to monarch population recovery. These non-orienting individuals could mate with wild monarchs and introduce non-migratory variation in the wild population. With an increasing number of captive-raised monarchs released into the wild that have a low rate of success to complete the long migratory journey, if these "less-fit" individuals survive to reproduce, over time it could potentially lead to the entire migration phenomenon being lost!



Impact on Scientific Research

Conservation efforts and policies require good reliable scientific data of monarch populations and their migration, among other things. Released captive-reared monarchs can potentially interfere with the accurate data collection. They can locally bias the estimate of the total population in a region that is abundant in monarch activity. Conversely, in regions where monarchs are not common, reared monarchs can lead to false population estimates.

When commercially-bred butterflies are shipped out to different regions where they are released, far from where they were bred, it could distort the estimates of genetic diversity of the population of that region.

Captive-reared butterflies can also cast doubts on any observed rarities. For example, in April 2015, a monarch was documented in Minnesota and reported on Journey North — a citizen science program that engages citizen scientists to report sightings of monarchs during their spring migration. This observation was such an anomaly in terms of its time of the year for the location that it was subsequently removed from the database because of its likelihood of being a locally-reared monarch that was released. But anomalies in nature are not uncommon, and this could have been a natural event where the butterfly did arrive early in the season, in which case it was a very valuable piece of information to develop a better understanding of the

butterfly and possible behavioral changes. Unfortunately, the data had to be discarded and a potentially valuable observation was missed!

Arguments

One might argue that for all the studies that made a comparison between the wild-caught and the captive-reared monarchs, it is possible that the monarchs that were caught in the wild were actually reared or bred in captivity and then released. While that is certainly possible and there is a finite probability of the same, however, the wild monarchs number in tens of millions while those reared in captivity would, at the most, amount to a few hundred thousand. Hence, the probability of catching a reared monarch from a random sample of monarchs caught in the wild at any given location is extremely low. According to Dr. Orley "Chip" Taylor of University of Kansas and founder of Monarch Watch, while the exact number depends on the location and the population size in a given year, still the overall probability of sampling a reared monarch in the wild is a fraction of one percent, with some estimates being less than one-tenth of a percent. For this reason, Monarch Watch requires citizen scientists to report all the monarchs caught in the wild (for tagging purposes) as “wild”.

There are best practices that are recommended when rearing monarchs. Those involve, among other things, rearing the larvae in individual cages and regularly cleaning and disinfecting the enclosures in which the monarchs are reared. Some people who rear monarchs diligently follow the guidelines, such as sanitizing the cages and regularly inspecting the adults for diseases and parasites before releasing them into the wild. But most people do not, or are not able to, follow all the guidelines for safe rearing. Research labs, such as the Altizer lab at University of Georgia, Athens, raise several hundred monarchs in the labs for research purposes. They house them individually or at low densities in sterile “hospital-like conditions”, and shut down their rearing facility once every year for a thorough cleaning. But even under such conditions and after taking extreme precautions, they experience outbreaks of diseases from time to time.

Lastly, all the studies that investigated the difference between wild-caught and captive-reared monarchs, had carefully followed all the best practices and safety protocols when rearing them in their labs. Yet, the physiological, morphological and behavioral differences that they reported for the reared monarchs, compared to wild monarchs, were observed after taking all the safety precautions and best practices while rearing them!

Hobby and Citizen Science

Citizen science is scientific research, conducted in part or in whole, by amateur citizens. Citizen scientists are typically non-professional scientists. Citizen science harnesses the curiosity or concern and care about a certain thing of participating citizens and engages them in an organized scientific research. In a way, citizen science turns hobby into science or science into hobby! However, there is still a big difference between hobby and citizen science. Both 'hobby' and 'citizen science' are pursued for personal pleasure or for a desire to satisfy one's interests, but while hobby doesn't need to be organized and follow any protocols, citizen science is performed in an organized fashion and by following consistent protocols. Even though amateur scientists, citizen scientists are 'scientists' nonetheless, and must observe largely the same general scientific protocols and adhere to the same responsible conduct that applies to any professional scientist. It is incumbent upon the scientist — professional or amateur — to inform themselves of the implications of their work.

A Lesson from History

Well before the term 'citizen science' was even formalized, hobbyists and amateurs have been making observations and collecting specimens of things that would interest them, which would sometimes be applied to formal research and the specimens contributed to museum collections.

Both professional and amateur ornithologists (or birders) have been fascinated with bird eggs and studying bird reproduction for centuries. Nest monitoring became increasingly popular in the 19th century, and originated from the scientific discipline of ***oology***. Oology is a branch of ornithology that involves studying bird nests and breeding behavior. The term is derived from the Greek word *oion*, meaning egg. Nineteenth century was the period prior to the development of high-powered optical instruments and cameras, and hence the only way to study bird reproduction was to collect nests and eggs. While the scientists understood that an invasive mode of study would likely have a negative impact on the birds, it needed to be done in order to enhance the scientific understanding of birds. Many nests and eggs were collected by volunteers and enthusiasts, which greatly helped advance the scientific knowledge of birds.

The onset of the 20th century welcomed the advent of photography and affordable optical equipment. Bird nests could now be viewed and photographed from a distance. Now it was no

It was the egg shells collected by citizen scientists and hobbyists during the 19th century, which were preserved in museum collections, that helped scientists to learn, several decades later, that DDT (Dichlorodiphenyltrichloroethane) — an insecticide widely used in agriculture in the 20th century — had the effect of thinning bird egg shells. DDT was eventually banned from any agricultural use in the United States in 1972.

longer justified to continue with the invasive practice of collecting large number of bird nests and eggs for scientific purposes. Scientists also advised that bird eggs should never be collected unless something can be learned from it. However, the practice of collecting bird eggs had become a very popular hobby, and it concerned the conservationists with the negative impact it was having on birds. Finally, collecting wild bird eggs was outlawed in the United States through the Migratory Bird Treaty Act of 1916, which protected migratory birds as well as their nests and eggs.

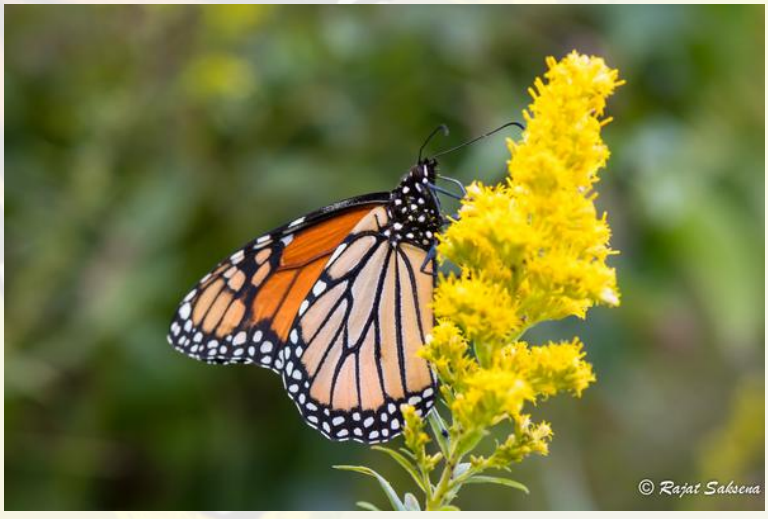
Hobby can be turned into citizen science, but hobby by itself doesn't necessarily qualify for science!

Responsible Conservation

The best and safest way to help the monarchs is by creating more habitat for the butterflies — planting their host plant as well as other nectar-bearing plants. Habitat loss is the greatest cause for the decline of monarchs. For example, due to herbicide-resistant crops and the widespread use of the herbicide glyphosate (Roundup), it is estimated that in just 13 years, from 1999 to 2012, there was a 64% decline in overall milkweed in the Midwest. Consequently, in 2012, it was estimated that the Midwest produced 88% fewer monarchs than it did in 1999. [To learn about how glyphosate destroys monarch habitat and promotes monoculture, the reader is referred to the July 2020 issue of Project Nature newsletter.]

Another way to look at it is that if we do not create sufficient food source and breeding opportunities for the butterflies, rearing them in captivity to increase their populations wouldn't serve any purpose because when the resources are limited and not sufficient to support the larger number of butterflies, the numbers wouldn't be sustained through the next generation. Habitat creation and restoration is of utmost importance for the success of any species. For example, the Giant Panda became endangered because of habitat loss and habitat fragmentation. And while the captive breeding program of several decades has been successful, the success of the captive-bred animals in the wild after release is still a big challenge. One of the chief reasons for this is lack of sufficient habitat. The little remaining bamboo forests in China are disconnected by human development, isolating the few wild pandas from one another and making it difficult for the wild population to thrive. Realizing the importance of habitat for the success of the animal in the wild, the Chinese government has pledged to spend over a billion dollars and create a 10,000 square mile panda national reserve to connect the fragmented habitats for the Panda.

Conservation starts with gathering data. Good data forms the basis for designing and planning conservation efforts. Good observation is good science and the most crucial element of conservation and restoration. Reporting sightings of monarch adults as well as eggs and caterpillars, and monitoring their habitat are one of the most valuable contributions citizen scientists make towards helping the butterflies. The data contributed by citizen scientists across the North American continent helps create a spatial as well as temporal distribution of the butterflies and their habitat. It helps the scientists better understand the threats monarchs face — locally as well as on a larger scale. Observations reported by citizen scientists not only help the scientists create conservation strategies but also assess the effectiveness of conservation projects.



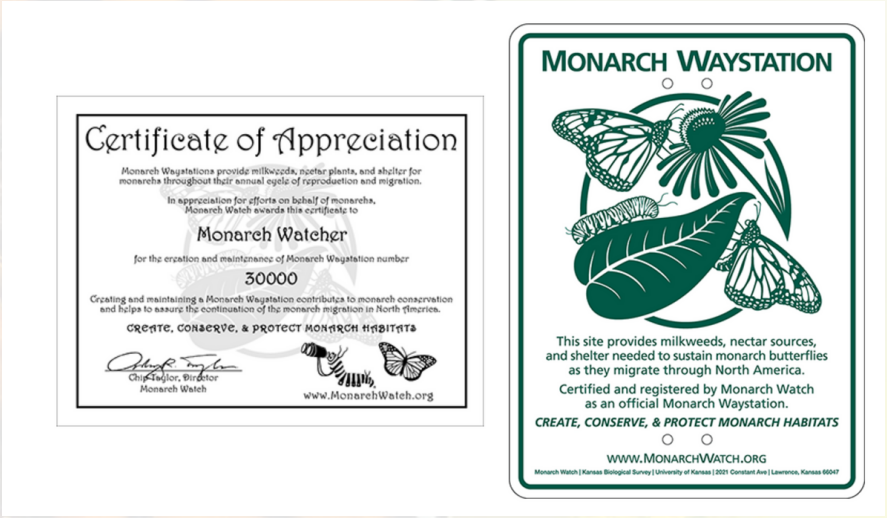
Several conservation organizations as well as government agencies work tirelessly in their commitment towards saving the monarchs. Some are research-based organizations, focusing on understanding the science of monarch biology and factors that affect them; others focus on restoration projects as well as educating and engaging the general public with monarch conservation. Most of these programs not only involve citizens, but they rely on the wealth of data contributed by citizen scientists!

Monarch Watch

Monarch Watch (monarchwatch.org) is a nonprofit education, conservation, and research program based at the University of Kansas that focuses on the monarch butterfly, its habitat, and its fall migration. The program focuses on research on monarch migration, biology and population dynamics, as well as educating the public about the butterfly and its spectacular migration.

Monarch Waystation Program

(monarchwatch.org/waystations) is a citizen science project by Monarch Watch to create a corridor of habitat patches with nectar sources as well as milkweed host plants for the migrating monarchs to help the butterfly find necessary food and also breed to produce successive generations. Thousands of citizens across the continent participate in this program to create **Monarch Waystations** at home gardens, schools, businesses, parks, nature centers, and other places. These pocket habitats are planted with two or more different species of native milkweed along with several other nectar-producing plants that bloom sequentially, such that a few plants are always flowering throughout the course of the season. Monarch Waystations can be registered with MonarchWatch for a formal certification.



Monarch Waystation Network

(monarchwaystationnetwork.ku.edu) is another project of Monarch Watch, specifically developed to connect and support schools that have pollinator gardens and/or incorporate monarchs in their curriculum, with the goal of using the gardens as learning centers.

Journey North

Journey North (journeynorth.org/monarchs) is a citizen science program dedicated to tracking the northern migration of the monarch butterfly, among many other projects. Founded by Elizabeth Howard in 1994, who led the project for 25 years, and funded by Annenberg Learner, a division of the Annenberg Foundation, the project has broad participation from families, teachers, schools, nature centers, and professional scientists. The project has over 60,000 registered sites in the US, Canada, and Mexico. The citizen scientists committed to the project contribute over 50,000 monarch sightings per year. In 2019, Journey North officially became a part of the University of Wisconsin-Madison Arboretum.

Monarch Joint Venture

Monarch Joint Venture (MJV) (monarchjointventure.org) is a partnership of federal and state agencies, non-governmental organizations, businesses and academic programs working together to protect the monarch migration across the United States. MJV brings together partners from across the United States in a unified effort to conserve the monarch migration. These actions are organized in an annually updated **Monarch Conservation Implementation Plan**, which serves as a framework to guide conservation planning for individuals, partners, or other interested stakeholders nationally.

Integrated Monarch Monitoring Program is a citizen science program of Monarch Joint Venture (monarchjointventure.org/mjvprograms/science/immp) to monitor key indicators of monarch population health and habitat characteristics using spatially balanced sites across the monarch's U.S. range.

Monarch Larva Monitoring Project (monarchjointventure.org/mlmp) is another citizen science program of MJV to better understand the distribution and abundance of breeding monarchs and to use that knowledge to inform and inspire monarch conservation. The project was developed in 1997 by researchers at the University of Minnesota to collect long-term data on larval monarch populations and milkweed habitat. The project focuses on monarch distribution and abundance during the breeding season in North America.

The Xerces Society for Invertebrate Conservation

The Xerces Society (xerces.org) is a science-based international organization dedicated to the conservation of invertebrates and their habitats. The organization conducts its own research and utilizes the most recent information to guide its conservation efforts. In 2016, the Xerces Society prepared a comprehensive report for the US Fish and Wildlife Service that provides an assessment of overwintering sites of western populations of the monarch butterfly in California, and summarizes existing overwintering trends and identifies the highest priority sites for active management and protection. In addition to leading research efforts, Xerces Society also hosts several citizen science programs to engage the public with monarch conservation.

Western Monarch Count

(westernmonarchcount.org) is a citizen science project to monitor the status of the western monarch populations during the overwintering season — approximately, from October through March. This effort has been coordinated by Mia Monroe, Shawna Stevens, and Dennis Frey in the past, and is now coordinated by Mia Monroe and The Xerces Society. The major effort in this program is the **Western Monarch Thanksgiving Count**, which runs for three weeks. Since 2017, the volunteers have expanded the monitoring effort with an additional **New Year's Count**. The valuable data collected through this concerted citizen science effort, which began in 1997, has revealed that the western overwintering monarchs have undergone a significant decline from over 1.2 million, recorded in 1997, to only 292,674 in 2015. Adjusted for differences between sites and in the effort put in over time, it is estimated that the population has declined by 74% since late 1990s, which is similar to the decline in the population of eastern monarchs overwintering in central Mexico. The decline estimated since 1980s for the western monarch population is over 95%.

Western Monarch Milkweed Mapper

(monarchmilkweedmapper.org) is a citizen science project to map and better understand monarch butterflies and their host plants across the western United States. The effort helps improve our understanding of the distribution and phenology of monarchs and milkweeds, identify important breeding areas, and help us better identify monarch conservation needs. The project is a collaborative effort between Idaho Department of Fish and Game, Washington Department of Fish and Wildlife, and The Xerces Society, and funded by National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service.

National Wildlife Federation

The National Wildlife Federation (NWF) (nwf.org) is an organization dedicated to wildlife conservation. NWF conducts several programs for the conservation of the monarch butterfly by engaging citizen scientists as well as works with the state and federal governments to coordinate conservation efforts. National Wildlife Federation's **Mayors' Monarch Pledge**, which is a tri-national initiative with the U.S., Mexico, and Canada, connects mayors and other local and tribal government chief executives to make a coordinated effort towards conserving the butterfly. As part of an agreement with U.S. Fish and Wildlife Service, the NWF helps and supports its state affiliates to host state Monarch Summits. Monarch Summits create an action plan and share resources for monarch conservation among state agencies, nonprofit organizations, businesses, and individuals.

Garden for Wildlife (nwf.org/Garden-for-Wildlife/Certify) is a citizen science program of NWF that provides an opportunity for gardeners to earn recognition for their efforts in helping monarchs and other wildlife via the **Certified Wildlife Habitat®** designation. Similarly, the **Schoolyard Habitats®** program encourages students to create habitat for monarchs and other pollinators on their own school grounds. Using The *Monarch Mission* curriculum, students also learn about and improve habitat for monarchs by creating *Monarch Recovery Gardens* at their schools.

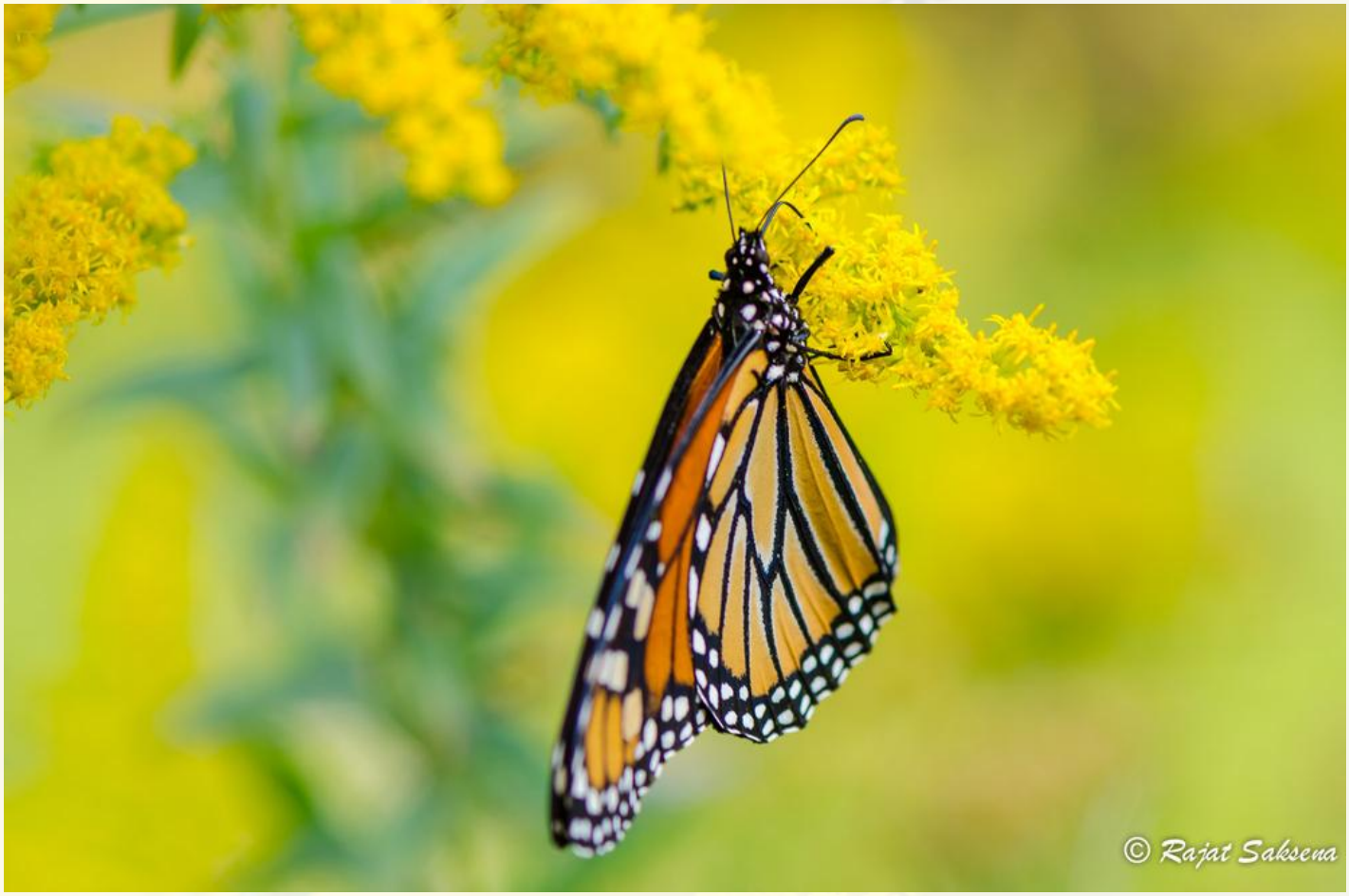
Butterfly Heroes (nwf.org/Butterfly-Heroes) is another citizen science program of NWF focused on engaging children. The program aims at bringing awareness to the declining population of monarchs and connect gardeners and kids and families alike to help the monarchs and other pollinators.

In addition to organizations and citizen science programs listed above, there are numerous other groups and organizations as well as individual citizens who are dedicated to the conservation of this precious and beautiful butterfly. Many of such citizen science programs can be found at Monarch Joint Venture's website (monarchjointventure.org/get-involved/study-monarchs-citizen-science-opportunities).

Rearing Monarchs for Research

Rearing monarchs for research purposes is a "necessary evil". Several citizen science projects, such as the Monarch Larva Monitoring Project or the Monarch Health, require collecting monarch eggs and larvae and rearing them in captivity (in individual cages while following a careful safety protocol, such as maintaining optimal temperature and moisture, supplying fresh milkweed leaves and cleaning the cages every day) to monitor the parasitism in caterpillars collected from a given site and their survival, or studying the OE parasites in adults. Such studies are extremely important to better our understanding of these butterflies in order to inform the most effective ways to protect them.

But such citizen science programs do not call for rearing more than a handful of monarchs, and there is no reason to rear hundreds of them.

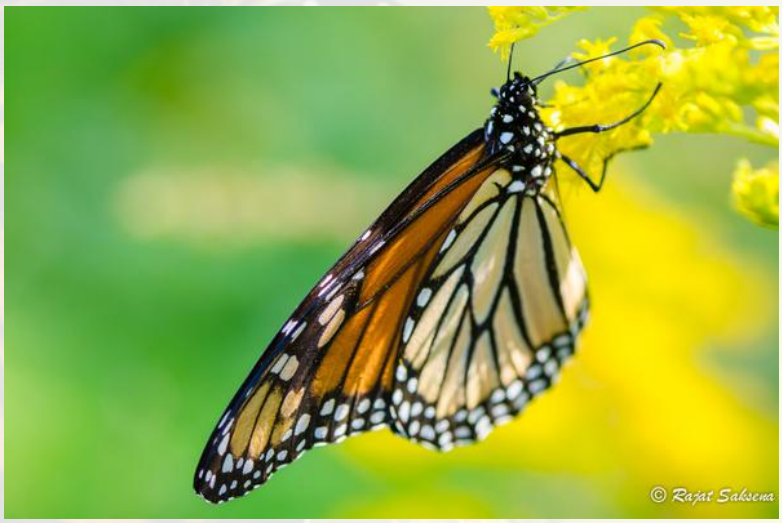


Simple Ways to Help

Creating more habitat for the monarchs by planting milkweed and other native nectar-bearing flowers is the key to saving monarchs. We can help the monarchs in our own backyards, workplace, schools, or place of worship by planting regionally appropriate native milkweed and other flowering plants that provide nectar. For a regional and season specific plant list, Xerces Society provides a comprehensive guide for each region of the continent (xerces.org/monarchs/monarch-nectar-plant-guides). Similarly, the National Wildlife Service's Native Plant Finder (nwf.org/NativePlantFinder/Plants) has a database for native plants, and helps one find the right milkweed host plants for the monarchs by zipcode.

Follow Best Management Practices, such as adjusting timing of mowing to not interfere with monarch breeding or nectaring along the migration route. Monarch Joint Venture provides easy-to-follow details for Best Management Practices. (monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf)

Eliminate or minimize the use of pesticides. Insecticides can directly kill the butterflies but even herbicides can indirectly harm them by eliminating their host plants and energy sources. If pesticides are to be used, instead of using a generic pesticide, it is advisable to use the pesticide specific to the pest. Additionally, the time of application should be such as to avoid monarch activity periods.



In the western region of monarch overwintering sites, an arborist should be consulted prior to cutting or thinning tree stands. It is recommended that any cutting or thinning of tree stands be done outside the overwintering season, which is approximately from October through March.

Additionally, citizens should support GMO-free agriculture to help monarchs and other wildlife.

Epilogue

There is still a lot to be learned about the monarchs reared in captivity and their impact on the wild populations. Researchers continue to work towards gaining a greater understanding of the subject. However, at this point there is enough evidence to cast a reasonable doubt on the efficacy of rearing monarchs in captivity.

We have already hurt the environment and damaged the valuable habitat for this precious creature we all adore, which has brought these magnificent butterflies to this point that we fear they may go extinct. And as we enthusiastically charge ahead to save our beloved monarchs, let's take a little time to inform ourselves, because nothing would be more unfortunate than the realization that in our efforts of helping the butterfly, we actually ended up hurting them. We must realize it before it's too late!

The joy of seeing a single butterfly — in any form of its life stage — out in the wild in its natural habitat is far greater than seeing hundreds of them in captivity!

The value of rearing monarchs for educational purposes in classrooms and nature centers cannot be undermined. It is extremely important to educate people — kids and adults alike — about these marvelous creatures and their wondrous life cycle. But that can be easily achieved by raising just a handful of monarchs; we do not need to rear hundreds of them. But even as we make such noble efforts towards educating our children, we must take a pause and ask ourselves — *why do we need to bring nature indoors to teach our children; why can't we take our children (and adults) out in nature and let them explore and learn by experiencing nature?* We must ask ourselves if in doing so, we are inadvertently contributing to the "nature-deficit disorder" in our children — a term described by Richard Louv in his famous 2005 book "Last Child In The Woods"! Watching a monarch in its different life stages in captivity is not much different than watching the same on a video screen (there are plenty of high-quality time-lapse videos available that beautifully show the metamorphosis of the butterfly). Instead, we must allow the children and adults (there is a little bit of child in all of us!) a chance for an experiential learning. Hiking out in the field, turning milkweed leaves to look for monarch eggs or caterpillars, then look for chrysalises hanging from a tree branch, would not only be a great fun "detective" activity, but the educational impact and effectiveness would be infinitely greater than watching or rearing the butterflies in captivity. Out in the wild, not only do we

have the opportunity to educate about monarchs, but everything associated with them. Learning about monarchs out in the nature also helps in gaining an understanding as well as an appreciation for the ecosystem, in general. In the field, the curious observers can see for themselves the critical importance of the necessary habitat for the butterflies, and how everything in nature is connected with one another in this intricate web of ecosystem. In our attempt to educate our children about nature by bringing nature indoors, we are not only depriving them of the physical exercise but also robbing them of the valuable spiritual nourishment and a learning experience necessary for the overall development of the mind and body.

Raising monarchs at home and then releasing them has somewhat become a part of culture and family tradition for many. And there is absolutely no harm in rearing a few butterflies at home for such emotional reasons. But if we keep raising them in large numbers and buying commercially-bred monarchs to release at festive events, to the very least, let's not do that in the name of conservation!

Let's plant more milkweed and other nectar-producing native plants!

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