Proceedings of the Trinational Monarch Science Meeting:

Moving Forward on the Conservation of the Monarch Butterfly in North America

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Cover photo : Greg Mitchell

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Jose Ignacio Mijares

Acknowledgments

We would like to thank the following people who helped make our visit to the Piedra Herrada Sanctuary an unforgettable experience.

Ejido San Mateo Almomoloa

Commissioner: **Juan Hernández Martínez**

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Managers of the Touristic Area: **Rosalío Hernández Hernández** and **Alicia Peña Flores**

And all the *ejidatarios* that carry out recreational activities inside the Sanctuary: surveillance personnel, tourist guides, horse owners (*caballerangos*), and cooks.

Technical personnel from the Natural Protected Area

Doris Martínez Vera

Rutilo León García

Overview

In 2017, the Commission for Environmental Cooperation (CEC) initiated a project, entitled "Science for Monarch Butterfly and Pollinator Conservation," that focused on the need for cohesive coordination of monitoring and research, contributing to adaptive conservation for monarchs, and leveraging the efforts of the Trinational Monarch Conservation Science Partnership (T-MCSP), created through the CEC in 2016.

The Trinational Monarch Science Meeting took place in Mexico City, Mexico, from 29 January to 1 February 2019. The meeting objectives were to:

- Celebrate successes in trinational monarch conservation.
- Share the state of research and monitoring on the monarch butterfly.
- Discuss research priorities for the monarch butterfly and its habitat.
- Promote trinational collaboration and communication.

The meeting convened government experts, researchers and key stakeholders from Canada, Mexico and the United States, who shared innovative research and important scientific findings on the monarch butterfly, established further collaborations for data sharing, and identified trinational research and monitoring priorities to support further monarch butterfly and pollinator research in North America.

Meeting participants shared knowledge and participated in working sessions focused on four trinational priorities:

1. Monarch breeding habitat
2. Overwintering populations
3. Pollinator conservation
4. Monarch migration

In addition, meeting participants visited the monarch butterfly overwintering colony at Piedra Herrada, in the state of Mexico and, during the last day of the meeting, shared knowledge through presentations organized around:

- Population ecology
- Breeding/migration/overwintering colony
- Citizen and community science and monitoring

Welcome remarks were given by **Andrew Rhodes**, National Commissioner for the National Commission of Protected Natural Areas (*Comisión Nacional de Areas Naturales Protegidas*—Conanp). Domestic updates on priority research and monitoring topics were given by **Greg Mitchell** (Environment and Climate Change Canada), for Canada, and **Víctor Sánchez-Cordero** (Institute of Biology, UNAM), for Mexico. **Chip Taylor** (University of Kansas) gave the keynote presentation on "Celebrating citizen science trinational efforts."

This report includes the presentation abstracts submitted by the presenters and summaries of the

Working Sessions

During each session, participants were asked to:

1. Share the state of knowledge.
2. Identify shared research priorities and opportunities for collaboration.
3. Focus on identifying science gaps.

Monarch Breeding Habitat

Knowledge gaps and research priorities

- Evaluate agricultural incentive programs and tax abatements as opportunities to create pollinator habitat in intensive agriculture areas.
- Evaluate where management actions should be applied to effect the greatest change in populations at the lowest possible monetary and non-monetary costs to management agencies and societies.
- Quantify density / nutrition / variety / abundance of nectar plants needed for breeding and migration.
- Evaluate if nectar uptake varies between flower species (including invasive species), considering temperature, relative humidity, and competition.
- Assess whether nectar availability is a limiting resource for monarchs at any stage of their annual cycle.
- Develop an index of body condition relative to lipid mass for live monarchs.
- Monitor body condition of monarchs throughout migration to understand when and where monarchs are limited by food.
- Assess water availability and its importance as a limiting factor.
- Determine importance of water versus carbohydrates from nectar for monarch survival.
- Assess mass-specific metabolic rate over a range of temperatures, considering its implications for carbohydrate and nectar acquisition.
- Assess the importance of the Canadian population to the broader migratory population and its potential importance in the future, given climate change.
- Examine the role of climate change in current population declines and its importance in the future.
- Consider if current recovery actions are sufficiently robust, given predicted patterns of climate change.
- Assess the importance of stopover / roosting sites along the Great Lakes, given current extensive development there.
- Consider if weather at the wintering grounds has an important impact on phenology and reproductive ability, and survival during return migration.
- Assess the role of mowing regimes in rights-of-way for milkweed and nectar resource availability and quality.
- Disseminate information on how monarchs benefit other species and ecosystem processes – demonstrating stacked benefits.
- Develop a better understanding of the effects of agricultural chemicals on monarchs, e.g., breeding success, body condition, migration, survival rates and choice of mates.
- Assess effects of agrochemical drift and transport on habitat being restored areas in places surrounded by intensive agriculture.
- Assess monarch use of roadside habitats, including when, where, and how often roadsides are used, and the effects of collisions with vehicles on mortality.
- Assess the effects of pathogens, parasitoids, and natural enemies on monarch reproductive success across life stages, habitats, regions, climate, and the interaction of these stressors with climate change.
- Examine possible Allee effects at low population densities related to mate searching.

- Examine multi-year recolonization patterns and their relationship to the previous year's productivity and spring conditions.
- In terms of human dimensions, evaluate the barriers to creating and maintaining monarch habitat.
- Assess the importance of scale in restoring habitat patches; patch size-thresholds and value across scales.
- Validate current assumptions about milkweed stem estimates with respect to geographic sectors and habitat types.

Overwintering Populations

Knowledge gaps and research priorities

- Maintain collaborative research and management to maintain overwintering habitats (top priority).
- Consider a holistic approach on research and monitoring of natural disturbances (e.g., fire) and human activities to understand their relationship with maintenance of overwintering refuges, biodiversity and ecosystem health.
- Identify and conserve priority sites throughout the migratory flyways.
- Develop studies on water (quality, quantity and availability) as an essential component of the forests where overwintering occurs to avoid unsustainable water use by human activities.
- Foster the exchange of experiences and knowledge with research and conservation groups from California and compare their observations with those of the Eastern population.
- Evaluate and follow-up on restorations of disturbed overwintering sites.
- Perform long-term retrospective analysis of changes in ecological conditions in the overwintering forests.
- Promote systematic ecological restoration, including monitoring to assess effectiveness.
- Use GIS models of habitat suitability to detect other overwintering colonies and promote their conservation (e.g., Lagunas de Zempoala, Bosques de Guerrero, etc.).
- Develop a monarch butterfly research program to seek funding from the National Science Council of Mexico (Conacyt).
- Promote the use of the Trinational Monarch Knowledge Network (TMKN) among protected area management staff.
- Carry out a holistic research study on mortality factors and generate base lines to understand spatial and temporal dynamics.
- Carry out holistic research studies on habitat dynamics and conditions in the overwintering sites, including aspects of ecological succession.
- Increase attention on the overwintering sites in California, considering their essential role in the conservation of the monarch butterfly.

Greg Mitchell

Climate change

- Increase the study of climate change and its trends to support effective reforestation and ecological restoration within a climate change framework.
- Increase the monitoring of climate and microclimate conditions at the overwintering sites.

Tourism management and land use planning

- Considering the increased number of visitors to overwintering sites, support local communities to improve the management of tourism activities.
- Improve public communication to avoid negative impacts from visitors at overwintering sites.
- Promote diversification of economic activities in local communities throughout the year.
- Regulate irregular visits in the Nevado de Toluca to overwintering sites that are not open to the public, since these colonies might be increasingly important for the survival of the monarch butterfly.
- Control cattle ranching activities to avoid negative impacts on the overwintering forests.
- Study successful cases of managing heavy tourism in areas important to conservation.

Public awareness

- Implement public awareness campaigns with local communities to better convey the role of scientific research, its results, and current priories in conserving monarch butterflies.
- Promote environmental culture at a local level to benefit environmental health in the entire region.

Pollinator Conservation

Knowledge gaps and research priorities

Social and communication aspects of pollinator conservation

Monarchs can play a role as a symbol and "gateway" species for pollinator conservation, more broadly; however:

- The pitfalls of single-species conservation should be avoided (e.g., need to promote a diversity of plants, not just milkweed or plants attractive to monarchs).
- Work is needed to shape/influence the messaging to the public, emphasizing that habitat is necessary for the entire insect community/ecosystem.
- Other species can be identified as symbols of pollinator conservation across national borders, e.g., bats, moths.
- Messaging can focus on other species that are important pollinators of agricultural crops.
- Integrated Pest Management techniques can be promoted, rather than heavy pesticide use.
- Social scientists should be engaged to better develop the human dimensions of monarch and pollinator conservation.

Habitat protection, creation, and restoration

- Continue to promote pollinator habitat protection, creation and restoration in a variety of landscapes and considering a variety of audiences, including urban/suburban, farms and ranches (and other "working lands"), roads, other rights-of-ways, etc.

Monitoring and research

- Need to identify key species to start monitoring in protected areas in northern Mexico.
- Need for more baseline monitoring on species other than monarchs and honeybees. (e.g., another group starting to gain better baseline data are the bumblebees, via Bumble Bee Watch).
- Leverage existing citizen science efforts (e.g., eButterfly)
- Use targeted sampling to establish baseline abundance, diversity, richness, etc. (e.g., using DNA barcoding techniques)
- Improve understanding of the impacts of invasive plants on pollinators, particularly on specialist species.
- Research is necessary on vital rates of different pollinator groups (including monarchs) in habitats with different levels of pesticide loading.

Policies and coordination

- Improve regulation on the movement of commercially raised bees (e.g., bumblebees, honeybees) to minimize the negative impacts of disease transmission on wild, native bee populations.
- Improve coordination to address the regulation and use of pesticides—particularly of neonicotinoid insecticides, which are associated with sub/lethal effects and even population declines, in monarchs and other species of butterflies and bees.

Monarch Migration

Monarch migration considers: 1) timing of departure from breeding grounds, 2) en route movements, 3) nectaring/refueling, and 4) roosting.

Knowledge gaps and research priorities

Fall migration

- Optimization modeling is required.
- Evidence suggests local weather conditions affect decisions to migrate. However, there is a need for finer-scale data of conditions when populations start migrating.
- Information on flights/fueling, duration of daily flights, nectaring requirements and body condition indices (e.g., lipids) is necessary.
- Monitoring of overwintering fat is required.
- Research is necessary on:
  - Energetics
  - Lipid assays or a non-destructive index (mass/wing length)
  - Metabolism (diurnal patterns and effects of temperature)
  - Differences in fat load between migration sites and overwintering sites, addressing nectaring needs

Spring migration

- Poorly understood aspects include:
  - Survivorship in Texas
  - Use of radio tagging
  - Returning recolonization
  - Later generation recolonization (tracked with stable isotope assays)

Presentations

(abstracts submitted by the authors)

Greg Mitchell

Plenary Sessions

1. Is the monarch decline due to habitat loss or an increase in mortality during the fall migration?

Orley "Chip" Taylor, **Jim Lovett**, **Ann Ryan**, Monarch Watch, Kansas Biological Survey, University of Kansas, Lawrence, KS, United States **John Pleasants**, Department of Ecology, Evolution and Organismal Biology, Iowa State University, Ames, Iowa, United States, **Ralph Grundel** and **Sam Pecoraro**, US Geological Survey, Chesterson, IN, United States

The decline in monarch numbers has been attributed to a loss of habitats containing milkweeds in the western part of the Upper Midwest (100-90°W longitude and north of 40°N latitude). In spite of evidence supporting this view, an alternative interpretation has been offered to explain the decline. The authors of four papers have asserted that the decline is due to mortality during fall migration, based on the assumption that butterfly counts in areas east of 90W should predict overwintering numbers. We used data produced through Monarch Watch's long-term monarch tagging program to examine these interpretations. These data show that the numbers tagged each fall are correlated with the overwintering numbers. Further, there has been no decline in the proportions of monarchs recovered over the last 18 years, an expected outcome if mortality during the migration had increased during this period. Because of the adoption of herbicide-tolerant crop lines, milkweeds largely disappeared from row crops by 2006. To determine whether this change contributed to the decline, we analyzed tagging before and after 2006. Tagging success declined in the areas west of 90°W after 2005, while it increased in areas to the east. This result is consistent with the interpretation that habitat loss is the main driver of the decline. In addition, an analysis of tagging and recovery of monarchs tagged east of 90°W indicates that monarch production in that region is not correlated with overwintering numbers. Rather, it is the production west of 90°W that determines the size of the overwintering population.

Greg Mitchell

2. The Trinational Monarch Knowledge Network (TMKN) – enabling large-scale monarch research and conservation through openly accessible data

Maxim Larrivée, **André-Philippe Drapeau**, *Insectarium de Montréal,* Montréal, Québec, Canada, **Denis Lepage,** Bird Studies Canada, Canada, and **Rodrigo Solis**, Simon Fraser University, British Columbia, Canada

Until now, outside of predictive model extrapolations, broad geographic and habitat-specific knowledge of North American monarch and milkweed densities was lacking. Most data were scattered among a number of monitoring organizations across the continent. Each organization possessed its own monitoring protocol and database structure, making data incompatible and halting comprehensive, continental-scale analyses. Large-scale threats to migratory monarch populations are present across the butterfly's whole life cycle and still poorly understood. In order to run large-scale analyses on monarch and milkweed trends in space and time, common data standards must be adopted by monarch monitoring organizations so data can be combined and made readily accessible. Using international biodiversity information standards to manage monarch and milkweed data was identified as a top priority of the trinational committee on monarch conservation. The Trinational Monarch Knowledge Network (www.monarchknowledge.net) was built to achieve this goal. This online platform combines monarch and milkweed data from different North American monitoring programs into a common, open-access database. The platform allows uploading, downloading, and visualization of monarch and milkweed data from all three countries directly through the portal. This will facilitate and accelerate analyses to build new and valuable broad-scale monarch conservation knowledge that can be implemented across the continent. [A brief outline of the TMKN and its tools was also presented.]

3. Application of LiDAR for the assessment of colony size and overwintering density of monarch butterfly populations

Nickolay Hristov, Louise Allen, Center for Design Innovation, Winston Salem, NC, United States and Winston-Salem State University, Winston Salem, NC, United States, **Dennis Nikolaidis**, Winston-Salem State University, Winston Salem, NC, United States and **Tatjana Hubel**, Royal Veterinary College, London, United Kingdom

The monarch butterfly is in danger, threatened across much of its distribution range by a fast-changing world. To save this iconic species, the global community of scientists, policymakers and the public must select the right tools and act fast to support an unprecedented effort. The ability to assess population numbers and long-term trends at a fine temporal and spatial scale is important and necessary to measure a species' wellbeing. To date, few such tools exist for monarchs. LiDAR technology and its associated computational tools offer a promising method to assess the abundance and density measures needed to build on decades-long efforts to monitor monarch populations in Mexico and the US. We will share the results from the ongoing development of the Subtractive Volume Estimation (SVE) suite of techniques that rely on the inherent accuracy of terrestrial laser scanning, combined with computational metrology and shape analysis of polygonal geometry, based on data from the US West Coast and overwintering monarch sanctuaries in Mexico. Collectively, this work represents the first efforts to estimate accurately and automatically, the size of large monarch aggregations at the individual level. The adaptation and application of innovative technologies into robust practice is an ongoing, iterative process of refinement and improvement that transforms the seemingly impossible into an everyday practice. LiDAR and SVE promise to become a powerful tool in the assessment of widespread monarch conservation efforts.

4. Effects of sex, collection date and vital status on natal origins of overwintering monarch butterflies from eastern North America

Tyler Flockhart, University of Maryland Center for Environmental Science, United States and
Isabel Ramírez, *Centro de Investigaciones en Geografía Ambiental*, UNAM, Mexico

Understanding migratory connectivity between the breeding and wintering grounds is critical for the development of effective conservation strategies for migratory animals. Eastern North American monarch butterflies (*Danaus plexippus*) overwintering in central Mexico first demonstrated that the measurement of stable-hydrogen ($\delta^{2}H$) and carbon ($\delta^{13}C$) isotope ratios in monarch wing chitin could be used to infer natal origins and therefore allows the identification of key zones of production across the United States and Canada. An untested assumption is that historic samples of monarch butterflies collected dead show similar patterns in assign natal origin compared to monarchs that were collected alive while accounting for mortality effects over the overwintering period. We collected alive and dead monarchs across the overwintering season of 2015–2016 and 2017–2018 and used stable-hydrogen and -carbon isotope ratios to assign a natal origin. We applied novel spatial regression models to understand how variation in spatial natal origin patterns across the breeding distribution were explained by sex, collection date, vital status, year, and body weight. Overall, and consistent with previous studies, the main area of productivity was the Midwest. Monarchs collected dead were significantly more likely to have natal origins in a band across the central United States, from central Kansas to eastern Tennessee, and significantly less likely to have natal origins in a small area of the Midwest and the northern half of Minnesota compared to monarchs collected alive. Male monarchs were significantly more likely to have natal origins in the central Midwest compared to females. Monarchs with low dry body mass were significantly more likely to have natal origins in the south-central United States between Texas and Nebraska and east to the Carolinas. Our study provides evidence of differential mortality of monarchs in Mexico and therefore has implications for making long-term collections and deriving robust inference regarding population productivity and conservation planning. Our analytical approach provides a method to identify spatial variation in natal origin across space that can be coupled with long-term collections to provide a complete overview of changes in natal origin of monarchs over space and time. These approaches help to provide foundations for using historic biological samples for restoration planning purposes and robust techniques to monitor responses to landscape-scale restoration activities.

Greg Mitchell

5. Monitoring efforts in northwest Mexico

Francisco Botello, Conbiodes A.C.

The monarch butterfly (*Danaus plexippus*) population fell drastically in the 2013–2014 season. This population decline led to intensified monitoring of the species along their migration routes. However, the data collected in 2016–2017 pointed to a lack of information on the importance of the states in northwestern Mexico to monarch butterfly populations and their western migratory path. This work describes five training workshops that deal with scientific knowledge on the monarch butterfly, monitoring, and the collection of data and biological samples. The workshops were given to personnel of protected natural areas, civil society organizations, academia, government institutions and the public at large interested in the monarch butterfly. The publication also describes the National Digital Platform for monarch butterfly monitoring and training for its use. This platform is intended to form networks and join efforts in the different states in northern and northwestern Mexico to obtain a large quantity of systematized data. As a result of the training and manual and digital data entry, historical records from 2008 to 2019 were obtained, recording eggs, larvae, pupae, and adults flying, perching and feeding. The data have been incorporated into maps of the region to identify priority monarch butterfly conservation zones, as well as to establish a permanent monitoring network in northwestern Mexico.

6. Nectaring sites and lipid reserves of monarch butterflies in northeastern Mexico

Rogelio Carrera-Treviño, *Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nuevo León,* Nuevo León, México, **Rocío Treviño-Ulloa**, *Programa Correo Real, Profauna*, Saltillo, Coahuila, México and **Blanca X. Mora-Álvarez**, Department of Biology, Western University, Ontario, Canada

The accumulation of lipids determines the survival of migratory and overwintering monarchs. Monarchs migrating from Canada to Mexico need to accumulate lipids during their migration to survive the winter. Nectaring in Texas and Mexico on their migration south is key for monarchs to store lipids to survive the winter. We collected 450 monarchs during migration in 2018 (65 in spring and 385 in fall) to assess lipid reserves. We used available historic data from citizen science programs on nectaring monarchs in northeastern Mexico to identify important areas for nectaring during fall migration, and to model potential impacts of climate change using GIS. Lipid contents in spring were consistent with reported values in Texas, Louisiana and Oklahoma, when monarchs are close to the end of their life cycle. Lipid reserves during fall were considerably lower than what have been reported for Texas and suggested that monarchs during fall migration in 2018 had to accumulate reserves south of northeastern Mexico in order to survive the winter. Potential nectaring areas identified human-dominated landscapes along the eastern Sierra Madre Oriental mountain range, with decreasing probability of nectaring sites toward the coast and the Altiplano regions. The most important variables in predicting nectaring sites were distance to irrigated agriculture, precipitation, and slope. An increase in temperature, a decrease in precipitation, and an increase in irrigated agriculture under climate change scenarios is predictive of increased nectaring areas, but caution must be used in interpretation since data were provided by citizens in human-dominated landscapes.

7. Using pollen identification techniques to determine plant species frequented by monarch butterflies

Mauricio Quesada, Oliverio Delgado-Carrillo, Armando Aguirre-Jaimes, Francisco Javier Balvino-Olvera, Jorge Cortez Flores, Edson Jacob Cristóbal-Pérez, Gumersindo Sanchez-Montoya, Violeta Patiño-Conde, Ulises Olivares-Pinto, *Laboratorio Nacional de Análisis y Síntesis Ecológica, Escuela Nacional de Estudios Superiores, Unidad Morelia, Universidad Nacional Autónoma de México*, Mexico, **Eduardo Rendon-Salinas, Angélica Navi Reyes-Ruiz,** World Wildlife Fund, Mexico**, María Eugenia González-Díaz, Jerónimo A. Chávez-Cisneros,** *Ecosistemica A.C.,* Mexico, and **Rogelio Carrera-Treviño,** *Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nuevo León*, Nuevo León, Mexico

The massive migration of monarch butterflies (*Danaus plexippus* L.) in North America is a unique biological phenomenon that has attracted the attention of scientists and public in general over two centuries. Monarch butterfly populations that hibernate in Mexico have unfortunately decreased over the last three decades. A reduction in habitat and floral resources for food are among the main factors affecting the decline of monarch populations. Nectar obtained from flowers during the journey is essential for the roundtrip migration of monarch butterflies. Little is known about the identity and quantity of floral species used along migratory pathway of monarchs in Mexico. We characterized in situ the taxonomic composition and abundance of available floral resources used by monarch butterflies in Mexico. We will also use last generation meta-genomic DNA techniques to determine the identity of pollen mixtures carried on the butterflies bodies. We sampled nine sites located within the migratory pathway to estimate the diversity and abundance of floral resources used by the monarch butterflies. These sites are representative of the eastern migratory route of the monarch butterfly in Mexico. A total of 17 plant families and 65 flowering species were identified. *Asteraceae* is the family systematically present in all sampling sites and monarch butterflies were observed feeding on the flowers of several species (i.e., *Cosmos bipinatus*, *Tithonia tubiformis*, *Helianthus* spp.) of this family. This study will provide information to design strategies for the conservation of nectar corridors for monarch butterflies.

8. Conanp and its monarch butterfly monitoring efforts

Gloria Tavera, *Comisón Nacional de Áreas Naturales Protegidas*, Conanp

The National Program for the Conservation of the Monarch Butterfly Migratory Phenomenon, led by Conanp, has allowed the facilitation of actions throughout Mexico. For the past five years (2014–2018), Conanp has been actively working on the establishment of agreements, objectives and goals, the facilitation of participatory forums and the implementation of projects. The Monarch Butterfly National Monitoring Network in Mexico held its fifth meeting in Saltillo, with an outstanding participation from across the country. In addition, the creation of the National Partnership for the Conservation of Monarch Butterfly in Mexico—the first national effort developed for the conservation of monarchs in Mexico–was able to facilitate the collaboration of the 23 states that are part of the migratory route and that host overwintering sites. The National Platform for the Monitoring of the Monarch Butterfly in Mexico was developed to integrate monarch butterfly data based on the national monitoring protocol. Outreach campaigns have allowed the engagement of citizens and promote the conservation of this important North American emblematic species.

Population Ecology Session

9. Status of the western monarch: Population viability below the quasi-extinction threshold?

Elizabeth E. Crone, Tufts University, Medford, MA, United States, **Cheryl B. Schultz**, Washington State University, Vancouver, WA, United States, **Emma M. Pelton**, **Sarina Jepsen**, and **Scott Black**, Xerces Society, Portland, OR, United States

The western monarch population is in steep decline. In summer 2017, we completed an analysis that indicated the population had declined from millions of monarchs in the 1980s to a few hundred thousand butterflies. We predicted a 72% probability of dropping below the quasi-extinction threshold in the next 20 years. The quasi-extinction threshold, set by knowledge of western monarch biology and expert opinion, was set at 30,000 monarchs. The Western Monarch Thanksgiving Count of 2018 indicates that we are already below that threshold, less than two years after completing the 2017 analysis. Our monitoring across the West, through the breeding seasons in 2017 and 2018 indicates that, with fairly high certainty, the decline in abundance occurred between the time when monarch butterflies leave wintering sites on the California coast and when they arrived on summer breeding grounds. However, we do not believe there is a single "event" that caused the sharp decline—but rather that the sharp decline in 2018 is the result of long-term declines in face of cumulative stresses to the population, in combination with large population swings that are an inherent aspect of butterfly population dynamics. For the population to recover would require bolstering it sufficiently for it to be able to again experience natural population swings.

10. Size of the Canadian breeding population of monarch butterflies is driven by factors acting during spring migration and recolonization

Greg W. Mitchell, Wildlife Research Division, Environment and Climate Change Canada, Canada, **Tara L. Crewe**, National Data Center, Bird Studies Canada, Port Rowan, Ontario, Canada & College of Engineering, IT and Environment, Charles Darwin University, Darwin, NT, Australia and **Maxim Larrivée**, *Insectarium de Montréal*, Montréal, Québec, Canada

The eastern North American monarch butterfly population has shown a long-term population decline. While there is general agreement that forest loss on the wintering grounds and milkweed loss throughout the breeding range are at least partly responsible, there is much less certainty regarding the factors driving year-to-year variability around the current population level. Using 15 years of butterfly count data, we used a community-based approach to determine the stage of the annual cycle where the Canadian population is most strongly limited. We compared annual fluctuations in size of the breeding population of monarch butterflies in Canada to fluctuations in 13 additional butterfly species, which either migrate long distances to Canada or are resident but breed in similar habitats as monarchs. We show that the breeding population of monarchs in southern Canada shows a high degree of synchrony with other long-distance migrants but not with breeding residents and that annual fluctuations of all migratory species shows a positive correlation with the number of 21˚C days during spring migration and re-colonization. Further, we found that size of the monarch breeding population is not predicted by the previous overwintering population size, but instead that the breeding population size is positively correlated with the following winter's population size. Combined, our results suggest that monarchs in Canada are limited by factors acting during spring migration, and that climate plays an important role in the ability of the monarch to successfully re-colonize and breed in the northern portion of their summer range.

11. Multi-scale seasonal factors drive the size of winter monarch colonies

Elise Zipkin, Michigan State University, **Sarah P. Saunders**, Science Division Audubon Society, **Leslie Ries**, **Naresh Neupane**, Georgetown University, **M. Isabel Ramírez**, *Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México*, Michoacán, México, **Eligio García-Serrano**, *Fondo Monarca*, Mexico, and **Eduardo Rendón-Salinas**, World Wildlife Fund México

Monarch butterflies in eastern North America have declined by 84% on Mexican wintering grounds since the observed peak in 1996. However, coarse-scale population indices from northern US breeding grounds do not show a consistent downward trend. This discrepancy has led to speculation that autumn migration may be the critical limiting period. We address this hypothesis by examining the role of multi-scale processes impacting monarchs during autumn, assessed using arrival abundances at all known winter colony sites over a 12-year period (2004–2015). We quantified effects of continental-scale (climate, landscape greenness, disease) and local-scale (colony habitat quality) drivers of spatiotemporal trends in winter colony sizes. We also included effects of peak summer and migratory population indices. Our results demonstrate that higher summer abundance on northern breeding grounds led to larger winter colonies, as did greener autumns, a proxy for increased nectar availability in southern U.S. floral corridors. Colony sizes were also positively correlated with the amount of local dense forest cover and whether they were located within the Monarch Butterfly Biosphere Reserve, but were not influenced by disease rates. Although we demonstrate a demographic link between summer and fine-scale winter population sizes, we also reveal that conditions experienced during and after autumn migration impact annual dynamics. Monarchs face a growing threat if floral resources and winter habitat availability diminish under climate change. Our study tackles a long-standing gap in the monarch's annual cycle and highlights the importance of evaluating migratory conditions to understand mechanisms governing long-term population trends.

12. Understanding the Monarch's Migration; A System Dynamics Approach

Rodrigo Solis-Sosa, **Arne Mooers**, **Sean Cox**, Simon Fraser University, British Columbia, Canada, **Christina Semeniuk**, University of Windsor, Ontario, Canada, and **Maxim Larrivée**, *Insectarium de Montréal*, Montréal, Québec, Canada

The monarch butterfly, iconic species that migrates annually across North America, has steeply declined in numbers over the past decade. Currently, the most studied and supported cause of the monarch's plight is the milkweed-limiting hypothesis. This hypothesis states that milkweed loss across the monarch's breeding range due to the use of GM-specific herbicides has been the bottleneck of its migratory and biological cycle. Recently, evidence has accumulated suggesting that this might not be the only factor affecting the monarch, and perhaps not the most important. Here, we built a population model of the monarch butterfly through a System Dynamics approach to assess the leverage that different alternative factors (anthropogenic and non-anthropogenic) might have in the overall trends seen in the overwintering colonies. Namely, we wanted to explore if the monarch was affected by patch configuration (depensatory effects), by parasitism (change in sex ratio over time), and by climate change (increase on extreme weather events during the fall migration), and compared them with the effect of the primary current hypothesis, the milkweed-limiting hypothesis. This research is still undergoing effort, but some preliminary results and insights will be shared.

Greg Mitchell

Breeding/Migration/Wintering Ecology Session

13. Estimates of mortality of monarch butterflies crossing two highways during fall migration in northeastern Mexico

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Monarch butterflies face several causes of mortality during their lifecycle but, in general, collisions with vehicle traffic have been much overlooked. Monarchs are especially vulnerable during fall migration when they are known to cross several major highways in large numbers, especially in northeast Mexico. During the fall migration of 2018 (15 October to 11 November), we quantified monarch crossing and subsequent roadkills at two crossings: La Muralla, Highway MEX-057, Saltillo-Monclova km 128 (26º 36' 72.15"N, 101º 35' 53.17" W) and Santa Catarina, a toll-highway MEX-40D, Saltillo-Monterrey km 58 (25º 39' 18.54"N, 100º 27' 12.24" W). We established a series of 500 m road transects (Six at La Muralla and five at Santa Catarina) where all roadkilled monarchs were removed and counted. During 15 days at La Muralla, 601 monarchs were collected and during 19 days at Santa Catarina 11280 monarchs were collected. Highest mortality occurred between 14:30 and 16:30 and coincided with lower flights associated with searches for nectaring and roost sites. Low vulnerable flights also occurred during inclement (rain) weather periods. We monitored traffic volumes and vehicle speeds at both sites and generally found that posted signs warning of monarch mortality are ineffective. We suggest that more effort to reduce road mortality, especially at Santa Catarina, is required for the short duration of monarch crossing. This could involve greater enforcement, temporary speedbumps or means of deflecting monarchs above the roadway.

14. The migratory route of monarch butterfly in Mexico through citizen science

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Since 2012 we have used Naturalista citizen science platform www.naturalista.mx as a tool to record plant and animal species in Mexico. To analyze the monarch butterfly migratory route, I used two projects: the first one contains all monarch butterfly records in Mexico (observations = 5,977 and participants = 1,005) and the second, includes only overnight roosts in the migratory route (observations = 315 and participants = 77). In this study I analyze roosting sites in each of the states with records (Coahuila, Nuevo León, Tamaulipas, San Luis Potosi, Guanajuato, Querétaro, Michoacán and the State of México) and the seasonality of observations in different years (2014–2018). Some roosting sites used in different years and in the fall (July to December) and spring migration (March and April) are documented. Observations of overnight roosts are increasing but it is still necessary to identify more sites, in particular, those used during the spring migration when the butterflies are heading north. Societal participation has been crucial in the documentation to begin understanding some of the geographic aspects of the monarch butterfly migratory route. All the information from citizen science is shared along with scientific collection records in the platform Enciclovida <www.enciclovida.mx>. It is imperative to maintain and restore overnight roosting sites both outside and inside protected areas to promote the continuity of the migratory phenomenon.

Greg Mitchell

15. Tracking origins of lipids in migrating and overwintering monarch butterflies

Keith A. Hobson, Department of Biology, University of Western Ontario, Canada and Environment and Climate Change Canada, Canada, **Blanca X. Mora Álvarez**, Department of Biology, University of Western Ontario, Canada, **Oscar García Rubio**, *Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro*, Mexico, **Eligio García Serrano**, *Fondo Monarca*, Michoacán, Mexico, **Isabel Ramírez**, *Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de Mexico*, Michoacán, Mexico, **Orley Taylor**, Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, KS, United States and **Rogelio Carrera-Treviño**, *Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nuevo León*, Nuevo León, Mexico

The accumulation of sufficient lipid stores to fuel migration and facilitate overwinter survival is crucial to the conservation of monarch butterflies wintering in Mexico. However, transporting lipids is costly and an optimal strategy would be to time lipid accumulation late in the migration period and close to wintering sites. Previous research has identified Texas as a key region for nectaring and fat accumulation in fall migrant monarchs but it is becoming increasingly clear that nectaring sites in northeast Mexico also play an important role. Stable isotope ($\delta^{2}H$ and $\delta^{13}C$) analyses of wing chitin have become a standard tool to approximate natal origins of migratory monarchs but lipids also contain high amounts of H and C which may also provide spatial information on sources of plant water and carbohydrates for lipid synthesis. We measured $\delta^{2}H$ and $\delta^{13}C$ in lipids and wings of fall migrating (Nuevo León, Coahuila, Querétaro, Guanajuato) and overwintering (Sierra Chincua, Piedra Herrada, La Mesa, Cerro Pelón) monarchs from 2015 through 2018 to evaluate the potential of this approach. We also conducted captive experiments on monarchs using known nectar sources to ground truth isotopic discrimination factors between nutrients and manufactured lipids. Our results indicate that despite broad natal origins, lipids are accumulated in a narrow geographic range. During the overwintering fasting period, lipids did not change in isotope values, suggesting that sampling could be performed throughout the winter period. While assignment to "liposcapes" remains elusive, isotopic analyses of bulk lipids has promise as an important monitoring and research tool.

16. Does parasite infection pose a threat to North American monarch migration?

Sonia Altizer, Richard Hall, **Ania Majewska** and **Dara Satterfield**, Odum School of Ecology, University of Georgia, Athens, GA, United States

Throughout their global range, monarchs are affected by a specialist neogregarine protozoan parasite. Parasites are transmitted when caterpillars ingest protozoan spores deposited onto eggs or milkweed by adult monarchs. Infections can reduce monarch size, survival, reproduction, and flight performance. Past work showed that long-distance migration reduces infection prevalence by allowing monarchs to periodically escape from habitats where pathogen stages have accumulated, and because infected monarchs migrate less well. Infection prevalence in migratory monarchs has historically been low, but can reach high levels in areas where monarchs breed throughout the winter months and do not migrate. Several important questions are: (1) does the presence of winter breeding monarchs in the southern US increase infection risk for migrating monarchs? (2) under what conditions can parasitic infections negatively impact monarch abundance? and (3) will habitat loss and crowding increase the future prevalence of infections in wild monarchs? Analyses of citizen science data show that parasite prevalence fluctuates within seasons and between years, and increases with local monarch density. Field monitoring of infections in winter breeding monarchs showed that fall and spring migrants can acquire infections from heavily infected local populations along their migratory flyway. Exploration of mathematical models of parasite transmission indicate that local crowding of monarchs and extended duration of the breeding season can increase parasite prevalence. Models further predict that prevalent parasitic infection can reduce local monarch abundance by up to 50%, suggesting that the protozoa could contribute to future declines of North American monarchs.

17. Are soil microfauna at monarch overwintering sites affected by secondary plant compounds sequestered by monarch butterflies?

Jeremy N. McNeil, Zoe Lindo, Department of Biology, University of Western Ontario, Canada, and **Isabel Ramirez**, *Centro de Investigaciones en Geografía Ambienta, Universidad Nacional Autónoma de México,* Michoacán, México

Many monarchs die in the roosting colonies at the overwintering sites in Mexico, and we tested the hypothesis that, upon decomposition of the butterflies, the release of cardiac glycosides and pyrrolizidine alkaloids, sequestered by monarchs as protection against natural enemies, would impact the soil microfauna. The analysis of duff and soil samples collected within and outside the roosting colonies, collected in February and May, 2018, revealed a significant decrease in both overall density of microfauna and species diversity of orbatid mites within the roosting sites. The possible role of changes in soil due to the release of secondary plant compounds and monarch fidelity to roosting sites will be discussed.

18. Monarch larval performance and oviposition preference on 9 Midwestern milkweed species

Victoria Pocius, Department of Entomology, Penn State University, State College, PA, United States and **John Pleasants**, Department of Ecology, Evolution and Organismal Biology, Iowa State University, Ames, IA, United States

Efforts are underway to restore milkweeds in the summer breeding range for monarch butterflies to help increase the monarch population. But of the many milkweed species that could be included in restorations which are most beneficial, i.e., which species are good for larval survivorship and female egg laying? Tori Pocius examined nine milkweed species found in the US Midwest. In the lab, larval survival to adulthood varied on the nine species, but for *Asclepias hirtella* and *A. sullivantii* larval survival was especially poor. In the lab, when presented with a single milkweed species, females were more inclined to lay eggs on *A. incarnata* and *A. syriaca* and less likely to lay eggs on *A. tuberosa* and *A. verticillata*. When presented with a choice of these four common species, the same preferences were found. Across multiple Iowa field plots consisting of all nine species, the species' preferences with regard to egg laying mirrored those of the lab studies. Thus, the species most likely to be used for restorations, *A. syriaca*, is in fact a highly beneficial species and, in addition, can be planted in a variety of habitats, unlike *A. incarnata* which, is restricted to wet habitats. Interestingly, there is a disconnect between which species females prefer to lay eggs on and larval survivorship. Larvae do well on *A. tuberosa* but females are less inclined to lay eggs on this species. Females are inclined to lay eggs on *A. sullivantii* but larvae do poorly on this species.

19. Experimental evidence that strategic mowing of common milkweed in linear right-of-ways can increase monarch butterfly egg abundance

Samantha M. Knight, **D. T. Tyler Flockhart**, **Rachael Derbyshire**, and **D. Ryan Norris**, Department of Integrative Biology, University of Guelph, Canada

The eastern North American migratory population of monarch butterflies (*Danaus plexippus*) has declined precipitously over the past few decades and some evidence suggests this decline could be due, in part, to the widespread decline of its obligate host plant, milkweed (*Asclepias* spp.). Linear right-of-ways (e.g., roadsides, powerline corridors) are believed to be a significant source of milkweed and represent a valuable target for restoration efforts. Most current management practices in these habitats are detrimental for monarchs because they are mowed too frequently. However, strategic mowing could be beneficial for monarchs if it produces young milkweed at the right time of season. The objective of our study was to determine whether a strategic mowing regime could improve milkweed quality and increase reproduction of monarchs in managed landscapes. Forty-nine paired experimental and control plots containing common milkweed (*Asclepias syriaca*) were established along habitat adjacent to a two-lane highway in southern Ontario. Groups of seven experimental plots were mowed at a specific time between early June and early August. Milkweed growth and the presence of monarchs at all life stages were monitored on all plots. Overall, mowed plots had higher egg abundance than controls, with the maximum number of eggs occurring between 20–28 days after mowing. There was no difference in larval survival rates between mowed and control plots. Within mowed plots, egg abundance was highest in plots mowed between the fourth week of June and the third week of July. At this latitude (43°N), mowing past this window was too late to benefit reproduction and would have resulted in high mortality of developing monarchs. Our results suggest that mowing common milkweed once in early July could maximize monarch butterfly reproduction in managed landscapes, such as right-of-ways and that, in order to allow enough time for eggs to develop into adults, mowing should not occur more frequently than once during the breeding season.

20. The role of indirect effects of climate change on the monarch butterfly (*Danaus plexippus*)

Heather M. Kharouba, Department of Biology, University of Ottawa, Canada

Research on the monarch related to climate change has thus far focused on direct effects of climate change but it can also influence species via indirect effects (e.g., resources, enemies). These effects are often less explored in climate change ecology but have been shown to amplify or diminish the direct effects, and are therefore important in understanding the overall implications of climate change. For the monarch, such indirect effects are likely to occur via changes in the timing of events in the monarch's life history events (e.g., the larval stage) relative to the timing of key stages in the milkweed life history stages (e.g., peak biomass, flowering). The relative timing between the monarch and milkweed could be disrupted by changes in the timing of spring or fall migration due to climate change and/or differential responses of the monarch and milkweed to warmer summer temperatures within the breeding grounds (i.e., they develop at different rates). Changes to the timing of the monarch-milkweed interaction may also disrupt synchrony with their natural enemies. I will present results from lab and field experiments whose aims were to isolate direct from indirect effects of warming on milkweed versus monarch performance and discuss the broader implications of these findings for the butterflies.

Greg Mitchell

Citizen and Community Science/Monitoring Session

21. Another side of Mission Monarch

Sonya Charest, **Maxim Larrivée** *Insectarium de Montréal,* Montréal, Québec, Canada, **André-Philippe Drapeau-Picard**, *Insectarium de Montréal,* Montréal, Québec, Canada, and *Institut de recherche en biologie végétale*, Québec, Canada

Mission Monarch, a participatory science project par excellence, has truly taken flight. This success of course serves the interests of science, and is mainly focused on identifying the best breeding sites for monarchs. However, *Mission Monarch* is also a remarkable vector for education. In that sense, 2018 was a particularly fruitful year. In order to inspire very young children, inculcate science education, and provide an opportunity to act in favour of biodiversity, the scenarios for *Mission Monarch* activities were developed for elementary school pupils. These activities have been tested with teachers and will be recommended to all schools at the end of this school year, when the monarchs return. The *Mission Monarch* team also participated in public events on science and environment-related issues throughout Quebec. These events raised the awareness of participants on the importance of saving the monarch and encouraged them to take action. They undoubtedly contributed to increasing the data collected this past year. To increase the ranks of *Mission Monarch* ambassadors—persons motivated to recruit project supporters—we need to count on more help than just the team at the Insectarium. Thus, during a major tour of Quebec and Ontario, over 230 volunteer team leaders were trained and are now equipped to mobilize their communities. As a signatory of the *Mayor's Monarch Pledge*, the City of Montreal held a gala event last August: the *Fiesta monarque*. This magical moment, celebrating citizens' involvement in efforts to save the monarch butterfly, was a great success. And naturally *Mission Monarch* was there to encourage citizens to keep up the good work. Finally, these projects and activities all made a lot of noise and attracted media coverage, i.e., enviable visibility for the campaign to save the most beautiful of the butterflies, and for *Mission Monarch*, as well.

22. The 2018 Trinational Monarch Monitoring Blitz: An unprecedented mobilization

André-Philippe Drapeau Picard, *Institut de recherche en biologie végétale*, Québec, Canada and *Insectarium de Montréal,* Montréal, Québec, Canada, **Sonya Charest** and **Maxim Larrivée**, *Insectarium de Montréal,* Montréal, Québec, Canada

The Trinational Monarch Monitoring Blitz was launched to estimate the breeding population of migrating monarchs in North America. Held from 28 July to 5 August 2018, it was the first time such an event took place in all three countries of North America. Beginning in late April, representatives from organizations in Canada (Montreal Insectarium/Space for Life Foundation, Environment and Climate Change Canada), the United States (US Fish and Wildlife Service, Monarch Joint Venture) and Mexico (*Comisión Nacional de Áreas Naturales Protegidas*) held bi-weekly meetings to establish timelines, discuss logistics, identify partners, etc. The communications teams of every participating organization contributed to developing and implementing a communications plan. The Blitz mobilized nearly 500 observers, who counted approximately 55,000 milkweed plants and 14,000 monarchs in 324 locations. In addition to the considerable data collected, the event attracted widespread media attention, thereby generating major visibility for the monarch, as well as for the organizations participating in the Blitz.

23. Tracking monarch migration with Journey North – a 25-year retrospective

Elizabeth Howard, Journey North, Vermont, United States

Founded in 1994, Journey North is a citizen science project that tracks monarch migration each fall and spring as the butterflies travel to and from Mexico. Everyday people are collecting data, raising questions, and shedding light on key facets of monarch migration biology. The late Dr. Lincoln Brower marveled at the value of citizen science and the contributions made through Journey North. *"Without this sort of citizen input, imagine how much we would never know!"* he'd say. In his honor, we look at what we'd never know—and what we've learned—after 25 years of tracking migration, a critical stage of the monarch's annual cycle.

24. Integrated Monarch Monitoring Program implementation

Cariveau, A, W Caldwell, **L Lukens, K Kasten, J Thieme, K Tuerk, K Oberhauser, W Thogmartin, E Weiser, P Ward, J Newman, P Drobney, R Drum**, **J McIntyre**, **T Turner**, **D Konzek**, **R Easterbrook**, **A Gilbert**, **K Hamilton**, **K Kinkea**d, **R Grundel, K Baum**, **J Pleasants**, **H Holt**, and **G Butcher**, Monarch Joint Venture, United States

Steep declines in North American monarch butterflies (*Danaus plexippus*) have prompted continent-wide conservation efforts. Long-term geographically and ecologically representative data for monarchs and their habitats across their breeding ranges will improve these efforts. Citizen scientists contribute vast amounts of data to biological monitoring programs, but many of these rely on incidental observations. The Integrated Monarch Monitoring Program builds protocols from existing monitoring programs to monitor milkweed and nectar resources, monarch reproduction and survival, and adult monarch habitat use. We engage agency personnel, conservation partners, researchers, and citizen scientists to collect rigorous and repeatable data regarding monarch habitat and use throughout the country. We prioritize stratified random site locations across the US while also accommodating data from non-random sites, particularly conserved or enhanced habitats, in order to learn more about the effects of conservation activities on habitat conditions. Participants choose from the protocols to suit local interests or institutional monitoring objectives. Data collected on local conditions then contribute to a national dataset available for local, regional, or continental analyses. A centralized database, electronic data submission, and multiple training formats facilitate participation. We describe program development and long-term goals, linking data to research needs and conservation programs, and strategies to promote program adoption.




25. Conservation of monarch butterfly in Mexico and the role of the social society

Eduardo Rendón-Salinas, **A. Martínez-Pacheco,** C. Forero, and **M.J. Villanueva**, World Wildlife Fund México

On December 2017, we found monarch overwintering colonies in 2.48 hectares of forest, which represented a drop of 15% in the eastern population; with the forest monitoring in 2018 we established that 6.7 hectares were affected and only 1.4 of them corresponded to illegal logging. Monarch monitoring was coordinated with Conanp and forest monitoring with UNAM. By 2008 we accumulated 13,501 hectares of reforestation with 14.9 million planted trees, 98% of which were grown in 13 community nurseries supported by WWF and by our national and international partners. In May 2018 we supported the integration of five databases produced by citizen science programs for monarch migration and produced the baseline map that includes those records; this information is key to designing and implementing conservation actions along the Mexican flyway. During October 2018 we participated in the formation of the National Network for Monarch Conservation. Throughout fall 2018 we performed systematic monitoring of the migration in 17 sites along the [migratory] route in Mexico. This monitoring included: estimates of the migrating population, a rapid assessment of the monarchs' physical condition, measuring their wet weight, and identifying nectar sources and the butterflies' perching habitats along the route. We also established nine pollinator gardens and are currently promoting the establishment of a pollinator garden network in Mexico.

26. Next steps for pollinator conservation in Canada

Sheila R. Colla, York University Toronto, Canada

Pollinator decline is an environmental issue of considerable importance to the public and to policymakers. Over the past decade, scientific research on the ecology, distribution and threats to wild pollinators, particularly bees, has expanded significantly. This presentation will discuss the current status of native bumblebees (*Bombus* spp.; *Apidae*; *Hymenoptera*) in North America and highlight next steps for the conservation management of species deemed at risk of extinction. This will enable us to better understand the importance of evidence-based policy and management for future pollinator conservation planning.

27. Passive and active ecological restoration of Abies religiosa forests using nurse plants, and assisted migration in the Monarch Butterfly Biosphere Reserve, Mexico

Arnulfo Blanco-García, **Aglaen Carbajal-Navarro**, **Gerardo Guzmán-Aguilar**, *Facultad de Biología, Universidad Michoacana de San Nicolás de Hidalgo* (UMSNH), Michoacán, México, **Esmeralda Navarro Miranda**, *Instituto de Investigaciones Agropecuarias y Forestales* (IIAF), UMSNH, Michoacán, México, **Fernando Pineda-García**, *Escuela Nacional de Estudios Superiores* (ENES)*, Universidad Nacional Autónoma de México*, Michoacán, México, **Roberto Lindig-Cisneros**, *Instituto de Investigaciones en Ecosistemas y Sustentabilidad*, UNAM, Michoacán, México and **Greg O'Neill**, British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development, British Columbia, Canada

Increasing ecological disturbance associated with climate change is creating new ecological restoration challenges. We compared the effectiveness of passive versus active ecological restoration. Passive restoration (elimination of disturbance agents, allowing natural regeneration) was evaluated by following natural recruited *Abies religiosa* (sacred fir) seedlings inside the core zone of the Monarch Butterfly Biosphere Reserve (MBBR). We found that seedling density is associated with gaps in the canopy (where 25 x 25 m is favorable). After emergence, seedling survival was 52% at the end of following dry season (June 2016), where the highest mortality (14%) was registered in April (the driest and warmest month). The critical factor for survival appears to be the presence of moss and adequate soil moisture. For active ecological restoration (e.g., reforestation), we established two high-elevation (3360 m and 3440 m.a.s.l.) assisted migration *A. religiosa* provenance field tests, by planting 6 to 10 seed sources (with provenance from high elevation) in two: under the shade of bushes (like *Baccharis conferta* serving as nurse plants) and exposed on the open field. After 1.5 to 3.5 years, we found an average of 81% survival rate when the saplings were planted under nurse plants, and only 14% survival when they were planted in open exposure. We found that an upwards shift in elevation to as much as 400 m difference between the seed source and the reforestation site was feasible, as assisted migration would compensate for warmer future climates. We recommend planting local species of shrubs to serve as nurse plants approximately two years before reforestation, with *A. religiosa*. That will require growing bushes for transplanting in forest nurseries, not a current practice.

List of participants

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1. **Adriana Nelly Correa**; Director - *Parque Ecológico Chipinque*
2. **Amado Fernández Islas**; Director Protected Area Izta Popo – Conanp
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25. **Selene González Carrillo** – Special Programs Support – The pollination project
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5. E**lizabeth Crone**; Professor – Tufts University
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8. J**ohn Pleasants; Professor** – Iowa State University
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12. **Ryan Drum**; Ecologist – USFWS (Remote Participation)
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14. **Tyler Flockhart**; Professor – University of Maryland

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