# Recommendations for integrating monarch butterfly monitoring data in North America to address conservation and management needs

**A Report to the Commission for Environmental Cooperation**

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**Edited by: A. Davis, S. Altizer, K. Oberhauser and L. Ries**

**With contributions from: D. Frey, T. Crewe, E. Howard, E. Rendon-Salinas, R. Bartel, R. Batalden and N. Nibbelink**

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## 1. EXECUTIVE SUMMARY

Each year, North American monarch butterflies undergo a spectacular two-way long-distance migration from breeding locations in Canada and the USA to overwintering sites in Mexico and California. Throughout their annual cycle, monarchs utilize habitats in three different countries and require different resources at different life stages. This complexity and shifting spatial distribution poses challenges for identifying key threats to monarch populations and assessing their conservation status. Monarchs have been studied extensively and a number of relatively long-term monitoring programs (and associated data sets) exist for North America populations. This wealth of data represents a rare scientific resource for understanding how biological, environmental and anthropogenic factors influence the population dynamics and movement patterns of a migratory species. At the same time, a great need exists to integrate existing data sets and make them available to the scientific and conservation communities for analysis and interpretation of population trends.

In June 2009, a team of 11 scientists with collective expertise in monarch butterfly biology and the management and analysis of large-scale data sets met in Athens, GA, USA to develop a framework for improving access to and collaborative use of monarch butterfly observational data. Our team included individuals from academic institutions, conservation organizations/NGOs, and leaders of major monarch butterfly citizen science monitoring projects. Two team members had limited experience with monarch butterflies but a strong background in GIS, database management and analysis of spatiotemporal data sets. Prior to our meeting, the team reviewed key goals of the CEC's RFP (Project No. 1.14.1.1.1.1), which included (i) preparing an inventory of existing data repositories, (ii) identifying gaps in existing data sets, (iii) analyzing and addressing barriers to use of the data, and (iv) describing a system for integrated data management and oversight. We also reviewed our original proposal for addressing these goals, and each participant prepared an abstract and presentation on the data sets and analyses for which they were most familiar. The 4-day meeting consisted of individual presentations, large-group brainstorming and discussion sessions, break-out groups to focus on specific problems, and writing initial drafts of this report (See details of the meeting in Appendix 2).

In this report, we outline a vision for the integration, management and sharing of monarch butterfly observational data. Our primary recommendation is the formation of the North American Monarch Monitoring Network (a.k.a. *MonarchNet*), with an associated steering committee and partners who collect and contribute data. A major goal of this program is to develop a web-based data portal that provides access to monarch observational data for the scientific and conservation communities. We also recognize the need to integrate existing data sets for analysis and interpretation of both within-season and longer-term population trends, and communicate these findings to the public and policy makers to further monarch conservation.

This report is divided into seven sections. Following the executive summary (section one) and fundamental background on monarch biology and conservation (section two), we summarize data available from existing monitoring programs in section three. The fourth section identifies major gaps in existing data sets based on key phases of the monarch's annual life cycle. Section five outlines a framework for improving access to and use of existing monarch observational data at all life stages throughout North America. In section six, we summarize some of the major biological questions that can be addressed using monitoring data and connect those questions to the relevant data sets. The final section provides a vision for future funding needs to support both data integration and analysis effort. Finally, we provide an Appendix with supporting materials including a list of meeting participants, abstracts of individual presentations, and a detailed summary of the meeting schedule.

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## 2. BACKGROUND

Each year, North American monarch butterflies undergo a spectacular two-way migration from breeding locations in Canada and the USA to overwintering sites in Mexico (Malcolm 1993, Oberhauser and Solensky 2004). Throughout their annual cycle, monarchs utilize habitats in three different countries and require strikingly difference resources at different life stages. This complexity and shifting spatial distribution poses challenges for identifying key threats to monarch populations and assessing their conservation status. On the other hand, monarchs have been exceptionally well studied scientifically, and due to their high profile among the public, many long-term monitoring programs exist within North America that track different life stages. This wealth of data represents a rare scientific resource, particularly for understanding how biological, environmental and anthropogenic factors influence migratory species.

The details of monarch biology, their conservation requirements, and existing monitoring programs are well-summarized in the North American Monarch Conservation Plan (Commission for Environmental Cooperation 2008) and the overview of monitoring initiatives and protocols (Commission for Environmental Cooperation 2009). These documents, and many of the scientific literature cited within them, detail evidence for dramatic swings in population abundance (10-fold or greater) both within seasons and between years, and many of the ways in which humans are altering the abundance and distribution of their host plant species and nectar resources. The habitats that monarchs utilize are increasingly altered by humans, including areas affected by agricultural intensification, urban development, and climate change. The resulting shifts in their spatial distribution poses challenges for identifying key drivers of monarch population dynamics and assessing their conservation status.

The synthesis work that took place at our workshop sets the stage for new approaches to addressing questions related to monarch conservation over large spatial or temporal scales. Importantly, we note that a large body of previous work has focused on understanding monarch biology at limited spatial and temporal scales, and future integrative studies can build on this existing knowledge base. For example, a number of studies have examined monarch individual physiology and behavior, including work on cold tolerance and the use of lipid reserves during the overwintering period (e.g. Anderson and Brower 1996, Alonso-Mejia et al. 1997). Other studies have focused on monarch orientation and stopover ecology during migration (e.g. Brower 1996, Davis and Garland 2004), and the effect of migration on infectious disease (Altizer et al. 2000, Altizer et al. 2004). Perhaps some of the best-known scientific work has characterized monarch sequestration of cardenolides from their milkweed host plants and unpalatability (Malcolm and Brower 1989, Alonso-Mejia et al. 1994), and predation rates (Brower and Calvert 1985, Prysby and Oberhauser 2004). At larger spatial scales, we will build on existing knowledge of the impacts of overwintering habitat quality in Mexico and California (Calvert et al. 1986, Leong 1990) and the current scope of habitat loss (Brower et al. 2002), and the progression of monarch spring migration (Cockrell et al. 1993, Davis and Howard 2005).

New advances in understanding monarch butterfly ecology and conservation will be made possible by integrating existing databases collected across large spatial and temporal scales. We are especially excited about the potential to explore large-scale patterns of abundance, recruitment or movement throughout the monarch's annual life-cycle. Our workshop brought together a team that will be able utilize a wide variety of existing data to develop an integrated understanding of the multiple biotic and abiotic factors that affect monarch distribution and abundance. This issue was identified as a priority in the recently-published North American monarch conservation plan (Commission for Environmental Cooperation 2008). By integrating the data from existing monitoring programs into a unified framework, our ability to track changes in population status, make predictions about future response to environmental change, and to further understand the spatial and temporal dynamics of populations will be enhanced tremendously.

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## 3. SUMMARY OF MONARCH DATA SETS

As the goal of this meeting was to develop recommendations for improving data collection and integration, our first task was to outline the various programs and projects that collect data on monarchs in North America. We identified 18 programs that assemble monarch butterfly data in North America and that could be included in any plans for integrating data. The temporal span of these data sets ranged from five to over 35 years. Similarly, the available databases also vary in geographic extent, some have continent-wide coverage and others consist of annual surveys from a single location. Most data sets focus on either a single life stage of monarchs (e.g., counts of adults) or a single stage of their annual life history (e.g., fall migration counts, overwintering colony size, and summer reproduction).

Monarch monitoring programs that collect observational data, together with the variables recorded and temporal and geographic coverage, are summarized in Table 1. Below, we summarize the protocols of each program and what is currently known on challenges to their use. One recurring challenge we identified was that many organizations do not maintain their data in a standardized manner or one that is easily accessible. Also, many operate on minimal (or no) budgets, such that the long-term viability of such data sets is not clear. On the positive side, these data sets collectively represent vast quantities of observational data, and if combined would be extremely useful for conservation purposes, to inform managers of regional programs, and for developing statistical models of the population dynamics of this species.

## 3.1 POINT SUMMARY OF PROGRAMS AND BARRIERS

### Spring and fall migration

Journey North – spring and fall migration sightings

**Spatial extent:** Canada, USA

**Protocol:** Participants must register online to contribute observations, in the spring--report first sightings of migrating butterflies, milkweed or eggs, in the fall--report sightings of overnight roost and migrating monarchs

**Barriers:** 1) Effort not standardized (# observers/observer-hours not known, observers not evenly or randomly distributed, 2) ID errors, 3) Time and expense to cull erroneous data, 4) Need more expertise (scientists, statisticians, GIS specialists

**Lead contact**: Elizabeth Howard, ehoward@journeynorth.org

Monarch Watch – capture and tag program of fall migrants

**Spatial extent:** Canada, USA, Mexio

**Protocol:** 1) Volunteers request tagging kit from UK (must use new tags every year), 2) Taggers obtain butterflies by either rearing wild-caught immatures or catching adults with a net. 3) Tag the butterfly

**Barriers:** 1) Not all volunteers return data sheets (~1/3 of recoveries not associated with tagging data, 2) Size of database, 3) Lack of standardization of tagger names

**Lead contact:** Chip Taylor; monarch@ukansas.edu

Long Point Migration Census - Daily census of fall migrants

**Spatial extent:** Ontario, Canada

**Protocol:** 1) Data collected daily from mid-August to end-September (breakwater) or November (tip) 2) Participants conduct one-hour walking census, 3) Record total # monarchs sighted

**Barriers:** At tip site, some monarchs may be counted more than once, as at Cape May and Peninsula Point; full migration is not captured at Breakwater.

**Lead contacts:** Tara Crewe; tcrewe@bsc-eoc.org; Jon McCracken; jmccracken@*bsc*-eoc.org

Cape May Migration Census – Daily census of fall migrants

**Spatial extent:** Northeastern USA

**Protocol:** Participants conduct driving census of migrating monarchs 3 times daily in September-October

**Barriers:** Site is on a peninsula, so stopover monarchs may get counted more than once, most monarchs tagged at this location do not make it to Mexico, driving census biased toward monarchs flying low

**Lead contact:** Dick Walton; rkwalton@earthlink.net

Peninsula Point Migration Census - Daily census of fall migrants

**Spatial extent:** Midwestern USA

**Protocol:** Participants conduct walking census 3 times daily September-October, counting migrating monarchs

**Barriers:** Similar to Cape May, peninsula location means some fraction of monarchs stopover and may be counted more than once, walking census also biased toward low-flying monarchs
**Lead contact:** Janet Ekstrum; email: jekstrum@fs.fed.us

**<u>Summer reproduction and abundance</u>**

Monarch Larva Monitoring Project – census of breeding populations
**Spatial extent:** Canada, USA
**Protocol:** 1) Estimate weekly monarch densities: monarchs/milkweed plant, 2) Track weather conditions, 3) Estimate parasitism rates, 4) Compare milkweed plants occupied and un-occupied by immature monarchs.
**Barriers:** 1) Volunteer errors (non-random observations, ID errors), 2) Lack of negative data, 3) Problematic data need to be culled, 4) Current protocol may not be appropriate for all milkweed species
**Lead contact:** Karen Oberhauser; email: oberh001@umn.edu

MonarchHealth – estimates prevalence of *Ophyrocystis elektroscirrha* parasite in adults
**Spatial extent:** Canada, USA, Mexico
**Protocol:** 1) Volunteers catch wild adult monarchs, 2) Sample abdomen with provided stickers, 3) Samples analyzed at UGA lab, 4) Results sent to volunteers
**Barriers:** 1) High effort and cost to distribute monitoring kits and process samples, 2) Participant contamination (false positives), 3) Need to increase volunteer base and maintain interest between years
**Lead contact:** Sonia Altizer; email: saltizer@uga.edu

Illinois Butterfly Monitoring Network – census of breeding adults
**Spatial extent:** Illinois
**Protocol:** Walking census with varied transect length and survey time, counts conducted several times yearly
**Barriers:** Very concentrated around Chicago
**Lead contact:** Doug Taron; email: djtaron@chias.org

Ohio Butterfly Monitoring Network - census of breeding adults
**Spatial extent:** Ohio
**Protocol:** Walking census with varied transect length and survey time, counts conducted several times yearly
**Barriers:** Data has not been used for scientific purposes yet, may have problems getting it ready for analyses
**Lead contact:** Jerome Widemann; email: widemannj@iskbc.com

North American Butterfly Association – Annual survey of breeding adults
**Spatial extent:** Canada, USA
**Protocol:** Modeled after Christmas Bird Counts: 1 to several people count all butterflies sighted within a 15-km radius in a single day. Counts conducted between 1 and 3 times yearly (until recently, only once yearly)

**Barriers:** Single monitoring event may miss monarch peaks and inter-annual fluctuations; wide state-to-state variation in number of census sites
**Lead contact:** Jeffrey Glassberg; email: naba@naba.org

Texas Monarch Watch – phone-in system for reporting adults and larva in TX
**Spatial extent:** Texas
**Protocol:** 1) Participants can report any monarch sighting to the Texas Monarch Hotline, 2) Some participants keep a monarch calendar
**Barriers:** Inconsistent effort and lack of continuing support
**Lead contact:** Bill Calvert; email: wmcalvert@sbcglobal.net

Correo Real Data Set
**Spatial extent:** Unknown
**Protocol:** Participants report monarch sightings, behavior and weather conditions
**Barriers:** Not consistent effort
**Lead contact:** unknown

Door County Monarch Counts
**Spatial extent:** Door County, MI
**Protocol:** Annual census of early summer monarchs and milkweed at a site in Door County, Wisconsin (Newport State Park)
**Barriers:** Data set not consistent
**Lead contact:** Lincoln Brower; email: brower@sbc.edu

Cross Creek Monitoring Program
**Spatial extent:** Cross Creek, FL
**Protocol:** Annual census of milkweed status and counts of spring monarchs returning to breeding sites in Florida
**Barriers:** Early data is casual
**Lead contact:** Lincoln Brower, brower@sbc.edu

Art Shapiro Data - (ASBD) - occurrence and abundance of butterflies at ten locations across California
**Spatial extent:** across California central valley to east side of Sierra Nevada Mts.
**Protocol:** Participants walk fixed routes at 10 sites to record presence/absence data on over 150 butterfly species. Count data available at five sites. Monitoring occurs at 10 sites, each at 2 week intervals
**Barriers:** None
**Lead contact:** Art Shapiro; website: http://butterfly.ucdavis.edu

## Overwintering biology

Monarch Butterfly Biosphere Reserve (MBBR) and World Wildlife Fund Mexico – estimates size of Mexican overwintering colonies
**Spatial extent:** Mexican overwintering colonies

**Protocol:** Participants estimate forest surface occupied by monarch colonies every 2 weeks
**Barriers:** Incomplete monitoring prior to 1993, unknown relationship between colony area and monarch number
**Lead contact:** Eduardo Rendon-Salinas; email: erendon@wwfmex.org

California Natural Diversity Database (CNDDB) - maps location and natural history information for special status animals, plants, and natural communities (monarch wintering sites)
**Spatial extent:** California
**Protocol:** Participants record presence data for special status plant and animal species and natural communities
**Barriers:** Inconsistent data formatting, data entered in text boxes, $600 dollar user fee
**Lead contact:** California Department of Fish and Game; Brian Acord; email: BACORD@dfg.ca.gov

Western Monarch Thanksgiving Count (WMTC) – Estimates size of western overwintering populations
**Spatial extent:** Wintering sites from Mendocino County California to Northern Baja California Mexico
**Protocol:** Conducted annually during two week period centered on Thanksgiving holiday; walking census conducted early when temperature is below flight threshold
**Barriers:** Not all sites monitored every year
**Lead contact:** Mia Monroe; email: mia_monroe@nps.gov

Monarch Alert
**Spatial extent:** California
**Protocol:** 1) VWS biologists visit a site to determine habitat suitability, evaluate stand condition and search for clustering monarchs, 2) Volunteers follow weekly to collect specific cluster data
**Barriers:** None known
**Lead contact:** Dennis Frey; email: dfrey@calpoly.edu

**Table 1. Current repositories of monarch butterfly monitoring data in North America (shading separates programs by migration, summer or overwintering)**

| Program (Steward) | Stored at (Structure) | How updated | Data Collected By | Variables recorded | Time Span | Effort |
|---|---|---|---|---|---|---|
| Journey North (E. Howard) | Server (SQL) | Volunteers online | Volunteers | 1) Date, 2) Location, 3) Monarch presence | 1994-present | 41,751 participants, 35,868 monarch sightings |
| Monarch Watch (O. Taylor, UK) | Recoveries- server, all tagged monarchs (unknown structure) | Volunteers sent data sheets to UK | Volunteers | 1) Release date, 2) Unique tag number, 3) Sex, 4) Whether caught as adult or reared from immature, 5) Location | 1992-present, past tagging efforts since 1952 | >1600 tagging kits sent each year, 210,000 tags issued/year, >1.2 million monarchs tagged since inception, 13,000 recoveries |
| Long Point Monarch Migration Monitoring | LPBO, Bird Studies Canada (Comma-delimited text) | BSC | LPBO staff and volunteers | 1) Date, 2) # monarchs ,3) Record weather (temperature, cloud cover, wind speed and direction) | 1991 - present, standardized since 1995 | |
| Cape May (D. Walton, Cape May Bird Obs) | Dick Walton (Excel) | Participants mail data to Andy Davis | Volunteers | 1) # monarchs observed/mile, 2) wind speed and direction, 3) cloud cover, 4) temperature | 1992-present | 2783 censuses, 66,164 monarchs sighted |
| Peninsula Point (A. Davis, UGA) | US Forest Service, A. Davis (Excel) | Participants mail data to Andy Davis | Volunteers | 1) # monarchs observed/observer hour, 2) wind speed and direction, 3) cloud cover, 4) temperature | 1996-present | 1321 censuses, 39,470 monarchs sighted |
| MLMP (K. Oberhauser, UM) | Commercial server, UMN (Access, moving to SQL) | Online by volunteers after monitoring events | Volunteers | Depends on activities completed. All volunteers record: 1) Date, 2) # milkweed plants monitored, 3) # eggs and larvae | 1997 - present, | > 900 sites, >600 volunteers |
| Monarch Health (S. Altizer, UGA) | UGA (Excel) | Monarch Health staff | Volunteers | 1) Date, 2) Location, 3) Parasitism presence/absence, 4) Caught as adults or larva, 5) Sex of butterfly | 2006 - present, | >60 volunteers |
| IL BMN (Chicago Nature Museum) | All data: excel. Data from 1987 – 2006: Access | Participants enter online | Volunteers | 1) Date, time, 2) Cloud cover, wind estimate and temperature 3) presence of butterfly species by transect | 1987-present | 3713 surveys observed a total of 27,036 monarchs |
| OH BMN (Ohio Lep. Soc.) | Access database | Participants enter online | Volunteers | Counts presence of adult butterfly species | 1996-present | 2708 surveys observed a total of 14,484 monarchs |
| NABA | NABA (and Leslie Ries) (Access) | Participants enter online | Volunteers | 1) Date and location, 2) Party-hours, 3) Party-miles, 4) Count and species of adult butterflies observed | 1975-present | ~475 counts yearly<br>4317 surveys observed a total of 85,124 monarchs |

| Program (Steward) | Stored at (Structure) | How updated | Data Collected By | Variables recorded | Time Span | Effort |
|---|---|---|---|---|---|---|
| Texas Monarch Watch (TX Parks Wildlife) | Unknown (Excel) | Volunteers send monarch calendars to TPW | Volunteers | Monarch calendar: 1) Date, time, duration of observations, location, 2) Habitat description, 3) Temperature, wind direction, speed, 4) # monarchs sighted, 5) Behavior | Unknown | Unknown |
| Correo Real (Rocio Treviño) | Rocio Treviño (unknown structure) | Hard copy mailings | Volunteers | 1) Date, location, 2) Weather, 3) # butterflies, 4) Monarch behavior 5) Plant species | 1992-present, | 200 participants |
| Cross Creek FL (L. Brower, Sweet Briar) | Lincoln Brower (Excel) | Annually by Lincoln Brower | Lincoln Brower and colleagues | Milkweed census, counts of eggs and larvae, counts of adults, | 1981-present | Coordinated by multiple investigators over the years |
| Door County WI (L. Brower, Sweet Briar) | Lincoln Brower (Excel) | Annually by Lincoln Brower | Lincoln Brower and colleagues | Number of adults, sex ratios, adult wet, dry, lean and lipid wt., forewing length, condition and mating status<br>Egg and larval census | 1985-present | Coordinated by multiple investigators over the years |
| Art Shapiro Butterfly Data (A. Shapiro, UC Davis) | Information Center for the Environment at UC Davis (unk. structure) | Updated by AS | Art Shapiro and colleagues | 1) Species presence/absence, 2) Some count data | 1972-present | 150+ species and subspecies; 5,700+ site-visits; 74,000+ individual records; 1980 monarchs |
| MBBR (WWF) | WWF (Excel) | WWF Staff | WWF and MBBR Staff | 1) Sex ratio, 2) Forest structure, 3) Mortality, 4) Colony dynamics, 5) Occupied area | 1976—present, multiple investigators | |
| California Natural Diversity Database | Online database CA DFG | Unknown CA DFG staff | Volunteers | maps location and natural history information for special status animals, plants, and natural communities (monarch wintering sites) | 1979 - present | unknown |
| WMTC (Mia Monroe, Xerces Society) | Xerces Society (Excel) | Participants send data to Mia Monroe, Dennis Frey updates database | Volunteers | # Monarchs clustered, # Monarchs sunning, tree species, cluster aspect, cluster height | 1997-present, protocol standardized in 1998 | In 2008: •46 persons participated; varied backgrounds<br>•115 wintering sites monitored; 12 Counties<br>•2.2 persons per site |
| Monarch Alert (Ventana Wildlife Society) | Ventana Wildlife Society (unknown structure) | Unknown | VWS biologists and volunteers | 1) Date, time, 2) Site, 3) Observers, 4) nectar and water, 5) Observations of tagged or mating monarchs, 6) For trees with clusters: # butterflies, tree species, tree ID, cluster aspect and height, 7) # flying or on the ground | 2001-present | 9 sites monitored |

## 4. GAPS IN DATA COVERAGE

Although data continue to accumulate each year from multiple sources, our team identified several gaps that should form a focus for developing future monitoring programs and funding priorities. Some of these are gaps in data collection at particular regions or times of year, and we also point out several conceptual or quantitative gaps that need to be addressed. Below we summarize information on specific gaps, organized by monarch life stage, to identify our most pressing needs.

For the ***overwintering stage*** we need a robust way to estimate colony population size (i.e., number of monarchs) from the current data collected on area of forest occupied (in hectares) for each Mexico wintering colony. This effort will be complicated by the fact that average densities of monarchs can vary over time and among colonies. For example, the total area occupied by each colony is impacted by weather, with individuals spreading out more as temperature increases from early to late in the wintering season. This change can introduce a seasonal bias in colony size that is not related to actual population number. The Western Monarch Thanksgiving Count program provides information about monarch abundance at approximately 110 wintering sites annually, monitoring more frequently throughout the season would provide valuable information regarding habitat use-patterns and the onset of spring migration.

***Spring migration*** is monitored mainly through observations of first sightings of adults by Journey North volunteers and observations of early eggs and larva through the MLMP program. Unfortunately, there are few volunteers focused on the regions just beyond the location of wintering colonies, so it is unclear how far monarchs travel before recruitment into the next generation begins. Increasing participation in the Journey North and MLMP programs in Mexico, Texas and California would help fill these gaps.

During the ***summer breeding season***, there is a great deal of monitoring of adults, eggs and larvae in their core reproductive habitat. The abundance of adults is estimated by multiple butterfly monitoring programs in North America (ASBD, NABA, IL, OH, FL), and MLMP records egg-laying and stage-structured survival estimates. A major gap in summer monitoring program is that we have very little information about the distribution of milkweed, the monarch's host plant. Careful mapping of milkweed abundance patterns throughout North America, and information about within and between-season changes in abundance and condition would provide critical information to model and analyze what factors drive both the spatial and temporal patterns of monarch abundance.

***Fall migration*** in eastern N. America is mainly monitored through Journey North observations and also three roosting/stopover sites are intensively monitored. However, the current monitoring sites for fall migration coincide with unusual geographic features (peninsulas) that may be funneling individuals and therefore are not representative of densities throughout the landscape. In addition, all three fall migration monitoring stations are located above 40 N latitude, leaving a significant gap in monitoring fall migration along major flyways farther south. Thus, our team concluded that migration census stations in more inland locations (i.e. not on peninsulas) and farther south (i.e., along the central flyway in Texas and northern Mexico) would provide additional information on monarch fall abundance and migratory patterns. Fall migration data would also be enhanced by more monitoring of roosting sites and their landscape features. We also note that no fall migration monitoring data are available in California or other parts of the monarch's range in western N. America.

Finally, one important biological phenomenon that currently is not well monitored is the presence of adult monarchs and **breeding activities during the winter months** in the southern USA and in close proximity to monarch wintering sites in Mexico and California. This pattern of behavior has been noted indirectly through sightings of winter monarchs via the Journey North monitoring program, and could be affected by a combination of mild winter temperatures and the planting of tropical milkweeds (e.g., *Asclepias currassavica*) which, unlike native milkweeds, do not die back during the fall and winter. Because this could be an important ecological phenomenon in response to aspects of global climate change, more systematic efforts are needed to record breeding activity of monarchs (i.e., adults, eggs and other immature stages present) at southern latitudes outside of the regular breeding season (i.e., Nov – Mar). Related information that is needed includes weather or climate conditions, host plant species present at these sites, and the infection status of adults.

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## 5. RECOMMENDATIONS FOR DATA INTREGRATION

After discussing challenges posed by integrating existing monarch monitoring data, we universally agreed that the best strategy for accomplishing this task is to immediately form an umbrella organization that could spearhead these efforts. The organization would be called the North American Monarch Monitoring Network (*MonarchNet*) and would be modeled after the Avian Knowledge Network (www.avianknowledge.net), a successful portal for ornithological data. All of our initial workshop participants would form the steering committee for this network, and our task would be to oversee the integration of multiple monarch monitoring programs.

We envision *MonarchNet* as being a virtual network of monitoring programs, with each program considered as a partner. We would begin by soliciting each of the organizations listed in Table 1, via an official request letter, and asking them to become a partnering member of *MonarchNet*. As a partner, they would be asked to contribute some or all of their data to the collective. This initial solicitation would be a critical first step, as it would lay out the guidelines of the initiative and the expectations for each program, and serve as an informal contract of participation. These agreements will be tailor-made for each partner, renewed every five years, and with the option of non-renewal by either the partner or *MonarchNet* at any time.

The meeting participants also agreed that the best way to accomplish the task of data integration is through a virtual database, or web-based portal, and this would be one of the most important components of the *MonarchNet* initiative. The portal will have a hierarchical structure illustrated in Figure 1 (below), with most data housed on partners' independent websites. Thus, all partnering programs would still maintain independence, which was a concern raised by some at the meeting, but they would share key aspects of their data that would contribute to a larger, centrally-housed database.

The *MonarchNet* program would make every effort to ensure that the contributed data is of high quality. As such, we would only include data from partners having data sets that are at least three years old, that show evidence of quality data and data management, have standardized procedures, a long-term plan for data collection, and in most cases, have institutional backing. In addition, *MonarchNet* could serve as a repository for data from monitoring projects that have ended, and for projects that do not have an existing system for archiving their data. As we identify and link to databases through *MonarchNet* (see Table 1), we will make note of cases in which data may be duplicated in different databases; for example, Peninsula Point observers may report the same monarch roost to Journey North that they count for a migration count. In some cases, these duplications will not be a problem; in the above example, the Journey North program notes the occurrence of the roost while Peninsula Point provides a count. However, it is important to keep duplication in mind as we build the portal.

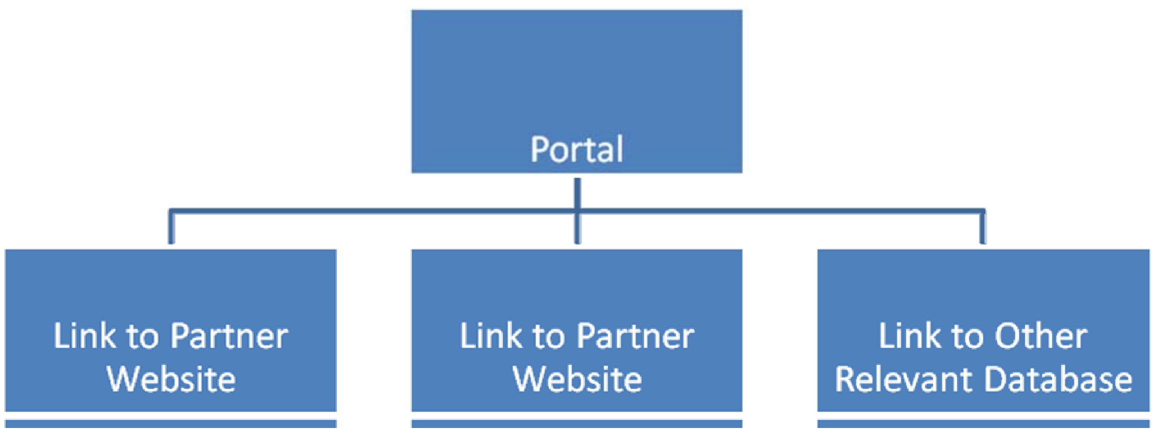


**Figure 1.** ***Structure of the web-based portal***: Key components will include background on partners and monitoring programs, trend graphs, the ability to query individual partner databases, an updated list of publications utilizing the data, and a blog/forum for data users. ***Partner Websites:*** In most cases, MonarchNet will link to existing databases of partner organizations. In some cases, partner data are not available online. MonarchNet may set up websites for these programs that allow data entry by participants, and access to data via queries or requests to program managers. ***Other Relevant Databases:*** We will also link to plant, phenology and weather databases that would be useful in analyses of monarch monitoring data.

One of the most important features of the web-based portal will be the ability for users to query or access user-specified data sets and display summary information such as trend graphs. In the beginning these may be static, with the eventual goal of having dynamic and automatically updatable charts and/or tables. These graphs could illustrate data such as participation in the program, the number of sites represented in the database, or summary indices of monarch abundance or condition and their trend over time. The content of these graphs will be agreed upon by the partner and network, will be formalized within the contract between partner and network, and will serve to provide exciting information to portal visitors. One individual from each *MonarchNet* partner will coordinate the submission of graphs to the network on an annual basis, and the *MonarchNet* manager may use these or other data to create synthesis trend graphs that represent the overall status of the monarch population or monarch monitoring programs.

We envision a portal that will have the following information (or metadata) listed for each monitoring program, which will be submitted and updated by each partner as part of their contractual obligations:

- *Abstract:* a brief summary of the goals and methods of the monitoring program, including the questions and hypotheses (where relevant) that are being addressed, a description of the participants and the timeframe over which the data have been collected.
- *Access and use constraints:* any constraints to access of the data (ranging from freely available to anyone to available upon request to not available at all: see description of access levels below).
- *Study design and data collection protocols*: a brief summary of the design and methods of the program, links to a more complete online description, data sheets and/or data entry processes
- *Field definitions:* a description of the data fields that exist in the data set, including, when relevant, whether the data are count or occurrence data and whether absence data are included.
- *Quality control procedures:* how data accuracy are ensured at collection and data entry
- *Preliminary processing, derivation, extrapolation, or estimation procedures*: a summary of steps that have been taken to remove or modify questionable data, and reasons for these steps.
- *Quirks/peculiarities*: any problems with the data that might require the professional judgment of the data manager. For example, some MLMP sites do not record eggs, so their data would not be useful to survival analyses, but would be useful for presence/absence analyses.
- *Features of the data that could constrain their use for certain purposes*: data constraints that are not due to inaccuracy, but due to issues such as accuracy of spatial scale (for example using zipcodes to estimate location) or biases that could arise from the lack of negative data. It is possible that some of these constraints, e.g. spatial scale/spatial accuracy, could be metadata fields of their own.
- *Citation for the data*: How the partnering program prefers the data to be credited in publications and reports.

**Data Fields.** Setting up usable data query capabilities will require many conversations with partners by the *MonarchNet* web designer to determine appropriate data fields and formats. These conversations will help us to assess what partners are already using, what fields are necessary to make their data usable, and what changes are needed to make their data compatible with data from other programs. All data fields will need to clearly indicate what the data represent, with a complete description in the metadata. For example, if the data field was ‘ObservationCount,’ the metadata should clearly indicate whether the butterflies were counted while flying or on the ground. Observation counts should also be clearly differentiated from occurrence (i.e., presence/absence) data. Many databases will need to be modified to address these standardization requirements.

While some data fields will be specific to individual programs, others will be constant across all programs and will require standardization. We will have standard formats for date (day, month, year in separate fields), location (latitude/longitude, fields that indicate location precision in meters and the kind of GPS unit used), time (military time), and observer. As data agreements become established, a master database will be constructed that will help facilitate standardization by summarizing all fields, data types, potential overlaps and conflicts (Figure 2, below).

**Figure 2.** ***Vision for Master Database structure.*** This single database would allow users to view available databases, their breadth and potential issues for integration. The primary table (a) is a copy of Table 1 loaded into MS Access (or an SQL relational database). The link table (b) is a list of all fields by database ID with the data types and descriptions. This format allows the user to build queries in to facilitate evaluation of each database. For example, queries can be built as in (c) that identify the number of databases that contain a particular field name, such as the "COUNT" field which exists in 3 of the 6 databases used in this sample query. However, note in (d) that the 3 "COUNT" fields are each counts of different biological features. As an initial step, building this master database of sources and fields will be critical for normalizing fields among data sources without loss of information. Also, this process will avoid using multiple sources of data in analyses where one source might not include appropriate information. Ultimately this database could be used actively for the web interface on www.MonarchNet.org.

a.

| dbID | dbName | dbCode |
|---|---|---|
| 1 | Journey North | JN |
| 2 | Monarch Watch | MW |
| 3 | Monarch Larva Monitoring Program | MLMP |
| 4 | MonarchHealth | MH |
| 5 | IL BMN | IL BMN |
| 6 | OH BMN | OH BMN |
| 7 | MBBR | MBBR |
| 8 | NABA | NABA |
| 9 | Art Shapiro | AS |
| 10 | CNDDB | CNDDB |
| 11 | WMTC | WMTC |
| 12 | Cape May | CM |
| 13 | PPoint | PP |

b.

| dbID | SubTableNa | FieldName | DataType | Description |
|---|---|---|---|---|
| 1 | | DATE | text | date |
| 1 | | SITE | text | site |
| 1 | | UTM_X | integer | utm easting |
| 1 | | UTM_Y | integer | utm northing |
| 1 | | COUNT | integer | adult monarch |
| 2 | | DATE | date | date |
| 2 | | LOCATION | text | site by name |
| 2 | | COUNT | integer | eggs on plant |
| 4 | Samples | ID | float | |
| 4 | Samples | Observer | text | |
| 4 | Samples | Site | text | |
| 4 | Samples | City | text | |
| 4 | Samples | State | text | |

c.

| FieldName | DataType | CountOfdbII |
|---|---|---|
| Census | integer | 2 |
| City | text | 1 |
| COUNT | integer | 3 |
| Date | date | 4 |
| DATE | text | 1 |
| Date Collected | date | 1 |
| Date Processec | date | 1 |
| Date Sampled | date | 1 |
| DATUM | text | 1 |
| Day | integer | 2 |

d.

| FieldName | Description | CountOfdbII |
|---|---|---|
| COUNT | adult monarch numbers on roost | 1 |
| COUNT | adult monarch on milkweed | 1 |
| COUNT | eggs on plant | 1 |
| DATE | date | 3 |
| DATUM | datum | 1 |
| Infected? | presence of infection | 1 |
| LAT | latitude | 1 |
| LOCATION | site by name | 1 |
| LONG | longitude | 1 |
| Observer | initials | 2 |
| Sex | gender | 1 |
| SITE | site | 1 |
| Sun | 0 to 1 | 2 |
| UTM_X | utm easting | 1 |
| UTM_Y | utm northing | 1 |

**Recognizing data contributors**. We will develop an effective reward structure for all partners, recognizing that their participation will require significant investments. Rewards for partners will include recognition in publications (either acknowledgement or authorship depending on agreements between *MonarchNet*, the partner, and the data user), the knowledge that they are contributing to the greater good of increasing understanding of monarch biology and conservation, acknowledgement of program volunteers (data collectors), citations of the database, added publicity and possibly new participants, and possibly helping make programs sustainable. Any use of the data will require acknowledgement of the funding sources for the individual programs and of *MonarchNet.* In some cases, *MonarchNet* will provide support for digitization of partner data and making it possible for participants to store and upload data to a website.

**Recognizing *MonarchNet* contributors.** Any agencies or organizations that provide significant support for the development or the maintenance of the MonarchNet portal will be recognized on the webpage under a funders' section.

**Independence of Data Owners and Data Users.** An important component of *MonarchNet* is that is would simultaneously allow data integration and independence of each partnering program. As such, all data owners will determine what data are shared and not shared, with whom, and under what conditions. In some cases, historical data may be less accessible than future data. We will develop different levels of access that are tailored for each partner, and individuals who utilize data will need to register and log in so that data use and download statistics can be calculated. The portal will include a statement that encourages collaboration of the data user with the data owners, and, possibly, a requirement that if data are used for purposes other than the original intent upon download, the users need to submit a separate proposal, unless the data are freely available without an application process. We propose the following levels of access, which may evolve as we work with *MonarchNet* partners:

1. Metadata information only, none of the raw data are available to outside users
2. Metadata information, data (or a subset of the data) are available on request, summary plots of data are available on portal or partner website
3. Metadata information, some data are freely available via queries from the portal, some data are available on request, summary plots of data are available on portal or partner website
4. Metadata information, all data are freely available via queries from the portal, summary plots of data are available on portal or partner website

Any use of partner data for scientific publication will require a statement of use and citation. Partners may require the inclusion of a clause stating that the data owner doesn't necessarily agree with the conclusions of the publication, and when appropriate, authorship of the data collector or owner should be included. However, we will strongly discourage partners from requiring that publications require their approval before submission.

**Cooperative agreements.** Agreements between *MonarchNet* and partner organizations will be formal contracts that describe the roles of each organization, and any restrictions on and requirements for data use. These agreements will be renewed every five years, and can be non-renewed by either the partner or *MonarchNet*, and will be tailor-made for each partner.

**MonarchNet development and management**. Undertaking the steps described above will require significant funding and investment by partners. The following initial steps need to be taken:

- Establish partnerships: contact potential partners, develop cooperative agreements that specify the needs for each partner to be involved (as described above). We recommend that the coordinator of the Monarch Joint Venture lead this initiative, if other members of the MJV steering committee agree.
- Create an initial website (www.monarchnet.org): this website will include background on the network, partners as they're added, and possibly summaries of initial data analyses conducted by the *MonarchNet* steering committee.
- Develop network (data accessing and serving structure): initial development of the network will require a grant. We will hire one or two individuals to flesh out all attributes of the databases and determine how they'll fit together, and set up the portal and its front-end query structure. We will solicit the advice of Denis Lepage (Bird Studies Canada, via Tara Crewe), and may hire a programmer to work with Nate Nibbelink (UGA) on this task. This job will entail normalizing data attributes, creating an optimal relational structure and interface, and developing query tools.
- Ongoing management: the network website will require ongoing upkeep, including posting annual trend updates in cooperation with partnerships, trouble-shooting and technological updates, and other web maintenance and improvement tasks. In addition, it will require developing and supporting relationships with partners, users, and relevant stakeholders for whom monarch population data are useful.

In summary, the vision for *MonarchNet* is to be a ***virtual network of monarch butterfly monitoring programs that will foster collaboration, streamline efforts and ultimately serve as a resource for all persons and organizations with a stake in monarch biology and conservation.*** The web-based portal would allow users to access any monitoring program and retrieve information on the fly. This information could be long-term trend graphs of population size, which would encompass data from all parts of the life cycle, or it could be region-specific information like what state produces the greatest numbers of larvae per year, and in what area is mortality the highest. Some of the potential users of this resource would be government officials who wish to know the current status of monarch populations, scientists who wish to use the database to answer questions about monarch butterfly biology, or individuals who participate in the various citizen-science programs, and who wish to see how their efforts are contributing to monarch conservation.

## 6. BIOLOGICAL QUESTIONS NEEDING INTEGRATED DATA

Monarchs have been studied intensely for decades by scientists; much is known of their basic biology, and the literature includes hundreds of references to monarch chemical defenses, reproductive behavior, overwintering ecology, orientation and migratory behavior. Nevertheless, many aspects of monarch biology remain a mystery and must be addressed before scientists can make informed predictions about future population status. Perhaps the largest gap in scientific knowledge centers on questions at large spatial or temporal scales. Specifically, there has been little exploration of continent-wide patterns of monarch abundance, recruitment or movement throughout their annual life-cycle. This deficit is largely due to a lack of knowledge about and access to vast volumes of existing data, as well as statistical and logistical challenges to integrating large-scale data originating from multiple sources, usually volunteer-based.

As noted above, the observational data outlined in Sections 3 and 4 represents a virtually untapped resource for scientific inquiry into the biology of the monarch butterfly. If harnessed appropriately, these data sets could be used to develop a robust understanding of how multiple biotic and abiotic factors affect monarch distribution and abundance. Implicit in the recently published North America Monarch Conservation Plan (Commission for Environmental Cooperation 2008) was the need to obtain current and accurate information on patterns and drivers of monarch distribution and abundance, thus allowing for informed management decisions by conservation organizations and government entities concerned with protecting monarchs and their habitats.

Here, we identify several fundamental questions about monarchs that could be addressed by using specific combinations of the previously identified data sets. A primary scientific goal is to understand what drives spatiotemporal patterns of abundance within and between years on both breeding and wintering grounds. A related goal is to develop a modeling framework that can capture the important factors driving each life stage and that can be used to predict population trends. For each fundamental question (goal), we list a number of related sub-questions and briefly summarize what is known to date, list the data needed for optimal analyses, and identify gaps in data availability and model development.

**Goal 1: Investigate the within-season spatial distribution of monarchs throughout their breeding grounds.** Across their breeding range in both eastern and western N. America, monarch abundance varies both spatially and over time. For example, breeding activity in the southern USA peaks in spring (Apr-May) and again in late summer (Aug-Oct), whereas monarch breeding activity in the upper Midwest is highest during mid-summer (Jul-Aug) (Prysby and Oberhauser 1997). Over time, monarch densities increase from early spring to late summer and peak during the fall migration.  Niche models have been developed for monarch breeding activity (Batalden et al. 2007) that could be validated with other data sets. However, the spatial and temporal patterns of monarch abundance have not been mapped or analyzed in a comprehensive way. Examining this issue is crucial for identifying locations, times of season and types of habitat that are most important for monarch breeding activity (i.e., identifying geographic centers for monarch recruitment). In addition, the temporal dependence of abundance patterns among regions is not known -- for example, do early-season densities in southerly locations predict late-season abundance or fall migration counts farther north? Several key questions that could be addressed as a result of more open access to existing data sets include:

*(1) What is the spatial pattern of abundance during the monarchs' breeding season?*
*(2) What determines habitat quality on monarch breeding grounds?*
*(3) What is the relative contribution of different regional breeding populations to monarch wintering colonies?*

The data sets needed to answer these questions include: the Art Shapiro Butterfly Data (ASBD), NABA adult butterfly counts, Ohio Butterfly Monitoring Network (OBMN), Illinois Butterfly Monitoring Network (IBMN), Monarch Larva Monitoring Project data (MLMP), and Journey North (JN). Other data that could be utilized in analyses are large-scale land cover, topography and weather data from online sources. A major gap to address these questions is the need for spatially referenced data on milkweed host plant occurrence and abundance and nectar availability. A possible partnership with the National Phenology Network could provide these data in the future.

**Goal 2: Identify the pattern and cause of long-term (inter-annual) changes in monarch abundance**. At present, no detailed analyses exist for long-term changes in monarch abundance at the population level. These analyses are essential to determine whether monarch populations are declining or remain stable, and to identify the pattern and causes of fluctuations over time. In eastern N. America, long-term fall migration counts indicate that abundance peaks every 2 to 4 years, based on analyses of Cape May (Walton et al. 2005) and Peninsula Point data (Meitner et al. 2004). An earlier study by (Swengel 1995) used summer count data to show some evidence for alternating high and low abundance between years; similarly, data on wintering colony sizes from WWF-Mexico shows no obvious long-term trends. In western N. America, preliminary analyses of both summer count data and winter colony sizes show evidence for long-term declines (S. Stevens & D. Frey; L. Ries, unpublished data). Investigating the inter-annual patterns of monarch abundance and underlying biotic and abiotic causes is essential to predicting the long-term viability of monarch populations (i.e., are monarchs declining, and if so, why?) and can be a starting point to determine how monarchs might respond to future environmental changes. Specific questions to be addressed in this section include:

(1) *Are there long-term trends in overall monarch abundance, and how does this vary between eastern and western populations?*
(2) *Do monarchs at system-wide and/or regional spatial scale show evidence for regular (and predictable) population cycles?*
(3) *What factors drive variation in abundance between years (either regular or stochastic)?*
(4) *By how much do monarch populations increase between spring and fall migration, and what factors determine the level of increase?*
(5) *How is the habitat changing throughout the migration flyways?*

Data needed to answer these questions include the summer counts noted for Goal 1 above, plus annual counts of monarchs during fall migration and estimates of winter colony sizes (i.e., Cape May Migration Counts (CMMC), Peninsula Point Migration Census (PPMC), Long Point Migration Census (LPMC), Western Thanksgiving Monarch Counts (WMTC), and Monarch Butterfly Biosphere Reserve (MBBR) counts). To examine question (3), Monarch Health (MH) parasite infection data will be needed in addition to weather on weather and habitat quality.

Current methodological gaps include the need for indices to estimate population size at Mexican wintering sites from colony size measures, and the need to apply appropriate statistical methods and population process models to test population trends for periodicity and identify underlying causes.

**Goal 3: Examine the key drivers of migration dynamics, including success associated with different migratory routes.** For monarch spring migration in eastern N. America, the timing of colony break-up and colonization of breeding habitats by monarchs is known (Howard and Davis 2004), but not causes of variation in this timing. Similarly, it is assumed that monarchs begin breeding in the southern USA (e.g., Texas and Florida) several weeks after leaving Mexico, but there is no information on potential breeding activity before monarchs reach the USA. Less is known for monarch spring migration in western N. America because monarchs are monitored throughout the season over a limited landscape (ASBD) and both Journey North (JN) and Monarch Larva Monitoring Program (MLMP) participation is low there. However in a study involving over 24,000 monarchs tagged at eight wintering sites across four California counties, Stevens (2005) confirmed female-biased dispersal from western wintering grounds. Among fall migrating monarchs, the central USA appears to be the major flyway contributing to wintering populations in Mexico (Wassenaar and Hobson 1998, Howard and Davis 2009) there is evidence that most monarchs traveling along the east coast flyway do not reach Mexico, perhaps getting trapped in Florida or Cuba (Dockx et al. 2004). Among spring and fall migrating monarchs, key environmental determinants of the timing of migration have not been well tested, although weather, including prevailing winds, is thought to be important and intensive focus on lipid reserves suggests that nectar availability may also be critical. Specific questions to be addressed for this goal include:

(1) *What influences the timing of colony break-up and the start of spring migration?*
(2) *Where does breeding begin after individuals leave the colony?*
(3) *Are there consistent "flyways" and, if so, are some routes dead-ends?*
(4) *What are the factors underlying any variability in migration routes (both temporal and spatial through time)?*

Data needed to answer these questions include dates of colony break-up and first sightings (JN, MW, MLMP, ASBD), fall migration count data for multiple sites (CMMC, PPMC, LPMC, and Texas MonarchWatch counts), and environmental climate data from other sources. Major gaps that will need to be addressed include the lack of spring or fall migration data for the western USA, a lack of MLMP data for Mexico to evaluate potential breeding activity, and a lack of fall migration count data along southern flyways, especially for Texas. Other challenges will be posed by differences in effort and detectability among the multiple monitoring programs focused on spring and fall migration.

**Goal 4: Investigate the main factors affecting overwintering populations.** The location and attributes of monarch overwintering habitats and estimates of colony size have been previously described. The effects of forest quality on monarch overwintering dynamics has been studied in both Mexico and California (Tuskes and Brower 1978, Frey and Schaffner 2004, Leong et al. 2004). No studies however, have explicitly compared wintering site parameters between eastern and western locations. An important phenomenon that also has not been well investigated is the degree to which monarchs overwinter in parts of their breeding range; for example, some individuals remain in Florida and Texas throughout the year and lay eggs (unpublished MLMP and Journey North data). An anecdotal account showed that two individuals tagged in coastal VA in an unusually warm year were recaptured there the following spring. In addition, it is not presently known whether individuals that breed out-of-colony during the winter months can mix with (or rejoin) the migrating population the following spring. Specific questions to be addressed in this section include:

1) *What determines the location and size of overwintering colonies?*
2) *How does the biology of monarchs change throughout the overwintering season?*
3) *How does habitat quality (forest structure, microclimate and hydrology) influence overwintering dynamics?*
4) *What is the effect of human activities (tourists, residents) on the colonies?*
5) *What factors influence the distribution of out-of-colony overwintering individuals (in the "breeding" grounds), and how do they influence monarch population dynamics?*

Data needed to answer these questions include winter colony size measurements, landscape and climate data that may be important drivers of habitat quality, and observations of adults, eggs and larvae can be used to establish presence and reproduction during the overwinter period in off-colony sites (such as from MLMP and Journey North). Data gaps include the need for more frequent monitoring of monarch colonies in California (throughout the wintering season), and more comprehensive monitoring data on potential winter breeding sites in the eastern and western USA.

**Goal 5: Identify past, current, and projected anthropogenic drivers of monarch population dynamics and migration.** It has been well established that monarchs have lost crucial wintering habitat in Mexico and California in recent decades (Brower et al. 2002, Frey and Schaffner 2004), although this effect of habitat loss on current monarch abundance is not clear. It is also likely that monarchs have lost critical habitat across their breeding range in eastern and western N. America owing to conversion of old fields and natural areas to urban/surburban development; the growing use of herbicide tolerant crops poses another threat in the form of lost milkweed and nectar resources. In addition, monarchs could be affected by climate change in several ways, experiencing changes in temperature and rainfall at wintering sites, and through northern shifts in the location of prime breeding habitats. Monitoring data can play a crucial role in predicting monarch responses to these and other forms of human activity, with key questions involving:

(1) *What is the expected effect of climate change on monarch wintering and breeding habitats, and patterns of annual migration?*
(2) *How will changes in land use and agricultural practices affect monarchs at different stages of their annual life cycle?*
(3) *What are the expected changes in nectar availability and how will this influence monarch migration?*
(4) *What is the contribution of the butterfly breeding industry (i.e., captive-bred monarchs sold for release to the wild) on monarch distributions, abundance and disease?*

Data needed to answer these questions include much of the monarch monitoring data already referenced in goals (1) – (4) above. In addition, current and projected future environmental variables (e.g., temperature, rainfall, land use change) can be obtained from outside data sources to determine habitat suitability and monarch abundance or vital rates.

## 7. FUNDING NEEDS

The meeting participants recognize that accomplishing the goals outlined above will require significant time and resources and funds to support future work. We also recognize that this process may take 1-2 years to complete and will require several additional meetings to coordinate activities. Below we list three major sets of activities that we think are necessary to achieve the goals and recommendations set out in this report, and identify possible funding sources to support each:

1. ***Future collaborative meetings.*** We think that bringing together individuals with personal knowledge of existing monarch monitoring programs and those with expertise in data management and analysis in a focused working group was crucial for the development of this report. No one person has the full set of skills, knowledge or access to data necessary to accomplish such a task. Future meetings of the same (or similar) individuals would be needed to launch and refine the *MonarchNet* program and website, and to conduct analyses of combined monarch monitoring data that address questions outlined in section 6 of this report. Based on our experience with the June 2009 meeting, the cost of hosting 10-12 individuals for a 3-4 day period is approximately $20,000 US, depending on the location. Appropriate sources of funding to support future meeting might include NCEAS (National Center for Ecological Analyis and Synthesis, Santa Barbara), CEC, and both national and local conservation or wildlife management agencies

2. ***Development of the database and web-based portal.*** Accomplishing activities outlined in section 5 of this report will require significant investment in key personnel. In particular, an individual with extensive experience in both website development and database structure and integration is needed to program the initial user interface and link up data from existing monitoring programs. We also believe that a second individual is needed to develop content for the MonarchNet website and to facilitate communication and cooperation among the partners. Together, these activities could require two professional/technicial staff persons working at least 50% time for 1-2 years. Minimal costs are therefore estimated at $50,000/yr, assuming salary and fringe for two half-time workers. Appropriate sources of funding for such personnel might include NSF (National Science Foundation; Biological Databases and Infrastructure Program), CEC, WWF, and the USGS National Biological Information Infrastructure (NBII) program.

3. ***Data analyses to investigate biological questions.*** In section 6 of this report, we outlined a number of outstanding questions that can only be addressed using integrated data from multiple monarch monitoring projects. Answering these questions will require not only access to existing data but also the contributions of several individuals with quantitative expertise (i.e., in spatiotemporal statistical methods) to detect patterns in the data and test for underlying relationships among variables. Since members of the MonarchNet steering committee have many of these skills, these questions could form the basis of a proposal for a collaborative project involving members of the MonarchNet steering committee, and one which could be targeted to NSF (Population and Community Ecology Program) or other federal funding agencies such as the USDA, EPA, National Wildlife Foundation and US Fish and Wildlife Service.

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**APPENDIX 1.** List of Meeting Attendees

| Name | Organization | Program/Specialty |
|---|---|---|
| **Sonia Altizer** | University of Georgia | Monarch parasite interactions and MonarchHealth monitoring project |
| **Andy Davis** | University of Georgia | Migration Monitoring in USA |
| **Karen Oberhauser** | University of Minnesota | Monarch Larva Monitoring Project |
| **Leslie Ries** | University of Maryland | Spatiotemporal analysis of NABA data |
| **Eduardo Rendon-Salinas** | WWF Mexico | Overwintering Program in Mexico |
| **Tara Crewe** | Bird Studies Canada | Migration monitoring in Canada |
| **Reba Batalden** | University of Minnesota | Monarch Larva Monitoring, monarch responses to climate change |
| **Elizabeth Howard** | Journey North | Spring and Fall Migration Data |
| **Dennis Frey** | Cal Poly State University (emeritis) | Western Population Monitoring |
| **Nate Nibbelink** | University of Georgia | GIS/Database consultant |
| **Becky Bartel** | University of Georgia | Monarch parasites data analysis, GIS consultant |

**APPENDIX 2.** Meeting Summary

Goals

The primary focus of the Monarch Butterfly Monitoring Workshop was to engage individuals with unique access to monarch databases and with the expertise required to carry out meaningful analyses in an interactive format to establish recommendations for improving and managing monarch butterfly datasets and monitoring programs in North America. Our objectives included 1) constructing a shared vision for merging monarch monitoring and citizen science data, 2) outlining a logical framework for analyzing these data, 3) compiling a summary of identified databases and analysis of their coverage, 4) creating a synthesis of exciting and pressing questions that could be addressed with the combined data, 5) identification of gaps in both data collection and analysis of merged data, and 6) summary of future funding needs to formally construct the proposed architecture to merge datasets, minimize barriers with information access and use, and facilitate ongoing data management.

Schedule

**June 22 (Day 1):**

After initial introductions, each of the 11 participants presented information focused on a specific monitoring program/data set. In these ~30 minute presentations, participants addressed the following points: monitoring protocols, number of observers and specific variables recorded, time span over which data were collected, structure of the data, current format and file size (i.e., number of lines of data), who maintains the data, and challenges encountered with the data or issues that could be improved on. Presenters also provided a short overview of analyses and papers that have stemmed from the data thus far. Presentations were divided into the following sections: summer breeding biology and abundance (Monarch Larva Monitoring Program-K. Oberhauser) and parasite infections in breeding populations (Monarch Health-S. Altizer), spring and fall migration (Monarch Watch-K. Oberhauser, Journey North-E. Howard, Long Point data-T. Crewe, and various monitoring programs in eastern N. America-A. Davis), overwintering colonies (Mexico-E. Rendon-Salinas and western N. America-D. Frey), analyses in progress (Monarch Larva Monitoring Program-R. Batalden and Monarch Health-R. Bartel).

**June 23 (Day 2):**

Presentations continued with exploring correlations among existing data sets (NABA 4th of July Butterfly counts and Monarch Larva Monitoring Project-L. Ries) followed by issues and recommendations on how best to combine multiple environmental data sets in a single data interface (N. Nibbelink). Following these presentations, everyone participated in a large group discussion and brainstorming session to categorize challenges and opportunities with monarch monitoring data sets. These efforts resulted in the group identifying several sections relative to (i) data collection and integration, (ii) biological questions and analyses, and (iii) identifying specific gaps in both data sets and analyses. To explore these issues in finer detail, we formed two smaller break-out groups focused on data integration and biological questions, with both groups addressing data gaps in the respective sections (detailed below).

**June 24 (Day 3):**

Small group discussions continued throughout the day and resulted in each of the respective break-out groups presenting their proposals to the larger working group. After large group discussion, the entire team concentrated on synthesis of the break-out group outcomes. We also discussed how best to integrate our conclusions into the final written report for the CEC and drafted an outline for this report. In addition, we discussed plans for scientific analyses and proposal writing for continued funding for future meetings and network construction.

**June 25 (Day 4):**

Prior to afternoon travel and departures, participants formed small groups (or worked as individuals) on writing specific CEC final report sections. Local organizers along with R. Batalden and K. Oberhauser outlined a timeline of project events for both data integration and data analyses for the next three years.

<u>Detailed summary of break-out group sessions:</u>

To better understand how to merge and analyze monarch monitoring data from multiple datasets, we divided into two break-out groups. The first of these focused on data integration, in which we designed an approach to combine current datasets, approach new partners, organize a collaborative network, and design a database interface for potential users. Through this discussion, we developed several priorities for facilitating integration of data: 1) identify existing databases, 2) develop standard protocol for recording metadata for each database, 3) define standardized data fields, 4) construct effective reward structures for data contributors, 5) design multiple-level data access configuration, 6) write cooperative agreements and contract for data use permission for partners and contributors, and 7) outline a long-term plan for development and management of the online monitoring network.

The second break-out group developed a vision for what we saw as the most pressing biological questions that could be addressed with merged datasets. These questions included: 1) What is the long-term status of the North American monarch population? 2) What are the key biotic and abiotic factors influencing spatiotemporal patterns of monarch abundance? 3) How do anthropogenic factors such as land-use change and climate change impact monarch populations? 4) What are the mortality rates during different life stages and migratory phases? 5) Can winter mortality rates or body condition predict spring abundance levels?

In addition to recognizing biological questions, this group also identified several data needs and gaps in current data analyses. The most important data needs we identified were as follows: 1) time series of crucial environmental variables influencing monarch abundance and movement patterns (e.g., spatiotemporal data for host plants and nectar sources, land-use change), 2) acquisition of additional spatial data in the southern region to estimate wintering populations outside of Mexico, 3) estimates of final wintering populations in Mexico including approximation of causes of mortality and estimates of body condition, and 4) increased participation levels in existing citizen science monitoring programs and encouraging overlapping participation in multiple programs. The large group also classified several research areas where data analyses need further development, including: 1) evaluating how congruent are estimates of abundance across the different regions of the various projects, 2) building a model to estimate population indices of overwintering colonies in Mexico, 3) exploring long-term population trends using a population viability analysis to determine the different extinction thresholds of breeding and wintering populations, and 4) combining the available data to construct a stage-structured population model to investigate effects of different drivers on patterns of monarch abundance and movement.

***Meeting Outcome***

The immediate result of the Monarch Butterfly Monitoring Workshop is that our group agreed to form an official organization to oversee the merging of monarch butterfly data. We selected a name for our group, the North American Monarch Monitoring Network, which we referred to as 'MonarchNet' for short. The steering committee for this network includes all 11 workshop members, and A. Davis was elected the chair of this committee. Our eventual base of partners will include a network of volunteers and scientists that collect and compile monarch monitoring data. An initial webpage will be developed by A. Davis (http://www.monarchnet.org) which will eventually be designed to display data from all existing monarch monitoring programs as well as provide synthesized trend graphs of monarch populations. The website will also include descriptions of each of the current data sets and monarch monitoring projects administered by committee participants.

This committee also established a series of recommendations for improving and managing monarch butterfly datasets and monitoring programs in North America; these will form the primary focus of the final report to CEC. The summary of current data repositories databases and description of their coverage and gaps in the context of the critical biological questions will guide analysis of merged data and acquisition of additional data. Finally, several sources for future funding were identified that would be required to formally construct the proposed online data portal to continue to merge datasets, minimize barriers with information access and exchange, and facilitate ongoing data management.

**APPENDIX 3.** Abstracts of presentations

### Project *MonarchHealth*: Rationale, protocols and challenges for a new citizen science project

Sonia Altizer, University of Georgia

Project *MonarchHealth* is a citizen-science survey of the occurrence of the protozoan parasite *Ophryocystis elektroscirrha* (OE) across North America. This debilitating parasite is transmitted from adult butterflies to eggs and larvae when monarchs scatter spores onto milkweed leaves during oviposition and other activities. OE parasites occur in all monarch populations examined to date, with lowest prevalence in migratory monarchs from eastern N. America, and high prevalence in year-round breeding populations that do not migrate. To date, sampling of OE infections at monarch wintering grounds has provided the most reliable and comprehensive assessment of annual parasite prevalence within migratory populations. However, because new infections arise during the breeding season only, it is also important to investigate where within the monarchs' breeding most transmission occurs, and what biological and environmental conditions are associated with a high frequency of infections. Project *MonarchHealth* was launched in 2006 as a way to accomplish this scientific goal by monitoring OE infections in monarchs sampled throughout their summer breeding range in North America. Volunteers sample wild adult monarchs for OE infections (or capture and rear wild larvae) using materials provided in a free kit distributed through the University of Georgia. Samples are returned to UGA for standardized analysis of infection status and we record the location, date, observer name, capture stage (adult or larva), sex, and infection status in a multi-year database. Volunteers are provided with feedback on the infection status of their sampled butterflies within 1-3 months of sample receipt. To date, a small number of observers (50-70/yr) are located across much of eastern N. America and include elementary and middle school teachers, nature center leaders, retirees and other volunteers. Results showing within- and between-year changes in infection prevalence across N. America will be presented by R. Bartel. Challenges we have faced in launching this project include the high cost and labor required in distributing kits and analysis of results, the small number of observers recruited to date, and high infection rates in a small number of captive-reared samples. Because OE infections can negatively affect monarchs and can spread rapidly in captive setting such as classrooms and nature centers, the broader mission of project *MonarchHealth* is to enhance awareness of monarch parasites by disseminating information through the WWW and by creating educational resources for teachers and volunteers.

### Movement patterns, habitat use and parasite transmission in migratory monarch butterflies: Preliminary results from Project Monarch Health

Becky Bartel, University of Georgia

Over the past two decades, scientists have become increasingly aware of the threats posed by infectious diseases for wild populations. Although known cases of pathogen-driven host extinction are rare, pathogens have caused declines in previously thriving populations and can threaten already declining species. Importantly, host dispersal across a landscape can prevent host population extinction in the face of a debilitating pathogen, and long-distance movements could further allow animals to escape contaminated habitats or cull infected animals from the population. To investigate relationships between host movement patterns, seasonal habitat use and infection prevalence, I used a host-parasite system of monarch butterflies (*Danaus plexippus*) and a neogregarine protozoan, *Ophryocystis elektroscirrha*. While monarch butterflies occur worldwide, most research has focused on the eastern North American population that breeds east of the Rocky Mountains and migrates annually to Central Mexico. To avoid prolonged freezing temperatures, this monarch population has exploited temperate resources through the evolution of a spectacular two-way migration. Using spatiotemporal citizen science data, I examined how host breeding densities, the duration of habitat use and landscape characteristics affect parasite transmission and accumulation in the environment. Because monarchs are accessible and understanding their biology is of conservation interest, there are multiple citizen science projects in North America that involve the public in recording observations on monarch butterfly migration. I used datasets from several of these ongoing programs to examine patterns of parasite infection in the eastern migratory population. First, I analyzed citizen science monitoring data from Project *MonarchHealth* to assess geographic and temporal variation in parasite occurrence during the summer months across the breeding range. Next, I examined relationships between local breeding densities and parasite transmission rates, utilizing data obtained from the *Monarch Larval Monitoring Project (MLMP)*. Lastly, I assessed prevalence patterns in conjunction with geographically explicit data obtained on the timing of colonization of different breeding sites obtained from a third citizen science program, *JourneyNorth*.

Initial results showed that parasites occur across the eastern migratory monarch population and prevalence varies by year sampled and by geographic region. Trends of infection observed from Project *MonarchHealth* were similar to those detected in overwintering wild populations in Mexico for 2006-2008, suggesting this program is capable of capturing real biological patterns. Results from data collected from 1997-2008 by the *MLMP* project showed monarch larval density estimates also varied over time and by geographic region. Ongoing analyses will determine how trends of recruitment influence rates of parasite infection. Data from 1997-2008 data of the *JourneyNorth* program suggest that the duration of habitat use were similar across regions but varied over time. Additional analyses will be necessary to evaluate how these patterns are related to prevalence. Collectively, these results are relevant for understanding complex relationships between monarch migration patterns, population sizes, habitat use, and parasite infection and vital for informing future monarch conservation plans.

**Using MLMP Data to Predict Monarch Responses to Climate Change**

Reba Batalden, University of Minnesota

The Monarch Larva Monitoring Project (MLMP) involves citizen-scientists in weekly censuses of monarch egg and larvae densities. This program focuses on monarch distribution and abundance during the breeding season, with its main goal to understand how and why monarch populations vary in time and space. MLMP began in 1997 at the University of Minnesota. From 1997 to 2005, over 600 participants monitored 514 sites in 34 US states and 2 Canadian provinces. Monitoring locations include underdeveloped sites like restored prairies and developed areas like roadsides or backyard gardens. To establish the potential impacts of climate change on monarch butterflies, I used MLMP data in two applications: 1) to determine their current and future breeding niches using ecological niche modeling and 2) to investigate possible causes for breeding in Texas during the fall migration. Monarchs in the eastern North American population show a series of range shifts during their breeding season. I collaborated with Karen Oberhauser and A. Townsend Peterson to use ecological niche modeling to study the environmental context of these shifts (Batalden et al. 2007). Using MLMP data to build the ecological niche models, we identified the ecological conditions that monarchs use in successive summer months. Monarchs use a consistent ecological regimen through the summer, but these conditions contrast strikingly with those used during the winter. Hence, monarchs exhibit niche-following among sequential breeding generations but niche-switching between the breeding and overwintering stages of their annual cycle. We projected their breeding ecological niche onto monthly future climate scenarios, which indicated northward shifts, particularly at the northern extreme of their summer movements, over the next 50 yrs; if both monarchs and their milkweed host plants cannot track these changing climates, monarchs could lose distributional area during critical breeding months.

MLMP volunteers in Texas report monarch eggs and larvae throughout the fall and winter, even though conventional wisdom is that monarchs are in diapause and migrating to Mexico at this time. It is unclear whether these eggs and larvae are due to the presence of a non-native species of milkweed, *Asclepias curassavica*, which is commonly planted in landscaped areas. Throughout the year more eggs per milkweed plant are found in sites with *A. curassavica* than in sites without the introduced milkweed. Because the non-native milkweed often grows in manicured sites, it may be in better condition than native species, particularly in the hot summer and fall months. Some MLMP volunteers collect data on the percent of a milkweed plant that is yellow or dying, but there is no difference in the condition rating of native and *A. curassavica*. This is an optional activity, and volunteers may stop monitoring when the milkweed quality deteriorates.

### Monarch migration monitoring and mark-recapture at Long Point, Lake Erie, Ontario

Tara L. Crewe, Bird Studies Canada

Bird Studies Canada is a non-governmental organization which engages the skills, enthusiasm and support of its members, volunteers and the general public to advance the understanding, appreciation and conservation of wild birds and their habitats. Long Point Bird Observatory (LPBO) is a program of Bird Studies Canada, and is a member station of the Canadian Migration Monitoring Network. Monarch migration has been monitored at two of LPBO's field stations since 1991 (standardized since 1995) as part of their landbird migration monitoring program. Long Point is approximately 40 km long and 1 km wide at its thickest point. It was designated an International Monarch Butterfly Reserve by the Government of Canada, based on the large number of monarchs that funnel through the area each year. Long Point is also a National Wildlife Area, World Biosphere Reserve (UNESCO) and Wetland of International Significance (Ramsar Convention). As part of LPBO's monarch migration monitoring program, daily "census" counts have been collected daily during fall since 1995, with the purpose of monitoring the change in number of monarchs moving through Long Point over time. Counts occur between mid-August and end of September at the Breakwater field station (mid-way between the base and tip of Long Point) and between mid-August and the beginning of November at the tip field station (eastern-most tip of Long Point). Counts consist of a one-hour walking census along a standardized path, during which all monarchs observed flying, feeding or roosting are counted. Counts are made by volunteers of LPBO, which vary in person and in number within a season and among years. Each day, volunteers also record the temperature (degrees Celcius), cloud cover (tenths), wind speed (Beaufort Scale) and wind direction (16 point scale). Because this is a relatively small dataset with few parameters, data are stored in a text file (*.csv), with one observation per line. Structuring data as a flat file, instead of as a matrix or relational database (with, for example, a different column for each day), provides for more efficient data management and analysis. We also use the standard field names applied to our bird monitoring data, to allow more easy application of available analysis programs to this dataset.

In 2008, LPBO also ran a monarch mark-recapture program, which will continue in fall 2009. The purpose of this program was to examine how site (geographic placement along a peninsula), weather, habitat and monarch condition affect the stop-over duration of monarchs, and how this in turn might influence daily counts and annual population estimates. Monarchs were captured daily between mid-August and late September and tagged using the Monarch Watch tagging procedure. Each monarch was measured (forewing length), examined for wing damage (tears or pieces missing), condition of scales, abdomen girth and sexed. Preliminary analysis of this data using program MARK has shown that monarchs do not tend to stop-over at the Breakwater station, but do stop-over and are potentially counted on several consecutive days at the tip station. This dataset is stored as a ‘*.csv’ file, with data for each individual on a separate line (flat file).

## Monarch Migration Monitoring at Peninsula Point MI and Cape May NJ with notes on Chincoteague VI

Andy Davis, University of Georgia

The spectacular migration of monarch butterflies in eastern North America provides an opportunity to estimate annual fall population sizes by monitoring the numbers of adults that pass through specific locations throughout the fall, with the assumption that these numbers are representative of the numbers in regions to the north of the site. Two such locations have monitored fall migrants in a standardized fashion for many years, Peninsula Point MI and Cape May, NJ, and these data are the focus of this presentation. In both programs, the number of monarchs seen during 3 daily censuses is recorded during 2-3 months each fall. At PP, the census is conducted at a walk along a trail through various shoreline habitats (of northern Lake Michigan) and the data set spans 13 years (1996-2008) with 1321 lines of data (each line is a census) in Excel. At CM, a driving census is conducted along a standardized route (at 40km/h) three times daily and these data span 17 years (1992-2008) with 2835 lines of data in Excel. Each census line also contains data on the start time, the air temperature, the amount of cloud cover and wind direction and speed at the beginning of each census. The PP data from 96-02 was examined in a study of environmental effects on monarch stopover (Meitner et al. 1994) and the CM data from 92-04 examined to describe the within and among-season patterns of migration (Walton et al. 2005). Results from these projects will be briefly discussed. One other monitoring site was established in 1997 at Chincoteague VI, although it is no longer in operation. Further, comparisons of those data with CM indicated highly consistent annual trends, which on the one hand demonstrated the validity of migration monitoring for assessing population trends, but on the other the importance of spacing monitoring stations adequately to minimize redundancy. This evidence, combined with recent findings on fall migration routes, indicates that future fall monitoring sites should be located in Texas or other low-latitude, central states where monarchs concentrate in the fall and where there are currently no stations.

**Western monarch population monitoring**

Dennis Frey, Cal Poly State University San Luis Obispo

There are three monitoring programs and attendant data sets that provide spatial and ecologically relevant information about western North America monarch populations. These data sets are: (1) the monarch component of the California Natural Diversity Base (CNDDB), (2) the monarch component of Art Shapiro's Butterfly Surveys, and (3) the Western Monarch Thanksgiving Count data base (WMTC). The CNDDB and WMTC survey wintering generation monarchs only. The Shapiro Surveys are conducted from early spring through late fall and thus include information for both breeding and migratory (wintering) generations. The CNDDB is a natural heritage program that maps location and natural history information of special status plants, animals, and natural communities in California. Since 1979 there have been 334 monarch wintering habitats (i.e., a special status natural community) included in the data base. Qualitative assessments of habitat characteristics are included for some habitats. Non-systematic seasonal estimates of monarch abundance are given for some years. The CNDDB is part of the Biogeographic Data Branch of California's Department of Fish and Game and it is available via a user-fee ($600 per year). Dr. Arthur Shapiro (UC Davis) has monitored butterfly populations at 10 sites across central California. He conducts surveys at approximately two week intervals and some of the sites have been surveyed since 1972. Sites are strategically located as a transect across the Sacramento River drainage basin to the Sierra Nevada foothills and to the eastern side of the Sierra Nevada Mts. Occurrence records exist for over 150 species and subspecies of butterflies, including monarchs. Since 1999 actual count data has been recorded at five of the sites. The surveys take place along fixed routes and follow standardized protocols. The Shapiro data is managed by the Information Center for the Environment at UC Davis and the current data administrator is Dave Waetjen. The Western Monarch Thanksgiving Count program (WMTC) was initiated in 1997 by the Monarch Program, a non-profit organization. Since 2001 it has been administered by a network of monarch researchers and naturalists in collaboration with the Xerces Society. Since its inception the WMTC program has monitored abundance at 83 to 140 sites annually along the coastal wintering range. Counts are conducted by many experienced monarch researchers, naturalists, and docents within a 2 week period centered on the Thanksgiving holiday using standardized field protocols. Mia Monroe (National Park Service) organizes the annual system-wide counts and count data are available on the Xerces Society web-portal for the California Monarch Campaign.

**Spring and Fall Monarch Butterfly Migration: Overview and Insights Based on Citizen Science Data from Journey North**

Elizabeth Howard, Journey North

Journey North is a nonprofit organization whose primary mission is to engage K–12 students in a global study of migration and seasonal change. Journey North tracks spring and fall monarch butterfly migration by collecting observations from citizen scientists across Canada, the United States, and Mexico. Spring migration is tracked through 'first sightings' of adult monarch butterflies, and fall migration is tracked through observations of 'overnight roosts'. Journey North's datasets provide a real-time, dynamic view of the timing and pathways of monarch migration. The historic records provide baseline data of spring migration (since 1995) and fall migration (since 2002). Three scientific papers have been published based on Journey North data. We calculated spring recolonization rates based on the cumulative area occupied by monarchs and the rate of movement of the advancing wave-front and found that spring migration moves more quickly than previously estimated, progresses in four distinct phases, and the temporal patterns observed each year are remarkably consistent. Analysis of fall roost-site data illustrated two flyways used by monarchs, a ‘central flyway’ that appears to lead directly to Mexico and an ‘eastern flyway’ that lags behind and appears to be suboptimal.

The opportunity to combine Journey North data with other monarch monitoring data—particularly weather and climate data—will allow questions like the following to be explored: How do warm winters affect the monarch’s winter range and spring migration patterns, particularly along the Atlantic and Gulf Coasts, and could an overall warmer climate alter these patterns similarly? How does each spring’s unique temperature profile influence the pace and direction of migration, and what are the conservation implications especially for 1st generation reproduction? How can the continent-wide perspective that Journey North’s fall roost-site data provides inform site-specific data collected at fall monitoring sites (and visa versa)? How do North America’s synoptic weather patterns with their associated winds impact fall monarch migration, and are these weather patterns changing? Can we find correlations between the annual winter population estimates made at the overwintering sites in Mexico and Journey North’s spring and/or fall migration data?

Journey North datasets are available for use by scientists with the goal of helping to further identify migration pathways and critical times of passage, to understand the weather events and human activities that affect the monarch population during migration, and to understand the potential impact of climate change on the monarch’s migration and range.

## Monarch Larva Monitoring Project

Karen Oberhauser, University of Minnesota

The Monarch Larva Monitoring Project (MLMP) involves volunteers from across the United States and Canada, and was developed in 1997 to collect long-term data on larval monarch populations and milkweed habitat. The overarching goal of the project is to better understand monarch distribution and abundance during the breeding season in North America. Volunteers conduct weekly monarch and milkweed surveys, measuring per plant densities of monarch eggs and larvae and milkweed quality. Most volunteers have monitor one or a few sites in which milkweed grows and that they can monitor regularly (ideally weekly) during the time that milkweed is present. These individuals register as MLMP volunteers, and provide detailed information about their sites. Other volunteers report anecdotal observations at sites that they are unable to monitor regularly.

Volunteers engage in four main monitoring activities, in addition to entering information about their monitoring sites and themselves. Activity 1, which almost all volunteers conduct, involves estimating per milkweed plant monarch densities by observing as many plants as they can, and recording the number of monarch eggs and larvae (identified to instar) on those plants. Most published analyses of MLMP data have utilized these data. Activity 2 involves collecting temperature and rainfall data at each site. Fewer volunteers participate in this activity, and we have not utilized the data. Activity 3 is focused on rates of parasitism by insect parasitoids, mainly tachinid flies. Volunteers collect and rear larvae, recording whether they are parasitized.

Approximately a third of our volunteers have reported parasitism data, and we have published one paper using these data and additional parasitoid data collected by a subset of volunteers. In activity 4, volunteers compare several characteristics of plants are occupied by monarchs to randomly-chosen plants. This activity is the most difficult to conduct, but also teaches volunteers a great deal about the "milkweed community". While we have not published any findings using these data, we have shared them with educators, and are currently using them in a study of milkweed plant condition and use by monarchs in the southern US during the monarch fall migration.

MLMP data are maintained in a relational database (currently Access, being switched to SQL Server). There are almost 600 sites in the database, and all data are connected to a single site. The data are maintained by a professional web programmer, who works on an hourly basis with program managers. Funding has been an issue for the MLMP. We have been funded by the NSF to develop the program, but because NSF funds have come from the Informal Science Education program, we have had much more support for its educational aspects than its scientific aspects. As such, we have not been able to conduct some analyses that would further our understanding of monarch biology.

## Monarch Butterfly Overwintering Monitoring in Mexico 2004-2009

Eduardo Rendón-Salinas[1]., A. Valera-Bermejo[2] and C. Galindo-Leal[3].

[1] World Wildlife Fund (WWF) México.
[2] Hombre y Alas de Conservación, (HALCON) A.C.
[3] Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO).

Since the overwintering season 2004-2005 and until 2008-2009 World Wildlife Fund (WWF) Mexico Program in coordination with the Monarch Butterfly Biosphere Reserve Direction, have been monitoring the forest surface occupied by the Monarch butterfly overwintering colonies in Mexico. During these last five seasons, the smallest number of colonies counting 7 and the smallest historical surface was reported with 2.19 hectares for 2004-2005. Twelve colonies were reported through two seasons, when the surface was greater than 5.5 hectares and 11 colonies during two seasons when the surface was less than 5.5 hectares. The reported forest surface corresponds to December, although the monitoring activities are developed through the five overwintering months. Sixteen colonies had been reported in 11 sanctuaries. The colonies from El Rosario and Cerro Prieto in Michoacan located within the Reserve, and the colonies from San Antonio Albarranes and San Mateo Almomoloa in Estado de Mexico and outside the Reserve, have been constant during the five seasons. Four colonies have been present through four seasons and four more during three seasons. One colony was present two years and three colonies for only one season. The surface occupied by the overwintering colonies in the last five monitoring seasons is 2.19, 5.92, 6.87, 4.61 and 5.06 hectares, corresponding to season 2004-05, 2005-06, 2006-07, 2007-08 y 2008-09 respectively. These surfaces are below the average (7.6 hectares) of the last 16 years (1993-94/2008-09). During the last five seasons no catastrophic mortality events due to weather factors have been reported. The last snow storm that caused extraordinary butterfly mortality was registered in January 2004, for the 2003-04 season.

**Correlations between multiple data sets recording monarch adult and juvenile stages**

Leslie Ries, University of Maryland
and Karen Oberhauser, University of Minnesota

There are several general butterfly surveys that capture information about adult monarchs during the breeding season in the United States and Canada. The three largest such programs are the North America Butterfly Association's Annual July 4th counts and two state-wide monitoring programs, one in Illinois and the other in Ohio. These three programs are volunteer run and monitor hundreds of sites throughout the US and Canada each summer. We stratified the continent into five regions and compared phonological and year-to-year trends within each region between these three programs, as well as with egg data collected as part of the Monarch Larva Monitoring Project and migration data at Cape May and Peninsula Point. Comparisons between the three adult data sets were only carried out in two of the five regions (North Central and Mid Central). Correlations were consistently positive and generally high (and significant) between the three sets, although generally stronger in the North Central region where there were more data. Correlations were weaker when comparing adult to egg counts, which may reflect both methodological differences as well as underlying biology (adults may not always be laying eggs). However, even in these very different data sets, correlations were generally positive and often significant, especially when comparing year-to-year trends. Correlations were weak, however, between the three monitoring programs and counts of fall migrants at two sites. In my presentation, I will detail the specifics of the three monitoring programs, present the results of the correlation analyses in detail, and also show our plans to build models linking egg, reproduction, migration and over-wintering stages to determine what factors most drive yearly abundances.