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STATUS OF *DANAUS PLEXIPPUS* POPULATION IN ARIZONA

Gail M. Morris
Southwest Monarch Study, 6120 W. Ivanhoe St., Chandler, AZ 85226, USA email: phoenixmonarchs@yahoo.com

Christopher Kline
Butterfly Ridge Butterfly Conservation Center LTD, 6220 Sugar Grove Road, Sugar Grove, Ohio 43155, USA
email: chris@butterfly-ridge.com

and

Scott M. Morris
445 N 5th St, Phoenix, AZ 85004, USA email: scottmorrisphx@gmail.com

ABSTRACT. We report results of a ten year study to understand the distribution, breeding and migration of the monarch butterfly (*Danaus plexippus*) in Arizona. We observed breeding and migratory monarch populations throughout the state and small overwintering aggregations in some locations. Migration occurred to known migration destinations in both California and Mexico. We found that the destination is not random. Wind significantly affects whether migrating monarchs are recovered. This study provides new insights into the breeding, overwintering and migratory strategies of Arizona monarchs.

Additional key words: *Danaus plexippus*, Arizona, Southwest Monarch Study, Migration, Monarch Butterfly

While much is known about the monarch butterfly (*Danaus plexippus* L., Nymphalidae) migration and breeding in the eastern portion of North America, little is documented about the southwest United States. Through tagging studies, Urquhart (1987) concluded there were two monarch populations in North America. He identified an extensive "Eastern Population" overwintering in Mexico and a "Western Population" that overwinters in California as well as a resident population in Florida. Urquhart maintained that the two populations are not geographically isolated and migrants from west and east of the Rocky Mountains both move through river valleys especially in Idaho and Montana, particularly along the Snake River tributaries. He noted that it was likely that genetic material was also exchanged in other mountain passes. Monarchs west of the Rocky Mountains migrate to the coastal sites of California extending in smaller numbers to Baja California in Mexico (Leong et al. 2004). Howard et al. (2010) demonstrated that small numbers of monarchs also spend the winter along the Gulf coast and in Texas. Many have questioned if eastern and western monarchs are one population (Brower 2005). Recent genetic studies of migrating eastern and western monarchs support the hypothesis that they may form one admixed population (Lyons et al. 2012).

An early map of fall monarch western migration movement by Urquhart (1960) noted that Arizona was in an area with no reported collections or recorded observations. Later, Urquhart (1977) reported that few adult monarch butterflies were ever collected in Arizona and New Mexico. R. Bailowitz's (pers. comm.) database for Arizona butterflies listed 150 monarch sightings from 13 August 1975 to 7 October 1984 primarily in Santa Cruz and Cochise counties in southeast Arizona but also in smaller numbers in other counties across the state (Appendix 1). Urquhart (1987) posted observations from Louis Schellbach at the Grand Canyon reporting monarchs moving south through the state during the migration. In particular Schellbach observed monarchs flying south along U. S. Hwy 89 from Salt Lake City, Utah between two mountain ranges. Urquhart (1987) also recorded limited sightings of monarchs in Flagstaff, Arizona and Ridgefield, Utah. Bailowitz and Brock (1991) noted that monarchs were most common "during its southward migration, in late summer and early fall" in southeast Arizona.

Pyle (1996) travelled through Arizona during the fall migration while researching monarch movement and observed occasional monarchs in the southern part of the state flying to the south. R. Gilmore (pers. comm.) in October 1997 and again in 1998 noted monarchs flying north along the Colorado River at Lake Havasu then turning west along I-40 at Needles and flying west through the mountain pass into California. He also observed hundreds of dead monarchs on the front grills of semi-trucks parked at a truck stop near Kingman after driving east through the same pass. The Arizona

Sonora Desert Museum Migratory Pollinator Program on Monarch Butterflies (1999) research noted monarchs flying south along the San Pedro River through Guadalupe Canyon into Mexico. They also recorded monarchs flying south through Buenos Aires National Wildlife Refuge and Organ Pipe Cactus National Monument in southern Arizona continuing south across the border. The observations of Bailowitz, Brock, Pyle and the Arizona Sonora Desert Museum researchers provided evidence that some western monarchs may migrate to the Mexican overwintering sites and that not all Western monarchs fly to overwintering sites on the west coast (Pyle 1999, Brower and Pyle 2004). Observations of Pyle and Dingle et al. (2005) suggested the possibility of monarch migration flyways in eastern Arizona along the New Mexico border and San Pedro River as well as along the Colorado River on the western border.

There have been conflicting reports regarding monarch breeding in Arizona. A map of eastern and western monarch populations in Journey North (2011) excluded most of Arizona as monarch breeding habitats. Stevens and Frey (2010) studied monarch host plants and climate patterns in western North America and noted Arizona had 22 species of *Asclepias* according to their model that included only extreme western Arizona. Of these, in Arizona only *A. erosa*, *A. linaria*, *A. speciosa* and *A. tuberosa* had growing seasons extending to August and September to produce a migratory generation. Earlier Urquhart (1960) mentioned briefly that Louis Schellbach found monarch larvae feeding on native milkweed at the Grand Canyon but provided few additional details. Funk (1968) reported 48 monarch larvae on *Asclepias tuberosa*, not native to the lower elevation of Yuma, as well as six pupae and three adults in Yuma in December 1965. He observed oviposition on 16 January 1966 as well as 18 and 27 February 1966, although copulation was not observed. Bailowitz and Brock (1991) noted monarchs were common in the Canelo Hills in southeast Arizona where they seemed to breed and reported the primary food plant as *Asclepias asperula* in the nearby Huachuca Mountains. J. Brock (pers. comm.) found a female ovipositing on *Asclepias tuberosa* along Turkey Creek in Canelo on 1 June 1994. He returned on 16 June 1994 and found monarch larvae. Brower and Pyle (2004) noted a report of 65 monarchs on 2 August 2003 along the San Pedro River between Hereford and Palominos near a stand of *Asclepias subverticillata*.

Monarchs were observed during the winter months in Yuma and Tucson. Funk (1968) observed monarch adults flying in the Yuma area on warm days in January 1966. Bailowitz and Brock (1991) reported limited monarch sightings during the winter in the Tucson area. Brower and Pyle (2004) reported small numbers of monarchs during the winter months in the Yuma area and along the Colorado River as well as Tucson.

Brower and Pyle (2004) hypothesized that occasional east to west influxes of eastern monarch butterflies increased the western population. In 1996 a poor spring remigration in the eastern United States from Mexico was followed by a large population increase in the western monarch population the following fall. This shift correlated with a documented major westward wind pattern shift in March and April also affecting the warbler migration. Winds could have displaced monarchs into New Mexico and Arizona aiding the western California overwintering population recovery. In this scenario Arizona could be a flyway.

A unique annual weather phenomena in Arizona is the summer monsoon season from 15 June to 30 September. The normal dominating westerly winds shift to prevailing winds blowing from the south, southeast and east to the north, northwest and west. It is a time of frequent to daily intense storm activity with locally heavy rainfall and damaging winds. During September the winds aloft are unstable as the season ebbs and flows, but intense storms are triggered and amplified by increased pacific hurricane remnants or cold fronts sweeping through the state. This results in severe storms over large areas of the desert, particularly southeast and central Arizona (National Weather Service 2008). This arrival of the annual monsoon triggers the time of greatest insect activity as well as plant growth around the state and is particularly pronounced in southeast Arizona (Bailowitz and Brock 1991).

The natural history of the monarch in Arizona is fragmented and incomplete. This paper presents field observations of a citizen science study and the results of a tagging program that addresses both monarch breeding and heretofore unknown migratory movements of the monarch butterfly in Arizona.

MATERIALS AND METHODS

Early locations for exploration of *Danaus plexippus* absence/presence were based on data reports on the Southwest U.S./Northwest Mexico Leps list (1999) and personal communications with several butterfly enthusiasts in Arizona. Collections of *Asclepias* were researched in SEINet (Southwest Environmental Information Network 2014) database to locate possible breeding habitats. Opportunities for Citizen Scientists to participate in monitoring and tagging monarchs were publicized on the Boyce Thompson Arboretum website, newspaper articles and an occasional television feature.

Fig. 1. Arizona climate zones. Blue indicates mountainous regions, Green, high desert and cool plateau highlands, Yellow, low and mid altitude desert.

In 2010 the Southwest Monarch Study web site was developed to promote tagging and monitoring opportunities as well as a Facebook page. Permits and/or permissions to enter, monitor and tag on private or government properties were acquired. Data collection of monarchs tagged or monitored in a site where it was unclear whether proper landowner permission had been obtained or later denied were omitted.

Tags were provided free of charge to volunteer citizen scientists to encourage active participation by the public. Tagging trips began in 2003 in southeast Arizona, known for the Sky Islands, rich in biologic diversity and density (Bailowitz and Brock 1991). Tags were purchased through Monarch Watch with Southwest Monarch Study contact information printed on the tags. The tags were made from a 2 mil all-weather white polyester facestock, paired with a 2 mil 3M adhesive layer. They were 8.89 mm in diameter and weigh less than 0.01g. From 2003 to 2011 the tags were blue; 2012 to 2014 the tags were white.

Sightings. The general public as Citizen Scientists was invited to monitor their own backyards and search natural areas for the presence of species of *Asclepias*, monarch breeding or migration activity and send in reports. In addition training workshops were held around the state. Sightings and photos of species of *Asclepias*, *Danaus plexippus* adults, eggs, larvae and pupae around Arizona and the Southwest were reported via email or posted to the Southwest Monarch Study Facebook page. Photo documentation was required for participants if they were new to monitoring to assure proper identification of adults or immatures due to the easy confusion with *Danaus gilippus*, queen butterflies, in the field. In addition, Southeast Arizona Butterfly Association (SEABA), Central Arizona Butterfly Association (CAzBA) and other butterfly lists were monitored for monarch sightings and reporters were contacted for details.

Breeding Habitats. Field trips were organized to investigate possible breeding habitats based on monarch sightings, *Asclepias* collections and reported riparian habitat. Protocols for identifying species of *Asclepias* were designed using herbarium and other resources (Kearney and Peebles, 1961, Woodson, 1954). For the purpose of this study we used the following divisions to identify elevations in Arizona: Low and Mid Altitude Desert (below 1,067 m) including Phoenix, Tucson, Lake Havasu, Parker and Yuma, High Altitude Desert and Cool Plateau Highlands (1,067 m to 1,829 m) including Prescott, Payson, Patagonia, Canelo and Sierra Vista, and Cold Mountainous Regions (above above 1,829 m) including Flagstaff, Pinetop/Lakeside, the Grand Canyon and Springerville/Eager (Davison, 1999) (Fig.1). When monarch breeding was noted, the location, date, weather conditions, species of *Asclepias*, and species of nectar in bloom were noted. In addition, mating, oviposition, eggs, larvae, pupae and adults were recorded. There were multiple visits to identify breeding habitats and to monitor field conditions.

Overwintering Monarchs. Monarch sightings during the winter months were recorded and possible habitats were explored for monarch absence/presence weekly. The number of adult monarchs, species of nectar, tree species used for night roosting, clustering, presence of milkweed as well as any copulation and presence of immatures were recorded for the season.

Field Methods: Tagging Wild Monarchs. Volunteer citizen scientists were trained in netting techniques, data collection and *Danaus plexippus* identification. Using a standard 46 to 61 cm (18 to 24 in.) deep insect net, live wild monarchs were captured for tagging, especially during summer and fall. Some monarchs were also captured by using fingers to lift them from flowers.

Date, name of tagger, tag number, and location, were recorded along with butterfly sex. The behavior at the time of tagging was recorded (such as nectaring including species of nectar plant if known), time of tagging and condition (freshly eclosed, excellent, good,

fair, poor) were recorded on data sheets with room for additional comments. All were recorded as wild monarchs. After tagging, the butterflies were released. Any sightings of other *Danaus plexippus* already tagged in the field were recorded.

In addition to tagging, habitat conditions including species of *Asclepias* and nectar, approximate number of monarchs present, weather conditions and time of day were noted for further site analysis when possible. Starting in 2010, occasional sampling of monarchs was sent to Monarch Health at the University of Georgia for analysis of *Ophryocystis elektroscirrha* (OE) parasite load. Samples were tested for infection status by researchers at the University of Georgia associated with Project Monarch Health (www.monarchparasites.org). Samples were collected from monarchs by pressing transparent tape against adult monarch abdomens. Samples were scored for the presence/absence of OE infection based on the presence of > 100 parasite spores per sample following Bartel et al. (2011).

Field Methods: Tagging Farm Monarchs. In addition to tagging wild caught monarchs, each fall from 2004 to 2012, the Desert Botanical Garden (DBG) in Phoenix tagged and released up to 50 farmed monarch butterflies a week with the public. DBG purchased these monarchs from a butterfly breeder farm in California and all activity was conducted under appropriate USDA permits DBG obtained. Other limited additional opportunities arose to tag farmed monarchs in other settings such as butterfly events sponsored by local nature centers or churches who purchased farmed monarchs for special celebrations. The sponsors of the events and the farms where they purchased the butterflies were responsible for legal compliance. All farmed monarch tagging was conducted by the same method employed for wild monarchs except they were recorded as farm monarchs. We tested some of the farm monarchs purchased for special events for *Ophryocystis elektroscirrha* with the same protocols as Wild Monarchs. The Southwest Monarch Study never purchased farmed monarchs or was involved in monarch breeding.

TABLE 1: *Asclepias* Favored by *Danaus plexippus* by Climate Zone. **H** = Mountainous regions, **M** = High desert and cool plateau highlands, **L** = Low and mid altitude desert

H	M	L	
-	-	x	*A. albicans***
-	x	x	*A. angustifolia***
x	x	x	*A. asperula*
x	x	x	*A. engelmanniana*
-	-	x	*A. erosa*
-	x	x	*A. linaria***
x	x	x	*A. nyctaginifolia*
x	x	-	*A. speciosa*
-	-	x	*A. subulata** **
x	x	-	*A. subverticillata* *
x	x	-	*A. tuberosa*
-	-	x	*Funastrum cynanchoide* (*Sarcostemma cynanchoides*)

* primary *Asclepias* for breeding

** evergreen

FIG. 2. Mating monarchs on *Pinus ponderosa*, near an *Asclepias subverticillata* meadow, Maswik Lodge, Grand Canyon National Park South Rim. Photo by Bob Morris.

Peak Migration. The monarch migration is correlated with sun angle (sun's elevation above the horizon at solar noon) which is dependent on latitude and date. In the east, the leading edge of the monarch migration begins at a sun angle of 57° to 56° and ends at 47°, slowing then to a trickle in most years (O. R. Taylor pers. comm.). We compiled monarch sightings and tagging numbers to see if they increase during these periods. It has been observed that the peak migration occurs when the sun angle is 53° to 52° (Monarch Watch 2014). When tagged monarchs are recovered or sighted at overwintering sites in Mexico or California the sun angle at the time of tagging was determined using the NOAA Solar Calculator (2014) to compare with peak migration observations by latitude in the east.

Wind and Migration Destination. The shift in wind direction during the summer monsoon in Arizona, especially during the transitional period in September,

could play a role in migration destination from southeast Arizona. Gibo and Pallett (1979) found that head winds, crosswinds, and tail winds affect monarch flight. The most efficient flight when favorable conditions are present for migrating monarchs is soaring by gliding in rising air thermals to conserve lipids. Lift can be generated by two means: thermal lift and slope lift. Thermal lift is frequently used by soaring birds as well as monarchs and occurs when air masses are heated by the sun. Slope lift occurs on the upwind side of mountain passes and occurs in hilly or mountainous terrain. While monarchs can soar and glide at many heights, the most common used is 300 m (Gibo 1981). Since southeast Arizona is most deeply affected by the moist monsoon wind shift and is also located in mountainous terrain we formulated two hypotheses regarding migration from this location.

Based on this information:

1. We predicted that monarchs tagged on a single day in southeast Arizona will travel to the same migration destination (California or Mexico).
2. We predicted that wind direction on the day of tagging in southeast Arizona affects whether a monarch was recovered.

We obtained wind speed and direction from the National Weather Service in Tucson (Thompson 2014). The wind data were interpolated to 305 m (1000 ft) intervals above ground level (AGL), based on twice-daily weather balloon releases in Tucson. The balloons were tracked via GPS to calculate wind speed and direction, and altitude was calculated from the air pressure. We standardized to the 0000 h UTC (1700 h MST) sounding at 305 m (1,000 ft) AGL.

Results

Monarch Presence. Adult monarchs were reported in every month in some years in Arizona but at varying elevations. In warm winter years without a hard freeze (temperatures less than or equal to -2.7°C for two or more hours (NOAA, 2014)), monarchs were reported most commonly from September until mid-May in the lower desert elevations including Phoenix, Tucson, Yuma, Parker and Lake Havasu. In years with a hard freeze, monarch sightings plummeted until late March through May when a small number of monarch observations were reported. In the High Altitude Desert and Cool Plateau Highlands including Pine, Sedona, San Rafael Valley, Sierra Vista and Canelo, monarchs were reported in some years as early as the last week of March in the southeastern portion of the state but more commonly in July through October, sometimes longer with an extended favorable fall season. In the Cold Mountainous Regions including Flagstaff, the Grand Canyon and Springerville, monarchs were present from mid-June through September.

Breeding Habitats. Arizona has a variety of elevations providing diverse climates supporting many *Asclepias* species. Monarchs were seen ovipositing and eggs, larvae and pupae were observed on the following species of *Asclepias* in each plant climate zone. During the summer breeding season in the Cold Mountainous Regions of Arizona, *Asclepias subverticillata* was the primary host plant closely followed by *Asclepias speciosa*. In the High Altitude Desert and Cool Plateau Highlands elevations, *Asclepias subverticillata* was primary but other milkweeds were also utilized (Table 1). Evergreen milkweeds were host to mainly fall breeding monarchs in

Table 2: Breeding nectar. **H** = Mountainous regions, **M** = High desert and cool plateau highlands, **L** = Low and mid altitude desert.

H	M	L	Plant Name	Family Name	Common name
x	x	x	*Apocynum cannabinum*	Apocynaceae	Indian Hemp
x	x	x	*Asclepias* spp.	Apocynaceae	Milkweed
-	x	x	*Baccharis salicifolia*	Asteraceae	Seep Willow
x	x	-	*Carduus nutans*	Asteraceae	Nodding Thistle
x	x	x	*Cirsium* spp.	Asteraceae	Various Thistles
x	x	x	*Helianthus annuus*	Asteraceae	Common Sunflower
x	x	x	*Medicago sativa*	Fabaceae	Alfalfa
x	x	-	*Senecio flaccidus* var. *flaccidus*	Asteraceae	Threadleaf Groundsel
x	-	-	*Trifolium pinetorum*	Fabaceae	Cow Clover
x	-	-	*Verbena macdougalii*	Verbenaceae	New Mexico Vervain
-	-	x	*Vitex agnus-castus*	Lamiaceae	Lilac Chaste-Tree

FIG. 3. Monarch larva on *Asclepias subulata*, Chandler Environmental Center, Chandler, AZ, 28 September 2009 High temperature 38.8° C, Low temperature 17.7° C (Weather Underground). Photo by Gail Morris.

FIG. 4. Roosting *Danaus plexippus* and one *Danaus gilippus*, South Mountain, Phoenix, 11 November 2007. Photo by Tatsuyo Schultz.

TABLE 3: Clusters of migrating monarchs

Date	Location	Number of D. plexippus
11/7/2010	South Mountain, Phoenix	6 + 1 D. gilippus
11/21/2010	South Mountain, Phoenix	5
10/6/2012	Arivaca Cienega, Arivaca	20
10/27/2012	Rotary Park, Lake Havasu	60
9/28/2013	Montosa Canyon, Santa Rita Mountains	13
10/5/2013	Canelo	23
11/8/2013	Buckskin State Park, Parker	125
9/6/2014	South Rim, Grand Canyon	28
10/6/2014	Alamo Lake	12
10/12/2014	Alamo Lake	12

the Low and Mid Altitude Desert. In particular *Asclepias subulata* was heavily favored although *Asclepias angustifolia* was also used frequently in backyard gardens. Abundant summer monsoon rains triggered a second growing season in some years especially in the lower deserts. Eggs, immatures and monarch oviposition were frequently reported in the fall on *Asclepias nyctaginifolia*, *Asclepias asperula* and *Asclepias erosa* in addition to the evergreen milkweeds. There were no collections (SEINet 2015) or observations of *Asclepias curassavica* growing in roadside ditches or any other naturalized areas. This milkweed was limited to an irrigated garden specialty.

Most breeding areas in Arizona hosted two to three generations (sometimes more) in the High Altitude Desert and Cool Plateau Highlands during the summer months, allowing the monarch population to expand substantially at these locations before the fall migration. In particular Elgin, Turkey Creek and the San Rafael Valley in southeast Arizona had the largest monarch populations in the state. By mid-September it was not unusual to find over 100 monarch adults present in a 0.5 km^2 field along Turkey Creek as well as larvae and pupae. The greater Prescott area and Tonto Natural Bridge State Park in Pine also documented breeding in late July until September.

In the Cold Mountainous Regions monarchs usually successfully completed two generations before the fall migration. Monarchs were reported in Flagstaff at Buffalo Park with extensive fields of *Asclepias subverticillata*. Monarchs were recorded on the South Rim of the Grand Canyon flying out of the inner Canyon along Bright Angel Creek on the South Rim

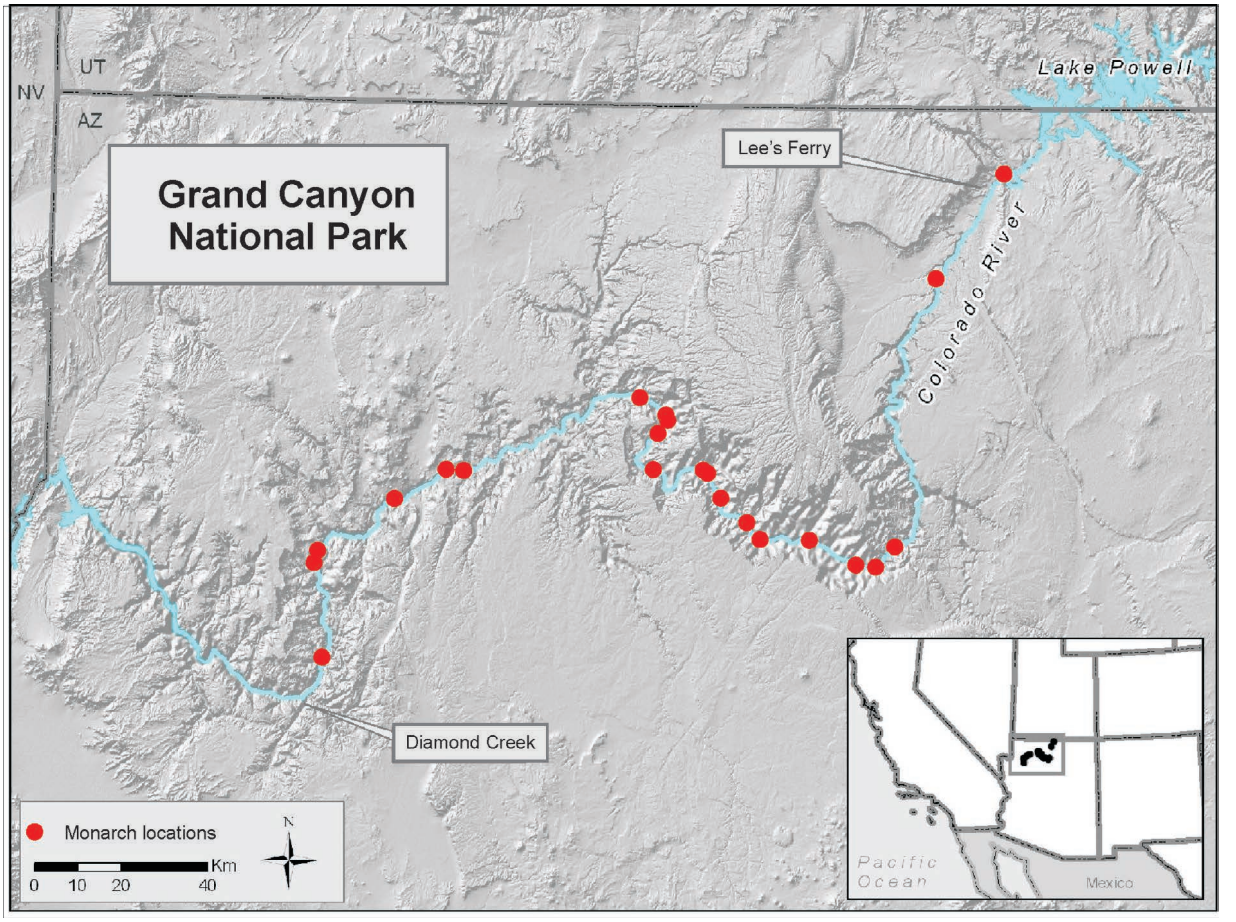


Fig. 5. Locations of monarch sightings on the Colorado River in the Grand Canyon between 23 October 2008 and 10 November 2008. Each red dot represents a GPS sighting. No monarchs were tagged in the park during this time period.

during July and August. Extensive oviposition, larvae and pupae were noted in low-lying, moist meadows filled with *Asclepias subverticillata* while breeding was documented in nearby Ponderosa Pines (Fig. 2). The White Mountains, including Pinetop/Lakeside, Springerville and Eager had abundant breeding primarily on *Asclepias subverticillata* and *Asclepias speciosa* in meadows and riparian areas. After the Wallow Fire in Springerville in the summer of 2011, monarchs were notably absent in July, but were present the second week of August and completed only one generation before leaving on their migration.

While limited reports of spring breeding were noted in the Low and Mid Altitude Deserts, fall was the premier breeding season in Phoenix, Yuma, Lake Havasu, Kofa Mountains and Tucson. In the final days of August through early September monarchs returned into the area and they were breeding with heavy oviposition documented (Fig. 3). Temperatures in the lower desert can still reach 43°C or above in some years in early September and egg, larvae, and pupae demise have been documented in years with high temperatures. In years of warm fall temperatures both migrating and breeding monarchs were observed in late September and October. Some locations documented one to two generations.

Breeding Season Nectar. *Asclepias* spp. in bloom was the favored nectar for breeding monarchs at all elevations. Monarchs were also observed feeding on additional nectar plants commonly in season (Table 2), a variety of trees in bloom such as *Prosopis velutina* (Fabaceae), Velvet Mesquite, and *Robinia neomexicana* (Fabaceae), New Mexico Locust, in addition to other lesser nectar sources. Monarchs were opportunists when nectar sources were limited and were seen nectaring on invasive species such as *Convolvulus arvensis* (Convolvulaceae), Field Bindweed, and *Tamarix chinensis* (Tamaricaceae), Salt Cedar. In home gardens zinnias, cosmos, sunflowers, tithonia, coreopsis and asters were favored.

Migration Sightings. Small, loose clusters of monarchs during the migration were occasionally

TABLE 4: Fall migration nectar. **H** = Mountainous regions, **M** = High desert and cool plateau highlands, **L** = Low and mid altitude desert.

H	M	L	Plant Name	Family Name	Common name
x	x	x	*Asclepias* spp.	Apocynaceae	Milkweed
-	x	x	*Baccharis salicifolia*	Asteraceae	Seep Willow
-	x	x	*Baccharis sarothroides*	Asteraceae	Desert Broom
-	-	x	*Bebbia juncea*	Asteraceae	Sweetbush
	x		*Bidens laevis*	Asteraceae	Smooth Beggartick (Marsh Sunflower)
x	x	-	*Carduus nutans*	Asteraceae	Nodding Thistle
x	x	-	*Ericameria (Chrysothamnus)* spp.	Asteraceae	Rabbit Brush *
x	x	x	*Cirsium* spp.	Asteraceae	Various Thistles
x	x	x	*Helianthus annuus*	Asteraceae	Common Sunflower *
x	x	-	*Senecio flaccidus* var. *flaccidus*	Asteraceae	Threadleaf Groundsel
x	x	x	*Verbesina encelioides*	Asteraceae	Golden Crownbeard
-	-	x	*Vitex agnus-castus*	Lamiaceae	Lilac Chaste-Tree

* Favored

reported (Fig. 4) as well as multiple monarch movement during September through November (Table 3). In addition there were late sightings of monarch movement along rivers such 16 monarchs along the Colorado River through the Grand Canyon in November 2008 (Fig. 5), one monarch at the Hassayampa River Preserve near Wickenburg (elevation 610 m) on 23 November 2014, and three monarchs on the Agua Fria at Rock Springs (elevation 610 m) on 9 December 2014.

Migration Nectar. Monarchs were observed to favor, but were not limited to, fall blooming species of *Asclepias* in bloom as well as other nectar plants (Table 4). In home gardens, fall blooming zinnias, cosmos, sunflowers, tithonia, coreopsis, ageratum and asters were favored.

Overwintering aggregations. Several small overwintering aggregations of 3 to 45 monarchs were found to spend the winter in the greater Phoenix area each year. Two sites were along the Salt River (Rio Salado Habitat Restoration Area and Tempe Marsh) and one was at Desert Botanical Garden in Phoenix. The populations at Desert Botanical Garden and Tempe Marsh were decimated by a hard freeze of -2°C on 31 December 2010. A second hard freeze of -2°C occurred one month later on 2 February 2011. The monarch population at Rio Salado Habitat Restoration Area was able to partially survive these conditions (Fig. 6). By weekly monitoring of nearby *Asclepias subulata* the Rio Salado overwintering monarchs appeared to be in diapause until early February (Fig. 7). In 2012 overwintering aggregations were also found at Singh

TABLE 5: *Ophryocystis elektroscirrha* (OE) infection rates

Year	Total count	Zero		1 to 10		11 to 100		More than 100	
2010	47	37	79%	2	4%	2	4%	6	13%
2011	115	110	96%	1	1%	1	1%	3	3%
2012	170	162	95%	1	1%	0	0%	7	4%
2013	44	44	100%	0	0%	0	0%	0	0%
2014	87	75	86%	5	6%	3	3%	4	5%
Total	463	428	92%	9	2%	6	1%	20	4%
Farm	14	9	64%	1	7%	0	0%	4	29%
Wild	449	419	93%	8	2%	6	1%	16	4%

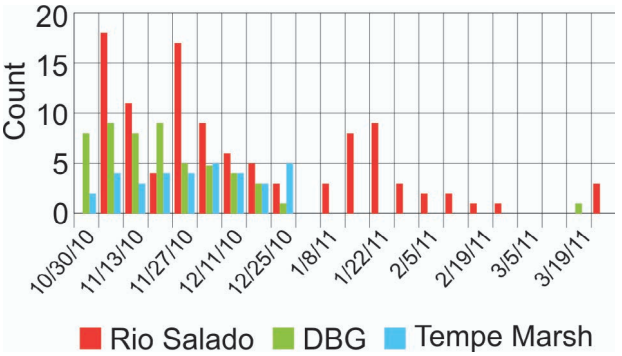


Fig. 6. Comparison of adult monarch sightings at three locations with overwintering monarchs pre and post freeze. A hard freeze occurred on 31 December 2010. Monarchs normally begin mating and dispersing early February.

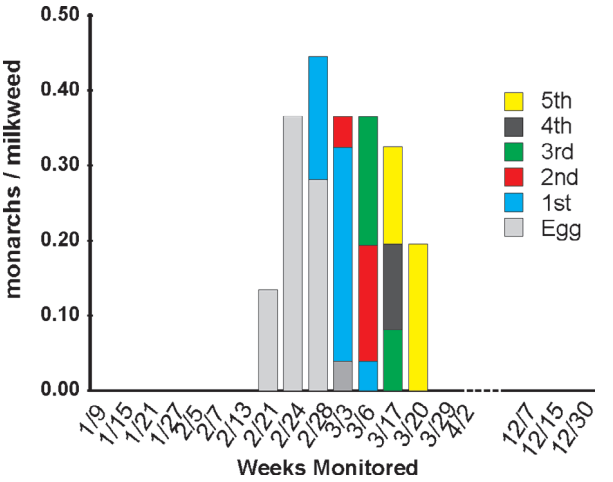


Fig. 7. Monarch Density. Monarch egg and larvae by instar, absence and presence at Rio Salado Habitat Restoration Area, Phoenix, Arizona, with weekly monitoring of thirty-two *Asclepias subulata* plants.

Farm in Scottsdale. Adult monarchs were tagged and monitored weekly. We found both breeding monarchs and a small number of monarchs that lived for three months indicating the possibility of a mixed population of breeding and nonbreeding monarchs. During the warm winter of 2013, three monarchs overwintered at Boyce Thompson Arboretum in Superior (elevation 735 m) in Eucalyptus (*Eucalyptus* spp.) trees. One was tagged on 26 October 2013 and sighted flying in the area on 26 January 2014. In most years winters were too cold for monarch survival at this location.

In warm winters without a hard freeze, small numbers of monarchs were reported in backyards in the greater Phoenix area, Tucson, and Yuma. In most years monarchs were also reported at the Arizona Sonora Desert Museum in Tucson. Trained docents tagged monarchs present at the museum. By the longevity of some tagged monarchs as well as photo documentation of others ovipositing, the monarchs appeared to be a mix of nonbreeding and breeding monarchs. The immature phase was as long as six to eight weeks in response to average night temperatures hovering near 1.6°C and low daytime temperatures. On warm days monarchs at Rio Salado Habitat Restoration Area and Tempe Marsh nectared primarily on *Baccharis salicifolia*, as well as *Bebbia juncea*, *Lycium* spp. and *Pluchea sericea* when available and stayed primarily in *Salix gooddingii* but also *Populus* spp. trees at night. Monarchs at the Desert Botanical Garden and Arizona Sonora Desert Museum visited a variety of winter garden flowers in addition to *Calliandra californica* and *Lycium* spp.

Small aggregations were also noted along the Colorado River from Parker to Lake Havasu including 125 monarchs found in *Acacia salicina* trees at Buckskin State Park in Parker along the Colorado on 8 November 2013. The following morning many flew south along the Colorado River. Later, 25 monarchs were found at the same location on 18 January 2014. One of approximately 60 monarchs sighted and later tagged on 27 October 2012 at Rotary Park in Lake Havasu along the Colorado River was spotted in the city of Lake Havasu on 17 February 2013, suggesting an overwintering population. Others tagged at the same time were observed flying north and a few also flew south along the Colorado River the following morning.

Ophryocystis elektroscirrha. We submitted 463 samples to Monarch Health at the University of George to test for *Ophryocystis elektroscirrha* (OE). Results for the submitted specimen analysis indicate low levels of *Ophryocystis elektroscirrha* in Arizona (Table 5). Test results were provided in three levels: 1 to 10 spores (Level 1), 11 to 100 spores (Level 2) and 101 and above spores (Level 3). Level 3 is where the infected monarch likely acquired the infection as a larva and is the primary point of comparison as a heavily infected monarch. In Arizona, the number of Level 3 infections dropped from 13% in 2010 to 0% in 2013 and 5% in 2014. The Canelo breeding habitat in southeast Arizona had the highest level of Level 3 infected monarchs. Overall, 449 wild monarchs sampled had a 4% Level 3 infection rate. Fourteen farm monarchs tested had a 29% rate.

TABLE 6: Enumeration of recovered wild monarchs. Sun angle is the sun's elevation angle above the horizon at solar noon on the day of tagging, calculated with NOAA calculator http://www.esrl.noaa.gov/gmd/grad/solcalc/. Single-letter tags are wild monarchs.

TAG	Tagging date	Tagging Location	Sun Angle	Recovery Location
A	27 September 2007	Canelo	57	El Rosario MX
B	7 September 2008	San Rafael Valley	64	Ellwood Main CA
C	26 September 2008	Elgin	57	El Rosario MX
D	1 October 2008	Canelo	55	El RosarioMX
E	1 October 2008	Canelo	55	El Rosario MX
F	1 October 2008	Canelo	55	El Capulin MX
G	6 October 2008	San Rafael Valley	53	El Rosario MX
H	15 September 2010	Canelo	61	Halcyon CA
I	30 September 2010	Elgin	55	Cerro Pelon MX
J	30 September 2010	Elgin	55	Cerro Pelon MX
K	30 September 2010	Elgin	55	Macheros MX
L	19 November 2011	Chandler	37	Kino Bay MX
M	19 September 2012	Gardenerville	52	Santa Cruz CA
N	20 September 2012	Canelo	59	El Rosario MX
O	29 September 2012	Canelo	56	El Rosario MX
P	30 September 2012	Elgin	55	El Rosario MX
Q	2 October 2012	Canelo	55	El Rosario MX
R	2 October 2012	Canelo	55	El Rosario MX
S	8 September 2013	Elgin	64	El Rosario MX
T	14 September 2013	Canelo	62	Pismo Beach CA
U	15 September 2013	Canelo	61	Pismo Beach CA
V	15 September 2013	Hereford	61	Cayucos CA
W	20 September 2013	Elgin	59	San Simeon CA
X	20 September 2013	Elgin	59	Black Lake CA
Y	20 September 2014	Canelo	59	Big Sur CA
Z	22 September 2014	Canelo	58	Pacific Grove CA

Water. Migrating monarchs were reported mainly along water sources, especially rivers. The Colorado River in particular was heavily favored as a migration flyway through the Grand Canyon as well as below Lake Havasu as were the Little Colorado, San Pedro, Santa Cruz, Verde, Gila, Hassayampa, Bill Williams and Salt Rivers. Breeding and migrating monarchs were frequently found in larger densities near (but not limited to) water, including cienegas, rivers and creeks (especially flood plains), washes, roadside ditches and irrigated gardens. During periods of low humidity monarchs were frequently found puddling in moist soils and in shallow creeks and streams (Fig. 8).

Tagged monarchs. A total of 12,088 monarchs were tagged between 2003 and 2014 by 384 individuals in 276 locations. This includes 7,809 wild monarchs and 4,279 farmed monarchs; 7,133 were males, 4,662 were females, and sex was not reported for 293. In addition to tagging sites, 134 unique sighting locations of monarch adults and/or immatures were reported (Fig. 9).

Recoveries of tagged monarchs. Recoveries at the overwintering sites in Mexico were reported to

Fig. 8. Monarch drinking water from stream, Huachuca Mountains, 3 October 2012. Photo by Bob Herrmann.

volunteers of Southwest Monarch Study, Monarch Watch and others. The campesinos who live at the overwintering sites and actually found the tags were paid 50 pesos (about five dollars) per tag. Most monarch recoveries in Mexico were based on tags that were found on dead monarchs at each location. Only one female monarch spotted at Kino Bay, Sonora, was a live sighting. Recoveries in California were all from live monarchs sighted or photographed by citizen observers.

The total count of wild monarch recoveries was 15 in Mexico and 9 in California (Fig. 10a) (Table 6). In addition to the identified tagged monarchs, two blue Southwest Monarch Study tagged monarchs were spotted at Camp Pendleton in Oceanside, CA by David Marriott on 8 January 2009. However, despite repeated photographs, the tag numbers remained unreadable for these two tags. The number of recoveries in California varied by year:

- 2008 (3; including 2 unidentified tags at Camp Pendleton)
- 2009 (0)
- 2010 (1)
- 2011 (0)
- 2012 (0)
- 2013 (5; all tagged in the same week in southeast Arizona)
- 2014 (2; tagged 2 days apart in southeast Arizona)

There were 12 additional sightings in Arizona of wild tagged monarchs under 50 km from their tagging sites in Chandler, Canelo, Elgin, Gilbert, San Rafael Valley, Scottsdale, Springerville, and Tempe.

The total number of farm monarch recoveries was 5 in Mexico and 0 in California (Fig. 10b) (Table 7). One farmed monarch tagged at the Desert Botanical Garden in Phoenix flew northwest 34.3 km and was sighted in Sun City and later was re-sighted in Tonopah, 61.8 km to the southwest. There were 13 sightings of tagged farm monarchs from the Desert Botanical Gardens to the south and southeast under 50 km in Ahwatukee (3), Mesa (4), Chandler (3), and South Mountain (3).

From 2003 to 2011, the overall recovery rate was 1 recovery out of 564 monarchs tagged. The recovery rate nearly tripled for 2012 and 2013 becoming 1 recovery for every 198 monarchs tagged.

Wind and migration destination. Observation of data showed perfect concordance with our hypothesis that monarchs tagged in a single day in southeast Arizona would travel to the same overwintering location (Mexico or California). In every instance where multiple recovered monarchs were tagged on a single day, they all were recovered at the same location. This effect was statistically significant by Fisher's Exact test with ≤ 0.05, allowing us to reject the null hypothesis that migration direction is random.

Our hypothesis was that wind direction on the day of tagging in southeast Arizona affects whether the monarch was recovered. Results are shown in (Table 8) (Fig.11). We found wind direction does significantly affect whether the monarch was recovered by Fisher's Exact test with $p \leq 0.05$.

Peak Migration. The earliest two migrating monarchs recovered to date both had sun angles at the time of tagging of 64°. One was recovered at Ellwood Main in California, the other at El Rosario, Michoacan,

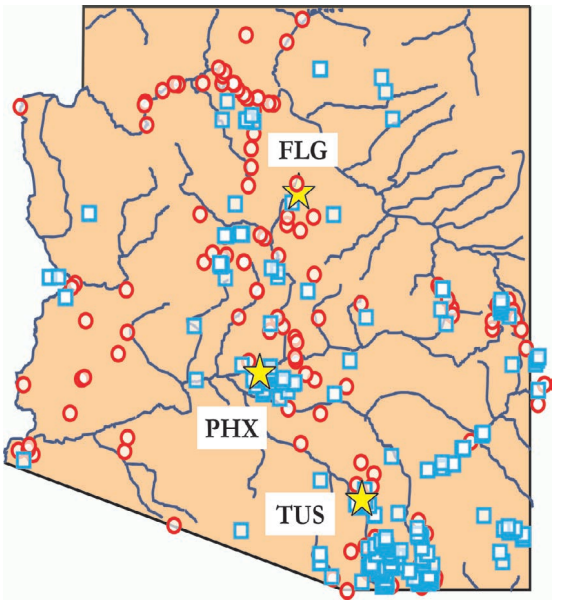
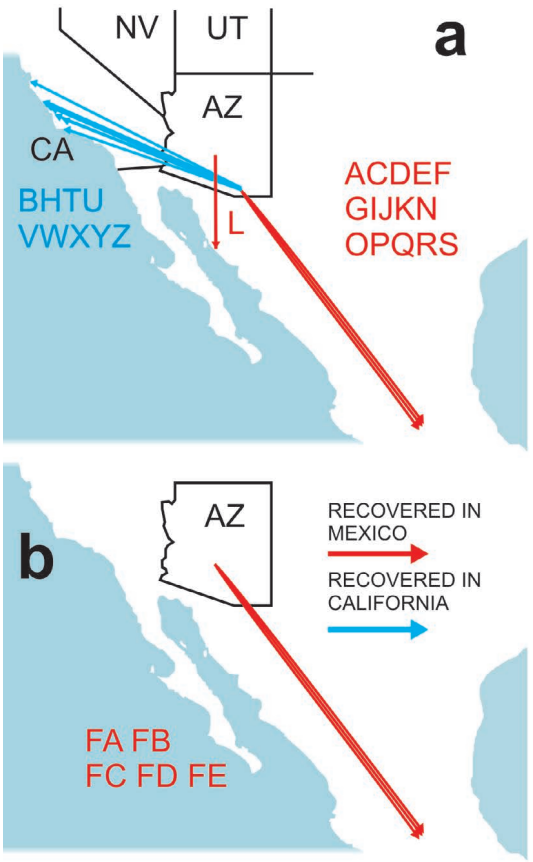


Fig. 9. Locations of Monarch Tagging and Sighting. Each blue square represents the location where one or more monarchs was tagged. Each red circle represents the location where one or more monarch sightings have been reported.



FIGS. 10a & 10b. Recovery Locations of Monarchs Tagged in Arizona. **a,** wild monarchs. **b,** farm monarchs. Letters next to each set of arrows individually identify the monarchs (Table 6; Table 7).

TABLE 7: Enumeration of recovered farm monarchs. Sun angle is the sun's elevation angle above the horizon at solar noon on the day of tagging, calculated with NOAA calculator http://www.esrl.noaa.gov/gmd/grad/solcalc/. Two-letter tags are farm monarchs.

TAG	Tagging date	Tagging Location	Sun Angle	Recovery Location
FA	8 October 2004	DBG	50	El Rosario
FB	4 October 2007	DBG	52	Cerro Pelon
FC	11 October 2007	DBG	49	Cerro Pelon
FD	14 October 2010	DBG	50	El Rosario
FE	4 October 2012	DBG	52	El Rosario

Mexico (Fig. 12). Both monarchs were freshly eclosed and tagged in the San Rafael Valley in southeast Arizona on 7 September 2008 and 8 September 2013, respectively. Most of the recoveries of tagged monarchs in Mexico are in alignment with migration observations for latitude in the east. Most California recoveries occurred before the times observed in the east. We had one late recovery of a freshly eclosed monarch tagged in Chandler on 19 November 2011 that was sighted in Kino Bay, Sonora, Mexico on 14 December 2011 that had been tagged with a sun angle of 37°. When we averaged all the tagging over the life of the study there is a surge of monarchs tagged the first week of October (Fig. 13).

DISCUSSION

Danaus plexippus was present and at times abundant in Arizona at different elevations throughout the year. Breeding populations were observed at all elevations seasonally and they utilized a variety of native species of *Asclepias*. Habitats were most numerous in riparian areas. Both adults and immatures were reported at all elevations. During the breeding season monarchs favored species of *Asclepias* for nectar as well as oviposition but also used other available nectar. We also identified migration nectar sources and learned *D. plexippus* favors riparian areas and rivers during their migration when available and sometimes were found puddling. Both breeding and migrating monarchs were frequently seen in city backyards and parks when *Asclepias* spp. and favored nectar were available. Backyard gardeners can help create rest stops for migration refueling.

The lower elevation deserts have small numbers of overwintering monarchs in warm winters without a hard freeze. They were recorded from 2009 onward every year and appear to be a regular occurrence. The largest aggregations were found at Rio Salado Habitat Restoration Area in Phoenix and there were other small locations along the Salt and Colorado Rivers. Yuma, Phoenix, Lake Havasu, Parker and Tucson areas also

TABLE 8. Tags and recoveries from southeast Arizona, broken down by wind direction at 305 m AGL (1,000 ft) at 1200 h GMT (1700 h MST) on the day of tagging.

Wind to	Wind from Compass Heading	Tags	Recoveries
SW	0° to 90°	415	0
NW	90° to 180°	752	10
NE	180° to 270°	1084	1
SE	270° to 360°	1945	13

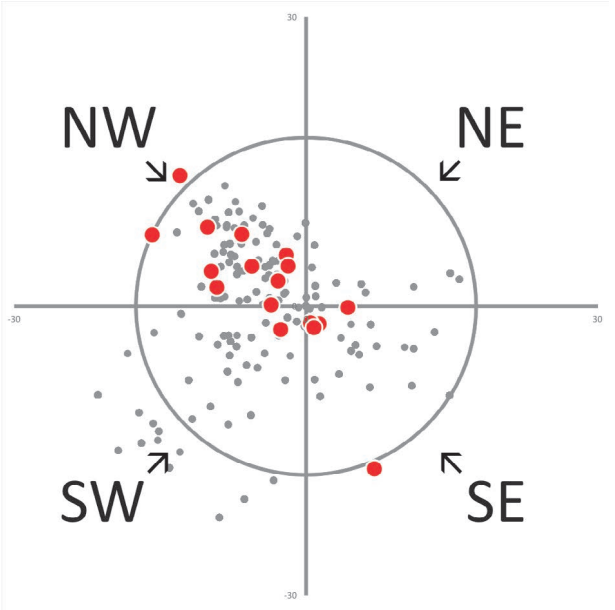


Fig. 11. Wind Speed and Direction on Day of Tagging. Each black dot represents the wind speed and direction at 305 m (1,000 ft) AGL (above ground level) on a day on which one or more monarchs was tagged. Red dots represent the same data for the days on which one or more recovered monarch was tagged. The speed is proportional to the distance from the center. The circle represents 9 m/sec. The direction of the wind is from each marker to the center.

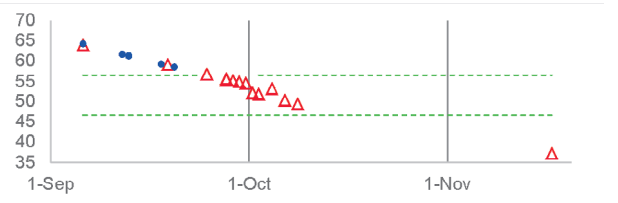


Fig. 12. Recoveries by sun angle (sun's elevation angle above the horizon at solar noon) on the day of tagging. Recoveries in Mexico are represented by red triangles; California by blue circles. Vertical axis is sun angle in degrees. Horizontal axis is the tagging date. Dashed green lines indicate elevation of 46.5° and 56.5°, the nominal values for the migration.

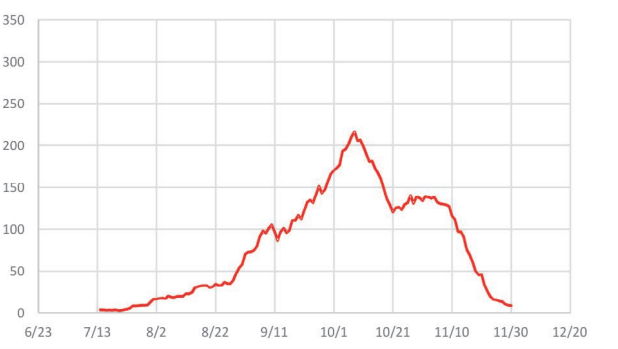


Fig. 13. Counts of monarchs tagged by date, sum of all years. The counts are displayed as a seven day running average to remove the artifacts caused by day of week.

reported winter monarch sightings. There were reports of limited monarch breeding during the winter but at other locations breeding was not evident. Native evergreen milkweeds were most common near these locations. With a record warm year in 2014 in Phoenix (National Weather Service 2015), especially in the fall, together with a general warming trend in recent years, it will be critical to monitor the effects on the overwintering numbers in the future.

Ophryocystis elektroscirrha levels were low in monarchs over the past five years in Arizona with an average rate of 4%. Monarchs were tested in breeding areas, during the migration, in overwintering aggregations and in backyard gardens throughout the year. While levels should continue to be monitored to detect a changing trend, current levels indicate this is not a serious threat to the monarch population at this time. Arizona has evergreen milkweeds utilized by the monarch population for both oviposition and nectaring, but they do not appear to contribute to a higher *Ophryocystis elektroscirrha* infection rate. Nor does the presence of *Asclepias curassavica* in occasional irrigated gardens. It is possible Arizona's high temperatures and low humidity limit the transmission of *Ophryocystis elektroscirrha*.

Monarchs in Arizona migrate to known overwintering destinations in both Mexico and California while small numbers overwinter in the lower deserts in Phoenix, Tucson, Yuma, Parker and Lake Havasu. All the monarchs recovered in California were tagged in southeast Arizona near fields of abundant *Asclepias subverticillata*. Most of these early migrators appeared to be recently eclosed from local fields.

Winds play a significant role in the southeast Arizona monarch migration. When multiple monarchs were tagged at the same location and later recovered, they were always all found in California or all reported in Mexico, a significant finding. There were several sets of two or three recoveries from tagging on the same day. We were surprised when we plotted the recoveries on the radar chart (Figure 10) to learn that the direction of the wind determined if there would be a recovery. Each data point on the chart only represents the wind on a day where one or more monarchs was tagged. We discovered that almost all recoveries occurred when winds originated from the southeast or from the northwest. There were no recoveries when the wind blew from the northeast to the southwest, normally considered a favorable wind direction for the monarch migration in the east and only one when the wind was

from the southwest. Continued monitoring of tagged recoveries will show if this pattern persists. We are developing a model that will describe the factors determining the migration destination. With more recoveries we will improve its accuracy.

The flyways of Arizona monarchs migrating to California are unknown. Frey and Schaffner (2004) found monarch movement in response to weather patterns at the California overwintering sites, especially in response to temperature and winds. Monarchs were observed moving north along the California coast from the southern coastal areas (Urquhart 1987). It is unknown if monarchs from Arizona fly west to reach the coast and then fly north to reach the location where they were sighted or directly northwest.

Our data indicates monarchs tagged in Phoenix migrate to Mexico but more tagging will help us learn if they also fly to California as well. More information is also needed about the migration destinations around the state, especially the northern and western portions. Western flight has been observed near Lake Havasu and Alamo Lake. While there has been extensive tagging at the Grand Canyon, Flagstaff, Prescott, Camp Verde, Springerville/Eager, Lake Havasu and other locations, we have not had recoveries at this time. Future recoveries may open up new understanding of migration destinations from these locations.

We found that farmed butterflies shipped from California to Arizona, tagged and released at the Desert Botanical Garden in Phoenix, flew to Mexico rather than returning to California. All five recoveries in Mexico were tagged during the time of predicted peak migration for latitude in Phoenix. Not all of the tagged farm monarchs migrated. In addition to the one farm monarch sighting in Sun City later reported in Tonopah, thirteen tagged farm monarchs were reported in locations to the southwest, south and southeast. Three tagged monarchs were spotted in the same yard in successive years on South Mountain, a slightly southwest flight path.

The migration window for *D. plexippus* in Arizona was larger than anticipated, with recoveries from monarchs tagged at the beginning of September with a sun angle of 64° to mid-November at 37°. While the largest number of recoveries occurred during the predicted range of 57° to 47°, most in this range migrated to Mexico. Earlier sun angle recoveries were mainly in California, but a few also migrated to Mexico. Baum and Mueller (2015) noted in the southern Great Plains there is a movement of reproductive monarchs into the area in August and September prior to the peak fall migration. F. X. Villablanca of Monarch Alert (pers. comm.) noted only 5% of monarchs at the California overwintering sites are reproductive. Furthermore, the longevity of a monarch tagged near Canelo in southeast Arizona on 20 September 2014 and sighted in Big Sur, California on 29 January 2015 gives additional credence that this monarch was in reproductive diapause. Based on these observations the migration appears to begin in early September through middle October in Arizona with occasional late migrators later.

Tagging recoveries increased from 1 of 564 monarchs to 1 of 198 monarchs tagged in 2012 and 2013. We learned using new tags every year increased our recoveries. Earlier tags were purchased in bulk to save cost but the adhesive decayed over time, especially when the tags were left in hot conditions. Purchasing new tags each year increased our recovery ratios.

Citizen science. The Southwest Monarch Study is a volunteer non-profit Citizen Science study. Volunteers spent endless hours in the field and used their own personal funds for nets, transportation and any lodging/camping fees. We forged working relationships with monarch experts across the country to create field strategies and protocols. There may be some who question the accuracy of the data we've collected. Droege (2007) notes that in many instances volunteers are more invested than paid college students who are in attendance for a few years and move on. Volunteer Citizen Scientists take their job collecting data more seriously and are more accurate. Volunteers come because they want to, not because they have to. Oberhauser et al. (2015) notes that the data generated in Citizen Science projects are carefully analyzed and provide an avenue to answer questions that would likely never be addressed in traditional academic research. Our continuing study of monarchs in the southwest has documented new insights about the breeding and migratory movements of *Danaus plexippus* in Arizona.

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Southwest Monarch Study volunteer Citizen Scientists spent time living with the monarchs in the fields of Arizona. They watched and observed, photographed when possible, and wrote detailed descriptions of their encounter including presence and absence. Their data is priceless and opens a new chapter in understanding monarch butterflies in Arizona. We've likely only scratched the surface of understanding monarch biology in the southwestern United States.

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Appendix 1: Arizona Monarch Sightings by Richard Bailowitz, 1975 to 1984

Date	County	Location	Date	County	Location
25 June 1976	Apache	Rte 273 s. of Springerville	23 October 1983	Pima	Quitobaquito, Organ Pipe CNM
15 July 1980	Apache	Springerville	28 January 1984	Pima	Elkhorn Ranch, Baboquivaris
7 July 1981	Apache	South Fk Ranch, White Mtns	25 August 1984	Pima	Elkhorn Ranch, Baboquivaris
13 August 1975	Cochise	Chiricahua Mtns	1 September 1984	Pima	4M W Arivaca
31 May 1976	Cochise	Parker Cyn Lake	1 September 1984	Pima	Fraguita Wash, S of Arivaca
27 June 1976	Cochise	Chiricahua Mtns	5 October 1984	Pima	Arivaca Cienega
9 August 1978	Cochise	Cottonwood Cyn, Peloncillos	21 August 1979	Pinal	Oracle Junction
12 August 1978	Cochise	Parker Canyon	11 October 1975	Sta.Cruz	Sycamore Cyn, Atascosas
17 September 1978	Cochise	Chiricahua Mtns	4 September 1976	Sta.Cruz	west of Pena Blanca Lake
24 September 1978	Cochise	below Parker Canyon dam	18 August 1977	Sta.Cruz	Sonoita Creek
20 October 1979	Cochise	Ash Springs, Perillas	20 August 1977	Sta.Cruz	Sycamore Cyn, Atascosas
20 October 1979	Cochise	Leslie Cyn	27 August 1977	Sta.Cruz	12 M S Sonoita
27 April 1980	Cochise	San Bernardino Ranch	3 September 1977	Sta.Cruz	Patagonia
8 August 1980	Cochise	San Bernardino Ranch	11 September 1977	Sta.Cruz	Sonoita Creek
24 August 1980	Cochise	Guadalupe Cyn	17 September 1977	Sta.Cruz	Sycamore Cyn, Atascosas
27 September 1980	Cochise	San Bernardino Ranch	20 November 1977	Sta.Cruz	Flux Cyn, Patagonia Mtns
4 October 1980	Cochise	French Joe Cyn, Whetstones	3 December 1977	Sta.Cruz	Sonoita Creek
26 October 1980	Cochise	San Bernardino Ranch	11 December 1977	Sta.Cruz	3M SW Patagonia
25 April 1981	Cochise	Leslie Cyn, Swisshelm Mtns	5 February 1978	Sta.Cruz	Rock Corral Cyn, Tumacacori Mtns
24 May 1981	Cochise	Reiley Cyn, Winchester Mtns	25 February 1978	Sta.Cruz	3M SW Patagonia
19 July 1981	Cochise	Montezuma Cyn, Huachucas	14 May 1978	Sta.Cruz	Sheehy Sprgs, San Rafael Vly
22 July 1981	Cochise	Babacomari Ranch	11 August 1978	Sta.Cruz	Sycamore Cyn
29 July 1981	Cochise	Babacomari Ranch	13 August 1978	Sta.Cruz	Sycamore Cyn, Atascosas
5 August 1981	Cochise	Babacomari Ranch	18 August 1978	Sta.Cruz	Sonoita Creek
9 August 1981	Cochise	Babacomari Ranch	19 August 1978	Sta.Cruz	Flux Cyn, Patagonias
12 August 1981	Cochise	San Bernardino Ranch	21 August 1978	Sta.Cruz	Rock Corral Cyn, Tumacacoris
26 August 1981	Cochise	Babacomari Ranch	23 August 1978	Sta.Cruz	lower Sycamore Cyn
5 September 1981	Cochise	San Bernardino Ranch	2 September 1978	Sta.Cruz	Sycamore Cyn, Atascosas
5 September 1981	Cochise	Guadalupe Cyn	1 October 1978	Sta.Cruz	Sonoita Creek
6 September 1981	Cochise	Leslie Cyn, Swisshelms	7 October 1978	Sta.Cruz	Sycamore Cyn, Atascosas
27 September 1981	Cochise	San Bernardino Ranch	15 October 1978	Sta.Cruz	Washington Pass, Patagonias
1 November 1981	Cochise	Guadalupe Cyn	22 October 1978	Sta.Cruz	Patagonia
5 September 1982	Cochise	Ash Sprgs, Perilla Mtns	22 July 1979	Sta.Cruz	Sonoita Creek
19 September 1982	Cochise	Dixie Cyn, Mule Mtns	29 September 1979	Sta.Cruz	Mt.Hopkins, Sta.Ritas
23 October 1982	Cochise	Bisbee	26 May 1980	Sta.Cruz	Grosvenor Hills

Appendix 1: Arizona Monarch Sightings by Richard Bailowitz, 1975 to 1984 (continued)

Date	County	Location	Date	County	Location
21 August 1983	Cochise	Ash Cyn, Huachuca Mtns	11 August 1980	Sta.Cruz	Sycamore Cyn
10 September 1983	Cochise	Guadalupe Cyn	6 September 1980	Sta.Cruz	Sonoita Creek, below dam
10 September 1983	Cochise	Leslie Cyn, Swisshelms	2 November 1980	Sta.Cruz	Sycamore Cyn
11 September 1983	Cochise	W.Turkey Ck, Chiricahuas	11 November 1980	Sta.Cruz	Patagonia
11 September 1983	Cochise	Stronghold Cyn, Dragoons	29 March 1981	Sta.Cruz	California Gulch
15 October 1983	Cochise	east of Elfrida	5 April 1981	Sta.Cruz	5M SW Patagonia
16 October 1983	Cochise	Guadalupe Cyn	2 May 1981	Sta.Cruz	5M SW Patagonia
13 November 1983	Cochise	San Pedro R, 3M S St.David	3 May 1981	Sta.Cruz	California Gulch
11 August 1984	Cochise	Palominas	25 July 1981	Sta.Cruz	Babacomari Ranch
8 September 1984	Cochise	Parker Cyn, Canelo Hills	8 August 1981	Sta.Cruz	5M SW Patagonia
8 September 1984	Cochise	Garden Cyn, Huachucas	16 August 1981	Sta.Cruz	California Gulch
15 September 1984	Cochise	Swisshelm Mtns, due E of Elfrida	19 September 1981	Sta.Cruz	Babacomari Ranch
15 September 1984	Cochise	Leslie Cyn, Swisshelm Mtns	8 April 1982	Sta.Cruz	California Gulch
16 September 1984	Cochise	Guadalupe Cyn, Peloncillo Mtns	4 September 1982	Sta.Cruz	O'Donnell Cyn, Canelo Hills
16 September 1984	Cochise	Cottonwood Cyn, Peloncillos	12 September 1982	Sta.Cruz	Research Ranch, Elgin
24 June 1976	Coconino	Parks	18 September 1982	Sta.Cruz	Research Ranch, Elgin
21 July 1976	Coconino	De Motte Camp, Kaibab	25 September 1982	Sta.Cruz	A.W.Research Ranch, Elgin
14 September 1976	Coconino	Schultz Pass, San Fran Pks	9 October 1982	Sta.Cruz	Research Ranch, Elgin
27 September 1975	Gila	Tonto Nat'l Bridge	10 October 1982	Sta.Cruz	California Gulch
14 August 1976	Gila	12 M E Payson	15 October 1982	Sta.Cruz	Research Ranch, Elgin
15 May 1982	Gila	Cherry Ck, Sierra Anchas	30 October 1982	Sta.Cruz	Research Ranch, Elgin
23 September 1979	Graham	High Creek Cyn, Galiuros	6 November 1982	Sta.Cruz	Research Ranch, Elgin
31 May 1980	Graham	20M SW Thatcher	13 November 1982	Sta.Cruz	Post Cyn, Canelo Hills
15 July 1983	Graham	Nantak Rim, Pt. of Pines	28 May 1983	Sta.Cruz	Research Ranch, Elgin
8 August 1978	Greenlee	Big Lue Mtns	3 September 1983	Sta.Cruz	Research Ranch, Elgin
17 July 1979	Greenlee	White Mule Cyn, Big Lue Mtns	4 September 1983	Sta.Cruz	Sonoita Ck, 5M SW Patagonia
17 July 1980	Greenlee	Blue River	18 September 1983	Sta.Cruz	Research Ranch, Elgin
2 August 1980	Greenlee	Campbell Blue river	9 October 1983	Sta.Cruz	Rock Corral, Tumacacori Mtns
7 October 1984	LaPaz	north side, Harquahala Pk	21 October 1983	Sta.Cruz	California Gulch
20 July 1976	Mohave	Colorado City	11 November 1983	Sta.Cruz	Research Ranch, Elgin
29 July 1980	Mohave	Littlefield	5 August 1984	Sta.Cruz	Warsaw Cyn, Atascosa Mtns
29 July 1980	Mohave	Colorado City	26 August 1984	Sta.Cruz	Sycamore Cyn
25 June 1976	Navajo	east of Show Low	2 September 1984	Sta.Cruz	Sonoita Ck, 5M SW Patagonia
17 July 1983	Navajo	2M S Alchesay Fish Hatchery	10 September 1975	Yavapai	west side Mingus Mtn
6 September 1976	Pima	Box Canyon, Sta.Ritas	23 May 1976	Yavapai	Mingus Mtn
28 May 1978	Pima	Arivaca	24 August 1976	Yavapai	Yarnell
9 September 1978	Pima	3M W Arivaca	28 September 1976	Yavapai	nr Cleator
7 October 1979	Pima	Cienega Creek	16 August 1983	Yavapai	3M S Seligman
31 July 1981	Pima	Bear Cyn, Sta.Catalinas	10 October 1976	Yuma	north of San Luis
7 November 1981	Pima	Bull Pasture, Organ Pipe CNM			