Dugesiana 29(2): 181-193
Fecha de publicación: 15 julio 2022

ISSN 1405-4094 (edición impresa)
ISSN 2007-9133 (edición online)

Artículo

Monarch Butterflies in Sonora and Adjacent Northwestern Mexico

Mariposas Monarcas en Sonora y el Noroeste de México Adyacente

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ABSTRACT

Since 1979, observations of monarch butterfly (*Danaus plexippus* L.) in Sonora, Mexico have been low. There are 10 records of monarchs breeding in Sonora on *Asclepias curassavica, A. lemmonii, A. linaria,* and *A. subulata* (Apocynaceae).

In July-August, monarchs from the Canelo-Hereford area in Arizona fly to the Río San Pedro, Sonora, south to the Cananea area, and then in the Río Sonora through central Sonora to Hermosillo and the Gulf of California. From the Río Sonora, they move up into the Sky Island Mountain ranges. In Hermosillo, they thrive in urban gardens. Higher humidity along the coast allows them to disperse in arid habitats from Bahía de Kino north to Punta Chueca and south to Guaymas. Individuals observed in northwestern Sonora may be from the Colorado River population in western Arizona-southeastern California.

The population in tropical southern Sonora and western Sinaloa with winter feeding and breeding may be resident, reflecting the continuously blooming and abundance of the native *A. curassavica* in large areas of tropical deciduous forest converted into agricultural fields.

Monarchs tagged in southeastern Arizona recovered in Michoacán (Morris *et al.* 2015; Billings 2019) likely traveled eastward to the Janos area in northwestern Chihuahua on the east side of the Sierra Madre Occidental to join the southward migration across the Mexican Plateau.

From the relatively few monarch records in Sonora, the few observations in the Sierra Madre Occidental in Sonora and Chihuahua, and winter feeding-breeding populations in tropical southern Sonora and western Sinaloa, we conclude that the Sonoran population is not connected to the eastern migration to overwintering sites in Michoacán. Like the Rocky Mountains, the Sierra Madre Occidental is more a barrier to migration than a corridor.

Key Words: Monarch butterfly, Sonora, Sinaloa, Chihuahua, migration, breeding, resident population, overwintering, northwestern Mexico.

RESUMEN

Desde 1979, las observaciones de la mariposa monarca (*Danaus plexippus* L.) en Sonora, México han sido pocas. Hay 10 registros de orugas de monarcas en Sonora en *Asclepias curassavica, A. lemmonii, A. linaria* y *A. subulata* (Apocynaceae).

En julio-agosto, las monarcas del área de Canelo-Hereford en Arizona vuelan hacia el río San Pedro, Sonora, hacia el sur hasta el área de Cananea y luego en el río Sonora cruzando del centro de Sonora hasta Hermosillo y el Golfo de California. Desde el río Sonora, suben a las sierras Islas Serranas. En Hermosillo visitan los jardines urbanos. Con la humedad de la costa se dispersan en hábitats áridos desde Bahía de Kino al norte hasta Punta Chueca y al sur hasta Guaymas. Las observaciones en el noroeste de Sonora pudieran ser de la población del río Colorado en el oeste de Arizona-sureste de California.

La población de monarca en el sur tropical de Sonora y el oeste de Sinaloa alimentándose y reproduciéndose en invierno puede ser residente, lo que refleja la floración continua y la abundancia de *A. curassavica* nativa en grandes áreas de selva baja caducifolia convertida a campos agrícolas.

Las monarcas marcadas en el sureste de Arizona recuperadas en Michoacán (Morris *et al.* 2015; Billings 2019) probablemente viajaron al este hasta el área de Janos en el noroeste de Chihuahua, al oriente de la Sierra Madre Occidental, para unirse a la migración hacia el sur cruzando la Altiplanicie Mexicana.

Debido a los registros relativamente pocos de monarca en Sonora, las pocas observaciones en la Sierra Madre Occidental en Sonora y Chihuahua y las poblaciones invernales alimentándose y reproduciéndose en el sur tropical de Sonora y el oeste de Sinaloa, concluimos que la población de Sonora no está conectada con la migración del este a sitios de hibernación en Michoacán. Similar a las Montañas Rocosas, la Sierra Madre Occidental es más una barrera para la migración que un corredor.

Palabras clave: mariposa monarca, Sonora, Sinaloa, Chihuahua, migración, reproducción, población residente, pasar el invierno, noroeste de México.

Some monarch butterfly (*Danaus plexippus* [Linnaeus, 1758], Nymphalidae, Danainae) populations are regional residents (Nail *et al.* 2019), but the eastern North American subspecies (*Danaus p. plexippus*) is notable for its annual southward late summer/autumn migration of part of its population from southern Canada and the northern and

central United States and overwintering in southern Mexico (Urquhart and Urquhart 1976). The migration route in Mexico is along the coastal plain of the Gulf of Mexico and on the Mexican Plateau, which is bound in the east by the Sierra Madre Oriental and in the west by the Sierra Madre Occidental. Millions of monarch butterflies overwinter in the Monarch Butterfly Biosphere Reserve on the border of the states of Michoacán and México (100 km northwest of Mexico City) in the Trans-Mexican Volcanic Belt (Solís-C. 2004). From October to March, they hang in dense 'curtains' in forests of sacred fir/*oyamel* (*Abies religiosa* (Kunth) Schltdl. & Cham.)-smooth-bark Mexican pine/*chamite* (*Pinus pseudostrobus* Brong.) forests at about 2580 m elevation (Brower *et al.* 2008).

West of the Rocky Mountains, monarchs migrate from Washington and Oregon south to California and Baja California and to the southeast through Idaho and Utah to southeastern Arizona (Pyle 1999). They are known to overwinter in California and Arizona (Figures 1 and 9). Monarchs tagged synchronously in southeastern Arizona have been discovered at overwintering sites in California and Michoacán (Morris *et al.* 2015, Billings 2019; Figure 2).

In this paper, we summarize the records, distribution, foods, and seasonality of monarch butterflies in the state of Sonora with relevant observations from the adjacent states of Chihuahua and Sinaloa.

MATERIALS AND METHODS

The records of monarch butterflies used in this study are available in the Madrean Discovery Expeditions (MDE) database (madreandiscovery.org), which contains observations from extensive biotic inventories in the Sky Island Region in Sonora, Mexico since 2009. There are 82 records from Sonora (most were single individuals), 49 from Chihuahua, and 28 from Sinaloa in the database. Records from iNaturalista (http://www.naturalista.mx) with expanded localities and edited images through October 2021 were also added to the MDE database. Our expertise in the flora of Sonora (Van Devender and Reina-G. 2021) and Sinaloa (Ruiz *et al.* 2015, Vega-A. *et al.* 2021) facilitated the identifications of the plants in the iNaturalista images. Our observations in Coahuila, San Luis Potosí, and Zacatecas during the October 2017 migration on the eastern side of the Mexican Plateau are also in the database.

RESULTS

Monarch butterflies in Sonora, Mexico

The numbers of monarch butterfly observations for the state of Sonora from the Arizona border south into Sinaloa in northwestern Mexico have been low since 1979. Bailowitz *et al.* (2017) reported that this species is widespread in Sonora. Although they have been seen in many parts of the state, observations are more common in northern Sonora near the Arizona border. A few monarchs have been seen in the Sonoran Desert along the Río Colorado in northwestern Sonora, near Pitiquito and Hermosillo, and along the coast of the Gulf of California. The greatest numbers of monarchs were seen in the Sonoran Desert in urban gardens and agricultural fields in and near Hermosillo (Figure 3). In March 1995, dozens of them were seen in eucalyptus trees (*Eucalyptus camaldulensis* Dehnhardt) adjacent to Presa Abelardo L. Rodríguez in Hermosillo (Jim Brock, pers. comm., 2022). Nearby is Parque Recreativo La Sauceda, a large urban recreation area with water features and gardens. Monarchs probably overwintered in this area that year.

The presence of monarchs at low elevations in the Sonoran Desert likely indicates that they can handle high temperatures if the humidity is sufficient. They were seen in both lowland tropical (foothills thornscrub [FTS] and tropical deciduous forest [TDF]) and upland temperate montane (desert grassland [DG], oak woodland [OW], and pine-oak forest [POF]) habitats (Van Devender and Reina-G. 2021).

Most of the Sonoran monarch observations were in riparian habitats, which pass through other vegetation types. They were seen in lowland riparian FTS or TDF along the Río Cuchujaqui at Sabinito Sur (Río Fuerte drainage); the Río Mátape at La Galera; the Río Sonora at El Gavilán; and the Río Yaqui near Tónichi. Observations in upland riparian DG, OW, or POF were from along the Río San Pedro west of Naco; the Río San Bernardino and Cajón Bonito east of Agua Prieta (Río Yaqui drainage); the Río Magdalena at Agua Caliente; and the Ríos Bavispe and Gavilán near Mesa Tres Ríos (Río Yaqui drainage).

Monarchs were occasionally seen in non-riparian FTS, TDF, and POF habitats in southern and eastern Sonora. Observations from POF near Mesa Tres Ríos and Yécora and OW near Güisamopa are the only records from the Sierra Madre Occidental (SMO) in Sonora. They have been seen in OW and POF in the Sky Island mountain ranges in the Madrean Archipelago, including the Sierras de Los Ajos, Bacadéhuachi, Juriquipa, Los Locos, Mariquita, and El Tigre. The natural habitat with the most observations was POF. They have been observed in urban settings in Álamos, Cananea, Hermosillo, Magdalena, Moctezuma, and Ures (Figure 3).

Monarchs have been seen in Sonora in every month of the year except May and June in the hot, dry fore-summer. The greatest numbers of observations were from September to November. Their greatest geographic distribution was greatest in November-December with observations from the Arizona border to Álamos in the south and the coast of the Gulf of California to the west. They were only seen in upland OW and POF in the Sky Island mountain ranges in Sonora in August-September. Beginning in December, observations in Sonora declined, but a few were seen as late as April, documenting overwintering.

Foods

Potential larval food resources for monarchs are adequate and widespread in Sonora with 36 species of

Asclepias and four of *Funastrum* (Van Devender *et al.* 2010) compared with 30 species of *Asclepias* and three of *Funastrum* in southern Arizona (Kearney and Peebles 1951; SEINet 2022). Adults were observed feeding in Sonora on flowers of Palmer's agave (*Agave palmeri* Engelm. [Asparagaceae]), tropical milkweed/señorita (*Asclepias curassavica* L.; Figures 4A and 4B), various Asteraceae (*Baccharis salicifolia* Torr. & A. Gray, *B. sarothoides* A. Gray, *Cirsium neomexicanum* A. Gray, *Lagascea decipiens* Hemsl. [Figure 1], *Helianthus annuus* L., *Senecio flaccidus* Less., *Tithonia thurberi* A. Gray, and cultivated *Zinnia peruviana* (L.) L.), non-native Chilean mesquite (*Prosopis chilensis* (Molina) Stuntz [Fabaceae]), cultivated oleander (*Nerium oleander* L. [Apocynaceae]), and Goodding's willow (*Salix gooddingii* C.R. Ball [Salicaceae]). In Sinaloa, adults were seen feeding on the flowers of Arizona milkweed (*A. angustifolia* Schweigg.; Figure 5) and *A. curassavica*. In Chihuahua, adults were feeding on the flowers of *A. curassavica*, pineneedle milkweed/hierba del cuervo (*A. linaria* Cav.), Asteraceae (*Baccharis salicifolia, Baileya multiradiata* Harv. & A. Gray, *Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & G.I. Baird, *Guardiola arguta* Robinson, *Helianthus annuus,* and *Zinnia peruviana*), smooth puccoon (*Lithospermum cobrense* Greene [Boraginaceae]), alfalfa (*Medicago sativa* L.), and honey mesquite (*Prosopis glandulosa* Torr. [Fabaceae]). A monarch was observed feeding on desert broom/*romerillo* (*Baccharis sarothroides* A. Gray, 1882) flowers in Douglas, Arizona.

Breeding

Morris *et al.* (2015) reported monarchs on the Colorado Plateau in northern Arizona most commonly breeding on *Asclepias speciosa* Torr. and in southeastern Arizona on *A. subverticillata* (A. Gray) Vail. The Canelo region (Elgin, Turkey Creek, and the San Rafael Valley) was reported as the richest breeding area in Arizona from late July to September (Morris *et al.* 2015). *A. speciosa* does not occur in Sonora. *A. subverticillata* is a grassland species that is widespread in the southwestern United States but in Sonora is rare from Agua Prieta east to Rancho El Valle immediately south of the Arizona border.

SEMARNAT and CONANP (2018; see Figure 6) only reported summer breeding in monarch butterflies in the United States, not northwestern Mexico. Brower (1996) states that the eastern monarchs overwintering in Michoacán are not breeding.

Breeding has been documented ten times in eight areas in Sonora and five areas in Sinaloa (Table 1; Figure 6). Caterpillars were found feeding on *Asclepias linaria* in OW in the Sierras Juriquipa (Figure 7) and Los Locos, both in August. A larva was found on Lemmon milkweed/talayote (*A. lemmonii* A. Gray; Figure 8) in the Sierra de los Ajos in September. A larva was seen near Puerto Peñasco in November and an old pupal case southwest of Hermosillo in May on skeleton milkweed/jumete (*A. subulata*). A larva was seen on *A. curassavica* near Ónavas in November. Larvae have been seen on *A. curassavica* near Álamos in December and January. Sinaloa breeding records (2 larvae, 3 pupae) are for August (1), December, February (1, *A. curassavica*), and March (2, *A. angustifolia, A. curassavica*). Biologists at the Jardín Botánico de Culiacán collected eggs of monarch butterflies from cultivated *A. curassavica*, starting in December, reared them in a greenhouse, and released them back into the garden (TV Azteca 2021).

Monarch breeding records in Sonora and Sinaloa (Figure 6) appear to reflect two different populations. The breeding records in the Sky Island mountain ranges in northern Sonora in August-September are synchronous with temperate breeding in the Canelo-Hereford region just to the north in Arizona (Morris *et al.* 2015). To the south in the New World tropics, they are breeding later in the year. Breeding records from Ónavas to Álamos, Sonora are from November to January. Breeding records in Sinaloa are mostly December to March, with an August observation. A breeding record from near Puerto Peñasco on *A. subulata* in the Sonoran Desert in November is likely related to breeding populations along the Colorado River in Arizona (Morris *et al.* 2015).

Regional movements

The only documented record of a monarch moving from Arizona to Sonora was an individual tagged by Gail Morris as it emerged from chrysalis on November 18, 2011 (tag #60061; female) in Chandler, Arizona. It was recovered in Bahía de Kino, Sonora on the coast of the Gulf of California on December 14, 2011 (Morris *et al.* 2015).

Brower and Pyle (2004) reported observations on October 5, 1998, of monarchs flying southward toward Sonora from Senita Basin and near Quitobaquito Spring, both localities in Organ Pipe National Monument, Arizona just north of the Sonora border. The Río Sonoyta immediately south of the border is one of the few perennial water sources in the Sonoran Desert in northwestern Sonora. A local resident in Sásabe, Arizona (2 km from the Sonora border west of Nogales) saw an overnight aggregation of hundreds of individuals on a mesquite in September 1996, that were gone the next day and assumed to have flown south (Pyle 1999).

Monarch movements into Sonora come primarily from southern Arizona along riparian corridors. There are a few observations in the Lower Colorado River Valley near Ciénega El Doctor (December) and El Golfo de Santa Clara (November) in northwestern Sonora. These are likely from the population along the Colorado River from southwestern Arizona (Figures 3 and 9) or southeastern California. Monarchs have been documented moving along the Colorado River in Arizona southward in October and northward in March and April (Gail M. Morris, pers comm, January 2022).

Observations in the Sierra Pinacate, Sonoyta area, and

at Puerto Peñasco could be from this population or from Organ Pipe Cactus National Monument to the northeast (Figure 3).

A few monarchs were observed south of Nogales at Ímuris and Magdalena along the Río Magdalena. The name of this river changes from Arroyo Bambuto to the Ríos Magdalena, Altar, and Asunción before reaching the Gulf of California at Desemboque. The record from Pitiquito (Figure 3) in the Sonoran Desert is 105 airline kilometers south-southwest of the Sásabe, Arizona observation (Pyle 1999).

Concentrations of monarchs are well-known in the Canelo Hills-Hereford area in Arizona in July-August (Morris *et al.* 2015, Billings 2019). The dynamic increase in observations in Sonora beginning in July likely indicates that there is a seasonal movement southward along riparian corridors from Arizona. The headwaters of the Santa Cruz River are in the San Rafael Valley less than 10 kilometers southeast of Canelo. In Sonora, the Río Santa Cruz flows southward about 25 kilometers to San Lázaro and loops back northward to re-enter Arizona east of Nogales. At San Lázaro, there are gentle drainage divides into both the Ríos Cocóspera (Río Magdalena) and San Pedro.

Canelo, Turkey Creek, and Elgin are in the Babocomari River drainage, which flows north, east around the Mustang Hills to join the San Pedro River north of Sierra Vista in Arizona. Brower and Pyle (2004) reported southward-flying monarchs in the San Pedro River between Hereford and Palominas in Arizona. Hereford is 30 kilometers north-northwest and Palominas six kilometers north of the Sonora border.

The headwaters of the Río San Pedro are near the Huachuca Mountains in Arizona on the west, the Cananea area to the south, and the foothills of the Sierra Los Ajos east of Cananea. There are monarch observations in the Río San Pedro just south of the Huachuca Mountains from Rancho Los Fresnos (Figure 10) east toward Naco, where the Río San Pedro turns north back into Arizona. Although they commonly visit *A. subverticillata* in the San Rafael Valley just north of the Arizona border (Morris *et al*. 2015), the only milkweed that is common in the grasslands from the Río Santa Cruz east to Rancho Los Fresnos and Naco is *A. asperula* (Decne.) Woodson. *A. involucrata* Engelm. and *A. nummularia* Torr. (a very small species) are rare in the area. Arroyo Barrilito is a southern tributary of the Río San Pedro that is a corridor for monarchs from the Arizona borderlands into the Cananea area. *A. asperula, A. nummularia*, and *A. nyctaginifolia* A. Gray are in the grasslands near Cananea, with *A. elata* Benth. in Sierra Elenita and *A. lemmonii* in the Sierra Mariquita in OW and POF west of Cananea. In the Sierras de Los Ajos and Buenos Aires to the east, *A. elata, A. lemmonii, A. linaria, A. ovata* M. Martens & Galeotti, and *A. tuberosa* L. are present in the higher elevations.

On the east side of Cananea there is a gentle divide into the Río Sonora, an important central Sonoran corridor to Hermosillo (about 220 km airline to the south-southwest) and the Gulf of California in the Sonoran Desert (Figure 3). From Bahía de Kino, higher humidity and estuaries allow monarchs to move along the coast north to Punta Chueca and south to Tastiota and Guaymas. From the Río Sonora, they disperse up into montane habitats in the Sky Island Mountain ranges (Sierras de Los Ajos, Juriquipa, and Los Locos).

A monarch was observed in Douglas, Arizona in November 2015 across the border from Agua Prieta, Sonora. South of Agua Prieta, the Río Cabullona reaches upstream to Nacozari de García which is the divide into the south-flowing Río Moctezuma. From this corridor, they can fly up into the Sierra de Los Ajos to the east, the Sierras Nacozari and Juriquipa, and south to Moctezuma (Figure 3). Pyle (1999) reported two individuals near the border between Douglas and the Slaughter Ranch on the road to Guadalupe Canyon, which cuts the southeastern corner of Arizona from southwestern New Mexico into Sonora. This is just north of the Río San Bernardino and Cajón Bonito observations east of Agua Prieta. All drainages in the Agua Prieta area drain south into the Río Bavispe, a major tributary of the huge Río Yaqui drainage basin. The Río Bavispe provides access to both sides of the Sierra El Tigre and a corridor east into the SMO near Mesa Tres Ríos and Yécora (Figure 3).

Monarchs are recorded overwintering in Arizona in low numbers in Lake Havasu (Fig. 9), Phoenix, Tucson, and Yuma (Morris *et al.* 2015). In part, urban overwintering reflects plantings of *A. curassavica*, which flowers all winter. Monarchs are documented to migrate from Arizona to California. Where did the large numbers of breeding individual monarchs in June and July in the Canelo Hills and Hereford come from? Is there a return migration from California to Arizona?

Bower and Pyle (2004) hypothesized that in some years there is an influx of monarchs from Mexico into southwestern New Mexico and southeastern Arizona. The rarity of spring observations from northwestern Chihuahua and northern Sonora in our records does not support this idea. Monarchs observed flying north along the San Pedro River near the border in March (Gail Morris, pers. comm., January 2022) were probably from the local Hereford population, not Sonora. The greatest numbers of observations in Sonora were from August to November, with the majority in September-November when the Arizona monarchs are migrating to California or Michoacán (Morris *et al.* 2015, Billings 2019).

Tropical monarchs

Although the northern limit of the New World tropics is often said to be the Tropic of Cancer (23.4394°N) just north of Mazatlán, Sinaloa, the northernmost TDF is in the Sierra San Javier, Sonora (28.6˚N; 300 km south of the Arizona border) 665 km to the north-northwest. FTS is a transitional vegetation between TDF and Sonoran desertscrub (SDS) in southern Sonora and between OW

and SDS in central Sonora (Van Devender *et al*. 2013, Van Devender and Reina-G. 2021). Tropical FTS extends northward in river valleys to ca. 30.4˚N (104 km south of the Arizona border; Van Devender *et al.* 2013). In the north as winter become colder, FTS merges into temperate desert grassland. Typical FTS species such as the Thornscrub Hook-nosed Snake (*Gyalopion quadrangulare* (Günther, 1893), Neotropical Vinesnake (*Oxybelis aeneus* (Wagler, 1824)*;* Van Devender *et al.* 1994), coralbean/*chilicote* (*Erythrina flabelliformis* Kearney), kidneywood/*palo dulce* (*Eysenhardtia orthocarpa* (A. Gray) S. Watson), jaguar (*Panthera onca* (Linnaeus, 1758)), and ocelot (*Leopardus pardalis* (Linnaeus, 1758)) reach their northern distribution limits in DG and OW in southern Arizona.

The winter activity of monarchs near Álamos in southern Sonora is interesting. The lower Río Yaqui is a potential monarch dispersal corridor from more temperate areas into the New World tropics in southern Sonora but that may not be the best interpretation. In lowland Sinaloa, most of the iNaturalista records are in November-December, with a few in each month from January to May. There are single observations in August and October but none from June, July, or September. The seasonal pattern in lowland Sinaloa and southern Sonoran populations, including feeding and breeding (Figure 6), is later than in northern Sonora and southeastern Arizona. The population in tropical lowlands with mild winter temperatures is likely resident in this part of northwestern Mexico. Observations of monarchs near Baborigame and Batopilas (on *A. curassavica*) in southern Chihuahua are likely eastward extensions from the tropical population from southern Sonora-Sinaloa into the SMO in the bottom of the Barranca del Cobre.

Asclepias curassavica is native to the New World tropics from South America north to Sinaloa and Sonora (Figure 4). Most of the Sinaloan monarch observations are in disturbed coastal agricultural or urban areas (Culiacán, Mazatlán). The historical clearing of TDF for agriculture in most of coastal Sinaloa (Shreve 1937) very likely expanded the populations of *A. curassavica.* This milkweed is not winter dormant and the monarch population in Sinaloa and southern Sonora is likely resident with winter or continuous breeding. Cultivated tropical milkweed in gardens in California, Texas, South Carolina, and Florida has disrupted monarch migrations by stimulating breeding instead of diapause (Majewska and Altizer 2019). *A. curassavica, A. angustifolia, A. linaria,* and *A. subulata* are commonly cultivated in gardens in Tucson, Arizona.

Long distance migration

On October 23-24, 2017, we observed monarchs at 24 locations at 1306 to 2683 m elevations in the Chihuahuan Desert on the east side of the Mexican Plateau between Real del Catorce and Huertecitas in San Luis Potosí, from Huertecitas to Concepción del Oro in Zacatecas, and from Gómez Farías to Saltillo and Parras in Coahuila. This is in the priority area for protection of migrating monarchs in Mexico (SEMARNAT and CONANP 2018; see Figures 6 and 23). In the mornings, clusters of 10 to more than 100 individuals were hanging on shrubs. Traveling by car, individuals were seen crossing the highway every few minutes all day long. Thus, 200-300 monarchs can easily be seen in a day during the migration.

The official 2018-2024 action plan for monarchs in Mexico (SEMARNAT and CONANP. 2018; see Figure 6) did not recognize Chihuahua, Sonora, or Sinaloa as part of the eastern migration. In Sonora, only 82 observations of monarchs have been made in 42 years, mostly of single, isolated individuals.

Morris *et al.* (2015) cited 15 records of monarchs tagged in Canelo, Elgin, and the San Rafael Valley, Santa Cruz County, Arizona that were recovered in Michoacán, Mexico. In 2018, the Southwest Monarch Study reported 24 individuals tagged in Arizona recovered in Mexico (https://www.swmonarchs.org/az-recoveries.php), including the single record of a monarch recovered in Sonora. They discuss the influence of the wind direction on the ultimate destination of migrating monarchs. We point out that the tagging dates of September 20 to October 5 are after the end of the summer monsoon rains in the time when circulation patterns bring tropical storms and hurricanes from the Pacific Ocean across the Baja California Peninsula to reach Sonora and Arizona from the southwest. The few monarchs tagged in Arizona overwintering in Michoacán probably flew eastward into Chihuahua and joined the migration on the eastern side of the SMO southward on the Mexican Plateau. iNaturalista records in the Janos area in northwestern Chihuahua (east of the SMO) could have reached the area from southeastern Arizona or southwestern New Mexico. They have also been seen near Cd. Chihuahua (Río Conchos, urban) and near Delicias and Pedro Meoqui (Río San Pedro, urban) in central Chihuahua and between Ojinaga and Manuel Benavides across from the Big Bend National Park in Texas in eastern Chihuahua. These areas are in the Río Bravo/Grande drainage system and are likely part of the main eastern migration.

The arrow depicting monarch migration from Arizona to Michoacán in Figure 10 in Morris *et al* (2015) appears to pass through Chihuahua on the Mexican Plateau, and not west of the SMO through Sonora and Sinaloa. There are a few records from the east slopes of the SMO from east of Yécora, Sonora near Chuichupa, Madera, and Mátachic in western Chihuahua. They could be part of the main eastern migration and moved into the mountains from the east rather than crossing the SMO from the Sonoran side. On the Mexican Plateau, elevations increase southward from the Río Bravo on the United States-Mexico border. Incursions of Arctic air masses (blue northers) channel very hard freezes that affect the entire Plateau in north-central Mexico as far south as Guadalajara and Mexico City (Neilson 1987, Schmidt 1979). In the SMO, winter minimum temperatures gradually increase southward (Van Devender and Reina-G. 2016). In the Monarch Butterfly

Biosphere Reserve in Michoacán, winter temperatures are cool with occasional lethal freezes, but herbs like *Salvia* flower all winter (Solis-C. *et al.* 2004, Van Devender and Reina-G. personal observation). Overwintering monarchs live on stored fats, only occasionally nectaring, and do not breed until late February (Solis-C. *et al*. 2004).

Brower and Pyle (2004) hypothesized that monarchs migrate southeast across the Sonoran Desert to the SMO to overwinter in high-elevation forests in Durango. They were observed along MEX 40 from Mazatlán to Durango in TDF at La Guásima (November) and Pánuco (March) and in POF in the SMO on *A. angustifolia* (Figure 5) in clearings near El Palmito in November (5), February, and March. These observations were too late to be part of the main eastern fall migration.

We conclude that the monarch population in Sonora is not connected to the eastern mid-continental migration to overwinter in Michoacán because of the relatively few total observations in the state, the few observations in the SMO in Sonora and Chihuahua, and winter feeding-breeding populations in tropical southern Sonora and western Sinaloa. Resident breeding populations are inherently easier to protect than populations impacted by different activities along migration routes. Like the Rocky Mountains, the Sierra Madre Occidental is better viewed as a barrier to west-east migration than a corridor.

Conservation and research needs

With the recent declines in both the eastern and western North American populations, the U.S. Fish and Wildlife Service (FWS) was petitioned to list the eastern subspecies of the monarch butterfly (*Danaus p. plexippus*) under the Endangered Species Act of 1973 (Center for Biological Diversity *et al.* 2014). FWS conducted a Species Status Assessment to evaluate the status and viability of the species, including populations in regions outside of eastern and western North America (Nail *et al.* 2019, U.S. Fish and Wildlife Service 2020). On December 15, 2020, the FWS announced that listing the monarch as endangered or threatened under the Endangered Species Act is warranted. The monarch is now a candidate species that will be reviewed annually until a listing decision is made.

In Mexico, *Danaus plexippus* has the status of Protección Especial in the NOM-059 Mexican endangered species law, which indicates that the species is threatened by factors that impact its viability and may warrant restoration or conservation actions (Diario Oficial de la Federación 2010).

Differences in protection status led to different kinds of citizen science in the two countries. In the United States, tagging has yielded enormous amounts of knowledge about monarch migration patterns. Federal listing in the future may make tagging efforts more difficult. In Mexico, citizens are prohibited from handling NOM listed species but are encouraged to post their monarch observations and images on iNaturalista. Although these social media efforts can be very useful, the system in general has little quality control, errors in identification and localities, poor images, records submitted more than once by different individuals with different data, and cryptic observer names. A rigorous tagging program is needed to better understand patterns of regional migrations and resident populations of monarch butterflies in northwestern Mexico.

ACKNOWLEDGEMENTS

Richard A. Bailowitz, James Brock, Doug Danforth, Edward Pfeiler, Anays Blanco, Enrique Ballesteros, Cecilia Aguilar, Professors Hugo Silva, Gertrudis Yanes, and María de la Paz Montañez, and student Diana Moreno from Universidad de la Sierra, Valeria Cañedo, and members of the Alianza Mariposa Monarca group at the Universidad de Sonora contributed their butterfly observations to MDE database. The observations and images in iNaturalista have been very important, especially those from CONANP (Mexican Protected Natural Area) biologists in Áreas de Protección de Flora y Fauna (APFyF) or Reservas de la Biósfera. We especially thank biologists in APFyF Bavispe (F. Isaias Ochoa-G.), Reserva de la Biósfera El Pinacate y Gran Desierto de Altar in Sonora, APFyF Meseta de Cacaxtla in Sinaloa, and Reserva de la Biósfera Janos in Chihuahua. Lydia Lozano from Reserva Monte Mojino (Nature and Culture International) in Álamos, Sonora also contributed important observations. Anays Blanco, Cecilia Aguilar, Doug Danforth, Gail M. Morris, Carlos M. Valdez, and an APFyF Meseta de Cacaxtla biologist provided images. We thank Richard Bailowitz, James Brock, John Palting, Sue Carnahan, several anonymous reviewers, and especially Gail Morris for helpful comments on the manuscript. Greater Good Charities sponsors the Madrean Discovery Expeditions program and database. Dennis Caldwell drafted the map in Figure 3 and the graph in Figure 6.

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Figure 1. Monarch butterfly feeding on doll's head/*confituría amarilla* (*Lagascea decipiens*) cultivated in Tucson, Arizona on December 25, 2018. Photo by Reina-G.

Figure 2. Monarch butterfly tagged in Canelo, Arizona on September 11, 2017, and recovered at El Rosario, Michoacán on February 10, 2018. Photo by Gail M. Morris.

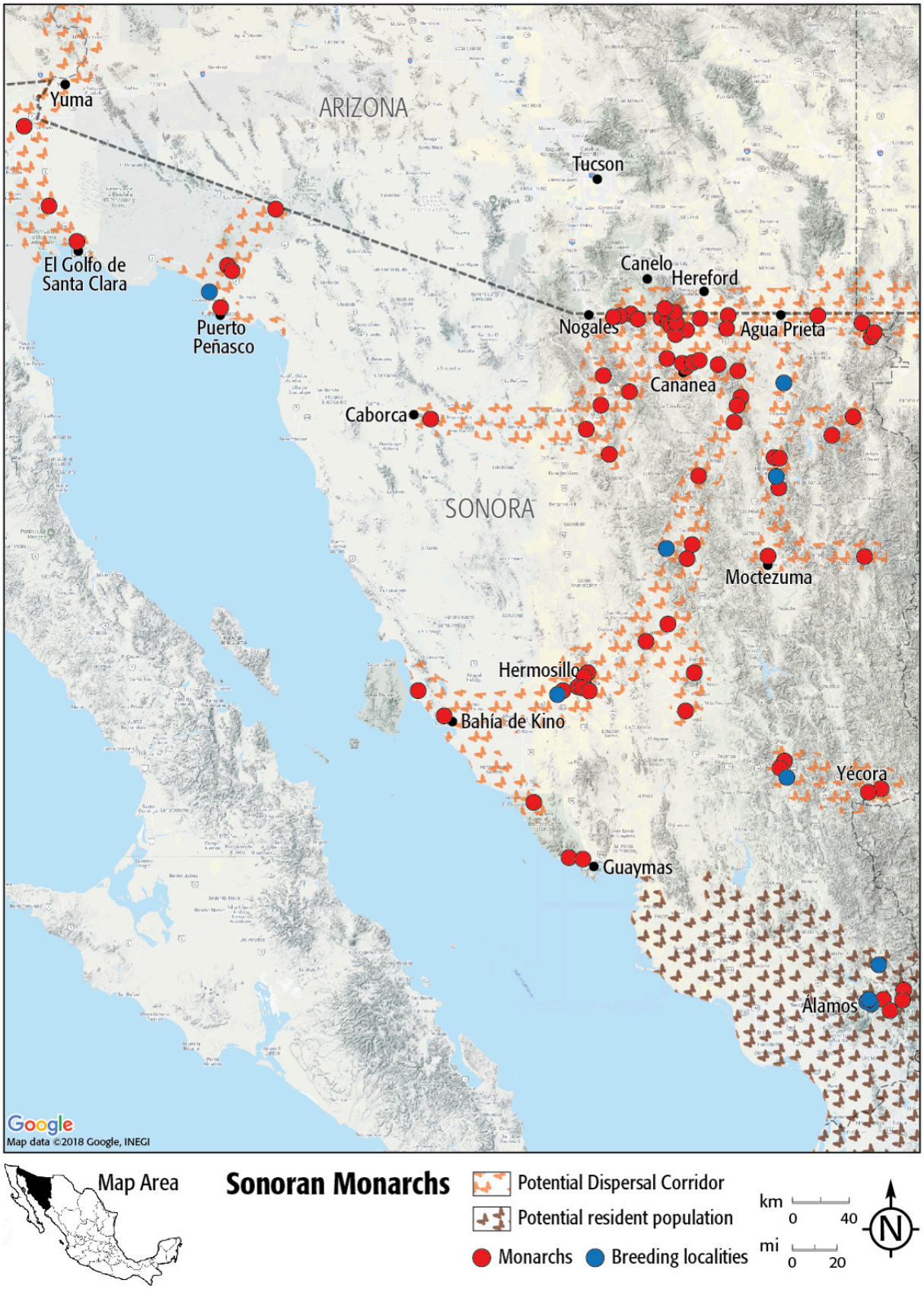

Figure 3. Map of the distribution of monarch butterflies in Sonora, Mexico. Blue spots are breeding records. Orange stipple areas are inferred local migration corridors. Brown stipple area is likely a resident population.

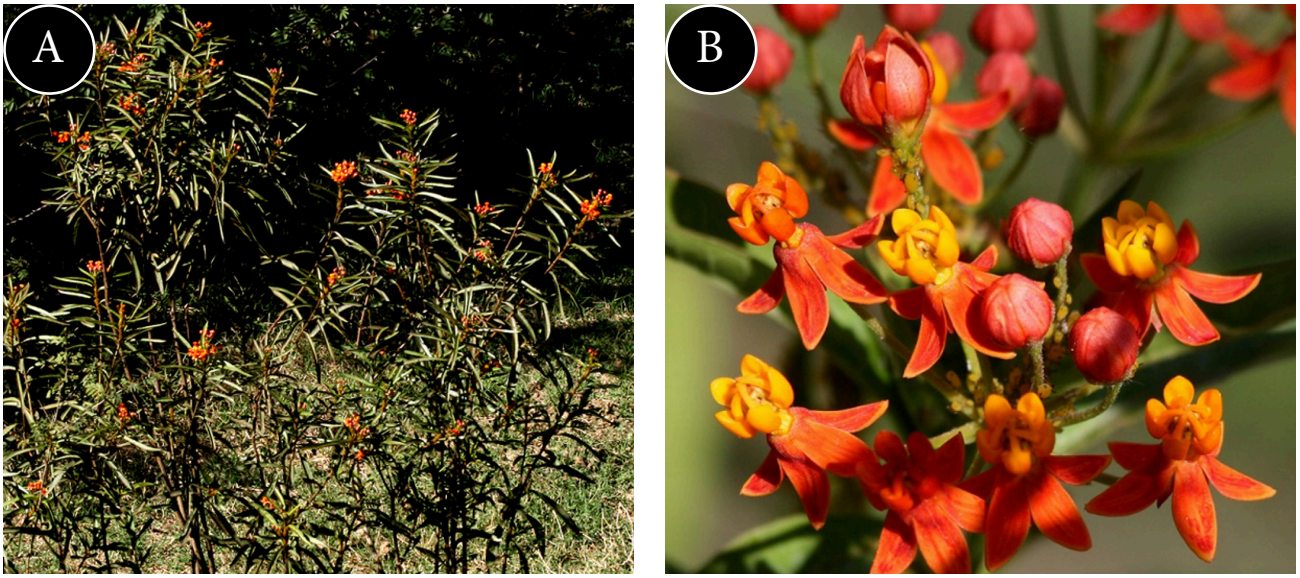

Figure 4A, 4B. Plant and flowers of *Asclepias curassavica* near Navojoa, Sonora in March 2007. Photo by Doug Danforth.

Figure 5. Monarch butterfly feeding on flowers of *Asclepias angustifolia* at Ejido El Palmito, Sinaloa on November 20, 2017. Photo by APFyF Meseta de Cacaxtla biologist.

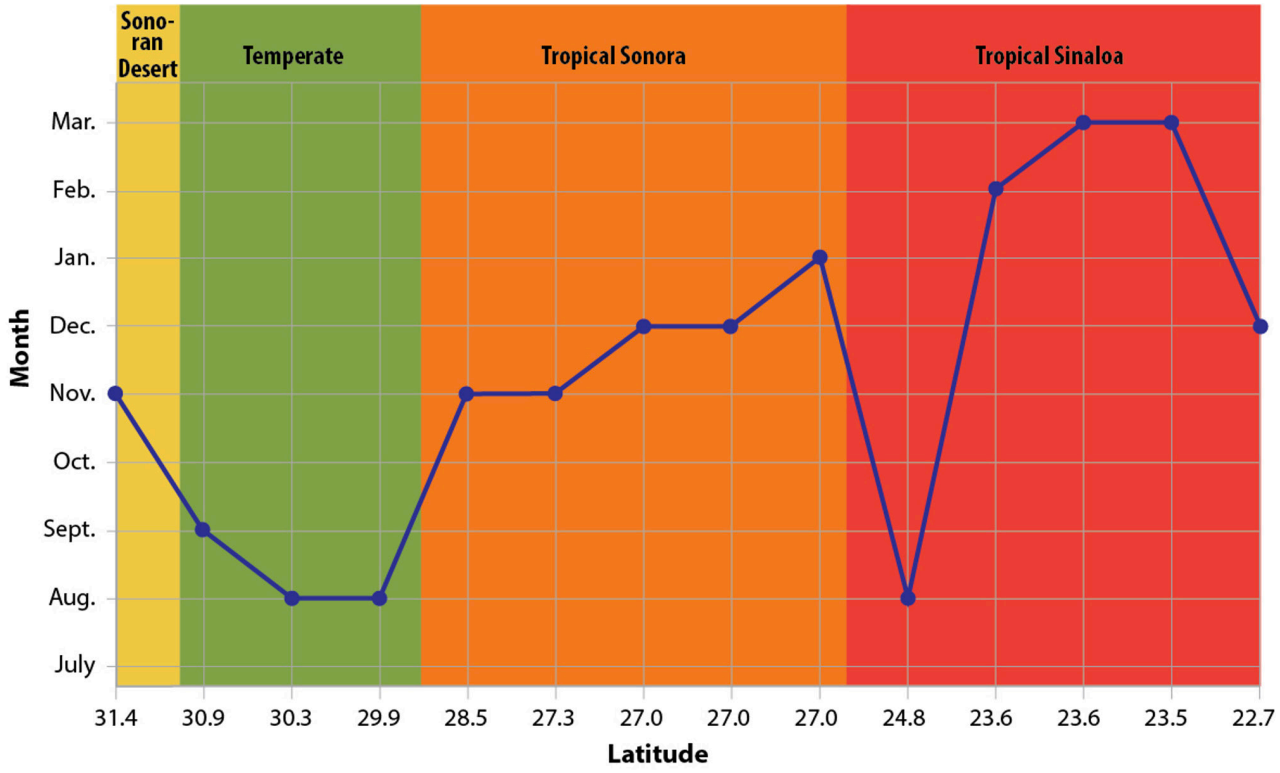

Figure 6. Date and latitude of monarch butterfly breeding records in Sonora and Sinaloa, Mexico.

Figure 7. Monarch butterfly larva feeding on *Asclepias linaria* in the Sierra Juriquipa, Sonora on August 14, 2017. Photo by Anays C. Blanco.

Figure 8. Monarch butterfly larva feeding on *Asclepias lemmonii* in the Sierra de Los Ajos, Sonora on September 14, 2017. Photo by Cecilia Aguilar-M.

Figure 9. Monarch butterfly aggregation on cultivated Aleppo pine (*Pinus halepensis* Mill.) along the Colorado River at Lake Havasu, Arizona on December 2, 2016. Photo by Gail M. Morris.

Figure 10. Monarch butterfly on old leaves of Fremont cottonwood on Rancho Los Fresnos, Sonora on October 8, 2016. Photo by Carlos M. Valdez.

Table 1. Monarch butterfly reproductive records in Sonora and Sinaloa. All are larvae except last thre Sinaloa records are pupae.

Municipio	Localitiy	Coordinates	Elevation	Vegetation	Observer	Date	Host	Stage
Sonora								
Puerto Peñasco	12.7 km NW of Puerto Peñasco.	31.432°N 113.573°W	13	Sonoran desertscrub.	S. Blackwell	November 15, 2018	*Asclepias subulata*	larva
Fronteras	32.3 km W of Fronteras, Sierra de los Ajos.	30.925°N 109.895°W	1589	Oak woodland.	L. Grijalva	September 14, 2017	*Asclepia lemmonii*	larva
Nacozari de García	14.4 km ESE of Nacozari de García, Sierra Juriquipa.	30.285°N 109.575°W	1567	Oak woodland.	A.C. Blanco-G.	August 14, 2017	*Asclepias linaria*	larva
San Felipe de Jesús	14.5 km WNW of San Felipe de Jesús, Sierra Los Locos.	29.878°N 110.387°W	1304	Oak woodland.	T.R. Van Devender	August 5, 2019	*Asclepias linaria*	larva
Hermosillo	Cerro La Meneja, 23 km (by air) SW of Hermosillo.	29.003°N 111.185°W	169	Sonoran desertscrub.	Barbara Natural	May 1, 2021	*Asclepias subulata*	Old pupal case.
Ónavas	Río Yaqui, ca. 1.0 km WSW of Ónavas.	28.458°N 109.539°W	155	Riparian. Foothills thornscrub.	L. Ortiz-V.	November 21, 2020	*Asclepias curassavica*	larva
Álamos	29.0 km NNE of Álamos.	27.286°N 108.885°W	225	Tropical deciduous forest.	S. López-L.	November 4, 2018	*Waltheria indica*	larva
Álamos	Álamos.	27.025°N 108.943°W	392	Urban. Tropical deciduous forest.	L. Lozano	December 7, 2016	*Asclepias curassavica*	larva
Álamos	Álamos.	27.025°N 108.943°W	391	Urban. Tropical deciduous forest.	L. Lozano	December 8, 2016	*Asclepias curassavica*	larva
Álamos	Álamos.	27.025°N 108.943°W	392	Urban. Tropical deciduous forest.	L. Lozano	January 9, 2017	*Asclepias curassavica*	larva
Sinaloa								
Culiacán	Near Carrizlejo, ca. 8.0 km (by air) E of Culiacán.	24.811°N 107.291°W	86	Agricultural field.	sjmr22	August 26, 2020		pupa
Concordia	4.5 km (by air) NE of El Palmito.	23.595°N 105.810°W	1611	Pine-oak forest.	APFF Meseta de Cacaxtla	March 9, 2018		pupa
Concordia	El Palmito.	23.563°N 105.839°W	1941	Urban. Pine-oak forest.	APFF Meseta de Cacaxtla	February 2, 2018	*Asclepias angustifolia*	larva
Concordia	4.3 km (by air) NW of Pánuco.	23.451°N 105.932°W	1027	Tropical deciduous forest.	APFF Meseta de Cacaxtla	March 6, 2018	*Asclepias curassavica*	larva
Esquinapa	17.4 km (by air) SSW of Esquinapa de Hidalgo.	22.687°N 105.842°W	2	Agricultural field.	E. Barraza	December 11, 2016		pupa

