Monarchs (*Danaus plexippus*) and milkweeds (*Asclepias* species)

THE CURRENT SITUATION AND METHODS FOR PROPAGATING MILKWEEDS

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A male monarch feeding on common milkweed. Photo by Dave Wendelken

ABSTRACT

An international effort is under way to conserve populations of the monarch butterfly (*Danaus plexippus* L. [Lepidoptera: Nymphalidae]). Monarchs complete an impressive migration each year, flying from winter roosts on the California coast and the central mountains of Mexico to breeding areas throughout North America. Monarchs depend on habitats along their migratory paths that contain milkweed species (*Asclepias* L. [Apocynaceae])—larvae are obligate feeders on leaves, and adults visit flowers for nectar. More than 130 species of milkweeds grow in North America and are readily propagated using seeds, or in some cases, cuttings. To assist monarchs and other native pollinators, native plant nurseries and their clients can incorporate milkweed species into restoration plantings in suitable habitats within the native range of individual species.

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KEY WORDS
restoration, seeds, seed propagation, butterfly, Lepidoptera, Nymphalidae, Apocynaceae

NOMENCLATURE
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Monarch (*Danaus plexippus* L. [Lepidoptera: Nymphalidae]) migrations to overwintering sites in central California and central Mexico are well known as one of the unique and spectacular biological phenomena in North America. Continued loss and degradation of habitat in breeding, migratory, and overwintering sites pose negative risks to monarch populations. Key to the persistence of this species is the protection, conservation, and restoration of habitats supporting milkweed (*Asclepias* L. [Apocynaceae]) populations and other important nectar species in North America. In the US, milkweed populations have declined because of habitat loss due to urban development and broadscale use of postemergent herbicides in agricultural areas and roadsides.

Two populations of the monarch butterfly, totaling more than 100 million butterflies (Monarch Watch 2013), occur in North America: eastern and western. Although both populations migrate, the flight of the eastern population is especially remarkable (Figure 1). The eastern population mostly overwinters in 2 concentrated areas within the oyamel forests of central Mexico (Miller and others 2012). These forests are high altitude (2400 to 3600 m [7800 to 11,810 ft]), dominated by *Abies religiosa* (Kunth) Schltdl. & Cham. (Pinaceae), and occur in the cloud belt that forms in these mountains during the summer wet season (Sáenz-Romero and others 2012). In spring, the monarchs move north and lay eggs in northern Mexico and the southern US. The adults of the next generation move farther north, until they reach their breeding range, which includes the central and eastern US and as far north as southern Canada (Malcolm 1993). About 10% of monarchs sampled in the northern US overwintered in Mexico, confirming that at least some overwintering adults reach northern latitudes (Miller and others 2012). Typically 2 more generations occur at the northern latitudes. In the Great Lakes region, 62% of the monarchs sampled were from the central US, highlighting the importance of this region for sustaining breeding populations in northern areas (Miller and others 2012). In fall, the final generation of monarchs flies all the way back to central Mexico, covering more than 3000 km (1864 mi) (Miller and others 2012).

The western population breeds in the western US and western Canada and winters near the California coast (Figure 2) at more than 300 aggregation sites (Leong and others 2004; NAMCP 2008). Western monarchs lay eggs on host milkweed species (*Asclepias* spp.) and milkweed vines (*Funastrum* Fourn. spp., *Cynanchum* L. spp., and *Matelea* Aubl. spp. [Apocynaceae] [Ackery and Vane-Wright 1984]) in the mountains and foothills of California, the Pacific Northwest, and the Great Basin states.

Most recently, Brower and others (2012) found that during the 2009–2010 overwintering season, following a 15-y downward trend, the total area in Mexico occupied by the overwintering eastern North American population reached an all-time low. Although the population rebounded slightly in 2010–2011,

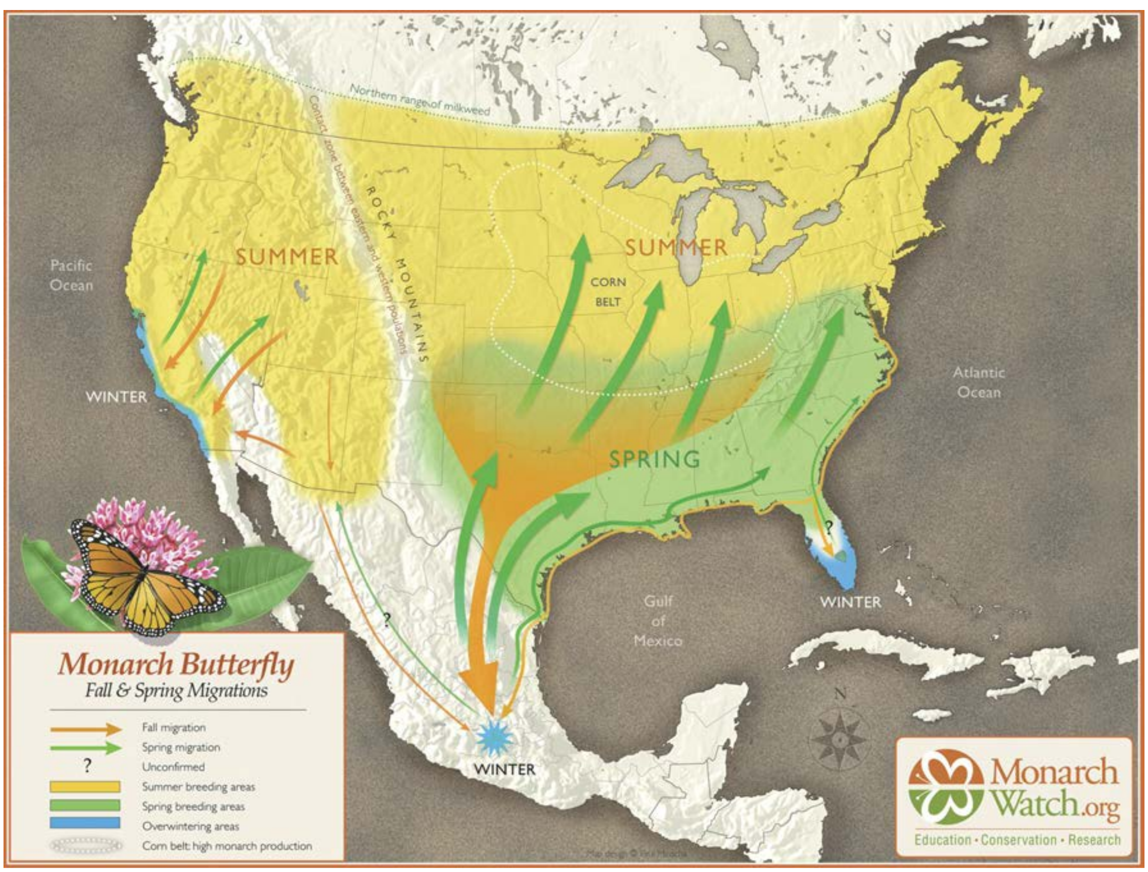

Figure 1. Migration routes of monarchs in North America. Reprinted with the generous permission of Monarch Watch

Figure 2. Clusters of monarchs on eucalyptus trees at Natural Bridges State Beach in Santa Cruz, California. Photos by Eliya Selhub

they described 3 factors that appear to have contributed to this decline: 1) degradation of the forest in the overwintering areas; 2) the loss of breeding habitat in the US due to the expanded use of herbicide-resistant crops and conversion of agricultural lands; and 3) extreme weather.

Degradation of Overwintering Sites

In Mexico, many organizations are involved in conserving critical monarch wintering habitat. Because logging of the forests supports the local communities, some organizations, such as the Monarch Butterfly Fund (2013), are involved with reforestation, environmental education focusing on the importance of these forests to butterflies, sustainable economic development to alleviate pressure to harvest trees, and research on monarch biology. Ecotourism may have a role in supporting local economies as well (Monarch Watch 2013). In the western US, monarchs aggregate in more than 25 winter roosting sites in southern California, particularly around Pacific Grove and Santa Cruz. Critical winter roosting areas are being protected through conservation easements, land trusts, and land-use planning laws (Monarch Watch 2013).

Loss of Breeding Habitat

Improving habitat for monarchs is key to conserving their populations. In the summer breeding ranges of the US, population decreases are due to the increased use of genetically modified crops in the Great Plains and the Midwest (Brower and others 2012). Transgenic *Bacillus thuringiensis* (Bt) corn pollen, naturally wind-deposited on common milkweed from adjacent corn fields, can cause significant mortality of monarch larvae (Hansen Jesse and Obrycki 2000). Genetically modified herbicide-resistant crops, such as Roundup Ready® soybeans and corn, are contributing to the loss of milkweed (Brower and others 2012) and other nectar plants along migratory paths. Monarchs use nectar sources to build fat reserves, which are necessary for migration and the overwintering period (Brower and others 2006; Miller and others 2012). Thus, conservation of nectar plants in Texas and Mexico are crucial. Important nectar sources during the fall migration include late-flowering genera of the Asteraceae, such as goldenrods (*Solidago* L. spp.), asters (*Symphyotrichum* Nees spp. and *Eurybia* (Cass.) Cass. spp.), gayfeathers (*Liatris* Gaertn. ex Schreb. spp.), and coneflowers (*Echinacea* Moench) in the north (Figure 3), and frostweed (*Verbesina virginica* L.) in Texas (NAMCP 2008). Cultivated alfalfa (*Medicago sativa* L. [Fabaceae]), clover (*Trifolium* L. [Fabaceae]), and sunflowers (*Helianthus* L. [Asteraceae]) are also critical nectar sources. Conversely, spring flora in northern Mexico, Texas, and California are necessary for fueling spring migrations.

Extreme Weather

Brower and others (2012) discuss a series of extreme weather events that depleted the 2009–2010 overwintering population of monarchs in Mexico to their lowest recorded levels. A combination of above-normal temperatures in Texas in the spring of 2009, followed by the lowest average temperatures in the US cornbelt in 42 y reduced the size of the population migrating to Mexico. When the monarchs finally returned to

Figure 3. Species that bloom late in the summer and in early fall, such as this *Echinacea* species, are important food sources for migrating monarchs. Photo by Joseph G Strauch Jr

Figure 4. A tagged monarch on the Wayne National Forest in southeastern Ohio. Photo by Lynda Andrews, USDA Forest Service

Mexico, they were exposed to record amounts of precipitation as well as a major storm with heavy precipitation and high winds that was followed by cold temperatures (–6 °C [21 °F]). They conclude this storm was responsible for killing 50% of the overwintering monarchs. The vulnerability of overwintering monarchs to weather extremes is worrisome considering the variable weather predicted with climate change (Oberhauser and Peterson 2003).

THE USDA FOREST SERVICE RESPONSE

The Monarch Joint Venture is a partnership of many government agencies, nongovernmental organizations, and academic programs committed to a science-based approach for conserving and protecting monarch populations (Monarch Joint Venture 2013). This project is guided by the North American Monarch Conservation Plan (NAMCP 2008), which aims to conserve monarch butterflies along their migration routes by restoring habitats containing nectar species and milkweeds. One partner is the USDA Forest Service, which has initiated dozens of projects across the eastern half of the US and internationally. In 2008, the Forest Service International Programs, in partnership with other agencies and schools, initiated Monarch Live—A Distance Learning Adventure, which connected 500,000 students in classrooms across Canada, the US, Mexico, and other countries by way of the Internet (USDA FS 2013). Much work is being done on the ground as well. For example, in 2011 alone, treatments to improve habitat for monarchs and other pollinators were conducted on 405,000 ha (1 million ac) on more than 20 National Forests. In addition, native plant and pollinator gardens were established at office, parking, and trailhead sites, and Forest Service personnel provided regular workshops to citizens and tagged monarchs to track their migration (Figure 4) (USDA FS 2013). Forest Service research scientists were also involved. For example, they evaluated how fire could be used to restore habitat and to increase abundance of nectar species along the eastern migratory path (Rudolph and others 2006), and developed vegetation management options for conserving the important Mexican winter habitat in the face of climate change (Sáenz-Romero and others 2012).

NATIVE PLANT NURSERIES CAN HELP

The native plant nursery industry can facilitate monarch recovery by providing viable seeds and plants of milkweed and nectar species for urban and wildland landscapes. In addition, nurseries can help distribute educational materials (for example, from Monarch Watch 2013) that encourage customers to plant milkweeds in their gardens, yards, and wild areas. To support these efforts, in this article we will discuss milkweed ecology and provide a synthesis of propagation techniques.

Figure 5. Monarch caterpillars are vividly striped to warn potential predators that they taste poorly and are toxic, a result of their diet on milkweeds. Photos by Carolyn Henne, USDA Forest Service (*left*) and Joseph G Strauch Jr (*right*)

MILKWEED SPECIES ECOLOGY AND HABITAT

Monarch larvae are obligate herbivores of milkweed species in the genus *Asclepias* as well as of the milkweed vines in the genera *Funastrum*, *Cynanchum*, and *Matelea* (Figure 5) (Ackery and Vane-Wright 1984). Seventy-six milkweed species are native to US and Canada; when including Mexico and Central America, the number increases to about 130 species (Fishbein 2013). At least 29 milkweed species occur within the critical habitat of the central US (McGregor 1986; Fishbein 2013) and about 36 species occur in Texas alone (Correll and Johnson 1979; Fishbein 2013).

The most widely used monarch host plant in the northern US and southern Canada is the common milkweed, *A. syriaca* L. (Malcolm and others 1989), which readily occupies disturbed areas and has expanded its range due to conversion of grasslands and forests to agriculture in the central and northeastern US and southeastern Canada (Malcolm and others 1989; Brower 1995; NAMCP 2008). As many as 70% of monarchs that migrated to Mexico may have fed on milkweed growing on agricultural land (Oberhauser and others 2001).

Other milkweeds identified as important host species in the southwestern and southeastern US include green antelope horn (*Asclepias viridis* Walter), antelope horns (*A. asperula* (Decne.) Woodson), and zizotes milkweed (*A. oenotheroides* Cham. & Schltdl.) (NAMCP 2008). *Asclepias incarnata* L., *A. tuberosa* L., and *A. syriaca* L. are important species used on USDA Forest Service sites in the eastern US (Stritch 2013). The most common species in the Great Plains region and throughout the western US is showy milkweed (*A. speciosa* Torr.). California hosts 15 native milkweed species (Jepson 2012). Additionally, 2 milkweed species in the US are on the Federal Threatened and Endangered Species List: Mead's milkweed (*A. meadii* Torr. ex A. Gray), a known host for monarchs, is found in the tallgrass prairie region of the Upper Midwest US (USFWS 2003) and Welsh's milkweed (*A. welshii* N.H. Holmgren & P.K. Holmgren) is a highly restricted species found on only a few sites within the Navajo Nation of Arizona and southeastern Utah (USFWS 1992). Mexican butterflyweed (*A. curassavica* L.) is likely the most important host species in Mexico (NAMCP 2008). Recently, monarch eggs and larvae were found on nodding milkweed (*A. glaucescens* Kunth) in the State of Michoacán, Mexico (Montesinos 2003). Some interesting milkweeds and their distributions are shown in Table 1.

Milkweeds produce perfect flowers in umbels during summer. Milkweeds are neither fully self-fertile nor fully self-incompatible and may occasionally hybridize (Wilbur 1976; Wyatt 1976; Bookman 1983; Kahn and Morse 1991; Ivey and others 1999). These insect-pollinated flowers are noted for their unique structure (Wyatt 1981; Bookman 1984). Pollen does not occur as free grain but is instead contained within pollinia.

TABLE 1

*Some interesting milkweeds (*Asclepias *spp.) of the US, including their common names, ranges, and the photographers.*

A. amplexicaulis Sm. Bluntleaf milkweed
Central Great Plains, Midwest, and northeastern US south to Florida and Texas
Joseph G Strauch Jr

A. asperula Dcne. Antelope horns
Southwestern US, northern Mexico
Mark Fishbein

A. californica Greene California milkweed
California, northern Baja, Mexico
Bobby Gendron

A. exaltata Poke milkweed
Ontario, Minnesota, and northeastern US south to Georgia
Joseph G Strauch Jr

A. incarnata L. Swamp milkweed
Nova Scotia to US Great Plains south to Florida and New Mexico
Betsy Strauch

A. purpurescens L. Purple milkweed
Southeastern Canada, and Midwest and northeastern US
Chip Taylor

A. syriaca L. Common milkweed
Throughout North America east of the Rocky Mountains
Joseph G Strauch Jr

A. tuberosa L. Butterfly milkweed
Southeastern Canada, Midwest, and northeastern US to Utah and Arizona, and northern Mexico
Joseph G Strauch Jr

A. viridiflora Raf. Green comet milkweed
Southern Canada and the US east of the Rocky Mountains
Thomas G Barnes

Figure 6. Maturing fruits (follicles) of common milkweed (*left*); mature follicles of showy milkweed with a portion of one fruit removed to show seeds (*center*); and seeds emerging from swamp milkweed (*right*). Photos by Jack Greenlee, USDA Forest Service; Tara Luna; and Betsy Strauch, respectively

During pollination, pollinia attach to hairs on the feet or heads of insect pollinators and are then carried to other individual milkweeds. Most milkweed species are self-incompatible, meaning that for the development of viable seeds, individuals must receive pollen from other individuals of the same species (Kephart 1981; Bookman 1983; Kahn and Morse 1991; Browles and Wyatt 1999; Ivey and others 1999). Flowers develop into dehiscent fruits, known as follicles, which mature in late summer through fall. Follicles split open on one side to release ripe seeds that are flattened, brown, and attached to long, silky, white hairs that facilitate wind dispersal of upland species and water dispersal of swamp milkweed (*A. incarnata* L.) (Wilbur 1976; Pavek 1992; Kantrud 1995).

GROWING MILKWEED FROM SEEDS AND CUTTINGS

Milkweeds are generally easy to propagate. Below is some basic propagation information for 6 species important to monarchs: swamp milkweed (*A. incarnata*), oval-leaf milkweed (*A. ovalifolia* Decne.), showy milkweed (*A. speciosa*), common milkweed (*A. syriaca*), butterfly milkweed (*A. tuberosa*), and green comet milkweed (*A. viridiflora* Raf.). These general methods would likely apply to other species as well.

Seed Propagation

As mentioned, insect-pollinated flowers give rise to follicles that mature during late summer through fall. Mature follicles rupture and seeds are dispersed by means of long, silky, white hairs (Figure 6). Follicles can open quickly so they should be checked regularly and collected when they turn yellow and begin to split open (Rock 1981; Heon and Larsen 1999; Cullina 2000; Schultz and others 2001a,b). Seeds of common and green comet milkweeds can be collected as soon as they turn brown (Figure 7), regardless of follicle appearance (Heon and Larsen 1999). To avoid seeds blowing away after the follicles rupture, follicles can be put inside mesh bags (Glick 2004) or tied with a piece of string around their middle (Grabowski 1996).

Figure 7. Seeds of butterfly (*left*) and common milkweed (*right*). Note the edge of the penny in the left photo and the 5-mm line in the right photo. Photos by Joseph Scianna, USDA Natural Resources Conservation Service (*left*) and Steve Hurst, USDA Agricultural Research Service, Systematic Botany and Mycology Laboratory (*right*)

Number of seeds per follicle differs by species: 64, 84, and 236 seeds per follicle are common for butterfly, green comet, and common milkweed, respectively (Wilbur 1976); and Bookman (1983) reports 115 for showy milkweed. Although follicles can be stored in paper bags in a warm, dry area until they split open and release seeds, Cullina (2000) recommends opening follicles and pulling the brown seeds from the wet hairs immediately after collection. Showy milkweed seeds have been separated in a brush machine with a sandpaper drum (to remove silky hairs) followed by an air-screen machine (Bartow 2003), or with a clipper machine (no screens, medium speed, medium air flow) (Barner 2007). Little is known about seed storage and longevity for this genus, but general recommendations are dry and cold storage (0 to 3 °C [33 to 38 °F]) (Phillips 1985; Cullina 2000; Schultz and others 2001a,b; Barner 2007). Shultz and others (2001a,b) have stored swamp and common milkweed seeds under these conditions up to 3 y. Seeds per kg ranges from 110,000 to 200,000 (50,000–90,000/lb) depending on species (Table 2).

In general, fresh seeds of some species (for example, common and butterfly milkweed) germinate without stratification, but germination capacity, uniformity, and speed are improved by stratification followed by exposure to warm temperatures (Baskin and Baskin 1977; Bir 1986). Specific stratification recommendations vary by species, ecotype of widely distributed species (for example, common and butterfly milkweed), and by researcher (Table 3). In general, seeds are either naked stratified or sometimes mixed with moistened perlite or vermiculite. Seeds should be checked often during stratification for mold or for germination (Dumroese and others 2012).

After stratification, specific but similar nursery practices have been described for swamp (Schultz and others 2001a), common (Schultz and others 2001b), showy (Bartow 2003), and butterfly milkweed (Blessman and Flood 2001). Although no specific regimens were found for oval-leaf and green comet milkweed, they and other *Asclepias* can likely be grown with similar techniques. Stratified seeds are usually sown during late winter or early spring into containers filled with commercially available "plug" or "seedling" media. Seeds of common and swamp milkweed are known to germinate without exposure to light (Baskin and Baskin 1977; Schultz and others 2001a,b) and are covered with a fine layer of medium. Containers used for milkweeds have had these size ranges: 98 to 200 ml (6 to 12.5 in^3) in volume, 3.8 to 5 cm (1.5 to 2 in) in diameter, and 10 to 21 cm (4 to 8.25 in) in depth. Often, controlled-release fertilizer (for example, Osmocote 17N:$6P_2O_5$:$10K_2O$ at a rate of 5 kg/m^3 [8.5 lb/yd^3]) is added to the medium. Target greenhouse temperatures (day and night) are 18 to 24 °C (65 to 75 °F) and 10 to 12 °C (50 to 55 °F). Containers are hand-watered and germination (75 to 85%) generally occurs within 2 wk. Poor medium aeration (or overwatering) can prevent healthy growth (Borland 1987). Good air flow under and around plants improves plant health (Grabowski 1996). Depending on growth, seedlings having true leaves may also receive additional (50 to 200 ppm) nitrogen (as part of a complete fertilizer) through the irrigation water.

TABLE 2

Seeds per kg (lb) for 6 species of milkweed in the US.

Species common name	Seeds per kg (lb)	Source
Swamp	110,000 (50,000)	Garbisch and McIninch (1992)
Showy	158,000 (72,000)	Wilbur (1976)
Common	200,000 (90,000)	Wilbur (1976)
Butterfly	154,000 (70,000)	USDA NRCS (2012)
Green comet	195,000 (85,000)	USDA NRCS (2012)

TABLE 3

Stratification recommendations for 6 species of milkweed in the US.

Species common name	Stratification duration	Germination temperatures °C (°F)	Sources
Swamp	7 to 90 d at 4 °C (39 °F)	27/16 (80/60)	Young and Young (1986); Cullina (2000); Schultz and others (2001a)
Oval-leaf	120 d	18 to 21 (65 to 70)	Green and Curtis (1950)
Common	7 d to 11 mo at 5 °C (41° F)	30/20 (86/68)	Evetts and Burnside (1972); Lincoln (1976); Baskin and Baskin (1977); Bhowmik (1978); Farmer and others (1986)
Butterfly	21 to 120 d at 5° C (41° F)		Salac and Hesse (1975); Bir (1986); Young and Young (1986); Borland (1987); Grabowski (1996); Heon and Larsen (1999); Cullina (2000); Baskin and Baskin (2001); Blessman and Flood (2001); Stevens (2001)
Green comet	30 d	18 to 21 (65 to 70)	Baskin and Baskin (1998)

Once plants reach their target heights, plants can be moved to an outdoor growing area, liquid fertilizer applications are generally reduced, and plants are allowed to dry-down between irrigations. Blessman and Flood (2001) have successfully top-pruned butterfly milkweed that had grown too tall (from 20 to 25 cm [8 to 10 in] to 8 to 10 cm [3 to 4 in]), taking care to remove clippings to prevent disease. Showy milkweed plants often senesce during the summer months but reappear in October (Bartow 2003). Within 5 to 7 mo of sowing, most milkweeds are ready for outplanting. Seedlings that are not outplanted that fall or the following spring can be held over, but transplanting to a larger container may be necessary to avoid root binding. Because plants have large taproots without many fibrous roots, transplanting or outplanting can be difficult and large amounts of medium around the crown are often lost (Blessman and Flood 2001; Schultz and others 2001a,b; Bartow 2003). This lack of a firm root plug might be mitigated by using Jiffy pellets (Jiffy Products of America, Lorain, Ohio) because the entire container is outplanted.

Vegetative Propagation

Common milkweed is considered a common agricultural weed that spreads when its extensive root system is severed by farm implements, so root cuttings can be used to propagate it. Given that oval-leaf, showy, and butterfly milkweed are similar to common in their ability to spread by rhizomes (Kiltz 1930; Wilbur 1976; Bhowmik 1978; McGregor 1986; Gleason and Cronquist 1991; Kantrud 1995; Cullina 2000), propagation by root cuttings should be considered for most *Asclepias* species. Some possible exceptions include swamp milkweed that only occasionally reproduces by rhizomes (Pavek 1992; Schultz and others 2001a) and green comet milkweed (McGregor 1986).

The general recommendation is to collect root sections from dormant plants (Phillips 1985; Grabowski 1996; Stevens 2000). Although Stevens (2000) suggests that each root propagule contain at least one shoot bud, Evetts and Burnside (1972) report that 15-cm (6-in) root fragments of common milkweed reproduced independently of visible shoot buds, most likely because this species readily develops adventitious root buds (Polowick and Raju 1982). Shorter root segments (3 to 5 cm [1.2 to 2 in]) of butterfly milkweed also readily produced new plants (Phillips 1985; Ecker and Barzilay 1993; Grabowski 1996) with shoots and flowers emerging earlier from cuttings taken from upper sections of the plant than those from lower portions (Ecker and Barzilay 1993). Cullina (2000) cautions, however, that butterfly milkweed plants from cuttings often have poor crown development and sometimes overwinter poorly. Root sections can be struck into a sandy rooting mix that is kept slightly moist (Phillips 1985; Grabowski 1996).

Butterfly milkweed has been propagated from 8 to 10-cm (3 to 4-in) stem cuttings taken from the terminal shoot before the plant begins to flower (Phillips 1985; Grabowski 1996). Keep cuttings cool and moist, and process them immediately by removing the leaves from the basal portion. Cuttings can be struck into containers filled with pure sand or equal parts of sand and peat moss. Maintain high humidity through regular misting and by covering the container with a tent of clear plastic. Cuttings root within 6 wk (Phillips 1985; Grabowski 1996).

For root and shoot cuttings, once new shoots appear, grow the plants following the same techniques described for seedlings.

Figure 8. Monarchs visiting a mud hole on their wintering grounds in central Mexico. Photo by Dennis Curtin

SUMMARY

Throughout North America, efforts to effectively conserve eastern and western monarch populations should include protection and restoration of habitats along migratory paths that contain milkweed species and nectar species. Restorationists and native plant nurseries can incorporate milkweed species into restoration plantings in suitable habitats within the native range of individual species—such efforts can help to sustain populations of monarchs (Figure 8). Native plant nurseries can propagate milkweeds and can educate and encourage citizens to plant these important species in their yards and gardens. Additional research is needed on seed germination requirements for the more than 130 native milkweed species required for the conservation and support of monarch populations.

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