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Saving the Monarchs

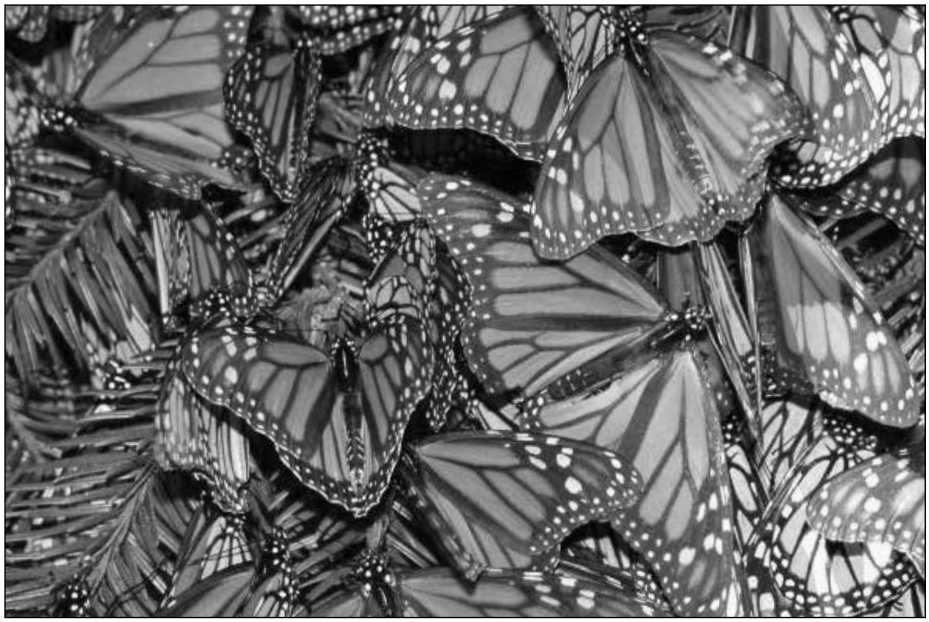
By William Quarles

The pandemic year of 2020 was bad for almost everybody, but it was an especially bad year for U.S. populations of the western migratory monarch butterfly, *Danaus plexippus*. Overwintering numbers have plunged from about 167,000 in 2016 to about 1,600 in 2020 (Schultz et al. 2017; McKnight 2021a). The current population has dropped 99.9% from the four million seen in the 1980s, and is only about 1% of that seen in 2016. Western migratory monarchs are on the brink of extinction (Pelton et al. 2019; Schultz et al. 2017).

There are two populations of migrating monarchs in the U.S.—the eastern population that breeds east of the Rockies, then travels to overwinter in Mexico, and the western population that breeds in California, Oregon, Utah, and Idaho, then overwinters on the California coast, especially in areas such as Monterey and Pacific Grove near the San Francisco Bay Area (Urquhart 1976; Brower 1977; Tuskes and Brower 1978; Urquhart 1987; Oberhauser and Solensky 2004; Oberhauser et al. 2015).

The Xerces Society for Invertebrate Conservation has been monitoring western migratory populations at overwintering sites along the California coast at Thanksgiving and New Years for the last five years. Despite an increase in the number of sites monitored, the monarch numbers have been dropping dramatically (McKnight 2021a; Pelton et al. 2019). (See Table 1).

In the 1980s millions of monarchs were seen at the West Coast overwintering sites. The author was fortunate enough to witness this amazing spectacle. Wiggling clusters of brightly colored monarchs completely covered tree canopies. Populations have seen a sharp drop, and at many sites there are now no monarchs at all (McKnight 2021a; Malcolm 2018).



Courtesy Jim Lovett, www.MonarchWatch.org

Monarchs form overwintering clusters that protect against cold and predators. Winter populations of western migrating monarchs have dropped from millions to about 2,000. Western monarchs are on the brink of extinction.

Tipping Point

Fewer monarchs have been showing up at overwintering sites, and the destruction continues even there. Over the last five years there have been 36-49% monarch losses each year at western overwintering sites. And about 21 overwintering sites have been damaged or destroyed (McKnight 2021a; Malcolm 2018; Pelton et al 2019).

We may have reached a tipping point where population losses themselves lead to further population losses. Monarchs cluster to protect against predators and get warmth from the aggregate assembly. But fewer monarchs mean more exposure to cold weather and predators. In fact, overwintering monarchs may shift sites to compensate for the low numbers. Xerces monitored 149 sites at Thanksgiving in 2020 and New Years in 2021. At 77 sites (52%), no monarchs were found. At 15 sites (10%) numbers increased between Thanksgiving and New Years,

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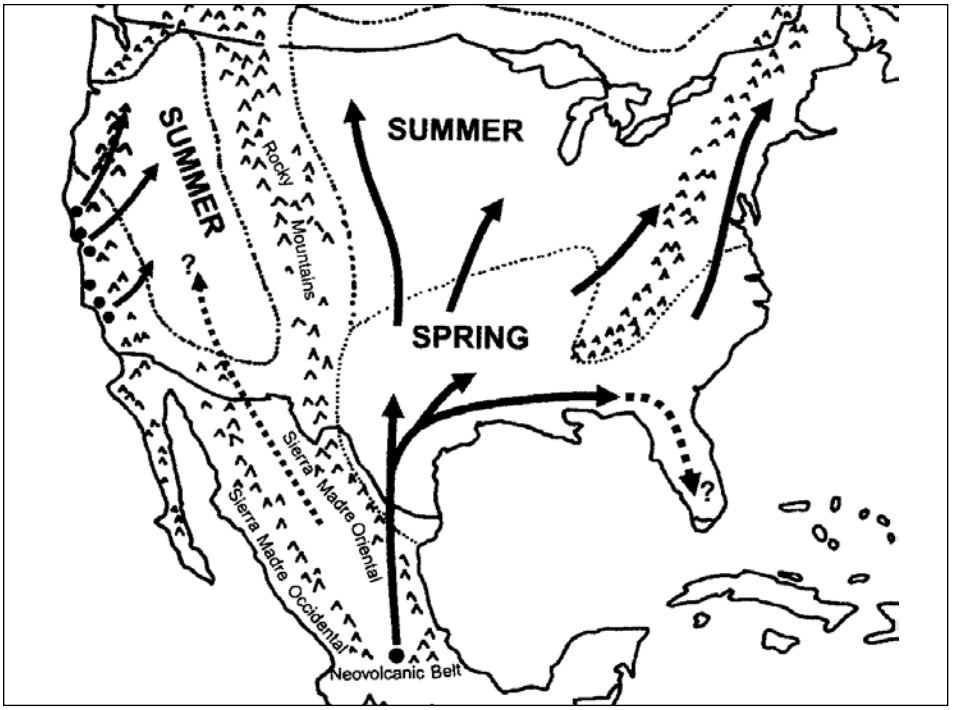

Courtesy of the University of Minnesota Monarch Lab

Western monarchs leave overwintering sites on the California coast in the spring and fly inland. On return flights in the fall, they may have to fly through forest fires. Eastern monarchs leave Mexico in the spring, establishing new generations in Texas, the Midwest, and the Northeast.

and at 54 sites (36%) populations decreased (McKnight 2021a). In 1978, when populations were large, monarchs rarely moved from an overwintering site until the spring (Tuskes and Brower 1978).

Importance of Parasites

Much has been written about the importance of monarch parasites. Monarchs are weakened by the protozoan parasite, *Ophryocystis elektroscirrha*. Spores deposited by infected females on milkweed plants during egglaying are the major source of infection. New infections start when larvae eat the spores (Altizer 2001; Altizer and deRoode 2015).

But by themselves, parasites are not a likely cause of the catastrophic decline. Leong et al. (1992) found that monarchs collected in 1990 at two western overwintering sites had infection rates of 53-68% (N= 540). About 17% were heavily infected (>50,000 spores). Migrating populations were still robust at that time, numbering about a million. Infection caused no adult mortality at the cool overwintering temperatures (10°C; 50°F), but some of them died as they were subjected to increased temperatures in the laboratory (19°C; 66.2°F) (Leong et al. 1997ab; Leong et al 2004).

Hazardous Migrations

In contrast, Satterfield et al. (2016) measured infection frequency at several western overwintering sites between 2013 and 2016, and found a low 8% (N=2135) infection rate. The discrepancy between the 53-68% infection rate in 1990 and the low 8% infection rates seen recently may be important.

In the early 1990s there were fewer hazards during the western migration, and millions of infected monarchs were able to make the journey successfully. There were no systemic pesticides, no genetically engineered crops using glyphosate, and catastrophic wildfires were fewer. Hazards increased in 2013-2016, and more of the weaker infected monarchs were killed. Systemic pesticides were used during this time, and the effects of climate change, such as drought and wildfires had increased. Fewer

monarchs arrive at overwintering sites now, but those that do have less disease (Quarles 2012; 2018).

Pesticides and Land Use

Monarch decline is part of the worldwide disappearance of insects and wildlife. Human populations have nearly doubled in the last 40 years, and wildlife populations have decreased by 50% or more. Specialist insects such as the monarchs are affected more than generalists (Quarles 2019; Sanchez-Bayo and Wyckhuys 2019).

Pesticides, loss of milkweed and nectar plants, climate change, development, and forest fires have likely led to the vanishing monarch population. Crone et al. (2019) found that land use factors such as development at overwintering sites, destruction of breeding habitat, and pesticide applications in breeding areas were more important for western migratory monarch decline than climate change and global warming. Neonicotinoids accumulate in milkweed and nectar plants, and nectar plants and milkweed can be killed by herbicide drift from glyphosate crop applications (Pecenka and Lundgren 2015; Krischik et al. 2015; Goulson 2013; Malcolm 2018). Permethrin and other mosquito sprays contaminate milkweed, killing larvae that eat it and adults that contact it (Oberhauser et al. 2006).

Courtesy Glenda Dennison, UW Madison LNP

Western migrations are hazardous. Pesticides, loss of milkweed and nectar plants, drought and forest fires are killing the monarchs.

But drought and wildfires associated with climate change may be becoming more important. Flying through burning vegetation could not be pleasant. Monarchs fly across California toward the coast in September, October and November when the fires are most frequent. And due to drought, levels of early season milkweed in coastal hills and the Central Valley of California in the spring are often not sufficient to support monarch caterpillars (Frey and Schaffner 2004; McKnight 2021a; Malcolm 2018).

Monarchs and Fire

The eastern migratory population has also seen steep declines (see below), but declines have so far been limited to about 80-84%. Both eastern and western populations are exposed to the extreme weather events caused by climate change. The eastern population is exposed to many of the same negative factors as the western population, except there is one big difference—the widespread western forest fires (WWF 2021).

Table 1 shows western overwintering populations and the number of acres burned in California each year. There is a rough correlation between acres burned and overwintering numbers. As acres burned go up, overwintering populations go down. The most catastrophic reductions occur during, or one year after, the most devastating forest fires. Populations dropped 6-fold from about 150,000 in 2017 to about 25,000 in 2018 when fire acreage approximately doubled from less than a million in 2016 to more than 1.5 million acres in 2017 and 2018. The 10-fold catastrophic drop from about 20,000 to about 2,000 in 2020 occurred when fires increased about 16-fold to more than 4 million acres (McKnight 2021a; Cal Fire 2020).

Milkweed, nectar plants, and monarchs are likely burned during these periods. Dense smoke may interfere with the migratory pattern. Fires are also markers for drought conditions that impact survival of milkweed and nectar plants (McKnight 2021a; Malcolm 2018).

Table 1. California Fires and Overwintering Monarch Populations*

Year	Number Monarchs Thanksgiving	Number Monarchs New Years	Sites Monitored	Fire Acres	Number Fires	Average Fire Acres
2016	167,582	94,908 (2017)	44	669,534	6,954	96
2017	147,343	74,728 (2018)	115	1,548,429	9,270	167
2018	25,253	16,063 (2019)	130	1,975,086	7,948	248
2019	21,944	11,970 (2020)	117	259,823	7,860	33
2020	1642	1039 (2021)	149	4,257,863	9,917	429

*From McKnight 2021a and Cal Fire 2020, 2019, 2018, 2017, 2016

Chance for Recovery

There is a hard road ahead for the western migratory monarch. At New Years 2021, there were only about 1,000. Since adult monarch populations are about 50% female, approximately 500 of the survivors were probably females (McKnight 2021a). Each female lays 300-400 eggs, but there is a high attrition rate from natural enemies, weather and humans. More than 90% are killed in the egg, larval, and pupal stage. Natural enemies include spiders, ants, ladybugs, lacewing larvae, paper wasps, parasitoid wasps, and tachinid flies. In many cases, 98% are dead before they become 3rd larval instars. In realistic conditions, about 3-8 survive to become reproductive adults (Prysby et al. 2004; Oberhauser 2004).

From these figures, the best case for the 2021 western monarch is about 4,000 adults in the first generation, but 2021 is expected to be a drought year in California. If the trend follows that of the last three years, the overwintering population will likely be the same or smaller than in 2020 (see Table 1). In the worst case, if there are catastrophic fires similar to 2020, the population might vanish.

Resident Populations

Some monarchs do not take part in the annual migration, but decide to become local residents. Because of global warming with its milder winters and early springs, resident populations have been increasing slightly. There have been resident populations in Los Angeles since 1970. Recently, resident populations have been found in the San Francisco Bay Area. Residents may have been encouraged by conservation efforts in urban areas with the planting of milkweed and nectar resources (McKnight 2021b; Satterfield et al. 2016).

Planting of milkweed and nectar sources in urban gardens should continue, even if this encourages residents in warmer areas. If the migrating monarchs go extinct, at least we will have the residents. The slight increase in resident populations has not caused the dramatic decrease at overwintering sites. One estimate of the resident population in the SF Bay Area in 2020 is about 12,000 (Crone et al 2021). This number is about 7% of the western migratory population seen in 2016 and 0.3% of the population seen in 1980. The resident population may outnumber the current migratory population of about 2,000, but does not explain the drop from millions in the 1980s or even the drop from about 167,000 seen at overwintering sites in 2016.

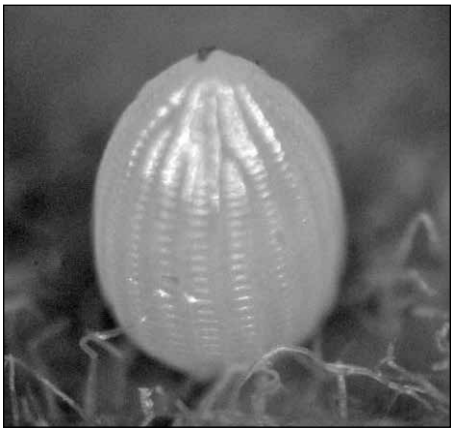

Photo courtesy Michelle Solensky

Each female can lay 300-400 eggs, but 98% of developing monarchs are killed before the pupal stage.

Photo courtesy Jim Lovett, www.MonarchWatch.org

Mating monarchs are capable of producing large numbers of replacements. Monarchs are resilient and survived the asteroid that killed all the dinosaurs 65 million years ago. But they will need help to survive the environmental insults created by humans.

Eastern Populations Also Decline

The eastern monarch populations are also declining. Possible factors are phenological disruption due to global warming, loss of milkweed breeding sites, nectar food supply disrupted by pesticides and habitat destruction, bad weather, and logging at the overwintering sites in Mexico (Thogmartin et al. 2017).

The World Wildlife Fund has been monitoring overwintering populations in Mexico for the last 28 years. There is considerable year to year fluctuation, but the trend is generally downward from a high of 44.95 acres (18.2 ha) in 1996 to a low of 1.66 acres (0.67 ha) in 2013—a drop of 96.3%. Using extreme endpoints for measurement may overestimate the losses, and use of trend lines gives estimates of 80-84% loss since 1996 (Saunders et al. 2019; Pleasants 2017).

Overwintering populations are measured by the area of the site. Brower (1977) calculated that each acre contained about 4 million monarchs (9.9 million/ha). The U.S. Fish and Wildlife Service has estimated 8.5 million/acre (21 million/ha) (USFWS 2020).

The World Wildlife Fund Mexico announced February 25, 2021 that the overwintering population occupied 2.1 ha (5.10 acres) during the winter of 2020-2021. This acreage represents a drop of about 26% compared to the previous winter (2.83 ha; 6.99 acres) (McKnight 2021c). The population size considered to be a buffer against extinction is 6 ha (15 acres)(Pleasants 2017).

Milkweed Loss

Milkweed destruction in breeding sites is a major factor in the East (Pleasants and Oberhauser 2013). The milkweed population dropped from 2.2 billion in the Midwest in 1999 to 1.34 billion in 2014, a decline of 40%. Much of the loss was in agricultural fields treated with glyphosate (Roundup®). Because 3.4 times as many eggs are laid on milkweed inside agricultural fields, the decline in reproductive capacity was 71% (Pleasants 2017).

The milkweed decline from 2000 to 2008 was exponential, and the most favorable milkweed has been lost. If half of the milkweed is destroyed, egglaying on that remaining must double up to maintain the population. The more crowded the plant, the less available nutrition (Pleasants 2017). Pleasants et al. (2017) believe that less milkweed has simply made it more difficult for females to find it, and that has led to the monarch population decline.

The milkweed hypothesis fits with data obtained from other butterfly species. Conservation biologists believe that crashing populations of butterflies can best be restored by establishing optimum stands of larval habitat (Thomas et al. 2011).

Photo courtesy Joop de Roode

Monarch caterpillars such as this one feed only on milkweed. Milkweed contains cardenolide steroids that protect them against their protozoan parasite, *O. elektroscirrha*. The steroids also give them a bad taste that deters vertebrate predators.

Failing Fall Migration

Some researchers cite citizen surveys of summer monarch populations to claim that there has not been a loss in summer monarch populations despite the loss of milkweed. Their conclusion is based on surveys of egg and adult monarch populations in the Midwest and other areas (Davis and Dyer 2015; Ries et al. 2015; Inamine et al. 2016).

These surveys have led to the conclusion that monarchs are not making it back to Mexico during the fall migration. Populations may be weaker due to crowding on remaining milkweed plants. Or because of global warming they may start the migration late and do not find the same food supply as before (Agarwal and Inamine 2018; Agarwal 2019).

Migrating monarchs may also encounter poisoned nectar plants. Nectar plants and milkweed throughout the breeding grounds have been poisoned by pesticides. Neonicotinoid insecticides are used in corn and soybean fields throughout the Midwest. Krupke et al. (2017) estimated that 42% of the State of Indiana was contaminated by neonicotinoids. Neonicotinoid contamination goes out at least 100 m (328 ft) beyond fields, and may be poisoning monarch food plants and milkweed through drift and water runoff (Hladik et al. 2018; Mogren and Lundgren 2016).

Saunders et al. (2019) propose that drought encountered by the fall migration in Texas has contributed to smaller overwintering populations. When satellite imagery shows the migratory route is less green, overwintering populations are smaller. Drought and less green landscapes mean fewer nectar plants to feed the migrating butterflies.

Systematic Flaws and Climate

Pleasants et al. (2017) believe that the summer counts have a systematic error. Citizen scientists have not included agricultural areas in their counts. Milkweed and monarchs have vanished from agricultural fields, and populations have shifted into areas where citizen scientists have made their counts. This systematic error leads to an

overestimate of summer populations. Monarch overwintering losses, then, are mostly due to milkweed and habitat losses in the breeding grounds, but there are undoubtedly losses during the fall migration (Flockhart et al. 2015; Saunders et al. 2019).

Climate may also be a factor. Flockhart et al. (2017) found monarch origins at overwintering sites varied from year to year according to regional climate in the breeding grounds, but numbers from all areas have recently shrunk. About 40% of the overwintering population came from the Midwest.

Conservation Efforts Should Continue

The Xerces Society recommends planting native milkweed and nectar sources more than five miles from the California Coast in the Sierra Foothills, Central Valley, and in the Northern part of the state toward Oregon. They recommend California milkweed, *Asclepias californica*; heartleaf milkweed, *A. cordifolia*; and woollypod milkweed, *A. eriocarpa* in Northern California and desert milkweed, *A. erosa* in Southern California. The Xerces Society should be contacted for seed sources (McKnight 2021a).

Milkweed and nectar plants should also be established for the eastern migration. Monarch Watch, Monarch Joint Venture, and other organizations (see Resources) should be contacted for the types of milkweed and nectar plants. Milkweed species most frequently utilized by the eastern monarchs are *A. viridis* and *A. humistrata* that support spring monarchs in the south, and *A. syriaca* that supports summer and fall monarchs in the north (Malcolm and Brower 1989).

If you cannot obtain locally sourced seeds, and you are in the Eastern U.S., it is better to buy commercially available *A. syriaca* seeds than to not plant milkweed at all (see Resources). About 92% of the overwintering Eastern population feeds on *A. syriaca* (Malcolm and Brower 1989).

Although *A. syriaca* is the best adapted to monarchs, many gardeners do not like to plant it because it is aggressive in gardens, spreading from root buds. Growing in raised beds will minimize this, but there are other native milkweeds such as butterfly weed, *A. tuberosa*, or purple milkweed, *A. purpurascens* that may be more appropriate in some gardens (Popkin 2014).

Photo courtesy of the University of Minnesota Monarch Lab

About 92% of eastern monarchs develop on common milkweed, *Asclepias syriaca*.

Nectar Plants

Monarch adults need nectar to survive, and the migrating generation consumes nectar to build fat reserves for overwintering. Some of the nectar can come from milkweed, but other sources are necessary. When planting, choose natives when possible. Fall nectar sources are important, and these include *Ageratina hvanensis, Bacharis neglecta, Helianthus maximiliani, Liatris mucronata, Solidago nemoralis,* and especially *Vebesina virginica* (Brower et al. 2012). Other good nectar plants are *Lupinus, Senecio, Stevia,* and *Bidens* (Brower 1977). Native nectar sources in the spring include violets, *Viola* spp. and serviceberries, *Amelanchier* spp. In the summer, sumacs, *Rhus* spp.; coneflower, *Echinacea purpurea*; and blazing stars, *Liatris* spp. can provide nourishment. And in the fall, asters, *Symphyotricum* spp. and witch hazels, *Hamamelis* spp. can provide nectar (Popkin 2014). Organizations such as Monarch Watch, Wild Ones, and Monarch Joint Venture have online lists of monarch friendly plants (see Resources).

If natives are not available, plants attractive to butterflies include butterfly bush, *Buddleia davidii*; yarrow, *Achillea millefolium*; aster, *Callistephus* sp.; lavender, *Lavendula* sp.; lilac, *Syringa* sp.; Mexican sunflower, *Tithonia diversifolia*; burning bush, *Dictamnus* sp. and others. Much information on butterfly gardens is available on the internet and in classic books on the subject (Xerces 1990; 2016).

Tropical Milkweed

One argument against encouraging residents where migrations are vanishing is that this may lead to increased monarch infections. Some resident populations have shown increased parasites compared to migrating monarchs in the same area. Satterfield et al. (2016) monitored monarch disease frequency in Southern California from 2013 to 2016. They found the infection rate was nine times higher (N=1290, 74% infected) for monarchs breeding on tropical milkweed, *Asclepias curassavica*, in urban gardens compared to monarchs at overwintering sites (N=2135, 8% infected).

As mentioned above, infections are low in overwintering sites because current migrations are hazardous, and the weakest individuals are killed. Attrition occurs both in the west and in the east. The eastern migration is a difficult journey over 2500 miles, and infection rates at overwintering sites in Mexico are about 9.3%, which is similar to the 8% now found on the West Coast. Eastern infection rates at summer breeding grounds are 14.1% (Satterfield et al. 2015; Altizer and deRoode 2015; Bartel et al. 2011).

Photo courtesy Jim Lovett, www.MonarchWatch.org

Resident populations often develop on tropical milkweed, *Asclepias curassavica*.

Medical Milkweed

One explanation for increased infections in residents is that tropical milkweed is a sink for infected individuals. Infected monarchs may be drawn out of the migrations toward tropical milkweed in urban gardens. It has one of the highest steroid contents of any milkweed available (10.6 mg per gram of milkweed dry weight). Tropical milkweed has 20 times the steroid content of *A. syriaca* (0.5 mg/gram) and many other native U.S. milkweeds (Malcolm 1991; Quarles 2016). Cardenolide steroids ingested from milkweed are known to decrease virulence and lessen the biological impact of the monarch parasite (de Roode et al. 2008; Sternberg et al. 2012).

There are resident populations of monarchs in warm areas such as Florida, Texas, Arizona and California. Some of these are heavily infected, but there is no evidence that these populations are declining (Satterfield et al. 2015; Glassberg 2014; Majewska et al. 2019). Infected monarchs feeding on tropical milkweed live longer than those feeding on the native *A. incarnata* (de Roode et al. 2008). Though spores can accumulate when milkweed is limited, spores on milkweed lose 80% of their viability over the course of a year (Leong et al. 1997a; de Roode et al. 2008). Planting new milkweed each year should reduce the accumulation of spores in the resident populations.

If resident populations grow large, some of the resident monarchs may resume the migrations. Both monarchs and tropical milkweed are natives of Mexico, and monarchs evolved with the ancestral tropical milkweed plant. Overpopulation likely led to the start of migrations two million years ago. Monarchs were so successful populations outgrew the local milkweed supply, and the monarchs went north looking for additional sources (Rapini et al. 2007; Zahn et al. 2014).

Reduce Pesticides

We can help the monarchs by reducing pesticide applications in gardens and in agricultural situations. We should be sure that nursery plants have not been treated with systemic pesticides. IPM methods can be used to control pests. For example, crop rotation, soil treatment with nematodes, and adult beetle baits can be used to control the western corn rootworm, *Diabrotica virgifera virgifera* (Quarles 2017).

Concerted Social Effort

Monarch restoration is the goal of several environmental groups. Bringing Back the Monarchs is a project of Monarch Watch. Monarch Watch encourages home gardeners to plant milkweed and nectar plants, and in return will register the garden as a Monarch Way Station (see Resources). Recommendations include an area of at least 100 ft^2, six hours of sun a day, low clay soils with good drainage, at least ten milkweed plants, preferably from different species, and at least four species of nectar plants. Nearly 13,000 Monarch Way Stations have been registered. Other organizations with pollinator and butterfly garden certification programs include the Xerces Society, Monarch Joint Venture, the North American Butterfly Association, and Wild Ones (see Resources) (Popkin 2014).

Network of Garden Clubs

There are millions of backyard gardeners in the U.S. and 40 million acres (16.2 ha) of lawns. Local action such as planting bee and butterfly gardens can have a national impact. A network of Garden Clubs with similar plans and policies could convert local conservation efforts into a national program (Quarles 2019).

Monarchs Along the Roadside

There are 10 million acres (4 million ha) of roadsides in the U.S. Conversion of these from herbicide management to integrated vegetation management (IVM) and native plants could bring back needed habitat for bees, birds, and monarchs (Quarles 2003). For instance, conversion from herbicide management to IVM and native plants increased the number of roadside milkweed sites in Iowa by about 64% (Hartzler 2010).

Photo courtesy Tony Morosco

Monarchs are fond of sunflowers, *Helianthus* spp.

Endangered Species Protection

The U.S. FWS (US Fish and Wildlife Service) received a petition in 2014 to list *Danaus plexippus* as an endangered species. On December 15, 2020 the Trump administration denied a listing as endangered, despite finding that monarchs meet the criteria. The listing assigned is "warranted but not precluded." This category means that monarchs will be evaluated each year for endangered species protection. U.S. FWS said that the monarchs were not listed because 161 other species have a higher priority. Perhaps the Biden administration will list monarchs as endangered (USFWS 2020).

Mitigation of Climate Change

Efforts should not be limited to planting milkweed and nectar resources and reducing pesticide applications. Drought and forest fires linked to climate change may be factors in the western migratory collapse. We should encourage increased use of regenerative agriculture, changes of diet to include more vegetables, increased renewable energy, and decreased reliance on fossil fuels to mitigate effects of climate change (Quarles 2007; Quarles 2018).

Conclusion

Monarchs have been migrating for two million years, and they survived the worldwide destruction that killed the dinosaurs 65 million years ago. We should not let such a beautiful work of nature go extinct. In the short term we can help them by providing milkweed, nectar plants and other resources they need. In the long run, we must reduce emissions of greenhouse gases. Monarchs will be encouraged by mitigation of drought, forest fires, and the extreme weather effects caused by global warming. By making things better for the monarchs, we can also make things better for ourselves.

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Resources

Organizations

Bio-Integral Resource Center (BIRC), PO Box 7414, Berkeley, CA 94707; 510-524-2567; www.birc.org

California Native Plant Society, 2707 K St., Suite 1, Sacramento, CA 95816; 916-447-2677; www.cnps.org

Golden Gate Audubon Society, 2530 San Pablo Ave., Suite G, Berkeley, CA 94702; 510-843-2222; www.goldengateaudubon.org

Monarch Joint Venture, 135 Skok Hall, 2003 Upper Buford Cir., St. Paul, MN 55108; 612-624-8706; www.monarchjointventure.org

Monarch Watch, University of Kansas, 1200 Sunnyside Ave., Lawrence, KS 66045; 785-864-4441; www.monarchwatch.org

North America Butterfly Association, 4 Delaware Rd., Morristown, NJ 07960; www.naba.org

Sierra Club, 85 2nd St., Suite No. 2, San Francisco, CA 94105; 415-977-5500; www.sierraclub.org

Wild Ones, PO Box 1274, Appleton, WI 54912; 920-730-3986; www.wildones.org

Xerces Society, 628 NE Broadway, Suite 200, Portland, OR 97232; 855-232-6639; www.xerces.org

Seeds and Plants

Applewood Seed, 5380 Vivian St., Arvada, CO 80002; 303-431-7333; www.applewoodseed.com

Educational Science, PO Box 747, League City, TX 77574; 281-554-9783; www.educationalscience.com

Hedgerow Farms, Winters, CA; 530-662-6847; www.hedgerowfarms.com

Ion Exchange, 1878 Old Mission Dr., Harpers Ferry, IA 52146; 563-535-7231; www.ionxchange.com

Pacific Coast Seed, Livermore, CA; 925-373 4417; www.pcseed.com

Prairie Moon Nursery, 32115 Prairie Lane, Winona, MN 55987; 800-585-2788; www.prairiemoon.com

Roundstone Native Seed, 9764 Raider Hollow Rd., Upton, KY 42784; 888-531-2353; www.roundstoneseed.com

S&S Seeds, Carpinteria, CA; 805-684-0436; www.ssseeds.com

Sierra Seed Supply, Greenville, CA; 530-284-7926; www.sierraseedsupply.com

ESA 2019 Meeting Highlights

By Joel Grossman

The 2020 ESA Conference was cancelled because of the coronavirus pandemic. These Conference Highlights were selected from among 2,885 presentations at the Nov. 17-20, 2019 Entomological Society of America (ESA) Annual Meeting in St. Louis, Missouri. The next ESA annual meeting is October 31 to November 3, 2021 in Denver, CO. For more information contact the ESA (3 Park Place, Suite 307, Annapolis, MD 21401; 301/731-4535; http://www.entsoc.org).

Visually Interesting Small Gardens

"Enthusiasm for pollinator gardening has ignited interest in native plants that can support biodiversity," including milkweeds supporting monarch butterflies and pollinators, said Helena Cybriwsky (Univ Kentucky, S225 Ag Sci North, Lexington, KY 40546; hecy222@uky.edu). "Straight native species, however, aren't the only options. Native plant cultivars, so-called 'nativars', are gaining attention too. Such plants, natural variants of native species selected for attributes such as plant stature, leaf color, and floral display open the door to vast ornamental potential and new introductions that provide breeders, growers and consumers the best attributes of natives and ornamentals."

"Native plant cultivars, nevertheless, are not without controversy, and consumers want to know 'do they provide the same conservation benefits as straight species'?" said Cybriwsky. "Some environmental organizations decry 'nativars', arguing that their mass production, promotion, and use could diminish genetic diversity in urban landscapes."

An ongoing study is comparing pollinator and monarch butterfly responses to 'nativar' and 'straight species' of milkweed. "Cultivars such as *Asclepias incarnata* 'Soulmate', that have been selected for bloom display, attracted a larger number of pollinators compared to the straight species," said Cybriwsky. In cage studies, monarch caterpillars developed well on varied milkweed cultivars; defensive characteristics such as trichome density and latex made no difference. The bottom line being that "cultivars selected for floral display may be more attractive to pollinators" and "are as suitable as 'straight species' for monarchs." In other words, visually interesting small gardens and conservation values need not be mutually exclusive.

Naturescaping Vineyards

"Beauty with Benefits" is a Pacific Northwest (PNW) vineyard program utilizing native plants to conserve butterflies, endangered species, pollinators and natural enemies, said David James (Washington State Univ, 24106 North Bunn Rd, Prosser, WA 99350; david_james@wsu.edu). "At least 50-75 species of butterflies in the PNW are considered suitable for conservation within low-pesticide input cropping systems that incorporate native plant enhancement."

"A number of native plant species have great dual potential as attractors and sustainers of natural enemy populations and as larval hosts for butterfly species," said James. Big sagebrush, *Artemisia tridentata*, rich in predators, parasitoids and pollinators whether in or out of bloom, "characterizes and dominates the sagebrush steppe, the largest temperate semi-desert ecosystem in North America." In 2011-2015, 120 native wildflower species were sampled for arthropods in remnants of the native shrub-steppe ecosystem (hot, dry summers; cold winters) cleared for wine grape vineyards east of Washington state's Cascade Mountains. Unlike conventional cover crops, these native plants are pre-adapted to little irrigation.

Over a 5-8 year period, four habitat-enhanced vineyards (30-60 native plant spp. under 50 m (164 ft) from vineyards) were compared to four conventional vineyards (herbicides sprayed between rows; <10 native plant spp.). Habitat-enhanced vineyards had significantly more natural enemies and significantly fewer pests; as well as 300% more butterfly species (30) than conventional vineyards (10); also, pollinators lingered longer.

Native desert buckwheats, *Eriogonum* spp, were amazingly durable groundcovers in habitat-enhanced vineyards: "You can drive tractors over them and they comeback," said James. Besides pollinators, wild buckwheats host beautiful blue, copper and hairstreak butterflies; as well as green lacewings, lady beetles, big-eyed bugs, pirate bugs, predatory thrips, syrphid flies, parasitoid wasps and other natural enemies. Native PNW stinging nettles, *Urtica dioica*, also harbor a huge early-summer array of native pollinators and natural enemies (e.g. predatory pirate bugs, carnivorous flies, parasitic wasps), as well as larger Nymphalidae butterflies.

The list of useful native plants is long, and includes yarrow, coyote mint, showy fleabane, Oregon sunshine and parsnip. The top 10 native butterfly plants include willows, lupines and showy milkweeds. Besides monarch butterflies, *Danaus plexippus*, native milkweeds such as *Asclepias speciosa* and *A. fascicularis* host an array of native pollinators and beneficial insects providing pest suppression. Monarch butterfly springtime colonization of vineyards with narrow-leaved milkweed, *A. fascicularis*, was so great from both within-row and refugia plantings that James began tagging and studying the butterflies. Summer caterpillars provided evidence of monarch breeding, and some vineyards were officially designated Monarch Waystations. Small boutique vineyards

are interested in replicating this low-input sustainable program for its multiple benefits, even as far away as Ashland, Oregon, where monarch butterfly interest is high. Similar programs are happening in New Zealand and Europe.

Golf Biocontrol Wildflowers

The USA has 16,000 golf courses, each about 100 acres (40.5 ha), with 40-70% of that acreage out-of-play spaces such as roughs, which when sown with wildflowers can be transformed into beneficial insect habitats for biological control of turfgrass pests otherwise sprayed with pesticides, said Adam Dale (Univ Florida, 1881 Natural Area Dr, Gainesville, FL 32611; agdale@ufl.edu). "Golf courses around the world are converting out-of-play areas to naturalized or flowering habitats, but few do so using evidence that maximizes their conservation benefit." Benefits in the urban USA could be immense, as golf courses are "among the largest, most ubiquitous highly maintained urban green spaces in the USA."

To provide "evidence" and "develop guidelines for tailoring insect conservation practices" for urban green spaces, Dale setup three 5,000 ft^2 (465 m^2) plots, some rich in wildflowers (9 spp) and others with low wildflower diversity (5 spp), at multiple Florida golf course locations.

"Our results indicate that golf courses can provide valuable resources for beneficial insects, both flying and ground-dwelling, in urban areas," said Dale. Monitoring revealed 13 genera of native bees, with more pollinator diversity with more wildflower species. Natural enemy abundance also increased. For example, red and black mason wasps were observed flying in and out of wildflower areas with caterpillar prey to provision their nests. Biocontrol was measured as a 50% reduction in caterpillars from sentinel prey stations. Golf course chemical use was not measured, but the results convinced golf course superintendents to increase beneficial insect habitat to reduce turfgrass pests.

Quercetin Rescues California Almond Bees

Almost 100% of California almond growers spray tank mixtures of insecticides such as chlorantraniliprole (Altacor®) and fungicides such as propiconazole (Tilt®) during bloom, and "beekeepers providing pollination services have sporadically reported high mortality of workers and problems in queens in weeks after almond pollination," said Ling-Hsiu Liao (Univ Illinois-Champaign, 320 Morrill Hall, Urbana, IL 61801; liao19@illinois.edu). After spraying, almond pollen has 400 ppb of chlorantraniliprole and 900 ppb of propiconazole. Worker bees feed honey and pollen plus pesticide residues to developing larvae, along with natural plant chemicals (botanicals; phytochemicals) in whatever pollens and nectars are part of the diet.

Almond pollen laden with realistic field-levels of insecticide and fungicide residues altered honey bee nursing behavior, with fewer visits to tend larvae; normally larvae are fed royal jelly, which is highly antimicrobial. "Consuming pollen contaminated with both propiconazole and chlorantraniliprole reduced the duration of queen cell visits and delivery of royal jelly by nurse bees," said Liao.

"Developmental impairments in larvae reared by nurses consuming pesticide-contaminated pollen suggest that pesticide consumption by nurse bees alters their behavior or physiology to the detriment of queen quality," said Liao. However, certain phytochemicals, such as quercetin, a common honey bee dietary component from pollen and nectar foraging, act as pesticide antidotes. Adding quercetin to lab diets acted as an antidote or "rescue," ameliorating pesticide-related behavioral impairments.

Caffeine Cures Infected Honey Bees

Honey bees foraging on *Citrus* spp and *Caffea* spp regularly consume 0.5-98 ppm of caffeine, "which improves longevity of honey bees infected with *Nosema ceranae*," said Edward Hsieh (Univ Illinois-Champaign, 320 Morrill Hall, Urbana, IL 61801; emhsieh2@illinois.edu). "Caffeine consumption at naturally encountered concentrations increases survival of infected bees." However, in the absence of infection, higher late season caffeine concentrations can be detrimental to honey bees. Thus, foraging bees may be "self-medicating" by seeking out sources with higher caffeine levels when infected.

This suggests that "caffeine supplementation can be a practical method of treating viral infection" in honey bees, said Hsieh. In caffeine dose experiments on honey bees infected with Israeli Acute Paralysis Virus (IAPV): 25 ppm of caffeine made no difference; but 100 ppm caffeine helped bees cope with and reduce IAPV. Research is underway to determine the mechanism by which caffeine helps bees fight viral and other infections.

Citrus Psyllid Exclusion Mesh

A non-chemical solution to Asian citrus psyllid, *Diaphorina citri*, vectoring *Candidatus Liberibacter asiaticus* (CLas), the putative causal agent of huanglongbing (HLB), is: "Grow citrus under a protective screen (CUPS)," said Timothy Ebert (Univ Florida, 700 Experiment Station Rd, Lake Alfred, FL 33850; tebert@ufl.edu). The key questions are: "What is the size of the psyllid and the size of holes in the screen? What is the penetration risk of specific mesh sizes?"

Mesh screens should exclude the smallest psyllids, allow sufficient air flow and be reasonably priced. Holes that are too small may provide excellent exclusion, but will be more costly and impede

air flow. "The width of the insect may be more important than height in determining whether the psyllid can pass through the screen," said Ebert. "Mesh sizes of 40 or higher are safe for construction of CUPS. Lower mesh sizes will allow some psyllids to pass through the screen."

Plant Oils Tame Resistant Bed Bugs

During decades of pesticide exposure, bed bugs, *Cimex lectularius*, developed resistance to synthetic insecticides via over-expression of detoxification enzymes, making an IPM approach with mattress encasements and botanicals necessary, said Sudip Gaire (Purdue Univ, 901 W State St, West Lafayette, IN 47907; sgaire@purdue.edu). An advantage of plant oils is that they are EPA-exempt and relatively safe for humans and the environment. Thyme, oregano, clove, geranium and coriander oils were compared with deltamethrin, a pyrethroid insecticide, and EcoRaider®, an essential oil-based insecticide. Two bed bug strains were tested: 1) Harlan, a susceptible strain raised in the laboratory for over 40 years without pesticide exposure; 2) Knoxville, a field-collected strain highly resistant to deltamethrin.

Thyme, oregano, clove, geranium and coriander oils all killed deltamethrin-resistant Knoxville bed bugs; i.e. no cross-resistance. All five plant-based essential oils also synergized deltamethrin, increasing its toxicity against Knoxville bed bugs. Combining deltamethrin with thyme and oregano oils gave over 90% control of deltamethrin-resistant bed bugs in 24 hours. Plant essential oils inhibit bed bug detoxification enzymes that would otherwise neutralize insecticides such as deltamethrin. EcoRaider, with its essential oil blend, may work in the same manner.

Pepper Weevil Alternatives

A pest of Central America origin, pepper weevil, *Anthonomus eugenii*, is "one of the most economically damaging arthropod pests of pepper crops" in North America, significantly impacting Ontario, Canada's $419 million greenhouse pepper crop, said Roselyne Labbe (Agric Agri-Food Canada, 2585 County Rd 20, Harrow, ON N0R 1G0, Canada; roselyne.labbe@canada.ca). Lab bioassays of 15 conventional, reduced-risk and microbial insecticides found 8 providing over 60% adult pepper weevil mortality: 1) spinetoram 25%; 2) *Beauveria bassiana* strain GHA; 3) *Beauveria bassiana* strain PPR15339; 4) cyantraniliprole 10.2%; 5) thiamethoxam 25%; 6) *Beauveria bassiana* strain ANT-03; 7) mineral oil 98%; 8) *Metarhizium anisopliae* strain F52.

Kaolin clay 95%, which provided only 40% control in lab bioassays, was the best tested compound in 3-week (3 treatments/week) greenhouse cage trials; and was as effective as the neonic thiamethoxam (positive control). Mineral oil and *Beauveria bassiana* strain ANT-03 also effectively suppressed pepper weevil populations in greenhouse trials.

"Plants onto which kaolin clay, mineral oil or *Bacillus thuringiensis* strain SDS-502 were applied also had significantly lower percentage fruit abortion," said Labbe. "Future research will investigate the compatibility of these products with arthropod biological control agents used to target either the pepper weevil or other pests commonly associated with pepper crops."

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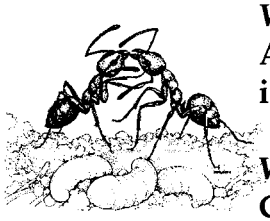

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