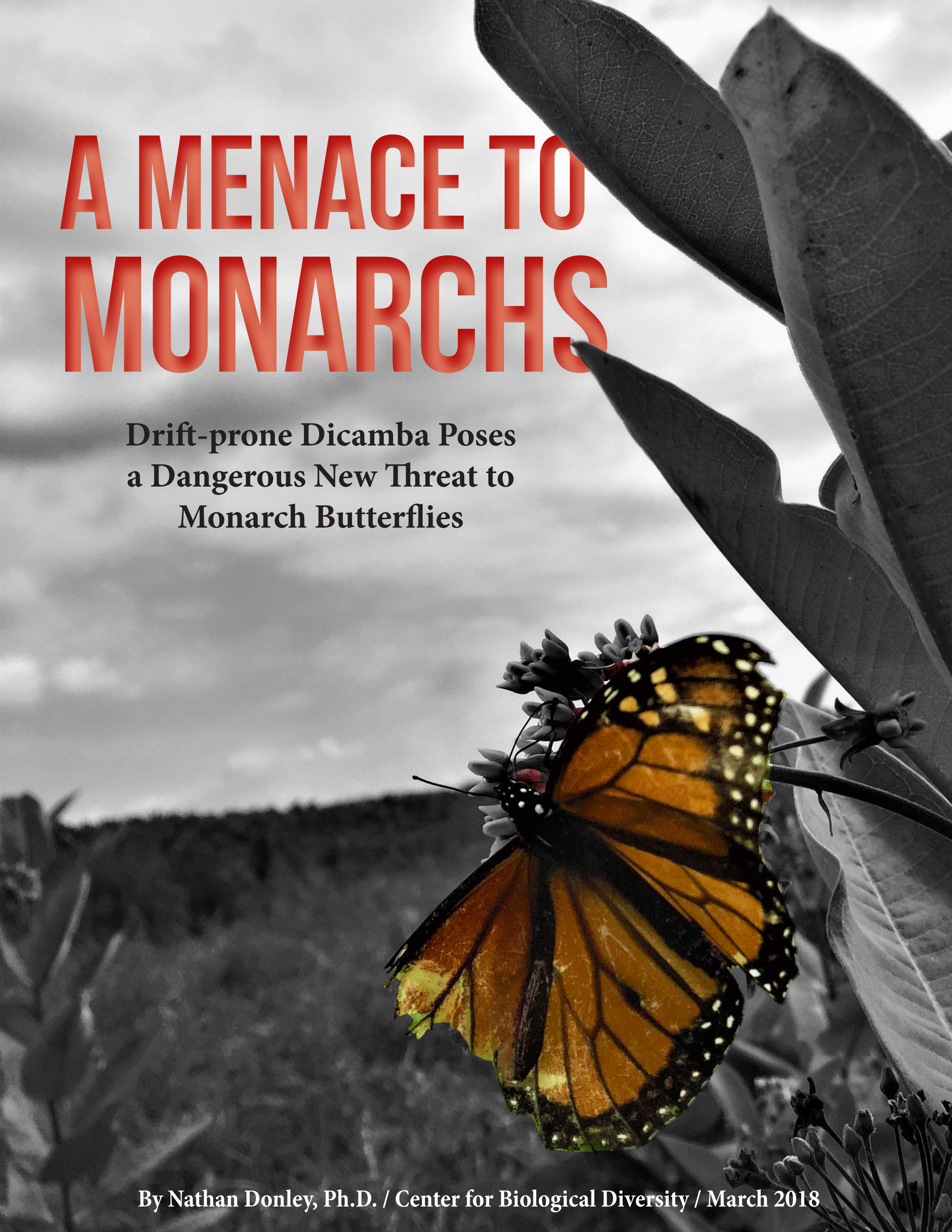
# A MENACE TO MONARCHS

## Drift-prone Dicamba Poses a Dangerous New Threat to Monarch Butterflies



By Nathan Donley, Ph.D. / Center for Biological Diversity / March 2018

## Executive Summary

Already imperiled by escalating pesticide use and other human activities, the monarch butterfly's epic annual migration across North America now faces a dangerous new threat.

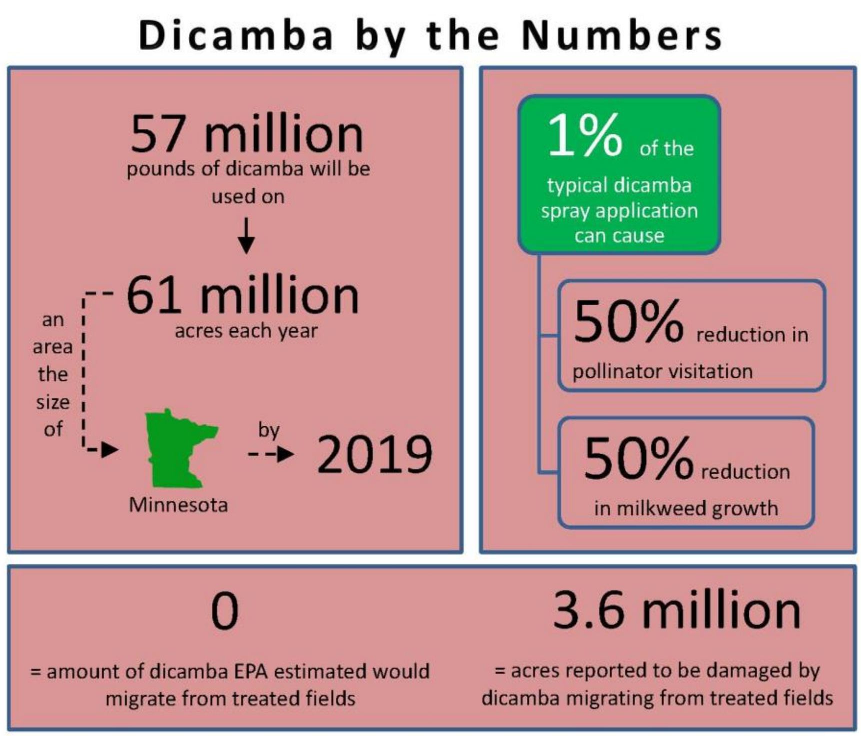
For this analysis we examined monarch habitat and projected usage rates for dicamba, a drift-prone, weed-killing pesticide applied to genetically engineered cotton and soybeans that's extremely harmful to native plants and milkweed, the only plant that feeds monarch offspring. We were particularly concerned with examining the effects of increased use of dicamba in the coming years, which is projected to reach about 57 million pounds annually.

**Our key finding: By 2019 more than 60 million acres of the monarch's migratory habitat across the heart of the United States will be doused with dicamba. The projected increase in dicamba use across an area larger than the state of Minnesota poses a quickly escalating new threat to monarch populations that have already fallen by 80 percent in the past two decades.**

Other key findings include:

- **Accelerating harm:** Using reported drift damage from dicamba in 2017, we project that an additional 9 million acres of monarch habitat could be threatened by drift of the pesticide.
- **Deadly timing:** The timing and geographical distribution of dicamba use coincides precisely with the presence of monarch eggs and caterpillars on milkweed.
- **Double trouble:** Dicamba degrades monarch habitat both by harming flowering plants that provide nectar for adults as they travel south for the winter and by harming milkweed that, as the only food source of the monarch caterpillar, provides an essential resource for reproduction.
- **Greater menace to milkweed:** Research has shown that just 1 percent of the minimum dicamba application rate is sufficient to reduce the size of milkweed by 50 percent, indicating it may have a greater impact on milkweed growth than glyphosate.

The decline in monarchs in recent decades has coincided with the surge in crops genetically altered to tolerate glyphosate. The overuse of glyphosate triggered the decline of milkweed and the proliferation of glyphosate-resistant weeds across millions of acres in the Midwest.




In response, farmers have turned to dicamba to combat glyphosate-resistant weeds, compounding the danger and damage to monarch habitat.

The Environmental Protection Agency in 2016 approved new dicamba products for use on genetically engineered cotton and soybeans. In 2017 there were reports of at least 3.6 million acres of off-target, herbicide-induced damage to agricultural crops and an unknown amount of damage to native plants and habitats, including forests. More troubling still, the EPA's 2016 approval for expanded use of dicamba, including nearly 500 pages of ecological analyses, glaringly omitted any mention or examination of the threat to monarchs.

**Recommendations:** At the permissible levels approved by the EPA, dicamba will have serious and far-reaching consequences for monarch butterflies, their habitat and the ecological health of vast areas of the country. **The EPA registration of dicamba on genetically engineered cotton and soybeans expires in late 2018, and the agency should not renew its approval.**

# A Menace to Monarchs

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## The Spectacular Journey of the Monarch Butterfly[1]

Each year the orange, black and white monarch butterfly embarks on one of the longest and most spectacular insect migrations on Earth. Beginning in fall adult monarchs east of the Rocky Mountains make their way from southern Canada and the North American Midwest all the way down to south-central Mexico. During the fall migration a single adult monarch can travel thousands of miles to make it to the Mexican oyamel fir forests in the Sierra Madre Mountains, which provide the precise microclimate necessary for the monarch's survival through winter. A much smaller population west of the Rockies overwinters along the coast of California.

Once monarchs have successfully overwintered they begin their epic journey north in early spring, which must carefully coincide with the emergence of milkweed – the only plant that the monarch butterfly will lay its eggs on. As the adult butterflies move north, the females lay their eggs on milkweed plants that have emerged from the ground in northern Mexico and the southern United States. The adults die and the next generation continues the movement north to seek out fresh milkweed. After several generations, the process culminates at the end of summer with the birth of the "super generation" that will migrate south and survive until the following spring to begin the entire cycle anew. The monarch's continued survival depends on its ability to overwinter in Mexico, the ability of multiple generations to have access to milkweed as the migration continues north during the spring and summer, and the ability of adults in the super generation to survive a southern migration of thousands of miles in the fall.

Monarch butterfly on showy milkweed. Photo by Tom Koerner/USFWS. (CC BY 2.0)

In recent decades the continued migration of these amazing creatures has been greatly threatened. Populations have dropped by more than 80 percent since the mid-1990s, and research from the U.S. Geological Survey indicates that there is an 11 percent to 57 percent chance that monarch numbers will plummet so low in the next 20 years that loss of the eastern migratory population would be inevitable.[2] The monarch faces multiple threats, including habitat loss due to development and urbanization, loss of overwintering habitat in Mexico, disease, insecticide use for agriculture and mosquito and grasshopper control, and global climate change.[3] The widespread use of herbicides in modern agriculture, particularly those used in conjunction with genetically engineered crops, has also been widely implicated as a major factor in the population decline by reducing milkweed habitat and nectar resources on an enormous scale throughout the migration route.[3] This packs a one-two punch by not only limiting reproductive success as monarchs move north, but also reducing food resources on the long southern journey down to Mexico.

## The Rise of Roundup and the Pesticide Treadmill

In 1996 Monsanto commercialized its first genetically engineered crop, the Roundup Ready soybean, which was designed to survive being sprayed with glyphosate — the active ingredient in its flagship product, Roundup. Roundup Ready (glyphosate-resistant) soybeans became popular with farmers who sought to combat weeds by spraying their entire fields with Roundup throughout the growing season. This popularity led to the development and commercialization of multiple other Roundup Ready commodity crops like corn, cotton, canola, alfalfa and sugar beets.[4] Ultimately this achieved two things: 1) it made farmers who bought into the technology more likely to use glyphosate as their primary weed-control method; and 2) it allowed farmers to use the herbicide more frequently, and at different times of the growing season, than the herbicide had been used in the past. These changes, when implemented on many of the most widely grown U.S. crops, resulted in the skyrocketing use of glyphosate across millions of acres each year. Between 1996, the year Roundup Ready soybeans were introduced, and 2013, total glyphosate use on just corn and soybeans rose from around 10 million to 200 million pounds per year, a 20-fold increase.[5]

With nearly 300 million pounds of glyphosate used in the U.S. agricultural sector annually,[6] it's far and away the nation's most widely used pesticide. For some perspective, the nation's second most widely used pesticide is atrazine, at around 70 million pounds per year.[7] This unprecedented use of a chemical herbicide, concentrated largely in the monarch habitat of the Midwest and used throughout key times in the monarch and milkweed lifecycles, has made it a major factor in the decades-long decline in the migrating butterfly.[3] Unlike some other herbicides, glyphosate is particularly effective at killing milkweed, and the increasing use of glyphosate correlates with plummeting milkweed and monarch numbers over the past two decades.[8]

However, over-reliance on this single herbicide has directly led to the development of glyphosate-resistant weeds, commonly known as "superweeds."[9] No species of milkweed have currently developed resistance to glyphosate, but other weeds like glyphosate-resistant pigweed and waterhemp are very common throughout many regions in the United States.[10] Glyphosate-resistant weeds were essentially nonexistent before Roundup Ready crops were commercialized,[11] but now there are superweeds on 100 million acres of farmland in 36 different U.S. states that can't be killed by glyphosate.[12] Farmers are scrambling to find a way to manage these superweeds in order to prevent yield loss from weed overgrowth.

Instead of promoting sustainable pest-control strategies that would have long-term efficacy and reduce our reliance on harmful chemicals, the USDA and EPA have been active participants in the agrochemical industry's efforts to keep farmers on the pesticide treadmill by hastily approving new GE crops that withstand multiple herbicides and the chemical cocktails that accompany them. As a result the current direction in agriculture is to replace Roundup Ready crops with new crops that have resistance to multiple chemicals. The rationale for this decision is that if glyphosate is sprayed together with other herbicides on crops, then weeds that are not killed by glyphosate will be killed by the other herbicides in the mix. However, many of the herbicides being used to kill glyphosate resistant weeds are themselves ineffective against other weeds that have, over time, developed resistance to them.[13] So as weeds begin to develop multiple chemical resistances, which is already occurring,[14] chemical companies have been developing crops that can be sprayed with three or four pesticides as the next temporary fix (see the below section - **Pesticide Treadmill: From a Jog to a Sprint**).

Two of the newly designed "crop systems" that are widely expected to replace Roundup Ready commodity crops in the coming years are Dow's Enlist™ crops (2,4-D and glyphosate resistant) and Monsanto's Xtend™ crops (dicamba and glyphosate resistant). The recent approval of new dicamba use on Xtend soybeans and cotton will be the focus of this report.

## Expanding Use of Dicamba in Space, Time and Mass

*Space*

Before the 2016 approval of new dicamba products on GE cotton and soybeans, dicamba had only been used on a very small fraction of the cotton and soybean acreage in the United States.[15] Monsanto estimates that 25 million acres of Xtend cotton and soybeans were planted in 2017, the first year that dicamba was approved for use on the crops.[16] This area of land will likely substantially increase as more farmers are projected to switch to Xtend crops in the coming years. Monsanto projects that 55 million acres, more than 60 percent of all soybean acreage in the United States, will be planted with Xtend soybeans by 2019.[17] In addition, at least 6 million acres of Xtend cotton, half of all cotton acreage, are expected to be planted by that time (see methods). This comes to 61 million acres of U.S. farmland that are expected to be planted with Xtend crops and likely to be sprayed with dicamba. This means that a land area the size of Minnesota will be newly exposed to dicamba by 2019.

In 2017 dicamba sprayed on the 25 million of acres of Xtend cotton and soybeans resulted in a reported 3.6 million acres of damaged crops due to drift and volatilization.[18] Extrapolating the off-target damage to the 61 million acres of Xtend cotton and soybeans to be planted by 2019, an additional 8.8 million acres are expected to be damaged by off target movement.[19] This is likely an underestimate, as crop damage is extremely underreported and off-target damage to non-agricultural plants was not taken into account.

*Time*

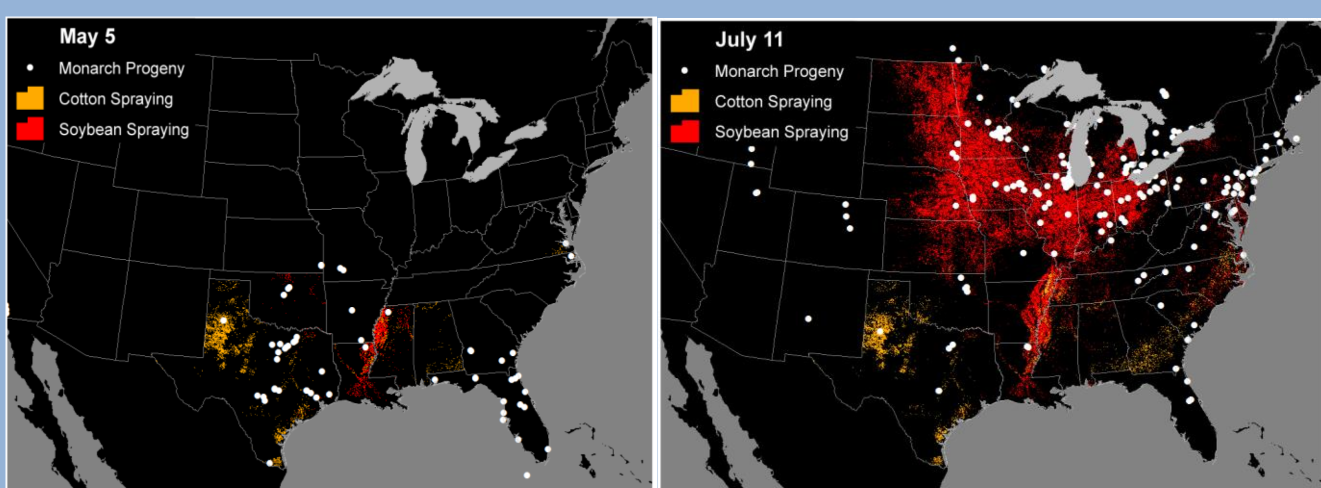
Until very recently dicamba use has been restricted to early spring, before the planted crop has emerged from the ground or immediately before harvesting in the fall. On a few crops, like corn and sorghum, dicamba use was allowed after the crop had emerged from the ground, but only until it reached 8 inches in height.[20] These restrictions had limited dicamba use to early- to mid-spring and in fall and greatly limited exposure during the remainder of spring and summer,

## Nationwide Mapping of Dicamba Use and Monarch Progeny

To gauge the significance of massively increased dicamba use on the imperiled migratory monarch population, we mapped approved dicamba-use sites with reported monarch egg and caterpillar sighting locations (See interactive map). Detailed methodology on how the map was constructed is provided in methods.

Beginning in March, April and May, monarchs begin to lay eggs as they move north from Mexico. The presence of monarch eggs and caterpillars are concentrated in the southern half of the United States at the same time that dicamba is projected to be used on cotton and soybeans in those southern states. From the end of May to July, monarch eggs and caterpillars are widely prevalent across the northern Midwest and East at the same time that dicamba will be sprayed on soybean acreage in those states.

This indicates that dicamba will be used across the South, East and Midwest at the precise time of year when milkweed is absolutely essential to perpetuate the northern migration of monarchs.




Click here for an interactive map

when many native plants were growing and reproducing.

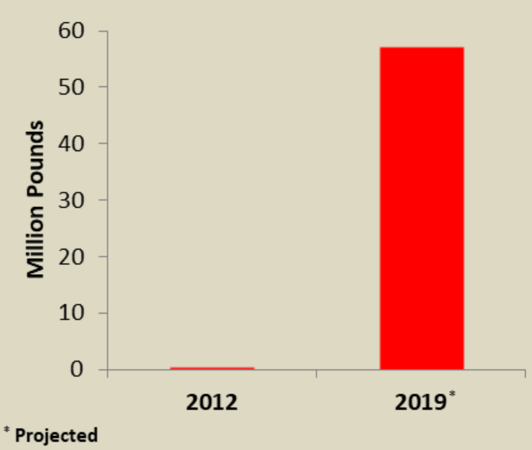
Xtend crops were genetically altered to tolerate dicamba specifically so the pesticide can be sprayed on soybeans and cotton after they have emerged from the ground and throughout much of the growing season. For soybeans this can happen anytime until the plant reaches R1 phase[21] (first flower, which generally happens from late June through August). With cotton, this can happen anytime up to seven days pre-harvest[21] (which generally happens from September to November). This will be the first time this pesticide will legally be used in late spring and summer, which is the time of year that many plants provide essential habitat and forage for a wide array of animals.

*Mass*

Due to its extreme volatility, dicamba has historically been tightly restricted in how and when it could be applied, thus keeping the total amount applied to cotton and soybeans each year relatively low (around 0.6 million pounds in 2012).[22] However, the total amount of dicamba used on farmland each year is set to increase dramatically in the United States as a result of the easing of these restrictions by the EPA.[23] As part of the approval process for Xtend soybeans and cotton, Monsanto estimated that dicamba use would increase by 25.1 million pounds per year at the time of peak crop adoption.[24] But this is certainly an underestimate, because the company assumed use rates that are the absolute minimum or *below* the minimum required use rate on the pesticide label.[25] Therefore, in some cases farmers would actually be using the pesticide against the instructions on the pesticide label if they were to apply dicamba at the low, single-use rates estimated by Monsanto.[25] Monsanto also underestimated the Xtend crop adoption rates that have been projected for 2018 and beyond.[26]

When estimating future dicamba use with rates that are more likely to be used in the field, taking into account increased planting of cotton and soybeans in recent years, and using a crop-adoption rate that more closely aligns with current projections, we estimate the increase in annual dicamba use to be 57.2 million pounds by 2019 (see methods). With only 597,000 pounds of dicamba used on non-Xtend cotton and soybeans in 2012,[22] the 95-fold increase in use of this pesticide will be directly attributable to genetically engineered, dicamba resistant crops (Fig. 1). This is more than double what Monsanto told the USDA would be used upon approval of these GE crops.

**Figure 1: Amount of Dicamba Used Annually on Cotton and Soybeans**




This expanding use of dicamba in the next few years will not displace glyphosate use, as Xtend crops are designed so that both pesticides can be used together and there are many weeds on which glyphosate is effective, but dicamba is not. So whereas glyphosate use on soybeans and cotton may plateau, it is not expected to decrease appreciably.

## The Poison That Won't Stay Put

Dicamba is notorious for its ability to drift in the air as a liquid following spraying and its ability to turn from a liquid to a gas and travel in the atmosphere (volatilize).[27] This makes spray drift and volatilization the primary sources of off-target exposure to dicamba, although contamination of surface- and groundwater via runoff is also a concern.[28]

The approval of new dicamba formulations on GE cotton and soybeans was predicated on these products being purportedly less prone to volatilization than older products, as demonstrated by unpublished research that Monsanto submitted to the EPA but refused to allow independent scientists to confirm.[29] In fact this was a major factor in the EPA's decision not only to approve these products, but also to reduce the required field buffer from omnidirectional to

*"…the EPA expects that exposure will remain confined to the dicamba (DGA) treated field."*

- EPA, in announcing the 2016 approval of new dicamba products.[33] The following year a reported 3.6 million acres of crops and an untold number of native plants were damaged from dicamba migrating from treated fields.

only downwind.[30] However, recent studies from independent researchers have found little difference in volatility between older and newer formulations. Research out of the Universities of Arkansas and Missouri show that newer dicamba formulations not only result in volatility, but can do so at levels similar to older formulations, which are known to be highly volatile.[31]

In approving the new dicamba use on Xtend cotton and soybeans, the EPA put in place label restrictions meant to reduce spray drift of dicamba but not volatilization.[32] The EPA was so confident in these label restrictions, that the agency assumed that absolutely no offsite movement would occur when they looked at toxicity to plants and animals. So the agency's conclusion was that if the plant or animal did not reside or forage in the actual soybean or cotton field that was sprayed, then it would not be exposed to dicamba at a level that could cause any harm.[33]

The 2017 growing season — the first for which new dicamba products had been approved for use on Xtend crops — proved both Monsanto and the EPA wrong, and was a stark reminder of just how faulty this new pesticide approval was. Extensive damage to non-Xtend soybeans, other crops and native plants and trees from dicamba use on nearby crops was reported on more than 3.6 million acres of farmland in 25 states[34] and the damage to non-Xtend soybeans accounted for 4 percent of the total U.S. soybean crop in 2017.[35] The problem was so severe that at least eight states either banned or placed greater restrictions on dicamba use for the remainder of the 2017 growing season,[36] and many have taken proactive steps for the 2018 growing season. So, contrary to the EPA's assumptions, the evidence indicates dicamba frequently travelled away from the areas where it was applied and did so at concentrations that were harmful to other plants and on a scale that affected millions of acres.

## Food and Sex – Dicamba's Impact on Monarch Habitat

### *Nectar Resources*

This scale of off-target movement of dicamba has the potential to degrade monarch habitat on a level that has not been seen since glyphosate use began to explode 20 years ago. Plants that exist in the margins between agricultural fields are some of the only sources of biodiversity in the sea of crop monocultures that extend across much of the Midwest. This plant diversity is absolutely necessary to sustain animal populations that need nectar, pollen and food throughout the year in these regions. Dicamba levels far below those estimated to be contained in particle and vapor drift are known to reduce plant diversity.[37] Similarly, drift-level rates of dicamba were found to reduce flowering of multiple plants, a reduction scientists have found coincides with reduced visitation by pollinators.[38]

Monarchs rely on nectar from flowering plants throughout their migration, but this is particularly important for the southern migration, in which the butterfly must acquire the fuel and fat reserves to help it travel hundreds to thousands of miles and sustain it throughout the winter. Any significant reduction in the flowering of plants along the migration route could heavily impact adults' ability to make the migration, survive the winter and breed again in the spring.

*Milkweed and Monarch Reproduction*

Milkweed is the sole host plant for the monarch butterfly. It is the only plant the adult will lay eggs on and is intrinsically tied to reproductive success. Dicamba's ability to kill milkweed is well established: Multiple species of milkweed are listed as being controlled by dicamba on the label of pesticide products.[39] Early studies of dicamba's effect on milkweed (*Asclepias spp*.) used high doses of the pesticide and generally found dicamba to be effective at killing milkweed and/or reducing its growth.[40]

Monarch caterpillar (*Danaus plexippus*). Photo by John Brandauer. (CC BY-NC-ND 2.0)

Notably, more recent studies that have used much lower doses of dicamba — meant to replicate the amount of the pesticide that is contained in vapor and particle drift — have found that milkweed growth can be impaired by dicamba at levels that will be present outside of agricultural fields where the pesticide has been used.

Researchers at the EPA studying how herbicides affect above ground plant biomass (plant material available for caterpillars to eat) found that common milkweed (*Asclepias syriaca*) has a similar sensitivity to dicamba as soybean (*Glycine max*), with just 3 percent of the minimum field application rate being sufficient to reduce the size of the milkweed plant by half.[41] Similar results were found by researchers at Pennsylvania State University, where just 1 percent of the minimum dicamba application rate was sufficient to reduce the size of milkweed by 50 percent.[42] Interestingly, at these lower rates both studies found dicamba to be more effective at reducing plant biomass than glyphosate, indicating that, by some measures, dicamba may have a greater impact on milkweed growth than glyphosate.[43]

It's clear that dicamba is effective at killing milkweed at field application rates and — at very low levels meant to estimate concentrations contained in drift or volatilization — can affect milkweed growth in a way that could reduce the quality or quantity of forage for monarch caterpillars. Soybean is thought to be one of the plants most sensitive to dicamba exposure, a conclusion further solidified by the widespread reports of drift damage during the 2017 growing season. And milkweed and soybean plants are very similar in their sensitivity to dicamba.[44] The demonstrated effects to soybean in 2017 indicate that milkweed plants in proximity to agricultural fields may have been similarly harmed.

The extent to which dicamba milkweed damage will impact monarch reproductive success remains to be seen as this vast chemical experiment unfolds. Early research out of Iowa indicates that monarchs will still lay eggs on milkweed that has been damaged to some extent by dicamba,[45] but whether those eggs can thrive and produce healthy caterpillar, pupae and adult butterflies is still unknown. It *is* known that even low levels of dicamba can have indirect effects on caterpillars; studies have shown that butterfly caterpillars that fed on broadleaf plants exposed to dicamba were much smaller and had a lower pupal mass than those feeding on healthy plants, which can influence their survival and reproductive capacity as adults.[46] The impacts of dicamba to this imperiled species' habitat are of great concern, especially since edge habitats adjacent to agricultural fields and marginal agricultural land are currently a key focus in habitat restoration efforts[47] — efforts that will be undermined by dicamba drift and volatilization.

## Conclusions and Discussion

With the approval of Xtend soybeans and cotton and the new accompanying dicamba formulations, we estimate that more than 57 million additional pounds of dicamba will be used on more than 60 million additional acres of cropland over the next 2-3 years in the United States. Much of this use will be in the late spring and summer months, a time of year when many plants and animals are more likely to be exposed. In fact, our mapping has found dicamba use on GE soybeans and cotton will coincide spatially and temporally with the presence of monarch eggs and caterpillars on milkweed in the eastern half of the United States. Milkweed is very sensitive to dicamba, with effects like reduced growth and mass, which can reduce the quantity and quality of food available to caterpillars, occurring at very low levels. Dicamba is also known to affect the flowering and diversity of plants — the same plants that provide important nectar resources for adult monarchs. Therefore, dicamba is expected to affect monarch habitat via two routes: reducing the flowering of plants that provide nectar for adults as they travel north in the spring and south for the winter and degrading milkweed that provides an essential resource for monarch reproduction.

We conclude, based on our mapping and the available science, that dicamba has the potential to impair monarch habitat above and beyond the current degradation caused by ongoing glyphosate use. The chemical properties of dicamba make it more likely than glyphosate to travel from the field where it is applied, as evidenced by the millions of acres of non-target soybeans and native flora damaged by dicamba in 2017. In addition to its greater propensity for off-target harm, recent research indicates that milkweed may be more sensitive to dicamba than glyphosate for certain sublethal outcomes and just as sensitive to dicamba as soybean plants that are not genetically engineered for dicamba resistance. Given the demonstrated damage to soybeans from off-target dicamba use, we believe that dicamba will travel off field at levels that can damage milkweed and nectar plants. Glyphosate and dicamba will also be used alongside each other for the first time on a wide scale, which can lead to greater toxicities through chemical interaction.[48]

It is still unknown whether dicamba use in the South, Midwest and East will degrade monarch habitat enough to significantly impact the eastern migratory monarch population. However, the evidence presented here indicates that this is a distinct possibility. Unfortunately, as with glyphosate, this threat to the iconic monarch butterfly didn't even register on the EPA's radar: In the nearly 500 pages of ecological risk analysis the EPA published in conjunction with its approval of dicamba on GE cotton and soybean, there is not a single mention of the monarch butterfly.[49] This is an organism that has a unique lifecycle and a dependence on milkweed and effects on this species cannot be accurately estimated using the EPA's typical surrogate species approach. This approach involves the assumption that toxicity to a test species, like a tomato plant or a mouse, is identical to all other species within that taxon; it is extremely imprecise and can drastically underestimate harms to certain species, particularly those with atypical lifecycles, migratory patterns and relationships with other organisms. Given the threats the monarch is already facing from other pesticides, adding yet another layer of chemical harm to its habitat jeopardizes the future of this incredible creature.

### *Moving Forward*

After the disastrous 2017 growing season and ensuing public outrage at the millions of acres reportedly damaged by dicamba, in October the EPA announced that it had reached a deal with industry to make some modest changes to the label of new dicamba formulations.[50] These changes, including reducing the allowable wind speed during application of the pesticide, giving the new products restricted use status, and additional record-keeping requirements, are better than nothing. However, the EPA failed to make any changes that would address dicamba's ongoing volatility problem, which is thought to be the major route of travel off field.[51] Furthermore, while the new label restrictions will result in a reduction in the number of days where spraying conditions are suitable, they will not necessarily reduce the amount of dicamba that will be sprayed. Researchers in Indiana looked at the number of days that this type of restrictive label would have allowed spraying in June and July of 2017.[52] They found that there would only have been 50 hours in the whole month of June and 100 hours in the month of July where spraying would have been legal in parts of Indiana. That simply won't work with many farmers' schedules; once weeds reach a certain height, dicamba isn't very effective anymore. With only a small window when spraying is allowed, this could end up promoting the use of dicamba in such a way that all farmers in a particular region spray dicamba in the same 2-hour window resulting in aggregate exposures that are much more harmful. Alternatively, it could also promote off-label dicamba use, which would be absolutely disastrous for the flora and fauna that call these agricultural lands home.

In the absence of leadership from the federal government, some states have stepped up to protect farmers and the environment from this harmful chemical. By the close of 2017, Arkansas, North Dakota, Minnesota and Missouri had banned or were in the process of banning the use of new dicamba products during certain times of the growing season in 2018. However, the temporary nature of these bans and the presence of ongoing litigation brought by Monsanto against the state of Arkansas make them very precarious. And ultimately, while we fully support these state actions, a state-by-state approach is not the best way to tackle this issue; the problem needs a federal solution.

There is no scenario where using a pesticide at this magnitude will not have serious consequences for the monarch butterfly, its habitat and the ecological health of vast areas of our country. Dicamba has a time limited regulatory federal approval that is subject to expiration by Nov. 9, 2018 unless it is

## Pesticide Treadmill: From a Jog to a Sprint

The first herbicide-resistant crops were deregulated in the United States in 1994.[53] From 1994-2012 an average of two crops containing a herbicide-resistant trait were approved for commercialization by the USDA each year. From 2013 to 2017 it grew to an average of four crops per year.[54] This doubling in herbicide-resistant crop approval is largely due to the stacking of multiple traits to generate crops that can withstand treatment by 2 or more herbicides.

USDA approval for Monsanto's glyphosate and dicamba resistant (Xtend) cotton also included the glufosinate-resistance trait.[55] USDA approval for Dow's 2,4-D and glyphosate resistant (Enlist) corn and soybeans also included quizalofop-resistance (corn) and glufosinate-resistance (soybean).[56] Therefore, once weeds develop resistance to dicamba and 2,4-D, which has already started to happen in many regions,[57] agrochemical companies have already laid the groundwork to further increase reliance on more pesticides.

The current landscape of deregulated, herbicide resistant traits — which can be combined through conventional breeding without any further regulatory oversight — have the potential to further increase herbicide use and harm already degraded habitat for the monarch butterfly in the future (Table 1).

**Table 1. Deregulated Herbicide-Resistant Traits by Crop (1994-2017)**

| Crop | Glyphosate | Glufosinate | Dicamba | (ACCase inhibitors) | 2,4-D | (Imidazolinones) | (Pyrimidinylthiobenzoates) | (Sulfonylaminocarbonyltriazolinones) | (Triazolopyrimidines) | (Sulfonylureas) | Bromoxynil | (HPPD inhibitors) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa | X | | | | | | | | | | | |
| Canola | X | X | | | | | | | | | | |
| Corn | X | X | X | X | X | X | | | | | | |
| Cotton | X | X | X | | X | | | | | X | X | X* |
| Flax | | | | | | | | | | X | | |
| Rice | | X | | | | | | | | | | |
| Soybean | X | X | X | | X | X | X | X | X | X | | X |
| Sugar Beet | X | X | | | | | | | | | | |

* Approval Pending
By individual herbicide or (class)

Data compiled from: USDA Animal and Plant Health Inspection Service. Petitions for Determination of Nonregulated Status.

renewed by the EPA.[58] The most responsible way forward would be for the EPA to let this registration expire and revisit the issue only when the agency can address the inadequacies in its pesticide-approval process that allows for extremely harmful pesticides to be used in ways that are not in the long-term best interests of this country.

## References


[1] The following is a good resource for comprehensive information about the monarch's lifecycle and threats: Petition to protect the monarch butterfly (*Danaus plexippus plexippus*) under the Endangered Species Act. Submitted to Secretary of the US Department of the Interior by The Center for Biological Diversity and Center for Food Safety, joined by The Xerces Society and Dr. Lincoln Brower. Aug. 26, 2014. Available at: https://www.biologicaldiversity.org/species/invertebrates/pdfs/Monarch_ESA_Petition.pdf.

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[3] Petition to protect the monarch butterfly (*Danaus plexippus plexippus*) under the Endangered Species Act. Submitted to Secretary of the U.S. Department of the Interior by the Center for Biological Diversity and Center for Food Safety, joined by The Xerces Society and Dr. Lincoln Brower. Aug. 26, 2014. Available at: https://www.biologicaldiversity.org/species/invertebrates/pdfs/Monarch_ESA_Petition.pdf; and Thogmartin, W. E., R. Wiederholt, K. Oberhauser, R. G. Drum, J. E. Diffendorfer, S. Altizer, O. R. Taylor, J. Pleasants, D. Semmens, B. Semmens, R. Erickson, K. Libby and L. Lopez-Hoffman (2017). "Monarch butterfly population decline in North America: identifying the threatening processes." R Soc Open Sci 4(9): 170760.

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[6] U.S. Geological Survey: National Water-Quality Assessment (NAWQA) Program. Pesticide National Synthesis Project, pesticide use maps – glyphosate. Accessed Nov. 29, 2017; Available at: https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2015&map=GLYPHOSATE&hilo=L&disp=Glyphosate.

[7] U.S. Geological Survey: National Water-Quality Assessment (NAWQA) Program. Pesticide National Synthesis Project, pesticide use maps – atrazine. Accessed Nov. 29, 2017; Available at: https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2015&map=ATRAZINE&hilo=L&disp=Atrazine.

[8] Petition to protect the monarch butterfly (*Danaus plexippus plexippus*) under the Endangered Species Act. Submitted to Secretary of the U.S. Department of the Interior by the Center for Biological Diversity and Center for Food Safety, joined by The Xerces Society and Dr. Lincoln Brower. Aug. 26, 2014. Available at: https://www.biologicaldiversity.org/species/invertebrates/pdfs/Monarch_ESA_Petition.pdf

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[10] Heap, I. The International Survey of Herbicide Resistant Weeds. Weeds Resistant to EPSP synthase inhibitors (G/9). Accessed on Nov. 29, 2017. Available at: http://www.weedscience.org/Summary/MOA.aspx?MOAID=12.

[11] EPA (2016). "Ecological Risk Assessment for Dicamba DGA Salt and its Degradate, 3,6-dichlorosalicylic acid (DCSA), for the Proposed Post-Emergence New Use on Dicamba-Tolerant Cotton (MON 8770 I)." Pg. 36. Available at: https://www.regulations.gov/document?D=EPA-HQ-OPP-2016-0187-0005.

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[13] Heap, I. The International Survey of Herbicide Resistant Weeds. Database search with "2,4-D" and "dicamba." Accessed Dec. 6, 2017. Available here: http://www.weedscience.org/Summary/ResistByActive.aspx.

[14] Heap, I. The International Survey of Herbicide Resistant Weeds. Accessed Jan. 13, 2018. Available here: http://www.weedscience.org/default.aspx.

[15] Around half a million pounds of dicamba were used on both crops in 2015 (*see* U.S. Geological Survey: National Water-Quality Assessment (NAWQA) Program. Pesticide National Synthesis Project, pesticide use maps – dicamba. Accessed Dec. 1, 2017; Available at: https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2015&map=DICAMBA&hilo=L&disp=Dicamba). That amount was used on 94 million acres of cotton and soybean crops in 2015 (*see* USDA, National Agricultural Statistics Service. Acreage. June 30, 2015. Available at: https://www.usda.gov/nass/PUBS/TODAYRPT/acrg0615.pdf)

[16] Gray, B. "Dicamba damage is back — and possibly worse than before." St. Louis Post-Dispatch. June 25, 2017. Accessed Dec. 1, 2017. Available at: http://www.stltoday.com/business/local/dicamba-damage-is-back-and-possibly-worse-than-before/article_2e33ec05-ae98-5468-92f8-bccf6bcd7698.html

[17] Polansek, T and Flitter, E. "Exclusive: EPA eyes limits for agricultural chemical linked to crop damage." Reuters. September 5, 2017. Accessed Dec. 27, 2017. Available here: https://www.reuters.com/article/us-usa-pesticides-epa-exclusive/exclusive-epa-eyes-limits-for-agricultural-chemical-linked-to-crop-damage-idUSKCN1BG1GT; and Goldberg, S. "Ban of Herbicide Could Benefit Agriculture Prices." Bloomberg. Oct. 2, 2017. Accessed Nov. 15, 2017. Available here: https://www.bloomberg.com/view/articles/2017-10-02/ban-of-herbicide-could-benefit-agriculture-prices.

[18] Bradley, K. "A Final Report on Dicamba-injured Soybean Acres." Oct. 30, 2017. Available here: https://ipm.missouri.edu/IPCM/2017/10/final_report_dicamba_injured_soybean/.

[19] 3.6 million acres divided by 25 million acres equals 0.144. Multiplied by 61 million acres equals 8.8 million acres of proportionate off-target damage.

[20] BASF. Clarity Herbicide label. Available at: http://www.cdms.net/ldat/ld797012.pdf.

[21] See EPA approved master label for new dicamba products. Section 12. Available here: https://www3.epa.gov/pesticides/chem_search/ppls/000524-00617-20171012.pdf.

[22] In 2012, 233,000 pounds of dicamba were used on soybean fields and 364,000 pounds on cotton fields (*See* USDA. Final environmental impact statement. *Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba Resistant Soybean and Cotton Varieties.* EIS appendix, 2014. Pages 4-16 and 4-24. Available from: http://www.aphis.usda.gov/brs/aphisdocs/dicamba_feis_appendices.pdf).

[23] Mortensen, D, Egan, J.F., Maxwell, B.D., Ryan, M.R., Smith, R.G. (2012). "Navigating a Critical Juncture for Sustainable Weed Management." BioScience, 62(1): 75–84; and Bohnenblust, E. W., Vaudo, A. D., Egan, J. F., Mortensen, D. A. and Tooker, J. F. (2016). "Effects of the herbicide dicamba on nontarget plants and pollinator visitation." Environ Toxicol Chem, 35: 144–151.

[24] Monsanto estimated 20.5 million pounds of dicamba to be used on soybeans and 5.225 million pounds on cotton at the time of peak Xtend crop adoption (*See* USDA. Final environmental impact statement. *Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba Resistant Soybean and Cotton Varieties.* EIS appendix, 2014. Tables 4-9 and 4-12. Available from: http://www.aphis.usda.gov/brs/aphisdocs/dicamba_feis_appendices.pdf). In 2011, 233,000 pounds of dicamba were used on soybean fields and 364,000 pounds on cotton fields (*See* pages 4-16 and 4-24 in EIS appendix). Total new dicamba use estimated to be 25,128,000 pounds.

[25] The EPA approved master label for new dicamba products direct the user: "Do not apply less than 22 fluid ounces (0.5 lb a.e. dicamba) per acre." Section 12. Available here: https://www3.epa.gov/pesticides/chem_search/ppls/000524-00617-20171012.pdf. Use rates in the company estimates to USDA ranged from 0.5 lb a.e. dicamba per acre (which is the minimum single use rate) to 0.375 lb a.e. dicamba per acre (*See* USDA. Final environmental impact statement. *Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba Resistant Soybean and Cotton Varieties.* EIS appendix, 2014. Tables 4-9 and 4-12. Available from: http://www.aphis.usda.gov/brs/aphisdocs/dicamba_feis_appendices.pdf).

[26] Monsanto estimated that 40 percent of soybean acres would be planted with Xtend soybeans at the time of peak adoption (*See* USDA. Final environmental impact statement. *Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba Resistant Soybean and Cotton Varieties.* EIS appendix, 2014. Page 4-16. Available from: http://www.aphis.usda.gov/brs/aphisdocs/dicamba_feis_appendices.pdf). The most current estimate is that 60 percent of soybean acres will be planted with Xtend soybeans (*See* Polansek, T and Flitter, E. "Exclusive: EPA eyes limits for agricultural chemical linked to crop damage." Reuters. Sept. 5, 2017. Accessed Dec. 27, 2017. Available here: https://www.reuters.com/article/us-usa-pesticides-epa-exclusive/exclusive-epa-eyes-limits-for-

agricultural-chemical-linked-to-crop-damage-idUSKCN1BG1GT; and Goldberg, S. "Ban of Herbicide Could Benefit Agriculture Prices." Bloomberg. Oct. 2, 2017. Accessed Nov. 15, 2017. Available here: https://www.bloomberg.com/view/articles/2017-10-02/ban-of-herbicide-could-benefit-agriculture-prices).

[27] Behrens, R. and Lueschen, W. (1979). "Dicamba Volatility." Weed Science, 27(5): 486-493; and Egan, J.F. and Mortensen, D.A. (2012). "Quantifying vapor drift of dicamba herbicides applied to soybean." Environ Toxicol Chem, 31(5): 1023-31.

[28] Carroll, M. J., Hill, R. L., Pfeil, E., & Herner, A. E. (1993). "Washoff of Dicamba and 3,6-Dichlorosalicylic Acid from Turfgrass Foliage." Weed Technology, 7(2): 437-442; and Ensminger, M.P., et al. (2013). "Pesticide occurrence and aquatic benchmark exceedances in urban surface waters and sediments in three urban areas of California, USA, 2008-2011." Environ Monit Assess, 185(5): 3697-710.

[29] Flitter, E. "Scant oversight, corporate secrecy preceded U.S. weed killer crisis." Reuters. August 8, 2017. Accessed Dec. 27, 2017. Available here: https://www.reuters.com/article/us-usa-pesticides-dicamba-insight/scant-oversight-corporate-secrecy-preceded-u-s-weed-killer-crisis-idUSKBN1AP0DN.

[30] EPA states: "Based on field volatility (flux) studies (conducted in accordance with the label conditions such as nozzle and ground speed limitations) and laboratory vapor-phase toxicity and exposure (humidome) studies, the 110-foot omnidirectional buffer for volatilization is no longer warranted for the dicamba DGA plus VaporGrip™ (M1768) formulation, because the expected exposure at field's edge is less than the NOAEC for plant risk." (*See* EPA. "Final Registration of Dicamba on Dicamba-Tolerant Cotton and Soybean." Nov. 9, 2016. Pg. 18. Available here: https://www.regulations.gov/document?D=EPA-HQ-OPP-2016-0187-0959)

[31] Norsworthy, J.K, Barber, T, Scott, B. Presentation to the Arkansas Dicamba Task Force. "Dicamba: What do we know?" Sept. 21, 2017. Appendix B. Available here: http://www.aad.arkansas.gov/Websites/aad/files/Content/6126295/Dicamba_Task_Force_Report,_sept_21_2017.pdf; and Bradley, K. Presentation to the Dicamba Injury Forum. Dicamba Update July 6, 2017. Available here: https://weedscience.missouri.edu/2017%20Dicamba%20Injury%20Forum.pdf.

[32] These mitigation measures included "…in-field buffers, aerial application prohibitions, boom height requirements, specific nozzle and spray pressure requirements, and wind and tractor speed limitations." (*See* EPA. "Final Registration of Dicamba on Dicamba-Tolerant Cotton and Soybean." Nov. 9, 2016. Pg 29. Available here: https://www.regulations.gov/document?D=EPA-HQ-OPP-2016-0187-0959). On Oct. 12, 2017 further mitigation measures were approved (see *Moving Forward* section in report above).

[33] EPA states: "Spray drift label mitigation language including an in-field spray drift buffer of 110 feet (for the 0.5 lb/A rate) and 220 feet (for the 1.0 lb/A rate) downwind at the time of application is expected to limit off site transport of dicamba DGA through spray drift. Therefore, the EPA expects that exposure will remain confined to the dicamba (DGA) treated field." (*See* EPA. "Final Registration of Dicamba on Dicamba-Tolerant Cotton and Soybean." Nov. 9, 2016. Pg 25. Available here: https://www.regulations.gov/document?D=EPA-HQ-OPP-2016-0187-0959).

[34] Bradley, K. "A Final Report on Dicamba-injured Soybean Acres." Oct. 30, 2017. Available here: https://ipm.missouri.edu/IPCM/2017/10/final_report_dicamba_injured_soybean/.

[35] Lipton, E. "Crops in 25 States Damaged by Unintended Drift of Weed Killer." New York Times. Nov. 1, 2017. Accessed Dec. 5, 2017. Available at: https://www.nytimes.com/2017/11/01/business/soybeans-pesticide.html.

[36] Association of American Pesticide Control Officials. Dicamba. Accessed Dec. 5, 2017. Available at: https://aapco.org/2015/07/02/dicamba/.

[37] Egan, J.F, Bohnenblust, E, Goslee, S, Mortensen, D.A, and Tooker, J (2014). "Herbicide drift can affect plant and arthropod communities." Agriculture, Ecosystems, and Environment, 185: 77-87.

[38] Bohnenblust, E.W, Vaudo, A.D, Egan, J.F, Mortensen, D.A, Tooker, J.F (2016) Effects of the herbicide dicamba on non-target plants and pollinator visitation. Environ Toxicol Chem, 35(1): 144–151.

[39] See EPA approved master label for new dicamba products. Pg 38. Available here: https://www3.epa.gov/pesticides/chem_search/ppls/000524-00617-20171012.pdf.

[40] Bhowmik, P.C. (1994). "Biology and control of common milkweed (Asclepias syriaca)." Rev. Weed Sci., 6: 227-250; Moshier, L. (1980). "Response of Honeyvine Milkweed (Ampelamus albidus) to Herbicide Applications." Weed Science, 28(6): 722-724; Moshier, L., Russ, O., O'Connor, J., and Claassen, M. (1986). "Honeyvine Milkweed (Ampelamus albidus) Response to Foliar Herbicides." Weed Science, 34(5): 730-734; and Cramer, G.L. and Burnside, O. (1981). "Control of Common Milkweed (Asclepias syriaca)." Weed Science, 29(6): 636-640. All studies show dicamba to be effective at killing milkweed or reducing its growth, albeit less effectively than glyphosate.

[41] Olszyk, D, Pfleeger, T, Lee, E.H, and Plocher, M (2015). "Glyphosate and dicamba herbicide tank mixture effects on native plant and non-genetically engineered soybean seedlings." Ecotoxicology, 24 :1014-1027. Minimum use rate is 0.5 lb. a.e. dicamba per acre (*see* EPA approved master label) which equals 562 g dicamba per hectare. 17 g per hectare was roughly the $EC_{50}$ in the study.
[42] Egan, J. F., Graham, I. M. and Mortensen, D. A. (2014). "A comparison of the herbicide tolerances of rare and common plants in an agricultural landscape." Environ Toxicol Chem, 33: 696–702. $ED_{50}$ was 7 g dicamba per hectare, roughly 1 percent of the minimum application rate of 562 grams per hectare.
[43] Egan et al. found an $ED_{50}$ of 7 g a.e. per hectare for dicamba and 258 g a.e. per hectare for glyphosate. Olszyk et al. found an $EC_{50}$ of roughly 3 percent of the field application rate for dicamba and the same outcome with 10 percent of the field application rate for glyphosate.
[44] Dicamba effects on soybean ($ED_{50}$) seen at >5.6 and 17 g dicamba per hectare (*See* Olszyk, D, Pfleeger, T, Lee, E.H, and Plocher, M (2015). "Glyphosate and dicamba herbicide tank mixture effects on native plant and non-genetically engineered soybean seedlings." Ecotoxicology, 24 :1014-1027 and Kelley, K., Wax, L., Hager, A., and Riechers, D. (2005). "Soybean response to plant growth regulator herbicides is affected by other postemergence herbicides." Weed Science, 53(1): 101-112) and dicamba effects on milkweed ($ED_{50}$) seen at 7 and 17 g dicamba per hectare (*See* Olszyk, D, Pfleeger, T, Lee, E.H, and Plocher, M (2015). "Glyphosate and dicamba herbicide tank mixture effects on native plant and non-genetically engineered soybean seedlings." Ecotoxicology, 24 :1014-1027 and Egan, J. F., Graham, I. M. and Mortensen, D. A. (2014). "A comparison of the herbicide tolerances of rare and common plants in an agricultural landscape." Environ Toxicol Chem, 33: 696–702).
[45] Hoey, B.L, Lizotte-Hall, S, Hartzler, B (Dec. 2016). "Effect of Growth Regulator Herbicide Injury to Common Milkweed on Ovipositioning by Monarch Butterflies." Poster presented at the North Central Weed Science Society in Des Moines, IA.
[46] Bohnenblust E, Egan J.F, Mortensen D, Tooker J (2013). "Direct and indirect effects of the synthetic-auxin herbicide dicamba on two lepidopteran species." Environ. Entomol., 42(3): 586-94.
[47] U.S. Fish and Wildlife Service. Newsroom, "Monarch responsibility in the Midwest." Sept. 9, 2016. Accessed Dec. 12, 2017. Available here: https://www.fws.gov/midwest/news/MonarchProjects.html; and Thogmartin et. al. (2017). "Restoring monarch butterfly habitat in the Midwestern US: 'all hands on deck'." Environmental Research Letters, 12(7): 074005.
[48] The evidence for synergistic interaction is mixed with some studies finding evidence of synergy and others finding no interaction or antagonism. This likely has to do with the different test organisms and different proportions of the two chemicals used in the studies. Regardless, it appears that under certain conditions glyphosate and dicamba can function synergistically when used together (*See* Soloneski, S., Ruiz de Arcaute, C. & Larramendy, M.L. (2016). "Genotoxic effect of a binary mixture of dicamba- and glyphosate-based commercial herbicide formulations on Rhinella arenarum (Hensel, 1867) (Anura, Bufonidae) late-stage larvae." Environ Sci Pollut Res, 23(17): 17811-17821; Flint, J.L and Barrett, M. (1989). "Effects of Glyphosate Combinations with 2,4-D or Dicamba on Field Bindweed (Convolvulus arvensis)." Weed Science, 37(1): 12-18; Satchivi, N.M and Wright, T.R. Dow Agrosciences LLC. (2011) Patent Application "Synergistic Herbicidal Composition Containing a Dicamba derivative and a Glyphosate Derivative."Patent application number 13099552; Kelley, K., Wax, L., Hager, A., and Riechers, D. (2005). "Soybean response to plant growth regulator herbicides is affected by other postemergence herbicides." Weed Science, 53(1): 101-112; Olszyk, D, Pfleeger, T, Lee, E.H, and Plocher, M (2015). "Glyphosate and dicamba herbicide tank mixture effects on native plant and non-genetically engineered soybean seedlings." Ecotoxicology, 24 :1014-1027).
[49] Documents EPA-HQ-OPP-2016-0187-0002, EPA-HQ-OPP-2016-0187-0004, EPA-HQ-OPP-2016-0187-0005, EPA-HQ-OPP-2016-0187-0006, EPA-HQ-OPP-2016-0187-0007, EPA-HQ-OPP-2016-0187-0008, EPA-HQ-OPP-2016-0187-0955, EPA-HQ-OPP-2016-0187-0956, EPA-HQ-OPP-2016-0187-0959 add up to 482 pages. Documents can be searched for and found on www.regulations.gov.
[50] EPA Chemical Safety and Pollution Prevention (OCSPP). News Releases. "EPA and States' Collective Efforts Lead to Regulatory Action on Dicamba." 10/13/2017. Accessed Dec. 7, 2017. Available here: https://www.epa.gov/newsreleases/epa-and-states-collective-efforts-lead-regulatory-action-dicamba.
[51] Norsworthy, J.K, Barber, T, Scott, B. Presentation to the Arkansas Dicamba Task Force. "Dicamba: What do we know?" Sept. 21, 2017. Appendix B. Available here: http://www.aad.arkansas.gov/Websites/aad/files/Content/6126295/Dicamba_Task_Force_Report,_sept_21_2017.pdf.

[52] Unglesbee, E. "Dicamba Questions. How Often Could Growers Legally Spray Dicamba in 2017?" DTN Progressive Farmer. Sept. 15, 2017. Accessed Dec. 7, 2017. Available at: https://www.dtnpf.com/agriculture/web/ag/news/crops/article/2017/09/15/often-growers-legally-spray-dicamba.

[53] Bromoxynil resistant cotton by Calgene and glyphosate resistant soybeans by Monsanto were deregulated in 1994. (*See* USDA Animal and Plant Health Inspection Service. Petitions for Determination of Nonregulated Status. Available from: https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/permits-notifications-petitions/petitions/petition-status)

[54] USDA Animal and Plant Health Inspection Service. Petitions for Determination of Nonregulated Status. Accessed Sept. 22, 2017; Available from: https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/permits-notifications-petitions/petitions/petition-status. 39 separate herbicide resistant events were deregulated from the 19 years between 1994 and 2012 for a total of 2.05 events/year. 20 separate herbicide resistant events were deregulated from the 5 years between 2013 and 2017 for a total of 4 events/year.

[55] USDA. Final environmental impact statement. *Monsanto Petitions (10-188-01p and 12-185-01p) for Determinations of Nonregulated Status for Dicamba Resistant Soybean and Cotton Varieties.* December 2014. Pg iii. Available here: https://www.aphis.usda.gov/brs/aphisdocs/dicamba_feis.pdf.

[56] USDA. Final environmental impact statement. *Dow AgroSciences Petitions (09-233- 01p, 09-349-01p, and 11-234-01p) for Determinations of Nonregulated Status for 2,4-D-Resistant Corn and Soybean Varieties*. August 2014. Pg iv. Available here: https://www.aphis.usda.gov/brs/aphisdocs/24d_feis.pdf.

[57] Heap, I. The International Survey of Herbicide Resistant Weeds. Database search with "2,4-D" and "dicamba." Accessed Dec. 6, 2017. Available here: http://www.weedscience.org/Summary/ResistByActive.aspx.

[58] EPA. "Final Registration of Dicamba on Dicamba-Tolerant Cotton and Soybean." Nov. 9, 2016. Pg 35. Available here: https://www.regulations.gov/document?D=EPA-HQ-OPP-2016-0187-0959.