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August 24, 2015

OPP Docket
Environmental Protection Agency Docket Center (EPA/DC), 28221T
1200 Pennsylvania Ave., NW
Washington, DC 20460-0001

Docket No. EPA-HQ-OPP-2015-0389

Comments to the Environmental Protection Agency on "Risk Management Approach to Identifying Options for Protecting the Monarch Butterfly" from Center for Food Safety and The Center for Biological Diversity

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Center for Food Safety (CFS) is a national nonprofit public interest and environmental advocacy organization founded in 1997 that works to protect human health and the environment by curbing the use of harmful food production technologies and promoting organic and other forms of sustainable agriculture.[1] In furtherance of this mission, CFS uses legal actions, groundbreaking scientific and policy reports, books and other educational materials, and grassroots campaigns, on behalf of its 700,000 members. CFS is a recognized national leader in promoting a safer and more sustainable agriculture, and improving regulation to achieve this goal.

The Center for Biological Diversity ("Center") is a non-profit environmental organization dedicated to the protection of diverse native species and their habitats through science, policy, education and law. The Center for Biological Diversity has over 900,000 members and online activists throughout the United States. Recognizing that pesticides are one of the foremost threats to the environment, biodiversity, and public health, the Center works to prevent and reduce the use of harmful pesticides and to promote sound pest management strategies.

CFS and the Center welcome EPA's initiative to identify efforts to protect the monarch butterfly by conserving the milkweed plant, as outlined in the document "Risk Management Approach to Identifying Options for Protecting the Monarch Butterfly." CFS and the Center have been engaged in efforts to protect and restore

[1] *See generally* www.centerforfoodsafety.org.

the monarch butterfly for several years, and have considerable expertise to share with the Agency to better inform and promote its initiative as well as U.S. government-wide efforts, led by the Department of Interior, to conserve the monarch butterfly.

On August 26, 2014, CFS together with the Center, The Xerces Society and Dr. Lincoln Brower petitioned the U.S. Fish and Wildlife Service to list the monarch butterfly (*Danaus plexippus plexippus*) as a threatened species under the Endangered Species Act. This petition provides a thorough discussion of the threats facing the monarch butterfly, including habitat loss and degradation in the monarch's Midwest breeding range. In February 2015, CFS released a report – *Monarchs in Peril: Herbicide-Resistant Crops and the Decline of Monarch Butterflies in North America* – that provides a more robust analysis of the factors responsible for the decline of the monarch's chief host plant, common milkweed (*Asclepias syriaca*), and their relation to the dramatic reduction of the monarch butterfly population in North America. This meticulously documented report (88 pages, with a bibliography of 221 references) provides the fullest treatment available of this subject to date, and will be referred to below as "CFS Monarch Report (2015), [section number]." The report cites a wealth of scientific and other literature relating to the impact of herbicides on milkweed populations. We are submitting the ESA listing petition and CFS Monarch Report (2015) as integral parts of these comments. We are also submitting a selection of some of the major studies cited in these comments.

While CFS welcomes EPA's initiative, we note at the outset that it can in no way be construed as an alternative to listing the monarch as a threatened species under the Endangered Species Act. This is particularly true as EPA's initiative is intended only "to provide guidance," "is not binding on either EPA or pesticide registrants," and as "EPA may depart from the guidance were circumstances warrant" and "pesticide registrants may assert that the guidance is not applicable to a specific pesticide or situation" (Federal Register, Vol. 80, No. 121, June 24, 2015). In short, none of the measures proposed or recommended in the guidance document will carry the force of law, and so cannot substitute for legally binding protections for the monarch that ESA listing would entail.

The ESA listing petition and CFS Monarch Report (2015) provide fully documented discussions demonstrating that the near-elimination of common milkweed from Midwest cropland over the past 15 years is the major factor driving the 90% reduction of the Mexican migratory monarch butterfly population over the past two decades; and that massive post-emergence use of the herbicide glyphosate with glyphosate-resistant (Roundup Ready) crop systems is primarily responsible for this milkweed decline. Accordingly, a key component of monarch conservation efforts must be to preserve and augment existing remnant common milkweed populations in Midwest cropland through prudent restrictions on herbicide use and other measures.

Why milkweed in non-cropland habitat cannot support a viable monarch population

The discussion below is based primarily on CFS Monarch Report (2015), Sections 2.3, 4.4 & 4.5. Based on extensive surveys in Iowa and corroborating data from other Midwest states, nearly half of the Midwest's milkweed was found in corn and soybeans fields in 1999. Today, only 1% of that cropland milkweed remains (Pleasants 2015). Because milkweed in cropland is nearly four times as productive of monarchs, on a per-plant basis, as milkweed growing in other habitats, its loss has had a disproportionately large negative impact on monarchs. Models keyed to empirical studies of the flight behavior, reproduction and other aspects of monarch biology provide further support for the critical importance of low-density milkweed scattered throughout the cropland "matrix" for monarch survival (Zalucki and Lammers 2010, Zalucki et al. 2015). These models suggest that elimination of low-density milkweed from cropland has reduced monarch egg-laying by 30% to 90% (Zalucki 2015). Milkweed growing on roadsides has remained roughly constant since 1999 (Hartzler 2010). While less certain, some data suggest that milkweed in Conservation Reserve Program land and pastures may have declined by roughly half since 1999 (Pleasants and Oberhauser 2012, Fig. 1, Table 1), far less dramatically than in cropland.

Because milkweed loss over the period of monarch decline has occurred overwhelmingly in cropland, and milkweeds in cropland produce far more monarchs per plant, monarch conservation efforts that fail to restore some low density of milkweed to cropland will likely be doomed to failure. This is not merely our opinion. It is supported by the hard data outlined above and modeling by one of the world's leading monarch biologists, Dr. Myron P. Zalucki:

> "Our objective here is to partly address what happens to a species persistence if the matrix is cleaned up and made a void, due to say herbicide usage on host plants (milkweeds) growing in agricultural fields. With Roundup Ready soybeans being widely grown in the north-eastern [sic] USA, such extirpation of low density milkweeds is occurring. We are in effect creating a landscape in which remnant patches of milkweed may still be present on old fields, and along verges of roadways, but the area in between is being made clean …
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> Even though conservation-minded consciences might be salved by leaving some fraction of the landscape with habitat, perhaps even a substantial area such as roadsides and the odd old field, an empty matrix may make a big difference for highly dispersive species with good searching capacity, like monarchs." (Zalucki and Lammers 2010)

The discussion below hence focuses on milkweed in actively farmed cropland.

Herbicides and milkweed: preliminary considerations

EPA has asked for information on the effects of various herbicides on milkweed plant species. Two important preliminary considerations are differential sensitivity at different growth stages and the degree of control achieved. Unless otherwise indicated, references to milkweed are to common milkweed.

Common milkweed is a perennial plant with two modes of reproduction (see Monarch Report 2015, Section 2, for the following discussion). It reproduces vegetatively, sending up shoots in the spring from its root system, and also produces seed pods with feathery seeds that float on the wind to colonize new areas, primarily disturbed habitat. Seedlings are more susceptible of herbicidal control than mature plants, and are also more easily killed by tillage. Because sharply declining cropland milkweed populations have obviously had little if any opportunity to successfully reproduce new plants by seed, the discussion below will focus on mature milkweed with established root systems.

Most herbicides provide some degree of milkweed suppression, but very few control it. Suppression is here defined as damage to above-ground plant tissues only, while control refers to impairing or preventing shoot emergence from root tissue such that milkweed stands die out. Suppression of milkweed has mixed effects on monarchs. Significantly fewer monarch eggs present on milkweed advance to the larval stage after the milkweed is sprayed with herbicide versus no-spray controls (Pleasants 2015), because the leaf tissue is killed, depriving any larvae that emerge of food. On the other hand, plants damaged by most non-glyphosate herbicides quickly sprout new branches from leaf axils and new stems from the root, appear to fully recover within 2-4 weeks (Pleasants 2015), and hence may regrow into viable monarch host plants later in the season. In contrast: "When glyphosate herbicide was used, most plants were killed; those that survived had little if any resprouting from leaf axils" (Pleasants 2015).

Similar to the effect of non-glyphosate herbicides, mowing stimulates buds on roots to sprout new shoots. In fact, regrowth of shoots following prescribed mowing of milkweed in July (upstate New York) has been found to extend the monarch's breeding season by providing suitable milkweed host plants later into the year (Fischer et al. 2015). The upshot is that herbicides that only suppress common milkweed may have little overall negative impact on monarch reproduction. This would be consistent with the continuing presence of common milkweed at levels sufficient to support substantial monarch populations over three to four decades of extensive and mostly non-glyphosate herbicide use on field crops from the 1960s through the end of the 1990s. For these reasons, we focus on herbicidal control rather than suppression of milkweed below as more relevant to monarch reproduction and survival.

Glyphosate's efficacy for control of common milkweed

It is well-established that glyphosate is extremely effective at control rather than mere suppression of common milkweed. Franz et al. (1997) explain that glyphosate's efficacy on perennial weeds in general is attributable to its systemic activity and its translocation to root tissue following absorption. Bhowmik (1982) showed that milkweed stands treated once with high rates of glyphosate were reduced by 90% or more in the two years after treatment, clear evidence of its ability to kill milkweed by preventing regeneration from roots. Zollinger (1998) found that high-rate glyphosate treatment reduced milkweed stands by 99% the year following treatment. In weekly observations dating to the years 2000 and 2002, Pleasants (2015) followed stands of milkweed in Iowa corn and soybean fields before and after herbicide use, and found that: "In soybean fields treated with nonglyphosate herbicide, the milkweeds recovered, as seen with corn, but in fields treated with glyphosate there was no recovery and only a small number of stems survived (Figure 14.2b)." Unlike most herbicides, glyphosate is labeled for control of common milkweed (e.g. Monsanto 2009, 12.7, 15.0). Section 3 of CFS Monarch Report (2015) provides a detailed discussion of how glyphosate use patterns in the Roundup Ready crop era have been particularly effective at decimating milkweed populations in Midwest corn and soybean fields. In brief, glyphosate has been applied more extensively, more frequently, at higher rates, and later in the season when milkweed is at its more vulnerable reproductive stages of growth when used with Roundup Ready crops than when used in a conventional crop setting.

Without restrictions on glyphosate use, there is little doubt that milkweed will soon be essentially extirpated from cropland in the monarch's Midwest breeding range.

Potential consequences for milkweed of restrictions on glyphosate use

EPA has raised the concern that restrictions on glyphosate use might lead to increased use of other milkweed-killing herbicides.

> The EPA also recognizes that it is possible that if EPA were to take regulatory action to reduce the potential impact from one herbicide to protect important monarch butterfly resources, such efforts could result in a market shift to other herbicides that would not be subject to similar risk mitigation measures. To the extent that happened, there could well be little or no improvement for monarch butterflies.

However, an examination of the available evidence from extension publications, the weed science literature and herbicide product labels makes it clear that such concerns are unfounded, because so few herbicides other than glyphosate effectively control common milkweed. The following two paragraphs are excerpted from CFS Monarch Report, Section 2.2.3 (see report for references):

> In the 1970s and 1980s, weed scientists in Nebraska advised farmers that "the widely used herbicides of the day often do not harm milkweed, but remove annual weeds that would otherwise compete with it" (Martin and Burnside 1977/84). North Dakota agronomists agree that "[c]ommon milkweed appears tolerant to most all labeled herbicides currently registered" (Zollinger 1998). Iowa weed scientist Bob Hartzler concurs: "....common milkweed emerging from vegetative rootstocks is not significantly affected by pre-emergence herbicides used in corn and soybean" (Hartzler 2010).
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> Controlled studies examining the effect of tillage regime and herbicide use on milkweed support these assessments. Buhler et al. (1994) found that small milkweed populations in corn and soybean fields were not reduced by annual use of common herbicides of the 1970s and 1980s, including atrazine, alachlor, cyanazine and metribuzin, over a 10-year period. A five-year study in which soybeans were grown every year in a conservation tillage system showed slightly increasing milkweed prevalence with annual use of the herbicides bentazon and imazethapyr, as well as one interrow cultivation and pre-emergence or post-harvest application of glyphosate each year (Colbach et al. 2000).

The only herbicides that have been found to rival glyphosate for control of common milkweed are amitrole and picloram, each of which provides nearly comparable milkweed stand reductions in the years following application (Bhowmik 1982, Bhowmik 1994). However, EPA cancelled all food uses of amitrole in 1971 because it causes cancer in laboratory animals; and cancelled all uses in 2014. Picloram (e.g. Tordon 22K) is a synthetic auxin herbicide that has long-term residual activity and is used to control broadleaf weeds in rangeland, pastures, Conservation Reserve Program (CRP) land, utility rights-of-way and other non-crop areas, and is not registered for food crop uses. Thus, neither herbicide can have played a role in the eradication of milkweed from cropland, nor can either serve as a substitute for glyphosate if use of glyphosate is restricted.

Herbicide labels are another useful source of information on the efficacy of herbicides against particular weeds. Manufacturers use labels to provide farmers with detailed information on weeds species controlled as well as the optimal rates and timing (e.g. weed size), in addition to other information.

CFS consulted the USDA National Agricultural Statistics Service's (NASS's) Agricultural Chemical Usage program to identify the top eleven corn herbicides and top twelve soybean herbicides used in American agriculture today (see tables below).[2] We presume that these leading herbicides – already labeled for corn

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[2] Leading herbicides are those used to treat the largest percentage of crop acres. Because some herbicides are sold in different forms (e.g. glyphosate, dicamba and 2,4-D) and listed separately by NASS, we have combined the percent area treated figures for these different forms of the same basic herbicide. The 28% figure for S-(metolachlor) in corn is the sum for S-metolachlor (27%) and metolachlor (1%). We use the most recent data available for corn (2014) and soybeans (2012).

and/or soybeans, and popular with farmers – would be the most likely candidates to substitute for glyphosate in the event of glyphosate usage restrictions. We then consulted typical labels for formulations of the various herbicides to identify those that listed any milkweed species, and common milkweed in particular, as among those it controlled or suppressed.

Of the 20 corn and soybean herbicides on the lists,[3] the labels for only two individual active ingredients claimed control and/or suppression of common milkweed: glyphosate (Roundup WeatherMAX) and dicamba (Clarity). According to the label for Classic (chlorimuron-ethyl), a tank-mixture of this product with thifensulfuron (Harmony GT XP) controls small common milkweed plants up to 6" tall. Three other herbicides either control (2,4-D 2-EHE and sulfentrazone) or suppress (fomesafen) other species of milkweed, but make no claims for common milkweed.

In the event of glyphosate usage restrictions, would increased use of any of these herbicides cause comparable damage to common milkweed and hence, as EPA fears, result in "little or no improvement for monarch butterflies"? It is possible that farmers would make greater use of a mixture of chlorimuron-ethyl + thifensulfuron, which like glyphosate are herbicides that are used primarily post-emergence. However, this mixture is labeled only for control of very small (< 6") common milkweed and is apparently not effective on more mature plants (DuPont Classic Herbicide label). Extremely widespread resistance of important weeds like waterhemp, Palmer amaranth, other pigweed (i.e. *Amaranthus*) species, and kochia to ALS inhibitors (the class to which both belong) also reduces the utility of these herbicides as glyphosate substitutes.[4] Increased use of fomesafen is still less likely to kill milkweed as glyphosate does, because fomesafen is a post-emergence contact herbicide that kills only leaf tissue it comes into contact with; unlike glyphosate, it does not have systemic activity and so is not translocated to root tissue (NDSU undated). This explains why it is labeled only for suppression and not control of certain milkweed species (although not common milkweed) (Solera Fomesafen 1.88 Herbicide Label).[5] Sulfentrazone is a pre-emergence, soil-applied, residual herbicide that is taken up by roots and is labeled for control of honeyvine but not common milkweed (FMC Spartan 4F Label). Sulfentrazone has seen increasing use in soybeans as a complement to post-emergence glyphosate to assist in control of glyphosate-resistant weeds (Krausz and Young 2003).

[3] Because glyphosate, 2,4-D and S-(metolachlor) appeared on both corn and soybean lists, the total number is herbicides is 20 rather than 23.
[4] See http://weedscience.org/summary/moa.aspx?MOAID=3.
[5] According to the label: "Even though Fomesafen 1.88 Herbicide and crop competition can suppress perennial weeds for a growing season, the rootstocks will continue to live and reestablishment will occur in subsequent years."

Top Eleven Corn Herbicides (2014) by Area Treated

Herbicide	% Area Treated	Class	Milkweed Species	Common Milkweed
Glyphosate	77	EPSPS inhibitor	Milkweed (generic and common)	X
Atrazine	55	PS-II inhibitor		
Acetochlor	29	Seedling shoot growth inhibitor		
S-(metolachlor)	28	Seedling shoot growth inhibitor		
Mesotrione	27	HPPD inhibitor		
Clopyralid	13	Synthetic auxin		
Flumetsulam	13	ALS inhibitor		
Isoxaflutole	11	HPPD inhibitor		
Dicamba	10	Synthetic auxin	Common, honeyvine, Western whorled	X
Thiencarbazone-methyl	9	ALS inhibitor		
2,4-D	8	Synthetic auxin	Climbing	

Top Twelve Soybean Herbicides (2012) by Area Treated

Herbicide	% Area Treated	Class	Milkweed Species	Common Milkweed
Glyphosate	98	EPSPS inhibitor	Milkweed (generic & common)	X
2,4-D	15	Synthetic auxin	Climbing	
Chlorimuron-ethyl	11	ALS inhibitor (SU)	Common, but only < 6" tall in combo w/ thifensulfuron	X
Flumioxazin	11	PPO inhibitor		
Clethodim	9	ACCase inhibitor		
Fomesafen	8	PPO inhibitor	Climbing & honeyvine (suppress only)	
Sulfentrazone	8	PPO inhibitor	Honeyvine	
S-metolachlor	7	Seedling shoot growth inhibitor		
Imazethapyr	5	ALS inhibitor (IMI)		
Thifensulfuron	5	ALS inhibitor (SU)		
Cloransulam-methyl	4	ALS inhibitor		
Saflufenacil	4	PPO inhibitor		

Source: USDA NASS Agricultural Chemical Usage surveys for corn (http://www.nass.usda.gov/Data_and_Statistics/Pre-Defined_Queries/2014_Corn_and_Potatoes/index.asp; for soybeans (http://www.nass.usda.gov/Data_and_Statistics/Pre-Defined_Queries/2012_Soybeans_and_Wheat/index.asp).

Even assuming this herbicide is effective on common milkweed, because "[s]ulfentrazone applied postemergence (POST) causes rapid desiccation and necrosis of plant tissue" (Krausz and Young 2003), it would not serve as a substitute for post-emergence glyphosate to kill weeds that emerge later in the season.

Among the synthetic auxin herbicides, clopyralid (Stinger) is labeled for suppression of perennial weeds in general, but not any species of milkweed. Zollinger (1998) found that June application of Curtail herbicide (clopyralid + 2,4-D) provided extremely little control of common milkweed by the fall of the same year (13%), and still less control (6%) the following year. 2,4-D (2-EHE) is labeled for control of climbing milkweed, while dicamba (Clarity) is labeled for suppression/control of three milkweed species, including common milkweed. CFS has summarized some of the major studies on the efficacy of 2,4-D and dicamba on common milkweed in CFS Monarch Report (2015), Section 5.1.3.2. In brief, both herbicides provide in-season suppression and some milkweed stand reduction the year following treatment. Dicamba is generally more effective than 2,4-D, and higher rates achieve somewhat greater stand reductions (on the order of 30% to 60%) in the year following treatment than lower rates (see also Bhowmik 1994, Table 5; and Zollinger 1998). Though neither rivals glyphosate, both have been recommended for common milkweed suppression in situations where glyphosate use is infeasible (Loux et al. 2001).

Among corn and soybean herbicides little used at present, glufosinate is one potential candidate for substitution of glyphosate, especially in view of the fact that glufosinate-resistant varieties of corn and soybeans are currently available, permitting the post-emergence mode of weed control favored by many farmers, especially in soybeans. However, the fact that glufosinate is so little used despite the availability of these glufosinate-resistant crops (1% of corn acres in 2014, 3% of soybean acres in 2012[6]) suggests it may nevertheless not be a preferred substitute for glyphosate. In any case, it is interesting to note that the label for one typical glufosinate product (Liberty 280 SL) claims suppression of common and honeyvine milkweed, although only when glufosinate is combined with "tank mix partners" or applied twice, sequentially. However, the label explicitly claims only suppression rather than control of common milkweed, making it equivalent to most non-glyphosate herbicides that only injure above-ground plant tissue without killing milkweed at the root. This is understandable given the fact that glufosinate is in effect a contact herbicide with very little translocation, making it in general weak on perennial weeds. Controlled tests of the efficacy of glufosinate and glyphosate on five weeds (three annuals and two perennials) found that "common milkweed was most tolerant of glufosinate…" and "[r]egrowth of the perennial weeds horsenettle and common milkweed was significantly less with glyphosate treatments versus glufosinate treatments" (Pline 1999).

[6] See USDA NASS Agricultural Chemical Usage references in the Sources for the tables above.

To sum up, there is a consensus in the weed science community that mature common milkweed tolerates non-glyphosate herbicides used in corn and soybean production. The only two herbicides that controlled studies have found to have efficacy rivaling that of glyphosate are no longer in use (amitrole) or not labeled for corn or soybeans (picloram). The great majority of leading corn and soybean herbicides in use today are not labeled for control of common milkweed or any other milkweed species. Of those few that do have milkweed species activity (most of them on species other than common milkweed), they are either far less effective than glyphosate, or would not be suitable substitutes for it. 2,4-D and dicamba stand out as two of the more milkweed-damaging non-glyphosate herbicides used in corn and soybean production, however neither rivals glyphosate's ability to kill milkweed. Thus, EPA's concern that restrictions on glyphosate use would lead to greater use of other herbicides that are equally damaging to common milkweed, and hence result in "little or no improvement for monarch butterflies," is unfounded.

Impact of new herbicide-resistant crop systems on common milkweed and monarchs

Negative impacts on milkweed species plants and monarchs will be exacerbated with the unregulated introduction of new herbicide-resistant (HR) crops (corn, soybeans and cotton), particularly those that are resistant to both glyphosate and either 2,4-D or dicamba. CFS has provided an in-depth, documented discussion of these impacts in Section 5 of CFS Monarch Report (2015).

In brief, it is anticipated that these new HR crops will be widely adopted by farmers with weeds resistant to glyphosate, which infest over 60 million acres of U.S. cropland. Developed by Dow and Monsanto, these HR crops are designed as crop systems, to be used in tandem with dual herbicide products comprising 2,4-D+glyphosate (Dow's Enlist Duo) or dicamba+glyphosate (Monsanto's Roundup Xtend). Based on the application regimes proposed by Dow and Monsanto, these crop systems will involve one to three high-rate applications of the dual herbicide products per season. Glyphosate use will continue at current high levels, accompanied by large increases in the use of 2,4-D/dicamba and herbicides overall. For instance, Dow and USDA have projected a three- to seven-fold increase in agricultural use of 2,4-D, depending on the extent to which 2,4-D/glyphosate-resistant crops are adopted. The combined use of glyphosate with 2,4-D or dicamba will continue to eradicate milkweed from cropland with roughly the same efficiency as glyphosate alone. Ohio State agronomists have recommended combined use of glyphosate and 2,4-D for control of common milkweed (Loux et al. 2001), and Enlist Duo is labeled for control of common milkweed. The glyphosate+dicamba product will be similarly and perhaps more lethal.

High-level use of 2,4-D and dicamba with these crop systems will have further adverse impacts on monarchs unrelated to killing milkweed (this subject is also discussed in Section 5 of CFS Monarch Report 2015). Monarch adults feed on the nectar of flowering plants, which they require for reproduction and their strenuous migration. Most flowering plants are broadleaves targeted by synthetic auxins like 2,4-D and dicamba. Both herbicides are prone to spray and vapor drift, and will be applied in much higher quantities, over a larger span of the growing season, than was possible before the advent of these HR crop systems. 2,4-D and dicamba drift will occur more frequently, at greater distances, and over a longer period of time, causing greater damage to flowering plants in the vicinity of treated fields, and thus reduce nectar resources for monarch adults. The higher temperatures coinciding with later application will exacerbate vapor drift in particular; vapor drift is less predictable, harder to control, and often occurs at much greater distances than spray drift. Although Enlist Duo and Roundup Xtend are said to contain less volatile forms of 2,4-D and dicamba, respectively, any drift mitigation thus achieved would be more than counterbalanced by the large increase in amounts applied, and their application later in the season when temperatures are higher.

With respect to these HR crop systems, then, EPA's concern that glyphosate use restrictions would lead to increased use of other herbicides that are just as detrimental to milkweed and monarchs is misplaced. Because these HR crops will be preferentially treated with dual herbicide products comprising glyphosate ***and*** 2,4-D or dicamba, restricting glyphosate would have the beneficial effect of simultaneously restricting the use of their companion auxins, which as discussed above pose clear risks to monarch nectar resources.

Restrictions on the use of glyphosate-containing products could take the form of frequency use reductions, which are in any case needed to stem the rapid evolution of weed resistance to glyphosate and multiple herbicides. Frustrated by this development and the complete lack of any meaningful action in response, six weed scientists recently stated that: "The time has come to consider herbicide-frequency reduction targets in our major field crops" (Harker et al. 2012). Shaner and Beckie (2014) likewise recognize the need for "reasonable [herbicide-]frequency use intervals" to forestall evolution of weed resistance. Thus, glyphosate use restrictions that slow milkweed loss would at the same time provide important agronomic benefits. Restrictions could also take the form of limits on the acreage that can be treated with glyphosate-containing herbicide products, at farm- or county-level.

Preservation of remnant milkweed in cropland not enough, restoration required

As discussed above, careful surveys in Iowa corroborated by data from other Midwestern states shows that only 1% of the common milkweed present in Midwest corn and soybeans fields in 1999 remains today. The monarch's precarious situation has resulted largely from this near-eradication of common milkweed from cropland, as also supported by modeling studies showing the disproportionately negative impact on monarch reproduction of emptying the cropland matrix of milkweed. Thus, preservation of remnant milkweed populations in cropland is not sufficient to ensure the monarch's survival. Restoration efforts are also required.

While it is beyond the scope of these comments to address in detail viable strategies for milkweed restoration to cropland, a few observations are appropriate. First, such an objective should not be regarded as inconsistent with the weed management needs of farmers. Common milkweed co-existed with highly productive agriculture throughout the 20th century, and even when it was more prevalent, common milkweed rarely represented a threat to crop yields. Below we reproduce Section 2.2.5 of CFS Monarch Report (2015).

> 2.2.5 PREVALENT BUT LOW-IMPACT WEED
> Despite its wide distribution and ability to survive in row crops, common milkweed has rarely posed a threat to crop yields. An Iowa agronomist reports that: "Although common, [common milkweed] rarely reaches population densities that impact crop yield and typically does not drive weed management decisions" (Hartzler 2010). Wisconsin agronomist Jerry R. Doll surveyed perennial weeds in Wisconsin from 1977 to 1994, and found that "milkweeds were rated as only a slight problem in the majority of both tilled and no-till fields" and "[i]n my more than 20 years as an extension weed scientist, rarely has anyone described a situation where milkweeds were an economic problem and sought advice on how to control them. Travels around the state during this period confirm that milkweeds are commonly found but seldom reduce crop yields" (Doll 2001).
>
> One good measure of a weed's importance is the attention it receives from weed scientists, whose research tends to focus on agriculturally damaging weeds. Table 1 shows that common milkweed has generated very little research interest in the weed science community relative to other weeds, indicative of its low impact.

Species	Common name	Citations	
		1950 to 1995	1996 to 2013
Asclepias syriaca	Common milkweed	7	7
Chenopodium album	Lambsquarters	55	205
Cyperus esculentus	Yellow nutsedge	67	159
Sorghum halepense	Johnsongrass	113	123
Abutilon theophrasti	Velvetleaf	124	243
Amaranthus palmeri	Palmer amaranth	12	148
Setaria glauca	Yellow foxtail	5	19

Table 1. Research interest in common milkweed versus more damaging weeds.
Results of Web of Science searches for the cited date ranges in the journals Weed Science, its predecessor Weeds, and Weed Technology on June 26, 2014. Topic: "Asclepius syriaca" – Publication: "Weed Science OR Weeds OR Weed Technology." Similar searches conducted for other named weeds.

Given the radical reductions of common milkweed in cropland over the past 15 years, there is thus considerable scope for milkweed restoration to cropland at levels that do not pose any appreciable threats to crop yield.

One promising strategy for milkweed restoration would be vigorous promotion of milkweed-containing prairie strips integrated into cropland.[7] USDA's Natural Resources Conservation Service is already promoting milkweed-containing pollinator habitat in the context of the Conservation Reserve Program (USDA NRCS 2011). While deserving of support, milkweed restoration efforts that focus exclusively on CRP lands and other areas outside of actively farmed cropland are not sufficient for monarch restoration for several reasons. First, milkweed in CRP lands tend to be present in fewer and denser, highly aggregated patches (Hartzler and Buhler 2000, Table 1), while more uniformly distributed milkweed as isolated plants or small patches typical of cropland are of much greater value to monarchs. Second, land enrolled in the Conservation Reserve Program has declined dramatically since 2007, and will continue to decline over the foreseeable future (CFS Monarch Report 2015, Sections 4.5.2 to 4.5.4).

In contrast, integration of milkweed-containing prairie strips in cropland would result in lower-density and more uniformly distributed milkweeds that provide much greater benefits, plant for plant, for monarch reproduction. Prairie strips also provide numerous other agronomic benefits. In a four-year, watershed-scale study in Iowa, Helmers et al. (2012) found that prairie strips integrated into no-till corn/soybean rotations effected dramatic reductions (by an average of 96%) in soil erosion versus no-till corn/soybeans without prairie strips, which also implies reductions in fertilizer runoff that impairs water quality. This is just one of many innovative farming practices that are urgently needed to make agriculture once more compatible with milkweed and monarch survival.

Conclusion

Preservation and restoration of milkweed to cropland is an indispensible component of monarch recovery efforts. Because glyphosate is unique among field crop herbicides in its efficacy against common milkweed, glyphosate usage restrictions are urgently needed. Increased use of other herbicides that might occur would not, as EPA fears, result in little or no improvement for monarchs. Milkweed restoration to cropland can be effected through vigorous promotion of innovative farming practices, such as prairie strips, that provide multiple additional benefits as well, such as reducing soil erosion and nutrient runoff.

[7] For example, see http://www.leopold.iastate.edu/strips-research-team and http://www.leopold.iastate.edu/strips-research-team.

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(Citations in excerpts from CFS Monarch Report 2015 not included, please refer to the report. Documents cited below also submitted, files named by first author and year.)

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