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Productive engagement with agriculture essential to monarch butterfly conservation

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Since the Green Revolution, the increasing productivity of agriculture has largely been driven by intensification, i.e. the use of monocultures of selected crop varieties coupled with increased applications of fertilizers and pesticides to increase crop yield. An unfortunate side effect of intensification is that agricultural landscapes around the globe have become increasingly simplified [1]. Where many different crops were previously grown and interspersed with noncrop areas, it is now common to find large areas consisting of only a few crops with little uncultivated habitat. This simplification of agricultural landscape structure is a global phenomenon and has led to documented losses in the diversity of plants, arthropods, birds, and mammals, and associated loss of ecological functions and services [2].

Intensification in the management of key crops in the Midwestern US has been implicated in declines of the Eastern migratory monarch butterfly, *Danaus plexippus* [3]. This once common butterfly is one of the most recognizable and beloved insects in North America. Noted not only for its beauty, the annual fall migration of adult monarchs from the northern US and Canada to their overwintering sites in the forested highlands of Mexico has captured the imaginations of many generations. However, this phenomenon is in danger as overwintering populations of monarchs in Mexico—measured by the area of forest covered by their overwintering aggregations—have decreased precipitously in the past few decades, to as little as 0.67 ha in the winter of 2013–14 [4]. While the reasons for the monarchs' decline are multifactorial, the widespread adoption of herbicide-resistant corn and soybeans has been implicated in the loss of milkweeds—their required larval food plant—from Midwestern crop fields, resulting in a shortage of critical larval habitat in the key summer breeding grounds. In response to the recent declines, in 2016, the US set a goal of supporting a minimum of 6 ha of overwintering aggregations by 2020 as a means to ensure a sustainable population of the Eastern migratory monarch butterfly.

In their recent analysis, Thogmartin *et al* [5] asked, what land-use sectors and levels of adoption would be required by stakeholders to replace the estimated 1.3 billion milkweed stems lost from Midwestern US croplands and reach the 6 ha goal? Using a combination of GIS and statistical modeling they created land cover maps which characterize the amount and distribution of five land use sectors: protected areas, Conservation Reserve Program lands (CRP), urban/suburban lands, right of ways, and agricultural lands. Then, based on the expert opinion of the authorship, they estimated rates of adoption of milkweed restoration practices and resulting increases in milkweed stems per land use sector. After exploring over 200 scenarios combining different levels of adoption of milkweed restoration by different sectors, they found that contributions of current agricultural lands to monarch habitat were essential to reaching the 6 ha overwintering goal. Moreover, due to the enormous footprint of agriculture in the region, they estimate that even with high contributions from other sectors, attaining the 6 ha goal would require converting approximately half of all marginal cropland in the Midwest—over 25 000 km² or about the size of Vermont—to 'CRP-like' conditions, i.e. mixed species grasslands containing milkweeds and nectar plants. This is likely a formidable task, considering that voluntary participation in CRP is declining.

While considerable uncertainties remain—for example estimates of the additional milkweed stems needed to reach the 6 ha goal vary by +23%—the study suggests that vast amounts of land in the Midwest will need to be restored to monarch habitat and that the participation of agriculture is essential to success. This raises several key questions. How do farmers view the issue and under what if any, conditions would they be willing to convert land to monarch habitat? Also, what types of habitat restoration may be most productive?

The authors focus on conversion of marginal croplands to monarch habitat, i.e. fields or parts of fields with low yield potential and therefore likely to be unprofitable. However, farmers are currently cropping

these lands and have their reasons for doing so. Understanding those factors will likely be key to any productive engagement of agriculture in monarch conservation. For example, even the term ‘marginal cropland’ may present a barrier if farmers perceive that as a negative reflection on their land quality or current stewardship practices. Participation of social scientists in understanding how farmers view their lands and stewardship practices will likely be key to successful engagement of agriculture in monarch conservation.

What types of monarch habitat to restore also remains a key unanswered question. In their model, the authors use estimates of monarch egg to adult survival typically observed from perennial grassland habitats. However, perennial grasslands harbor high populations of monarch predators that are far less abundant in annual croplands. Studies have shown that predation of Lepidopteran eggs over 48 h is significantly higher in perennial grasslands than in corn (mean = 47% versus 13% respectively) [6]. Moreover, female monarchs appear to lay up to 3.9 fold more eggs on milkweed in corn compared to milkweed in associated non-crop habitats [7]. While it is unclear if this is a true preference for oviposition on milkweed in corn, or a lack of predation in corn resulting in more eggs observed per unit time. In either case, it is likely that milkweed stems in crop fields may yield more adult monarchs than those in grasslands. Finding ways to restore milkweed in crop-like habitats may be a particularly productive approach.

While the outlook for the Eastern monarch remains uncertain, they are a resilient species. Overwintering population estimates in Mexico commonly doubled or tripled from one year to the next, demonstrating

that under appropriate conditions the species can increase dramatically. Focused efforts to enhance habitat throughout the monarch range are underway and the support of all sectors is needed, especially agriculture.

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