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MONARCH BUTTERFLIES USE REGENERATING MILKWEEDS FOR REPRODUCTION IN MOWED HAYFIELDS IN NORTHERN VIRGINIA

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ABSTRACT. The effects of mowing milkweeds in areas visited by monarch butterflies (*Danaus plexippus* L., Nymphalidae) were studied by counting the eggs and larvae on regenerating common milkweeds (*Asclepias syriaca* L., Apocyanaceae) in five adjacent mowed hayfields in northern Virginia in late summer 2015. At the same time monarch larvae were counted on mature senescent common milkweeds in unmowed areas adjacent or near to the mowed hayfields. Milkweeds supported populations of immature monarchs in both habitat types with initially many eggs and early instars found on regenerating plants in the mowed hayfields while late instars dominated the unmowed older milkweeds. As September proceeded, the censuses revealed an increase in the numbers of late instars on the mowed regenerating milkweeds whereas the abundance of larvae declined sharply on the older senescing milkweeds, many of which had lost all or most of their leaves. The study showed that late season mowing of hayfields provided adult female monarch butterflies with rejuvenated resources for reproduction during a time when senescent milkweeds were becoming unsuitable for the monarch larvae. Our findings have implications for managing land in ways to benefit monarchs and for mitigating the widespread decline of milkweeds, although the research raises several caveats and more needs to done to measure the fitness of monarch adults that are produced late in the flight season of the butterfly.

Additional key words: extension of breeding season by mowing, milkweed regeneration, monarch butterfly conservation

Monarch butterflies (*Danaus plexippus*) have experienced a dramatic population decline over the past two decades and various factors have been proposed as causes of this decline. Among the possible factors is (1) degradation of the Mexican high elevation forests of Oyamel fir (*Abies religiosa*, H.B.K., Pinaceae) where the monarchs overwinter (Brower et al. 2012, Vidal & Rendon-Salinas 2014, Brower et al. 2016) despite some success in protecting and reforesting critical overwintering habitat (Vidal et al. 2014). Another major contributor to monarch declines is (2) the widespread application of herbicides to herbicide-tolerant agricultural plants in the United States with the consequent loss of farm field milkweeds (Pleasants & Oberhauser 2012). Moreover, monarch butterflies are also affected by (3) the loss of extensive milkweed habitats in the United States to housing developments, industrial expansion, and the reduction of the acreage in the USDA Conservation Reserve Program (Taylor 2014). Flockhart et al. (2015) considered the losses of milkweed breeding habitat in the United States to be the key to understanding the population collapse of the monarch. As Taylor emphasized, government entities, conservationists, and the general public in the United States should try to restore milkweed populations so that the phenomenon of monarch butterfly migration will persist.

Increased awareness of monarch decline, highlighted by submission of a petition to the US Fish and Wildlife Service to designate the monarch as a threatened species (Crouch et al. 2015), has contributed to a focus on the possible causes of and suggested mitigations of the species' collapse. For example, Freese & Crouch (2015) and Mirocha (2015) have documented the massive increase over the past two decades in acreage planted with "Roundup Ready" corn and soybean crops that are genetically modified to resist the herbicide glyphosate that kills milkweeds and nectar source plants. The loss of milkweed has led several organizations (e.g., Journey North, Monarch Joint Venture, Monarch Watch, The Xerces Society) to encourage the planting of milkweeds in home yards and gardens, along right-of-ways, as well as to question the frequent mowing of roadside verges that often support milkweed populations.

In addition, Fischer et al. (2015) and Baum & Mueller (2015) have shown that appropriately timed mowing during the growing season can lead to the

regeneration of milkweeds, which provides a fresh supply of food for larval monarchs later in the season when most of the naturally growing milkweeds have senesced. It is this last possibility that we explore in northern Virginia.

MATERIALS AND METHODS

The abundance of monarch butterfly eggs and caterpillars were monitored by the first author in five large mowed hayfields at Monterey Farm, a 200+ acre farm in Fauquier County, VA, near 38°52'26"N, 77°54'21"W at approximately 165 m elevation. Most of the acreage of the farm is hayfield, and haying of the fields took place from 8 to 16 August 2015. The farm owners have an arrangement with a hay cutter that specifies a single cutting per summer and the retention of unmowed buffer strips between wooded areas and the hayfields.

On 30-31 August, regenerating common milkweeds, *Asclepias syriaca* L., in mowed areas were searched for monarch eggs and larvae, and twelve patches of unmowed mature milkweeds were also examined. Counts were made every five days from 30 August to 23 September, giving a total of six censuses, each requiring 90–120 min. The unmowed patches in the buffer strips were close to or adjacent to the mowed areas that were inspected and so could be readily monitored. No attempt was made to check the same plants in the hayfields on successive censuses. The main purpose of the study was to document whether the regenerating milkweeds attracted reproductive females by observing ovipositing females and larvae in this habitat. The hayfield milkweeds were largely *A. syriaca* but also present was the significantly less common honeyvine milkweed (*Cynanchum* leave (Michx.) Pers.) as well as very uncommon (in the hayfields) butterfly weed (*A. tuberosa* L.). In addition, the censuses were designed to reveal if and when the unmowed common milkweeds near the hayfields were simultaneously utilized by monarchs. Observations made as the season progressed were done to establish whether any caterpillars in the hayfields developed into mature larvae when the larvae were no longer present on the mature milkweeds in the buffer zones. This would demonstrate that the reproductive season of the butterfly had been extended by cutting the hayfield grasses and weeds.

RESULTS

Common milkweeds had begun regenerating in large numbers in the mowed hayfields by 24 August, 16 days after haying had begun and just a few days after rains on 20 and 21 August had drenched the fields. By 1 September, the milkweeds had grown substantially so that many hundreds were already between 25 cm and 50 cm in height, much taller than the grasses, which were slower to regrow (Fig. 1).

Between 3 and 16 September, observations of the mowed hayfields yielded 15 records of ovipositing females, three of which were laying on the leaves of *C. leave*, demonstrating that both regenerating milkweeds

FIG. 1. (**a**) Young regenerating milkweeds, *Asclepias syriaca*, in the mowed hayfields (photographed on 24 August 2015). (**b**) Plants of *A. syriaca* that have regrown rapidly (photographed on 1 September 2015). (**c**) A monarch butterfly egg laid on a leaf of the honeyvine milkweed (*Cynanchum laeve*) (photographed on 3 September 2015). Photos: J. Alcock.

did attract adult monarch females. On 17 September two females perched on larval foodplants and bent their abdomens into the egg-laying position but did not oviposit on the selected plants. On 18 September and afterwards, no females were seen exhibiting oviposition behavior in the mowed areas; however, one egg was found in the mowed hayfields on 23 September.

Fig. 2 presents the results of the six censuses of the mowed and the adjacent patches of unmowed milkweeds. Although the milkweeds in the unmowed patches were senescent in early September, their yellowed, tattered leaves were nevertheless being eaten by substantial numbers of late instar caterpillars at the outset of the study (Fig. 3). By the later censuses the unmowed milkweeds were occupied by only a few larvae of any size. In contrast, the regenerating milkweeds in the mowed field soon became populated by early instar larvae, so that late instar caterpillars were present on the regenerating milkweeds through 23 September. The significant comparisons in these data are between the numbers of juvenile stages in the two habitat types on the same date.

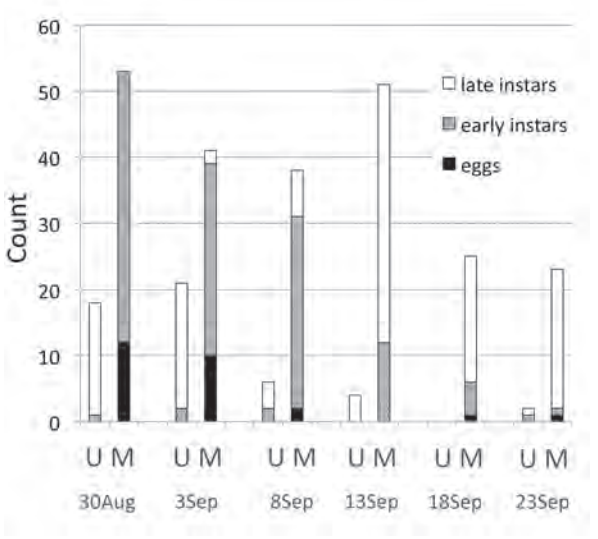

Fig. 2. The number of eggs, small larvae (first, second and third instars), and large larvae (fourth and fifth instars) found on senescent *Asclepias syriaca* in unmowed borders to the hayfields in comparison to the numbers of those found on regenerating *A. syriaca* and honeyvine (*Cynanchum laeve*) in the mowed hayfields. Six censuses were conducted from 30 August to 18 September 2015.

Discussion

The consequences of using mowing to promote regeneration by the common milkweed were examined by Fischer et al. (2015) in upstate New York during an experiment in which plots of milkweed-rich fields were mowed at three different times while control strips were left unmowed. The experimental and control strips were then monitored for milkweed regeneration and their use by monarch butterflies. The authors reported that milkweeds in the mowed strips did indeed regenerate and attract adult female monarchs but only if the mowing was done in July, not in August, to give time for the plants to regrow at this more northerly latitude. Therefore, the timing of mowing was critical to monarch reproduction. As the authors noted, the effectiveness of mowing as a conservation measure almost certainly depends not only on when the mowing occurs but on local phenology at that geographic location and the species of milkweeds involved.

The conclusion of Fischer and co-authors is supported by the current study in northern Virginia in which mowing of hayfields was not completed until mid-August and yet the milkweeds did regenerate sufficiently at this lower latitude to be used by ovipositing female monarchs well into September. The young regenerating milkweeds were quickly discovered in mid-August by the butterflies, and relatively large numbers of eggs and early instar larvae were quickly produced. In addition, females also had access to large numbers of the honeyvine, another perennial milkweed that regenerated strongly in the mowed fields. In contrast, the unmowed areas provided acceptable food for monarch larvae only early in the study even though the patches of *A. syriaca* at this time (mid-August) were dominated by senescent plants with yellowed and damaged leaves. By mid- to late September these senescent milkweeds often were leafless, and as a result, few caterpillars were found on them. At this time, surviving caterpillars in the mowed hayfields were primarily large, late-instar larvae. These results suggest that monarch reproduction in northern Virginia may benefit from mowing portions of overgrown fields with common milkweeds fairly late in the season while also maintaining the senescent common milkweeds in the borders to these fields or in places nearby. In the unmowed patches, mature monarch larvae were present in substantial numbers through 3 September whereas those in the mowed field were present through 23 September; that is, the breeding period was extended by nearly three weeks. Mowing in New York, about 3° latitude farther north than this Virginia site, extended the breeding period for at least two weeks, a similar length of time. A primary difference between the results in the NY and VA sites was that mowing in NY on 17 August produced very little milkweed regrowth, whereas mowing on the same date in the more southerly Virginia site did result in substantial new

FIG. 3. An unmowed patch of the common milkweed (*Asclepias syriaca*) photographed on 23 August 2015 at a time when the senescent plants still possessed many yellow, damaged leaves most of which had fallen off by mid-September. (INSET) A fifth instar monarch caterpillar that was feeding on the damaged leaves of an old milkweed growing in an unmowed patch photographed in September 2015. Photos: J. Alcock.

growth. In the future it would be valuable to conduct mowings at similar times across several latitudinally different sites to determine the degree to which the timing of one or more cuts can extend the geographic breeding windows. Much more work, however, remains to be done to determine the best mowing regimes at different latitudes.

Nevertheless, there are now two studies spanning 500 km (approximately 3°) of latitude indicating that mowing of late season milkweeds has the potential to provide fresh plants for ovipositing females, resulting in an extended growing season for the larvae that feed upon the regenerated milkweeds. If properly timed mowing were instituted on a broad scale, the current widespread loss of milkweeds suitable for monarch caterpillars caused by the increasing use of herbicides on household landscapes, commercial agricultural crops, roadsides, and power and gas line right-of-ways might be ameliorated to some degree. As seen in this study, however, management of land for increased use by monarchs may effectively combine regenerating milkweeds in mowed areas with uncut milkweeds in nearby unmowed habitat, thereby providing continuously available larval hostplants during mid to late summer extending the window of breeding.

There are, however, several caveats raised by the present study. The first is whether the loss of eggs and caterpillars during the mowing of the fields is compensated by reproduction on the regenerating milkweeds. As we have shown, the breeding season is extended but we do not know whether the offspring of monarchs produced during the lengthened reproductive can migrate successfully to Mexico. As Batalden and Oberhauser (2015) have demonstrated, senescing milkweed leaves are one of a constellation of migratory stimuli and their replacement by regenerating young milkweeds could slow adults from entering reproductive diapause and migrating. Another caveat is

that an extended breeding season could increase the possibility of infection by the protozoan parasite *Ophryocystis elektroscirrha* (Bartel et al. 2011, Satterfield et al. 2015). The use of regenerating milkweeds could in other words be an ecological trap for migrant adults that are induced by the availability of fresh milkweed plants to reproduce at a time when they normally would have little or no chance of increasing their production of viable young. Resolving these points is essential before we can say with certainty that the late season haying of fields with mature milkweeds provides a net benefit for monarch butterflies. However, this study and that of Fischer et al. (2015) effectively document that properly timed mowing can extend the time available for monarchs to reproduce.

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