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Enhancing Monarch Butterfly Reproduction by Mowing Fields of Common Milkweed

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Abstract.—To determine if manipulation of milkweed's natural phenology would increase monarch reproduction, strips were mowed in fields in upstate New York in early Jul., late Jul., and mid Aug., 2006, for comparison to an unmowed control. Common milkweed (*Asclepias syriaca*) was then monitored from Jul. 29 through Sep. 24 for plant height, vegetative stage, level of herbivory, condition, monarch eggs and larvae, and the position of eggs on leaves and stems. We found mowing on Jul. 1 and 24 spurred the regrowth of milkweed and sustained a more continuously suitable habitat for monarch oviposition and larval development than the control. Mowing on Aug. 17 proved too late for recovery of the milkweeds. Significantly more eggs were laid on the fresh resprouted milkweeds than on the older and taller control plants. In the strips mowed on Jul. 1, peak egg densities occurred in late Jul.; in the strips mowed in late Jul., peak egg densities occurred in early to mid Aug. Depending on the timing of mowing, the milkweed plant height, developmental stage, and condition differed. As predicted, the mowing of fields with *Asclepias syriaca* extended the monarchs' breeding season and increased overall monarch reproduction. However, timing of mowing was critical and must be determined empirically for different milkweed species and in different locations. This mitigation procedure could be fostered along roadsides, along edges of fields and pastures, in USDA conservation reserve program lands, and along power lines and other rights of way.

Introduction

Monarch butterflies (*Danaus plexippus L.)* east of the Rocky Mountains migrate each fall to high-altitude oyamel fir forests (*Abies religiosa* H.B.K.) in Mexico, return the following spring to the southern United States, and establish a new generation by laying their eggs on milkweeds of the genus *Asclepias*. This first spring generation then continues the migration northeasterly into the midwestern and northeastern states, where two or more additional generations develop over the spring and summer (Malcolm *et al.*, 1993; Brower, 1995; Howard and Davis, 2004; Miller *et al.*, 2011). The monarch migration has been designated an endangered biological phenomenon (Brower and Malcolm, 1991) in which the species as a whole may not be in jeopardy, but a major aspect of its biology, the migration of the entire eastern North American population to one small area in Mexico, is at risk. Given the

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precipitous decline of the eastern population of the monarch butterfly over the past decade (Brower *et al.*, 2012; Rendon and Tavera-Alonso, 2014), due in large part to the elimination of milkweeds by industrialized agriculture (Pleasants and Oberhauser, 2012), we asked if a timed mowing regime to enhance the regrowth of milkweeds could increase monarch numbers during their mid to late summer breeding time in two New York fields.

It has long been known the suitability of ephemeral butterfly habitats can be increased through periodic mowing that maintains or returns them to an appropriate successional stage (Marsh, 1888; Dethier and MacArthur, 1964; Kulman, 1977). More particularly, Borkin (1982) reported an extra late-summer generation of monarchs feeding on *Asclepias syriaca* L. in a mowed field in Wisconsin, and similar enhancement of breeding has been reported in Maryland by Gibbs (2010).

To explore how monarch reproduction could be enhanced by promoting new growth of milkweeds, we experimentally mowed sections of two fields containing *A. syriaca* and subsequently monitored the plants for the presence of monarch eggs and larvae. The experimental protocol included mowing at three different times during the summer and comparing milkweed growth and monarch reproduction among the three experimental areas and an unmowed control area. We predicted: (1) we would find full regeneration of mowed milkweeds; (2) monarch eggs and larvae would occur at higher density on the younger regrowing milkweed leaves; and (3) the timing of mowing would be critical for increasing monarch reproduction.

MATERIALS AND METHODS

STUDY SITES

Milkweed growth and the density of monarch eggs and larvae were monitored in two fields in Columbia County, New York, from Jul. 29 through Sep. 24, 2006. The field sites supported substantial populations of common milkweed, *A. syriaca,* and had not been treated with herbicides. The first field was at Braley's Farm (BF) (1.5 ha, 42°21′15″N, 73°35′01″W, elevation 150 m), and the second field (18 km distant) was at the Greenport Conservation Area (GC) (8.1 ha, 42°16′24″N, 73°46′21″W, elevation 36 m), which is owned and managed by the Columbia Land Conservancy and Open Space Institute. To compare the density of milkweeds in the two fields before monitoring began, on Jul. 24 ramets were counted in 1 m^2 quadrats at five pace intervals along randomly selected transects until a total of 100 quadrats had been surveyed in each field.

At the BF field, three 4.6 m wide strips, 100 m, 100 m, and 50 m long, and Separated by about 12 m of uncut vegetation, were mowed on Jul. 1 to serve as the early cut site. In the GC field, three parallel 4.6 m wide strips were mowed on Jul. 24 to serve as the intermediate cut site; another three strips were mowed on Aug. 17 to serve as the late cut site; and three strips in an unmowed part of the field served as a control. The three strips in each of the three treatments in the GC field were 15 m, 15 m, and 30 m long, for a total of 60 m per treatment. Strips were approximately 2 m apart. All mowing was with a brush hog to about 0.1 m vegetative height.

Within each 4.6 m wide strip, sampling was conducted from two belt transects that were 1m wide and separated by 2 m; this layout left margins of 0.3 m from the outer edge of each transect to the edge of the treatment strip. With two 1 m wide transects in each strip, sampling therefore took place from 500 m × 1 m in the Jul. 1 cut and from 120 m × 1 m for each of the Jul. 24 cut, the Aug. 17 cut, and the control. More space was available in the Jul. 1 cut; therefore, longer transects were used here to increase the sample size.

The two fields were similar old-field farmland habitats that had been regularly mowed for hay and were similar in topography and composition. Both fields were surrounded by mixed hardwood trees; the BF field had a cornfield to the north and a shrubby old-field to the south, while the GC field had a forb dominated field to the north. Common milkweed, *Asclepias syriaca,* was present in both fields as it commonly is throughout this agricultural area; other herbaceous vegetation in the fields included species of *Arctium, Aster, Chicorium, Cirsium, Daucus, Dipsacus, Solidago, Trifolium, Verbena,* and *Vicia. Rosa multiflora* and *Rubus* sp. were also present. Although having control plots in both fields would have been better, we were able to census an uncut control plot in only the GC field. Because of the overall similarity of the two fields, however, we are confident that any control in the BF field would have resembled the control in the GC field.

MONITORING OF MILKWEEDS, EGGS, AND LARVAE

Milkweed ramets were surveyed every 4–8 d from Jul. 29 to Sep. 24 by walking all transects within the three control and nine experimentally mowed strips. This protocol yielded full monitoring on each of 11 d across the 2 mo study period. The first 200 ramets encountered in the control and Jul. 24 mowed strips and the first 400 ramets encountered in the Jul. 1 mowed strips were inspected for eggs and larvae (the ramet numbers varied a little; *see* Table 1 for exact sample sizes). When an egg was found, the position on the plant (top, middle, or bottom third) was recorded as well as the surface of the leaf on which the egg was located (upper or lower). Larval instars were distinguished by measuring the head capsule size and tentacle lengths as described in Oberhauser and Kuda (1997). At normal summer temperatures, larvae hatch 4–6 d after oviposition; first through fourth larval stages each last 2–5 d; and the fifth stage lasts approximately 7 d (Zalucki, 1982). Because the transects were monitored every 4–8 d, the chance of the same individuals being doubly recorded at the same stage was slight. The height and developmental stage of every milkweed ramet with an egg or larva was recorded. To determine the density of plants where oviposition took place, the number of ramets were counted within square 1 m^2 quadrats centered around each plant on which there was an egg or larva.

To characterize the milkweeds available to the monarchs, a subsample of the milkweed ramets in Table 1 was surveyed for height, plant development stage, herbivory, and condition. Ramets were selected by choosing the plant closest to the left foot of the observer (SJF) at every fifth pace regardless of whether it had an egg or larva. The numbers of ramets tallied for these four parameters are shown in Table 2. The records included ramet height (cm), developmental stage (prebud, bud, anthesis, postanthesis, in fruit), herbivory (estimated as the percent of leaf area missing, 0%, <5%, 5–25%, >25%), and condition (% of leaf area yellow or dying ≤5%, 5–40%, 41–80%, 81–100%).

To determine if tachinid or braconid parasitoids (Oberhauser, 2012) were significantly reducing larval survivorship in the two fields, 38 larvae of instars 2–5 were collected from Aug. 12 to Sep. 24 from both fields and reared in a screened cage. Of the total, four (11%) were parasitized by tachinids, eight died for unknown reasons, and 26 eclosed successfully. Overall parasitism was similar to that found by Oberhauser *et al.* (2007). These rearing results indicate parasitoids were not a major factor in larval survivorship and the larval data in this study are representative of typical monarch butterfly survival and development.

STATISTICAL ANALYSIS

ANOVA was used for analysis of plant heights and densities, with Tukey posthoc comparisons. Additional comparisons of plant height were made by examining the 95% confidence interval error bars; nonoverlapping error bars indicate a difference of $P < 0.05$. The three ordinal scale data sets (developmental stage, herbivory, and condition) were analyzed with Kruskal-Wallis and median tests run with SPSS (IBM Corp., 2012). Chi square

TABLE 1.—Counts of eggs and early and late larvae on milkweeds in the control and two mowed areas, with the number of ramets monitored

	Control				Jul. 1 cut				Jul. 24 cut			
Date	Eggs	Early	Late	Ramets	Eggs	Early	Late	Ramets	Eggs	Early	Late	Ramets
Jul. 29	22	0	0	200	97	64	9	400	[a]			
Aug. 3	8	0	0	200	17	5	4	400	28	0	0	80
Aug. 8	22	7	0	391	21	3	2	400	178	36	0	376
Aug. 12	12	5	0	200	11	10	1	400	59	48	0	200
Aug. 19	5	2	0	200	2	7	2	200	42	42	4	200
Aug. 24	4	0	3	200	0	2	5	400	19	3	3	200
Aug. 31	0	0	1	200	1	4	3	400	5	17	3	200
Sep. 7	0	0	2	200	0	0	0	400	0	4	6	200
Sep. 10	0	0	1	200	0	1	4	400	0	3	5	200
Sep. 17	0	0	2	200	0	1	3	400	0	1	3	200
Sep. 24	0	0	0	200	0	0	2	400	0	0	5	200
Totals	73	14	9	2391	149	97	35	4200	331	154	29	2056
Immatures/ramet				0.040				0.067				0.250

[a] plants not yet recovered from cutting

comparisons were made of egg numbers in the different treatments and the location of eggs on upper or lower leaf surfaces, and on the top, middle, and bottom third of the milkweed stems.

RESULTS

MILKWEED GROWTH AND DEVELOPMENT

Milkweeds in the control area reached maximum height by mid Aug. (Fig. 1). Milkweeds in the mowed areas recovered through the survey period, with plants in the Jul. 1 cut reaching the same average height as the controls by Sep. 17 (Jul. 1 cut, 91.3 ± 10.9 cm, n = 34; controls, 91.2 ± 16.8 cm, n = 32). Milkweeds in the Jul. 24 cut also regrew, but their growth stalled, and by Sep. 24 they had averaged only about half the height (44.7 ± 10.5 cm,

TABLE 2.—The number of milkweed ramets monitored for height, vegetative stage, herbivory, and condition. These plants were a subset of the totals given in Table 1

Date	Control	Jul. 1 cut	Jul. 24 cut
Jul. 29	49	190	[a]
Aug. 3	37	53	63
Aug. 8	56	55	191
Aug. 12	45	49	106
Aug. 19	34	38	110
Aug. 24	35	37	48
Aug. 31	30	3[b]	51
Sep. 7	32	29	39
Sep. 10	31	35	36
Sep. 17	32	34	33
Sep. 24	30	32	33

[a] plants not yet recovered from cutting

[b] sample small because of weather interference

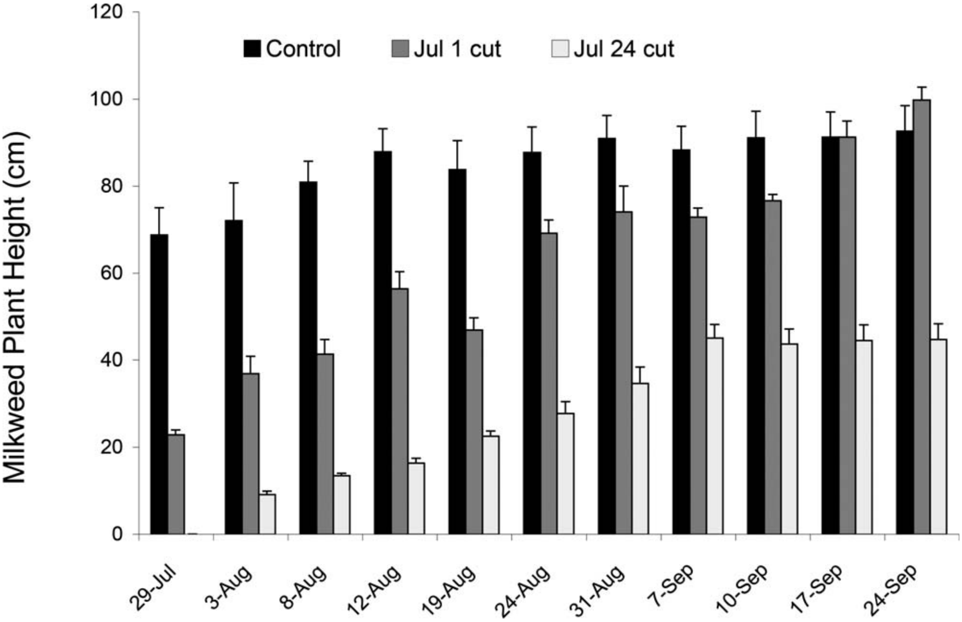

FIG. 1.—Average height of milkweed stems in the control and two experimental cut areas. Error bars represent 95% confidence intervals around the means. By the end of summer, regrowth attained maximum height in the Jul. 1 cut and nearly half maximum height in the Jul. 24 cut (milkweeds in the Aug. 17 cut have been excluded because of little measurable regrowth). Sample sizes are given in Table 2

n = 33) attained by milkweeds in both the control and the Jul. 1 cut (Fig. 1) ($F_{2,92} = 4.613$, $P = 0.012$; posthoc comparison, control = Jul. 1 > Jul. 24). Milkweeds in the Aug. 17 cut showed little measurable regrowth; therefore, we have excluded this treatment group from further analysis.

The developmental stage of the milkweeds (Fig. 2) depended on when the plants had been cut. From Jul. 29 to Aug. 24, the plants in the control were significantly more advanced in developmental stage than those that had been mowed (for each of these 6 dates, $P < 0.001$, Kruskal-Wallis Test). At the beginning of sampling on Jul. 29, most milkweeds in the control had flowered (36.8% in the pod stage), and by Sep. 24, 70% of control plants were in pod. In contrast to the controls, from Jul. 29 to Aug. 12 more than 95% of the plants in the Jul. 1 cut treatment were in the prebud or bud stage. These regrowing plants then began to flower, and by Sep. 7, 77% were flowering or past flowering; by Sep. 24, 69% were in pod. Developmental stages were delayed even more in the Jul. 24 mowed treatment. From Aug. 19 through Sep. 24, these plants were significantly behind plants in the Jul. 1 cut in developmental stage (comparison of the Jul. 24 cut to the control and the Jul. 1 cut, $P < 0.001$, median test). The first buds in the Jul. 24 mowed treatment did not appear until Aug. 19 and maximum budding reached 41.7% on Sep. 10. Based on general observations, milkweed in the control area varied more over time in phenology than did plants in the two mowed treatments.

The amount of herbivory in plants with monarch eggs and larvae was initially highest in the control plants and increased predictably in all three treatment areas throughout the sampling period. Milkweeds regrowing in both the Jul. 1 and Jul. 24 cuts showed less than

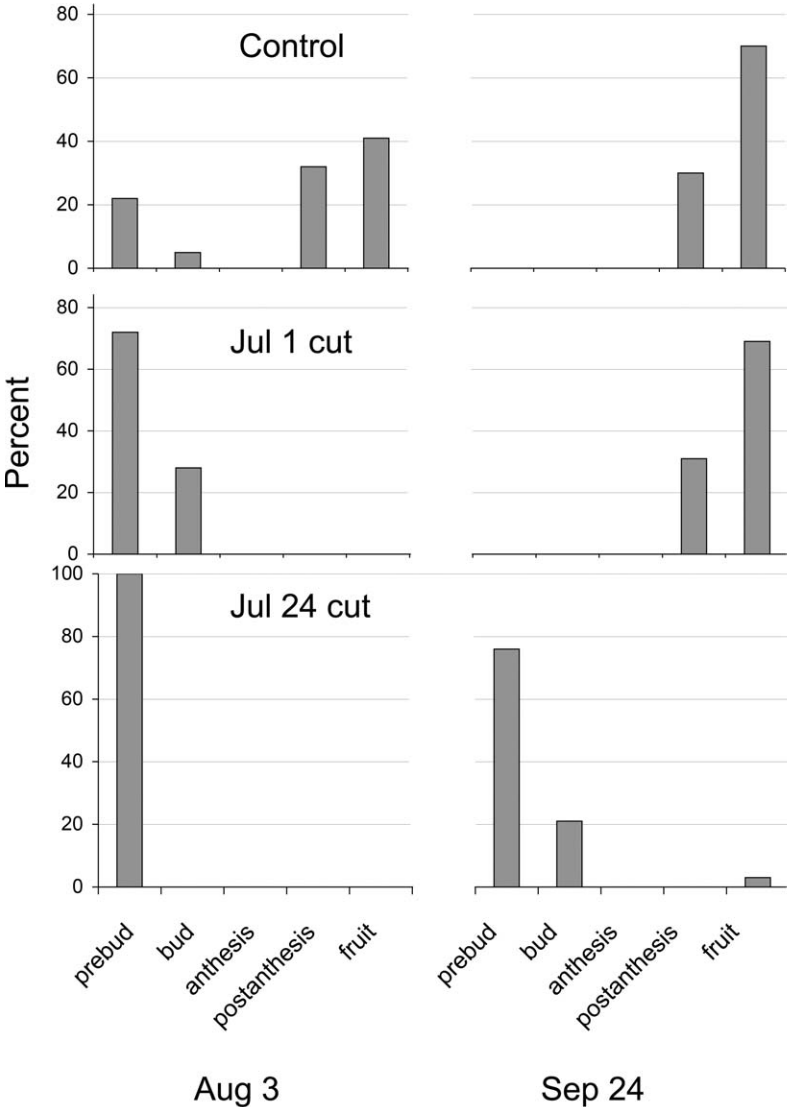

FIG. 2.—Developmental stage of milkweeds in the control and the two experimental cut areas early in the study period (Aug. 3) and at the end (Sep. 24). Control plants flowered and set pods during the study; milkweeds in the Jul. 1 cut progressed rapidly from bud to pod; and milkweeds in the Jul. 24 cut regrew but none matured

5% herbivory at the beginning of sampling, with an increase to 5–25% by Sep. 24. On the last sampling date, Sep. 24, the level of herbivory did not differ significantly among plants in the three treatments (median test, $P = 0.076$).

Control plants showed considerable senescence through the census period, from 5–40% yellow or dying on Jul. 29 up to 41–80% yellow or dying into Sep. In contrast plants in the Jul. 1 cut were in fresh condition at the beginning of the census period but increased to 5–40%

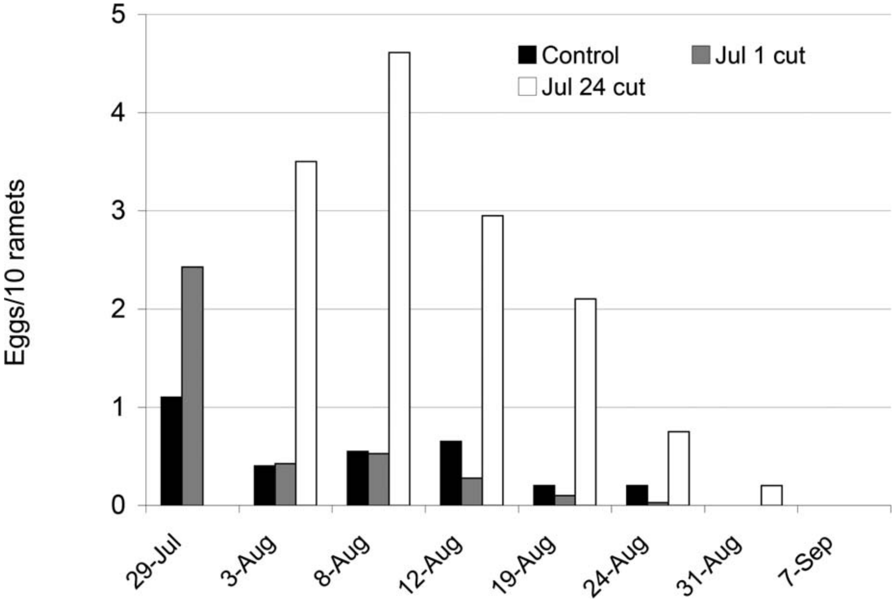

FIG. 3.—Egg density (eggs per ten ramets) in the control and two experimental cut areas. Egg density was higher on the experimental cut plants than on control plants, and the highest egg density was on the Jul. 24 cut milkweeds. Data from Table 1

yellow or dying by Sep. 17. Plants in the Jul. 24 cut showed no signs of senescence throughout the sampling period. The appearance of yellow color or signs of dying followed predictable patterns of plant aging over time, following the length of time since last being cut, and plants in the three areas were significantly different in the level of senescence on Sep. 24. At the end of the study, 47% of control plants, 23% of Jul. 1 cut plants, and 3% of Jul. 24 cut plants showed senescence (Kruskal-Wallis test, $P < 0.001$).

MILKWEEDS CHOSEN FOR OVIPOSITION

Within each of the three treatments (control, Jul. 1 cut, and Jul. 24 cut), plants with and without monarch eggs or larvae did not differ significantly in either height or developmental stage. Furthermore, plants with and without eggs and larvae did not differ in ramet density in the field (5.8 ± 3.7 ramets/m^2 with immatures and 5.7 ± 3.4 for ramets/m^2 without; $F_{1,1673} = 0.122$, n.s.). The similarity in density of ramets with and without immatures paralleled the similarity of densities of milkweeds in the two fields on Jul. 24 at the beginning of the experiment ($F_{1,198} = 1.900$, $P = 0.170$). Initial milkweed densities were 5.4 ± 0.6 stems in the BF field and 4.3 ± 0.6 stems in the GC field (mean with 95% C.I.; $P = 0.17$).

DENSITY OF EGGS AND LARVAE

The number of eggs per ramet differed among the three areas (a treatment effect) and over time (time × treatment interaction from analysis of treatment effects on different dates) (Table 1). Figure 3 summarizes the egg counts by density, calculated as the number of eggs per ten ramets. In the control egg densities were maximal on Jul. 29 and then lower until no eggs were present on Aug. 31. The Jul. 1 cut treatment had greater egg density than

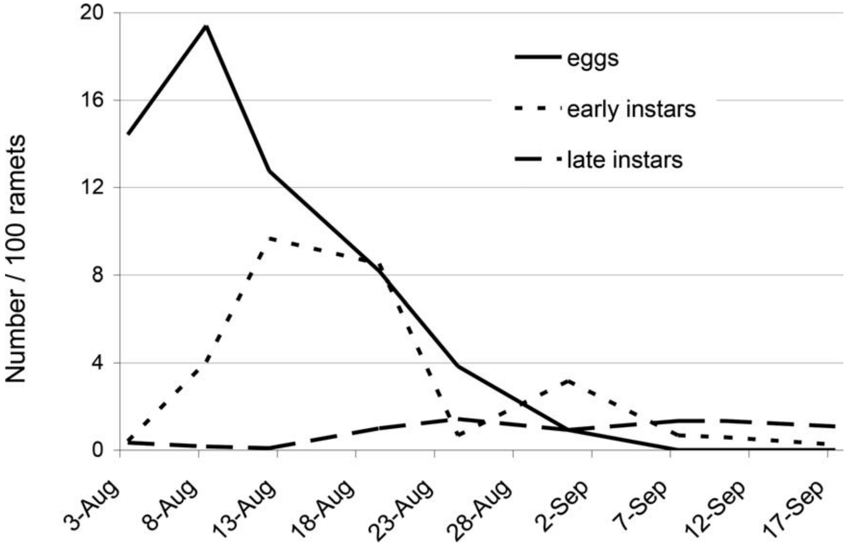

FIG. 4.—Densities of eggs and early instar (1–2) and late instar (3–5) larvae averaged from densities in the control, the Jul. 1 cut, and the Jul. 24 cut. Densities are the number per 100 ramets, calculated from the actual counts in Table 1. The peak in egg density was followed in about 6 d by the peak in early larval density, which was followed later on by a rise in late larval density

the control on Jul. 29 (Jul. 1 cut 0.23 eggs/ramet vs. control 0.145; $\chi^2 = 9.654$, df = 1, $P < 0.005$). From early Aug. on, both the control and Jul. 1 cut had similar low numbers of eggs until Aug. 31, when no more eggs were present. In contrast to the control and Jul. 1 cut, from Aug. 3 to Aug. 31 many more eggs were recorded in the Jul. 24 cut than in either of the other two areas. For example on Aug. 8, the Jul. 24 cut had 0.47 eggs/ramet, nearly 10 times the number in both the Jul. 1 cut, 0.052, and the control, 0.056 (by egg totals $\chi^2 > 100.0$, df = 2, $P < 0.001$). From Aug. 8 on, egg density in the Jul. 24 cut area declined until Sep. 7, when no further eggs were observed. The data show monarchs in Aug. oviposited most frequently on the freshest milkweed foliage, which was regrowing in the late Jul. cut treatment.

The number of early larvae (instars 1–2) peaked about 6 d after the peak in egg density and was then followed by an increase in the numbers of late larvae (instars 3–5) (Fig. 4). To examine the pattern of larval development, we calculated the number of eggs per ramet in the control, the Jul. 1 cut, and the Jul. 24 cut, and averaged those three values for each date. We made the same calculations for early and late larvae and presented the densities per 100 ramets in Figure 4. As seen in Table 1, early instar densities were consistently higher in the Jul. 24 mowed treatment than in either the control or the Jul. 1 mowed treatment. For example, on Aug. 12, the densities of early larvae per ramet were 0.240 in the Jul. 24 cut but only 0.025 in both the Jul. 1 cut and the control ($\chi^2 = 38.37$, df = 1, $P < 0.001$); that is, there were 10 times as many early larvae in the later cut.

Overall, in the early (Jul. 1) cut there were 1.67 times as many eggs and larvae per ramet than in the control, and in the later (Jul. 24) cut there were 6.25 times as many per ramet than in the control. Also, the ratio of early instars to eggs was higher in our two cut areas (63% in the Jul. 1 cut and 47% in the Jul. 24 cut) than in the control (15%), suggesting higher survivorship on the regenerating milkweeds.

LOCATION OF EGGS ON MILKWEED

Because of differences in the regrowing plants, the location of eggs in the top, middle, and bottom third of milkweed stems differed significantly among the three treatment groups ($\chi^2 = 73.79$, df = 2, $P < 0.001$). The more recent the mowing and younger the plants, the more eggs were found on leaves on the top third of the stems (Jul. 24 cut, 67% on the top third, n = 282; Jul. 1, cut 51%, n = 138; control, 8%, n = 67). In particular the Jul. 24 cut plants were the youngest and shortest and had the most eggs near the top of the plant. In the control and Jul. 1 cut, more than 90% of eggs (n = 215) were laid on the underside of leaves, whereas in the Jul. 24 cut, where plants were younger with their leaves oriented more vertically, only 74% of eggs (n = 287) were laid on the underside. This difference was significant ($\chi^2 = 14.68$, df = 1, $P < 0.001$).

DISCUSSION

Common milkweed, *A. syriaca,* followed a predictable pattern of growth in the three treatment groups. Unmowed control plants were already in an advanced vegetative stage (*i.e.,* past anthesis) on Jul. 29 at the beginning of the data collection and exhibited increased yellowing or dying leaves throughout the sampling period. In contrast regenerating milkweeds in the mowed strips provided younger, nonsenescent leaves. Our first hypothesis was supported: milkweeds showed healthy regrowth after mowing, although the Aug. 17 cut was too late to allow significant regrowth.

With milkweeds at different stages of growth in the different treatments, female monarchs exhibited a distinct oviposition preference. Monitoring through Aug. revealed eggs in all three areas, but eggs were laid at higher density in the two mowed treatments, which had younger plants with newer growth, than in the control area with older plants. Therefore, our second hypothesis was supported as well: age of the plant affected the quality of leaves, and oviposition was higher on the regenerating milkweeds than on the controls. Zalucki and Kitching (1982a) and Lynch and Martin (1993) also reported a preference of monarch females for younger leaves, and we have made qualitative field observations in Massachusetts and Virginia of increased monarch reproduction on *A. syriaca* regenerating in mowed fields (LPB, pers. obs.).

From the beginning of Aug. to early Sep., eggs were more abundant in the Jul. 24 cut than in the other two treatments. They were also more abundant in the Jul. 1 cut than in the control. Any loss of juvenile stages due to mowing was replaced by increased densities of eggs and larvae after mowing because of increased oviposition. Even though milkweeds in the mown areas were visually less conspicuous to us than those in the control plots, the presence of more immatures suggests olfactory and visual cues of fresh regrowth are important sensory cues for ovipositing monarch females. While contact chemoreception of chemicals in milkweed leaves has been studied in monarch larvae and adults (Bauer *et al.*, 1998), the distance-attraction of flying adults to milkweed has not yet been investigated. The use of distant cues is suggested by the results from this study and supported by numerous observations we have made of monarchs in Wisconsin and Florida searching for and ovipositing on newly emergent milkweeds (*A. syriaca*).

The peak in oviposition was followed about 6 d later by an increase in density of early instars (first and second), and the peak in later instars (thirds, fourths, and fifths) then followed. Many fewer late instars were observed than early instars, as expected because of predation and larval movement (Borkin, 1982; Zalucki and Kitching, 1982b). We did not follow the larvae to pupation. The rate of survivorship from eggs to early instars in our study was similar to that found by Zalucki and Kitching (1982b), who reported that 61–84% of eggs are lost and mortality through the early fifth instar ranges from 92–97%. Most of the larvae that developed from eggs in the Jul. 24 cut would reach adulthood in time to migrate southward but the last larvae likely would not. A few eggs were laid at the end of Aug., and a few late instar larvae remained near the end of Sep. (Table 1), which gives little time for completing development successfully. However, most oviposition in the Jul. 24 cut took place with sufficient time to produce adults. The data indicate, at latitudes similar to that of this study, mowing to provide regrowing milkweeds for monarch reproduction should take place no later than late Jul.

Any treatment of habitat for the purpose of conservation, such as that described here, requires planning and consideration of all effects of the treatment. Mowing in mid summer can lead to regrowth of milkweed leaves that have increased attractiveness to ovipositing monarchs, but the plants may not have sufficient time to flower again and set pods (Gibbs, 2010). Therefore, mowing can stimulate fresh larval food at the expense of seed production, although reproduction in the proximate area of a milkweed ramet is in general vegetative (Timmons, 1946). Mowing is not the only disturbance that can produce regenerating milkweeds; fire and grazing also can (Bowles *et al.*, 1998; Rudolf and Ely, 2000; Baum and Sharber, 2012; Moranz *et al.*, 2012; Baum and Mueller, 2014). Different species of milkweeds are likely to respond to disturbance differently (Vogel *et al.*, 2007); for example, mowing in Texas in late Apr. to early May did not lead to observed regrowth of *A. asperula* (R. Kiphart, pers. comm.). Furthermore, as shown by Swengel and Swengel (2013) and Vogel *et al.* (2010), well-intended management involving periodic burns can be detrimental to target species. The management of milkweed populations through mowing or burning requires knowledge about the biology and phenology of each milkweed species (Swengel and Swengel, 2001; Swengel *et al.*, 2010), of which there are about 130 present in North America including Mexico (Fishbein *et al.*, 2011).

In a comprehensive review of pollinator habitats, Hopwood (2013) noted roadsides in the U.S. exceed 10 million acres; therefore, managing them with mowing regimes that favor native forbs, including milkweeds, could increase valuable habitat. The following calculations are informative. There are 3.2 million miles of roads in the 37 states east of the Rocky Mountains (www.census.gov/compendia/statab/2012/tables/12s1089.pdf). If one assumes 25 ft on each side of a road could support the growth of milkweeds (some roads would be unsuitable, but median strips would add habitat), then roadsides could contribute 6 acres of habitat per mile or, for the eastern U.S., 19 million acres of potential roadside habitat, *i.e.,* about 3% of the 640 million acres that comprise the eastern North American breeding range (Brower, 1999). If two monarchs were produced per acre of roadside habitat, then roadsides in a managed mowing regime could support nearly 40 million monarchs.

In addition to roadsides, carefully designed mowing regimes in agricultural fields, old fields, power line corridors (Berg *et al.*, 2013), and other rights of way could contribute to an increase in overall monarch population size. With climate change and a potentially longer growing season, selective mowing may benefit several generations of monarchs. Whether on the local or landscape level, both conservation and management of favorable monarch habitats are important as milkweeds continue to be eradicated as a result of human induced landscape changes, especially through agriculture with crops genetically modified to tolerate herbicides in conjunction with treatment by glyphosate and other herbicides that eliminate milkweeds (Pleasants and Oberhauser, 2012). Any management of habitat for conservation purposes must consider all the species that may be affected, but, as we have shown, planned mowing is a treatment that can benefit monarchs. The expansion of milkweed gardens can add breeding habitat, but more extensive management of North American milkweeds including timed mowing could make a larger contribution to the Eastern migratory population of monarch butterflies.

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