biology letters

Biol. Lett. (2012) **8**, 968–971
doi:10.1098/rsbl.2012.0550
Published online 1 August 2012

Conservation biology

Fire creates host plant patches for monarch butterflies

Kristen A. Baum* and Wyatt V. Sharber†

Department of Zoology, Oklahoma State University, Stillwater, OK 74078, USA
**Author for correspondence (kristen.baum@okstate.edu).*
†Present address: Department of Biology, University of Miami, Coral Gables, FL 33124, USA

Monarch butterflies (*Danaus plexippus*) depend on the presence of host plants (*Asclepias* spp.) within their breeding range for reproduction. In the southern Great Plains, *Asclepias viridis* is a perennial that flowers in May and June, and starts to senesce by August. It is locally abundant and readily used by monarchs as a host plant. We evaluated the effects of summer prescribed fire on *A. viridis* and the use of *A. viridis* by monarch butterflies. Summer prescribed fire generated a newly emergent population of *A. viridis* that was absent in other areas. Pre-migrant monarch butterflies laid eggs on *A. viridis* in summer burned plots in late August and September, allowing adequate time for a new generation of adult monarchs to emerge and migrate south to their overwintering grounds. Thus, summer prescribed fire may provide host plant patches and/or corridors for pre-migrant monarchs during a time when host plant availability may be limited in other areas.

Keywords: *Asclepias viridis*; *Danaus plexippus*; migration; milkweed; prescribed fire; reproduction

1. INTRODUCTION

The range of the monarch butterfly (*Danaus plexippus*) extends from southern Canada through South America. The population that breeds during the summer in the Midwestern United States and southern Canada exhibits a long-distance migration to overwintering grounds in Mexico [1–3]. This combination of breeding, long-distance migration and overwintering behaviours and locations means that monarchs are potentially threatened not only by the elimination of their host plants (*Asclepias* spp.) throughout their breeding range, but also by the degradation and loss of their overwintering habitat [4–6]. In the southern Great Plains, monarch butterflies are uncommon or absent after the initial spring migration, suggesting that they move farther north in advance of high temperatures before passing back through the area during autumn migration [7–10].

Monarchs use a variety of milkweed species as host plants. In the southern Great Plains, *Asclepias viridis* is locally abundant and readily used by monarchs [11,12]. *Asclepias viridis* is a perennial that typically flowers in May and June, and starts to senesce by August under field conditions. We evaluated the effects of summer prescribed fire on *A. viridis* abundance and use by monarch butterflies by estimating the density of *A. viridis* plants and monarch eggs and larvae in plots burned and not burned during the summer.

Electronic supplementary material is available at http://dx.doi.org/10.1098/rsbl.2012.0550 or via http://rsbl.royalsocietypublishing.org.

2. MATERIAL AND METHODS

Our study sites were located at Oklahoma State University's Stillwater Research Range (SRR), which is located approximately 21 km southwest of Stillwater in northcentral Oklahoma. The SRR is predominantly a tallgrass prairie managed as rangeland with patch burning, which involves using prescribed fire to generate a mosaic of patches with different times since burn. We collected data in three pastures (45–65 ha) separated from one another by at least 2.5 km. Each pasture is divided into six subplots, approximately 200 by 400 m each, with one subplot burned every spring and one every summer, so that all subplots are burned once every 3 years. Although other *Asclepias* species occur at these sites, they are uncommon compared with *A. viridis*. We surveyed *A. viridis* in the subplots burned during July 2010 once every 7 days until *D. plexippus* eggs were found, and then every 3–5 days through early October, using methods similar to those developed for the Monarch Larva Monitoring Project [13,14]. We also surveyed other areas of the pastures (not burned during July 2010) once every two weeks for *A. viridis* and *D. plexippus* eggs and larvae.

To estimate milkweed density, we established 5 by 50 m transects within each subplot. In summer burned subplots, we randomly selected one transect to survey during each sampling period, with each transect being sampled only once. Within each transect, we recorded *A. viridis* plants and *D. plexippus* eggs, and the instar stage for any *D. plexippus* larvae. Once we completed a transect, we randomly searched within the subplot for additional *A. viridis* plants (by randomly walking around within the vicinity of each transect) until we recorded data for approximately 50 plants per subplot per sampling date. To survey subplots not burned during the summer of 2010, we randomly selected five transects to survey once every two weeks. It was not possible to survey these plots until 50 plants were found because of the low abundance of milkweed plants in the unburned subplots. Although the burned and unburned subplots were surveyed on different time schedules, the sampling intensity was the same. We compared milkweed densities among summer burned and spring burned subplots using a general linear mixed model with fire regime as a fixed effect and pasture as a random effect.

3. RESULTS

Asclepias viridis density was significantly lower in plots not burned during summer 2010 (GLMM: intercept, fire regime; $F = 6.626$, 50.372; d.f. $= 2$, 86; $p = 0.124$, <0.001). Prescribed fire removed the aboveground portion of the plants and produced a newly emergent population of *A. viridis* which was not present in areas not burned during summer 2010, where *A. viridis* had already senesced (see figure 1 and electronic supplementary material; *A. viridis* plants were abundant earlier in the year (K.A.B. 2010, personal observation)). Adult monarchs arrived in mid-August, approximately one month before the peak migration period for northcentral Oklahoma (i.e. late September to early October for an approximate latitude of 36; [15]), and laid eggs on *A. viridis* through early October in subplots burned during summer 2010. Monarch eggs and instars of all stages were found on *A. viridis* plants in summer burned subplots (see figure 2 and electronic supplementary material), whereas only one *D. plexippus* egg was found on a single *A. viridis* plant in subplots not burned during summer 2010. Egg density peaked during late August (figure 2*a*) in summer burned subplots, while larva density peaked during early September (figure 2*b*).

Received 10 June 2012
Accepted 10 July 2012

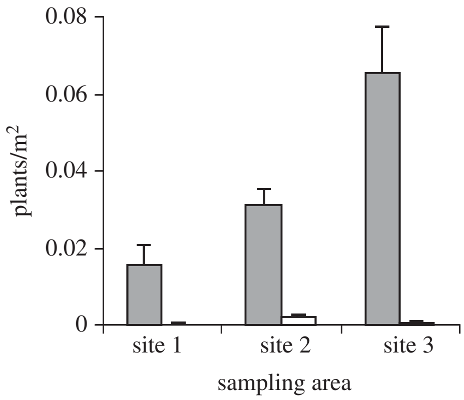

Figure 1. Density of *A. viridis* plants (mean ± s.e.) in plots burned and not burned during July 2010. Filled bars denote plots burned during summer 2010, whereas unfilled bars denote plots burned during spring 2010.

4. DISCUSSION

Summer fire removed the above-ground portion of *A. viridis* plants and generated re-growth during the time period in which the plants would normally senesce, providing tender new leaves preferred by ovipositing monarch butterflies [16]. In the absence of summer fire, *A. viridis* had already senesced by mid-August and was not available as a host plant for the monarchs (figure 1). Monarch eggs were first recorded in the summer burned plots in northcentral Oklahoma in mid-August. The adult monarchs that produced these eggs were probably newly eclosed individuals from northern latitudes that moved south early to reproduce (i.e. pre-migrant individuals), as adult and immature monarchs are not observed in Oklahoma during their summer breeding period, but are instead located farther north [13]. Larval densities were similar to those reported in the literature for the late breeding season (e.g. densities of third through fifth instars combined range from approx. 0.0125 to 0.0875 larvae/plant in the southern United States from 2006 through 2009 [17], compared with 0.0143 for comparable data from this study). The timing of egg laying corresponded with the amount of time needed for newly laid eggs to hatch, larvae to pupate and adult monarchs to emerge and join the peak southern migration [8] (figure 2). Thus, summer fire has the potential to provide host plant patches and/or corridors for pre-migrant monarch butterflies during a time when host plant availability may be limited in other areas. However, it is not clear if these reproductively active monarchs die after reproducing or make the trip south to the overwintering sites.

While we identify a benefit of fire for monarch butterflies, previous studies have provided mixed results on the effects of burning on butterflies, with some identifying positive effects [18,19] and others demonstrating negative effects [20]. Strategies that patchily apply fire to the landscape generate a mosaic of patches with different fire return intervals [21,22]. This heterogeneous application of fire has the potential to benefit a variety of butterfly species with differing habitat requirements and responses to fire. For example, unburned refuges for fire-intolerant species could be incorporated into areas with different burn seasons and times since burn for species dependent on fire-maintained ecosystems. However, the timing and frequency of prescribed fire plays an important role in its effect on the overall butterfly community.

Prescribed fire is frequently used for grassland management throughout the Great Plains. Spring burning is more common than summer burning, even though summer prescribed fire more realistically represents historic fire regimes that maintained native grassland ecosystem processes [23]. *Asclepias viridis* quickly re-grows after a summer burn, during the time frame in which it normally senesces under normal field conditions. Other practices that remove the above-ground portion of *A. viridis* plants also may increase *A. viridis* availability during this critical time period for monarch butterflies. For example, we have found monarch larvae on *A. viridis* in August and September in roadsides managed with mowing throughout the year (K.A.B. 2010, unpublished data). Again, the timing and frequency of these management practices influence the positive and negative effects of these activities on the overall butterfly community.

The spatial and temporal distribution of summer fire influence host plant availability and are therefore critical to the reproductive success of pre-migrant monarch butterflies. Thus, restoring historic fire regimes, including summer prescribed fire, could create host plant patches and/or corridors for monarch butterflies within the range of *A. viridis*. More information is needed on the effects of management strategies (e.g. prescribed fire and mowing) on the spatial and temporal distribution and abundance of milkweed, as well as whether these disturbance maintained patches of milkweed function as a source or sink for monarch butterflies. Also, additional research is needed to evaluate the contribution of pre-migrant monarch butterfly reproduction to the overall monarch population, with important implications for the conservation of this species.

We thank R. Henry and S. Parker for assistance with data collection, S. Fuhlendorf and C. Stansberry for access to field sites, and J. Belden, L. Smith, D. Saenz and K. Oberhauser for commenting on an earlier draft of this manuscript. Funding was provided by a Wentz Scholarship to W.V.S. and a USDA-NRI Managed Ecosystems Program grant (2009-35101-05170) to K.A.B.

1 Urquhart, F. A. & Urquhart, N. R. 1978 Autumnal migration routes of the eastern population of the monarch butterfly (*Danaus p. plexippus* L.; Danaidae; Lepidoptera) in North America to the overwintering site in the neovolcanic plateau of Mexico. *Can. J. Zool.* **56**, 1759–1764. (doi:10.1139/z78-240)
2 Brower, L. P. 1995 Understanding and misunderstanding the migration of the monarch butterfly (Nymphalidae) in North America: 1857–1995. *J. Lepid. Soc.* **49**, 304–385.
3 Howard, E. & Davis, A. K. 2009 The fall migration flyways of monarch butterflies in eastern North America revealed by citizen scientists. *J. Insect Conserv.* **13**, 279–286. (doi:10.1007/s10841-008-9169-y)
4 Oberhauser, K. S. *et al.* 2001 Temporal and spatial overlap between monarch larvae and corn pollen. *Proc. Natl Acad. Sci. USA* **98**, 11 913–11 918. (doi:10.1073/pnas.211234298)

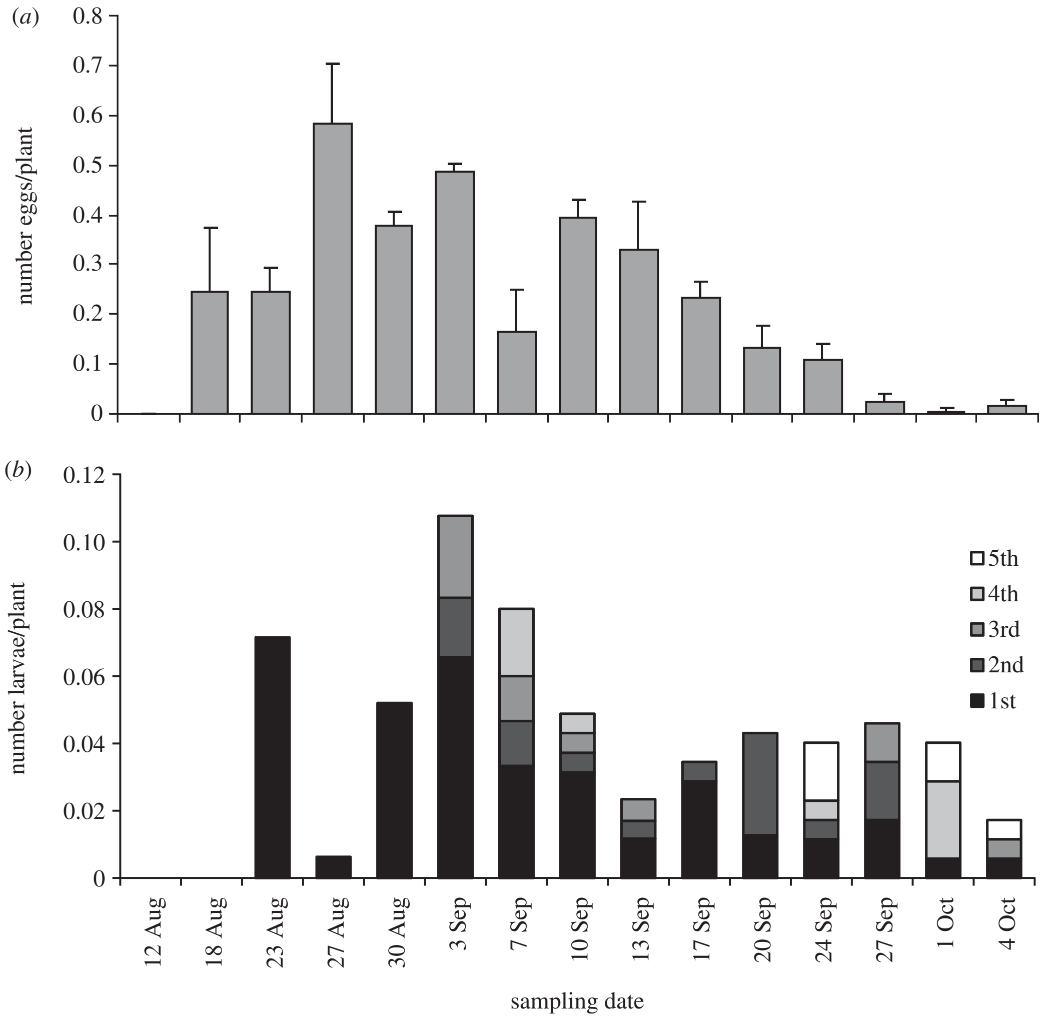

Figure 2. Density (mean ± s.e.) of *D. plexippus* in plots burned during July 2010. (*a*) Density of *D. plexippus* eggs. (*b*) Density of *D. plexippus* larvae by instar stage.

5 Brower, L. P., Castilleja, G., Peralta, A., Lopez-Garcia, J., Bojorquez-Tapia, L., Diaz, S., Melgarejo, D. & Missrie, M. 2002 Quantitative changes in forest quality in a principal overwintering area of the monarch butterfly in Mexico, 1971–1999. *Conserv. Biol.* **16**, 346–359. (doi:10.1046/j.1523-1739.2002.00572.x)

6 Brower, L. P., Fink, L. S. & Walford, P. 2006 Fueling the fall migration of the monarch butterfly. *Integr. Comp. Biol.* **46**, 1123–1142. (doi:10.1093/icb/icl029)

7 Rawlins, J. E. & Lederhouse, R. C. 1981 Developmental influences of thermal behavior on monarch caterpillars: an adaptation for migration. *J. Kansas Entomol. Soc.* **54**, 387–408.

8 Zalucki, M. P. 1982 Temperature and rate of development in *Danaus plexippus* and *D. chrysippus*. *J. Aust. Entomol. Soc.* **21**, 241–246. (doi:10.1111/j.1440-6055.1982.tb01803.x)

9 Malcolm, S. B., Cockrell, B. J. & Brower, L. P. 1987 Monarch butterfly voltinism: effects of temperature constraints at different latitudes. *Oikos* **49**, 77–82. (doi:10.2307/3565556)

10 Howard, E. & Davis, A. K. 2004 Documenting the spring movements of monarch butterflies with Journey North, a citizen science program. In *The monarch butterfly, biology and conservation* (eds K. Oberhauser & M. Solensky), pp. 105–114. Ithaca, NY: Cornell University Press.

11 Lynch, S. P. & Martin, R. A. 1987 Cardenolide content and thin-layer chromatography profiles of monarch butterflies, *Danaus plexippus* L., and their larval host-plant milkweed, *Asclepias viridis* Walt., in northwestern Louisiana. *J. Chem. Ecol.* **13**, 47–69. (doi:10.1007/BF01020351)

12 van Hook, T. & Zalucki, M. P. 1991 Oviposition by *Danaus plexippus* (Nymphalidae: Danainae) on *Asclepias viridis* in northern Florida. *J. Lepid. Soc.* **45**, 215–221.

13 Prysby, M. D. & Oberhauser, K. S. 2004 Temporal and geographical variation in monarch densities: citizen scientists document monarch population patterns. In *The monarch butterfly, biology and conservation* (eds K. Oberhauser & M. Solensky), pp. 9–20. Ithaca, NY: Cornell University Press.

14 Oberhauser, K. S. & Prysby, M. D. 2008 Citizen science: creating a research army for conservation. *Am. Entomol.* **53**, 103–105.

15 Monarch Watch. 2012 Peak migration dates: when will the migration peak in my area? (5 June). See http://www.monarchwatch.org/tagmig/peak.html.

16 Zalucki, M. P. & Kitching, R. L. 1982 Dynamics of oviposition in *Danaus plexippus* (Insecta: Lepidoptera) on milkweed, *Asclepias* spp. *J. Zool. Lond.* **198**, 103–116. (doi: doi:10.1111/j.1469-7998.1982.tb02063.x)

17 Bartel, R. A., Oberhauser, K. S., de Roode, J. D. & Altizer, S. Z. 2011 Monarch butterfly migration and parasite transmission. *Ecology* **92**, 342–351. (doi:10.1890/10-0489.1)

18 Huntzinger, M. 2003 Effects of fire management practices on butterfly diversity in the forested western United States. *Biol. Conserv.* **113**, 1–12. (doi:10.1016/S0006-3207(02)00356-7)

19 Vogel, J. A., Debinski, D. M., Koford, R. R. & Miller, J. R. 2007 Butterfly responses to prairie restoration through fire and grazing. *Biol. Conserv.* **140**, 78–90. (doi:10.1016/j.biocon.2007.07.027)

20 Swengel, A. B. & Swengel, S. R. 2007 Benefit of permanent non-fire refugia for Lepidoptera conservation in fire-managed sites. *J. Insect Conserv.* **11**, 263–279. (doi:10.1007/s10841-006-9042-9)

21 Fuhlendorf, S. D. & Engle, D. M. 2001 Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. *BioScience* **51**, 625–632. (doi:10.1641/0006-3568(2001)051[0625:RHOREM]2.0.CO;2)

22 Fuhlendorf, S. D. & Engle, D. M. 2004 Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie. *J. Applied Ecol.* **41**, 604–614. (doi:10.1111/j.0021-8901.2004.00937.x)

23 Howe, H. F. 1994 Managing species diversity in tallgrass prairie: assumption and implications. *Conserv. Biol.* **8**, 691–704. (doi:10.1046/j.1523-1739.1994.08030691.x)