The Effect of Deer Browse on Sundial Lupine: Implications for Frosted Elfins

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Abstract - The effect of *Odocoileus virginianus* (White-tailed Deer) on *Lupinus perennis* (Sundial Lupine) was quantified for a site in Worcester County, MD. The reproductive output of Lupine protected by deer exclosures was compared with Lupine that received no protection from deer. Lupine in the exclosures had a higher likelihood of producing seed pods and produced a greater number of seed pods per inflorescence. The implications of these results on *Callophrys irus* (Frosted Elfins) are discussed.

Introduction

Callophrys irus Godart (Frosted Elfins) are considered to be rare, imperiled, or extirpated in every state where they have been known to occur (NatureServe 2011). The primary threats to this butterfly species are destruction and alteration of their dry upland habitat through development, forest succession, and fire exclusion (NatureServe 2011, Wagner et al. 2003). The few remaining Frosted Elfin populations persist primarily as highly localized and fragmented populations (Allen 1997, Glassberg 1999, NatureServe 2011, O'Donnell et al. 2007, Pfitsch and Williams 2009, Wagner et al. 2003). *Odocoileus virginianus* Zimmermann (White-tailed Deer) can have a major impact on Frosted Elfins by consuming the larval host plants, *Lupinus perennis* (L.) (Sundial Lupine; hereafter also "Lupine") and *Baptisia tinctoria* (L.) Vent. (Wild Indigo), both of which are browsed by deer (Golden and Pettigrew 2005, NatureServe 2011, Schweitzer 2003, St. Mary 2007). Deer may also affect Frosted Elfins through the direct consumption of the butterfly's eggs and larvae. In Maryland, Frosted Elfins are present at fewer than ten sites and are currently listed as state-endangered. A single population in western Maryland uses Wild Indigo as a host plant, while the other known Frosted Elfin populations in the state occur on the Atlantic Coastal Plain and feed on Lupine. Sundial Lupine is listed as state-threatened and, like the Frosted Elfin, persists in small, fragmented populations. The few remaining Lupine sites in Maryland require active habitat management to maintain, achieved primarily through mechanical clearing of woody vegetation. Selective mechanical clearing can maintain early-successional clearings with low to moderate tree cover and relatively high light intensity, conditions under which Lupine has been shown to thrive (Pfitsch and Williams 2009, Smallidge et al. 1996).

The rarity of Lupine in the state is believed to be a limiting factor for Frosted Elfins. The largest known population of Lupine-feeding Frosted Elfins in Maryland occurs on a 2.1-ha parcel of private land. The Lupine was

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discovered at this site in 2005 following a timber harvest, and now represents the largest population in the state with several thousand plants. Along the road adjacent to the timber harvest site, Lupine has persisted since at least the 1970s, and those plants, although declining, have supported a population of Frosted Elfins for over 30 years. It was presumably these Frosted Elfins that quickly colonized the 2.1-ha parcel following the Lupine establishment in 2005. The 2.1-ha parcel is now held as a reserve for Frosted Elfins; the surrounding habitat is still harvested. Frosted Elfins have been monitored annually since establishment of the Lupines. While the population exhibits some variation in the number of individuals observed every year, it has persisted at the site since 2005.

In 2010, Lupine plants in the 2.1-ha site were producing almost no seed pods, especially in early-successional clearings where the majority of the Lupine was concentrated (S. Tangren, University of Maryland Arboretum, College Park, MD, unpubl. data). The only plants producing multiple seed pods were in, and adjacent to, a wooded buffer between the study site and the adjacent roadside. This lack of seed pod production is a concern because Frosted Elfin larvae subsist primarily on Lupine flowers and seed pods (NatureServe 2011, Pfitsch and Williams 2009, Schweitzer 1992, Swengel 1996). While an obvious decline in the numbers of Frosted Elfin adults at the site was not noted, the lack of flowers and seed pods raised concerns of a future population crash. The lack of seed pods was suspected to be the result of deer browsing. Accordingly, an experiment was initiated to study the effect of deer browsing on Lupine and to determine whether deer exclusion might be necessary to sustain theLupine and Frosted Elfin populations at the site.

Field-Site Description

The study was conducted in Worcester County, MD, on the Atlantic Coastal Plain east of the Chesapeake Bay. The area is predominantly made up of oak-pine forests underlain by relatively young (Tertiary and Quarternary) sediments of uniformly low-relief (Schmidt 1993). Warm, humid summers and mild winters are characteristic of the climate.

The study site was located on a 2.1-ha parcel of private property formerly harvested for timber. Much of the area is located on a sand dune of the Parsonsburg formation (Denny et al. 1979). The 2.1-ha study site is currently managed to slow forest succession by clearing regenerating *Pinus taeda* (L.) (Loblolly Pine) and limiting the growth of hardwoods (*Quercus* spp., *Carya* spp.) through selective, mechanical removal. The surrounding area is actively harvested for commercial timber production. Dominant shrubs and herbaceous vegetation include Lupine, *Vaccinium pallidum* Ait. (Blueridge Blueberry), *Gaylussacia baccata* (Wangenh.) K. Koch (Black Huckleberry), *Nuttallanthus canadensis* (L.) D.A. Sutton (Canada Toadflax), *Tephrosia virginiana* (L.) Pers. (Virginia Tephrosia), *Piptochaetium avenaceum* (L.) Parodi (Blackseed Needlegrass) and various sedges including *Carex tonsa* var. *tonsa* (Fernald) E.P. Bicknell (Shaved Sedge), *C. pensylvanica* Lam. (Pennsylvania Sedge)*, C. albicans* var. *emmonsii* (Dewey ex Torr.) Rettig (Emmon's Sedge), and *C. nigromarginata* Schwein. (Black Edge Sedge). While Lupine is scattered throughout the study area, there are two main concentrations, one on the eastern side of the dune and one on the western side.

Methods

In early April 2011, 41 clusters of Lupine were randomly selected for the deer-exclosure treatment. Deer exclosures were circular, constructed of vinyl green lawn fence, and were approximately 76 cm high and 91 cm in diameter (Fig. 1). The exclosures allowed access to butterflies and other insects but completely protected the plants within from deer browsing. Lupine clusters in 28 exclosures were randomly chosen to be "paired" with Lupine clusters that were not protected by a deer exclosure (Fig. 2). Because it is impossible to differentiate between individual Lupine plants in the field, I used individual inflorescences (Lupine flowering stems) as the sample unit. Every Lupine inflorescence within each exclosure was monitored. Unexclosed Lupine inflorescences were marked with wooden skewers pushed deep into the ground with only the upper 2" visible. In all cases, the original number of inflorescences inside the exclosures was comparable to those marked with skewers outside the exclosures in early April. However, as the study progressed, the number of inflorescences within the exclosure greatly outnumbered those that were marked outside the exclosure. As a result, a greater number of exclosed inflorescences were monitored as compared to the number of unexclosed inflorescences.

In a separate experiment, ten exclosures were modified so that the bottom 6–8 inches of the fencing was removed to allow access to rabbits and other smaller mammals, which also feed on Lupine (Zaremba and Pickering 1994, Zaremba et al. 1991). The sharp edges of the fencing were then bent upwards to discourage deer from reaching under the fencing to feed on Lupine flowers and seed pods. The number of inflorescences within these ten exclosures and the number of seed pods per inflorescence were compared with those of the 28 exclosures that were not modified to allow small-mammal access.

In both experiments, Lupine clusters were monitored approximately once a week from April 27 to June 14. I quantified (1) the number of inflorescences per cluster, (2) inflorescence state (intact or browsed), and, as the main measure of reproductive output, (3) the number of seed pods per inflorescence. Only pods that were dehisced (having produced seed) were considered in the final analysis. The number of pods that had failed to develop and had not dehisced was negligible.

The average number of seed pods per inflorescence for each treatment in both experiments (exclosed vs. unexclosed, small-mammal accessible vs. inaccessible) was compared. The data did not follow a normal distribution and were analyzed using Mann-Whitney U-Tests (Sokal and Rohlf 1969). In the main experiment comparing exclosed and unexclosed Lupine clusters, the data from the unexclosed plants was highly skewed (average number of seed pods, skewness = 1.5). In the second experiment, which compared exclosed clusters of Lupine accessible to small mammals with clusters that were inaccessible,

Figure 1. Photograph of caged Sundial Lupine plants taken on 2 May 2011.

Figure 2. Photograph of uncaged Sundial Lupine plants taken on 2 May 2011. This uncaged cluster of plants was "paired" for photographic comparison with the caged plants in Figure 1.

Figure 3. Partially browsed Sundial Lupine inflorescence.

Figure 4. Cluster of Sundial Lupine plants sheltered by a low-lying tree limb.

the smaller and unequal sample sizes also warranted use of the Mann-Whitney U-Test. All analyses used upper-bound tables for critical values of the Mann-Whitney U statistic. An online calculator (Avery 2007) was employed for all non-parametric analyses.

Results

Of the 41 original exclosures, three were excluded from the analysis because the Lupine never fully developed and did not produce inflorescences.

Exclosed vs. unexclosed clusters

Reproductive output was measured as the number of seed pods produced by each inflorescence. Twenty-eight exclosed and unexclosed clusters were compared (this number excludes those exclosures accessible to small mammals). The 28 clusters of unexclosed plants contained 144 inflorescences. Of these, 61 (42%) produced at least one pod. The 28 clusters of exclosed plants contained 753 inflorescences. Of these, 713 (95%) produced at least one pod.

Of the original 144 inflorescences that were not exclosed, the average number of pods per inflorescence was 1.78 (SD = 1.97; Table 1). Of the original 753 inflorescences that were protected by an exclosure, the average number of pods per inflorescence was 4.85 (SD = 1.56; Table 1). Pods per inflorescence was significantly different between exclosed and unexclosed clusters (Mann-Whitney U = 696, $n_1 = n_2 = 28$, $P < 0.0001$, $r = 0.67$).

Exclosures with and without access to small mammals

Ten exclosures were accessible to small mammals. These were compared with the 28 exclosures that did not allow access to small mammals. There were no significant differences in either the number of inflorescences per exclosure (Mann-Whitney U = 164, $n_1 = 10$, $n_2 = 28$, $P = 0.44$, $r = 0.13$) or in the average number of pods produced per inflorescence (Mann-Whitney U = 173, $n_1 = 10$, $n_2 = 28$, $P = 0.29$, $r = 0.18$). The data were also permuted three times to conduct the test using equal sample sizes (comparing the ten exclosures that allowed access to small mammals with three different sets of ten randomly selected exclosures that did not allow access to small mammals). These results also showed that there was no difference in the number of inflorescences per exclosure (Mann-Whitney $59 < U < 67$, $n_1 = n_2 = 10$, $0.21 < P < 0.53$, $0.15 < r < 0.28$) or in the number of pods produced per inflorescence (Mann-Whitney $56 < U < 64$, $n_1 = n_2 = 10$, $0.32 < P < 0.68$, $0.09 < r < 0.23$).

Table 1. Seed pod data for exclosed and unexclosed Sundial Lupine clusters.

Treatment	Original # stems	# stems producing seed pods	Mean # pods per stem (SD)	Mode	Median	Range	Variance	Skewness
Exclosed	753	713	4.85 (± 1.56)	5.7	4.95	2.3–7.9	2.43	0.12
Unexclosed	144	61	1.79 (± 1.97)	0.0	1.10	0.0–8.0	3.88	1.52

Discussion

Deer have a significant effect on Lupine at the site. Clusters protected from deer browsing exhibited both more inflorescences producing seed pods (95% vs. 42%) and a greater number of seed pods per inflorescence (4.85 vs. 1.78); photographs of an exclosed and unexclosed Lupine cluster are provided in Figures 1 and 2. In addition, deer were frequently photographed (motion-sensor camera) feeding in the Lupine clusters at night, and deer sign (tracks and pellets) were evident at the site. While rabbits and small mammals may have some effect on Lupine, the effect was not statistically significant.

Despite the presence of Frosted Elfins at the site every year, their success is almost certainly hampered by deer herbivory. In 2011, Frosted Elfin females were frequently seen ovipositing on the new inflorescences before the flower buds opened. As the buds started opening up, a large percentage of these were consumed by deer. Based on the data from this study, at least 58% of inflorescences were browsed entirely and 84% were partially browsed. This result suggests that not only are deer consuming the host plant, but they are likely consuming many Frosted Elfin eggs (and possibly larvae) as well.

Occasionally, but much less frequently, ovipositing Frosted Elfin females were observed laying eggs on the Lupine leaves, which did not appear to be affected by deer at this study site. This oviposition behavior was atypical, and it was far more common to see females ovipositing on new inflorescences, which coincides with what other researchers have reported (NatureServe 2011, Pfitsch and Williams 2009, Swengel 1996). Even if eggs that were laid on Lupine leaves were to hatch and the larvae spared direct mortality from deer browsing, it seems likely that many larvae would not survive to maturity, given the impact of browsing and the resulting likelihood that few or no flowers or seed pods would be available for their consumption. While there are no published studies on Frosted Elfin larval dispersal, it is generally accepted that due to their small size and relative immobility, Frosted Elfin larvae likely complete their development on a single plant or small cluster of plants and may not be capable of moving freely between Lupine clusters separated by large areas of open habitat.

Unprotected inflorescences produced few seed pods. In many cases, a blooming inflorescence was entirely consumed, but in other instances it was common for the lower one or two flowers to remain. Figure 3 shows an example of a partially browsed inflorescence in which several of the lower buds remained intact. Many times these flowers developed into seed pods that did reach maturity and eventually dehisced. It is not known if the presence of one or two single flower buds on an inflorescence provides enough food for a Frosted Elfin larva to complete its development.

Throughout the study site, unprotected inflorescences (including those that were monitored for this study and those that were not) that successfully set seed frequently met one of two conditions: (1) they were protected by low-lying tree limbs (Fig. 4) or large dead tree braches, or (2) they were relatively isolated from the large Lupine concentrations. It is worth noting that most of the ovipositing Frosted Elfin females that I encountered were found in areas with the high Lupine concentrations. It would be useful to know if female Frosted Elfins are less likely to encounter or oviposit on smaller, isolated Lupine clusters or Lupine inflorescences that are partially obscured by trees.

Finally, it is also noteworthy that Frosted Elfins on the adjacent roadsides have persisted for over 30 years, despite the fact that the concentration of Lupine along the road is much reduced compared to the concentration of Lupine at our study site. However, Lupine plants along the roadside are successful in producing large numbers of seed pods (S. Tangren, unpubl. data), probably because deer are less likely to feed on Lupine that occupy smaller and more isolated clusters along a narrow roadside with no shoulder. It is possible that many of the Frosted Elfin adults observed at the study site every year actually developed along the adjacent roadsides on Lupine with abundant flowers and seed pods. These roadside plants are also quite shaded, which may provide favorable microhabitat conditions for Frosted Elfin larvae. Albanese et al. (2008) suggests that in populations of Wild Indigo-feeding Frosted Elfins, adult females will oviposit on Wild Indigo plants across a range of microhabitats. Despite this seemingly indiscriminate microhabitat selection by adult females, Frosted Elfin larvae experienced increased larval success on plants that occurred in shaded areas; very few larvae reached maturity on plants that were in open areas exposed to full sun. Similar results have been reported for the Lupine-feeding *Lycaeides melissa samuelis* Nabokov (Karner Blue Butterfly) (Grundel et al. 1998, Lane and Andow 2003) and for two species of swallowtail butterflies (Rausher 1979). Other researchers have reported an increase in the density of Frosted Elfin butterflies in areas with some degree of canopy cover (Albanese et al. 2007, Pfitsch and Williams 2009, Swengel 1996), furthering the idea that some degree of shade may be required for the success of Frosted Elfin development. There is certainly a great need for data that assesses larval development and survivorship as a function of microhabitat differences for the Frosted Elfin as well as other imperiled Lupine feeders.

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Literature Cited

Albanese, G., P.D. Vickery, and P.R. Sievert. 2007. Habitat characteristics of adult Frosted Elfins (*Callophrys irus*) in sandplain communities of southeastern Massachusetts, USA. Biological Conservation 136:53–64.

Albanese, G., P.D. Vickery, and P.R. Sievert. 2008. Microhabitat use by larvae and females of a rare barrens butterfly, Frosted Elfin (*Callophrys irus*). Journal of Insect Conservation 12:603–615.

Allen, T.J. 1997. The Butterflies of West Virginia and their Caterpillars. University of Pittsburgh Press, Pittsburgh, PA. 388 pp.

Avery, L. 2007. Mann-Whitney U-Test online calculator. Available online at http://elegans.swmed.edu/~leon/stats/utest.html. Accessed June 2011.

Denny, C.S., J.P. Owens, L.A. Sirkin, and M. Rubin. 1979. The Parsonsburg sand in the central Delmarva Peninsula, Maryland, and Delaware: Surface and shallow subsurface geologic studies in the emerged coastal plain of the Middle Atlantic States. Geological Survey professional paper; 1067-B. US Department of the Interior, Washington, DC. 18 pp.

Glassberg, J. 1999. Butterflies through Binoculars—the East: A Field Guide to the Butterflies of Eastern North America. Oxford University Press, New York, NY. 242 pp.

Golden, D.M., and L. Pettigrew. 2005. Frosted Elfin Management Plan. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Trenton, NJ. 27 pp.

Grundel, R., N.B. Pavlovic, and C.L. Sulzman. 1998. The effect of canopy cover and seasonal change on host plant quality for the endangered Karner Blue Butterfly (*Lycaeides melissa samuelis*). Oecologia 114:243–250.

Lane, C.P., and D.A. Andow. 2003. Oak savanna subhabitat variation and the population biology of *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae). Annals of the Entomological Society of America 96:799–809.

NatureServe Explorer. 2011. An online encyclopedia of life [web application]. Version 4.6. Arlington, Virginia, USA: NatureServe. Available online at http://www.natureserve.org/explorer. Accessed July 2011.

O'Donnell, J.E., L.F. Gall, and D.L. Wagner. 2007. The Connecticut Butterfly Atlas. State Geological and Natural History Survey Bulletin No. 118, Department of Environmental Protection, Harford, CT. 376 pp.

Pfitsch, W.A., and E.H. Williams. 2009. Habitat restoration for lupine and specialist butterflies. Restoration Ecology 17:226–233.

Rausher, M.D. 1979. Larval habitat suitability and oviposition preference in three related butterflies. Ecology 60:503–511.

Schmidt, M.F., Jr. 1993. Maryland's Geology. Tidewater Publishers, Centreville, MD.

Schweitzer, D.F. 1992. Comments regarding *Erynnis persius persius* and *Incisalia irus*. The Ohio Lepidopterist 14:21–23.

Schweitzer, D.F. 2003. Panel Discussion Paper: Mitigating effects of intense deer herbivory. Pp. 16-17, *In* S. Damais, E. Stiles, and M. Dufort (Eds.). Proceedings of the State of the Forest Symposium: Ecological issues regarding Highlands Forest degradation and restoration. New Jersey Audubon Society, Bernardsville, NJ. 22 pp.

Smallidge, P.J., D.J. Leopold and C.M. Allen. 1996. Community characteristics and vegetation management of Karner Blue Butterfly (*Lycaeides melissa samuelis*) habitats on rights-of-way in east-central New York, USA. Journal of Applied Ecology 33:1405–1419.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry: The Principles and Practice of Statistics in Biological Research. W.H. Freeman and Company, San Francisco, CA.

St. Mary, M.K. 2007. A study on the effectiveness of transplanting vs. seeding of *Lupinus perennis* in an oak savanna regeneration site. M.Sc. Thesis. Bowling Green State University, Bowling Green, OH. 40 pp.

Swengel, A.B. 1996. Observations of *Incisalia irus* (Lepidoptera: Lycaenidae) in central Wisconsin 1988–1995. The Great Lakes Entomologist 29:47–62.

Wagner, D.L., M.W. Nelson, and D.F. Schweitzer. 2003. Shrubland Lepidoptera of southern New England and southeastern New York: Ecology, conservation, and management. Forest Ecology and Management 185:95–112.

Zaremba, R.E., and M. Pickering. 1994. Lupine ecology and management in New York State. Pp. 87–93, *In* D.A. Andow, R.J. Baker, and C.P. Lane (Eds.). Karner Blue Butterfly: A Symbol of a Vanishing Landscape. Minnesota Agricultural Experimental Station (Misc. Publication Series), St. Paul, MN. 220 pp.

Zaremba, R.E., M. Pickering, and B. Hunt. 1991. Preliminary results of the 1990 lupine (*L. perennis*) propagation project in the Albany Pine Bush. Report to the NYSDEC, Endangered Species Unit, Albany, The Nature Conservancy, NY Field Office, Albany, NY. 24 pp.