EFFECTS OF CONTROLLED BURNS ON VEGETATIVE GROWTH AND SEXUAL REPRODUCTION IN VALERIANA CILIATA IN A MICHIGAN FEN

Gary L. Hannan
Biology Department
Eastern Michigan University
Ypsilanti, Michigan 48197
ghannan@emich.edu

ABSTRACT

Valeriana ciliata T. & G. is a perennial plant restricted in Michigan to a small number of fens. A variety of management practices, including prescribed burns, is being used to control the establishment of alien woody species in fens. Response of V. ciliata to early spring burning was studied by examining plants in burned and unburned plots within a fen in southeastern Michigan. Neither growth, estimated as total number of leaves, number of rosettes and number of leaves per rosette, nor flowering, estimated as the proportion of plants flowering within quadrats, exhibited changes that could be attributed to burn treatments over the four year study. Early spring burning, therefore, can be employed as a management tool to control invasion of the fen by woody plant species without adversely affecting V. ciliata.

INTRODUCTION

Fire is an ecological factor that can induce a diverse array of responses at the individual, population and community levels of organization (Whelan 1995). Plant growth and reproductive effort can increase (Engle et al. 1998; Lamont & Runciman 1993; Singh 1993; Towne & Knapp 1996), decrease (Towne & Knapp 1996), remain unchanged (Grilz & Romo 1994; Towne & Knapp 1996) or stimulate shifts in allocation within plants (Brewer 1999; Johnson & Matchett 2001) in response to burning, although different populations of a species may vary in their response to burning (Brewer 1995), particularly when soils or topographic position differ (Engle et al. 1998). Initial responses of plants to fire may decrease in subsequent years (Pendergrass et al. 1999). Plant populations may increase (Johnson & Knapp 1995), decrease (Arthur et al. 1998; Johnson & Knapp 1995), or remain unchanged following burning (Howe 1995; Rooney et al. 1992). Interactions among post-fire changes may complicate analyses of plant response to burning (Briggs & Knapp 1995; Menges & Kimmich 1996).

When management goals include the maintenance of habitats that support fire-adapted or fire-neutral rare species, controlled burning may be an effective means of both maintaining those rare species and reducing the density of “undesirable” species. Species’ reactions to burning are highly individualistic; therefore, before fire can be used as an effective management tool, responses to fire by each species of interest must be studied in detail. Ideally, community-level re-
sponses to prescribed burning should be studied, particularly when unusual or rare habitats are involved.

In Michigan, fen habitats are uncommon. Consequently, species restricted to fen habitats are similarly scarce and are at risk of extinction if fens are overrun by invasive species, particularly woody species. Highland Cemetery Fen (in Ypsilanti, Michigan) and adjacent upland habitats support a diverse and dynamic flora that has been studied for many years (Brown 1905; Ohlsson 1970). *Valeriana ciliata* T. & G. (Valerian) grows in the fen with a variety of other typical fen species. The fen is currently managed by the Michigan Chapter of The Nature Conservancy to preserve its diversity. The primary threat to survival of the fen ecosystem is encroachment of the margin of the fen by alien woody species, primarily glossy buckthorn (*Rhamnus frangula* L.) (D. Ewert pers. comm.). Several management techniques designed to control invading alien species have been used, including cutting, herbicide application to stumps, and burning. Before fire can be used as a long-term management tool for this fen, the effects of fire on growth and reproduction (flowering) of *V. ciliata* must be investigated. This paper presents results of a study designed to test the hypothesis that early spring burning of the fen will affect growth or flowering of *V. ciliata*.

*Valeriana ciliata* occurs from Ohio and southern Ontario to Minnesota and Iowa and is closely allied to *V. edulis* Nutt. *Valeriana ciliata* is an herbaceous species that perennates in the form of a stout taproot and rhizome at, or slightly below, the surface of the soil. The rhizome branches as the plant grows, and each year it may produce a rosette of vegetative basal leaves on each branch. *Valeriana ciliata* produces opposite leaves usually at 2 to 4 nodes in a basal rosette. Some rosettes produce small lateral shoots in the axils of basal leaves, yielding much higher leaf counts for such rosettes. A flowering shoot produces an erect stem with one or two pairs of opposite, pinnately divided cauline leaves near its base. Leaves emerge above ground in early April, flowers mature in May and fruits mature by June. Rosettes produced by a plant remain connected by a discernible rhizome branch. Approximately 25% of plants in the population flower in a given year. *Valeriana ciliata* is reported to be polygamo-dioecious (Gleason & Cronquist 1991).

Growth and reproduction (both sexual and vegetative) are constrained by plant morphology (Waller 1988; Watson 1984). Perennial plant species are known to exhibit a range of growth and reproduction responses to changes in environmental conditions and aging (Andersson & Widen 1994; Braun & Toth 1994; Falinska 1995; Miller & Fowler 1994). Consequently, environmental changes within a habitat, including disturbances such as fire, may lead to significant differences in growth, vegetative reproduction and sexual reproduction in long-lived perennial plant species capable of vegetative reproduction. I hypothesize that *V. ciliata* will exhibit altered vegetative growth and flowering behavior following spring burning treatments.

**METHODS**

Highland Cemetery Fen is located at the base of a south-facing bluff at the south edge of the cemetery near the Huron River in Ypsilanti, Washtenaw Co., Michigan. Groundwater seepage from
the base of the bluff provides a constant supply of water to the fen. The slope of the fen faces approximately south and slopes downward by approximately 3 m to a wetter portion that does not support Valeriana ciliata plants. Glossy buckthorn currently is not in the V. ciliata population.

In April 1986 (prior to this study) the western half of the fen was burned prior to emergence of V. ciliata in an effort to reduce the density of glossy buckthorn before V. ciliata shoots emerge from the soil. In spring 1987, eight transects measuring from 10 to 30 m were established parallel to the slope of the fen at 5 m intervals, starting near the base of the bluff. Transect length was determined by the distance across the population of V. ciliata at each transect. Twenty eight 1 × 2 m quadrats were established at 7 m intervals along each transect, with the long axis of each quadrat oriented perpendicular to the axis of the transect. Transects contained from two to six quadrats each. The area burned in 1986 contained 12 quadrats on 3 transects and the unburned area contained 16 quadrats.

In April 1989 the southern half of the population was burned before Valeriana plants emerged, yielding a total of four different burn treatment areas: not burned (10 quadrats), burned in 1986 only (6 quadrats), burned in 1989 only (6 quadrats) and burned in both 1986 and 1989 (6 quadrats).

In May of each year, Valeriana ciliata plants were located in 10 by 10 cm grids overlaid on each quadrat and positions of all individuals were marked on scaled drawings of quadrats to allow identification of individuals from year to year. Because destructive sampling of this rare species was not permitted at this site, estimates of plant size were limited to the following dependent variables: total number of leaves per plant, number of rosettes per plant and number of leaves per rosette per plant (excluding cauline leaves of flowering rosettes). Leaf length and width were measured in 1987, but leaves continued to grow during the growing season, so they were not measured after 1987. Below ground structures could not be measured. Sexual reproduction in the population was estimated as the proportion of plants in flower within quadrats.

Data were analyzed in two stages. Initial evidence of the effects of the 1986 and 1989 burns was obtained from three-way ANOVAs using presence or absence of a burn in 1986, presence or absence of a burn in 1989, and sampling year (1987 through 1990) as independent variables and plant size characteristics as dependent variables. Plant flowering response was measured as the proportion of genets in flower per quadrat. Those data were arcsine-transformed to reduce the correlation between means and variances. Means and standard errors were back-transformed before reporting the results. A three-way ANOVA was applied to flowering data using the same design as for plant size.

All quadrats within a given burn treatment were located in the same area of the population because of the previously established burn pattern. Inherent differences in conditions in the four areas of the population, rather than differences induced by burn treatments, might be responsible for any significant differences suggested by the three-way ANOVAs. Such habitat differences could confound interpretation of results of the three-way ANOVAs and lead to falsely interpreting differences between burn treatment areas to burn effects rather than to other environmental factors associated with different parts of the site. In addition, pseudoreplication, an unavoidable design component of most studies of this kind, imposes limits on the confidence with which we accept our conclusions.

A more direct, although statistically less informative approach than the three-way ANOVA, was to test for differences in the annual change in size of individual plants between years using two sets of quadrats: those that had not been burned, and those burned only in 1989. The two-way ANOVA used change in plant size as the dependent variable with sampling year interval and burn treatment as independent variables. A difference in amount of annual change in plant size following a burn without a similar difference observed in the unburned quadrats would suggest an effect of burning on plant growth. The annual change in each plant characteristic was calculated for two independent periods: May 1987 to May 1988 (i.e., value for 1988 minus value for 1987) and May 1989 to May 1990. The burn treatments occurred in April of 1986 and 1989. The 1988 to 1989 period could not be used as an additional, independent measure of response to burning because it would require data from the same years as were used in the 1987 to 1988 and 1989 to 1990 period and, therefore, would not be a statistically independent measure of plant response. Only those plants present in successive years could be used to calculate change in plant size. Consequently, the change in average plant size between years (as tested using the three-way ANOVA) is not the same as the average change in individual plant size between years (as tested using the two-way ANOVA). A significant sampling year effect would not indicate a burn response by the plants. A significant burn treatment effect would not provide conclusive evidence of a burn effect on plant growth because the burned and unburned quadrats occur in different parts of the site (differences in site characteristics and burn treatment might be correlated). A significant interaction between time interval and burn treatment in the two-
way ANOVA would indicate an effect of burning on plant growth and flowering because the change in plant size between years would be influenced by burn treatment.

RESULTS

The three-way ANOVA that examined total number of leaves per plant revealed a significant interaction between 1986 and 1989 burn treatments (P < 0.001), but no significant interactions with year (P = 0.141 and P = 0.687 for interactions between year and 1986 burn and 1989 burn treatments, respectively). In three of the four burn treatment combinations, total leaf number increased each year (Fig. 1a). Increases in leaf number were observed in 1989 and 1990 whether plots were burned in 1989 or not. A similar pattern of change in leaf number was found in plots following the 1986 burn compared with plots not burned in 1986 (Fig. 1a).

The number of rosettes per plant differed among burn treatment areas. The unburned portion of the population had lower means each year than the other
treatment combinations, whereas the part of the population burned in both years had higher means than the other three areas (Fig. 1b). No significant interaction between year and burn treatment was found, however. The only significant interaction indicated in the three-way ANOVA was a two-way interaction between 1986 and 1989 burn treatments ($P = 0.046$).

The number of leaves per rosette showed no consistent relationship between year or presence or absence of a burn in 1986 or 1989. No significant three-way or two-way interactions were detected by the three-way ANOVA. Overall, mean number of leaves per rosette differed significantly by year. Mean leaf number per rosette increased in each successive year in all four burn treatment combinations except one (Fig. 1c). A slight decrease from 1989 to 1990 was found in the plants burned only in 1986.

The proportion of flowering plants per quadrat showed no three-way interaction between burn treatments and year effects ($P = 0.123$). One significant two-way interaction was found between the 1986 burn treatment and year ($P = 0.024$). The data showed differences between years in quadrats burned in 1986 and not burned in 1986, with higher means overall in the burned quadrats, although the highest mean values were not always in years immediately following the 1986 burn (Fig. 1d). For example, the highest proportion of flowering plants per quadrat was 0.689, obtained in 1987 in quadrats that were burned in 1986 and again in 1989. In the quadrats burned only in 1986, the 1987 mean was not the highest value among years in that group. Likewise, the year following the 1989 burn was not significantly higher than the year preceding the burn for quadrats burned in only 1989 or burned in both 1986 and 1989. The pattern of flowering response does not consistently correspond with the pattern of burning.

Results of the two-way ANOVA of annual change in plant size and flowering showed no significant interaction between time interval and the 1989 burn treatment for total leaf number per plant ($P = 0.493$; Table 1; Fig. 2a), number of rosettes per plant ($P = 0.613$; Table 1; Fig. 2b), number of leaves per rosette

<table>
<thead>
<tr>
<th>Change in:</th>
<th>Growth interval</th>
<th>Burned in 1989?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaves per plant</td>
<td>1987–1988</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>1989–1990</td>
<td>0.88 + 0.69 (68)</td>
</tr>
<tr>
<td>Rosettes per plant</td>
<td>1987–1988</td>
<td>0.12 + 0.13 (52)</td>
</tr>
<tr>
<td>Leave per rosette</td>
<td>1987–1988</td>
<td>0.24 + 0.21 (38)</td>
</tr>
<tr>
<td>Proportion of plants in flower per quadrat</td>
<td>1987–1988</td>
<td>-0.30 + 0.57 (53)</td>
</tr>
</tbody>
</table>

TABLE 1. Change in plant growth and flowering between 1987 and 1988 and between 1989 and 1990 in the 1989 burn treatment area [mean + se (n)]
The burn treatment effect on total leaf number (i.e., burned in 1989 vs. not burned in 1989) was significant ($P = 0.009$) because both 1987–1988 and 1989–1990 time intervals had mean changes in leaf number that were much higher than for the unburned quadrats (Table 1; Fig. 2a).

The direct comparison of change in number of rosettes per plant over the 1987–1988 and 1989–1990 time intervals by two-way ANOVA revealed no significant effects attributable to either burn treatment ($p = 0.139$) or to time interval ($P = 0.699$) (Table 1; Fig. 2b).

(P = 0.302; Table 1; Fig. 2c), or proportion of flowering plants per quadrat ($P = 0.284$; Table 1; Fig. 2d).
The change in number of leaves per rosette showed a significant effect of growth interval (1987–1988 vs. 1989–1990) \( (P = 0.02) \), but not burn treatment (burned vs. not burned in 1989). The 1987–1988 interval produced greater growth than in the 1989–1990 interval in both the burned and unburned quadrats (Table 1; Fig. 2c).

Those quadrats chosen for burning in 1989 had a greater change in proportion of rosettes flowering than did quadrats not chosen for burning in 1989, regardless of sampling period \( (P = 0.016; \text{Table 1; Fig. 2d}) \).

**DISCUSSION**

The goal of this study was to determine whether fire can be used as a management tool to protect fens in Michigan from encroachment by invasive glossy buckthorn without adversely affecting growth and flowering of *Valeriana ciliata*. Results of this study indicate that controlled burning of this fen in early spring, before *V. ciliata* emerged from the ground, had no adverse effects on either above-ground vegetative growth or flowering of *V. ciliata*.

Differences in plant size from years before a burn to years following a burn suggests an effect of burning on plant growth, but closer inspection reveals the fallacy of that conclusion. The lack of statistical interaction between year and burn treatment indicates that burning was not associated with differences between mean leaf number per rosette, number of rosettes per plant, or total number of leaves per plant. Yearly changes in plant size occurred in both burned and unburned quadrats, and occurred in quadrats prior to burning (Fig. 1). Factors other than burning must have induced plants to grow to different sizes between years. Other studies of plant responses to burning have shown that successional stage (Engle & Bidwell 2001), associated plant cover (Tyler & Dantonio 1995), and time since burning (Pendergrass et al. 1999; Quintana-Ascencio et al. 1998) can affect plant growth in burned areas. Under some circumstances, therefore, effects of burning may be overridden by other factors, including those that vary within a site. In this study, *Valeriana* plants in different treatment areas of the population differed in size before the 1989 burn, suggesting that habitat differences promoted different growth patterns in the absence of fire.

A much more sensitive measure of plant response to burning should be possible by comparing changes in growth by plants in the same quadrats from one year to the next. By comparing parallel changes in growth between plants in unburned quadrats to changes in plants in burned quadrats, using years that span a burn year, effects of annual fluctuations in growth conditions may be reduced. If burning has an impact on growth, one would expect to see significant differences in growth (change in plant size between years) before as compared to after burning, and those differences should not be found in the unburned quadrats; i.e., a significant interaction between annual growth and burn treatment should be found. The lack of such interaction suggests that burning has no effect on plant growth.

The lack of detected changes in vegetative growth in this study is consistent
with responses of some prairie forbs (e.g., *Dalea candida*, *D. purpurea*, *Desmodium illinoense*, *Lespedeza capitata*, *L. violacea*, *Psoralea tenuiflora*, *Schrankia nuttallii*) to April burn treatments (Towne & Knapp 1996). Those species exhibited similar biomass in sites that were burned annually vs. unburned sites, but overall effects of fire on plant growth can include changes in the ratio of above-ground to below-ground biomass, even if total plant biomass does not change (Brewer 1999). Nondestructive measures of above ground plant growth were required in this study of *Valeriana ciliata*, however, so partitioning of growth between structural components was not possible.

Some herbaceous perennials are induced to flower after a burn (Kettle *et al.* 2000; Kirkman *et al.* 1998; Lamont & Runciman 1993). Flowering of *Valeriana ciliata*, measured as percent of plants in flower per quadrat, was highly variable among quadrats. Higher proportions of flowering plants in the 1989 burn and 1986/1989 burn quadrats might suggest a burn effect; however, both high and low proportions of flowering plants occur prior to burning in the 1989 burn treatment. Flowering was low in the year of the burn in the 1989 burn treatment and rose the year following the burn, but no increase in flowering was observed in those same years in the quadrats burned in both 1986 and 1989 (Fig. 1d). Different patterns of flowering were found in different parts of the population, regardless of burn treatment, suggesting that burning did not effect the likelihood of flowering in *V. ciliata*.

A persistent theme in the analyses of growth and reproduction in this population is the overriding importance of habitat characteristics in determining growth and flowering behavior of *Valeriana ciliata*. Fire, at least at the intensities and season pertinent to this study, had no discernible effect on either plant growth or flowering. The diversity of plant responses to burning reported in the literature suggests that species exhibit individual responses to fire and that differences in fire characteristics (windspeed, temperature, litter depth, relative humidity, moisture content of fuel, etc.), in addition to season, combine to influence plant growth following fire (Bond & van Wilgen 1996; DeBano *et al.* 1998; Whelan 1995). Many aspects of the response of *V. ciliata* to fire were not addressed in this study, such as inflorescence size, number of rosettes in flower per plant, fruit set, seed germination, seedling establishment, or nutrient status of plants. All of these are potentially important to the long-term survival of the population, but at the gross level of plant size and flowering, burning in early spring has little effect on *V. ciliata*. Prescribed burning in early spring, therefore, is a useful management tool that can be used without harming adult *V. ciliata* plants.

ACKNOWLEDGMENTS

This study was supported, in part, by the Michigan Chapter of The Nature Conservancy through its Small Grants program. I thank Annie Hannan and Linda Turner for assistance in the field, Dr. Peter Bednekoff for statistical advice, Dr. David Ewert of the Michigan Chapter of The Nature Conservancy and Highland Cemetery for their cooperation and assistance.
LITERATURE CITED


Quintana-Ascencio, P. F., R. W. Dolan & E. S. Menges. 1998. Hypericum cumulicola demography in...


