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# PRECIPITATION AND FIRE EFFECTS ON FLOWERING OF A RARE PRAIRIE ORCHID

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**ABSTRACT**—A small, isolated population of the threatened western prairie fringed orchid (*Platanthera praeclara* Sheviak & Bowles) occurs at Pipestone National Monument, Minnesota, in a mesic prairie that is periodically burned to control invasive cool-season grasses. During 1995–2004, monitoring counts of flowering orchids in the monument varied considerably for different years. Similar precipitation amounts in the spring and histories of burning suggest that fire and precipitation in the spring were not the causes of the variation. For the eight non-burn years in the monitoring record, we compared the number of flowering plants and the precipitation amounts during six growth stages of the orchid and found a 2-variable model (precipitation during senescence/bud development and precipitation in the dormant period) explained 77% of the annual variation in number of flowering plants. We also conducted a fire experiment in early May 2002, the typical prescribed burn period for the monument, and found that the frequency of flowering, vegetative, and absent plants observed in July did not differ between burned and protected locations of orchids. We used the model and forecasts of precipitation in the spring to develop provisional burn decision scenarios. We discussed management implications of the scenarios.

**Key Words:** burn decision scenarios, Pipestone National Monument, prescribed fire, precipitation, western prairie fringed orchid

## INTRODUCTION

A small, isolated population of the threatened western prairie fringed orchid (*Platanthera praeclara* Sheviak & Bowles) (U.S. Fish and Wildlife Service 1996) occurs at Pipestone National Monument, Minnesota, in a mesic prairie that is periodically burned in the spring to control

smooth brome (*Bromus inermis* Leyss.) and other invasive cool-season grasses. In response to concerns that prescribed fires in tallgrass prairie in the spring can reduce forbs (Gibson and Hulbert 1987; Hartnett 1991), the monument initiated a monitoring program in 1995 to track the status of the orchid population over time. This included an annual census of flowering plants in mid-July. For the 10-year monitoring period, the number of flowering plants

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TABLE 1  
NUMBER OF FLOWERING WESTERN PRAIRIE FRINGED ORCHID PLANTS AND PRECIPITATION AMOUNTS DURING SIX GROWTH STAGES AT PIPESTONE, MINNESOTA, 1995–2004

Year	Number of flowering plants	Precipitation during growth stage (cm)					
		Year before flowering			Dormancy	Year of flowering	
		Mature growth	Senescence/bud development	Post-senescence		Emergence	Mature growth
1995	37	14.25	9.40	8.18	22.17	24.28	23.50
1996	55	23.50	8.15	8.89	17.04	11.28	11.13
1997	3	11.38	5.54	11.63	25.20	10.39	14.17
1998	0	14.17	2.82	4.88	20.83	10.67	14.30
1999	17	14.30	8.33	3.51	26.21	21.51	25.83
2000	125	25.83	5.82	3.43	9.32	27.53	9.63
2001	95	9.63	6.07	2.41	19.86	26.57	19.76
2002	124	19.76	2.03	7.98	18.34	9.98	17.22
2003	221	17.22	19.46	5.00	14.05	26.37	14.91
2004	146	14.91	4.24	10.90	15.16	19.89	20.24

varied considerably, with annual counts ranging from 0 in 1998 to 221 in 2003 (Young and Haack 2005) (Table 1).

Precipitation amounts (Bowles et al. 1992) and prescribed burning of orchid habitat (Currier 1982; Bowles 1983) likely influence flowering of the western prairie fringed orchid. In studies of individual orchid plants burned at Sheeder Prairie in Iowa, Pleasants (1995) found burning in early spring had a negative effect on flowering of the orchid if precipitation in the spring was below normal. Apparently, in a dry spring, plants at burned locations were moisture stressed and aborted flowers (Pleasants 1995). However, at Pipestone the monitoring data showed distinct differences in number of flowering plants in different burn years with similar amounts of precipitation in the spring. For example, a prescribed burn in late May 1997 during a dry spring (66% of normal precipitation for March, April, and May) was followed by a low number ( $n = 3$ ) of flowering plants in July, whereas a burn in early May 2002, also during a dry spring (84% of normal precipitation), was followed by a high number ( $n = 124$ ) of flowering plants in July. These data suggest that the timing of burns in a dry spring can affect flowering of the orchid.

However, in the non-burn years at Pipestone, the monitoring data also showed contrasting numbers of flowering

plants in different years with similar amounts of precipitation in the spring. For example, in 1999, following a wet spring (121% of normal precipitation), 17 orchids flowered, but in 2003, following another wet spring (141% of normal precipitation), 221 orchids flowered. The variation in number of flowering orchids in years without fire was similar to those with fire and suggested that a factor other than fire and/or precipitation in the spring may be the cause. That factor may be precipitation amounts during seasons of the orchid growth cycle other than spring. This is supported by Bowles (1983) and Pleasants (1995), who suggested lack of flowering in the orchid may reflect inadequate moisture conditions during development of the new tuber and perennating bud in the late summer of the previous year.

At Pipestone, the concurrent monitoring of the flowering of the orchid and precipitation, as well as records of individual prescribed fires, offers a unique opportunity to investigate precipitation and fire effects on flowering of the orchid. We examine the relationship between the number of flowering orchids in July for non-burn years in the monitoring record and precipitation amounts during six growth stages of the orchid as defined by Wolken (1995) (Table 2) for the same years to determine if precipitation during one or more stages is predictive of orchid flower-

TABLE 2  
PHENOLOGICAL STAGES OF THE WESTERN  
PRAIRIE FRINGED ORCHID

Stage	Date
Emergence	Late April–early May
Mature growth	Late June–early July
Senescence/bud development	Late August
Post-senescence	Late September
Dormancy	October–March

Source: Wolken (1995)

ing. Furthermore, we present data on a small experiment designed to compare flowering between orchids subject to spring burning and those protected from burning. Our goal is to provide management recommendations for the use of prescribed fire in orchid habitat under various precipitation histories and forecasts that will help conserve the orchid population over time.

## METHODS

### Study Site

Pipestone National Monument is a small, protected area of 114 ha in the Prairie Couteau region of southwestern Minnesota. In the monument, the western prairie fringed orchid is found in relatively undisturbed tallgrass prairie that supports a diverse flora including 305 vascular plant species (Becker 1986). The soil where the orchid occurs is a silty clay loam developed on loess overlying Sioux quartzite (USDA-SCS 1976). The prairie has been prescribed-burned in the spring on a three- to four-year rotation since 1972. Since the 1950s, the monument has collected daily precipitation data at a weather station located approximately 0.5 km north of the prairie.

### Annual Census

We obtained the yearly counts of flowering plants from the most recent annual report of the western prairie fringed orchid at Pipestone (Young and Haack 2005). The monument conducted the annual census of flowering plants following a systematic monitoring protocol (Willson 2000). We obtained precipitation data from the

records of the Pipestone Reporting Station (Midwest Regional Climate Center 2004).

### Fire Experiment

In July 2001, during the annual monitoring of the orchid population, we selected and marked 20 pairs of flowering plants. We paired plants based on similar height and numbers of flowers per inflorescence and their proximity to each other (i.e., plants were separated by no more than 4 m). We randomly assigned the location of one of each pair to be protected (i.e., unburned) and the other to be burned.

On April 30, 2002, we installed a cylinder of aluminum flashing, approximately 2 m in diameter and 2 m in height, around each orchid location assigned to the protected treatment. To provide an additional firebreak, we removed herbaceous fuel from a 20-cm-wide ring surrounding the outside of each cylinder. On May 2, 2002, the resource management staff at Pipestone burned the orchid habitat using a combination of head and backing fires. In July 2002, during the annual monitoring, we recorded the presence of a flowering or vegetative plant or the absence of a plant at the protected and burn treatment locations.

### Data Analysis

We used stepwise linear regression (SAS 1990) to assess relationships between number of flowering orchids in the eight non-burn years of the monitoring record and total precipitation during six orchid growth stages. For the 2002 fire experiment, we used the chi-squared test of independence (SAS 1990) to determine if the frequency of flowering, vegetative, and absent plants differed between the protected and burn treatments.

## RESULTS

Table 1 shows total precipitation during six stages of orchid growth for each of the 10 years in the monitoring record. For the eight non-burn years, we found a 2-variable model (precipitation during senescence/bud development in the previous August, or stage SB, and precipitation during dormancy in the previous October through March winter, or stage DO) explained 77% of the annual variation in number of flowering plants ( $F_{2,5} = 8.54$ ,  $P = 0.0244$ ,  $R^2 = 0.77$ ). The model equation is  $y = 196.73 + 7.28SB - 9.30DO$ ; variables SB and DO are not correlated ( $P = 0.6421$ ). Table 3 lists predicted (from the model) and

TABLE 3  
PREDICTED AND COUNTED NUMBERS OF  
FLOWERING WESTERN PRAIRIE FRINGED  
ORCHID PLANTS, PIPESTONE NATIONAL  
MONUMENT, 1995–2004

Year	Predicted	Counted
1995	59	37
1996	98	55
1997	3	3
1998	24	0
1999	14	17
2000	152	125
2001	56	95
2002	41	124
2003	208	221
2004	87	146

Note: Predictions were made using model  $y = 196.73 + 7.28SB - 9.30DO$ , where  $SB$  = senescence/bud development, and  $DO$  = dormancy.

counted numbers of flowering plants for the 10 years in the monitoring record.

Of the 20 paired plants selected for the fire experiment, we deleted 6 pairs because either the fire burned within the area protected by the cylinder or did not burn the location of the plant that was slated to burn. Thus, 14 pairs of plants remained. Table 4 shows the numbers of flowering, vegetative, and absent plants for the protected and burn treatments. We found no significant difference in the frequency of flowering, vegetative, and absent plants between treatments ( $\chi^2 = 2.68$ ,  $CV = 5.99$ ,  $P = 0.2605$ ).

## DISCUSSION

Our analysis of the non-burn years in the monitoring record suggests flowering of the western prairie fringed orchid at Pipestone is closely associated with precipitation during August of the year before flowering when orchid plants are developing perennating buds and during dormancy in the previous winter (October through March). We found a direct relationship between number of flowering plants and precipitation during the senescence/bud development period. This suggests that below-average precipitation during August hampers bud development and lowers the potential for subsequent flowering the

TABLE 4  
NUMBERS OF FLOWERING, VEGETATIVE, AND  
ABSENT PLANTS FOR PROTECTED AND BURN  
TREATMENTS, PIPESTONE NATIONAL  
MONUMENT, 2002

	Flowering	Vegetative	Absent	Total
Protected	6	6	2	14
Burn	9	5	0	14
Total	15	11	2	28

next July, whereas above-normal precipitation stimulates many plants to develop buds capable of flowering the next summer. In contrast, we found an inverse relationship between number of flowering plants and precipitation during the winter dormant period. This was likely the result of water-saturated soil in the orchid habitat in the late winter or early spring following snowmelt that stressed or killed plants and lowered the potential for flowering. Sieg and Wolken (1998) observed a similar situation in the Sheyenne National Grassland where, in wet years, flooding in the swale habitat contributed to high orchid mortality and few flowering plants.

Data from two of the non-burn years in the monitoring record illustrate the biological significance of the model. For example, in 1998, no flowering orchids were counted during the annual monitoring. Precipitation during the senescence/bud development period the previous August was below normal (36% of normal) and the second lowest of the monitoring period. Also, the precipitation in the previous dormant period was above average (154% of normal). Because of dry conditions the previous August, buds may not have developed sufficiently and saturated soil during or after the dormant period may have stressed or killed plants. In contrast, in 2003, 221 flowering plants were counted during the annual monitoring. Precipitation during the senescence/bud development period the previous August was above normal (247% of normal) and the highest of the monitoring record, whereas the precipitation during the previous dormant period was below normal (69% of normal). In this situation, a large number of buds may have developed sufficiently to support flowers and these plants survived or were not stressed during the dormant period.

We used the model developed from the non-burn years and precipitation data from the burn years (i.e., 1997 and 2002) to predict number of flowering plants for the burn

years and to compare the predicted numbers to the counts. Table 3 shows that predicted and counted numbers of flowering plants are identical for 1997 but very different for 2002. These results suggest that the flowering potential established by precipitation amounts during the previous bud initiation and dormancy periods was altered by prescribed fire in 2002 but not in 1997.

However, further examination of the burn years caused us to question this assumption. In 1997, precipitation during the winter dormant period prior to flowering was well above normal (154% of normal), and as stated before, water-saturated soil may have stressed or killed plants. Also, the prescribed burn in 1997 took place in late May after plants had emerged. Antlinger (1998) found that burning the habitat of lady's-tresses [*Spiranthes cernua* (L.) Rich.], another prairie orchid, after emergence of plants significantly reduced leaf area of the plants both in the burn and the following years. In orchid species, inflorescence size and number of flowers are positively correlated with leaf area (Calvo 1990). Furthermore, precipitation in the spring of 1997 was below normal. Lack of precipitation and increased loss of soil moisture following the burn may have stressed plants and caused flowers to abort. However, we believe the low number of flowering plants in 1997 ( $n = 3$ ) was primarily the result of stress on the plants from a wet dormant period. The removal of leaf area by the late May burn and lack of precipitation added little or no effect because few plants would have been capable of flowering anyway.

In 2002, the large difference between the predicted and the counted number of flowering plants is not easily explained. Precipitation during August 2001, when flower buds for the next season were developing, was below normal (26% of normal). Lack of precipitation would have hampered flower bud development and predicted a low number of flowering plants in 2002. But the number of flowering plants counted in 2002 was 124, the fourth highest of the monitoring record, and three times the number predicted by the model (Table 3). In the 2002 burn experiment, we found orchid plants emerged about two weeks earlier in areas burned versus areas protected from the fire (i.e., inside the cylinders). Initially, this suggested that the extended period of growth and adequate precipitation (123% of normal) in June 2002 may have countered the effects of dry conditions the previous August and stimulated the plants to flower. However, in 2002, we found no significant difference in the frequency of flowering, vegetative, and absent plants between the protected and burn treatments in the fire experiment. This argues that burning in early May had no significant effect on flower-

ing. A likely explanation may be that the model did not account for the effects of precipitation occurring before the bud development stage. Precipitation was slightly above normal (105% of normal) in June and July 2001, and although August was very dry (26% of normal), soil moisture was probably not depleted and may have been sufficient to support bud development. Clearly, additional monitoring is needed to refine the model.

## MANAGEMENT IMPLICATIONS

We believe the predicted number of flowering plants based on precipitation inputs to the model and a forecast of precipitation in the spring can be used by resource managers at Pipestone as a provisional guide for the use of prescribed fire in the orchid habitat. Table 5 shows eight burn decision scenarios based on these factors. We provide further explanation in the following discussion.

When the previous August was wet (i.e., above-normal precipitation) and the dormant season was dry (i.e., below-normal precipitation), the model predicts a very high number of flowering plants in relation to the range of numbers of plants counted during the monitoring years. In this scenario, the forecast of precipitation in the spring would be the most important factor in a manager's decision to burn or not. If the spring is forecasted to be dry, we recommend managers not burn, as burning could exacerbate soil moisture loss (Hanks and Anderson 1957; Knapp 1985) and cause the many plants capable of flowering to abort flowers (Pleasants 1995). (Although Pleasants [1995] reported reduced flowering following a prescribed burn in a dry spring, we did not. The difference in results may relate to the amount that precipitation deviated from normal. At Pipestone, precipitation in the spring of 2002 was 84% of normal. Although the spring was dry, the deficit in precipitation was not large and the amount or distribution of precipitation was sufficient to support orchid flowering following the prescribed burn). In contrast, if the forecast calls for a wet spring, we recommend that managers burn in early to mid-May, as fire during this period would have no negative effect on flowering (Pleasants 1995) and would likely produce beneficial effects such as reduced competition from cool-season exotic grasses, particularly smooth brome (Willson and Stubbendieck 1997).

When the previous August was dry and the dormant season was wet, the model predicts a very low number of flowering plants. In this scenario, the forecast of precipitation in the spring would have little effect on a manager's decision to burn. Because very few or possibly no plants would be capable of flowering, we suggest managers consider burning

TABLE 5  
PROVISIONAL DECISION TABLE FOR PRESCRIBED FIRE USE IN WESTERN PRAIRIE ORCHID HABITAT,  
PIPESTONE NATIONAL MONUMENT

Precipitation history		Model-predicted number of flowering plants	Spring precipitation forecast	Decision
Previous August	Dormant period			
Wet	Dry	Very high	Dry	No burn
Wet	Dry	Very high	Wet	Burn
Wet	Wet	Low	Dry	No burn
Wet	Wet	Low	Wet	Burn
Dry	Dry	Low	Dry	No burn
Dry	Dry	Low	Wet	Burn
Dry	Wet	Very low	Dry	Burn late?
Dry	Wet	Very low	Wet	Burn late?

in late May or early June if the control of invading woody shrubs such as sumac (*Rhus glabra*) is a critical objective (Solecki 1997). However, we caution that burning late, after nonflowering plants have begun to emerge, could remove the foliage of these plants and may affect their subsequent survival. Also, we would not recommend burning in late spring in any year during an extended drought period. In this situation, fire would have a direct negative impact (i.e., removal of leaf tissue) on the few plants capable of flowering and may cause them not to flower. With an extended drought, the loss of all or nearly all flowering plants in one or more years could increase the probability of the population in the monument going extinct.

When both the previous August and dormant period were dry or wet, the model predicts relatively low numbers of flowering plants. In these scenarios, the forecast of precipitation in the spring would again be the deciding factor. Generally, if the forecast for the spring is wet, we recommend managers burn in early to mid-May, but if the forecast is dry, we recommend managers not burn.

Finally, we caution managers that the burn decision scenarios are provisional and subject to change as managers at Pipestone acquire and analyze additional monitoring data. Also, we recommend that the model be tested at other locations where flowering of the orchid has been monitored, such as northwest Missouri (Ashley 2005) and west-central Minnesota (Sather 1991). Furthermore, to minimize any unforeseen negative effects of fire on the orchid population, we strongly recommend

only a portion of the habitat be burned in any year. A safe option would be to divide the orchid habitat and only burn one-half or less.

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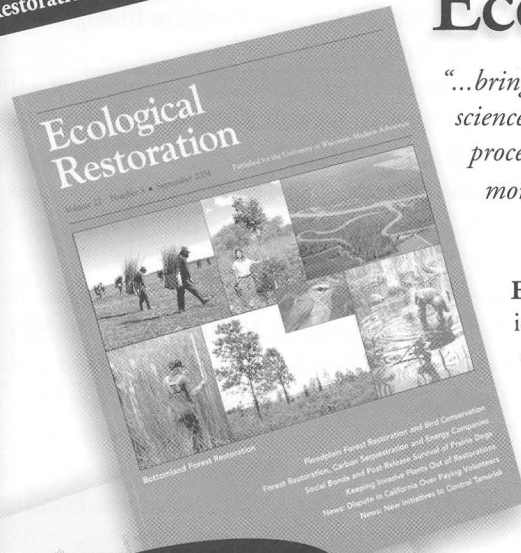
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