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Quantifying suitable habitat of the threatened western prairie fringed orchid

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Abstract

Land managers need accurate and quick techniques to identify suitable habitat of species of interest. For species protected by federal or state laws, identification of suitable habitat is critical for developing a conservation strategy that includes reestablishing populations and altering management to address this need. In this research, we quantified vegetative and edaphic habitat of the western prairie fringed orchid (*Platanthera praeclara* Sheviak and Bowles), a federally listed threatened plant. Lowlands (swales) that supported orchids in our southeastern North Dakota study area were characterized as having a higher soil moisture content within the top 10 cm, when compared to swales devoid of orchids. The vegetative composition of orchid-supporting swales reflected this higher moisture content. These data were then used in developing a logistic regression model to differentiate suitable habitat. The model correctly classified 84% of 38 swales as either orchid-supporting or non-orchid-supporting using 4 variables: percent canopy cover of Baltic rush (*Juncus balticus* Willd.) and hedge-nettle (*Stachys palustris* L.), soluble soil magnesium and August surface soil moisture. Land managers can use this model to rapidly assess the suitability of a site in this ecoregion for the orchid. By collecting data on the cover of just Baltic rush, which would take about 45 minutes, and entering it in the equation, a land manager could correctly classify 66% of the orchid swales as either suitable or unsuitable as orchid habitat. This approach, because it incorporates quantitative data and allows managers to rapidly and accurately identify suitable habitats, shows promise for other plant species.

Key Words: *Platanthera praeclara*; wetland; tallgrass prairie; threatened plant; edaphic factors; logistic regression; soil moisture; North Dakota.

Resumen

Los administradores de tierras necesitan tecnicas precisas y rapidas para identificar habitat adecuado de especies de interes. Para especies protegidas por leyes federales o estatales, la identificacion de habitat adecuado es critico para desarrollar una estrategia de conservacion que incluya el reestablecimiento de poblaciones y adecuar el manejo de acuerdo a estas necesidades. En esta investigacion, cuantificamos el habitat vegetativo y edafico de la orquidia del borde de la pradera oriental (*Platanthera praeclara* Sheviak and Bowle), una planta enlistado federalmente como amenazada. Tierras inundables (cienegas) que soportan estas orquideas en nuestra area de estudio en el sureste de North Dakota fueron caracterizadas como de mas alto contenido de humedad en los primeros 10 cm del suelo, cuando se comparan con las cienegas sin orquideas. La composicion vegetal de las cienegas que soportan orquideas reflejan este mas alto contenido de humedad. Estos datos fueron usados para desarollar un modelo de regresion logistica para diferenciar habitat adecuado. El modelo clasifico correctamente el 84% de 38 cienegas como adecuados o inadecuados para las orquideas usando cuatro variables: porcentajes de coberturas de junco Baltico (*Juncus balticus* Wiilld.) y ortiga (*Stachys palustris* L.), magnesio soluble en el suelo y humedad superficial del suelo en Agosto. Administradores de tierras pueden usar este modelo para evaluar rapidamente la aptitud de un sitio para las orquideas en esta ecoregion. Colectando datos de cobertura solamente de junco Baltico, que tomaria cerca de 45 minutos, y metiendolos en la ecuacion, un administrador podria clasificar correctamente un 66% de cienegas como habitat adecuadas o inadecuadas para orquideas. Este enfoque, porque incorpora datos cuantitativos y permite a los administradores identificar habitat adecuado con rapidez y precision, parece prometedor para otras especies de plantas.

Land managers need quantitative techniques to rapidly assess the suitability of habitats for rare plant species. This information may be used to delineate special management areas or to identify potential reintroduction sites. Establishment of new populations is imperative for the recovery and eventual delisting of threatened and endangered plant species (Schemske et al. 1994). Success of establishment efforts is greatest when individuals are replanted in the same microhabitat from which they were collected (Holsinger and Gottlieb 1991).

The western prairie fringed orchid (*Platanthera praeclara* Sheviak and Bowles) was listed as a threatened plant in 1989

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(U.S. Fish and Wildlife Service 1989). Its rarity is attributed to the conversion of most of the tallgrass prairie to croplands or other development (Samson and Knopf 1994). Currently, only 3 metapopulations of the orchid are known: 2 in the United States and 1 in Manitoba (U.S. Fish and Wildlife Service 1996). The North Dakota metapopulation is in the southeastern corner of the state, almost entirely on the Sheyenne National Grassland, in sedge meadows associated with lowland depressions (swales) (Sheviak and Bowles 1986, Bjugstad and Fortune 1989, Sieg and Bjugstad 1994). Although many subirrigated swales on the Sheyenne National Grassland support populations of the western prairie fringed orchid, there are also swales that do not support orchids. The objectives of this study were to: 1) isolate vegetative and edaphic factors associated with the patchy distribution of the western prairie fringed orchid, and 2) develop a technique (model) that can be used to differentiate between suitable and unsuitable habitat.

Materials and Methods

A paired design was chosen to compare environmental factors between swales that supported orchids and swales that did not. Using baseline data collected over the previous 7 years, 19 swales with a minimum of 10 orchids each were selected from the core of the Sheyenne National Grassland metapopulation. In addition, for each swale supporting orchids, we selected a nearby swale without orchids, for a total of 19 non-orchid swales. Criteria used in selecting non-orchid swales included close proximity to an orchid swale and similar management, exposure and topography. Potential non-orchid sites were searched carefully for orchids—including the smaller vegetative plants—to ensure that the site was devoid of orchids. We attempted to cover the range of swale environments exposed to a seed source and therefore potentially capable of supporting the orchid. We established an oblong or circular plot in each of the 38 swales that, depending on the size and shape of the swale and distribution of the orchid population, ranged in size from 250 to 500 m^2. The plots were dispersed among 6 study sites on the Sheyenne National Grassland. Two thirds of the plots were grazed by cattle either season long or were in a three-pasture rotation system. The remainder of the plots were in exclosures or along the railroad right-of-way.

In July 1992, plant composition in orchid and non-orchid swales was characterized by estimating percent plant canopy cover in a minimum of 20 and up to fifty, 20 x 50 cm quadrats. Cover was estimated to fall in 1 of 6 cover classes (1 = 0-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-95%, and 6 = 96–100%) (Daubenmire 1959). Quadrats were systematically placed at 1-m intervals along permanent transects (20 to 50 m in length). Variables estimated included: total plant canopy cover, total graminoid cover, total shrub cover, total forb cover, litter, bare ground, and cover by species. We used Great Plains Flora Association (1986) for taxonomic determination and nomenclature. During the height of the flowering season (late June through early July) in 1992 and 1993, orchids were permanently marked with numbered marker pins and mapped using a coordinate system.

Soil moisture was estimated in July and August of 1992 and June of 1993. A probe (48 cm long x 2 cm diameter tube) was used to collect 4 soil samples per swale. Each sample was stratified into 4 depths: 0–2 cm, 2–10 cm, 10–20 cm, and 20–30 cm. Samples were collected 15 cm from 4 separate orchid plants in orchid swales and randomly in non-orchid swales. Soil moisture was determined gravimetrically (dried at 105° C for 48 hours). In 1993, soils were completely saturated due to flooding. Therefore, depth of standing water was measured at 4 random points in each swale in July and August of 1993.

Additional soil samples were collected in August 1992 for chemical analyses. A total of 4 samples (10 cm deep by 4 cm diameter) were collected 15 to 20 cm from 4 separate orchid plants in each orchid swale and randomly in each non-orchid swale. Approximately 700 g of soil was taken per sample, stored in plastic bags and frozen for subsequent total nitrogen testing. Chemical analyses, conducted at the University of Wyoming Soil Testing Laboratory,Laramie, Wyo. included pH, electrical conductivity (EC), soluble cations: potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), and soluble sulfur (S), percent calcium carbonate ($CaCO_3$) (Richards 1954), percent total nitrogen (N) (Jones 1971), nitrate (NO_3) (Sims and Jackson 1971), available phosphate phosphorous (PO_4) (Olsen and Sommers 1982), percent organic matter (OM) (Greweling and Peech 1960), percent water at saturation, and texture (mechanical) (Day 1965).

Statistical Analysis

We designed the study to use paired t-tests to test for differences in vegetative composition, soil moisture, water depth, and soil chemistry between orchid and non-orchid swales. Assumptions of normality were tested with Lilliefors Test; the variances were tested using the Levene Test (Norusis 1990). The data for 42 of 51 variables were not normally distributed ($P < 0.05$). Elimination of extreme outliers and data transformation did not correct non-normality nor heterogeneous variances. Therefore, we used the Wilcoxon signed-rank test to compare variables between orchid and non-orchid swales. Significance of Wilcoxon signed-rank tests was estimated using Monte Carlo estimates of exact P-values based on 10,000 repeated samples, thus avoiding the assumptions attached to using the asymptotic P-values (Mehta and Patel 1995). We set $\alpha = 0.05$ for all tests.

We utilized logistic regression to identify variables that are most useful or "most likely" to distinguish between two classes (Press and Wilson 1978, Hosmer and Lemeshow 1989). Logistic regression provides an equation to predict the probability that a swale will support orchids and a multivariate comparison between orchid and non-orchid swales, plus it identifies those variables most associated with the presence and absence of orchids. The selection and contribution of each variable depends on the other variables in the model, so highly correlated variables may greatly influence the final model. We used a correlation matrix to identify these variables. Only 1 of a pair of highly correlated ($r > 0.85$) variables was used in the model; the variable with the least biological importance was eliminated. We applied forward stepwise logistic regression with the likelihood-ratio test. Misclassification rates for logistic regression models were estimated using "leave-one-out" cross-validation, which makes more efficient use of small data sets that are common in studies of rare species. This cross-validation method involves refitting the model by leaving 1 observation out, and then computing the predicted value for the *i*th observation; this is done for each observation at each step and then the average cross-validation sum of squares is computed (Efron and Tibshirani 1993). We summarized the average misclassification rate for orchid and non-orchid sites at each step. We used the SPSS/PC+ statistical package (Norusis 1990) to perform all analyses.

Table 1. Average (± SD) percent canopy cover of major plant species in orchid and non-orchid swales on the Sheyenne National Grassland, 1992.

Category / Species	Swale Type: Orchid	Swale Type: Non-orchid
	(%)	(%)
Total Cover	83.7 ± 8.7	82.4 ± 5.3
Total Litter	93.9 ± 4.2	89.2 ± 12.5
Bare ground	1.5 ± 2.1	5.5 ± 8.2
Total Forb Cover	41.4 ± 15.7	33.9 ± 15.8
western ragweed (*Ambrosia psilostachya* DC.)	4.7 ± 6.4	6.1 ± 5.9
meadow anemone (*Anemone canadensis* L.)	6.7 ± 10.7	2.8 ± 3.5
panicled aster (*Aster simplex* Willd.)	7.6 ± 8.7	4.0 ± 3.8
smooth scouring rush (*Equisetum laevigatum* A. Br.)	1.4 ± 2.4	1.2 ± 1.5
leafy spurge (*Euphorbia esula* L.)	5.2 ± 10.0	2.9 ± 4.6
euthamia (*Euthamia graminifolia* (L.) Nutt.)	1.8 ± 3.5	2.2 ± 3.1
wild strawberry (*Fragaria virginiana* Duchn.)	4.3 ± 7.0	4.3 ± 9.5
wild licorice (*Glycyrrhiza lepidota* Pursh)	0.7 ± 1.0*	4.4 ± 6.5
water smartweed (*Polygonum amphibium* L.)	1.3 ± 2.6	0.8 ± 1.6
Canada goldenrod (*Solidago canadensis* L.)	2.8 ± 2.9	3.2 ± 4.4
hedge-nettle (*Stachys palustris* L.)	1.0 ± 1.8**	0.0 ± 0.0
Total Graminoid Cover	65.8 ± 20.2	66.9 ± 14.6
big bluestem (*Andropogon gerardii* Vitman)	0.1 ± 0.3	3.7 ± 9.4
little bluestem (*Schizachyrium scorparium* Michx.) Nash	0.0 ± 0.0	1.9 ± 8.5
northern reedgrass (*Calamagrostis stricta* (Timm.) Koel.)	14.7 ± 18.7	6.9 ± 8.6
Wilcox dicanthelium (*Dichanthelium wilcoxianum* (Vasey) Freckmann)	3.3 ± 8.6	1.5 ± 2.3
Baltic rush (*Juncus balticus* Willd.)	5.4 ± 5.1**	1.7 ± 1.9
switchgrass (*Panicum virgatum* L.)	6.2 ± 6.6	4.9 ± 6.3
Kentucky bluegrass (*Poa pratensis* L.)	18.2 ± 21.5	22.3 ± 16.1
Indian grass (*Sorghastrum nutans* (L.) Nash)	0.8 ± 1.9	5.7 ± 11.9
reed canary grass (*Spartina pectinata* Link)	4.3 ± 7.4	3.4 ± 5.5
sedges (*Carex* L. spp.[1])	11.1 ± 9.2	15.3 ± 11.5
Total Shrub Cover	14.2 ± 14.6	11.3 ± 16.9
lead plant (*Amorpha canescens* Pursh)	0.1 ± 0.1	1.1 ± 2.4
white sage (*Artemisia ludoviciana* Nutt.)	0.0 ± 0.1	1.1 ± 4.4
willows (*Salix* L. spp.[2])	11.9 ± 12.3	7.2 ± 11.3

[1] Includes *Carex lanuginosa* Michx., *C. brevior* (Dew.) Mack. ex Lunell, and *C. granularis* Muhl. ex Willd.
[2] Includes *Salix exigua* Nutt. and *S. bebbiana* Sarg.
** Orchid and non-orchid swales significantly different ($P \leq 0.01$)
* Orchid and non-orchid swales significantly different ($P \leq 0.05$)

Results

Associated Vegetation

Orchid and non-orchid swales did not differ significantly (P > 0.05) in total plant canopy cover, litter cover, forbs, total graminoids, shrubs or bare ground (Table 1). Cover of wild licorice (*Glycyrrhiza lepidota*) (plant authorities are found in Table 1) was lower (P = 0.03) in orchid swales and cover of hedge-nettle (*Stachys palustris*) was higher (P = 0.002) in orchid swales. Leafy spurge (*Euphorbia esula*) was present in both swale types. Cover of Baltic rush (*Juncus balticus*) was higher (P = 0.01) on orchid swales compared to non-orchid swales. Kentucky bluegrass (*Poa pratensis*) and willows, including *Salix exigua and S. bebbiana,* were common on both swale types with similar (P > 0.05) cover values.

Soil Moisture

Surface soil moisture was consistently higher in orchid swales than in non-orchid swales (Table 2). July 1992 (P = 0.004), August 1992 (P = 0.002), and June 1993 (P = 0.05) soil moisture in the top 2 cm of soil was higher in orchid swales (24–52%), compared to non-orchid swales (16–45%). In addition, soil moisture at the 2- to 10-cm depth was higher in orchid swales than in non-orchid swales in August 1992. Soil moisture at greater depths (10–30 cm) did not differ between orchid and non-orchid swales.

Standing Water

Standing water depths in 1993 varied greatly within and among swales. In July, the water depth in orchid swales averaged 28.3 cm (± 18.9 SD), compared to an average of 13.3 cm (± 12.7 SD) (P = 0.001) in non-orchid swales. The maximum depth of standing water in orchid and non-orchid swales was 80 cm and 43.6 cm, respectively. The depth of standing water in August 1993 declined in most swales, but remained significantly higher (P = 0.007) in orchid swales (13.5 cm ± 12.2 SD) compared to non-orchid swales (4.3 cm ± 6.7 SD). Maximum water depths in August were 45.0 and 31.8 cm, respectively, for orchid and non-orchid swales; but some swales of both types had no standing water in 1993.

Soil Chemistry and Texture

With the exception of soluble magnesium, soil chemistry was similar in the 2 swale types (Table 3). Within the upper 10 cm of soil, soluble magnesium was significantly higher (P = 0.002) in non-orchid swales than in orchid swales. In general, the upper 10 cm of soil in all swales could be described as a neutral to slightly alkaline, fertile sandy loam. The range of soil textures included sand, loamy sand, sandy clay loam, and loam. The percentage sand (70%, ± 11.7 SD - orchid; 70% ± 14 SD - non-orchid), silt (16% ± 7.1 SD - orchid; 15% ± 7 SD - non-orchid), and clay (14%, ± 5.6 SD - orchid; 15% ± 7.4 SD - non-orchid) did not differ (P > 0.05) between orchid and non-orchid swales.

Table 2. Average (± SD) gravimetric soil moisture for orchid and non-orchid swales in July and August 1992 and June 1993, by depth on the Sheyenne National Grassland.

Depth	Swale Type	July 1992	August 1992	June 1993
(cm)		(%)	(%)	(%)
0-2	orchid	26.3 ± 7.7**	23.9 ± 8.9**	51.9 ± 17.0
	non-orchid	21.2 ± 6.0	16.3 ± 13.0	44.8 ± 15.5
2-10	orchid	30.3 ± 11.5	30.6 ± 13.7*	41.3 ± 15.0
	non-orchid	26.9 ± 13.2	24.9 ± 14.3	34.9 ± 15.7
10-20	orchid	19.9 ± 5.4	20.0 ± 6.9	25.0 ± 6.0
	non-orchid	20.4 ± 9.9	18.3 ± 9.6	24.3 ± 8.5
20-30	orchid	14.5 ± 3.9	14.9 ± 11.3	20.4 ± 4.5
	non-orchid	13.8 ± 5.1	12.7 ± 4.9	18.3 ± 5.5

**Orchid and non-orchid swales different (P < 0.01)
*Orchid and non-orchid swales different (P < 0.05)

Table 3. Average (± SD) nitrogen (N), organic matter (OM), calcium carbonate ($CaCO_3$), pH, electrical conductivity (EC), phosphate phosphorous (PO_4) P, nitrate (NO_3) N, potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), sulfur (S), and water at saturation for orchid and non-orchid swale soils on the Sheyenne National Grassland, 1992.

	Swale Type	
Analysis	Orchid	Non-orchid
N (%)	0.5 ± 0.4	0.5 ± 0.4
OM (%)	6.8 ± 5.5	5.1 ± 2.6
$CaCO_3$ (%)	9.3 ± 8.1	8.8 ± 8.4
pH	7.7 ± 0.2	7.6 ± 0.5
EC (ds/m)	0.7 ± 0.1	0.7 ± 0.2
PO_4 P (mg/kg)	8.7 ± 5.0	8.2 ± 3.1
NO_3 N (mg/kg)	13.2 ± 9.5	11.2 ± 7.7
K (meq/l)	0.3 ± 0.3	0.4 ± 0.3
Na (meq/l)	0.5 ± 0.2	0.4 ± 0.2
Mg (meq/l)	2.1 ± 0.8**	2.9 ± 1.3
Ca (meq/l)	4.9 ± 0.8	4.3 ± 1.5
S (mg/kg)	20.4 ± 12.0	18.5 ± 8.2
H_2O at saturation (%)	87.9 ± 35.2	78.5 ± 30.6

**Orchid and non-orchid swales different (P < 0.01).

Logistic Regression

The logistic regression analysis included 36 of the 51 independent variables (Table 4). These variables made sense biologically and were not highly correlated with each other. Percent cover of Baltic rush was the most useful variable in differentiating swales that support orchids from swales that did not (Table 5). With just Baltic rush in the model, the equation correctly classified 68% of orchid swales and 63% of non-orchid swales (Table 6). The addition of cover of hedge-nettle increased the percentage of swales correctly classified to an average of 71% for the 2 swale types. The addition of soluble magnesium enhanced the percentage of correctly classified swales to 79%. August soil moisture at the depth of 0–2 cm was the last variable to enter the equation. The final model correctly classified 84% of both the orchid and non-orchid swales:

Probability of an orchid swale =

$$1/ [1 + \exp(-1.10 + 0.60JUBA + 3.53STPA - 0.23Mg + 0.32ASM2)] \quad (1)$$

where JUBA = Baltic rush canopy cover, STPA = hedge-nettle canopy cover, Mg = soil magnesium, and ASM2 = August surface soil moisture.

Discussion

Managers need an understanding of habitat requirements of individual plants, and their relationship with other species and environmental parameters. Managers also need techniques that can be used to assess the quality of potential sites so they can alter management in areas likely to support threatened and endangered species or identify sites where reintroductions are more likely to be successful. This study provided a better understanding of the vegetation and soils of sites that supported the threatened western prairie fringed orchid, compared to sites devoid of this plant. We used these data to develop a logistic regression model that allows managers to quickly (and quantitatively) assess the likelihood that a given site will support orchids.

In many respects, the vegetative composition of both swales that supported and did not support orchids was similar, and included mixed grass and sedge meadow species. The vegetative differences between swales that supported orchids and those without orchids were a reflection of moisture conditions. Orchid-supporting swales had higher canopy cover of Baltic rush and hedge-nettle, yet lower cover of wild licorice. Baltic rush often grows in slightly alkaline sites, and along with hedge-nettle, is associated with high moisture habitats such as prairie sloughs, seepages and marshes (Great Plains Flora Association 1986).

We found that soil moisture was important in influencing the distribution of orchids, yet soil chemistry (with the exception of magnesium levels) was a poor indicator of orchid habitat. Swales that supported orchids were characterized by consistently higher surface (0–2 cm) soil moisture and deeper water in 1993 compared to those swales lacking orchids. Further, surface soil moisture was 1 of 4 variables in the final equation that best distinguished orchid swales from non-orchid swales. These data support Sieg and King's (1995) findings that orchid densities were associated with high surface (0-4 cm depth) soil moisture.

Subsurface moisture (2–10 cm) may also influence orchid habitat. In another phase of this study, 60% of the orchids Wolken (1995) examined had their rooting systems entirely within 10 cm of the surface. Soil moisture below 10 cm was less important in influencing orchid presence or absence. Similar soil moisture readings below 10 cm for both swale types indicate that soil moisture levels below the maximum rooting depth (16 cm) are not as critical as soil moisture levels within the lateral root system range (2–10 cm).

Unfortunately, this study also verified the presence of invasive species that threaten the quality of orchid habitat on the Sheyenne National Grassland. The

Table 4. Independent variables included[1] in the logistic regression analysis used to identify those most useful in distinguishing between orchid and non-orchid swales on the Sheyenne National Grassland.

Cover (%) of:	Other Variables
Total plant canopy	August soil moisture: 0-2 cm
Total forb	August soil moisture: 10-20 cm
Ambrosia psilostachya	June soil moisture: 0-2 cm
Aster simplex	June soil moisture: 20-30 cm
Euphorbia esula	Total N (%)
Euthamia graminifolia	OM (%)
Fragaria virginiana	$CaCO_3$ (%)
Juncus balticus	pH
Polygonum amphibium	EC (ds/m)
Solidago canadensis	PO_4 (available) (meq/l)
Stachys palustris	NO_3 (meq/l)
Litter	K (soluble cation) (meq/l)
Total graminoid	Na (soluble cation) (meq/l)
Total *Carex spp.*	Mg (soluble cation) (meq/l)
Calamogrostis stricta	Ca (soluble cation) (meq/l)
Dichanthelium wilcoxianum	S (soluble cation) (meq/l)
Panicum virgatum	
Poa pratensis	
Spartina pectinata	
Total *Salix* spp.	

[1]Variables excluded from the logistic regression analysis included: June soil moisture (10-20 cm), August soil moisture (2-10, 20-30 cm), Canopy cover (%) of: *Amorpha canescens, Anemone canadensis, Andropogon gerardii, Schizachyrium scoparium, Artemisia ludovicana, Equisetum laevigatum, Glycyrrhiza lepidota, Sorghastrum nutans,* total shrubs, and % water at saturation.

Table 5. Results of logistic regression analysis of variables characterizing orchid swales and non-orchid swales on the Sheyenne National Grassland, 1992–1993.

Step number	Variable[1] entered	Log likelihood	Model[2] Chi-square	Improvement[3] Chi-square
1	JUBA	-26.34	10.3**	10.3**
2	STPA	-21.21	18.7**	8.4**
3	Mg	-17.00	25.4**	6.7**
4	ASM2	-13.66	35.0**	9.6**

[1]JUBA = *Juncus balticus* canopy cover (%); STPA = *Stachys palustris* canopy cover (%); Mg = soil magnesium (mg/l); ASM2 = 1992 August soil moisture (%) at a depth of 0-2 cm.
[2]The model chi-square tests the null hypothesis that there is no difference between the constant and the model presented; a small P value indicates a significant change in the model.
[3]The improvement chi-square tests the null hypothesis that the addition of a variable does not change the model; a small P-value indicates improvement of the model with the addition of that variable.
** significant at $P < 0.01$

strong presence of Kentucky bluegrass in these swales was consistent with other recent studies (Sieg and King 1995, Sieg and Bjugstad 1994, Bjugstad-Porter 1993). Kentucky bluegrass tends to dominate and out-compete other plants (Reader et al. 1994), and orchid density in some years on the Sheyenne National Grassland was negatively correlated with Kentucky bluegrass cover (Sieg and King 1995). The invasion of leafy spurge, a perennial noxious weed, is a serious threat to orchid habitats on the Sheyenne National Grassland (Sieg and Bjugstad 1994).

Management of existing orchid habitat on the Sheyenne National Grassland should focus on sustaining the moist swales that support the orchid and its key vegetative associates. In the long run, sustaining orchid habitat depends on maintaining the hydrologic regime (U.S. Fish and Wildlife Service 1996). Further, understanding interspecific differences in gross root morphology, mycorrhizal associations and below-ground spatial and nutrient competition between neighboring species may be needed to fully describe the habitat needs of the western prairie fringed orchid (Jastrow and Miller 1993).

The logistic regression equation presented in this paper correctly classified 84% of 38 swales using 4 variables. By collecting data on the cover of just Baltic rush, which would take about 45 minutes, and entering it in the equation, a land manager could classify 66% of the swales in this ecoregion as either suitable or unsuitable as orchid habitat. The higher the estimated probability value (e.g., 0.99), the greater the probability the swale will support orchids (Norusis 1990). This technique can be used to prioritize sites for altering management activities such as treating leafy spurge, livestock grazing and prescribed burning. This technique also allows the identification of suitable habitat when attempting to expand an existing population or establish a new one, thus increasing the odds of successfully transplanting plants or germinating seeds on the new site (Holsinger and Gottlieb 1991).

Although this model is based on presence or absence of orchids, in reality, there is likely a spectrum of suitability that varies in time (Hof et al. 1999). Data from multiple years may increase our ability to model the capacity of the Sheyenne National Grassland landscape to support a metapopulation by assessing whether or not there are suitable, but unoccupied, swales that could be colonized by orchids. In the meantime, this model provides a valuable tool for evaluating potential orchid habitat in this ecoregion. In other ecoregions, or for other rare species, quantitative habitat data could be collected and used in developing similar models.

Table 6. Classification rates at each step of a forward step-wise logistic regression model based on 19 orchid and 19 non-orchid swales on the Sheyenne National Grassland. Classification rates were estimated using "leave-one-out" cross-validation (Efron and Tibshirani 1993).

Step	Variable[a]	Observed Swale type	Number predicted non-orchid	Number predicted orchid	Classification rate
1	JUBA	orchid	13	6	68.4
		non-orchid	7	12	63.2
		AVERAGE			65.8
2	STPA	orchid	14	5	73.7
		non-orchid	6	13	68.4
		AVERAGE			71.1
3	Mg	orchid	15	4	78.9
		non-orchid	4	15	78.9
		AVERAGE			78.9
4	ASM2	orchid	16	3	84.2
		non-orchid	3	16	84.2
		AVERAGE			84.2

[a]JUBA = *Juncus balticus* canopy cover (%); STPA = *Stachys palustris* canopy cover (%); Mg = soil magnesium (mg/l); ASM2 = 1992 August soil moisture (%) at a depth of 0-2 cm.

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