ECOLOGICAL MODEL FOR SERAL STAGE CLASSIFICATION AND MONITORING FOR SANDS-CHOPPY SANDS ECOLOGICAL TYPE IN NEBRASKA AND SOUTH DAKOTA

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ABSTRACT

A multivariate statistical model related to plant succession was developed to classify seral stages and to monitor succession for sands-choppy sands ecological type in the Sand Hills region of Nebraska and South Dakota. This model can be used by range and wildlife managers to evaluate management alternatives by evaluating changes in plant species cover and frequency of occurrence within and between seral stages. Four seral stages (early to late plant succession) were quantitatively identified with an estimated 91% level of accuracy. Three plant species provide the information to assign seral stages and monitor trends based on index values (canopy cover (%) x frequency of occurrence (%)) for sand bluestem (*Andropogon hallii* Hack.), hairy grama (*Bouteloua hisuta* Lag.), and little bluestem (*Schizachrium scoparium* (Michx.) Nash). Measurement of these three plant species is all that is required for the model.

Keywords

Succession, seral stages, key species, management, model, Sand Hills

INTRODUCTION

Rangeland ecological status undergoes change over time following natural and anthropogenic induced disturbances. This process of plant succession has been used in classification studies for western forests and rangelands for many years (Sampson 1919; Daubenmire 1952; Daubenmire 1968; Dyksterhuis 1949; Westoby et al. 1989). However, subjective interpretations often made it difficult to obtain consistent measurements of vegetation trend. These changes can be quantified using multivariate statistical models of plant succession (MacCracken et al. 1983; Uresk 1990; Benkobi et al. 2007; Uresk et al. 2010a; Uresk et al. 2010b). Multivariate quantitative models of plant succession allow resource managers to easily obtain quantitative measurements and relate current range status to management effects at one point in time and trends over a long-term period on a repeatable basis.

Over the last few decades, rangeland classification concepts have provided resource managers a framework for evaluating vegetation changes in response to natural events and to management activities (USDA-SCS 1976; Westoby et al. 1989; Holechek et al. 1989). Other multivariate and ordination techniques (Kershaw 1973; Mueller-Dombois and Ellenberg 1974; del Moral 1975) refined vegetation classification, but generally lacked practical tools such as quantitative models for range managers to quantify succession. Our quantitative model can be used by managers to determine seral stage classification and to determine succession and retrogression trends within and among seral stages.

State and transition models for plant succession have received much attention in recent years, primarily as an approach in ecological processes for plants (Friedel 1991; Samuel and Hart 1994; Bestelmyer et al. 2003; Briske et al. 2005). State and transition models are conceptual models that can include vegetation changes as a result of fire, grazing, climate, and management activities. The multivariate model we have developed is similar in concept but quantitatively defines discrete categories for community phases within a state and transition model of plant succession (Uresk 1990; Benkobi et al. 2007; Uresk et al. 2010a; Uresk et al. 2010b). These models are not linear and do not require a linear progression of plant succession from early to late by going through all seral stages. Plant succession may go from early to late bypassing middle seral stages. The current study provides discrete categories based upon a few fundamental ecological processes and relationships of key plant indicators for transition or plant succession (Stringham, et al. 2003; Bestelmyer et al. 2003). The objectives of the present study were to (1) develop a model for monitoring the sands-choppy sands ecological type, (2) define seral stages, and (3) provide a sampling and monitoring protocol. Common grasses that define sands-choppy sands ecological type include sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), prairie sandreed (*Calamovilfa longifolia* (Hook.) Scribn., needle-and-thread grass (*Heterostipa comata* Trin. & Rupr.) Barkworth), hairy grama (*Bouteloua hirsuta* Lag.), and blue grama (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths).

STUDY AREA

The study was conducted on the Nebraska National Forest in the Sand Hills of central Nebraska. The Sand Hills in Nebraska include sand dune hills to sandy basins and valleys. This study focused on vegetation in the sands and choppy sands ecological sites. A map and detailed site descriptions of both ecological sites are presented in USDA-NRCS (2000, 2001). The Sand Hill region covers approximately 5 million hectares (19,300 mi^2) in southern South Dakota and Central Nebraska (Bleed and Flowerday 1990). The specific study site is located in the north-central part of Nebraska, on the Samuel R. McKelvie District, and encompasses about 46,280 hectares (115,700 acres). The Bessey District has an additional 36,183 hectares (90,456 acres).

The climate is described as semi-arid (Burzlaf 1962) with a mean annual precipitation average of 53 cm (21 in) from three weather stations at Valentine, Halsey, and Nenzel from 1903-2006 (HPRCC 2007). Annual precipitation is 41 cm (16 inches) in the western Sand Hills to near 61 cm (24 inches) in the southeast part of the area. Seventy to 85% percent of the precipitation falls during the growing season (April-September) as short duration, intense thunderstorms. Average monthly temperature ranges from a low of -13 °C (9 °F) in the winter to a high of 32 °C (89 °F) during the summer.

Vegetation—Sand Hills flora has been described numerous times over the last century. An overall review of the ecology for plants and animals, soils, livestock grazing, climate, geology, hydrology, streams and lakes in the Sand Hills is presented by Bleed and Flowerday (1990). Stubbendieck et al. (1989) provided an additional review of the literature. Burzlaff (1962) divided into range sites the vegetation ground cover as a measure of forage production. Three range sites (dry valley, rolling sands, and choppy sands) describe much of the vegetation complex within the Sandhills uplands.

This study focused on vegetation in the sands and choppy sands ecological sites (USDA-NRCS 2000, 2001). Dominant plants include sand bluestem, little bluestem prairie sandreed, needle-and-thread grass, hairy grama, blue grama and sedge (*Carex* spp). Common forbs are green sagewort (*Artemisia* spp.), lemon scurfpea (*Psoraidium lanceolata* (Pursh) Rydb.) and cuman ragweed (*Ambrosia psilostachya* DC.). Plant nomenclature follows USDA-NRCS (2012).

METHODS

Data collection for canopy cover and frequency of occurrence followed Daubenmire (1959), and statistical analyses followed procedures developed by Uresk (1990). Data were collected on 61 macroplots (sites) during the summer of 1990. About half the plots were collected throughout the sands and the other half collected throughout the choppy sands ecological sites on Nebraska National Forest lands. Each macroplot was randomly selected within one of three perceived strata of early, mid, or late seral stages (Cochran 1977; Thompson et al 1998; Levy and Lemeshow 1999). At each macroplot, two parallel transects 30 m (99 ft.) long were spaced 20 m (66 ft.) apart. Canopy cover and frequency of occurrence were obtained for individual plant species and other variables (total cover, bare ground, and litter) sampled at 1-m intervals along each 30 m transect. All macroplot data for canopy cover and frequency of occurrence were averaged by site. An index was created based on the product of the mean site cover and the mean site frequency. Index = ((transect 1 cover + transect 2 cover)/2) * (transect 1 frequency + transect 2 frequency)/2)) (Uresk 1990). Data were analyzed with SPSS (1992) and SPSS (2003).

Chi-square analysis was applied to plant index data and evaluated for differences between sands and choppy sands ecological types. Because reduction of variables is useful when applying clustering techniques, we used stepwise discriminant analyses to reduce the number of variables derived from the perceived three seral satges (Uresk 1990). This procedure was used to obtain the number of variables relevant to classification and not as an evaluation of the three perceived seral stages. Principal component analysis is useful for data reduction and does not require the need for perceived seral stages; however, meaningful results are obtained only with far fewer variables. Data with reduced variables were subjected to a nonhierarchical cluster analysis using ISODATA which grouped the variables into seral stages (Ball and Hall 1967; del Morel 1975). The 61 sites (macroplots) were grouped into 4 distinct seral stages. Discriminant analyses (SPSS 1992, 2003) identified key variables for seral stage classification and provided a quantitative model to be used for future classification and monitoring (P < 0.05). Misclassification error rates were estimated with cross validation procedures (SAS 1988, SPSS 2003). Field-testing of the model was applied during the second year (1991). Most common and abundant (> 1%) plant species and other variables are reported in Table 4 and 5.

RESULTS

Seral Stages—Chi-square analysis showed no significant differences in plant cover-frequency index ($P < 0.05$) between sands and choppy sands sites. Therefore, sands and choppy sands ecological sites were combined into the sands-choppy sands ecological type for this study.

Table 1. Canopy cover, frequency of occurrence means (%) with standard errors (in parentheses) and index for key plant species by seral stages used in model development for Sands-Choppy Sands ecological type.

SERAL STAGE	N	SAND BLUESTEM	HAIRY GRAMA	LITTLE BLUESTEM
		Canopy Cover		
Late	5	8.4(1.6)	24.2(2.0)	14.1(4.6)
Late intermediate	12	30.9(6.4)	5.0(1.5)	15.6(2.9)
Early intermediate	14	5.0(1.1)	2.7(0.9)	36.1(2.2)
Early	30	7.9(1.1)	2.1(0.6)	4.8(1.2)
		Frequency		
Late	5	57.7(7.6)	88.7(3.2)	48.3(13.4)
Late intermediate	12	80.8(3.3)	35.0(9.2)	50.0(8.7)
Early intermediate	14	38.6(6.9)	20.8(6.1)	85.2(2.7)
Early	30	40.5(4.9)	13.7(3.6)	17.1(3.6)
		Index		
Late	5	507	2184	955
Late intermediate	12	2698	327	1031
Early intermediate	14	278	164	3121
Early	30	470	101	215

n= sample size

Table 2. Fisher's classification discriminant function coefficients used for classification of seral stages in Sands-Choppy Sands ecological type.

SPECIES	LATE	LATE INTERMEDIATE	EARLY INTERMEDIATE	EARLY
Sand bluestem	0.0024730	0.0034449	0.0018747	0.0006470
Hairy grama	0.0278607	0.0067453	0.0046673	0.0017406
Little bluestem	0.0046142	0.0042618	0.0083963	0.0008727
Constant	-34.65368	-9.335991	-15.09219	-1.719941

Table 3. An example of assigning seral stages by using Sands-Choppy Sands Fisher's discriminant coefficients with new index data (Index = Site cover mean x Site frequency mean) for sand bluestem, hairy grama, and little bluestem.

	SAND BLUESTEM		HAIRY GRAMA		LITTLE BLUESTEM			
SERAL	Coeff[1]	Index	Coeff	Index	Coeff	Index	CONST	SCORE
Late	(0.0024730 *	2150 +	0.0278607 *	500 +	0.0046142 *	950)	- 34.65368 =	-11.02
Late Int.	(0.0034449 *	2150 +	0.0067453 *	500 +	0.0042618 *	950)	- 9.335991 =	5.48
Early Int.	(0.0018747 *	2150 +	0.0046673 *	500 +	0.0083963 *	950)	- 15.09219 =	-0.75
Early	(0.0006470 *	2150 +	0.0017406 *	500 +	0.0008727 *	950)	- 1.719941 =	1.37

[1] Coeff = Fisher's discriminant classification coefficient, Const = Constant values from Fisher's discriminant model, Int. - Intermediate.

Seral stages were distinguished from one another by the distribution and abundance of key plant species that characterized the ecological type. The sands-choppy sands ecological type was classified into four seral stages that ranged from early to late plant succession ($P < 0.05$). Discriminant analysis allowed us to select sand bluestem, hairy grama, and little bluestem as the best prediction variables in the model for classification and monitoring by seral stages. Index values of these 3 key plant species illustrate the dynamics of these species in this ecological type (Figure 1, Table 1). Hairy grama was dominant in the late seral stage, sand bluestem in the late intermediate stage, and little bluestem dominates in the early intermediate stage. Lesser amounts of all three plant species described the early seral stage. Distributions of mean canopy cover, frequency of occurrence, and indices for the three key variables by seral stage are presented in Table 1.

Fisher's classification discriminant function coefficients define seral stages and provide model coefficients for predicting plant dynamics within the ecological system (Table 2). Key plant variables with the greatest indices by seral stage present the biotic potential for predicting plant species dynamics within the ecological system. An example of seral stage assignment for new data collected in the field with Fisher classification coefficients is presented in Table 3. To determine a seral stage score, multiply the mean site index values for sand bluestem, hairy grama, and little bluestem by the Fisher coefficients for each seral stage (row) and then sum the products for a score. The greatest score identifies assignment of seral stage. When the products summed are negative, the least negative score

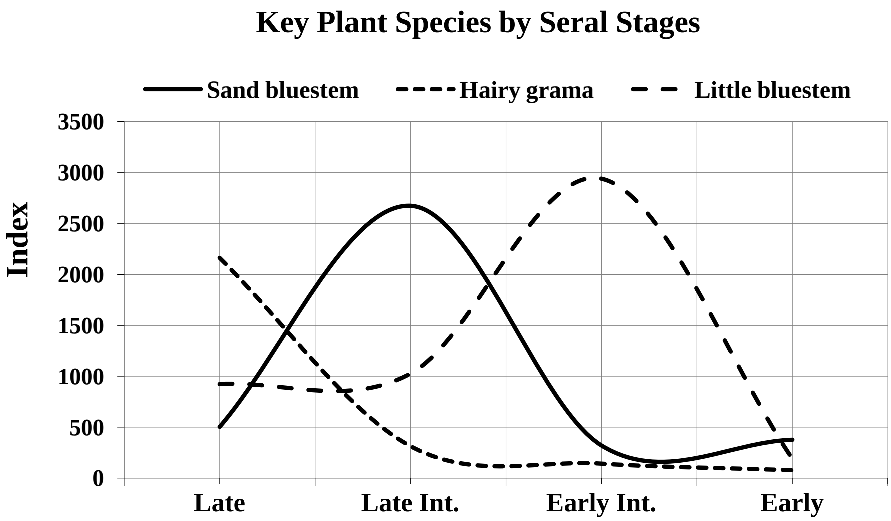

Figure 1. Key plant species with index values (canopy cover (%) x frequency of occurrence (%)) displayed throughout four seral stages in the Sands-Choppy Sands ecological type in Nebraska and South Dakota. Graph provides a guide for an approximate mixture of species at each seral stage.

is used for assignment of seral stage. An example from new index data collected in the field are sand bluestem = 2150, hairy grama = 500, and little bluestem = 950. In this example, the greatest score is 5.48, which assigns this site to late intermediate stage. The overall accuracy of the model for seral stage assignment based on cross validation is 91 %. Additional details on seral classification, successional trends, data collection, plot establishment, and programs for PDAs or other computers may be obtained from USDA-Forest Service web site at http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml. Benkobi et al. (2007) provide additional information on plot establishment, data collection, and interpretation.

Late seral stage—Plant species richness of the late seral stage consisted of 48 forbs, 20 graminoids, and 4 shrubs, representing 24 plant families (Figure 2). Approximately 76% of the plants were perennial species with only 14% annual species (10% biennial or other combination). The late seral stage was dominated by hairy grama, and little bluestem with 24% and 14% canopy cover and 89% and 48% frequency values, respectively (Table 1). Sand bluestem had lesser amounts of cover and lower frequency. Sun sedge and prairie sandreed had canopy cover values of 8% and 5% and a greater frequency (Table 4 and 5). Switchgrass (*Panicum virgatum* L.), rough dropseed (*Sporobolus compositus* (Poir.)), and sand lovegrass (*Eragrostis trichodes* (Nutt.) Alph. Wood) ranged in cover values between 2-4%, with frequency of occurrence ranging between 10-30% (Table 5). Total forb cover of approximately 10% in the late seral stage was the lowest amount recorded among the 4 seral stages, while frequency of occurrence was approximately 100%. Cuman ragweed was the most common forb species with canopy cover and frequency of occurrence at approximately 3% and 48%, respectively.

Table 4. Canopy cover means (%) and standard errors (in parentheses) of common plant species and other variables by seral stages in Sands-Choppy Sands ecological type.

SPECIES OR VARIABLE	LATE	LATE INTERMEDIATE	EARLY INTERMEDIATE	EARLY
Sun sedge *Carex inops*	8.1(1.4)	5.0(1.8)	5.2(1.5)	7.0(1.9)
Prairie sandreed *Calamovilfa longifolia*	5.0(0.9)	6.3(2.0)	3.6(0.6)	5.3(1.0)
Switchgrass *Panicum virgatum*	3.8(1.3)	4.6(1.5)	3.2(0.8)	5.6(2.7)
Rough dropseed *Sporobolus compositus* var. *compositus (S. asper)*	3.1(0.9)	1.9(0.5)	1.2(0.3)	2.9(0.6)
Sand lovegrass *Eragrostis trichodes*	2.1(1.8)	3.6(0.9)	6.8(1.7)	6.2(1.7)
Prairie Junegrass *Koeleria macrantha*	1.9(0.9)	1.5(0.7)	1.2(0.4)	1.0(0.5)
Heller's rosette grass *Dicanthelium oligosanthes*	0.4(0.4)	2.3(0.8)	2.6(0.9)	2.1(0.9)
Needle-and-thread grass *Hesperostipa comata* ssp. *comata (Stipa comata)*	0.5(0.40)	2.0(1.6)	2.8(1.3)	3.9(1.1)
Cuman ragweed *Ambosia psilostachya*	2.9(1.0)	4.4(0.9)	5.1(1.0)	7.3(1.4)
Prairie rose *Rosa arkansana*	3.1(2.2)	3.6(1.6)	3.7(0.9)	3.3(0.7)
Total Graminoids	**67.1(4.2)**	**76.1(2.9)**	**72.7(2.5)**	**59.9(4.1)**
Total Forbs	**9.5(1.0)**	**12.3(1.8)**	**14.5(2.3)**	**16.1(1.8)**
Total Shrubs	**5.6(2.2)**	**6.4(1.5)**	**10.3(2.3)**	**8.3(1.6)**
Total Litter	**52.5(6.3)**	**70.(4.5)**	**73.2(4.0)**	**53.9(5.6)**
Bare ground	**47.8(6.4)**	**27.6(4.3)**	**26.5(4.2)**	**45.0(5.6)**

Late Intermediate seral stage—Plant species richness consisted of 60 forbs, 28 graminoids, and 5 shrubs (Figure 2) in 23 plant families. One tree was reported within this seral stage. Approximately 69% of the plants were perennial, 17% annual and the remaining 14% biennial or a combination of annual, biennial, or perennial. The composition of vegetation in this seral stage was dominated by sand bluestem (Table 1). Little bluestem (16% canopy cover) was followed by sun sedge, hairy grama, prairie sandreed, switchgrass, and sand lovegrass with values between 3-5%, although frequency of occurrence ranged between 18-43% for these species (Tables 4 and 5). Total forb cover of 12% was slightly greater than was present in the late seral stage. The dominant species was cuman ragweed with 4% cover and a frequency of 52%.

Early Intermediate seral stage—Plant species richness included 64 forbs, 27 graminoids, and 7 shrubs (Figure 2), in 25 plant families. About 67% of the

Table 5. Frequency of occurrence means (%) and standard errors (in parentheses) of common plant species and other variables by seral stages in Sands-Choppy Sands ecological type[1].

SPECIES OR VARIABLE	LATE	LATE INTERMEDIATE	EARLY INTERMEDIATE	EARLY
Sun Sedge *Carex inops*	74.7(9.2)	42.9(13.9)	44.6(11.7)	40.2(7.6)
Prairie sandreed *Calamovilfa longifolia*	52.3(9.6)	39.6(7.3)	40.7(5.2)	39.4(5.4)
Switchgrass *Panicum virgatum*	21.3(6.7)	24.6(7.7)	18.6(5.0)	16.6(4.8)
Rough dropseed *Sporobolus compositus* var. *compositus (S. asper)*	37.33(6.0)	20.7(4.8)	17.0(3.5)	26.9(4.3)
Sand lovegrass *Eragrostis trichodes*	10.0(6.7)	18.1(3.8)	34.4(7.3)	22.8(5.3)
Prairie Junegrass *Koeleria macrantha*	22.33(11.7)	13.47(5.5)	16.49(5.2)	7.61(2.8)
Heller's rosette grass *Dicanthelium oligosanthes*	3.6(3.7)	19.0(5.7)	30.6(8.1)	14.6(4.4)
Needle-and-thread grass *Hesperostipa comata* ssp. *comata (Stipa comata)*	7.3(6.5)	11.4(6.9)	19.1(6.7)	21.1(5.2)
Cuman ragweed *Ambosia psilostachya*	47.7(12.5)	52.2(8.2)	54.5(8.0)	53.2(6.0)
Prairie rose *Rosa arkansana*	15.7(9.2)	20.1(8.7)	27.3(6.0)	20.4(4.3)

[1]Frequency of Occurrence for Graminoids, Forbs, Shrubs, Litter and Bare ground was 100%.

plants were perennial and 16-17% were either annuals or biennials. Little bluestem was the most common grass species in early intermediate seral stage with 36 % cover and 85% frequency of occurrence (Table 1). Sand bluestem and hairy grama, both key species, had cover values of 5% and 3% and frequency of occurrence value of 39% and 21%, respectively. Sand lovegrass and sun sedge cover was between 5-6% with a frequency of 34-45%. Prairie sandreed, switchgrass, Heller's rosette grass (*Dichanthelium oligosanthes* (Schult.) Gould) and needle and thread ranged between 2-4%, whereas frequency ranged between 19-41% (Tables 4 and 5). The most common forb was cuman ragweed with over 5% canopy cover and 55% frequency. Total forb cover was 15%.

Early seral stage—Plant species richness was represented by 78 forbs, 35 graminoids, and 7 shrubs in 33 plant families(Figure 2). In this seral stage only about 65% of the plant species were perennials with 23% annuals and 12% biennials. Plant species diversity was greatest for this seral stage. Within this seral stage, sand bluestem, little bluestem, and hairy grama exhibited canopy cover values of 8%, 5%, and 2% with frequencies of 41%, 14%, and 17%, respectively (Table 1). Graminoids with cover between 5-6% included sun sedge, sand lovegrass, prairie sandreed, and swtichgrass (Table 4). Frequency of occurrence

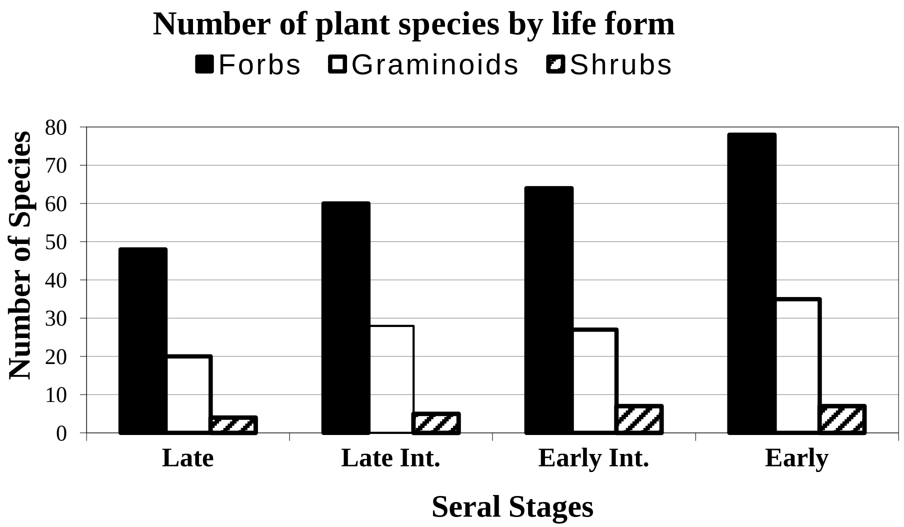

Figure 2. Number of plant species by life form category throughout seral stages in Sands-Choppy Sands, Nebraska.

for these species ranged between 23-40% (Table 5). Needle-and-thread and rough dropseed were common with 3-4% canopy cover and frequency between 21-26%. Cuman ragweed accounted for 7% of the forb cover which for all forbs totaled 16%.

DISCUSSION

Canopy cover of prairie sandreed, hairy grama, and little bluestem has been reported to be similar between the rolling sands and choppy sands range sites (Burslaff 1962; Barnes et al. 1984). Soil characteristics and vegetation communities represent a continuum across the Sand Hills landscape, but are more similar between the rolling sands and choppy sands and often significantly different when comparing these two sites to the dry valley range type (Burslaff 1962; Barnes et al. 1984). Barnes and Harrison (1982) found similar soil moisture between rolling sands and choppy sands and much greater soil moisture, especially as depth increased, in the dry valleys. Plant species for both sands and choppy sands were not different and were combined for these analyses. Similar soils and soil moisture for sands and choppy sands support combining the two ranges now defined as sands-choppy sands ecological type.

Management based on plant seral stages provides a powerful tool to achieve, evaluate, and monitor desired resource conditions or status of vegetation (Uresk 1990; Stubbendieck and Reece 1992; Benkobi and Uresk 1996; Benkobi et al 2007; Uresk et al. 2010a; Uresk et al. 2010b). Our model describes quantitative interrelationships of plant species occurring throughout the four seral stages from early to late. Thus, our model can be used to determine seral stages regardless of hypothetical past or future climax vegetation.

Managing for all four seral stages can be viewed as a management alternative. Inclusion of multiple seral stages is known to increase plant and animal diversity over the landscape (Rumble and Gobeille 1995; Benkobi et al. 2007; Fritcher et al. 2004). Because one seral stage is not practical for multiple-use management, the entire range of seral stages (from early to late) is desirable to accommodate the greatest plant species diversity, wildlife habitat and diversity, livestock production, and recreation. In the sands-choppy sands ecological type, late and intermediate stages of succession may be best for livestock production due to the greater availability of forage species. The early seral stage may be more important for specific wildlife species and rare plant species such as blowout penstemon (*Penstemon haydenii* S.Watson) (Stubbendieck et al. 1989).

Wildlife managers have recognized that wildlife densities, diversity, and plant succession are related and important for wildlife management. In addition, management of sands-choppy sands rangelands with seral stages provides a management tool that can be used across the landscape. The landscape scale could be the best level for managers to determine their management objectives. Approximately 10-15% of the landscape is recommended to be maintained in the early and late stages with the remainder of the area in the intermediate categories (Kershaw 1973; Mueller-Dombois and Ellenberg 1974). This would provide a mixture of habitats on the landscape to maintain plant and animal diversity (Uresk 1990; Benkobi et al. 2007; Fritcher et al. 2004; Rumble and Gobeille 1995; Vodehnal et al. 2009).

Bird species diversity was significantly greater in early seral stage compared to late-intermediate seral stage on Ft. Pierre National Grasslands in South Dakota (Fritcher et al. 2004). Birds with tall vegetation or residual vegetation (litter) habitat requirements were more abundant in later seral stages while birds that required sparse vegetation cover were common in the early seral stage. Therefore, all seral stages are necessary to maximize grassland bird species diversity and abundance across the landscape (Fritcher et al. 2004).

Perennial plants are generally considered more stable and fluctuate less on an annual basis compared to annuals and biennials. Land managers may consider management for later seral stages on soils more susceptible to wind erosion. Management for rare species that require specific seral stages, such as blowout penstemon which requires severe wind erosion areas (early seral), may require special management to create more habitat near known population centers to increase species abundance and viability.

Livestock grazing can be a tool to regulate changes in seral condition or status. Adjustments in timing, density, and rate of livestock grazing might result in a change to the preferred management alternative (desired seral stage) (Stubbendieck and Reese 1992). However, when early seral communities are the desired objective, additional management strategies or problems such as soil erosion must also be considered (Mergen et al. 2001). Although greater perennial plant cover is generally accepted as an effective method for reducing soil erosion, effective management practices for controlling erosion have not been established.

The classification and monitoring model developed in this paper can be used to quantify the relationship between various grazing intensities and plant succession to determine grazing levels necessary to maintain or restore a desired successional status (management objectives) of the vegetation. In addition, information about rare plant species and wildlife activities, soil erosion and their relationships to seral stages in plant communities need to be included in a management plan (Rumble and Gobeille 1995; Fritcher et al. 2004; Vodehnal et al. 2009).

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