Ecological Model for Seral Stage Classification and Monitoring within a Greasewood/Western Wheatgrass-Blue Grama Ecological Type

Daniel W. Uresk USDA Forest Service, Rapid City, SD 57701

Abstract

A multivariate statistical model was developed to classify seral stages and to monitor vegetation within a greasewood-western wheatgrass-blue grama (*Sarcobatus vermiculatus*/*Pascopyrum smithii-Bouteloua gracilis*) ecological type. Two key plant species, greasewood and western wheatgrass, provide the required information for the model to classify seral stages and monitor trends based on index values of both plants (canopy cover (%) and frequency of occurrence (%)). Three seral stages were quantitatively identified. Classification had an overall accuracy of 94% and all seral stages were significantly different ($P < 0.05$). Three seral stages (late, intermediate and early) provide resource managers quantitative options to evaluate alternatives and objectives associated with steady states and transitions between and among seral stages. Application of this model within the greasewood ecological type is simple to apply, repeatable, accurate and cost effective for field applications.

Key words: succession, seral stages, diversity, monitoring, greasewood, western wheatgrass, blue grama, management, state and transition.

Introduction

Monitoring natural resources and predicting impacts has received much attention in recent years for developing management plans and environmental impact analyses. Quantitative ecological models with input from field data can accurately predict impacts on resources and document current conditions (Uresk 1990, Uresk and Mergen 2014). However, subjective monitoring of the resources provides no quantitative information on the natural resource being impacted and is only available after a visual impact is observed (Kershaw 1973, Block et al. 1987). Quantitative monitoring is required to determine current condition and better predict future impacts to the natural resource. Increased public awareness of our natural resources and management has influenced public and private land managers to be provided with methods and models that are economical, accurate and simple to apply in the field yet powerful enough to monitor trends and predict resource effects prior to observing visual impacts.

Ecological statistical models offer a quantitative approach with input from field data to evaluate and monitor trends of resources based on patterns of plant succession (Uresk 1990, Mclendon and Dahl 1983, Huschle and Hironaka 1980, Friedl 1991, Uresk and Mergen 2014). Plant succession concepts have been used for many years on rangelands for resource management and monitoring (Sampson 1919, Dyksterhuis 1949, Stoddart and Smith 1955, Dyksterhuis 1985). Recently, USDA-Forest Service, Natural Resource Conservation Service (NRCS) and Bureau of land management have implemented state and transition models in the Ecological Site Descriptions (Briske et al. 2005, Bestelmyer et al. 2010 and USDI-USDA 2013). However, these models are qualitative and are based primarily on expert opinion (Twidwell et al. 2013).

The greasewood (*Sarcobatus vermiculatus*)/western wheatgrass (*Pascopyrum smithii*)-blue grama (*Bouteloua gracilis*) ecological type is generally limited to low lands, associated with high water tables and soils with relatively high levels of sodium (Thilenius et al. 1995, USDA-NRCS 2015). Greasewood primarily exists in the Great Basin and eastward to Wyoming and southward to New Mexico (Kuchler 1964), but occurs in most western states (USDA-NRCS 2013). Greasewood occurrence is limited to arid and non-saline sites. Greasewood and associated vegetation can occur as narrow bands adjacent to open water. Shrub density and associated understory plant species will vary in abundance. The greasewood/ western wheatgrass/blue grama is a unique vegetation type important to wildlife (Wallestad 1971, Ryder and Irwin 1987, Welch 2005) and provides forage to livestock (Costello 1944, USDA-NRCS 2015). Knowledge of the current seral status and successional trends of the greasewood type is necessary for resource managers when they determine desired management options and implement guidelines to meet compliance standards. The objectives of this study were: 1) to develop an ecological classification and monitoring model for the greasewood ecological type, 2) define and describe seral stages and 3) to provide sampling and monitoring protocols.

Study area

This study was conducted on the Thunder Basin National Grasslands (TBNG), Wyoming, in a greasewood ecological type on gently sloping saline lowland sites in the Cheyenne River valley (Thilenius et al. 1995). The Thunder Basin National Grasslands encompasses about 153,780 ha of National Forest Service lands. Small drainages include the Little Powder River, Antelope Creek, Little Thunder Creek and School Creek. Elevations in Thunder Basin range from approximately 1100 m to a maximum of 1800 m (Thilenius et al. 1995).

The climate of Thunder Basin is interior continental with hot summers and cold winters. The mean annual precipitation at the Dull Center is 32.8 cm in central TBNG for an 87-year period (HPRCC 2015). Short duration intense thunderstorms, sometimes accompanied by damaging hail, occur from May to September. The average minimum temperature is 0.1°C with a mean annual maximum temperature of 16.4°C. The frost-free period averages 120 days (Martner 1986).

Greasewood is located on low flood plains with soils having relatively high levels of sodium (Thilenius et al. 1995). However some areas with greasewood lack high levels of sodium in the soil. The dominant plants within the greasewood ecological type are western wheatgrass, blue grama, Sandberg bluegrass (*Poa secunda*), alkali sacaton (*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), saltgrass (*Distichlis stricta*), plains pricklypear (*Opuntia polyacantha*) and big sagbrush (*Artemisia tridentata*).

Methods

I conducted a field reconnaissance of the greasewood study area to assess the full range of variability from early to late plant succession within the ecological type based on Thilenius et al. (1995). The experimental design, data collection and analyses follow procedures developed by Uresk (1990). Site selection encompassed the entire greasewood ecological type to include the full range of natural variability. Sites were stratified into three pre-defined visual seral stages, early, mid and late based on key plant species and their previously described changes through plant succession (Cochran 1977, Thompson et al. 1998, Levy and Lemeshow 1999).

I collected data on 104 sites during the summer of 1995. I randomly selected each site within one of three perceived seral stages based on major plant species abundance defined for each seral stage by experienced range professionals. First, an area was located within a perceived seral stage for site selection. Once the area was located, a random direction and a random number of paces were established prior to actual site location for establishment of transects. This procedure was repeated for all sites. At each site, two, 30 m parallel transects were established 20 m apart. Canopy cover (six cover classes) and frequency of occurrence of plant species were estimated within 0.1 m^2 (20 x 50 cm) quadrats (Daubenmire 1959). These quadrats were located at 1 m intervals along each of the two transect for a total of 60 quadrats. Total plant cover, litter cover and bare ground were estimated within each quadrat. Once all data were collected for the site, it was assigned a perceived seral stage. All data were averaged by transect. The two transect means were then averaged for each site to generate a grand mean for data analyses. An index for plant species was created based on canopy cover means time the frequency means: Index = ((transect 1 cover + transect 2 cover)/2)* ((transect 1 frequency + transect 2 frequency)/2) (Uresk 1990, Uresk et al. 2010). Note that averaging canopy cover and frequency of occurrence over several sites and then multiplying the two variables will not provide the same indices for seral stage classification and monitoring. Additional details for macroplot establishment and transects may be obtained from USDA Forest Service website (Uresk et al. 2010): http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml

Preliminary data examinations of the overall index mean for the ecological type resulted in the removal of minor plant species (variables) from analyses with mean index values of <50. The remaining` plant species on 104 sites were used as variables for analyses in the following sequence (Uresk 1990, Uresk and Mergen 2014). The variables remaining after preliminary data reduction of variables were analyzed by principal component analyses for further variable reduction. The extraction method was used and the component matrix, component scores coefficient matrix and the mean index value for each variable were examined. There were no further analyses with principal component procedures.
A non-hierarchical cluster analysis (ISODATA) defined groupings based on the four variables for seral stages (Ball and Hall 1967, del Morel 1975). Stepwise discriminant analysis was used to estimate compactness of the cluster, to identify key variables that accounted for the differences between and among clusters and to develop Fisher classification coefficients (SPSS 2003, Uresk 1990). Discriminant analyses identified two key variables for model development and for classifying seral stages and monitoring. Misclassification error rates were estimated with a cross validation using a jackknife or "leave one site out" procedure (SAS 1988, 2012). In the cross validation procedure, each site was classified by the discriminant functions derived from all other sites other than the site left out. This was repeated for each of the sites and gave a true hold out prediction for each of the sites. The developed model was field tested the following years in 1992-93.

Results

A total of 71 plant species and categories for graminoids, forbs, litter and bare ground were sampled on 104 sites. Plant species remaining after initial data reduction, reduced the number of variables to 7 plant species: western wheatgrass, blue grama, prairie junegrass (*Koeleria macrantha*), plains pricklypear, sand dropseed, needle and thread (*Hesperostipa comata*) and greasewood. Principle component analysis further reduced the variables to four species: western wheatgrass, blue grama, prairie junegrass and greasewood. The clustering procedure grouped the 104 sites into 3 distinct clusters (seral stages). Then stepwise discriminant analysis further reduced the number of variables to two plant species, greasewood and western wheatgrass. These two key plant species based on cover x frequency indices were used for predicting seral stage classification and monitoring changes within and among the seral stages. Three seral stages (early, intermediate and late) were significantly different from each other ($P < 0.05$). The distributions of the two key variables throughout the seral stages show the ecological and biological dynamics from late to early succession (Fig. 1, Table 1). Both greasewood and western wheatgrass were minor components in the early seral stage with mean indices of 700 and 854, respectively. Greasewood dominated the late seral stage with a mean index 6769 and western wheatgrass with 1086. However, the mid seral stage of succession western wheatgrass was greater with an index 2946 compared to greasewood with an index 1964. Each variable individually and collectively describe the dynamics of the model within the greasewood/ western wheatgrass-blue grama ecological type. Blue grama was not a key variable for predicting seral stages within the greasewood ecological type. Indices for blue grama were low with little change through the system, with 85, 183 and 680 for late, mid and early seral stages, respectively. Blue grama decreased from early to late seral stage.

Fisher's discriminant function coefficients (SPSS 2003) for two key variables provided the biotic based potential for predicting and classifying seral stages within the greasewood/western wheatgrass-blue grama ecological type (Table 2). Applying Fisher's discriminant functions to

Table 1. Mean indices of key plant species for three seral stages in a greasewood/ western wheatgrass-blue grama ecological type in Eastern Wyoming.

		Mean Index	
Seral	n	Greasewood	Western wheatgrass
Late	16	6769	1086
Intermediate	31	1964	2946
Early	57	700	854

n=number of sites

Table 2. Fisher's discriminant function coefficients for classification of seral stages with key species within a greasewood/ western wheatgrass-blue grama ecological type in Eastern Wyoming.

Species	Late	Intermediate	Early
Greasewood	0.00945	0.00338	0.00116
Western wheatgrass	0.00293	0.00407	0.00121
Constant	-34.664	-10.408	-2.021

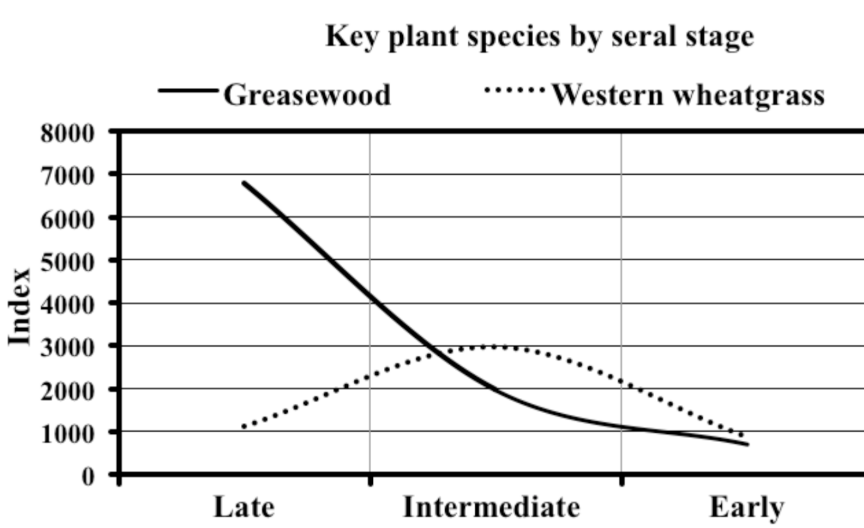

Figure 1. Index means of key variables, greasewood and western wheatgrass displayed throughout three seral stages in the greasewood/western wheatgrass-blue grama ecological type in Eastern Wyoming.

classify and monitor with new data collected for two key variables is presented in Table 3. Site index values for greasewood were 814 and 2418 for western wheatgrass, respectively. To determine seral stage assignment, multiply greasewood and western wheatgrass by the coefficients for each seral stage (row) and the products are summed (+ and -) including the constants for a score. The greatest positive or least negative score assigns the seral stage. In this example, the seral stage assignment was intermediate with a score of **2.18**.

The cross validation result for this model was 94% accurate for seral stage assignment (SAS 2012). Additional information on plot establishment, data collection, direct assignment of seral stage classification and trend monitoring with programs may be downloaded from USDA Forest Service website (Uresk et al. 2010): http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml. Programs may be used on most computer systems for data collection and summaries, seral stage classification and monitoring.

Late Seral Stage

The late seral seral stage was dominated by greasewood with a mean of 71% canopy cover and 95% frequency of occurrence for 16 sites (Table 4, Table 5). Western wheatgrass provided 13% canopy cover and 64% frequency of occurrence. Other common grasses were field brome (*Bromus arvensis*) also known as Japanese brome and cheatgrass (*Bromus tectorum*), both annuals. Perennial grasses included blue grama, Kentucky bluegrass (*Poa pratensis*) and crested wheatgrass (*Agropyron cristatum*). Total graminoid cover was 32%. The forb component was dominated by common pepperweed with 22% canopy cover and 63% frequency of occurrence followed with lesser amounts by burningbush (*Bassia scoparia*) also known as kochia . Total forb cover was 19%. Plant species richness in the late seral stage included 4 forbs, 17 graminoids and 4 shrubs (Fig. 2).

Intermediate Seral Stage

The intermediate seral stage was dominated with western wheatgrass with 36% canopy cover and 86% frequency of occurrence (Table 4, Table 5). Greasewood canopy cover was 33% and a frequency 55%. Canopy cover of other common grasses with this seral stage ranged from 0% to 4%. Frequencies of occurrences were low and ranged from 0% to 14%. Forbs were minor components present in the intermediate seral stage. Total canopy cover for graminoids, forbs and shrubs was 53%, 3% and 36%. Plant species richness was 21 forbs followed by 19 graminoids and 6 shrubs (Fig. 2).

Early Seral Stage

Both western wheatgrass and greasewood showed low canopy cover and frequency of occurrence within the early seral stage. Western wheatgrass canopy cover was 15% and frequency 47%. Greasewood cover and frequency was

Table 3. An example of assigning seral stages by using Fisher's discriminant coefficients with data collected from the field and a new index. Index =((transect 1 cover + transect 2 cover)/2)* ((transect 1 frequency + transect 2 frequency)/2).

	Greasewood				Western wheatgrass				
Seral Stage	**(Coeff[1]**	*****	**Index**	**+**	**Coeff**	*****	**Index)**	**Constant**	**=**	**Score**
Late	(0.00945	*	814	+	0.00293	*	2418)	-34.664	=	-19.87
Intermediate	(0.00338	*	814	+	0.00407	*	2418)	-10.408	=	**2.18[2]**
Early	(0.00116	*	814	+	0.00121	*	2418)	-2.021	=	1.85

[1] Coeff = coefficient

[2] Assigned seral stage

Table 4. Average canopy cover (%) and standard errors (in parentheses) for common plant species and other variables by seral stages in Eastern Wyoming.

	Late[1]	Intermediate	Early
Species or variable	**n = 16**	**n = 31**	**n = 57**
Western wheatgrass *Pascopyrum smithii*	12.9(2.5)	35.8(2.4)	15.1(1.2)
Blue grama *Bouteloua gracilis*	1.5(1.3)	3.5(1.1)	11.8(1.5)
Prairie Junegrass *Koeleria macrantha*	0	3.7(1.3)	2.6(0.9)
Sand dropseed *Sporobolus cryptandrus*	0	3.0(1.1)	4.0(1.0)
Needle and thread *Hesperostipa comata*	0	0	2.7(1.0)
Kentucky bluegrass *Poa pratensis*	2.9(1.2)	0	0
Field brome (Japanese) *Bromus arvensis*	7.2(1.9)	2.0(0.8)	1.9(0.6)
Crested wheatgrass *Agropyron cristatum*	3.8(2.5)	0	0
Cheatgrass *Bromus tectorum*	1.3(0.9)	2.5(1.0)	3.7(0.8)
Burning Bush *Bassia scoparia*	1.3(0.5)	0	0
Common pepperweed *Lepidium densiflorum*	20.8(3.5)	0	0
Plains pricklypear *Opuntia polyacantha*	0	1.1(0.3)	3.3(0.6)
Greasewood *Sarcobatus vermiculatus*	70.9(2.0)	33.0(2.3)	16.7(1.4)
Big sagebrush *Artemisia tridentata*	0	1.6(0.6)	0
Other species<0.1	**16**	**37**	**56**
Graminoid cover[1]	31.9(4.0)	53.2(2.7)	44.1(2.3)
Forb cover[1]	19.1(3.9)	2.6(0.4)	6.0(0.9)
Shrub cover[1]	71.7(1.8)	35.6(2.3)	17.5(1.5)
Litter	3.8(2.6)	32.1(2.4)	19.7(1.3)
Total cover[1]	97.3(2.8)	86.7(2.8)	66.8(2.0)

[1] Two dimension cover and not the sum of the individual plant species.

Table 5. Frequency of occurrence averages (%) and standard errors (in parentheses) for common plant species by seral stages in Eastern Wyoming.

	Late[1]	Intermediate	Early
Species or variable	**n = 16**	**n = 31**	**n = 57**
Western wheatgrass *Pascopyrum smithii*	64.1(7.0)	85.7(4.0)	47.2(2.7)
Blue grama *Bouteloua gracilis*	4.1(3.9)	10.7(3.0)	35.9(3.7)
Prairie Junegrass *Koeleria macrantha*	0	14.3(4.5)	10.2(2.6)
Sand dropseed *Sporobolus cryptandrus*	0	10.7(3.3)	13.7(2.9)
Needle and thread *Hesperostipa comata*	0	0	7.3(2.0)
Kentucky bluegrass *Poa pratensis*	22.7(6.3)	0	0
Field brome *Bromus arvensis*	34.1(6.2)	6.7(2.2)	6.4(2.4)
Crested wheatgrass *Agropyron cristatum*	13.4(7.5)	0	0
Cheatgrass *Bromus tectorum*	5.3(2.1)	9.4(2.7)	10.2(1.8)
Burning Bush *Bassia scoparia*	10.8(4.0)	0	0
Common pepperweed *lepidium densiflorum*	62.8(7.1)	0	0
Plains pricklypear *Opuntia polyacantha*	0	7.2(1.9)	14.5(0.6)
Greasewood *Sarcobatus vermiculatus*	94.6(1.2)	54.7(3.4)	32.9(2.2)
Big sagebrush *Artemisia tridentata*	0	6.6(2.9)	0
Other species <0.1	16	37	56

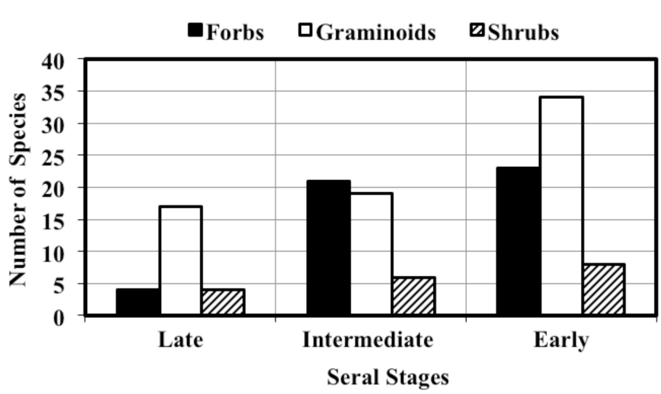

Figure 2. Number of plant species by life form category and seral stages in a greasewood/wheatgrass-blue grama ecological type in Eastern Wyoming.

17% and 33%. Blue grama grass exhibited 12% canopy cover and 36% frequency of occurrence. All other grasses were minor components within the early seral stage. Forbs were also minor components. Total graminoid cover was 44%, forb cover 6% and shrub cover 18%. Species richness was greater in this seral stage compared to other stages (Fig. 2). Forb richness was 23 species, graminoids 34 species and shrubs 8 species.

Discussion

The multivariate model developed for the greasewood ecological type can be used for seral stage classification and monitoring. The model is quantitative, accurate, repeatable and cost effective for describing plant ecological dynamics and plant species changes between and among seral stages using two key variables, greasewood and western wheatgrass, with a 94% accuracy. Current state and transition models used to describe successional dynamics through an ecological type are conceptual (Bestelmyer et al 2003, Briske et al. 2005). These models are qualitative, primarily derived from personal judgements and observations (Twidwell et al. 2013). Model coefficients developed herein can be incorporated into the conceptual state and transition models currently being used by USDA Forest Service, Natural Resource conservation Service and Bureau of Land Management (USDA-NRCS 2013).

Trends within the greasewood ecological type over time based on the two key variables as affected by livestock grazing, fire or climatic changes can be quantitatively documented to monitor if management goals and objectives are achieved. These disturbances may change plant species associations or seral stages from early to late within the greasewood ecological type. Depending upon the management objectives, livestock grazing can be used for modifying seral stages (Severson and Urness 1994, Costello 1944). Grazing intensity may be adjusted to modify a successional seral stage or transition from a non-preferred stage to a desired seral stage to meet the planned management objective. However, the successional process for change to meet desired management objectives can be slow (USDA-NRCS 2015).

The greasewood/western wheatgrass-blue grama ecological type described by Thilenius et al. (1994), based on five stands, reported that western wheatgrass and blue grama were widely distributed throughout the greasewood type. Canopy cover of blue grama reported by Thilenius et al. (1994) was 21 %. In our study, blue grama cover was 8% (104 sites). Although the blue grama cover was less than originally described by Thilenius et al., our data support the greasewood/western wheatgrass-blue grama type. Blue grama was variable throughout all seral stages in our study and not statistically defined as a key plant in the model for predicting seral stages.

Management of all three ecological seral stages within the greasewood ecological type provides the greatest plant and animal diversity. Non-game birds commonly use greasewood communities. Welch (2005) presented the importance of greasewood for small birds finding 4.4 species per mile and 17.9 birds per mile. Greasewood was also an important habitat for sage grouse broods during July-August (Wallestad 2015). Several species of small mammals (deer mouse (*Peromyscus maniculatus*), least chipmunk (*Eutamia minimus*)) were abundant in the greasewood type (Douglass 1989). Pronghorns were observed in the greasewood type near draws or bottomlands during winter months (Ryder and Irwin 1987). Overall, the greasewood ecological type is important for livestock grazing, non-game and game birds, small mammals and big game. However, current literature does not describe the importance of a seral stage for groups of animal species or individual species of birds, mammals and livestock for this ecological type. Plant species richness was greatest in the early seral stage.

Using individual seral stages is not practical for multiple use management because plant and animal species vary among seral stages. Fritcher et al. (2004), Uresk and Mergen (2014) recommend a mosaic of desired seral stages that will apply within the greasewood type across the landscape as ideal for management of plants, birds, mammals and livestock. To meet plant and animal species diversity, a 10-15% of greasewood type in the early and late seral stages was recommended, with the remainder managed for the intermediate seral stage (Kershaw 1973, Mueller-Dombois and Ellenberg 1974).

Canopy cover and frequency of occurrence for the two key plants (greasewood and western wheatgrass) for calculation of indices are the only field requirements for field data collections on a site to determine seral stage assignment and monitoring. It is recommended for data collection that western wheatgrass is near or at full expression for growth. Indices must be calculated for each individual site (See methods). Collection of data may be yearly or every few years with a minimum of two sites (macroplots) per section (640 acres) within the greasewood ecological type. Additional information may be obtained from USDA-Forest Service website (Uresk et al. 2010) at: http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml.

Aknowledgements

Thanks are extended to Lakhdar Benkobi and Jody Javersak for data collections and analyses. George Wiggins provided invaluable advice for locating greasewood, providing historical aspects and support from the Medicine Bow-Routt National Forest. Rudy King, Rocky Mountain Research Station statistician (retired), provided invaluable statistical advice throughout the study and statistical analyses. Partial funding was provided by the Medicine Bow-Routt National Forest.

Literature cited

Ball, G.H. and Hall, D.J. 1967. A clustering technique for summarizing multivariate data. Behavioral Science 12:153-155.

Bestelmyer,B.T., K.Mosely, P.L.Shaver, H.Sanchez, D.D. Briske and M.E. Fernandez-Goemeze. 2010. Practical guidance for developing state-and-transition models. Rangelands 32:23-30.

Block, W. M., K. A. With and M. L. Morrison. 1987. On measuring bird habitat: influence of observer variability and sample size. The Condor. 89:241–251

Briske, D.D., S.D. Fuhlendorf and F.E. Smeins.2005. State-and-transition models, thresholds and rangeland health: a synthesis of ecological concepts and perspectives. Journal of Range Management. 58:1-10.

Cochran, W.G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, New York. 428 pp.

Costello, D.F. 1944. Important species of the major forage types in Colorado and Wyoming. Ecological Monographs. 14:107-134.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science. 33: 43-64.

del Moral, R. 1975. Vegetation clustering by means of ISODATA: revision by multiple discriminant analysis. Vegetatio. 29: 179-190.

Douglass, R.J. 1989. Assesment of the use of selected rodents in ecological monitoring. Environmental Management. 13:355-363.

Dyksterhuis, E.J. 1949. Condition and management of rangeland based on quantitative ecology. Journal of Range Management. 2(1): 104-115.

Dyksterhuis, E.J. 1985. Follow-up on range sites and condition classes as based on quantitative ecology. Rangelands. 7(4): 172-173.

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: A viewpoint. Journal of Range Management. 44:422-426.

Fritcher, S.C., M.A. Rumble and L.D. Flake. 2004. Grassland bird densities in seral stages of mixed-grass prairie. Journal of Range Management. 57:351-357.

HPRCC. 2015 High Plains Regional Climate Center, Dull Center 1SE, WY. Available at http://www.hprcc.unl.edu/cgi-bin/cli_perl_lib/cliMAIN.pl?wy2725 [Cited July 24, 2015].

Huschle, G. and M. Hironaka. 1980. Classification and ordination seral plant communities. Journal of Range Management. 33:179-182.

Kershaw, K.A. 1973. Quantitative and dynamic plant ecology, second edition. American Elsevier Publishing Company, Incorporated. New York. 308 pp.

Küchler, A.W. 1964. Potential natural vegetation of the conterminous United States.American Geographical Society Special Publication. No. 36. 116 pp.

Levy, P.S. and S. Lemeshow. 1999. Sampling of populations: methods and applications, third edition. John Wiley and Sons Incorporated Publication, New York, NY. 525 pp.

Martener, B.E. 1986. Wyoming Climate Atlas. Lincoln, NE: University of Nebraska Press.

McLendon, T. and B.E. Dahl. 1983. A method for mapping vegetation utilizing multivariate statistical techniques. Journal of Range Management. 36:457-462.

Mueller-Dombois, D.and H. Ellenberg. 1974. Aims and methods of vegetation ecology. New York. 547 pp.

Ryder, T.J. and L.L. Irwin. 1987. Winter habitat relationships of pronghorns in Southcentral Wyoming. Journal of Wildlife Management. 51:79-85.

Sampson, A.W. 1919. Plant succession in relation to range management. U.S. Department of Agriculture Bulletin. No. 791. 76 pp.

Stoddart, L.A. and A.D. Smith. 1955. Range Management. McGraw-Hill Book Company, New York, NY. 433 pp.

SAS Institute Inc. 1988.SAS/STAT user's guide, 6.04 ed. SAS Institute Inc., Cary, NC. 1,028 pp.

SAS. 2012. SAS Institute Inc. Cary, NC, USA. Proprietary Software 9.4.

SPSS. 2003. SPSS Base 12.0 for Windows User Guide. SPSS Inc. Chicago, Illinois.

Severson, K. E. and P.J. Urness. 1994. Livestock grazing: A tool to improve wildlife habitat Pp.232-249. in M.Vavra, W.A. Laycock and R.D. Pieper, eds., Ecological implications of livestock herbivory in the west. Society for Range Management. Denver, Colorado. 297 pp.

Thompson, W.L., G.C. White and C. Gowan. 1998. Monitoring vertebrate populations.

Academic Press Inc., San Diego, San Diego, California, USA. 365 pp.

Twidwell,D., B.W. Allred and S.D. Fuhlendorf. 2013. Synthesis & integration: national-scale assessment of ecological content in the world’s largest land management framework. Ecosphere. 4:1-27.

Thilenius, J.F., G.R. Brown and A.L. Medina. 1995. Vegetation on semi-arid rangelands, Cheyenne River Basin, Wyoming. Gen. Tech. Rep. RM-GTR-263. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 60 pp.

Uresk, D.W. 1990. Using multivariate techniques to quantitatively estimate ecological stages in a mixed-grass prairie. Journal of Range Management. 43: 282-285.

Uresk, D.W., R. M. King, J.J. Javersak and T.M. Juntti. 2010. Ecological classification and monitoring. Available at: http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml [Cited 18 May 2015].

Uresk, D.W. and D.E. Mergen. 2014. Ecological model for classifying and monitoring green needlegrass/western wheatgrass/blue grama/buffalograss ecological type. Intermountain Journal of Sciences. 20:1-13.

USDA-NRCS. 2013. The PLANTS Database National Plant Data Team, Greensboro, NC 27401-4901 USA .Available at http://plants.usda.gov.[Cited 5 August 2013].

USDA-NRCS. 2015. Plant guide: Black greasewood Sarcobatus vermiculatus (Hook.) Torr. http://plants.usda.gov/plantguide/pdf/pg_save4.pdf [Cited 1 September 2015].

USDI-USDA. 2013. Interagency Ecological Site Handbook for Rangelands. Available at http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=33151.wba [Cited 4 August 2015]. 109p.

Wallestad, R.O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. Journal of Wildlife Management. 35:129-136.

Welch, B.L. 2005. Bird counts in stands of big sagebrush and greasewood. USDA Forest Service Research Note RMRS-RN-28. Fort Collins, Colorado.

Received 19 October 2015
Accepted 27 January 2016