Model for Classifying and Monitoring Seral Stages within an Idaho Fescue Type: Bighorn National Forest, WY

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Abstract

An ecological vegetation model was developed in sedimentary soils on the Bighorn National Forest, Wyoming to classify seral stages within an Idaho Fescue (*Festuca idahoensis*) type. Two key plant species based on canopy cover (%), Idaho fescue and rosy pussytoes (*Antennaria rosea*), provide the required information for the model to classify seral stages and monitor vegetation trends. Three seral stages were quantitatively identified by multivariate statistical analyses for classification and had an overall accuracy of 98 percent. All three seral stages were significantly different from each other ($P < 0.05$). These seral stages provide managers three quantitative options to evaluate alternatives and meet management objectives. Application of this model within the Idaho Fescue ecological type is simple to apply, repeatable, accurate, and cost effective for field applications and management.

Key words: plant succession, diversity, canopy cover, management, grazing, wildlife

Introduction

Grasslands are a very important resource for livestock, wildlife, fisheries, watersheds, and recreation on the Big Horn Mountains in Wyoming. Management agencies periodically assesses plant community composition based on successional status or trend as part of its management program, but how are these data to be interpreted? Plant succession concepts have been used and applied for many years on rangelands for management and monitoring (Sampson 1919). Still major impacts have frequently occurred before being detected (Kershaw 1973, Block et al. 1987). This study presents a validated ecological model with key variables derived from field data to evaluate vegetation resources and monitor trends based on patterns of seral stage succession.

Grassland vegetation for the Big Horn Mountains has been evaluated for various years and includes the effects of livestock grazing on the vegetation (Beetle1956, Hurd and Pond 1958, Beetle et al. 1961, Hurd 1961). Monitoring changes of plant species diversity within and among the ecological seral stages from early to late succession provides a framework to assess influences associated with natural events and resource management. Quantitative ecological models with minimal input from field data can accurately measure changes in vegetation from natural and induced stresses that will provide resource managers information to achieve desired conditions or goals (Uresk 1990, Benkobi et al. 2007, Uresk and Mergen 2014).

The successional status of the Idaho Fescue (*Festuca idahoensis*) type in sedimentary soils on the Bighorn National Forest, Wyoming was based on site data collected by Beetle (1956). The objectives of this current study were: 1) to develop an ecological classification model with seral stages for the Tongue Ranger District, 2) provide field sampling and monitoring protocols.

Study Area

This study was conducted on the Bighorn National Forest within north central Big Horn Mountains, Wyoming. The Idaho Fescue type for the grasslands are found in extensive open areas (Beetle 1956). Soils are sedimentary. Annual precipitation averages 53 cm at Burgess Junction, Bighorn National Forest (2463 m elevation) and ranges from 30 to 54 cm based on years from 1989 to 2017. Average monthly temperature ranges from 7.7 to 16.7^0 C with a yearly average of 1.7^0 C (HPRCC 2018). Growing season at Burgess Junction is 66 days.

Vegetation in the open meadows on the Tongue Ranger District is dominated by Idaho Fescue type in which Idaho Fescue is the dominant grass (Beetle 1956). Other grasses and grasslikes are mountain brome (*Bromus marginatus*), Sandberg bluegrass (Poa secunda) and sedges (*Carex* spp). Common forbs are lupine (*Lupinus*), rosy pussytoes (*Antennaria rosea*), oldman'whiskers (*Geum triflorum*), Hookers sandwort (*Arenaria hookeri*) and Rocky mountain phlox (*Phlox multiflora*). Additional information and overview on species richness, vegetation characteristics, topography, soils, and climate are presented by Beetle (1956), Beetle et al. (1961) and Hurd (1961). Plant nomenclature follows USDA-NRCS (2018).

Methods

Data used for this study are from Beetle (1956). Beetle collected data on eighty six transects (sites) that consisted of 10 units per transect. Each unit consisted of four square foot nested frames (0.372 m2 /unit or 3.72 m2/transect). Within each square foot frame, visual estimates of cover for each plant species were collected and averaged by unit and transect. The method was defined as the square-foot cover estimate and sampling was conducted over a three year period; 1953, 1954, and 1955.

Preliminarily, data of minor plant species were removed from analyses with mean values of ≤1 percent (Uresk and Mergen 2014). The remaining 16 plant species were used as variables for analyses following procedures by Uresk (1990).

Principal component analyses reduced 16 plant species to 6. Data for the six plant species were subjected to a nonhierarchical cluster analyses (ISODATA) to group the sites (Ball and Hall 1967, del Morel 1975). Stepwise discriminant analysis further reduced 6 species to Idaho fescue and rosy pussytoes. Data for these two species were analyzed with ISODATA for final groupings (seral stages) and provided Fisher classification coefficients to assign groupings defined as seral stages (SPSS 2003, Uresk 1990). Misclassification error rates were estimated with cross validation using a jackknife or "leave one site out" procedure (SPSS 2003). With the cross validation procedure, each site was classified by the discriminant functions derived from all the other sites other than the one left out. Once classified it becomes one of the other sites. The developed model was tested and validated on random sites located in the field on the USDA-Forest Service, Tongue Ranger District for two years, 2005 and 2006.

Results

A total of 16 major plant species and total canopy cover (two dimensional cover) on 86 sites are presented in Table 1. Additional plant species for grasses-sedges forbs are presented by Beetle (1956), and Hurd (1961). After initial data reduction, six species: Idaho Fescue; rosy pussytoes, old man's whiskers, sedges, timber oat grass (*Danthonia intermedia*), and Rocky Mountain phlox remained for further analyses. Additional data reduction with discriminant analyses resulted in two plant species, Idaho Fescue and rosy pussytoes. Cluster analyses of these two species grouped the data into three seral stages; early, intermediate, and late based on plant succession.

The distributions of Idaho Fescue and rosy pussytoes within the three seral stages show the ecological dynamics of these species throughout the system from early to late plant succession (Fig. 1, Table 2). These

Table 1. Average canopy cover (%) and standard errors (in parentheses) for common plant species and other variables by seral stages in sedimentary soils on the Bighorn National Forest, WY (Beetle 1956). Serial stages are significantly different from each other ($P < 0.05$)

Species or variable	Late[1] n = 35[2]	Intermediate n = 12	Early n = 39
common yarrow *Achillea millefolium*	2.3(0.3)	2.6(0.7)	4.3(0.5)
pale agoseris *Agoseris glauca*	1.9(0.4)	0.3(0.1)	2.7(0.5)
slender wheatgrass *Elymus trachycaulus*	1.3(0.2)	0.3(0.2)	3.3(0.7
sosy pussytoes *Antennaria rosea*	5.5(3.9)	21.5(1.4	2.4(0.4)
Hooker's sandwort *Arenaria hookeri*	5.3(0.7)	8.4(2.3)	2.8(0.3)
sedge *Carex spp*	9.9(1.1)	19.1(1.7)	8.6(1.4)
field chickweed *Cerastium arvense*	3.3(0.5)	0.5(0.3)	4.0(0.6)
timber oatgrass *Danthonia intermedia*	3.7(0.7)	1.1(1.1)	3.3(0.6)
Idaho fescue *Festuca idahoensis*	24.9(1.0)	17.4(2.0)	9.5(0.6)
old man's whiskers *Geum triflorum*	04.6(0.8)	5.5(1.7)	4.5(0.9)
silky lupine *Lupinus sericeus*	2.6(0.6)	1.5(1.4)	3.11.0)
Rocky Mountain phlox *Phlox multiflora*	4.0(0.6)	3.0(1.2)	4.0(0.8)
Sandberg bluegrass *Poa secunda*	3.3(0.3)	3.1(0.5)	4.1(0.5)
Potentilla *Dasiphora spp*	2.4(0.4)	0.6(0.2)	3.6(0.6)
Rocky Mountain spikemoss *Selaginella densa*	2.4(0.8)	3.0(1.4)	1.1(0.4)
common dandelion *Taraxacum officinale*	1.3(0.3)	0.6(0.5)	3.6(0.7)
Total cover[1]	97.3(2.8)	86.7(2.8)	66.8(2.0)

[1] Two dimension cover of individual plant species

[2] Number of sites.

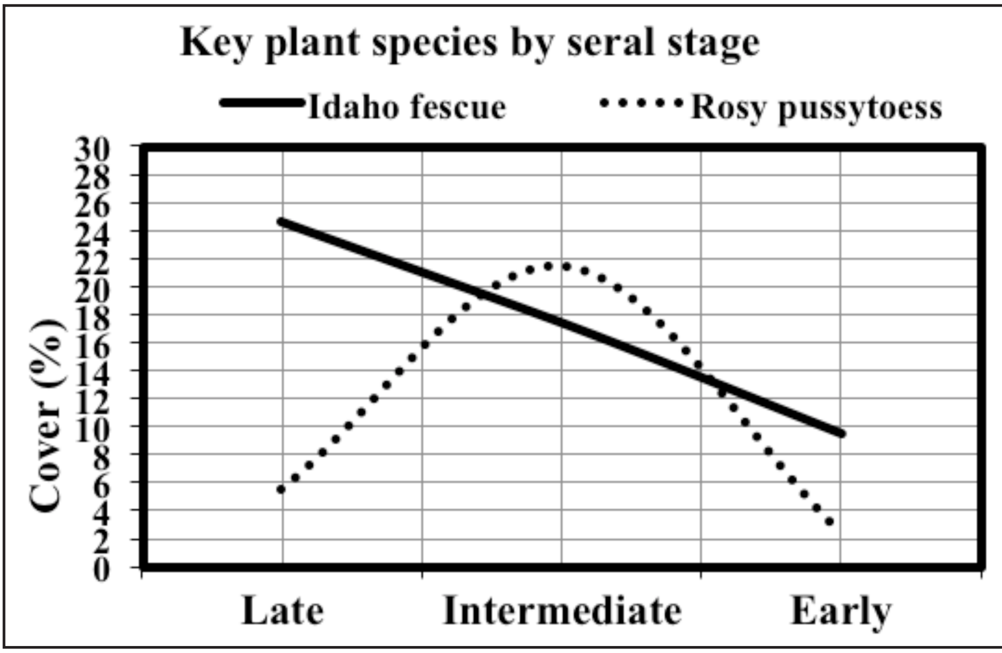

Figure 1. Canopy cover of key variables, Idaho fescue and rosy pussytoes displayed throughout three seral stages in the Idaho fescue association in sedimentary soils on the Bighorn National Forest, WY (Beetle 1956).

Table 2. Mean canopy cover (%) of key plant species for three seral stages within an Idaho Fescue association in sedimentary soils on the Bighorn National Forest, WY (Beetle 1956).

		MEAN CANOPY COVER	
Seral	n	Idaho fescue	Rosy pussytoes
Late	35	24.5	5.5
Intermediate	12	17.4	21.5
Early	39	9.5	2.4

n = number of sites

three seral stages were significantly different from each other ($P < 0.05$). Idaho fescue dominated the late seral stage (25% cover) followed by rosy pussytoes (6% cover). The intermediate seral stage was greatest for rosy pussytoes (22% cover) followed by Idaho fescue (17% cover). Both plant species in the early seral stage had low canopy cover with 10 percent and 2 percent for Idaho fescue and rosy pussytoes, respectively.

Fisher's classification discriminant function coefficients present the biotic potential and significance of each plant species for predicting and classifying seral stages (Table 3). The species with the greatest coefficient by seral stage expresses the biological indicator value of these two plants within this ecological type. An example of applying the discriminant function coefficients for new field data collected on a site to calculate seral stage assignment and monitoring is presented in Table 4. A seral stage assignment is determined by multiplying Idaho fescue and rosy pussytoes canopy cover for each seral stage (row) and the products are summed

Table 3. Fisher's discriminant function coefficients for classification of seral stages of key species within an Idaho fescue association in sedimentary soils on the Bighorn National Forest, WY (Beetle 1956).

Species	Late	Intermediate	Early
Idaho fescue	0.868	0.558	0.331
Rosy pussytoes	0.376	1.689	0.169
Constant	-12.935	-24.112	-2.89

(+ and -) including the constants for the score in each row. The greatest positive or the least negative score assigns the seral stage for this site. For this example, the site is assigned to early seral stage of plant succession with a value of **3.43** (Table 4). Developed coefficients may be programed into a personal digital assistant (PDA) for assignments of seral stages in the field for classification and monitoring at 98 percent accuracy.

Late seral stage

Idaho fescue dominated the late seral stage with 25 percent canopy cover for 35 sites (Table 1). Sedges provided 10 percent, followed by rosy pussytoes, Hooker's sandwort, old man's whiskers, and Rocky Mountain phlox with 6 percent, 5 percent and 5 percent, respectively. Eleven other plant species displayed less canopy cover. Total canopy cover was 97 percent.

Intermediate seral stage

Rosy pussytoes contributed the greatest cover with 22 percent (Table 1). Sedges exhibited 19 percent cover, Idaho fescue 17 percent, Hooker's sandwort 8 percent, and old man's whiskers 6 percent. The other 11 plant species displayed lower cover. Total canopy cover was 87 percent. Twelve sites were in the intermediate seral stage.

Early seral stage

All canopy cover values for plant species in the early seral stage were low ranging from 1 percent to 10 percent for 39 sites (Table 1). Idaho fescue provided the greatest cover at 10 percent followed by sedges, old man's whiskers with 9 percent and 5 percent correspondingly. Total canopy cover was 67 percent.

Discussion

The ecological model we present for Idaho fescue type on sedimentary soils is based on plant community succession and classification by seral stage. Plant dynamics and species changes between and among seral stages are quantitative estimates and they may be applied to meet resource management objectives. Disturbances such as livestock and wildlife grazing, fire, and climatic factors will move plant species associations within and between seral stages for the ecological type (Beetle 1956, Beetle et al. 1961, Hurd 1961).

The quantitative model developed was based on canopy cover (Beetle 1956) and defined three seral stages which may serve as resource management objectives. These seral stages represent a continuum over the landscape but are discrete categories for purposes of management. The model can be applied to allotments and/or pastures. Seral classification and monitoring between and among the stages is based on two key species, Idaho fescue and rosy pussytoes, with a 98 percent accuracy. Livestock grazing intensity and length of time may be adjusted to modify present seral stages to meet planned resource management objectives (Beetle 1956, Beetle et al. 1961, Hurd 1961, Severson and Urness 1994). A particularly useful feature is that of monitoring intra-seral stage changes to estimate movement toward or away from a

Table 4. An example of assigning seral stages by using Fisher's discriminant coefficients with site data collected by Beetle (1956) in the Idaho fescue association in sedimentary soils on the Bighorn National Forest, WY.

Seral Stage	Idaho fescue (Coeff[1] * Cover	+	Rosy pussytoes Coeff * Cover)	Constant	=	Score
Late	(0.868* 16	+	0.376 * 6)	-12.935	=	3.209
Intermediate	(0.558 * 16	+	1.689 * 6)	-24.112	=	-5.050
Early	(0.331 * 16	+	0.169 * 6)	-2.89	=	**3.43**[2]

[1] Coeff = coefficient

[2] Assigned serial stage

management objective. Periodic collections of plant community data for evaluation with application of the model are an important asset in evaluating the resources. The model is quantitative, accurate, repeatable, and cost effective.

Managing for all three seral stages is a preferred alternative and provides for plant and animal diversity within the Idaho fescue type. The recommendation is to have 10-15 percent of the landscape in early and late seral stages with approximately 70 percent in the intermediate stage (Kershaw 1973, Mueller-Dombois and Ellenberg 1974). A mosaic of seral stages across the landscape will provide optimum plant and animal diversity (Rumble and Gobeille 1998; Fritcher et al. 2004; Uresk and Mergen 2014). Management for a single seral stages is not adequate or practical for multiple use management based on abundance and species diversity. The intermediate seral stage that approximates 70 percent of the recommended landscape and is approximately equal to moderate grazing (Beetle et al. 1961). This equates to band 5 on the modified Robel pole for the Tongue Ranger District on the Bighorn National Forest, Wyoming (Uresk and Juntti 2008).

Collection of new field data for a relative small site to determine seral stage classification and monitoring canopy cover only requires data collection of two key plants, Idaho fescue and rosy pussytoes. Two transects, 20 m in length with 20 Daubenmire frames (20 cm x 50 cm) per transect that equates to 4 m2 per site (Daubenmire 1959). Beetle (1959) reported 3.7m2 per site. Transects are widely spaced ≥ 20 m at a minimum for a total of 40 quadrats each spaced 1m apart per transect. Two sites per section (640 acres) are recommended (Benkobi et al. 2007). Species should be at or near full expression for growth. Collection of data may be yearly or 3 to 5 year intervals. For further information see USDA-Forest Service website (Uresk et al. 2010).

The model we present is restricted to the Idaho fescue type, however the protocol used to develop the ecological model has been applied and used by managers on montane to prairie grasslands (Uresk 1990, Uresk et al. 2012, Uresk and Mergen 2014). Additional 15 vegetation types for developed ecological models with publications that have been applied and used by managers are presented by Uresk et al. (2010). In many cases, the development of these models would be useful in interpreting voluminous plant community data for other geographical areas and community composition of plant species.

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