ECOLOGICAL MODEL FOR CLASSIFYING AND MONITORING BOXELDER IN NORTHWESTERN NEBRASKA

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ABSTRACT

The objectives of this study were to develop a multivariate statistical model related to plant succession for boxelder ecological type (*Acer negundo-Celtis occidentalis-Symphoricarpos occidentalis*) to classify plant seral stages for monitoring resource changes based on management or environmental stresses in northwestern Nebraska. The developed boxelder classification and monitoring system was based on plant succession. Multivariate analyses and methods were used to determine key plant variables that best predict seral stages. Key plant variables were boxelder basal area, hackberry basal area, and percent canopy cover of snowberry. Four seral stages were quantitatively defined with a 96% accuracy of seral classification. These seral stages give resource managers four options to evaluate management alternatives and objectives. However, all stages must be present to maintain plant and animal diversity. In addition, plant and animal species diversity, livestock grazing and relationships to seral stages can be related to each of the four seral stages. This tool provides a simple, reliable, repeatable, accurate, and cost effective (time saving) alternative for classification of sites and for monitoring changes between and within seral states.

Keywords

modeling, succession, trees, seral stages, monitoring trends

INTRODUCTION

Little attention has been given to Boxelder (*Acer negundo* L.) ecological type (*Acer negundo-Celtis occidentalis-Symphoricarpos occidentalis*) for monitoring and seral stage classification. The sustainability of boxelder has been a concern for land managers. Boxelder is primarily found within deciduous woodlands confined to riparian drainages and upland draws on the Northern Great Plains and occupies less than 1% of the area (Bjugstad 1978). Maeglin and Ohmann (1973) present a review of boxelder which shows that it has a wide range of distribution throughout most of the temperate world. Boxelder is generally more abundant in areas of greater soil moisture, but can also occupy drier sites (MacCracken et al. 1983; Girard et al. 1989). Boxelder may be common to rare in woodlands and grows in soils ranging from heavy clays to sandy soils.

Over the past few decades, the concepts of seral classification have given resource managers a framework to evaluate the response of plant communities to both current management and natural events. State and transition models have received much attention for describing plant succession. The model that we developed is similar in concept and quantitatively defines discrete categories based on a multivariate statistical analysis of fundamental key variables to define plant community phases within a state and transition model of plant succession (MacCracken et al. 1983; Uresk 1990;, Benkobi et al. 2007). The boxelder ecological model defined by ecological plant seral stages reported in this research provides resource managers a statistically accurate quantitative tool for measuring effects of resource management and/or natural events such as drought or disease. This model is based on the interrelationships of key variables that best describe the ecological type throughout the range and variability of plant succession. The objectives of this study were to (1) develop a model for monitoring the boxelder ecological type in northwest Nebraska, (2) define seral stages and (3) provide sampling and monitoring protocols with management implications.

STUDY AREA AND METHODS

This study was conducted on the Nebraska National Forest near Chadron in wooded draws and riparian areas. Trees in this woodland type are boxelder, hackberry (*Celtis occidentalis*), green ash (*Fraxinus pennsylvanica*) and cottonwood (*Populus deltoides*). Common shrubs included snowberry (*Symphoricarpos occidentalis*) and chokecherry (*Prunus virginiana*). Grasses, sedges, and forbs were common in the understory, but data were not collected for herbaceous species.

Data collection for canopy cover followed (Daubenmire (1959) and analyses followed procedures outlined by Uresk (1990). Data were collected on 28 macroplots randomly selected within three perceived seral stages; early, mid-, and late. Each macroplot was 20 m x 40 m with an area of 800 m^2. Some sites that were narrow required the use of two 10 m x 40 m sub-plots that were combined as one site for analyses and classification. At the macroplot boundaries, two 30-m transects were established for canopy cover. A single transect was established at the macroplot boundary for each of the two sub-plots (10 m x 40 m) for the narrow sites. Canopy cover for the major shrub species was sampled at 1-m intervals along each 30-m transect following methods by Daubenmire (1959). Diameter at breast height (DBH) of trees greater than 2.54 cm (1 in) in diameter and number of stems were recorded for the 800 m^2 macroplots. All macroplot data (28 sites) were averaged for each site for shrub and tree species. A total of 16 variables were collected.

Principal component analysis identified variables that accounted for much of the variation in the data; these variables were selected for further cluster and discriminant analyses. Data were then subjected to a nonhierarchical cluster analysis using ISODATA (for standardized data) which grouped the variables

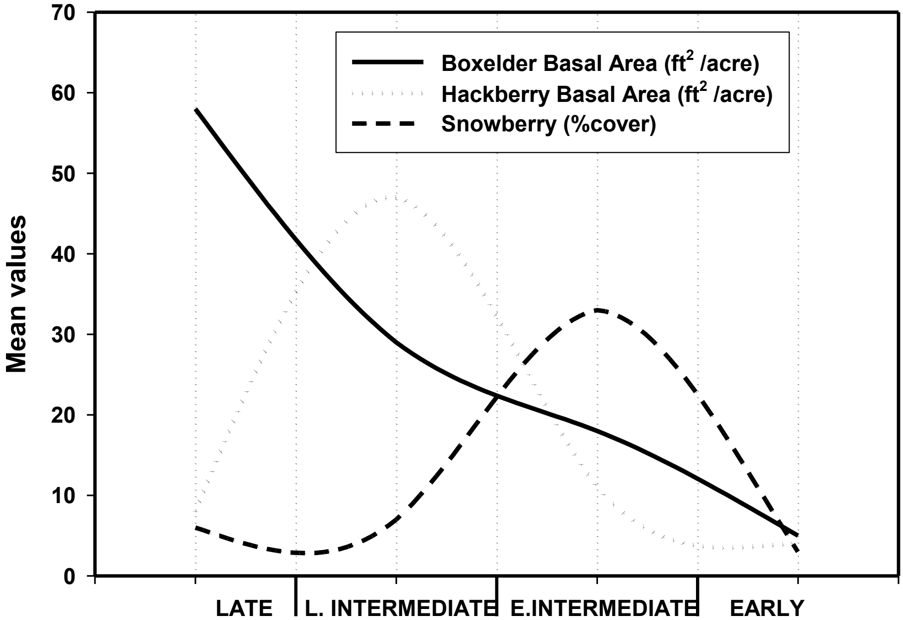

Figure 1. Boxelder ecological type variables by species through 4 seral stages in Northwestern Nebraska (adapted from Uresk et al. 2010).

into seral stages (Ball and Hall 1967; del Moral 1975). Stepwise discriminant analysis (SPSS 2003) identified important variables for seral stage classification and produced a quantitative model that can be used for future classification and monitoring ($P < 0.05$). Misclassification error rates were estimated using cross validation procedures (SAS 1988). We field tested the model by collecting additional data during the second year.

RESULTS

The boxelder ecological type was classified into four distinct seral stages ranging from early to late and was different between and among the groups ($P < 0.001$). This model was best defined by these four seral stages and by three variables: basal area of boxelder, basal area of hackberry, and percent canopy cover of snowberry (Figure 1). Boxelder is dominant in the late seral stage, hackberry in the late intermediate stage, and snowberry dominates in an early intermediate stage. Lesser amounts of all three species describe the early seral stage. Mean basal area of trees, number of tree stems, and canopy cover for snowberry are presented by seral stage in Table 1.

Fisher's discriminant function coefficients define the seral stages (Table 2). Variables with the greatest coefficient weights by seral stage reflect the biotic potential of each key plant species in predicting dynamics within the ecological system. An example of seral stage assignment is presented in Table 3. Multiplying the mean site values of boxelder and hackberry basal area and percent snow-

Table 1. Mean basal area (BA = ft²/acre), stems per acre and canopy cover (%) by seral stage based on three variables boxelder, hackberry and snowberry. n = sample size, mean ± standard error.

Variable	Late n=9	Late Intermediate n=4	Early Intermediate n=10	Early n=5
Boxelder (BA)[1]	58 ± 4	29 ± 15	18 ± 5	5 ± 3
Hackberry (BA)	8 ± 2	47 ± 6	11 ± 4	4 ± 2
Boxelder (stems/a)[2]	28	7	5	2
Hackberry (stems/a)	2	15	2	1
Snowberry (%)	6 ± 2	8 ± 8	32 ± 3	3 ± 2

[1]BA * 0.229 = m^2/ha
[2]stems * 2.47 = stems/ha

Table 2. Fisher's classification coefficients for ecological seral stages for boxelder ecological type in western Nebraska.

Variable	Late	Late Intermediate	Early Intermediate	Early
Boxelder (BA)[1]	0.260	0.124	0.130	0.028
Hackberry (BA)	0.067	0.500	0.124	0.038
Snowberry (%)[1]	0.168	0.147	0.419	0.048
Constant	-9.636	-15.351	-10.095	-1.608

[1]BA = ft^2/a * 0.229 = m^2/ha, % canopy cover

berry by the Fisher classification coefficients for each seral stage (row) and then summing the products results in a score. The greatest score identifies seral stage assignment for the site. When summed products for each stage are negative, the least negative value is used for seral stage assignment. Values for an example are boxelder basal area = 47, hackberry basal area = 12, and canopy cover of snowberry = 7%. In this example, the greatest score is 4.56, which assigns this site to late seral stage. Overall accuracy of the model based on cross validation is 96%.

As an alternative method for calculating seral assignment, Uresk et al. (2010) used canonical discriminant function coefficients and mean canonical coefficients (group centroids) for placement of posterior probabilities by seral stage and assignment of seral stage for new data. The seral stage assigned to a set of plant measurements is always associated with the greatest probability value. Details are available online at: http://www.fs.fed.us/rangelands/ecology/ecologicalclassification/index.shtml.

DISCUSSION

The ability to identify seral stages and relate them to prescribed management over time by measuring just three plant variables provides resource managers a powerful tool to evaluate and monitor conditions (Uresk 1990; Benkobi et al.

Table 3. An example of estimating assigned seral stage using Boxelder Fisher's discriminant coefficients and data for boxelder, hackberry, and snowberry.

	Boxelder				Hackberry				Snowberry					
Seral Stage	Coeff[1]		BA		Coeff		BA		Coeff		%	Const		Score
Late	(0.260	*	47	+	0.067	*	12	+	0.168	*	7)	-9.636	=	4.56
Late Int.	(0.124	*	47	+	0.500	*	12	+	0.147	*	7)	-15.351	=	-2.49
Early Int.	(0.130	*	47	+	0.124	*	12	+	0.419	*	7)	-10.095	=	0.44
Early	(0.028	*	47	+	0.038	*	12	+	0.048	*	7)	-1.608	=	0.51

[1]Coeff = Fisher's discriminant classification coefficient, BA = ft^2/a, Const = Constant values from Fisher's discriminant model, Int. - Intermediate.

1996; Benkobi et al. 2007). Knowledge of hypothetical climax vegetation or a reference plant community is not required with an ecological model when managers evaluate ecological types for management options. Selection of the three key plant variables for the model was quantitative and free from subjective information. Thus, for management purposes and monitoring, measuring the three plant variables is accurate and cost effective, providing a quantitative estimate of the system. Additional information and details on seral classification and monitoring may be obtained from Uresk et al. (2010).

State and transition models have received much attention during the past several years as an approach for describing the ecological processes for plants (Briske et al. 2005). The classification model developed for boxelder can be incorporated into state and transition models since the indicator species are diagnostic for differentiating seral stages or community phases. Our boxelder model is based on quantitative data collected throughout the existing range of succession for this vegetation type, and provides discreet categories along a continuum based on fundamental ecological processes. These discreet categories relate to plant community phases (seral stages) and can be incorporated into a state and transition model for this ecological type. Processes of plant succession can be at a steady state, continuous through succession, reversible or defined as at a transition based on data collected for this model (Uresk 1990; Benkobi and Uresk 1996;, Benkobi et al. 2007). Management objectives can be defined and results can be monitored within the context of defined seral stages or community phases.

Boxelder ecological type is uncommon on the northern Great Plains, but trees are found throughout the plains, generally within green ash woodlands (Maeglin and Ohmann 1973; MacCracken et al. 1983; Girard et al. 1989). MacCracken et al. (1983) found boxelder stem densities ranging from 260•ha^{-1} (105•a^{-1}) to 524•ha^{-1} (212•a^{-1}) within green ash woodlands in southeastern Montana. Girard et al. (1989) reported boxelder densities of 58•ha^{-1} (24•a^{-1}) in southwestern North Dakota. In the current study, by seral stage, mean stem densities ranged from 5•ha^{-1} (2•a^{-1}) to 144•ha^{-1} (58•a^{-1}). These lower stem densities in our study suggests that this area is a drier site than the area in southeastern Montana.

These woodlands are very important for wildlife including large and small mammals and non-game birds. In northeastern Montana, where boxelder was abundant, mule deer (*Odocoileus hemionus*) use was greatest during spring and summer while white-tailed deer (*O. virginianus*) use was primarily during the winter months (MacCracken and Uresk 1984). MacCracken et al (1985) further reported on rodent abundance within these same woodlands. Relative rodent abundance was greatest for deer mice (*Peromyscus maniculatus*), followed by meadow vole (*Microtus pennsylvanicus*). *Microtus* spp. were significantly correlated with boxelder (P < 0.001). Boxelder woodlands are important for nesting and maintaining species diversity for non-game birds on the Northern Great Plains (Walcheck 1970; Rumble and Gobeille 1998,; Emmerich and Vohs 1982; Faaness 1984). Bird species richness varied by seral stages in green ash woodlands (with boxelder present) from early to a late seral stage (Rumble and Gobeille, 1998). To maintain plant and animal diversity in a boxelder ecological type, all seral stages must be available and managed (Benkobi and Uresk 1996). Presence of an early seral stage may require additional management for boxelder; trees can disappear as a result of impacts of herbivore use and lack of regeneration (Boldt et al. 1978; Smith and Flake 1983; Uresk and Boldt 1986; Lesica 2009; Uresk et al 2009).

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