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Original Research

Broom snakeweed (Gutierrezia sarothrae) Population Change in Central New Mexico: Implications for Management and Control☆

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ABSTRACT

This paper examines changes in broom snakeweed populations (*Gutierrezia sarothrae* [Pursh] Britt. & Rusby) from 1979 to 2014 at three prairie grassland sites in New Mexico. Data gathered each fall were used to study broom snakeweed population dynamics and to estimate the probability that the relatively short-lived subshrub will die off or invade blue grama (*Bouteloua gracilis* [H.B.K. Lag]) rangelands. Annual broom snakeweed standing crop data were used to categorize populations as None (<100 kg ha^{-1}), Light (<300), Moderate (<750), or Heavy (≥750). Ordered logit regression was then used to estimate the frequency of transition between these categories over time depending on environmental and site factors. Significant variables found to influence annual variation in broom snakeweed included the broom snakeweed standing crop and density observed the previous period (+ effect for continued broom snakeweed); grass standing crop the previous period (−); rainfall received from April to June (+); and average temperatures during April (+) and June (−). The probability of broom snakeweed invading an area that is currently without the plant ranges from about 1% to > 40% depending on environmental conditions and the amount of grass standing crop present. Transition probability estimates were also used in a Monte Carlo simulation model to evaluate the economics of broom snakeweed control. The economics of chemical broom snakeweed control were most strongly related to the rate of snakeweed reinvasion on treated areas and to the probability of natural die-off if infested areas were not sprayed.

Introduction

Some ecologists have considered the presence of moderate to dense stands of broom snakeweed to be an indication of disturbance or overgrazing (Campbell and Bomberger, 1934; Parker, 1939; Jaynes and Harper, 1978; Pieper and McDaniel, 1989). Yet multiyear establishment, survival, and change in plant density has led others to describe broom snakeweed populations as episodic and with changes in plant numbers not necessarily tied to disturbance (Jameson, 1970; Sosebee et al., 1979). Climatic patterns, particularly precipitation amount, are now considered to be the principle factors driving regional broom snakeweed populations in the southwestern United States (McDaniel and Sosebee, 1988; Beck et al., 1996; Beck et al., 1999). Besides weather, other factors shown to influence broom snakeweed establishment and survival include grazing, physical disturbance, fire, insect damage, and other natural events (Pieper and McDaniel, 1989; Davis et al., 2000).

In central New Mexico, the second quarter of the year (April through June) is a particularly important time for broom snakeweed propagation and survival (Pieper and McDaniel, 1989). Broom snakeweed seedlings can emerge any time of the year, but optimal establishment occurs under moist conditions when surface soil temperatures range from 19°C to 25°C (Wood et al., 1997). A 5-yr broom snakeweed population field study on the New Mexico State University Corona Ranch reported highest fecundity rates in April and May and highest mortality rates in June (McDaniel et al., 1997; McDaniel et al., 2000). Pulse establishment of broom snakeweed can be anticipated during the second quarter when optimal environmental conditions occur, especially when soil moisture is sufficient and air temperatures are moderate (Wood et al., 1997; Ralphs and McDaniel, 2011). Broom snakeweed seedlings and mature plants are highly competitive for soil moisture, but both are vulnerable and succumb easily to drought when air temperatures are high in June (Ragsdale, 1969; Osman and Pieper, 1988; Wood et al., 1997). According to a 75-yr long-term data set compiled by Dittberner (1971) on the US Department of Agriculture (USDA) Jornada Experimental Range in southern New Mexico, broom snakeweed seedling survival is < 1% if June rainfall is not at least normal or above. Dittberner

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(1971) estimated the mean life span of broom snakeweed that survives the first year to be about 4 yr, but some plants may live longer than 15 yr.

Early economic evaluations of broom snakeweed control (Carpenter et al., 1991; Torell et al., 1988) followed traditional procedures and assumed an average annual benefit from broom snakeweed control over a specified treatment life. Net present value (NPV) of snakeweed control was found to be positive with average beef prices if the control treatment lasted with certainty for 5 yr. Uncertainty about treatment life was a noted limitation of both economic studies. Torell et al. (1989) expanded to a stochastic assessment using a first-order stationary Markov chain model (SMM) to incorporate uncertain future outcomes and treatment benefits into the economic assessment. NPV was estimated to be −$0.06/ha (break-even), and uncertainty about future snakeweed infestations was found to be a major factor limiting the economic potential of broom snakeweed control.

In this paper, we examine a 35-yr record of change in broom snakeweed density and standing crop at 3 prairie locations in New Mexico. The analysis is an update and improvement of the SMM procedure used to estimate the transition probabilities in the earlier economic research (Torell et al., 1992). The widely used SMM is based on the rather restrictive assumption that transition probabilities remain constant over time. Probability estimates are obtained by computing the proportion of times that the weed infestation level at time $t + 1$ was j, given that it was in state i at time t (Hillier and Lieberman, 2010). An emerging modeling alternative used to overcome the time-invariant limitation is to use multinomial logistic regression to estimate probabilities as a function of explanatory variables (ecological examples include Augustin et al., 2001; Boltz and Carter, 2006; Breininger et al., 2010; Bino et al., 2015). We use multinomial regression to estimate how broom snakeweed transition probabilities change in response to weather and vegetation conditions. We then use the probability estimates in a simulation model to determine how broom snakeweed removal by herbicide control influences expected gains in standing grass production over time. The improved estimates of transition probabilities were then used to revisit the economics of broom snakeweed control.

Methods

Study Sites

In May 1979, three study sites were established to examine the effectiveness of various herbicides for broom snakeweed control (McDaniel, 1984). Other sites were also included in the herbicide control study in other areas of the state, but they are not discussed here. The three study sites are located on private ranches near Vaughn, New Mexico in Guadalupe County (34°29'07.48" N 105°02'16.18" W); near Yeso, New Mexico in De Baca, County (34°25'51.32" N 104°41'45.45" W); and north of Roswell, New Mexico (33°50'45.09" N 104°54'08.26" W) in Chaves County. All sites are in the Prairie region of central New Mexico's Highland Major Land Resource Area designation by the Natural Resource Conservation Service (NRCS). A more complete description of each site and the original herbicide study design is found in McDaniel (1984).

Broom snakeweed growing in association with primarily blue grama (*Bouteloua gracilis* [Kunth in H.B.K] Lag. Ex Griffins) forms the vegetation mosaic on the three study sites. Broom snakeweed is the dominant overstory plant, with occasional scatterings of walking stick cholla (*Opuntia imbricata* [Harr.] DC.). Common warm season grasses in addition to blue grama include black grama (*Bouteloua eriopoda* [Torr.] Torr.), sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), and sand dropseed (Sporobolus cryptandrus Hitchc.). Annual or perennial broadleaf species were sparse on the sites and most commonly occurred following monsoonal rains. All three sites occur on undulating shallow limestone hills with a restrictive caliche layer at about a 30- to 35-cm depth. The primary climate-soil-plant community classifications of the NRCS (2013) are *Shallow* at the Vaughn site (Ecological Site ID: R070CY113NM, see https://esis.sc.egov.usda.gov/); *Shallow Plains (Cool)* at Yeso (Ecological Site ID: R070BY069NM); and *Gravelly* at North Roswell (Ecological Site ID: R070CY119NM).

Precipitation and temperature data for each site were obtained from nearby online cooperating weather stations managed by the Western Regional Climate Center (WRCC, 2016). Average temperature was recorded as the monthly average of the average daily temperature. Average quarterly rainfall totals were similar across the three study sites, averaging 3.79 ± 2.40 cm (mean ± SD) during quarter 1, 8.21 ± 5.31 cm during quarter 2, 16.04 ± 5.75 cm during quarter 3, and 6.32 ± 4.28 cm during quarter 4. Average annual air temperature ranged from 1.95°C in January to 23.4°C in July. Below-average rainfall totals occurred during 1980, 1983, 1989, 1993, 1995, 2003, 2009, and 2011 − 2012 at all three study sites (Fig. 1).

Vegetation Sampling

Untreated replicated (2) plots (0.1 ha in size) established at each site in the McDaniel (1984) study were monitored to follow the long-term change in the native broom snakeweed population. Chemically treated plots were not used in the assessment. Initially (from 1979 to 1987), every site was visited in the spring (April) and fall (October) and broom snakeweed seedlings and mature plants were counted to determine plant density. Later (1988 − 2014), sites were mainly visited in the fall and only occasionally in the spring to search for seedlings in those years when early-season rainfall was known to be above normal. In this paper, we include field data taken only in the fall. Broom snakeweed density was determined by counting new (first year seedlings) and mature plants separately within 20 sample frames (30 × 60 cm) placed in each replicated plot ($n = 40$). When making plant density counts, we considered a plant alive if any green tissue was observed from nodes on basal stems. Broom snakeweed standing crop (kg ha^{-1}) was determined by clipping plants in 10 sample frames per plot (every other frame previously counted) to a 3-cm stubble height. Placement of transect lines (two lines per plot, 38 m in length) was changed each year to prevent repeated harvesting. Grass standing crop (kg ha^{-1}) was determined within the 20 sample frames per plot by ocular estimate (McDaniel, 1984; McDaniel, 1989). Clipped grass material from two random frames per plot was weighed in the field and later oven dried to adjust estimates to a dry weight basis. Grass standing crop at the Yeso site was collected in 20 of the 35 study yr. Missing years were 1982 − 1990, 1992, 1994 − 1995, 1998, 2001, 2010, and 2011. Similarly, grass standing crop data were not collected at the other two sites in 2010 and 2011. When grass standing crop was not recorded, a modified version[1] of the sigmoid overstory-understory equation estimated by McDaniel et al. (1993) provided the grass standing crop estimate.

Grazing use was not specifically monitored during the study. However, when sites were visited each fall, an ocular estimate of standing crop removed by livestock (%) within the study plots was made. The study plots were located at least 1.5 km from a livestock water source, so typically grazing use was low and most years was rated as none to light (< 10% of herbaceous standing crop removed). As expected, grazing use varied by site and when use was rated above 10% we adjusted grass standing crop upwards to account for grazing biomass removal. Over the 35-yr study this correction was made 6 different yr on the Roswell and Vaughn sites and twice on the Yeso site. Landownership on these sites did not change, and our impression was that the ranchers adjusted herd size and grazing use responsibly according to prevailing weather and standing crop conditions. From 1979 through 1984 cattle and sheep grazed in mixed herds on the three ranches. However, when the wool market declined (roughly 1985), nearly all sheep were removed from the ranches by the late 1980s and replaced with cattle

[1] The sigmoid equation of McDaniel et al. (1993) was reestimated after adding quarter 3 rainfall measured the year before as an additional explanatory variable. The nonlinear revised equation was estimated to be $\widehat{Y}_t = 164.32 - 573.7(1 - e^{-.00124SWSC})^{0.6663} + 15.9\,RAINQtr_{2t} + 10.3RAINQtr3_t + 15.3RAINQtr3_{t-1}$. The additional lagged rainfall variable was found to be important in subsequent research reported by Torell et al. (2011).

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