An Investigation into the Relationship between Seed Bank Density and Juniper Abundance in Oregon's Sagebrush Steppe

Corinne M. Duncan, Richard F. Miller, and David A. Pyke

SUMMARY

Expansion of western juniper (*Juniperus occidentalis*) into the sagebrush steppe has resulted in significant changes in understory vegetation. A consequence of increased western juniper dominance may be a depletion of the seed bank. The seed bank represents seeds left in the soil from current and previous years' seed crops. Seed bank depletion can be a problem because a reduction in available seed weakens a site's ability to restore itself after disturbance. Our research evaluated the effect of increasing western juniper abundance on the number of seeds in the seed bank over 2 years (2006-2007). Specifically, we asked the question "does total number of seeds (or seed density) decrease in the seed bank as western juniper cover increases?" Two eastern Oregon juniper woodland-sagebrush steppe sites were selected. Each site contained western juniper that ranged from sparse to dense stands. Seed bank samples were collected in the fall of each year. To approximate the number of seeds in the seed bank we watered the samples in a greenhouse, and counted and identified the resulting seedlings. Total seed bank density, at both sites in the first year, decreased as western juniper cover increased; this relationship, however, was not consistent in the second year. Both sites received above-average precipitation in 2006 and received below or near average precipitation in 2007. We propose, and our data support, the hypothesis that in years receiving above average precipitation, areas with lower amounts of western juniper contain a higher abundance of seeds than areas with high amounts of western juniper. This hypothesis suggests that the ability of a site to recover after disturbance may be strongest in areas of low western juniper cover. Other studies support this hypothesis and we encourage the undertaking of a long-term study testing this idea and potentially providing confirmation of its value as a predictor for prioritizing restoration in sagebrush steppe, where encroachment of western juniper is a problem.

INTRODUCTION AND OBJECTIVES

Woody plant expansion is occurring throughout the world (Mariotti and Peterschmitt 1994, Hopkins et al. 1996, Roques et al. 2001, Silva et al. 2001). Of concern in the Great Basin is the expansion of pinyon and juniper woodlands (Miller and Wigand 1994, Miller et al. 2008). The northwestern representative of the pinyon-juniper zone is western juniper (*Juniperus occidentalis*) (Billings 1951). Research suggests that seed banks may become increasingly depleted as trees expand into shrub-dominated communities (Koniak and Everett 1982, Bakker et al. 1996, Price and Morgan 2008). The seed bank represents the seeds left in the soil from current and previous years' seed crops. This depletion is concerning because a reduction in the number of seeds weakens a site's ability to regrow vegetation after disturbance. This could translate to a decline in vegetative cover that protects the soil surface and thereby increase erosion (Pearson et al. 2007). Further, depleted seed banks could result in a compromised resistance to colonization by invasive species. Disturbance that removes a portion of the vegetation provides available open spaces for the establishment of new plants. If the seed bank is depleted of native seed, weedy species with high dispersal capabilities and high growth rates are more likely to become disproportionately established (Tausch 1999).

Identification of relationships between the abundance of expanding tree species and the composition of the seed bank may be useful for evaluating restoration potential. Such a relationship could indicate whether a community has the ability to recover on its own. To begin to investigate the possible effects of increasing tree dominance on seed banks in the sagebrush steppe, we evaluated total seed bank density (seed abundance) along a gradient of increasing western juniper canopy cover. Specifically, we asked the question "does total seed bank density decrease as western juniper cover increases?"

METHODS

Devine Ridge and Bridge Creek:
Two study sites, Devine Ridge and Bridge Creek, were selected to represent the juniper woodland-sagebrush steppe zone. These sites were located in eastern Oregon and were recently invaded by western juniper. Each location captured a range of western juniper cover varying from sparse to dense stands. Evidence of rapid tree growth and lack of large, spreading branches (Miller et al. 2005) suggested that most of trees on both sites established after the late 1800's.

The 62-acre Devine Ridge site was 9.9 mi north of Burns, Oregon at an elevation of approximately 4,900 ft, and was comprised of a mountain big sagebrush/Idaho fescue (*Artemisia tridentata* ssp. *vaseyana*/*Festuca idahoensis*) plant association. Soils were relatively shallow (8-20 inches), course, sandy loams. Temperature extremes over the last 30 years ranged from 99.0°F to -27.9°F. Long-term mean annual precipitation was 10.6 inches. Total precipitation for the 2005-2006 and 2006-2007 water years (September through August) were 16.5 inches and 8.9 inches, respectively (Oregon Climate Service 2008).

The Bridge Creek site was located about 1.8 mi northwest of Mitchell, Oregon at about 2,600 ft in elevation. The site was approximately 37 acres and was occupied by a basin big sagebrush/bluebunch wheatgrass (*A. tridentata* ssp. *tridentata*/*Pseudoroegneria spicata*) plant association. Soils were course, loam to sandy loams. Temperature extremes over the last 30 years ranged from 107.1°F to -27.0°F. Long-term mean annual precipitation was 11.3 inches. Total precipitation for the 2005-2006 and 2006-2007 water years were 14.6 inches and 12.5 inches, respectively (Oregon Climate Service 2008).

Data Collection:
Seed bank and tree cover data were collected during 2006 and 2007 within randomly selected 98- by 108-ft (0.25 acre) plots. Seventeen and 15 plots were established at Devine Ridge and Bridge Creek, respectively. At Devine Ridge, two additional non-randomly chosen plots were selected to ensure adequate sampling in the low end of the range of western juniper cover.

Canopy cover of western juniper was estimated by calculating the area covered by each tree from measurements of the longest width and the width perpendicular to the longest width of each tree. The areas for all trees rooted within a plot were summed, resulting in a single cover value for each plot.

Seed banks were sampled in late October and early November of 2006 and 2007 after most of plants had disseminated their seed and before field germination began to occur. During the fall of 2006, early snows prevented full sampling at Bridge Creek when only 9 of the 15 plots were sampled; however, a full sampling was obtained in 2007. At each plot, 10 soil cores were collected at 10-ft intervals along 4, evenly spaced 98-ft transects for a total of 40 cores. Both mineral soil and litter were included in each sample.

Germination was used as a proxy for estimation of the viable seed bank. To increase the probability of breaking dormancy, the samples were subjected to periods of cold-wet and warm-dry conditions. After collection, samples were moistened to field capacity and transferred within 3 days to a refrigerator held at 34°F for 60-days. Samples were then spread over sterile sand in 10- by 20-inch flats, and were randomly placed on greenhouse benches. Two control flats were added to test for possible contamination from windborne seed or the possibility of remaining viable seed in the sterile sand. Samples were then manually watered to initiate germination, and were subsequently checked once per day and watered as needed. As soon as seedlings could be identified, they were removed. Once germination ceased, after approximately 4 months, samples were placed under warm-dry conditions for a period of 14 days by withholding water and keeping the flats in the greenhouse. Samples were then mixed and watering was reinitiated. This second germination phase lasted for another 4 months resulting in a total germination period of 8 months, occurring January through August.

Statistical Analysis:
Due to site differences in soils and big sagebrush (*Artemisia tridentata*) subspecies, Devine Ridge and Bridge Creek were analyzed separately. Simple linear regression was employed to test for a relationship between total seed bank density and western juniper cover. Both sites and years warranted log-log transformation.

RESULTS AND DISCUSSION

Results:
No seedlings germinated in the control trays and so we assumed that contamination was insignificant. Mean seed bank density per plot at Devine Ridge was 132 seeds/ft^2 in 2006 and 72 seeds/ft^2 in 2007. At Bridge Creek, mean seed bank density per plot was 424 and 157 seeds/ft^2 in 2006 and 2007, respectively.

In 2006, western juniper cover was significantly related to seed density at Devine Ridge ($P < 0.001$). We estimated that for each doubling in western juniper percent cover, seed density decreased by 21 percent (Fig. 1). At Bridge Creek in 2006, an increase in western juniper cover was also related to a decrease in seed density ($P = 0.08$). It was estimated that every doubling of western juniper percent cover was associated with a 40 percent decrease in seed density (Fig. 1). No relationships were detected at either site in the second year (Devine Ridge: $P = 0.32$; Bridge Creek: $p = 0.15$).

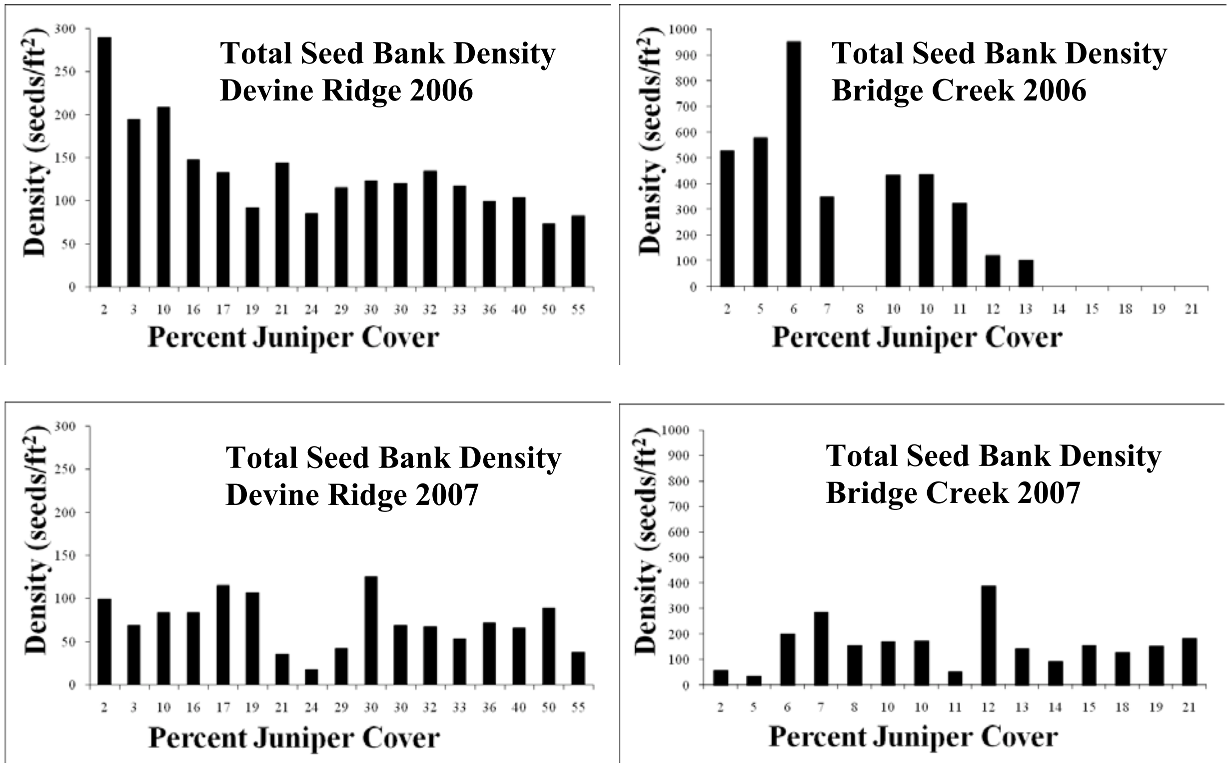

Figure 1. Total seed bank density per plot in relation to percent western juniper cover at Devine Ridge and Bridge Creek.

Discussion:
Seed bank density is related to a site's ability to recover after disturbance and thus its capacity for successful restoration (Lavorel et al. 1994, Lavorel 1999). Total seed density decreased as a function of increasing western juniper at both sites during the first year, but similar results were not observed in the second year. Other studies from the pinyon-juniper zone have also reported incongruous results. Our first year findings agree with Koniak and Everett (1982) who found that seed bank density decreased as singleleaf pinyon (*Pinus monophylla*) cover increased. Bakker et al. (1996) reported that the number of species in the seed bank decreased with increasing common juniper (*Juniperus communis*) cover. In contrast, Allen and Nowak (2008) found that both seed bank density and the number of seed bank species did not change as singleleaf pinyon/Utah juniper (*J. osteosperma*) cover increased. It is possible that this apparent inconsistency of findings may be due to variability in precipitation.

The first year of our study included a period of above-average precipitation. Precipitation for the 2005-2006 water-year (September through August) at Devine Ridge was nearly 156 percent of the average. At Bridge Creek (where the response was not as strong) precipitation for this period was 129 percent of the average. The highest total seed densities were found in the low western juniper canopy cover range (cover values below approximately one-third of maximum potential tree cover). The following year, precipitation at Devine Ridge was 84 percent of the average, while Bridge Creek received 110 percent of average. It is possible that increases in seed bank density are only expressed during considerably wetter than average years, at least in areas of low western juniper cover. We propose the hypothesis that open stands of western juniper express higher total seed bank densities than closed stands in years receiving above-average precipitation, thus suggesting that a site's ability to recover may be higher in areas of low western juniper cover. Koniak and Everett (1982), Bakker et al. (1996), and Allen and Nowak (2008) support this hypothesis. Both Koniak and Everett (1982) and Bakker et al. (1996) showed a negative response in the seed bank related to increases in tree cover. The water year prior to sampling by Koniak and Everett (1982) was 44 percent (3.9 inches) above average (California Weather Database 2008). During the Bakker et al. (1996) study period, precipitation was reported to be 46 percent (7.9 inches) above average. Finally, Allen and Nowak (2008) did not find a seed bank density response, reporting that the water years prior to their study were 34 percent and 30 percent (4.7 and 4.3 inches) below average.

MANAGEMENT IMPLICATIONS

Our results suggest that areas in the early stages of woodland expansion have a greater potential to contain higher seed bank densities in wetter than average years. Prioritization of these areas for tree removal would be wise as their resilience is likely to be greater. Validation of this relationship would allow for better prediction of recovery rates subsequent to control of woody expansion species, and we encourage further investigation into this topic.

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