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Native Warm-Season Grasses Resist Spotted Knapweed Resurgence

Neil W. MacDonald

Grand Valley State University, macdonan@gvsu.edu

William J. Bottema

Catholic Central High School, Grand Rapids, MI

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6 Spotted knapweed (*Centaurea stoebe*), a nonnative perennial forb, has invaded many
7 areas throughout North America, requiring active management to restore native plant
8 communities (Sheley et al. 1998). Restoration attempts often utilize combinations of control
9 methods and seeding to replace knapweed with native species, but many studies have been based
10 only on short-term experiments (Kettenring and Adams 2011). Long-term studies of the
11 persistence of seeded species on knapweed-infested sites are needed to inform long-term
12 restoration strategies because some seeded species may not remain competitive after the effects
13 of site preparation treatments have diminished (Rinella et al. 2012).

14 Between 1999 and 2005, we studied the establishment of native warm-season grasses on
15 a degraded, knapweed-infested site in western Michigan. The soil, landform, and remnant native
16 species present were consistent with presettlement vegetation communities that included warm-
17 season grasses, making the establishment of native grasses a first step towards the restoration of
18 a native plant community (MacDonald et al. 2007). We employed a factorial arrangement of
19 treatments in a randomized complete block design, including two levels of fertility amendment
20 (0 and 12 Mg ha⁻¹ municipal sewage sludge) and three levels of herbicide application (none, 2,4-
21 D, and glyphosate), as detailed in MacDonald et al. (2003). The experiment included 48 2 × 2-m
22 plots with 1.5-m buffer strips between plots and a 3-m buffer strip surrounding the entire
23 experiment. Each summer from 1999 to 2005, we controlled knapweed in the buffer using a
24 single annual mowing. In mid-May, 1999, we seeded the plots at a rate of 60 kg ha⁻¹ with a seed
25 mix that included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium*
26 *scoparium*), switchgrass (*Panicum virgatum*), and Indian grass (*Sorghastrum nutans*). Between
27 1999 and 2001, we made plant counts and sampled aboveground biomass every summer on four
28 randomly located 0.1-m² quadrats on each plot. During the first two years of the study, both

herbicide treatments reduced knapweed density and biomass, and the seeded grasses successfully established on all treatment combinations. By 2001, warm-season grasses appeared to be competing successfully with knapweed, but persistence of adult knapweed (4.2 ± 1.0 plants m^{-2} , mean $\pm$ SE) suggested that continued management might be required to maintain native grass dominance and prevent knapweed resurgence (MacDonald et al. 2003).

As an experimental management strategy, we incorporated burning as a fully crossed factor into the study in the spring of 2003 (MacDonald et al. 2007). Twenty-four randomly selected plots were burned each year from 2003 to 2005 in late April to late May. In mid-August of each of these years, we counted all knapweed plants and sampled aboveground biomass of all plants on four randomly located 0.1-m^2 quadrats per plot. Burning effectively increased biomass and dominance of warm-season grasses and decreased biomass and dominance of spotted knapweed. By 2005, mean adult knapweed densities on both burned (0.4 ± 0.3 m^{-2}) and unburned (1.3 ± 0.4 m^{-2}) treatments had declined to levels where we concluded that the seeded grasses would persist with normal management (MacDonald et al. 2007). Between 2005 and 2013, no knapweed control measures were applied either on or between the plots. As a result, the restored native grass plots were exposed to knapweed seed fall from the unmowed buffer strips from 2006 to 2012.

To determine the degree to which spotted knapweed had reinvaded and native grasses had persisted on the restored plots, we resampled them in late July and early August, 2013. We used a fiberglass measuring tape to mark the boundaries of the 4-m^2 plots and counted and clipped all adult knapweed in each plot. We placed one 0.25-m^2 quadrat at a random location within each plot, and clipped all vegetation within the quadrat and sorted it into native grasses, other grasses, and other forbs, following the methods of MacDonald et al. (2003, 2007). To

provide an untreated comparison for the restored plots, we also counted all knapweed and gathered biomass samples on 12 randomly located 0.25-m² quadrats placed within adjacent unrestored areas of the study site. We dried all plant samples at 70 °C for 48 hours and weighed them to estimate biomass for each major species group. To estimate adult knapweed densities in the buffer zones between restored plots, we counted bolted knapweed on 12 randomly selected 1.5 × 1.5-m quadrats located between adjacent plot corners in late May, 2014. We used PERMANOVA, a nonparametric, permutational analysis of variance (M. J. Anderson, Department of Statistics, University of Auckland, Auckland, NZ) to test for residual treatment effects within the original study, and to compare each block of the restored plots (n = 12 plots each) to the buffer zones and unrestored areas. To compare results from 2005 to those of 2013, we used the Friedman non-parametric two-way analysis of variance.

While burning maintained reduced spotted knapweed density and biomass and increased native grass biomass and dominance in 2005, these effects had dissipated by 2013, producing similar plant communities on both burned and unburned treatments (Table 1). Similarly, there were no residual effects of the original sludge or herbicide treatments on any of the variables measured in 2013 except for knapweed density and biomass. Both knapweed density (PERMANOVA; $F = 3.51$; $p = 0.04$) and biomass (PERMANOVA; $F = 4.47$; $p = 0.04$) tended to be greater on sludge-fertilized plots (0.4 ± 0.1 plants m⁻²; 2.7 ± 0.7 g m⁻²) than on unfertilized plots (0.2 ± 0.1 plants m⁻²; 1.5 ± 0.9 g m⁻²), but these effects were not consistent among treatment combinations. Since sludge amendment may have contributed to slightly greater spotted knapweed density and biomass, fertilization should be avoided on such sites since it did not benefit the native grasses in the long term, and might favor the persistence of spotted knapweed.

Adult knapweed densities on the restored plots tended to decline from those measured in 2005 to a mean of $0.3 \pm 0.1 \text{ m}^{-2}$ in 2013, but this did not represent a significant change on either unburned (Friedman; $\chi^2_r = 0.4$; $p = 0.54$) or burned (Friedman; $\chi^2_r = 1.5$; $p = 0.22$) plots. In contrast, adult knapweed density within the surrounding buffers was $5.3 \pm 1.4 \text{ m}^{-2}$ and on the adjacent unrestored areas was $46.3 \pm 7.7 \text{ m}^{-2}$, both significantly greater than on the restored plots (PERMANOVA; $F = 9.44$; $p < 0.001$). In the 48 0.25-m^2 quadrats sampled on the restored plots, we observed only two knapweed seedlings (< 0.2 seedling m^{-2}) and no juveniles, while in the unrestored areas, we measured seedling densities of $5.7 \pm 2.1 \text{ m}^{-2}$ and juvenile densities of $4.7 \pm 2.4 \text{ m}^{-2}$. Knapweed biomass and dominance also remained substantially lower on the restored plots than in the surrounding unrestored areas, while native grass biomass and dominance remained high on the restored plots (Table 2). Persistence of higher densities of knapweed in the unrestored areas demonstrated that knapweed populations had not spontaneously declined at the study site through time, and the low densities and biomass of knapweed on the restored plots were consistent with continued suppression by the native grasses.

These results demonstrate the long-term success of restoring native warm-season grasses on a degraded site originally dominated by spotted knapweed. Once established, the native grasses maintained dominance ($> 85\%$ of total biomass) and effectively resisted knapweed resurgence for a period of 14 years, including eight years after cessation of burning. In adjacent unrestored areas, spotted knapweed continued to be the dominant species 14 years after study initiation. In contrast to several studies reported by Rinella et al. (2012), in which some seeded grass species either gradually disappeared or did not become dominant until up to 15 years after seeding, the native grasses that we seeded established dominance early on and continued to suppress knapweed even after active management ceased. We also observed native grasses that

had established in the buffer zones around the restored plots, further evidence that the warm-season grasses had become a self-sustaining population on this site (Rinella et al. 2012). We used a seeding rate that was four to six times greater than normally recommended for these species (Packard and Mutel 1997), so stands of warm-season grasses established using standard seeding rates (10 to 15 kg ha⁻¹) might take longer to become dominant on similar knapweed-infested sites. While burning effects did not persist through time, reinstituting burning at appropriate intervals would be feasible given the abundance of grassy fuel present and positive response of native grasses to burning (Packard and Mutel 1997). If additional knapweed suppression was desired, residual knapweed densities on restored plots remained low enough where hand pulling would be an effective and practical treatment (MacDonald et al. 2013). Our results are most applicable to the restoration of native warm-season grasses on degraded, knapweed-infested sites in the upper Midwest, and demonstrate that these native grasses can effectively suppress knapweed for extended time periods even in the absence of fire. Where the restoration of more diverse native plant communities is an important goal, the inclusion of these native grasses in a broad seed mix may similarly facilitate the gradual suppression of spotted knapweed.

References

- Kettenring, K. M., and C. R. Adams. 2011. Lessons learned from invasive plant control experiments: a systematic review and meta-analysis. *Journal of Applied Ecology* 48: 970-979.
- MacDonald, N. W., M. T. Koetje, and B. J. Perry. 2003. Native warm-season grass establishment on spotted knapweed-infested gravel mine spoils. *Journal of Soil and Water Conservation* 58: 243-250.

- MacDonald, N. W., L. M. Martin, C. K. Kapolka, T. F. Botting, and T. E. Brown. 2013. Hand pulling following mowing and herbicide treatments increases control of spotted knapweed (*Centaurea stoebe*). *Invasive Plant Science and Management* 6(4): 470-479.
- MacDonald, N. W., B. T. Scull, and S. R. Abella. 2007. Mid-spring burning reduces spotted knapweed and increases native grasses during a Michigan experimental grassland establishment. *Restoration Ecology* 15: 118-128.
- Packard, S., and C. F. Mutel (eds). 1997. *The Tallgrass Restoration Handbook for Prairies, Savannas and Woodlands*. Washington DC: Island Press.
- Sheley, R. L., J. S. Jacobs, and M. F. Carpinelli. 1998. Distribution, biology, and management of diffuse knapweed (*Centaurea diffusa*) and spotted knapweed (*Centaurea maculosa*). *Weed Technology* 12: 353-362.
- Rinella, M. J., J. M. Mangold, E. K. Espeland, R. L. Sheley, and J. S. Jacobs. 2012. Long-term population dynamics of seeded plants in invaded grasslands. *Ecological Applications* 22: 1320-1329.

Affiliation and Contact Information

- N. W. MacDonald: Natural Resources Management Program, Department of Biology, 215 Henry Hall, Grand Valley State University, Allendale, Michigan, 49401, U.S.A.
- W. J. Bottema: Catholic Central High School, 319 Sheldon Blvd. SE, Grand Rapids, Michigan, 49503, U.S.A.
- Address correspondence to N. W. MacDonald at macdonan@gvsu.edu, (616) 331-2697

Table 1. Plant biomass and dominance by major species groups on burned (n = 24) and unburned (n = 24) plots restored to native grasses in the Bass River Recreation Area, Ottawa County, Michigan. The last burning treatment was applied in May, 2005 and plots were unmanaged until being resampled in 2013. Means followed by different letters differ significantly: a and b compare biomass means between burning treatments within a single species group in 2005; x and y compare dominance means between burning treatments within a single species group in 2005; there were no significant burning effects that persisted into 2013. Biomass or dominance means within a single species group and burning treatment differ significantly between 2005 and 2013 at $p = *0.05$, $**0.01$, or $***0.001$ based on the Friedman two-way nonparametric analysis of variance. The 2005 data were originally reported in MacDonald et al. (2007).

Species Group	Treatment	Biomass (g m ⁻²)		Dominance (% of total biomass)	
		2005	2013	2005	2013
Spotted Knapweed	Unburned	5.2a	1.9	2.1	1.1
	Burned	0.9b	2.3	0.5	1.5
Other Forbs	Unburned	1.6	2.3*	0.6	1.0*
	Burned	0.0	5.0**	0.0	2.6**
Other Grasses	Unburned	38.8a	26.0	16.1x	9.9*
	Burned	2.6b	35.6***	1.0y	12.1***
Native Grasses	Unburned	214.4b	333.6	81.1y	88.0*
	Burned	263.8a	253.8	98.5x	83.9***

Table 2. Plant biomass and dominance on plots restored to native grasses as compared to adjacent unrestored areas in the Bass River Recreation Area, Ottawa County, Michigan, 2013. Native grasses were seeded in 1999 and remained dominant on restored plots through 2013. Biomass or dominance means within a single species group differ significantly between restored and unrestored areas at $p = **0.01$ or $***0.001$ based on Euclidean distances calculated from ln-transformed data analyzed using PERMANOVA.

Species Group	Biomass (g m^{-2})		Dominance (% of total biomass)	
	Restored	Unrestored	Restored	Unrestored
Spotted Knapweed	2.1	602.6***	1.3	82.3***
Other Forbs	3.7	7.6	1.8	1.9
Other Grasses	30.8	80.1**	11.0	15.8
Native Grasses	293.7	0.0***	85.9	0.0***