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Source: Rhodora, 122(989) : 48-52

Published By: New England Botanical Club

URL: https://doi.org/10.3119/19-05

RHODORA, Vol. 122, No. 989, pp. 48–52, 2020

doi: 10.3119/19-05; first published on-line May 21, 2020.

NEW ENGLAND NOTE

RESPONSE OF A WETLAND PLANT COMMUNITY TO MANAGEMENT OF *PHRAGMITES AUSTRALIS* (POACEAE) IN SOUTHWESTERN CONNECTICUT

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Many conservation organizations remove invasive plants with herbicides; however, few quantify the outcomes of management on the invaded plant community (Martin and Blossey 2013). *Phragmites australis* (Cav.) Trin. ex Steud. is a perennial grass, native to Eurasia, that is now found throughout temperate regions of North America in fresh water, brackish, and salt marsh environments (Meyerson et al. 2009). Despite considerable interest in the effects of *P. australis* on native wetland ecosystems, relatively little information exists on the efficacy of different management strategies and the response of plant communities to the removal of *P. australis*, especially over multiple years (Hazelton et al. 2014; Martin and Blossey 2013).

We examined the efficacy and effects of removing *Phragmites australis* from the perimeter of a 1-hectare pond at Highstead Preserve in southwestern Connecticut (41.327, –73.394) over a six-year period (2012–2017). Prior to the study, *P. australis* covered 30% of the shoreline around the pond and formed several small (< 100 m^2), dense patches and one relatively large patch ($\sim$1300 m^2). We used vegetation monitoring and three different herbicide (Rodeo® [53.8% glyphosate]) application techniques to treat *P. australis*: (1) handwipe 25% solution (leaves and upper half of stem wiped via cotton work glove worn over 15 mil nitrile glove); (2) wand 25% solution (leaves and upper half of stem wiped with long-handled brush applicator); and (3) spray 2.3% solution (whole plant with backpack sprayer). Prior to herbicide treatment in 2012, we sampled the pondside vegetation by randomly placing 28 quadrats 1 m^2 in patches invaded by *P. australis*. In each quadrat, we counted live stems of all vascular plant species with the exception of graminoids that grew in overlapping clumps (Farnsworth and Meyerson 1999). We identified the clumped graminoids to species (or genus) but pooled their combined abundances into a single value estimated by percent cover abundance. *Phragmites australis* dominated the vegetation and occurred in all 28 of the quadrats, while seven other species – *Galium* spp., *Impatiens capensis* Meerb., *Leersia* spp., *Solidago* spp., *Carex* spp., *Lemna* spp., and *Spirodela polyrrhiza* (L.) Schleid. – occurred in $\geq$ 40% of the quadrats. Quadrats were resampled following herbicide treatments in July–August of 2013, 2014, and 2017. Nomenclature followed Haines (2011).

In January 2013, we mowed all *Phragmites australis* stems and left all cut stems to decay in place. In June of 2013 and again in September–October 2013 we employed the three different herbicide application methods. After the first year of treatment, the handwipe approach was notably more effective (72% reduction) than were the spray or wand treatments (20–32% reduction) at reducing *P. australis* (Table 1). Damage to non-target herbaceous vegetation was also highest in the spray treatment. Stem densities of non-*Phragmites* herbs (combined forbs, graminoids, and ferns) declined by 76% in the spray treatment and remained largely unchanged in the wand and handwipe treatments. Woody stem densities changed little per treatment. Herb species richness declined significantly by 50% (12.6 species/plot to 6.3 species/plot; $p = 0.002$, two-tailed t-test) in the spray treatment, but only by 4.9% in the wand ($p = 0.32$) and none in the handwipe ($p = 0.41$) treatments (Table 1). Of the seven taxa that initially occurred in $\geq$ 40% of the quadrats, only *Leersia* spp. maintained a $\geq$ 40% frequency in the first year post treatment across all treatments. Given these results, we decided to treat all remaining *P. australis* stems in subsequent years with the handwipe method.

Following the second year of treatment in 2014, *Phragmites australis* stem density had declined by 98% across the 28 plots compared to 2012 values (Table 1). Herb densities increased by 390% in the original spray treatment and by 207% across all the plots. Herb richness also recovered in the original spray treatment, increasing from 6.3 species, on average, in the first year post treatment to 12.3 species in 2014. By 2017, herb richness surpassed pre-treatment (2012) richness across all plots by almost four species on average (29% increase; Table 1). Woody stem density (128%) and species richness (103%) also increased notably across all plots between 2014 and 2017. By 2017, 10 species occurred in $\geq$ 40% of the quadrats, indicating a more even distribution of species than in either 2013 or prior to treatment in 2012. These taxa included *Acer rubrum* L., *Bidens* spp., *Carex* spp., *Lemna* spp., *Leersia*

Table 1. Change in density of stems and species (no./m^2) over time and by herbicide application at the Highstead Pond in Redding, CT, U.S.A. Values are means with standard deviations in parentheses. Note: *Phragmites australis* stems in all plots were treated with the handwipe technique after 2013.

Year	Treatment	N	*Phragmites australis* density	Herb density	Herb species	Woody density	Woody species	Native species	Nonnative species
2012	Handwipe	7	38.1 (19.3)	73.4 (92.8)	14.9 (11.6)	1.6 (2.0)	0.9 (1.2)	13.1 (11.4)	0.3 (0.5)
	Spray	10	40.6 (19.4)	96.8 (109.8)	12.6 (6.0)	3.8 (5.8)	0.9 (0.9)	9.8 (5.7)	0.7 (0.8)
	Wand	11	34.3 (34.6)	61.7 (52.9)	13.0 (7.3)	3.2 (3.8)	1.6 (1.6)	10.5 (6.8)	0.9 (1.0)
2013	Handwipe	7	10.7 (6.4)	79.0 (82.9)	15.7 (11.7)	1.7 (2.4)	0.6 (0.8)	12.7 (9.9)	0.4 (0.8)
	Spray	10	27.2 (11.8)	23.0 (18.4)	6.3 (3.0)	3.5 (5.1)	0.9 (1.4)	5.0 (2.4)	0.3 (0.5)
	Wand	11	27.45 (27.5)	51.0 (41.6)	12.4 (7.9)	2.6 (3.0)	1.5 (1.6)	10.3 (7.7)	0.9 (0.8)
2014	Handwipe	28	0.78 (2.4)	147.3 (183.8)	14.1 (7.1)	3.6 (4.3)	1.6 (1.6)	11.3 (6.2)	1.2 (1.5)
2017	Handwipe	28	0.85 (2.5)	147.5 (79.8)	17.7 (7.1)	8.2 (8.6)	2.2 (2.3)	15.1 (7.0)	1.4 (1.6)

spp., *Microstegium vimineum* (Trin.) A. Camus, *Sparganium* spp., *Pilea* spp., *Equisetum arvense* L., and *Persicaria sagittata* (L.) H. Gross.

Native species richness increased by about four species (39% increase), on average, in all plots in 2017 compared to pre-treatment (2012) values, while nonnative species increased by 0.75 species, on average (110% increase) from 2012 to 2017. The notable invasive grass species, *Microstegium vimineum*, increased from 18% of the plots in the first year post treatment to 54% of the plots in 2017. The increase in both native and nonnative species richness following removal of *Phragmites australis* was not particularly surprising, given that nonnative species are generally well adapted to exploiting newly disturbed areas and often respond to the same environmental gradients and conditions that natives do (Gilbert and Lechowicz 2005). Nonetheless, it reveals a challenge to management: removing a single dominant nonnative species can potentially result in higher species richness of both native and nonnative species in areas where many other nonnative species are prevalent (cf. Alvarez and Cushman 2002).

This study highlights the benefits and challenges of managing a dominant invasive plant and promoting the growth of native vegetation, especially when uncertainties exist about the efficacy of different herbicide methods and corresponding impacts on non-target vegetation (Diaz et al. 2003; Williams et al. 2009). Our results suggest a handwipe approach, though more time consuming than spraying, is the most effective way to manage *Phragmites australis* in relatively small areas (or after stem densities have been reduced following a spray treatment in larger areas). Thirdly, our study highlights the resilience of a wetland plant community following initial damage from a spray treatment, with the rapid growth and recovery of a dense and diverse plant community (cf. Farnsworth and Meyerson 1999). Finally, our results corroborate a number of other studies that have noted the strong regenerative capacity of *P. australis* following single herbicide treatments (Farnsworth and Meyerson 1999). We achieved a 98% mortality of *P. australis* only after multiple years of herbicide treatments, and we will likely need to continue to spot treat new stems each year into the foreseeable future.

ACKNOWLEDGMENTS. We thank O. Lukas, A. Pachomski, A. Petzke, A. Lefland, J. Hautaniemi, and T. Hendrickson for vegetation monitoring; D. Peck and J. Hubbard for mowing and herbicide application; D. Whigham, T. Modzer, E. Hazelton, and especially E. Farnsworth for advice on study design, vegetation sampling, and chemical treatment; and B. Moorhead for plant identification. We also thank three anonymous reviewers and Associate Editor Tom Lee for their suggestions on the manuscript.

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