Controlling Italian Arum (Arum italicum)

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RESEARCH NOTE

Controlling Italian Arum (*Arum italicum*)

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ABSTRACT: Arum italicum (*Italian arum*) is a perennial herbaceous geophyte native to parts of Europe, Russia, and northern Africa. It has spread outside of cultivation in northern Europe, Oceania, and the Americas. Leaves emerge in the fall and are shed in the early summer; inflorescences form in the spring and fruits ripen in mid-summer. Successful documented treatment options are limited. To test new chemical control methods, we treated plants in a Washington, D.C., natural area in mid-March with three chemical treatments (triclopyr + metsulfuron methyl, triclopyr alone, glyphosate + metsulfuron methyl), and a control. Cover estimates in the spring and fall showed a decline in cover for treatments that included metsulfuron methyl but not for the triclopyr alone treatment.

Index terms: early detection, glyphosate, metsulfuron methyl, triclopyr

INTRODUCTION

Arum italicum (Mill.; Italian arum) is a perennial herbaceous geophyte in the Araceae. *A. italicum* has a native range that includes much of Europe, portions of Russia, and northern Africa (Flora Europa 2019). In its native range *A. italicum* can be found in a range of soil conditions and often in areas of disturbance (AstraNatura 2019). This species has been introduced to the Netherlands (Flora Europa 2019), New Zealand (Howell 2008), Australia (Atlas of Living Australia 2019), and Argentina (WSNWCB 2014). In the United States the species is reported from Alabama, California, the District of Columbia, Illinois, Maryland, Missouri, New York, North Carolina, Ohio, Oregon, Tennessee, Virginia, Washington, and West Virginia (EDDMaps 2019; USDA NRCS 2019). It was first reported in central Virginia in 1986 (Virginia Botanical Associates 2019) but not confirmed in northern Virginia until 2009 (Steury 2010).

Arum italicum leaves emerge in the fall and are shed in the early summer. In one study, plants averaged 31.6-cm tall and produced 2–8 leaves per plant (Albre and Gibernau 2008). Inflorescences form in the spring and plants produce up to five inflorescences per year (Méndez and Obeso 1993) that mature over an average of 17.3 d (Albre and Gibernau 2008). Inflorescences are receptive to pollen for 2 d and fruits are produced 93.6 d after pollination (Albre and Gibernau 2008). Plants may flower one, two, or three times in a season. For an extensive description of inflorescence biology and the pollination process in *A. italicum* see Gibernau et al. (2004). Fruits ripen in mid-summer. Plants can spread by bird-dispersed fruits (Méndez and Obeso 1993) or tubers introduced into park land by humans discarding yard waste (pers. obs.). Thick anchoring roots emerge from a rhizomatous tuber at the beginning of the growing season (Boyce 1993, cited in WSNWCB 2014). During the growing season each tuber produces an average of 7.6 (Méndez 1999) and a maximum of 30 daughter tubers (Thompson 1976). Tubers begin to grow when leaves begin to emerge (Méndez and Obeso 1993). The new tubers absorb the old tubers throughout the growing period, so the old tubers are totally absorbed by the time the leaves are shed (Méndez and Obeso 1993). Tuber density can reach several thousand per square meter, all in the top 10–15 cm of soil (Thompson 1976).

Studies related to the impact of *A. italicum* are limited. However, because *A. italicum* leaf presence overlaps with native spring ephemerals (February–May) we assume there is competition for light, space, and nutrients. Spring ephemerals are sensitive to disturbance (McLachlan and Bazely 2001) and have been documented to be in decline in eastern forests (Brewer 1980; Taverna et al. 2005). Although no testing for allelopathy has been done in our target species, allelopathy has been documented for other species in the family (e.g., Bhadha et al. 2014).

Some prior treatment efforts have been reported. Gunning (1967) conducted trials with a wide range of herbicides (2,3,6-TBA; fenac, 2,2-DPA/fenoprop; 2,4-D; dichlobenil; diquat; eptam; fenuron; paraquat; PP 831; metam; dicamba; picloram) and rates. After one year, dicamba and picloram showed the best control but after a second year of treatment only picloram provided substantial control. Thompson

(1976) tested a wide range of chemicals (bromacil; picloram; karbutilate; 2,4-D; diquat; amitrole; and glyphosate) and rates. Glyphosate and asulam were judged to be the most effective in the initial trial so they were tested at multiple rates and as repeated treatments. The most effective treatment was glyphosate at 4.0 kg ha^{-1}. The initial treatment was in the spring and the repeated treatment was one year later (Thompson 1976). Weedbusters (2019) recommends digging any time of year and using a mixture of metsulfuron methyl and glyphosate with a penetrant and diluted in water in three different ways: cutting and painting the stumps (1 g L^{-1} metsulfuron methyl and 10% glyphosate), applying a high-concentration foliar application (1 g L^{-1} metsulfuron methyl and 15% glyphosate) or a low-concentration foliar application (0.3 g L^{-1} metsulfuron methyl and 1.5% glyphosate). The rates and relative success by treatment are not reported.

After many years of treatment without observing excellent control results, and because of the limited number of published studies testing *A. italicum* control methods, we wanted to determine which chemical methods were the most effective. The published studies suggested picloram, glyphosate, and metsulfuron methyl were the chemicals most likely to be successful. We did not test picloram because it is more persistent in the environment than glyphosate, metsulfuron methyl, or triclopyr (USFS 1999, 2000, 2003a, 2003b). We included triclopyr because it is effective on many broad-leaved species. Our tested concentrations of triclopyr and glyphosate herbicides were informed by treatments that have been effective on other glossy-leaved herbs in our experience.

METHODS

Whitehaven Park is a small (approximately 10 ha) park administered by the National Park Service as part of Rock Creek Park in northwest Washington DC. (38.918638, −77.078569). The park includes forest and open areas. The forest in the study area is a Mesic Mixed Hardwood Forest dominated by an overstory of *Liriodendron tulipifera*, an understory of *Lindera benzoin*, and *Hedera* sp. and *Toxicodendron radicans* on the forest floor. The edges of the forest are dominated by early successional species including *Acer negundo*, *Prunus serotina*, and *Robinia pseudoacacia*. The small forest is heavily used by human pedestrians, off-leash dogs, and white-tailed deer (*Odocoileus virginianus*).

On 13 January 2015 the largest population of *A. italicum* in the forested portion of Whitehaven Park was divided into four sections with the center point roughly in the middle of the highest-density portion of the population and the dividing lines pointing roughly north–south and east–west. Five 1 × 1-m plots were arbitrarily established in each section. Plot locations were selected to include high-density patches of *A. italicum.*

For three consecutive years, we treated plants in mid-March on days when the temperature was above 10 °C and there was no rain in the forecast. Mid-March was chosen to coincide with the time in the life cycle of *A. italicum* when the plants begin actively growing after winter. Four treatments, one to each section, were applied on 12 March 2015, 10 March 2016, and 22 March 2017: triclopyr + metsulfuron methyl (Tri-Met), triclopyr alone (Tri), glyphosate + metsulfuron methyl (Gly-Met), and a control (no application). The herbicide containing triclopyr was 1.5% Element 3A (44.5% trimethylamine salt of triclopyr; Dow AgroSciences), the herbicide containing metsulfuron methyl was 0.015 g L^{-1} Escort XP (60% metsulfuron methyl; Bayer), and the herbicide containing glyphosate was 2.5% Rodeo (53.8% isopropylamine salt of glyphosate; Dow AgroSciences). In addition to the herbicides, each chemical mix included 0.50% of the surfactant Phase (methylated esters of fatty acids; Loveland Products), 0.1% Spray Indicator XL (Helena Chemical), and 12 g L^{-1} ammonium sulfate; they were all diluted in water. Ammonium sulfate was used to increase herbicide uptake under low temperatures (J. Cardina, pers. comm.). Each mixture was prepared as follows: first, the tank was filled with 70% of the water needed and then the ammonium sulfate was added. After the crystals were fully dissolved the Escort XP (if applicable) was added and that was fully dissolved. Next the liquid herbicides were mixed in, then the marking dye, and lastly the surfactant. Once all ingredients were included and mixed, water was added to achieve the desired final volume and the mixture was agitated before application.

Herbicide was applied on a spray-to-wet basis (cover foliage but avoid dripping) and native vegetation was avoided. We calculated application rates for each treatment event and determined an average of 0.92 kg ai ha^{-1} for triclopyr, 1.80 kg ai ha^{-1} for glyphosate, and 1.3 g ai ha^{-1} for metsulfuron methyl.

We monitored plots every 6 wk in early 2015 until plants senesced. Starting in the fall of 2015 we monitored plots monthly as long as leaves were present. The final monitoring event took place on 2 April 2018. At each monitoring event we collected percent cover estimates for the target species and established guilds (*A. italicum*, nonnative forbs, native forbs, nonnative graminoids, native graminoids, native woodies, nonnative woodies, bare ground, and dead vegetation). Plants above 2-m tall were not monitored.

Data Analysis

The goal of the data analysis was to determine if any of the herbicide treatments reduced *A. italicum* cover compared to the control treatment. One prior study, Gunning (1967), found that an immediate reduction in *A. italicum* may not lead to long-term control. Therefore, we needed to separate short-term and long-term effects in our analysis. We defined the short-term effects as changes to *A. italicum* cover in the "Spring" period (April to July) after the March herbicide treatments. Long-term effects were defined as the changes to *A. italicum* cover in the "Fall" period, from September, when leave emerge, until March, just prior to herbicide treatment. If the Spring period consistently has lower cover than controls, while the Fall period does not, this would indicate a short-term effect, with no lasting control.

We analyzed data in a Bayesian framework as a one-inflated generalized mixed beta regression.

The maximum *A. italicum* cover within each quadrant for each season in each year was used as the response variable. Each season was analyzed separately. Within each season, maximum *A. italicum* cover was modeled using *Year*Treatment* as the fixed effects and *Plot ID* as a random effect. "Year" ranged from 1 to 4, indicating each year of the study. A third analysis was performed on the pre-treatment data to establish the baseline conditions. This analysis was identical to the other two, but without year as a predictor.

Analysis was performed using the zoib function from the zoib package version 1.5.1 (Liu and Kong 2018) and rjags 4-6 package (Plummer 2018) for R 3.5.1 (R Core Team 2018). The analysis was run with three Markov chains, 250,000 iterations including a 20,000 iteration burn-in period, thinning set to 10, and the scale.unif parameter set to 2. Initial analysis indicated that treatment had no measurable impact on the shape parameter or the probability of a quadrant having 100% cover, so these were modeled as intercepts only. As 100% cover only occurred in the Fall, this term was only in the Fall model. All other settings were left as the defaults. Convergence of each analysis was verified by checking that the potential scale reduction factor (Gelman and Rubin 1992) of each parameter was less than 1.05. Gelman plots were examined to make sure that estimates of the scale reduction factor had stabilized. Chain lengths were chosen to ensure that all parameters had an effective sample size >10,000.

We analyzed the data to answer two questions: (1) did the percent cover of *A. italicum* for a given year and season differ from that of the control, and (2) did any treatment in either season show a trend over time. For the baseline analysis, a significant difference between the treatment and the control was indicated when the 95% highest probability density interval (HPDI) of a coefficient did not overlap zero. To look at the effects of treatment across years and seasons, the corresponding model (Spring or Fall) was used to calculate the HPDIs of predicted *A. italicum* cover of each treatment. If the HPDI of *treatment cover − control cover* did not overlap zero for a given season and year, then the treatment was significantly different from the control.

Trends over time for the control were assessed by determining if the HPDI of the *Yea*r coefficient of the Spring and Fall models overlaps zero. Trends in the treatments were determined by comparing the HPDIs of the coefficients of the *Year*Treatment* interactions to zero. Coefficients significantly lower than zero indicated that *A. italicum* cover was decreasing over time at a rate that differed from the control.

RESULTS AND DISCUSSION

Prior to herbicide application, all treatment plots except Tri had similar *A. italicum* cover (95% HPDIs overlap zero; Table 1). There was significantly more *A. italicum* cover in the pre-treatment Tri quadrants (48% cover vs. 69% cover; Figure 1A).

In the Spring analysis (Table 1), the control showed a slight but significant decline over time. Interactions between year and treatment indicated that Tri did not significantly differ from the control. Tri+Met and Gly+Met treatments had HPDIs for the *Year*Treatment* interaction that were entirely below zero, indicating that these treatments declined significantly faster than the controls. There was no significant difference in the interactions for these two treatments. Percent *A. italicum* cover did not significantly differ between treatments in year 1 (Table 2), and there was no difference between the control and Tri in any year (Figure 1B). The Tri+Met and Gly+Met treatments were never significantly different from each other, but had significantly lower *A. italicum* cover than the control in years 2–4 (Table 2).

Broadly speaking, the Fall analysis (Table 1) showed the same patterns as the Spring analysis. Neither the control nor the Tri treatment showed significant changes in *A. italicum* cover over time. HPDIs reveal sig-

Table 1. Model output of baseline, Spring, and Fall analysis. SD = standard deviation, 95% HPDI = 95% highest probability density interval. The first four rows are intercepts for each treatment and the second four rows are the slopes for each treatment. P1 is the probability of a plot having 100% cover, shape is the shape parameter of the beta distribution, and sigma is the variance of the random effects.

	Baseline analysis			Spring analysis			Fall analysis		
Variable	Mean	SD	95% HPDI	Mean	SD	95% HPDI	Mean	SD	95% HPDI
Control	−0.08	0.31	−0.70 to 0.54	1.67	0.45	0.78 to 2.56	1.09	0.48	0.15 to 2.03
Tri	0.92	0.46	0.003 to 1.83	0.60	0.65	−0.66 to 1.89	0.78	0.68	−0.54 to 2.14
Tri+Met	−0.03	0.45	−0.93 to 0.84	−0.33	0.62	−1.54 to 0.90	−0.75	0.71	−2.17 to 0.62
Gly+Met	0.21	0.45	−0.68 to 1.08	0.50	0.63	−0.73 to 1.75	0.04	0.68	−1.29 to 1.39
Year				−0.27	0.1	−0.47 to −0.07	−0.003	0.15	−0.30 to 0.28
Year * Tri				−0.22	0.15	−0.52 to 0.07	−0.61	0.21	−1.02 to −0.20
Year * Tri+Met				−0.67	0.15	−0.98 to −0.37	−1.23	0.28	−1.79 to −0.70
Year * Gly+Met				−0.79	0.15	−1.09 to −0.49	−1.24	0.24	−1.72 to −0.77
P1				−4.93	1.28	−7.54 to −2.81			
Shape	2.05	0.32	1.41 to 2.68	3.06	0.19	2.70 to 3.43	3.14	0.23	2.69 to 3.60
Sigma				0.57	0.27	0.18 to 1.10	0.62	0.31	0.18 to 1.22

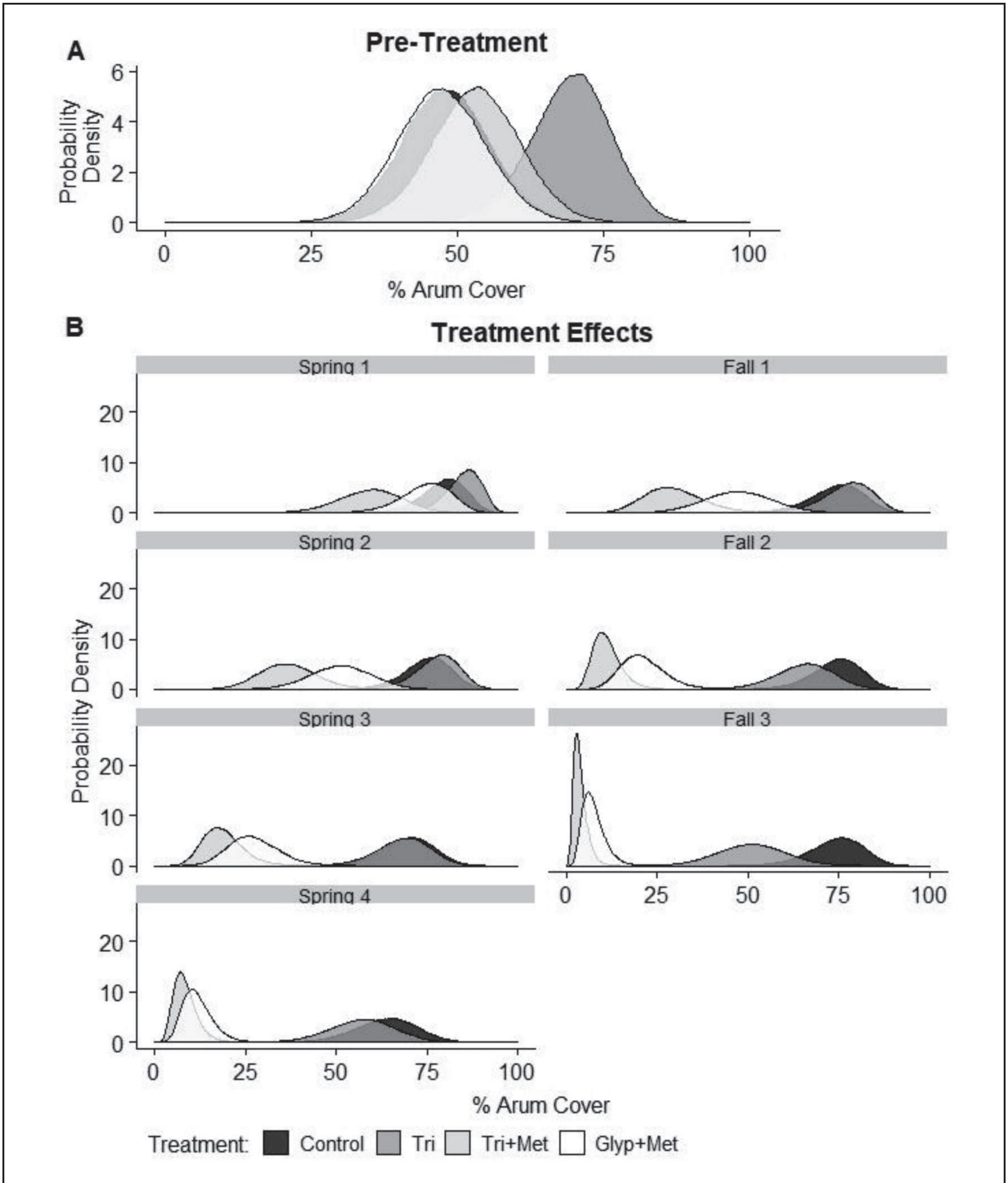

Figure 1. Maximum percent cover of *Arum* by year, season and treatment. (A) Baseline cover prior to any treatment. (B) Post-treatment cover.

Table 2. Modeled Spring and Fall maximum % *Arum* cover by treatment and year. Control, Tri, Tri+Met, and Gly+Met columns contain the 95% Highest Probability Density Intervals (HPDIs) for that treatment. Final three columns are the HPDIs for the difference between the control and herbicide treatments. An interval whose HPDI does not include zero is significantly different from the control.

	Control	Tri	Tri+Met	Gly+Met	Tri - Control	TriMet - Control	Gly+Met - Control
Spring 1	0.67 to 0.91	0.74 to 0.94	0.42 to 0.77	0.60 to 0.88	−0.11 to 0.22	−0.41 to 0.02	−0.24 to 0.14
Spring 2	0.61 to 0.87	0.65 to 0.89	0.21 to 0.53	0.34 to 0.68	−0.15 to 0.21	−0.59 to −0.18	−0.45 to −0.02
Spring 3	0.55 to 0.83	0.53 to 0.82	0.09 to 0.30	0.14 to 0.42	−0.22 to 0.20	−0.69 to −0.32	−0.62 to −0.22
Spring 4	0.47 to 0.80	0.39 to 0.74	0.03 to 0.15	0.05 to 0.20	−0.31 to 0.18	−0.72 to −0.36	−0.70 to −0.33
Fall 1	0.59 to 0.88	0.63 to 0.90	0.15 to 0.46	0.29 to 0.66	−0.17 to 0.25	−0.66 to −0.22	−0.51 to −0.03
Fall 2	0.60 to 0.87	0.49 to 0.81	0.04 to 0.19	0.10 to 0.34	−0.30 to 0.13	−0.79 to −0.47	−0.71 to −0.34
Fall 3	0.59 to 0.88	0.32 to 0.69	0.01 to 0.07	0.02 to 0.14	−0.47 to 0.01	−0.85 to −0.55	−0.82 to −0.50

nificant negative trends in *A. italicum* cover for the Tri+Met and Gly+Met treatments. As was seen in the Spring analysis, these trends were not significantly different from one another. The control and the Tri treatments did not have significantly different *A. italicum* cover at any time (Figure 1B, Table 2). Both Tri+Met and Gly+Met had significantly less *A. italicum* cover in all years. There were no significant differences in *A. italicum* cover between Tri+Met and Gly+Met in any year.

The remaining plant guilds (nonnative forbs, native forbs, nonnative graminoids, native graminoids, nonnative woodies, native woodies) showed no consistent response to treatment (not shown). Prior to treatment there was almost no native vegetation present, and the only significant nonnative vegetation consisted of woody plants. The 3-y duration of this study was insufficient to allow for native species to recolonize, and a full recovery may depend on further management actions, such as plantings. However, control of arum is a necessary precursor to further restoration activities. It is likely that nonnative woody vegetation does not compete with arum and thus was not impacted by the treatments.

Our application rates of glyphosate were much lower (1.8 kg ai ha^{-1} versus 4.0 kg ai ha^{-1}) than Thompson (1976) and our metsulfuron methyl concentrations (0.015 g L^{-1}) were much lower than Weedbusters (2019; 0.3–1.0 g L^{-1}) and required more treatments to achieve control.

Our study results suggest that successful chemical control of *A. italicum* can be achieved with metsulfuron methyl. However, the most successful tested methods failed to provide 100% control over 4 y. Variations in herbicide rates and the timing of application are likely needed to identify superior techniques. In addition, additional adjuvants may be identified that assist in the efficacy of the herbicides.

After seeing promising results for treatments that included metsulfuron methyl we began increasing the concentration of metsulfuron methyl for treatments in other areas and our anecdotal results suggest that success has improved.

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During this study Mark Frey managed the National Park Service's National Capital Region Exotic Plant Management Team. The team works in national parks across five states to map, prioritize, and control invasive plants. Before joining the National Park Service, he managed the habitat restoration program for the Presidio Trust.

John Paul Schmit is the Quantitative Ecologist for the National Capital Region Network Inventory and Monitoring Program. The program monitors a variety of ecological indicators such as water quality, forest composition, invasive plants, and bird populations in 11 parks near Washington DC. Prior to joining the National Park Service his research focused on fungal competition and biodiversity.

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