

Assessing management treatments for controlling invasive Italian arum (*Arum italicum*): 2025 final report



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Report for Jim and Birte Falconer

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Institute for Applied Ecology



PREFACE

IAE is a non-profit organization whose mission is the conservation of native ecosystems through restoration, research, and education. IAE provides services to public and private agencies and individuals through development and communication of information on ecosystems, species, and effective management strategies. Restoration of habitats, with a concentration on rare and invasive species, is a primary focus. IAE conducts its work through partnerships with a diverse group of agencies, organizations, and the private sector. IAE aims to link its community with native habitats through education and outreach.



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Assessing management treatments for controlling invasive Italian arum (*Arum italicum*): 2025 final report

EXECUTIVE SUMMARY

Italian arum (*Arum italicum*) is a noxious invasive species in the Pacific Northwest, posing a growing threat to both natural and restored habitats. From 2022 to 2025, the Institute for Applied Ecology (IAE) conducted a multi-year study in partnership with the Seattle Foundation and Jim and Birte Falconer to evaluate several management strategies for controlling this species across a range of habitat types. Five treatments—manual excavation, three herbicide combinations (glyphosate, imazapyr, and glyphosate + imazapyr), and mow and tarp (occultation)—were tested at three sites in Oregon and Washington. Results show that while all treatments provided some level of control, their effectiveness varied by site, treatment type, and environmental conditions, underscoring the need for site-specific, integrated management approaches. Key conclusions are:

- No single treatment provided complete control of Italian arum across all habitats.
- Occultation(mow and tarp) was the most effective treatment, achieving substantial above- and below-ground suppression, particularly in open, sunny locations.
- Herbicide treatments, especially those containing imazapyr, reduced Italian arum but also caused substantial non-target plant mortality, creating near “chemical fallow” conditions.
- Manual excavation required substantial labor (2–6 person-hours per m²) and resulted in limited control, as tubers often persisted below-ground.
- Site conditions strongly influenced outcomes—Fisherman Bay Spit Preserve (open prairie) showed the greatest response to treatments, while Salem Audubon Reserve (shaded oak woodland) was least responsive.
- Residual mother tubers persisted (at varying abundance) following each treatment, allowing for recolonization and highlighting the species’ strong regenerative capacity.
- Long-term success depends on repeated monitoring and adaptive management, with at least three years of follow-up recommended.
- Following treatments, seeding of native plants is necessary to stabilize soil and prevent reinvasion by Italian arum or other undesirable species.

Italian arum is a resilient and persistent invader capable of surviving diverse management pressures. Nonetheless, meaningful reductions in plant and tuber density are achievable through sustained effort, particularly when treatments are combined and applied over multiple years. Mow and tarp (occultation) offers the most promise as a low-cost, non-chemical option, while integrated strategies tailored to habitat type will likely yield the best long-term control. Continued research and monitoring will be essential to refine these approaches and support land managers in protecting Pacific Northwest ecosystems from this tenacious species.

1. INTRODUCTION

Italian arum (*Arum italicum*) is native to Asia, Europe, and Northern Africa, has established in North America, and has naturalized in Washington, Oregon, California, Missouri, Illinois, and North Carolina (WSNWCB 2014). It occurs in western Washington and throughout the Willamette Valley in Oregon, extending as far south as Douglas County.

Italian arum is a perennial herb in the Arum (Araceae) family and occurs in partial to full shade. It prefers moist, humus soil, but can grow in nearly any soil and is drought-resistant once established (WSNWCB, n.d.). The vegetative form is characterized by distinct sagittate leaves, a deep green color with prominent pale white venation, and a glossy texture (Figure 1). Younger leaves appear more oval shaped than mature sagittate leaves and lack white venation. A distinguishable feature of the Araceae family is the flowers, which consist of a spadix and spathe that are generally white to pale yellow in color. Flowers emerge and bloom in late April to June and have an unpleasant odor.

The roots are white and grow from horizontal-rhizomatous tubers up to 3 inches long and 1 inch thick (Mallon 2016). Adventitious buds will form along these tubers throughout the growing season, creating daughter tubers. The daughter tubers will then break off and can start producing plants within the first year. After a second growing season these plants can then start producing daughter tubers of their own (Boyce 1993). Additionally, Italian arum is also distributed by mammal activity such as birds consuming and digesting the seeds (WSNWCB 2014). The fruits of Italian arum are orange-red berries that form in tight, oblong clusters (Figure 1). All parts of the plant may cause skin irritation and eating the plant may result in serious illness requiring medical attention, these qualities also result in few natural predators. All these qualities make Italian arum able to spread rapidly and effectively.

Due to its difficulty to control, rapid spread, and tendency to outcompete native plants Italian arum is classified as a Class C Noxious Weed in Washington state and is present on the Early Detection and Rapid Response (EDRR) list of invasive plants by the city of Portland.

Control efforts have included both mechanical and chemical treatments. Mechanical treatments include mowing and covering top-killed plants with black tarp, as well as manually excavating the plants from the soil (including the above-ground shoot and the below-ground tubers). Chemical treatments utilized by other land managers have included applying various herbicides (Glyphosate, Imazapyr, Triclopyr and others). Currently no effective biological controls are known (WSNWCB 2014).



Figure 1. Italian arum fruiting structures and leaves. (Photo on left from USDA Plants Database.)

1.1 Project overview

In response to ongoing challenges with Italian arum control—and with support from Jim and Birte Falconer—the Institute for Applied Ecology (IAE) initiated a four-year experimental study (2022–2025) to evaluate multiple management treatments for Italian arum control. This study employs a Before-After-Control-Impact (BACI) design to assess the efficacy of five treatment methods:

1. Manual excavation (dig)
2. Glyphosate-only herbicide application
3. Imazapyr-only herbicide application
4. Combined Glyphosate + Imazapyr herbicide application
5. Mow and tarp (solarization)

Each treatment was compared to a no-treatment control to evaluate both above- and below-ground responses.

2. GOALS AND OBJECTIVES

This project is novel in being a long-term, replicated experiment that evaluates whole-plant responses to different management practices. The knowledge gained from this study will inform future management decisions for Italian arum in the Pacific Northwest.

The specific objectives of this study are to:

1. Identify the most promising methods for controlling Italian arum.
2. Quantify Italian arum response above- and below-ground three years following initial treatment.
3. Assess the logistical feasibility, cost, and limitations associated with each management treatment.



Figure 2. IAE Interns Cierra Dawson and Brooke Morrow dig up Italian arum at Washougal Oaks April 2022.

3. METHODS

3.1 Site descriptions

The following sites were monitored from late April to early May, with treatments within two weeks following the monitoring effort (Appendix B).

3.1.1 Fisherman Bay Spit Preserve

The Fisherman Bay Spit Preserve on Lopez Island, Washington is managed by the San Juan County Conservation Land Bank. This site is easily accessible to the public with walking trails around the preserve. Unlike the following two sites, the area that is occupied with Italian arum is an open coastal prairie that is largely dominated by introduced perennial graminoids (Appendix A, Figure 3.).

3.1.2 Salem Audubon Nature Reserve

The Salem Audubon Preserve is managed by the Salem Audubon Society. This 7-acre wooded hillside in West Salem is easily accessible to the public and includes walking trails. The portion of the site with high density of Italian arum has an Oregon white oak (*Quercus garryana*) overstory that provides partial shade (Appendix A, Figure 3.).

3.1.3 Washougal Oaks

The Washougal Oaks is managed by the Washington Department of Natural Resources, has limited access, and is located just north the Oregon-Washington state line and east of Washougal, Washington. The area occupied with Italian arum is within a partially shaded Oregon white oak overstory, has a highly diverse understory, and follows a drainage (Appendix A, Figure 3.).

3.2 Treatments

Treatments were selected after an extensive literature review, followed by a stakeholder meeting where input was solicited by land managers and weed control professionals from across the Pacific Northwest. Glyphosate and Imazapyr were selected in part based on previous work by Tim Miller (WSU Extension - retired, unpublished data) who tested 12 herbicides in a laboratory setting and found that six months post treatment, these two chemicals were among the most effective, eliminating more than 90% of above-ground biomass. Non-chemical methods were also selected (mowing and tarping, manual excavation) to provide options for land managers with herbicide restrictions.



Figure 3. Location of the three study sites in Oregon and Washington.

The following five treatments were conducted at the study sites between late April to early May 2022: 1) manual excavation (dig), 2) Glyphosate-only herbicide application, 3) Imazapyr-only herbicide application, 4) a combination of Glyphosate and Imazapyr herbicide applications, and 5) mow and tarp (solarization) (Appendix B). Person-hours were recorded for each treatment to quantify the amount of effort put toward each treatment.

3.2.1 Manual excavation (Dig)

Manual excavation, digging, is the hand-removal of Italian arum by digging out all tubers and daughter tubers from the ground using hand shovels (Figure 2, Figure 4). All excavated tubers were placed in a sealed bag and removed from the site, along with stems and berries to limit seed dispersal. Care was taken to not transfer soil with Italian arum as this may contribute to the spread of this introduced species. Manual excavation occurred annually from 2022-2024.



Figure 4. Italian arum tubers pre (left) and post (right) excavation. Note that the tubers can be red or white.

3.2.2 Mow and tarp

The Italian arum and surrounding vegetation were mowed with a hand mower to a height of <3". After mowing, the area was covered with shade cloth and ground staples were used to keep the cloth in place (Figure 5). Mowing occurred once during the experiment, and the tarp has since remained in place except during monitoring. During monitoring efforts, the integrity of the tarp was assessed and modified. The tarp was removed in October 2024, and the above-ground effects were monitored.



Figure 5. IAE staff member Denise Giles mowing (left) and the tarp application (right) for the Mow and Tarp treatment at Fisherman Bay Spit Preserve

3.2.3 Herbicide application

All three herbicide treatments were applied at 'spot-spray' rates; Glyphosate (Rodeo) was sprayed at a rate of 1.5% or (2 oz/gallon, 1.8gallons/acre), and Imazapyr (Alligare Imazapyr 4 SL) was applied at a rate of 0.2% (0.3oz/gallon, 0.5 gallons/acre). In all applications, an adjuvant (Li-700) was used to

help the herbicide stick to the leaves and penetrate the waxy cuticle. Herbicide treatments were applied annually from 2022 – 2024 following monitoring by IAE staff or land managers.

3.3 Above-ground plot set-up and monitoring

In 2022, IAE staff established 3 experimental blocks across three sites, 1) Salem Audubon Preserve, Oregon, 2) Washougal Oaks, Washington, and 3) Fisherman Bay Spit Preserve, Washington. One 6m x 4m experimental block was established at each site and divided into six 2m x 2m treatment plots. The corners of the experimental block were marked with concrete markers. Each treatment plot within the experimental block was randomly assigned one of the five treatments, with the remaining treatment plot assigned as the control (no treatment) (Figure 6, Appendix A).



Figure 6. Plot set-up at Washougal Oaks (left). The central 1m² of each 2m x 2m treatment plot was monitored (right, Fisherman Bay Spit Preserve).

A 1m² area was monitored in the center of each treatment plot prior to the treatment, to avoid any edge effects of the neighboring treatments. The number of Italian arum was counted in the 1m² monitoring plot and binned into one of 7 different size classes (1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 5-10 cm, and 10+ cm). Plants were assigned to a size class based on the widest part of the plant's leaf (Figure 7).

In 2022 pre-treatment data were collected as a baseline. Data was collected in 2023 and 2024 prior to the annual treatments. Final post-treatment monitoring was conducted in the spring of 2025.



Figure 7. Mature (left) and young (right) Italian arum leaves. White dashed line indicates where leaves were measured.

3.4 Below-ground biomass sampling

In the center of the above-ground sampling plots an approximately 0.0625 cubic meter area (50cm x 50cm x 25cm) was sampled. This involved digging a hole and collecting all the below-ground material (soil, corms, roots, rocks, etc.). This material was then sifted through a 1/4 inch mesh screen to collect the corms. To account for normal hole inconsistencies, the final hole was measured on all 12 sides and later averaged to determine the cubic area sampled for each sample. Additionally, the percentage rock content, soil structure, and soil texture were captured for each sample.

The extracted corms were counted and categorized by type (mother vs. daughter) and binned into size classes.

Mother corms were defined as those with visible daughter tuber scars; these corms tended to be larger and more elongated. Daughter corms showed no evidence of tuber scars and were generally smaller and more spherical.



Figure 8. (from left to right) Below-ground biomass sampling hole at Fisherman Bay Spit Preserve. IAE Staff sieving biomass at Fisherman Bay Spit Preserve. Mother corms collected at Salem Audubon Reserve.

3.5 Data analysis

Data were entered and checked using Microsoft Excel. Plotting and analyses were conducted with R Studio (Microsoft Corporation 2018, RStudio Team 2020). We assessed the strength of treatment effects with visual plots and tables. We were unable to test for statistical significance (e.g., via ANOVA or linear regression) because of low sample size ($n=3$ per treatment). To assess above- and below-ground treatment effects, we used the natural log of the response ratio (LRR). When visually assessing treatment effects, LRR is a useful metric, and more appropriate than using the simple response ratio, because deviation in the numerator affects LRR the same as deviation in the denominator (Hedges et al. 1999). $LRR = 0$ indicates no treatment response. A negative LRR value indicates that the treatment successfully reduced Italian arum.

For above-ground treatment effects, $LRR = \ln \left(\frac{\text{post-treatment 2025 count of arum plants}}{\text{pre-treatment 2022 count of arum plants}} \right)$

For below-ground treatment effects, we do not have pre-treatment data – collecting this data (i.e., digging a large hole) would have disrupted all the plots. In this case,

$$LRR = \ln \left(\frac{\text{post-treatment 2025 count of tubers}}{\text{2025 count of tubers in the control plot}} \right)$$

To assess change over time, we plot the number of individual plants by site, year, and treatment. The full raw dataset is included in Appendix C.

4. RESULTS

4.1 Treatment effect: above-ground vegetation

Three years post-treatment plant count responses varied by site and treatment (Figure 9). Overall, most treatments resulted in a decline in plant counts relative to the control, indicated by negative LRR.

The magnitude of treatment effects differed among sites, with Fisherman Bay Spit Preserve showing the strongest declines across all treatments. At this site, treatments involving herbicide applications (Glyphosate, Glyphosate + Imazapyr, and Imazapyr) and the mow + tarp treatment reduced plant counts by 89% or more.

Washougal Oaks exhibited more moderate responses, with treatments reducing plant counts by 12 to 65%. Only the control plots-maintained plant counts near baseline levels. In contrast, Salem Audubon Nature Reserve generally showed neutral to slightly positive effects for several treatments, including Glyphosate + Imazapyr, Imazapyr, and mow + tarp, indicating little to no reduction in plant counts under those management approaches (Figure 9, Table 1).

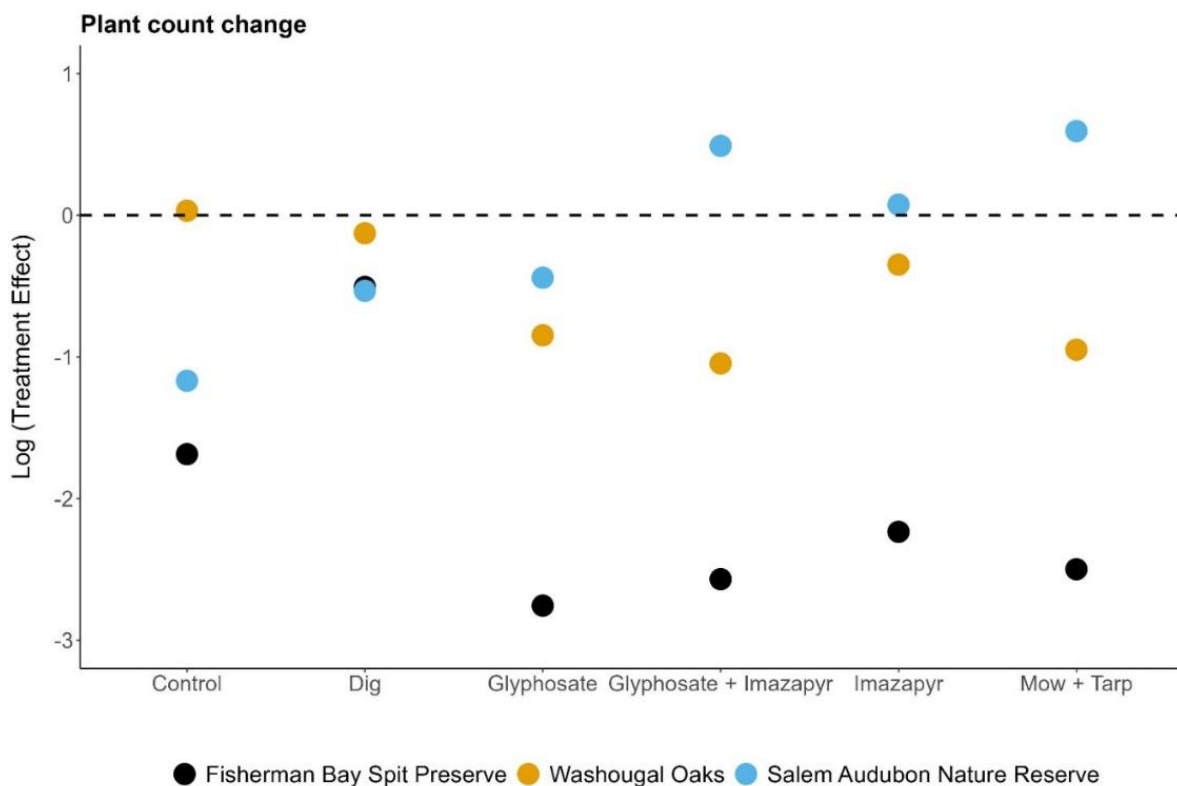


Figure 9. The log proportional change in plant count (treatment effectiveness) of five Italian arum treatments and the control across three sites three years following initial treatment. Points above the dashed line indicates that there was an increase in Italian arum cover. Points below the dashed line indicates that there was a decrease in Italian arum count.

All three sites exhibited varying degrees of treatment effect over the three years of the experiment. Mow + tarp was the only treatment that does not have consecutive data points since the tarp remained in place for the duration of the experiment.

Results for Fisherman Bay Spit Preserve show how consistent treatments (except Imazapyr) led to a decline in Italian arum. Washougal Oaks show similar results for the Glyphosate, and Glyphosate + Imazapyr treatments. Salem Audubon Nature Reserve was the only site that had an increase in treatment effect over time (Figure 10).

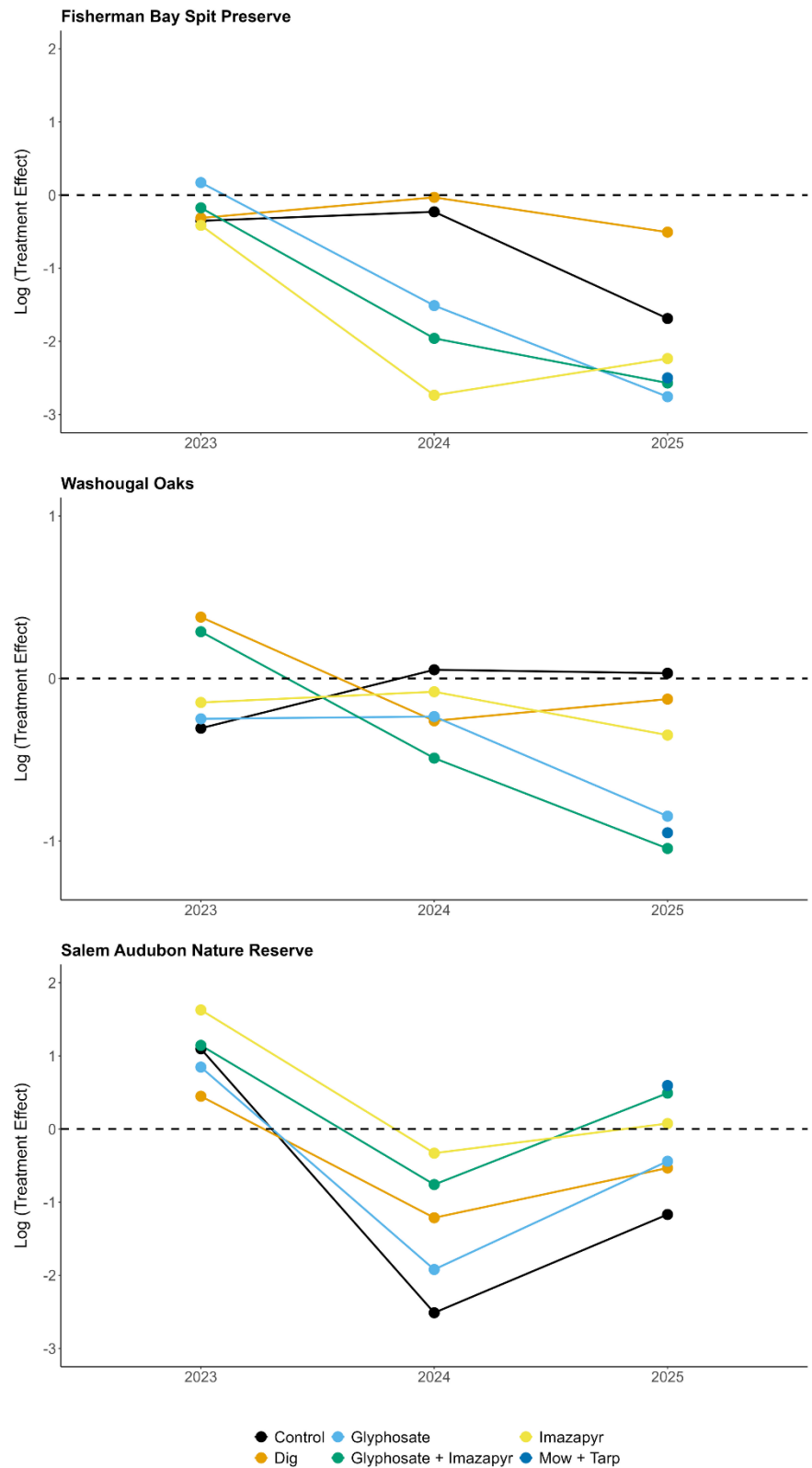


Figure 10. The log proportional change in plant count (treatment effectiveness) of five Italian arum treatments and the control across three sites and over three years

4.2 Treatment effect: *below-ground vegetation*

Changes in tuber density followed patterns similar to those observed for plant counts, with most treatments resulting in reductions that vary by site (Figure 11).

Across sites, Fisherman Bay Spit Preserve exhibited the largest declines in tuber density, particularly under the Mow + Tarp treatment (a 96% reduction in plant tubers!). Washougal Oaks treatment effects were more variable but generally moderate, with the strongest reduction occurred under the Mow + Tarp treatment, while herbicides and dig showed little to no decline. Salem Audubon Nature Reserve showed similar responses seen at Fisherman Bay Spit Preserve, except for Mow + Tarp where there was a negligible decline (Figure 11, Table 1).

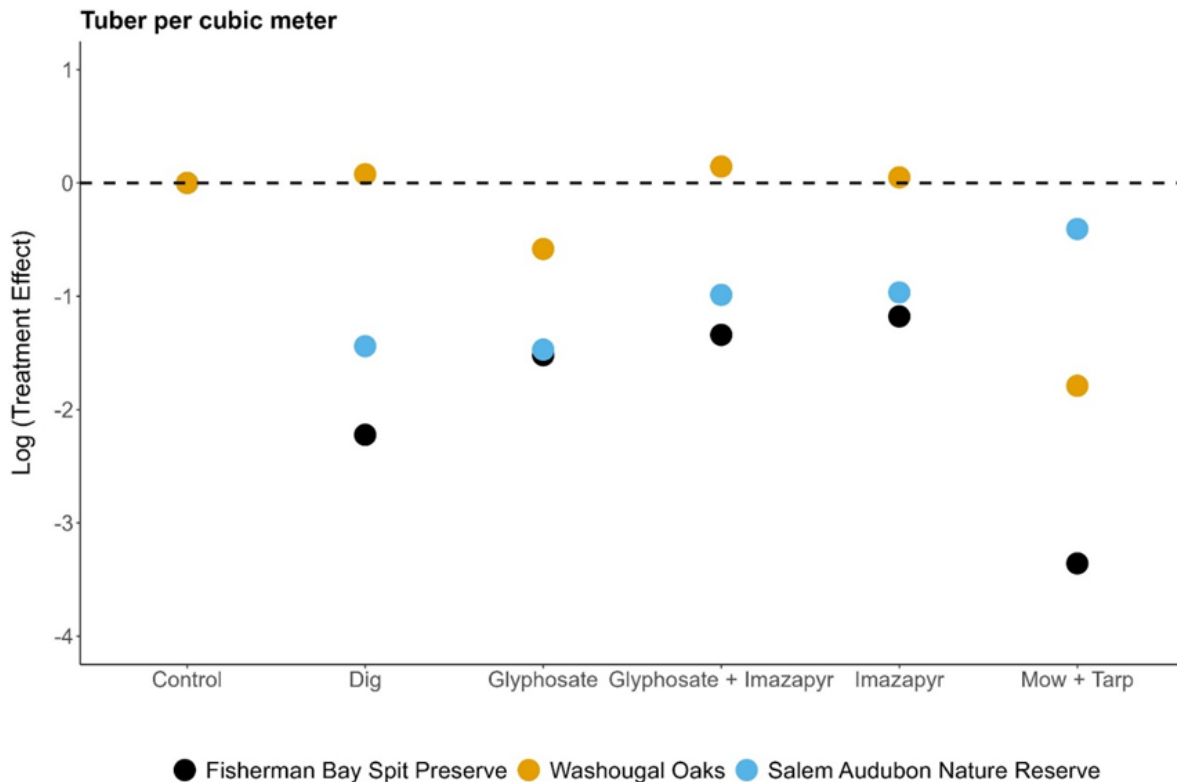


Figure 11. The log proportional change in tuber count per meter square (treatment effectiveness) of five Italian arum treatments and the control across 3 sites two years post-treatment. Points above the dashed line indicates that there was an increase in Italian arum cover. Points below the dashed line indicates that there was a decrease in Italian arum tubers. LRR = 0 for the non-treated control plot at each site.

The below-ground structures (mother and daughter tubers) varied substantially among sites. At Fisherman Bay Spit Preserve, total tuber densities were highest in the control plots, exceeding 200 tubers per cubic meter. The majority of tubers were daughter tubers, indicating active clonal reproduction under untreated conditions. All treatments resulted in sharp declines in tuber abundance, with Mow + Tarp and Dig producing the most substantial reductions. Herbicide treatments (Glyphosate, Glyphosate + Imazapyr, and Imazapyr) also suppressed both mother and daughter tuber densities relative to the control, though reductions were somewhat less (Figure 12).

At Washougal Oaks, total tuber counts were considerably lower than at Fisherman Bay Spit Preserve, with fewer than 25 tubers per cubic meter in all treatments. Differences among treatments were modest, though Glyphosate and Mow + Tarp treatments produced slightly lower tuber densities than the control. The proportion of daughter to mother tubers remained relatively consistent across most treatments, suggesting limited new tuber production regardless of management type. Mow + Tarp had no mother tubers present in the treatment area (Figure 12).

At Salem Audubon Nature Reserve, control plots supported the highest tuber densities (around 65 per cubic meter), driven primarily by daughter tubers. All treatment types reduced total tuber abundance relative to the control, with Dig and Glyphosate showing the greatest reductions. However, the Mow + Tarp treatment resulted in a rebound in daughter tuber density, suggesting possible tuber survival or regrowth under tarped conditions (Figure 12).

Overall, control plots consistently contained the highest tuber densities across sites, while all management treatments reduced both mother and daughter tuber abundance to varying degrees. The strongest suppression occurred at Fisherman Bay Spit Preserve, where total tuber densities declined by more than 90% under all active treatments.

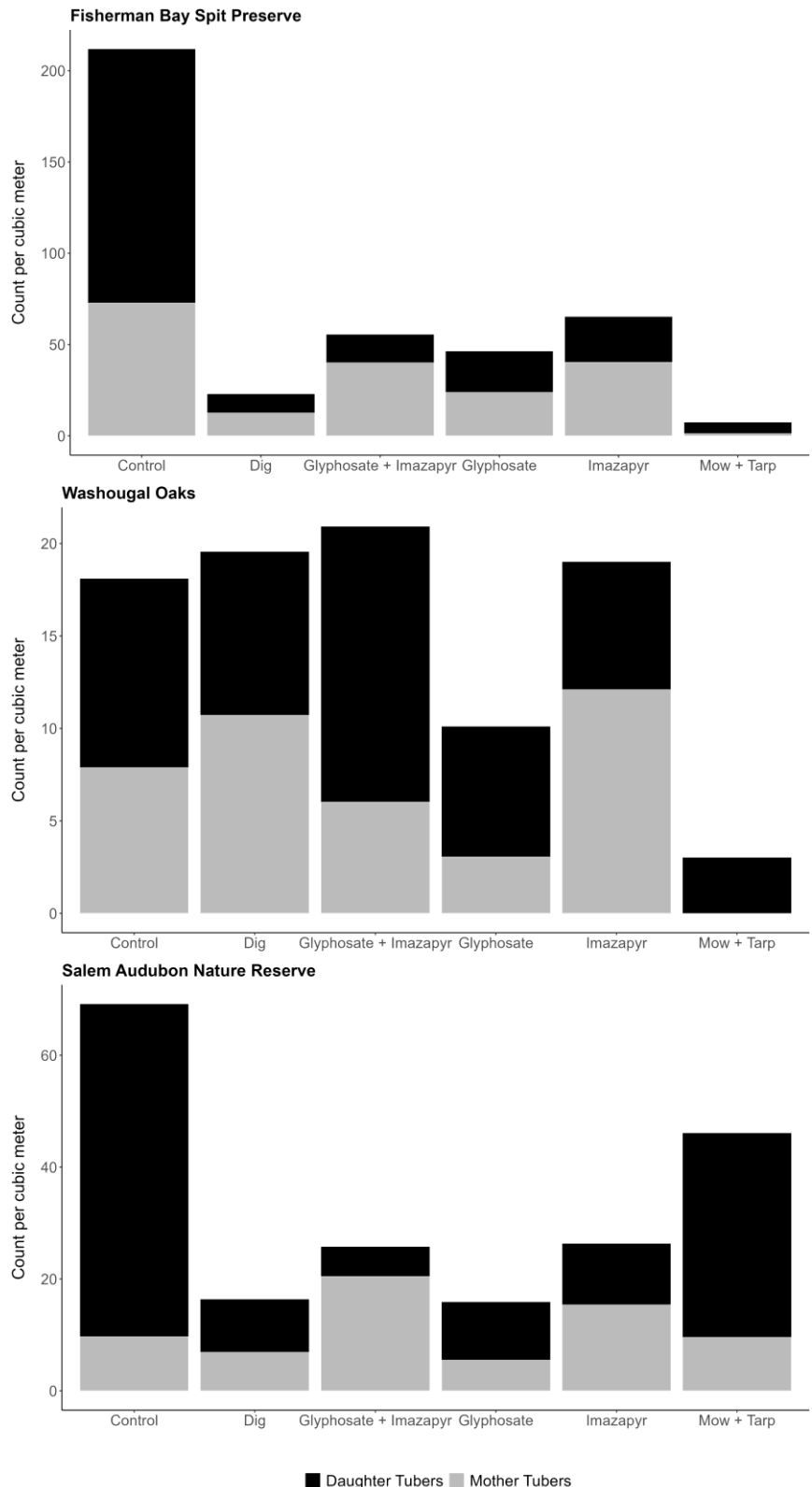


Figure 12. Count of daughter and mother tubers per cubic meter for five treatments and a control across three sites.

Table 1. Italian arum treatment count data and treatment effect data for above (plant) and below (tuber) ground vegetation. Cells highlighted represent a negative percent change relative to the control.

Site	Treatment	Above-ground Vegetation				Below-ground Vegetation				
		Plant Count (2022)	Plant Count (2025)	Percent Change	Plant Count Tx Effect ^a	Daughter Tuber Count	Mother Tuber Count	Total Tuber Count	Percent Change	Tuber Count Tx Effect ^b
Fisherman Bay Spit Preserve	Control	1961	363	-81%	-1.69	747	392	1139	0%	0.00
	Dig	559	337	-40%	-0.51	48	60	108	-91%	-2.22
	Glyphosate	1322	84	-94%	-2.76	70	186	256	-78%	-1.52
	Glyphosate + Imazapyr	2219	170	-92%	-2.57	119	128	247	-78%	-1.34
	Imazapyr	1327	142	-89%	-2.23	130	212	342	-70%	-1.18
	Mow + Tarp	791	65	-92%	-2.50	34	8	42	-96%	-3.36
Salem Nature Reserve	Control	148	46	-69%	-1.17	329	54	383	0%	0.00
	Dig	138	81	-41%	-0.53	50	377	87	-77%	-1.44
	Glyphosate	157	101	-36%	-0.44	26	102	128	-67%	-1.47
	Glyphosate + Imazapyr	109	178	63%	0.49	52	28	80	-79%	-0.99
	Imazapyr	64	69	8%	0.08	52	74	126	-67%	-0.97
	Mow + Tarp	176	319	81%	0.59	197	52	249	-35%	-0.41
Washougal Oaks	Control	91	94	3%	0.03	49	38	87	0%	0.00
	Dig	109	96	-12%	-0.13	51	62	113	30%	0.08
	Glyphosate	91	39	-57%	-0.85	74	30	104	20%	-0.58
	Glyphosate + Imazapyr	111	39	-65%	-1.05	39	17	56	-36%	0.15
	Imazapyr	51	36	-29%	-0.35	33	58	91	5%	0.05
	Mow + Tarp	62	24	-61%	-0.95	13	0	15	-83%	-1.79

^a Plant Count Treatment (Tx) Effect = $\ln(\text{Post-treatment}/\text{Pre-treatment})$

^b Tuber Count Treatment (Tx) Effect = $\ln(\text{Treatment Count}/\text{Control Count})$

5. DISCUSSION

This experiment provides one of the first replicated, multi-site evaluations of management strategies for controlling Italian arum (*Arum italicum*) in the Pacific Northwest. Across three distinct sites throughout the Pacific Northwest, we found that all active treatments reduced Italian arum abundance to varying degrees, but that treatment efficacy was strongly site-dependent. Among treatments, Mow + Tarp and herbicide applications generally achieved the greatest reductions in both above- and below-ground biomass. The following sections provide a more detailed discussion of each treatment and our recommendations from this experiment.

5.1 Manual excavation (dig)

Manual excavation requires substantial time and labor, taking between 2 to 6 person-hours to remove a 1 m² area of Italian arum and excavating up to 12 inches deep to effectively remove tubers. Given this investment, high treatment efficacy would be necessary to justify manual excavation as a viable control method. However, results showed minimal control of both above- and below-ground vegetation.

After three years of treatment, Fisherman Bay Spit Preserve showed above-ground vegetation counts comparable to pretreatment levels (Table 1). It was the only site that demonstrated a decline in below-ground vegetation (tuber density). This site, located in a grassland with deep, rich sandy loam soils averaging 11% gravel, 1% cobble, and 0% stone, provided a relatively easy substrate for excavation but also supported deep and abundant arum growth.

Due to the dense arum layer, entire infested areas required excavation to remove as many tubers as possible. This process also removed other plant species in the area. The removal of arum may temporarily reduce competition but can also create open space for surrounding arum plants to reinvade. Excavation may also have brought tubers closer to the surface, enhancing their opportunity to germinate. Although the soils at Fisherman Bay Spit Preserve are favorable for digging, the severity of infestation should be carefully considered before implementing this treatment (Figure 13).



Figure 13. The dig plot at Fisherman Bay Spit Preserve. Note the level of disturbance on the plot.

In contrast, Salem Audubon Nature Reserve and Washougal Oaks experimental blocks are located in oak forests with rocky, compact, and clay-based soils. These soil conditions make digging more difficult and limit the depth and abundance of arum growth. Both sites showed little change in plant abundance three years after treatment (Table 1). For below-ground vegetation, Salem Audubon Nature Reserve showed a moderate decline in tuber density compared to the control, while Washougal Oaks showed no notable decline. In both cases, rocky soils hindered effective excavation, reducing treatment success.

The labor intensity of manual excavation should not be underestimated. For example, at Fisherman Bay Spit Preserve, the first year of treatment required 24 person-hours to excavate four 1 m² plots

(Appendix B). For large infestations, this method is neither time- nor cost-effective. Manual excavation is best suited for small patches in areas with loose, easily excavated soils and minimal rock content, where tubers can be effectively removed.

5.2 Herbicide application

All three herbicide treatments (glyphosate only, glyphosate plus imazapyr, and imazapyr only) were applied as spot sprays once per year. The entire application process—from mixing chemicals to spraying—took less than 30 minutes to complete for a 1 m² area and was comparable across all three sites (Appendix B).

After three years of treatment, we observed varying levels of control of the abundance of Italian arum. Both Fisherman Bay Spit Preserve and Washougal Oaks showed evidence of decreased above-ground vegetation, while the Salem Audubon Reserve showed little change. Regarding below-ground vegetation, there was a moderate decrease in tuber density at Fisherman Bay Spit Preserve and Salem Audubon Reserve, while Washougal Oaks showed little change compared to the control.

Responses in surrounding (non-target) vegetation also varied among treatments. Most notably, treatments containing imazapyr resembled a chemical fallow, with few non-target species surviving the application. This effect was particularly evident at Fisherman Bay Spit Preserve and Salem Audubon Reserve, where most surrounding vegetation died back, yet Italian arum persisted—demonstrating the species' resilience (Figure 14).

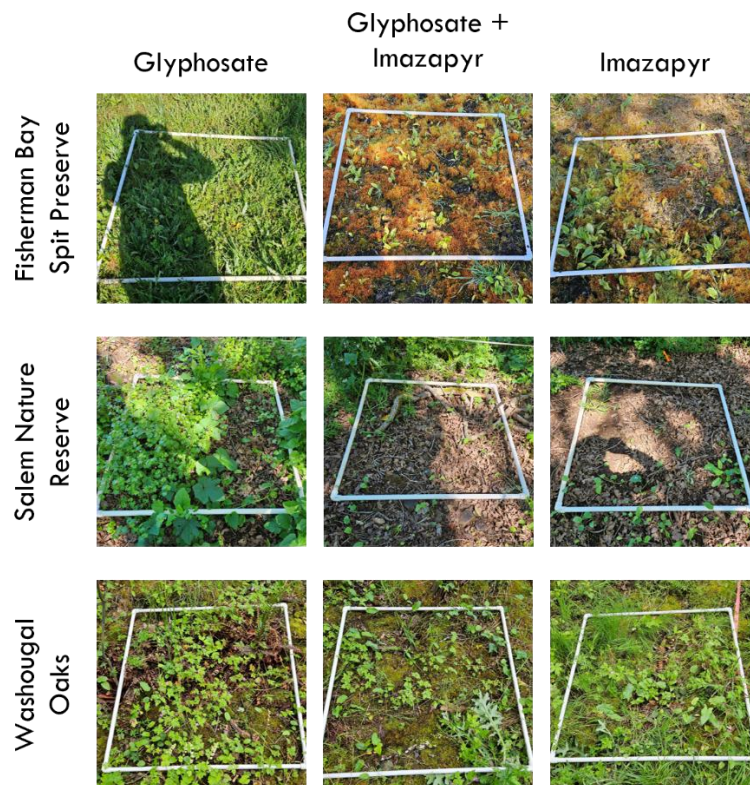


Figure 14. Above-ground vegetation response to 3 years of herbicide application.

Overall, all three herbicide treatments showed some level of effectiveness in controlling Italian arum, though results varied by site. These treatments are time- and cost-efficient, making them of high

management interest. However, the impacts on non-target species must be carefully considered, particularly for herbicide mixes containing imazapyr. Follow-up native seeding should be implemented after treatment to prevent recolonization by Italian arum and other aggressive invasive species. That said, we did not observe a sufficient reduction in below-ground vegetation to justify the use of chemical treatments at this time. Further investigation is warranted before recommending herbicide applications as a viable control method for Italian arum.

5.3 Mow and tarp

The mow and tarp treatment involved mowing Italian arum and surrounding vegetation to a height of less than three inches, then covering the area with weed cloth (tarp) secured with staples. This 1 m² treatment required approximately 30 minutes to complete initially, followed by brief maintenance visits lasting less than 30 minutes. The goal of this one-time treatment was to solarize the area, removing both above- and below-ground vegetation. This approach was the most time- and cost-efficient of the treatments tested and is ideal for sites where chemical treatments are undesirable.

In a traditional context, the use of black plastic is considered an *occultation* treatment, whereas the use of clear plastic creates a *solarization* treatment. These methods were developed in agricultural settings to reduce weeds in the weeks leading up to planting, typically lasting only several weeks (Voye 2025). Occultation is intended to shade out existing vegetation, while solarization promotes germination of the seed bank and then uses high heat to kill weeds and reduce future germination. In this experiment, the plots were covered for three years, so likely experienced a solarization effect in addition to occultation due to the prolonged duration.

Three years after the initial treatment, above-ground vegetation decreased at Fisherman Bay Spit Preserve and Washougal Oaks, while Salem Audubon Reserve showed an increase. Below-ground vegetation (tuber density) decreased across all three sites, following the same general trend as above-ground vegetation—Fisherman Bay Spit Preserve and Washougal Oaks showed the strongest response.

These results may be influenced by site-specific temperature and microhabitat conditions. Fisherman Bay and Washougal Oaks had full to partial sun exposure, which likely enhanced solarization in addition to the intended occultation effect. In contrast, the Salem Audubon Reserve plot was located directly beneath an oak tree, resulting in greater shade and leaf litter accumulation, which likely produced only an occultation effect.

Overall, the mow and tarp treatment showed the most promising results for both above- and below-ground control and has strong potential for future management. Given its low labor requirements and high treatment efficacy, this method is a strong candidate for continued use. However, because this treatment suppresses all surrounding vegetation, follow-up seeding with native species is recommended to reduce reinvasion by Italian arum and other aggressive species (Figure 15).



Figure 15. Immediately after pulling the tarp from the plot, and then 6 months after pulling the tarp.

5.4 Site-specific notes

As evident from the final results of this experiment, several trends appear to contradict the overall findings presented in this report. This section aims to highlight potential reasons for the observed site variability.

The Salem Audubon Nature Reserve emerged as an outlier when examining above-ground vegetation responses. Independent of this experiment, much of the site's success can be attributed to a dedicated group of volunteers committed to maintaining a beautiful natural park for their community. Our experimental block was located near the park entrance—an area easily accessible and among the first visible to visitors and volunteers (Figure 16). With this in mind, it is possible that the experimental plots were inadvertently tampered with by well-intentioned community members who may have been eager to assist with Italian arum removal.

Ultimately, given the low replication in this experiment, we cannot determine whether these patterns represent novel, site-specific anomalies or true landscape-level responses.

5.5 Stakeholder meeting discussion

On Aug 27th, 2025, IAE hosted a stakeholder meeting centered on presenting the findings outlined in this report and practitioner Q&A. We saw a high interest in this meeting, with representation throughout the Pacific Northwest in Canada and the United States, and across many entities. We estimated over 100 participants in this virtual stakeholder meeting. This meeting was followed by a survey to further investigate previous treatment effects.

Here are the biggest takeaways from this meeting and subsequent survey:

- Evidence of above-ground vegetation reduction does not guarantee Italian arum control or below-ground decline. Measuring tuber response to treatments is therefore essential for future evaluations.
- As previously discussed, the mow + tarp treatment was the most effective for both above- and below-ground control and remains the current recommended approach under this experiment.
- For larger Italian arum infestations, there remains strong interest in effective chemical control. Several herbicides (e.g., Competitor, Syl-Tac AE), herbicide mixtures, and alternative application methods (e.g., cut-and-treat) were suggested, providing a foundation for future investigation.
- For practitioners seeking non-chemical options, mechanical and cultural control methods were of particular interest. Building on the success of mow + tarp, other materials such as horse-stall mats, coffee bags, and clear plastic were proposed as potential future techniques to test.

Ultimately, there is no single “silver bullet.” Success appears to rely on persistent, multi-year, integrated strategies—combining well-timed, selective herbicide applications (where appropriate) with aggressive physical suppression (e.g., *mow + tarp*). Interest in identifying the most effective control methods for this noxious weed remains high, and leveraging that momentum will be critical for advancing future research and management efforts

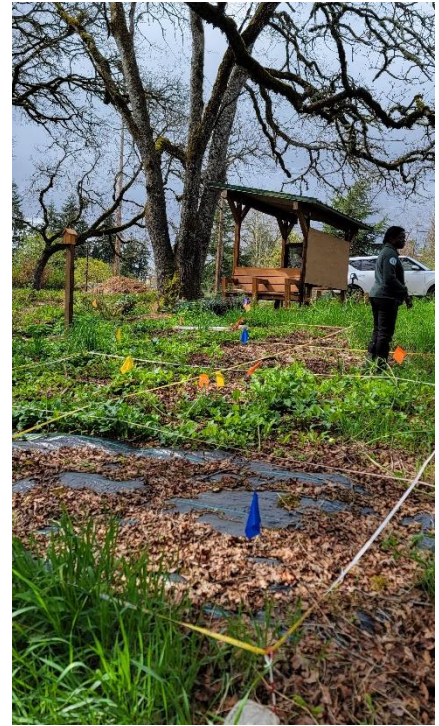


Figure 16. Salem Audubon Nature Reserve experimental block location. Note the distance of the plot to the parking lot.

6. CONCLUSION

This experiment provides valuable insight into managing a challenging and adaptable noxious weed like Italian arum (*Arum italicum*). Our findings show that no single treatment offers complete control across all habitat types. Instead, an integrated management approach tailored to site-specific conditions is likely to be most effective. In open habitats such as Fisherman Bay Spit Preserve, solarization (mow and tarp) treatments provided substantial suppression with relatively low maintenance. In contrast, in shaded, mesic oak woodland systems, mechanical removal followed by spot-spraying may be more practical and effective.

Long-term success will depend on sustained monitoring and adaptive management. Because Italian arum tubers can persist for multiple years and daughter tubers can establish within a single growing season, treatment sites should be revisited annually for at least three years post-treatment to prevent reinfestation. The predominance of daughter tubers in both treated and untreated plots highlights the species' strong capacity for vegetative reproduction, which complicates management. Even when above-ground foliage was eliminated, residual mother tubers often remained viable, allowing for future sprouting and recolonization.

This regenerative ability emphasizes the importance of treatments that target both above- and below-ground structures simultaneously—such as the mow and tarp method—which may provide more durable results. Ultimately, the results demonstrate that Italian arum is a highly resilient invader capable of persisting under a range of management pressures. However, meaningful reductions in plant and tuber density are achievable through sustained effort, particularly where treatments are combined and repeated over time. Further investigation will be required to truly find the “silver bullet” for the species.

This study contributes critical, field-based data to guide invasive plant managers in developing realistic, effective, and site-appropriate control strategies for Italian arum in Pacific Northwest ecosystems.



Figure 17. IAE staff and WDNR staff sifting soil for Italian arum tuber sampling.

7. REFERENCES

Boyce, P. 1993. *The Genus Arum*. HMSO. London.

Hedges, L. V., J. Gurevitch, and P. S. Curtis. 1999. The meta-analysis of response ratios in experimental ecology. *Ecology* 80:1150–1156.

Mallon, Z. 2016. *Arum italicum* “Glyphosate and Tarping Treatment Trials in a Greenhouse Setting And Seattle Distribution in 2016.”

https://depts.washington.edu/uwbg/research/theses/Zac_Mallon_MEH_2016.pdf.

Material Safety Data Sheet | Rodeo Herbicide. (n.d.). https://soundnativeplants.com/wp-content/uploads/rodeo_msds.pdf

Safety Data Sheet | Alligare. (n.d.). <https://alligare.com/wp-content/uploads/2018/08/imazapyr-4-sl-sds-v3.0-080618.pdf>

USDA Plants Database, NRCS 2023. The PLANTS Database (<http://plants.usda.gov>, 5 February 2023)

Voye, H. 2025. Improving reduced tillage vegetable systems for Northern Great Plains: How does early season soil tarping (solarization and occultation) reduce weeds, affect soil health, and protect yields? South Dakota State University.

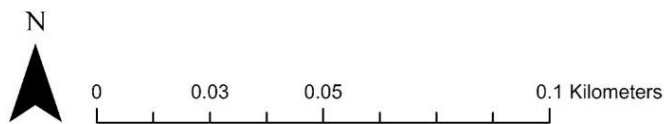
WSNWCB. 2014. Written Findings of the Washington State Noxious Weed Control Board. https://www.nwcb.wa.gov/images/weeds/Arum_italicum_draft_written_findings-2.pdf

WSNWCB. Italian arum control. (n.d.) Retrieved November 28, 2022, from https://www.nwcb.wa.gov/pdfs/ItalianArum_Brochure.pdf

Washington state noxious weed control board. (n.d.). Retrieved November 28, 2022, from <https://www.nwcb.wa.gov/weeds/italian-arum>

APPENDIX A. SITE MAPS AND PHOTOS

Fisherman Bay Spit Preserve



Map A1. Map of Fisherman Bay Spit Preserve. Plots established, monitored, and treated from 2022 - 2025.

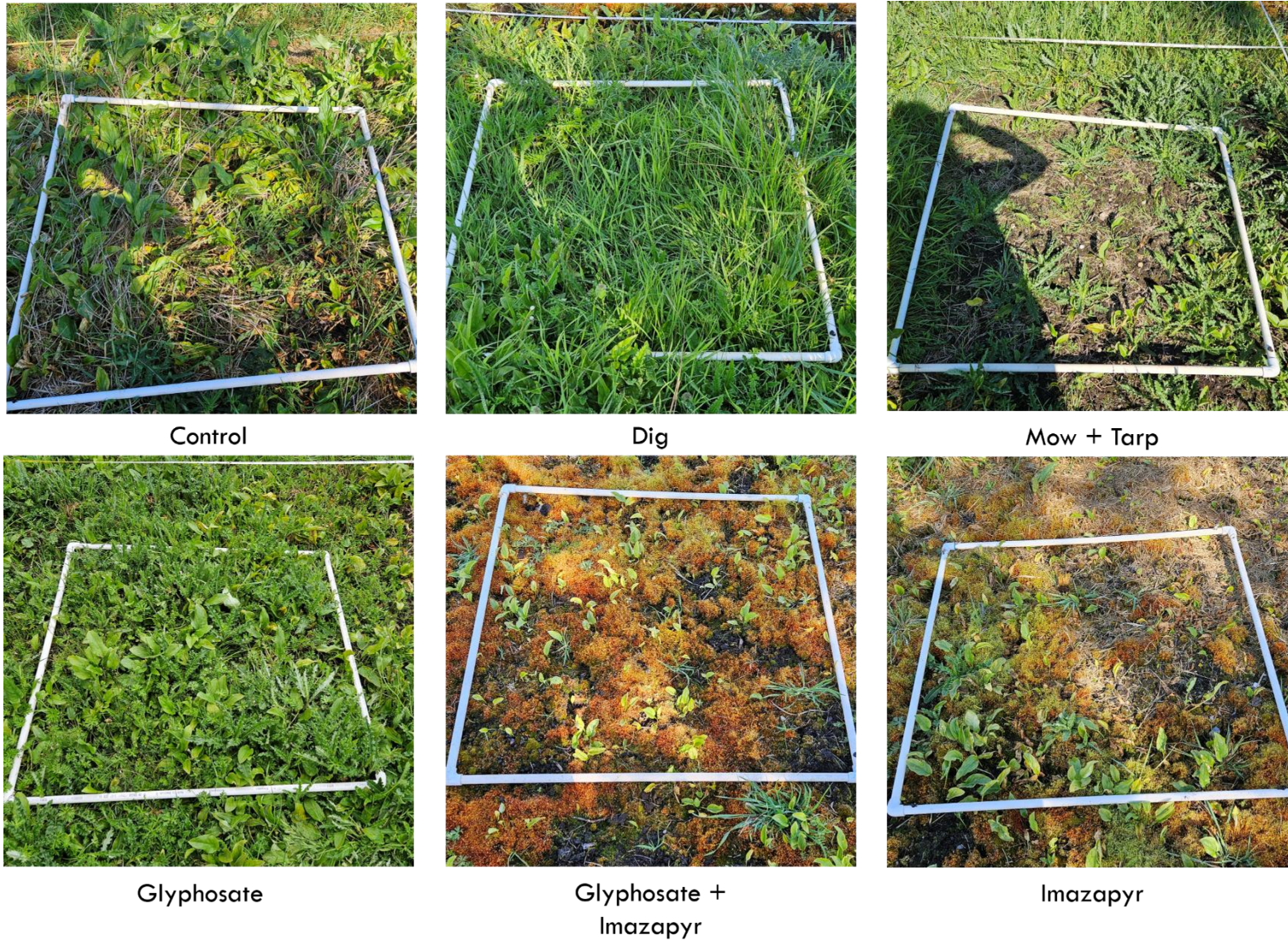
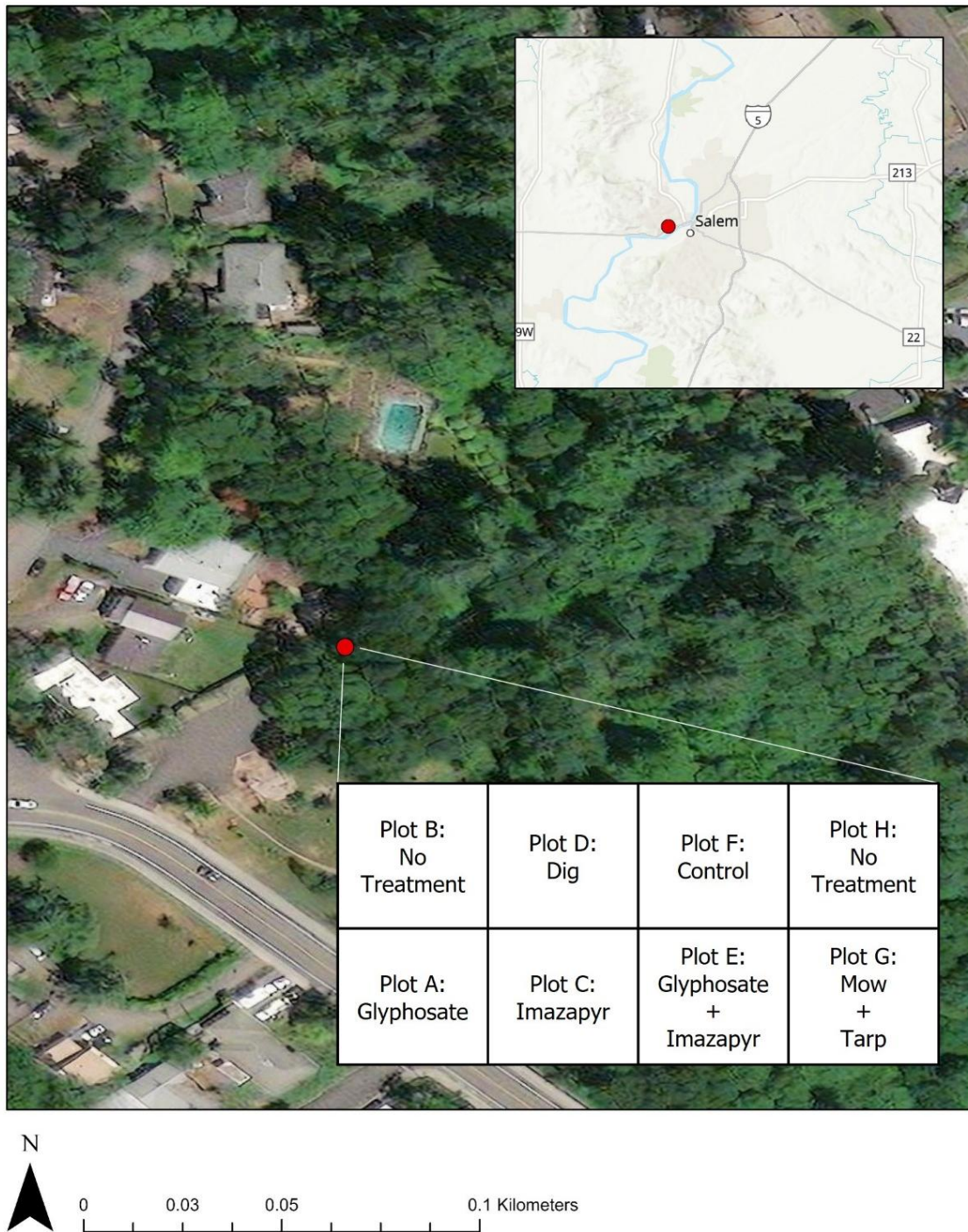


Figure A1. Photo points of treatment responses three years (2025) following initial treatments on Fisherman Bay Spit Preserve.

Salem Audubon Reserve



Map A2. Map of plots established, monitored, and treated from 2022 - 2025. Due to habitat constraints at the site, (and the lack of arum in some areas), the plot area was expanded to a 4m x 8m area.



Control



Dig



Mow + Tarp



Glyphosate



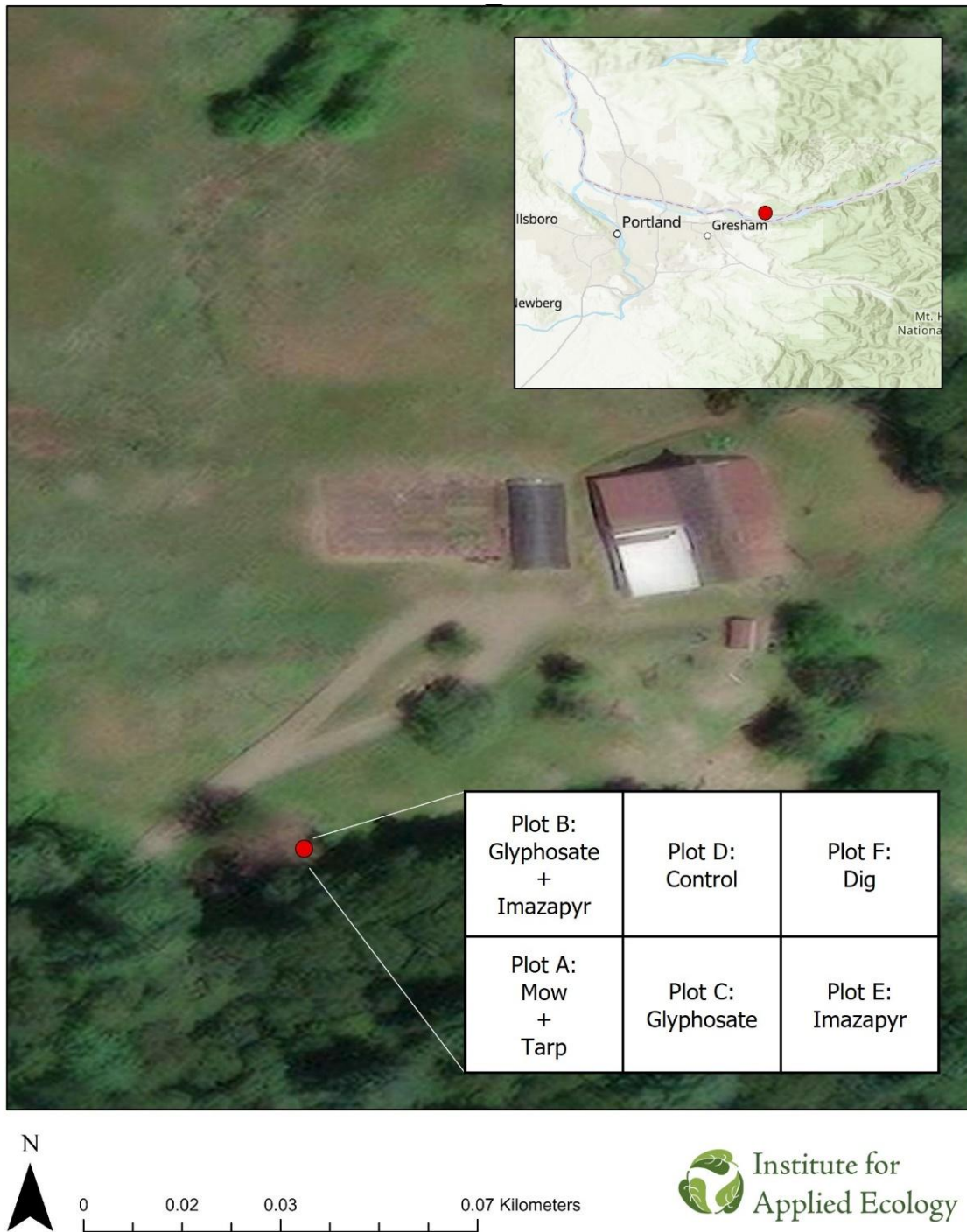
Glyphosate +
Imazapyr



Imazapyr

Figure A2. Photo points of treatment responses three years (2025) following initial treatments on Salem Audubon Reserve.

Washougal Oaks



Map A3. Map of plots established, monitored, and treated from 2022 - 2025 at Washougal Oaks.



Control



Dig



Mow + Tarp



Glyphosate



Glyphosate +
Imazapyr



Imazapyr

Figure A3. Photo points of treatment responses three years (2025) following initial treatments on Washougal Oaks.

APPENDIX B. TREATMENT DETAILS

Table B1. Sites and dates of the treatments from 2022 - 2024.

Site	Date of Herbicide Applications (Imazapyr, Glyphosate, and combo)	Date of other treatments (Digging)
Fisherman Bay Spit Preserve	May 9 th , 2022 May 8 th , 2023 May 2024	May 4 th – 5 th , 2022 April 26 th , 2023 April 30 th , 2024
Salem Audubon Preserve	April 29 th , 2022 April 25 th , 2023 May 9 th , 2024	April 26 th , 2022 April 24 th , 2023 May 9 th , 2024
Washougal Oaks	May 3 rd , 2022 May 3 rd , 2023 May 2 nd , 2024	May 3 rd , 2022 May 3 rd , 2023 May 2 nd , 2024

Site notes:

- Washougal Oaks had accidental overspray of Imazapyr on ~80% of the dig plot in 2024.
- Fisherman Bay Spit Preserve did not provide an exact treatment date for the 2024 herbicide treatment.
- Tarps were established 5/4 – 5/9/2022 removed 10/29 – 10/30/2024 on all three sites

Table B2. Treatments and the approximate time (people hours) it took to apply each treatment in each 2m x 2m treatment plot in each year.

Treatment	Fisherman Bay Spit Preserve	Salem Audubon Reserve	Washougal Oaks
Imazapyr	0.5	1.5	0.5
Glyphosate	0.5	1.5	0.5
Imazapyr + Glyphosate	0.5	1.5	0.5
Digging	14 - 24	8	6
Mow + Tarping	1	1	1
Control	---	---	---

Times are listed as person hours per 4m² plot. A crew of 2 -3 individuals contributed to treatment actions. Time does not include travel time to and from site or other preparatory activities. Times for herbicide treatments include time for mixing, and cleaning of spray equipment. Herbicide application took longer at Salem Audubon Preserve because temporary fencing was set-up (and taken down) to keep public and pets away from treated areas during the return entry interval.

APPENDIX C. ITALIAN ARUM DATA

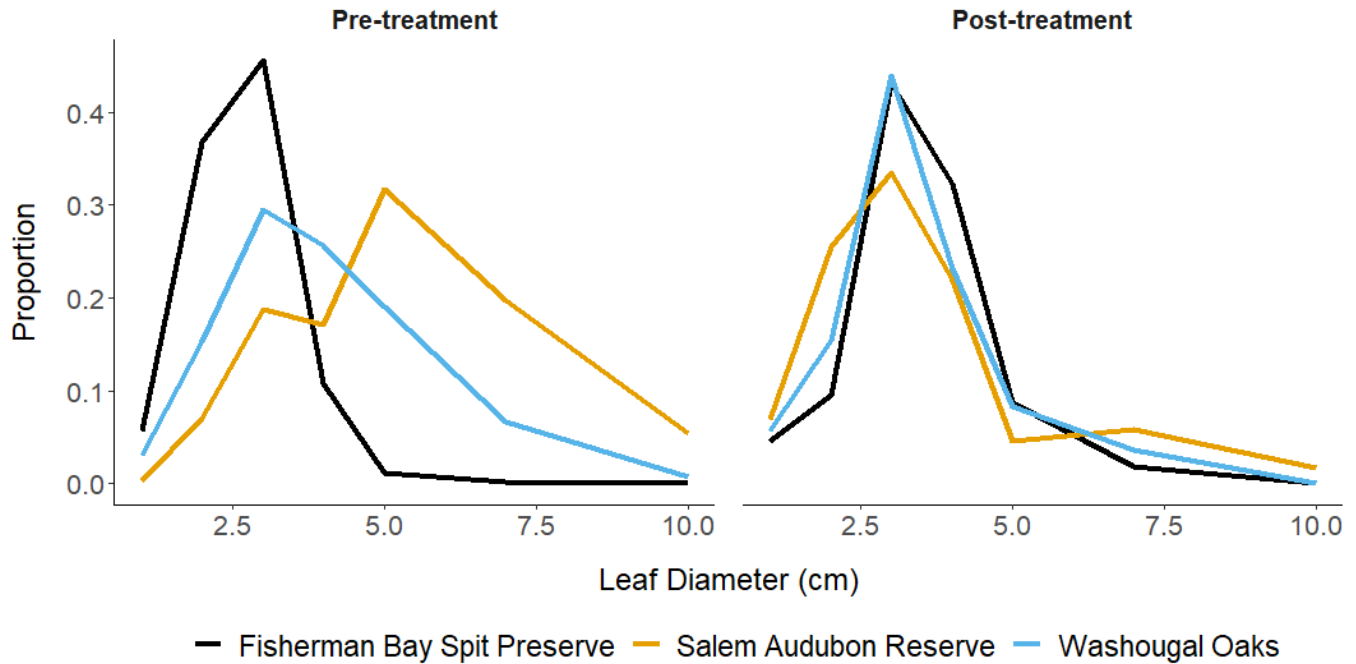


Figure C1. Italian arum plant size distribution pre-treatment and 2 years post-treatment at 3 study sites.

Prior to treatment, Italian arum leaf (plant) size and the number of plants varied across the three sites. Fisherman Bay Spit Preserve had the highest number of plants (8,179) and trended toward smaller plants, with 88% of plants ranging from 1 – 3 cm. Salem Audubon Nature Reserve had moderate numbers of plants (792) and trended toward larger plants, with 57% of plant ranging from 5 – 10+ cm. Washougal Oaks had the fewest number of plants (515) and had a diversity of sized plants, with 56% of plants ranging between 3 – 4 cm.

Two years post-treatment, there was a shift in the size of the plants, with large plants declining and an increase in smaller plants. Fisherman Bay Spit Preserve decreased in the total number of plants (2,794, 66% decrease), but maintained similar size trends seen in pre-treatment, with the majority (89%) of plants ranging from 1 – 4 cm. Salem Audubon Nature Reserve decreased in the number of plants (173, 78% decrease), and the size of plants decreased with the majority (88%) of plants ranging from 1 – 4 cm. Washougal Oaks decreased in the number of plants (389, 24% decrease), and the plant size decreased with the majority (88%) of the plants ranging from 1 – 4 cm.

Table C1. The log proportional change in plant count and tuber count of five Italian arum treatments and the control across three sites two years post-treatment. Treatment (Tx) effect values at zero indicates no effect. Values greater than zero indicates that the treatment increases Italian arum cover, and values less than zero indicates that the treatment reduced Italian arum cover. **Bold** values are less than 0 and *italic* values are greater than 0.

Treatment	Year °	Fisherman Bay Spit				Salem Audubon Reserve				Washougal Oaks			
		Tx Effect (above)	Tx Effect (below)	Above Count	Below Count	Tx Effect (above)	Tx Effect (below)	Above Count	Below Count	Tx Effect (above)	Tx Effect (below)	Above Count	Below Count
Control	2022	--		1961		--		148		--		91	
	2023	-0.35		1380		<i>1.01</i>		443		-0.31		67	
	2024	-0.23		1561		-2.51		12		<i>0.05</i>		96	
	2025	-1.69	0.00	363	1139	-1.17	0.00	46	383	0.03	0.00	94	87
Dig	2022	--		559		--		138		--		109	
	2023	-0.31		409		<i>0.45</i>		216		<i>0.38</i>		159	
	2024	-0.03		542		-1.21		41		-0.26		84	
	2025	-0.51	-2.22	337	108	-0.53	-1.44	81	87	-0.13	0.08	96	113
Glyphosate	2022	--		1322		--		157		--		91	
	2023	<i>0.17</i>		1569		<i>0.85</i>		366		-0.25		71	
	2024	-1.51		292		-1.92		23		-0.23		72	
	2025	-2.76	-1.52	84	247	-0.44	-1.47	101	80	-0.85	-0.58	39	56
Glyphosate + Imazapyr	2022	--		2219		--		109		--		111	
	2023	-0.17		1865		<i>1.14</i>		342		<i>0.29</i>		148	
	2024	-1.96		313		-0.76		51		-0.49		68	
	2025	-2.60	-1.34	170	256	0.49	-0.99	178	128	-1.05	0.14	39	104
Imazapyr	2022	--		1327		--		64		--		51	
	2023	-0.41		878		<i>1.63</i>		326		-0.15		44	
	2024	-2.74		86		-0.33		46		-0.08		47	
	2025	-2.23	-1.18	142	342	0.08	-0.97	69	126	-0.35	0.05	36	91
Mow + Tarp	2022	--		791		--		176		--		62	
	2023			431				508				87	
	2024			0				0				22	
	2025	-2.50	-3.36	65	42	0.59	-0.41	319	249	-0.95	-1.79	24	15