CITY OF PORTLAND

# Citywide Invasive Plant Management and Natural Areas Restoration

## ANNUAL REPORT 2018-19

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# Invasive Species Program Annual Report

2018 – 2019

Report prepared by the
City of Portland Bureau of Environmental Services
Portland, Oregon

## Acknowledgments

Portland Parks and Recreation
Bureau of Planning and Sustainability
Portland Bureau of Transportation
Portland Water Bureau
Portland Bureau of Development Services

## For More Information

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# Introduction

## Functioning watersheds provide critical services that strengthen the economy and protect human health.

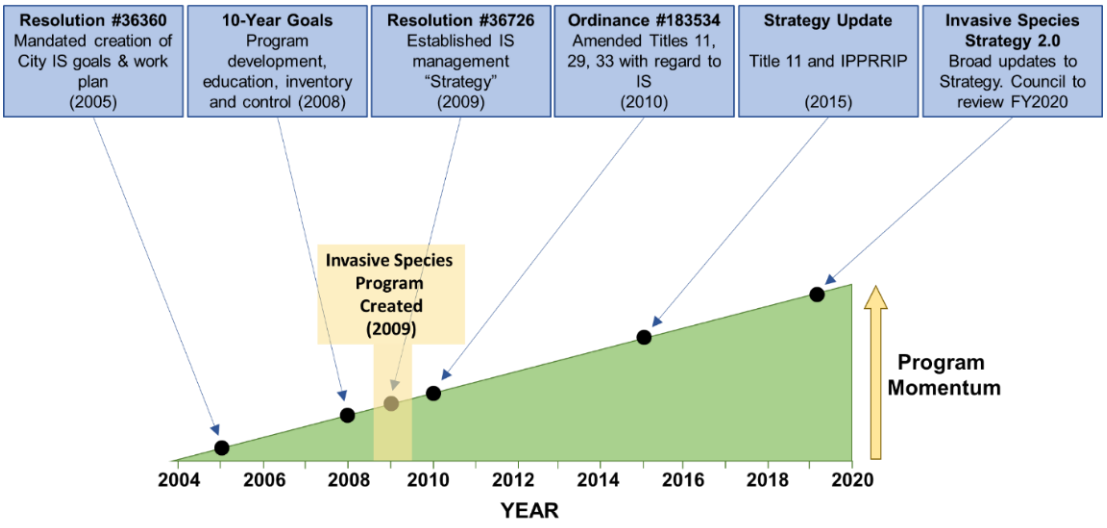
These services include hydrologic cycle regulation, water purification, native plant, pollinator and wildlife habitat, clean air, food, pollution interception, temperature regulation, slope stabilization, erosion prevention, and more.

Unfortunately, human activities such as landscape development and habitat fragmentation disturb these natural systems and reduce their functional capacity. Disturbed habitats are also more likely to be colonized by harmful invasive species, which on a global scale are second only to habitat loss as the leading threat to ecosystems, native species diversity, economies, and human health. To mitigate these impacts, the City of Portland has adopted policies that protect its natural areas and resources from the harmful impacts of invasive species.

Since 2009, the City of Portland's Invasive Species Program (Program) has worked to prevent environmental degradation by ensuring compliance with municipal code, state and federal provisions, and assisting efforts to mitigate the impacts of invasive species within the City. The Program was created as the product of two City resolutions (Figure 1). In 2005, Resolution 36360 mandated the creation of 10-year invasive species goals and a work plan to achieve them. In 2009, Resolution 36726 established a strategy for the management of invasive species titled *Invasive Plant Strategy Report* (Strategy), spurring further updates to City policies: Ordinance 183534, passed in 2010, amended the *Portland Plant List* (PPL), Title 11 (tree code), Title 29 (property maintenance regulations), and Title 33 (planning and zoning) regarding invasive species. The Program enacts the Strategy by coordinating management activities with other City programs, government agencies, private organizations, and citizens. The collaborative work of these partners ensures that the City meets regulatory requirements while protecting infrastructure, human health, biodiversity, and investments in habitat restoration and watershed services.

## Figure 1. Invasive Species and City Policy: Historical Timeline

Municipal policy spurred the development of the Invasive Species Program, which formed in 2009. By coordinating comprehensive, citywide partnerships, the Program continues to increase its capacity to protect and improve Portland watersheds.




## Program Implementation and Operation

*Coordinators and Partners—*

The Program is housed at the Bureau of Environmental Services (BES) and works extensively with other City programs to advise on invasive species issues, implement the 10-year work goals outlined in the Strategy, and ensure policy compliance (Figure 2). The following staff are bureau contacts for invasive species management:

- **Bureau of Environmental Services (BES)**
  - Dominic Maze (Program Coordination, Early Detection and Rapid Response)
  - Mitch Bixby (Early Detection Rapid Response)
  - Ryan Durocher (Watershed Revegetation Program)
  - Megan Hanson (Clean Rivers Education)
- **Parks and Recreation Bureau (PPR)**
  - Laura Guderyahn (Protect the Best)
  - Kendra Petersen-Morgan (City Nature West)
  - Michael Oliver (City Nature East)

    - Nichole Linehan (Integrated Pest Management)
    - Yoko Silk (Natural Areas Stewardship Program)
- **Portland Water Bureau (PWB)**
    - Angie Kimpo
- **Bureau of Transportation (PBOT)**
    - Rich Grant and Keri Munson
- **Bureau of Planning and Sustainability (BPS)**
    - Jeff Caudill
- **Bureau of Development Services (BDS)**
    - Kimberly Tallant

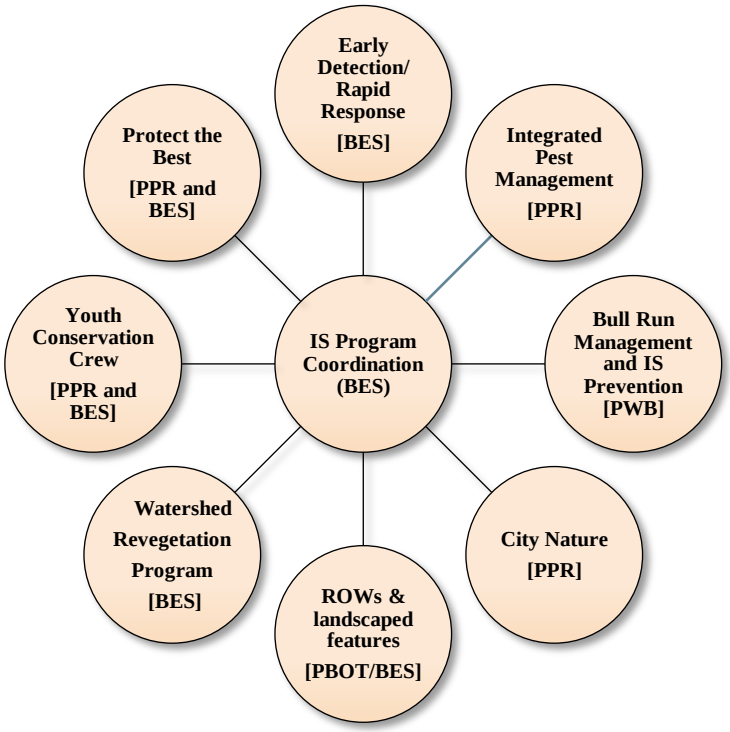



**Figure 2** City programs that work with the Invasive Species Program. Management efforts are coordinated across multiple city programs, allowing for a unified approach throughout the city.

Additional partners include regulatory agencies at the federal, state, regional, and local levels. Specifically, the invasive species coordinator communicates with staff at federal and state agencies to ensure that City management is consistent with federal and state regulations. Additionally, Program staff attend the 4-County Cooperative Weed Management Area (4CoCWMA) meetings as steering committee members and coordinate management efforts with the 4CoCWMA members, including East Multnomah Soil and Water Conservation District, West Multnomah Soil and Water Conservation District, Metro, Tualatin Soil and Water Conservation District, local watershed councils (Johnson Creek, Columbia Slough, and Tryon Creek), "Friends of" groups, the Willamette Partnership, the Forest Park Conservancy, and other non-governmental organizations. Finally, the engagement of citizens and private landowners provide critical support for Program objectives.

**Figure 3** Garlic mustard (*Alliaria petiolata*) rapidly spreads along disturbed areas such as roadsides, then proceeds to colonize undisturbed habitats such as forest interiors. Inset photo reveals why proper hand-pulling technique is critical: the plant stem easily breaks off due to an S-shaped root, which then regrows into a new plant.

*Policy and Regulation—*

Portland is renowned for unifying invasive species policies and actions across municipal code. City staff provide guidance to such policies regarding invasive species concerns as they relate to development and environmentally sensitive zones, with the aim of protecting infrastructure, human health, and the environment. More broadly, Program staff assist policy and regulatory analysts in crafting City opinions on statewide natural resource legislation.

## Policy and Regulation Highlights (FY2019)

A third-party audit was conducted to evaluate the first ten years of the Invasive Species Program Strategy (2009 to 2018), providing in-depth assessments of Program achievements as well as gaps and shortcomings. The audit reviewed management plans and policy, outreach, surveys with employees, surveys with stakeholders, analysis of invasion pathways, and the extent to which intended actions and 10-year goals were met. The results were very encouraging, demonstrating that 91% (40 out of 44) of the objectives put forth in the 2008 Invasive Species Strategy were completely or partially competed. Furthermore, the audit will further guide development of the updated Invasive Species Strategy 2.0 set to be reviewed and potentially adopted as policy by City Council in FY2020.

*Outreach and Education—*

The City's outreach and education efforts engage tens of thousands of people each year on an array of topics related to stormwater and wastewater management, plant identification, invasive plant control, and native plant revegetation efforts. Outreach events put on by Program staff and partners include workshops, volunteer events, and classroom instruction. Program staff also create written outreach materials for distribution at community outreach events and through the Bureau of Environmental Service's website.

## Outreach and Education Highlights (FY2019)

On 07-Nov-2018, BES hosted the Invasives 2.0 Summit at the World Forestry Center in Portland. The summit was attended by almost 200 participants, providing a forum for area managers, practitioners, and citizens to convene and discuss a variety of issues relating to invasive species and watershed health. The agenda included eight professional presentations, a round-table discussion, and a rapid-fire question and answer session. Forty anonymous comments were submitted as feedback and guidance for updating the City of Portland's Invasive Species Strategy.

Mitch Bixby, Botanic Specialist with BES EDRR, provided leadership for the 4CoCWMA, serving as chair to the Steering Committee and the Science and Technical Committee, and helped coordinate a noted annual conference ("Pull Together") designed to coalesce efforts of regional managers and workers.

The Clean Rivers Education Program (BES) worked extensively with students young and old this fiscal year, conducting both classroom and field programs. Classroom projects focused on riparian plant identification, emphasizing native and invasive plant recognition, and a second classroom program teaching addressing watershed awareness. Field programs were conducted in conjunction with Portland Parks and Recreation, and focused on invasive identification removal, as well as native planting and identification (Appendix I).

*Management and Control—*

Four City bureaus (BES, PPR, PWB, and PBOT) control invasive species on approximately 10,800 acres of City-owned property, rights-of-ways, and occasional private properties. PWB additionally manages invasive species in the Bull Run Watershed. Other entities, such as Oregon Department of Agriculture (ODA), the Oregon Department of Transportation, and the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), local watershed councils, and soil and watershed conservation districts also operate within the City on invasive species issues.

Integrated Pest Management (IPM) is the unifying principle among all partners' control programs. An IPM approach implements a range of science-based and common-sense techniques individually tailored for each situation to achieve management goals. Ideally, these goals are clearly stated at the project outset, then continually scrutinized and adapted as prevailing conditions and resources change over time. IPM techniques may include carefully timing treatments according to pest life cycles to maximize efficacy while minimizing harm to the environment and non-target species. Even the decision to tolerate rather than attempt to control a given species may be part of an IPM program, if it is decided that the ability to control a species in a certain area is a net loss given constraints of time, money, or personnel.

The focus on invasive species control efforts varies by bureau and program, wherein each focus emphasizes different Program objectives: **preventing** establishment of new invaders, **protecting** functioning habitats, or **restoring** ecosystem functions.

**The Bureau of Environmental Services (BES)** houses both the Watershed Revegetation Program and the Early Detection/Rapid Response program, which are focused on restoration and prevention, respectively. Preventing colonization of invasive species is the most effective strategy for evading massive management problems. Unfortunately, this is not always possible, which is why the practice of early detection/rapid response (EDRR) and eradication of newly arrived species is widely accepted as the next most cost-effective and labor-efficient way to minimize long-term impacts of harmful exotic species. The EDRR Program at BES actively manages a target list of approximately 20 species considered to be new but manageable threats. The program also maps known occurrences and monitors the City's control efforts.

**Portland Parks and Recreation (PPR)** manages more than 10,000 acres of parks and public lands. Management of these lands is allocated among several organizations within PPR, dedicated to different aspects of the Strategy: The Protect the Best (PTB)

Invasive Plant Management Team uses EDRR to treat small patches of invasive plants in relatively weed-free natural areas to **protect** them from becoming larger infestations. Invasive plants are removed from targeted habitats and the surrounding area, creating a weed-free buffer. PTB provides some of the most cost-effective invasive species control.

The Natural Areas Stewardship Program (PPR) expertly combines outreach and education with management goals by collaborating with schools, community organizations, "Friends of" groups, neighborhood associations, businesses and government agencies.

## Management and Control Highlights (FY2019)

**Bureau of Environmental Services**

- Revegetation Program managed 804.5 acres, 28.7 acres of which were initiated in FY2019 (Appendix II)
- The EDRR Program surveyed a total of 304 acres and treated 1.33 acres of invasive plants, which were distributed among 270 public and private sites, 140 miles of road, and 6.4 miles of stream habitat (Appendix II)

**Portland Parks and Recreation**

- Protect the Best (PTB) treated 316.1 acres at 19 different sites in FY 2018-2019. This is both fewer acres and more sites than PTB has worked on in the past. Some sites take longer to work through than others which is why, in addition to acreage, the number of days and crew hours are included. This gives a clearer picture of how much time the crew devoted to each site. PTB also spent more days planting than in past years which is not reflected in the acreage, which only measure weed treatments, but is reflected in the days and hours worked (Appendix II).
- Natural Area Stewardship Program collaborated with 46 schools, 43 community organizations, 16 "Friends of" groups and neighborhood associations, 9 businesses, and 7 government agencies (Appendix II)

## Management and Control Highlights (continued)

**Portland Water Bureau**

- 794 observations and treatment points of invasive species in the BRWMU
- 322 acres of off-road surveys for wildland invaders such as English and Irish ivy (*Hedera* spp.), English holly (*Ilex aquifolium*) and traveler's joy (*Clematis vitalba*) in the BRWMU Monitoring of Eagle Creek fire staging locations including 2.8 miles of decommissioned roads and 15 miles of firebreak
- Management of 294 acres of conservation easement on private riparian land in the Sandy Basin
- Planting of 8544 trees and 5000 shrubs in the BRWMU, on conservation easement sites and on large wood projects (Appendix II)
- Survey of all roads and trails in the BRWMU for high priority EDRR species

**Portland Bureau of Transportation**

- **PBOT** manages vegetation along many roads and highways. Invasive plants tend to colonize disturbed landscapes such as berms, traffic islands, ditches, etc., and vehicles and ditches efficiently transport seeds and other reproductive structures of many invasive plant species. FY2019, PBOT managed these areas using pesticide sprays (8.98 acres), as well as mowing 1578 locations (18,329.40 acres) (Appendix II).

**The Portland Water Bureau** is heavily focused on protecting the natural areas within the Bull Run Watershed Management Unit (BRWMU), since the Bull Run River is the primary source of drinking water for nearly one million people in the Portland Metro Area. Maintaining robust populations of native plant species, while minimizing or eradicating invasive species thereby promotes natural processes such as pollution filtration and erosion reduction.

*Inventory—*

The inventory of both native and invasive plants is needed to assess whether management goals are being met. The City prioritizes management actions in natural areas based on the presence of sensitive species, invasive species, riparian habitat, and other features. Information on the attributes is compiled through

regular surveys and analyzed to allocate funds and staff time to the highest priority restoration projects.

Invasive species control and restoration efforts are planned and tracked via City databases. Programs within each bureau (e.g., EDRR, Reveg, PTB, Youth Conservation Crew, and City Nature) maintain records and maps of their work that inform future efforts. PWB continues to map and track road projects, including road decommissions within the Bull Run Watershed. Invasive species occurrences and corresponding treatments are also tracked (Appendices).

In FY2019 the EDRR Program began efforts to formally quantify the efficacy of its control efforts. The preliminary analysis focused on ten target species distributed across 680 sites that had received pesticide spray treatments for exactly 4 consecutive years. Preliminary results suggest there is substantial variation in effectiveness across species, herbicide formulas, and sites (e.g., localized factors exert strong influence on outcomes). See preliminary analyses in Appendix III.

**Next Steps**

- Complete Invasives 2.0 and pass Resolution
- Continue to develop and promote analyses of treatment efficacy for all bureaus
- Submit proposals for adding *Impatiens* spp. to Oregon Department of Agriculture Watch List
- Develop and expand a "spotting network" of engaged citizenry to help with early detection of invasive plants and insects.
- Expand personnel of BES EDRR team

**Figure 4** *Petasites japonicus* (left) and *Impatiens balfourii* (right) are two target species under management by BES EDRR Program.

# APPENDIX I: Outreach Data

## Clean Rivers Program FY2019

| Classroom Programs | Grades | # Classes Taught | # Contact Hours (est.) | # Student Contacts |
|---|---|---|---|---|
| Riparian plants (native and invasive) | 3-12 | 43 | 43 | 1,039 |
| Watershed Awareness | 3-12 | 44 | 44 | 998 |

| Field Programs | Grades | # Field Trips | # Contact Hours | # Student Contacts | # Field Sites |
|---|---|---|---|---|---|
| Stewardship field trips (mostly in partnership with PPR: Invasive removal, native planting, plant ID, etc.) | 2nd-Adult | 85 | 170 | 1880 | 17 |

# Appendix II: Management and Control Data

## BES Early Detection Rapid Response Program

| NAME | | ACRES MANAGED | |
|---|---|---|---|
| COMMON | SCIENTIFIC | GROSS | NET |
| Tree of Heaven | *Ailanthus altissima* | <0.01 | <0.01 |
| Garlic mustard | *Alliaria petiolata* | 292.66 | 1.20 |
| False Brome | *Brachypodium sylvaticum* | 0.00 | 0.00 |
| Itlalian plumeless thistle | *Carduus pycnocephalus* | 0.00 | 0.00 |
| Drooping sedge | *Carex pendula* | 0.00 | 0.00 |
| Spurge laurel | *Daphne laureola* | 0.00 | 0.00 |
| Oblong (eggleaf) spurge | *Euphorbia oblongata* | <0.01 | <0.01 |
| Goatsrue | *Galega officinalis* | 0.26 | <0.01 |
| Giant hogweed | *Heracleum mantegazzianum* | <0.01 | <0.01 |
| Orange hawkweed | *Hieracium aurantiacum* | 0.21 | <0.01 |
| Kashmir balsam | *Impatiens balfourii* | 0.00 | 0.00 |
| Two-toned balsam | *Impatiens bicolor* | 0.32 | <0.01 |
| Policeman's helmet | *Impatiens glandulifera* | 0.00 | 0.00 |
| Smallflowered balsam | *Impatiens parviflora* | 0.00 | 0.00 |
| Floating primrose-willow | *Ludwigia peploides* ssp. *montevidensis* | 8.61 | 0.11 |
| Giant butterbur | *Petasites japonica* | 0.00 | 0.00 |
| Common reed | *Phragmites australis* | 0.00 | 0.00 |
| American pokeweed | *Phytolacca americana* | <0.01 | <0.01 |
| Japanese knotweed | *Polygonum cuspidatum* | 0.41 | 0.01 |
| Giant knotweed | *Polygonum sachalinense* | 0.14 | <0.01 |
| Sulfer cinquefoil | *Potentilla recta* | 0.00 | 0.00 |
| Kudzu | *Pueraria lobata* | 0.00 | 0.00 |
| Delta arrowhead | *Sagittaria platyphylla* | 0.00 | 0.00 |
| Blessed milk thistle | *Silybum marianum* | 1.27 | <0.01 |
| **TOTAL ACREAGE** | | **303.92** | **1.33** |
| | | * gross acres equal the total area surveyed | * net acres equal the percent of the surveyed area that were actually treated |

## Watershed Revegetation Program

| Natural Area | Acres Managed | Acres Initiated |
|---|---|---|
| **Balch Creek** | 0 | 0 |
| **Columbia Slough** | 396.5 | 17.9 |
| **Fanno Creek** | 23.7 | 1 |
| **Johnson Creek** | 169 | 2 |
| **Tryon Creek** | 26.6 | 3.8 |
| **WQF/SMF** | 0 | 0 |
| **Willamette River** | 160 | 4 |
| **TOTAL** | **775.8** | **28.7** |

## Protect the Best

**Effort by site as measured by time spent and acres treated**

| Site | Days Worked | Crew Hours Worked | Acres Completed | Treatment Focus |
|---|---|---|---|---|
| Trainings/Office Days | 24 | - | - | Crew trainings, education, office tasks, maintenance |
| Baltimore Woods | 1 | 6 | .86 | EDRR |
| Big Four Corners | 2 | 13.5 | 1.9 | Weedy vines in Alice Springs section |
| Buttes | 3.5 | 48 | 9.6 | EDRR |
| CCA | 3 | 39 | 1.25 | Tree thinning |
| Elk Rock Cliff | 3.5 | 33.5 | 1.15 | Maintenance sprays, weedy tree removal, planting |
| Erroll Heights | 6.5 | 54 | 5.5 | Air gapping and spraying of viney weeds, planting in the wetland |
| Forest Park | 21 | 226.5 | 61.9 | Gridded through retreatment sections for weedy trees and vines. Six days of roadside garlic mustard treatments |
| George Himes | 8 | 67.5 | 6.8 | Removed Norway maples, sprayed ivy |
| Maricara | 2 | 24 | 5.7 | Followed up on previous year's broadleaf treatments |

| | | | | |
|---|---|---|---|---|
| Marshall Park | 2.5 | 28.5 | 2.5 | Removed weedy trees. Retreated and expanded previous year's broadleaf weed treatments in Foley Balmer section. |
| Mitchell Creek | 3.5 | 23 | 12.3 | Treated broadleaf weeds in the northern, 'Llama Pasture' section. Performed EDRR treatments |
| Mt. Tabor | 0.5 | 4 | 10.9 | Assisted with yearly yellow hawkweed spray |
| Oaks Bottom | 41.5 | 318 | 35.7 | Second year of broadleaf weed treatments on the 'south bluff', EDRR treatments and Viburnum removal in Mosquito Hollow |
| Oaks Crossing | 2.5 | 16 | 3.14 | Two rounds of EDRR treatments |
| Powell Butte | 25.5 | 261.5 | 69.6 | Gridding for weedy trees in forested SW section, small hawthorn sprays in the grassland meadow, vegetation monitoring, and planting |
| Powers Marine | 1.5 | 9 | 1.2 | Assisted westside staff with ivy sprays |
| Riverview | 25 | 223 | 49.5 | Sprayed remnant viney weed patches, removed regrown weedy trees |
| Ross Island | 11 | 78.5 | 33.7 | EDRR |
| Whitaker Ponds | 4.5 | 40.5 | 2.9 | Tree thinning, EDRR, mowing weedy grasses |
| **Totals** | **192.5** | **1476** | **316.1** | |

## Natural Areas Stewardship Program

| | |
|---|---|
| # Native Plantings | 33,343 |
| Square Feet of Invasives Removed | 844,964 |
| Cubic Feet of Litter Removed | 1,799 |
| Linear Feet of Trails and Fences Built and Maintained | 94,023 |
| # Volunteers | *12,308* |
| # Volunteer Hours | *52,500* |

**APPENDIX III: EDRR Treatment Analysis**

The Bureau of Environmental Services' Early Detection/Rapid Response (EDRR) Program recognizes a strong need to evaluate the efficacy of prior and current treatment efforts employed by the EDRR Program in order to optimize future management strategies. Indeed, the use of data and analytics to enhance the cost efficiency of asset management was a key objective highlighted by Mayor Ted Wheeler in his General Fund Guidance for Fiscal Year 2020-21 (p.2, 03-October-2019). Here, we share our initial framework for conducting analyses of treatment efficacy, beginning with description of data collection methods, and follow with a sample of a quantitative analysis.

Since 2009, the EDRR Program has collected data associated with its weed management activities. The EDRR Program attempts to track all newly discovered, localized populations of harmful exotic species. When a new population is found, a GIS polygon is created to document its location and spatial extent. The size of this initial polygon does not change at any time in the ensuing years regardless of the true spatial coverage of the plant (i.e., the initial area of the patch polygon remains fixed for future reference). For each instance of monitoring and/or treatment, the following data are recorded and tracked in a customized SQL Database:

## Annual Data Collected by BES Early Detection Rapid Response Program

| Category | Description | Data Type |
|---|---|---|
| **Project Name** | Named region of Portland | Character |
| **Project ID** | 3-digit code representing Project Name | Numeric |
| **Patch ID** | Specific to polygon. Indicates # patches and # species within polygon | Alphanumeric |
| **Property ID** | Taxlot ID | Alphanumeric |
| **Phase** | Management Phase (Active, Monitoring, Assessment) | Character |
| **Species Present** | Yes/No | Character |
| **Site Addr** | Site address | Character |
| **Treatment Type** | Assessment, Basal Bark, Bend, Bend/Spray, Cut, Injection, Monitoring, Pull, Spray | Character |
| **Treatment Date** | Treatment Date | Date |
| **Herb 1** | Name of primary herbicide | Character |
| **Herb 1%** | Percent of primary herbicide | Numeric |
| **Herb 2** | Name of secondary herbicide | Character |
| **Herb 2%** | Percent of secondary herbicide | Numeric |
| **Surf** | Name of surfactant | Character |
| **Surf%** | Percent of surfactant | Numeric |
| **Hrs. of Treatment** | Duration of treatment | Numeric |
| **Total Spray Vol.** | How much total herbicide mix was used. This is difficult to estimate due to the nature of the backpack sprayer's | Numeric |

| | | |
|---|---|---|
| | measurement markings and difficulty leveling, etc. Another challenge occurs when working with crews on Alliaria petiolata and Ludwigia peploides, as there are many patches treated in rapid succession but herbidice volume assessed only periodically, so that estimated herbicide volume deployed at individual sites is often derived from knowing how much cumulative herbicide was used across several sites, then recalling the relative density in each patch and dividing using percentages. | |
| **Units** | Gallons or Ounces of Total Spray Vol. | **Character** |
| **% Area Treated** | The percent of the total polygon that was surveyed and treated. This can be difficult to estimate depending on several factors including: leaf morphology of species (e.g., if a plant is 3 feet tall and 1.5 feet wide, yet leave arise among several stems or nodes along its vertical axis, does this count as 3 x 1.5 x number of vertical 'levels'?). Also plants can be patchily distributed. Oftentimes square footage is estimated using volume of herbicide sprayed a proxy for area (e.g., 1 gallon equals 400 square feet treated). This is yet another challenge to assess herbicide volume sprayed per unit patch area (since estimates are in effect self-referential) | **Numeric** |
| **Square Feet** | Area of original polygon (typically purposefully oversized when initially drawn, yet static through time | **Numeric** |
| **Pre-Treatment Density** | ((Area Treated / 100) * Square feet of patch treated) / Area of polygon | **Numeric** |
| **Species** | Scientific name of species | **Character** |

When chemical treatments are necessary, herbicide is typically deployed from 4-gallon backpack sprayers. Spray volumes at a given polygon are typically estimated immediately following treatment. Small volumes (1-16 oz) are approximated rather than measured directly, while larger volumes (>16 oz) are measured by visual assessment of volumetric unit lines on backpack sprayers. The methods are somewhat different when working with contractor crews, as under these circumstances several polygons are treated in succession, and herbicide volumes are checked only intermittently. Then, at the end of each day these estimated volumes are partitioned among polygons (10% of 4.5 gallons on patch A, 25% of 4.5 gallons on patch B, etc.).

Populations of some of the most problematic and widespread species have been treated with herbicide for up to 4 consecutive years, making them well suited for evaluating the efficacy of consistent annual herbicide treatments. For these species and sites, the volume of herbicide sprayed gives some indication whether a population size is decreasing, increasing, or static (Fig. 1A). This is an imperfect

system, as there are many factors that introduce variation, e.g., different applicators among years may be a “lighter” or “heavier” than the average, plants get missed and go to seed, sites are not treated at the same time each year, etc. Nonetheless, if treatments are highly effective in reducing total coverage of invasive plants, the signal should rise above the noise, and there should be a measurable decrease in the amount of herbicide sprayed per site.

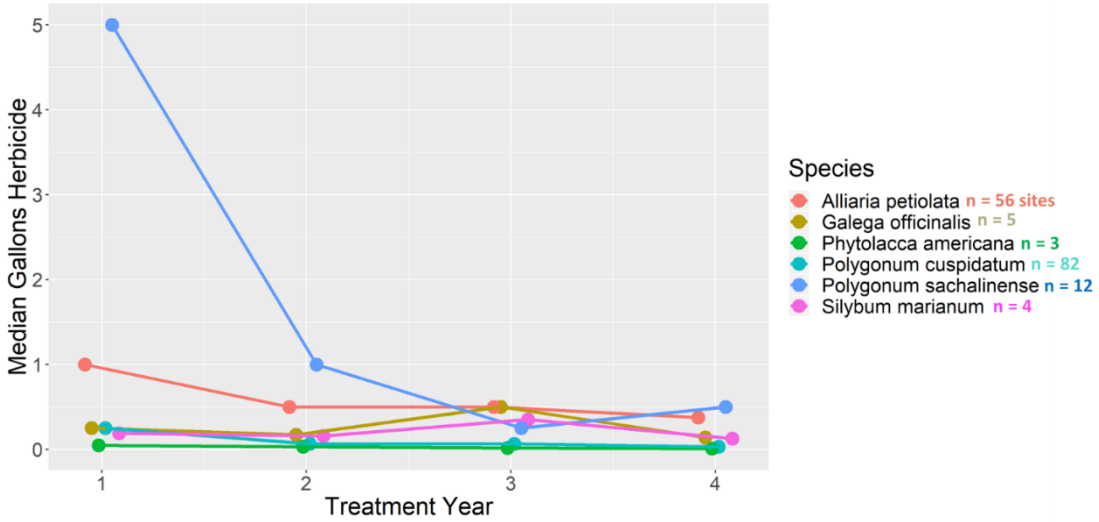



**Figure 1A** Points indicate median volume of herbicide sprayed across the multiple sites, and lines connect these same sites across years (see n-values in legend for number of sites contributing to medians). Treatment years (x-axis) are normalized according to first calendar year of treatment at that site (i.e., Treatment Year #1 could be 2010 for one site and 2012 for another site, yet they’d both be categorized as Treatment Year #1 in this figure).

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