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Vegetation Community Changes in Response to Phragmites Management at Times Beach, Buffalo, New York

Aaron N. Schad, Gary O. Dick, Kris Erickson, Paul Fuhrmann, and Lynde L. Dodd

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Abstract

Management of invasive phragmites (*Phragmites australis* [Cav.] Trin. Ex Steud.) in the United States has proven challenging over the last several decades. Various methods for control exist, but integrated approaches appear to have the most success. However, documentation of vegetation community–wide responses to these approaches remains limited.

This study monitored plant community changes at Times Beach, New York, over a five-year period. In concert with mowing and thatch removal in all areas, the study evaluated two herbicides separately and together, representing three experimental treatment areas (TAs), for control efficacy by measuring plant community structure. Phragmites was targeted for treatments, avoiding native and nonproblematic non-native species when possible, to preserve beneficial habitat during phragmites control efforts. Monitoring results showed significant drops in phragmites relative cover, relative frequency, and importance values due to integrated management, regardless of herbicide treatment, with corresponding increases in these same values for native and other plant species. This suggests that prudent removal of phragmites is compatible with beneficial plant restorative efforts to maintain and improve habitat in infested areas.

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Preface

This study was conducted for the Aquatic Plant Control Research Program (APCRP) under Funding Account Code U4351109 and AMSCO Code 099993. The APCRP is sponsored by Headquarters, US Army Corps of Engineers (HQUSACE), and is assigned to the US Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, Mississippi. The APCRP Program Manager was Dr. Linda Nelson.

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At the time of the publication of this report, COL Teresa Schlosser was the Commander of ERDC, and Dr. David W. Pittman was the Director.

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1 Introduction

Background

The Times Beach site is located within the Niagara River Area of Concern (AOC) and Niagara River Important Bird Area in Buffalo, New York, immediately adjacent to the Buffalo River AOC. Constructed as a confined disposal facility by the US Army Corps of Engineers (USACE) Buffalo District in 1971, the site was closed in 1976 after partial filling at the request of the Ornithological Society of Buffalo (Simmers and Lee 1997). The site is separated from Lake Erie by a rock berm and is composed of open water, emergent marsh, forested wetlands, and upland habitat (Figure 1). Eighteen hectares of the site are classified by the New York State Department of Environmental Conservation (NYSDEC) as a wetland BU-3 (Class I wetland); the remainder of the site consists of the NYSDEC-regulated 30 m[1] wide adjacent area, primarily uplands.

By 2011, several invasive species dominated portions of the site, including phragmites (*Phragmites australis* [Cav.] Trin. Ex Steud.), Japanese knotweed (*Fallopia japonica* [Houtt.] Ronse Decr.), common buckthorn (*Rhamnus cathartica* L.), and mugwort (*Artemisia vulgaris* L.). Phragmites occurred as the predominant invasive species across most wetland habitats but proved particularly problematic in the emergent marsh (about 5.7 ha), where it occurred in monotypic stands in some places. Other invasive species listed above occurred in colonies scattered within higher elevation areas. This special report focuses on efforts applied to the phragmites-infested marsh and resultant changes in the vegetation community in response to phragmites control.

Objective

This work evaluated vegetation community response to mechanical cutting and herbicide applications made over a five-year period for controlling invasive phragmites at Times Beach, a 22.5 ha[2] nature preserve located in

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Buffalo, New York. The work sought to replace the monotypic stands of phragmites with a more diverse assemblage of plants to improve ecosystem function.

Approach

In early 2012, the US Army Engineer Research and Development Center (ERDC), in collaboration with the USACE–Buffalo District and Ecology and Environment (E&E), developed a management and restoration plan to serve as a demonstration project for improving ecosystem function, which included removal of phragmites and other selected invasive species in combination with efforts to promote beneficial plant growth. The plan began in October 2012 with funding from the US Environmental Protection Agency's (EPA) Great Lakes Restoration Initiative (GLRI). The project was slated for 2012–2016 (Years 1–5); funds were secured for an additional year (2017) of management, but those results are not included in this report.

Figure 1. Times Beach (bordered in white) is a 22.7-hectare confined disposal facility located near the mouth of the Buffalo River in Buffalo, New York. (Photo credit: Google Earth)

Phragmites is a tall (up to 4 m), warm-season perennial grass occurring throughout the continental United States (USDA Plants Database 2018). At least 13 haplotypes have been identified in North America, 11 of which are considered nonaggressive, native varieties (Saltonstall 2002). One or more haplotypes, however, have been traced to Europe, and they are regarded as the sources of non-native, problematic infestations occurring along the Atlantic Coast, Mississippi Delta, and Great Lakes region (Meyerson and Cronin 2013; Saltonstall 2002; Chambers, Meyerson, and Saltonstall 1999; Kay 1995). Phragmites spreads by seeds, stolons, and rhizomes and is found in a variety of habitats, including freshwater wetlands (Cross and Fleming 1989; Marks, Lapin, and Randall 1994; Blossey and McCauley 2000). It also occurs commonly in areas where dredge material has been spread (Derr 2008), such as Times Beach.

Phragmites typically grows in dense stands, which may have a negative effect on many wetland plant species through competitive interactions, including excessive shading and crowding (Marks, Lapin, and Randall 1994; Blossey and McCauley 2000). Because of aggressive growth and impacts on wetlands, phragmites has become a major targeted invasive species in the United States, where more than $4.6 million was spent on phragmites control from 2005 to 2009 (Martin and Blossey 2013). Most of this spending reflected herbicide use for controlling phragmites, but other management techniques, such as cutting and burning, are also applied, alone or in conjunction with others.

A seed bank survey was conducted in 2011 in the emergent marsh area of Times Beach in preliminary work associated with, but prior to, initiation of the demonstration (Appendix A, Judy F. Shearer). Evaluating the seed bank served two purposes: identifying the presence of invasive and native species that might influence outcomes of proposed management and restoration actions and providing information on whether treatment strategies were favorable or unfavorable to the overall management and restoration plan. The seed bank survey identified 42 species of plants, including 23 native species and 19 introduced taxa. Because not all introduced species become problematic, some introduced species (16 of those identified) were deemed acceptable as members of the plant community at Times Beach. Three species were either targeted for control (phragmites) or were slated for management only if monitoring data indicated rapid, aggressive expansion over time (garlic mustard, *Alliaria petiole*; purple loosestrife, *Lythrum salicaria*).

In this demonstration, we applied annual mechanical and herbicide pressures against phragmites over a five-year period, with treatment differences in herbicides made in the second and third years. During the same time, we monitored vegetation to evaluate community changes in response to management application.

2 Materials and Methods

The 5.7 ha emergent wetland area at Times Beach was divided into three treatment areas (TAs) to permit efficacy evaluation of three different herbicide treatments conducted in Years 2 and 3 of the demonstration (2013 and 2014). TA 1, 2, and 3 were 1.9, 2.1, and 1.7 ha, respectively. Other management activities occurring at the site were similar between TAs, including mowing and thatch removal from Years 2–4 and follow-up herbicide treatments in Years 4 and 5.

Figure 2. The 5.7 ha emergent marsh portion of Times Beach was divided into three treatment areas (TAs) for evaluation of different herbicide applications during two years of the five-year project. (Photo credit: Google Earth)

Mechanical control

Mowing and thatch removal were included across the TAs to improve herbicide coverage during application and to increase opportunities for seed bank recovery at the site. The three TAs were mowed using an amphibious vehicle equipped with a tow behind mower in Years 1–3 (November 2012, 2013, and 2014). Mowing was deemed unnecessary in Years 4 and 5, with limited hand cutting occurring in Year 4. Following mowing, loaders and haul trucks removed cut material (thatch) from the site for offsite disposal.

Herbicide applications

Table 1 provides a schedule of herbicide applications at Times Beach. Per the NYSDEC, no management activities took place during the spring migratory and breeding bird seasons (April 1–August 31), which restricted vegetation management activities to later in the growing season in Years 1–3. A permit modification was acquired from NYSDEC in 2015 that allowed for late-spring applications in Years 4 and 5.

Table 1. Herbicide applications at Times Beach, New York.

Year	Month	TA1	TA2	TA3	Comments
1	---	none	none	none	
2	September	glyphosate (2%)	glyphosate & imazamox (1% & 2%)	imazamox (4%)	Site-wide foliar spray
3	September and October	glyphosate (2%)	glyphosate & imazamox (1% & 2%)	imazamox (4%)	Spot treatments foliar spray
4	September and October	glyphosate (2%)	glyphosate (2%)	glyphosate (2%)	Spot treatments foliar spray
5	July and October	glyphosate (2%)	glyphosate (2%)	glyphosate (2%)	Spot treatments foliar spray

In the fall of Year 2, following the first late-fall mow- and thatch-removal activities conducted in Year 1, initial herbicide applications were made. TA1 was treated with 2% glyphosate and 0.5% v.v. nonionic surfactant; TA2 was treated with a combination of 1% glyphosate plus 2% imazamox and 1% v.v. methylated seed oil; TA3 was treated with 4% imazamox and 1% v.v. methylated seed oil. Treatments were made by foliar application and applied using an amphibious vehicle equipped with a spray tower and boom. Because regrowth of phragmites following mowing and thatch removal was dense and widespread, large portions of the site required treatment, with exceptions near the open-water area, where cattails were avoided when possible by selectively spraying (spot-treating) phragmites colonies. A second herbicide application was made in Year 3 (following a second mow and thatch removal in late fall Year 2) on the same three TAs using the methods described above, but this application required only spot treatments of recovering patches of phragmites. Estimates indicating substantial phragmites control by Year 4 (Glomski et al. 2016) resulted in the project shifting to maintenance management of phragmites using 2% glyphosate with surfactant in all TAs in Years 4 and 5.

Vegetation community monitoring

Two permanent transects were established within each TA for vegetation community monitoring (Figure 2 and Table 2). Transects were set between the forest and emergent marsh edge and the shoreline of the open-water areas. Survey techniques were similar to Daubenmire (1959), which required field identification of plants to the lowest taxon possible and included estimates of unvegetated (bare or debris-covered) ground. Mean percent cover of all species was determined along each transect using line intercept techniques. A 1 m × 0.5 m quadrat was placed at 3 m intervals along each transect (alternating between the right and left sides) and percent cover of each species was recorded. The first (adjacent to forest) and last (adjacent to shoreline) 3 m of each transect was not evaluated. Numbers of quadrats along each transect varied from year to year, depending on water levels and position of each year's shoreline. Plants within the quadrat were identified to the lowest taxon possible, with percent cover of each visually estimated using the following cover class values: 1–5%, 6–25%, 26–50%, 51–75%, 76–95%, and 96–100%. The mean value for each cover class was used for importance value calculation and statistical analysis (that is, 2.5, 15, 37.5, 62.5, 85, and 97.5).

Table 2. Transects used for vegetation community monitoring at Times Beach 2012–2016.

Transect #	TA	Maximum length (m)	Minimum plots	Maximum plots
1	1	132	21	44
2		120	26	40
3	2	69	12	23
4		84	13	28
5	3	165	30	55
6		147	41	49

A baseline vegetation survey was conducted in Year 1 (August 2012), prior to mowing, thatch removal, and herbicide applications. Subsequent surveys were conducted in June of Years 2–5.

Data analysis

Transect survey data from within each TA were used to calculate three vegetation community structure dependent variables: (1) relative cover for each taxon (% total coverage of transect quadrats per transect, relative cover [RC]); (2) relative frequency (number of quadrats in which a taxon was identified, Relative Frequencies [RF]); and (3) importance values (sum of RC and RF, 200 maximum score). Each taxon was then assigned to one of seven vegetation groups for community structure analysis: natives (Group 1); acceptable nonnatives (Group 2); potential problem nonnatives (Group 3); purple loosestrife (Group 4); phragmites (Group 5); cattails (Group 6); and bare or debris (Group 7), with sums of taxa within a group used to calculate group RC, RF, and importance values (IV).

Vegetation community structure (RC, RF, and IV) along each transect (herein referred to as sampling site) in each TA in each sampling year was classified and ordinated with cluster analysis and nonmetric multidimensional scaling (NMDS) to assess spatial similarities and temporal trends. Annual sampling data (five years) and herbicide treatment (three levels: glyphosate, glyphosate + imazamox, and imazamox) were used to distinguish the 15 total sampling sites for similarity analysis. For all meaned transect vegetation community structure data, classification was done with cluster analysis using a Bray-Curtis similarity matrix (Jackson 1993; Clarke and Warwick 2001). Vegetation community structure data were log10 (x + 1) transformed and normalized (Jackson 1993; Heino 2000). Community groups were then delineated by ordination analysis using nonmetric multidimensional scaling (NMDS) (Kruskal 1964; Kenkel and Orloci 1986; Shin and Fong 1999). Cluster similarity dendrograms, NMDS delineations with resemblance levels, and NMDS native and phragmites bubble plots are all given. In the results and discussion section for sampling site classification and ordination, sites are coded as: herbicide—three levels (glyphosate alone, glyphosate and imazamox, and imazamox alone); labeled *G*, *GI*, and *I*; sampling date—five levels (Years 1,2,3,4,5); labeled *1*, *2*, *3*, *4*, *5*. All multivariate analyses were done using Primer 7 (Primer-E, Auckland, New Zealand).

3 Results and Discussion

During the five-year demonstration, this study identified 84 plant taxa along transects in the emergent marsh (Appendix B). Of these, 61.9% (52) were grouped as native; 30.9% (26) acceptable nonnative; 2.3% (2) potential problem nonnative; and 1.1% each for purple loosestrife, phragmites, and cattails. While mean numbers of taxa observed per transect varied from year to year, numbers were lowest in Year 1, then steadily increased in subsequent years, nearly quadrupling by Year 5 (Table 3).

Table 3. Number of plant taxa identified along transects at Times Beach, New York, in Years 1–5 (2012–2015).

Transect #	TA	Year 1	Year 2	Year 3	Year 4	Year 5
Transect 1	1 (glyphosate)	10	14	21	27	23
Transect 2		6	13	16	29	24
Transect 3	2 (glyphosate & imazamox)	4	12	15	21	15
Transect 4		5	12	13	20	18
Transect 5	3 (imazamox)	5	11	13	23	19
Transect 6		3	9	14	20	32
mean		5.5	11.8	15.3	23.3	21.8

Of the taxa that were found along transects, 26 represented 62% of those identified in the seed bank analysis conducted in 2011 (Appendices A and B). Seed bank taxa occurred in all groups (excluding bare or debris): 16 were grouped as native, 6 as acceptable nonnative, and 1 each in the other groups (potential problem nonnative, purple loosestrife, phragmites, and cattails). These occurrences indicate seed bank persistence at the site.

Cluster analysis and NMDS based on Bray-Curtis similarity matrices of the seven vegetation groups' RC identified 5 (>80%) similar location groupings of the 15 sampling sites (mean transect data for three TAs over five years; Figures 3 and 4). These RC resemblance groupings showed dissimilarities in vegetation community structure over time, highlighted by declines in phragmites. Results between the three TAs were similar in terms of relative cover, indicating no differences in herbicide efficacy, confirming the conclusions of Glomski et al. (2016) that no differences in efficacy between glyphosate, imazamox, and the combination of the two exist. The RC of other groups were similar to one another across TAs, increasing or remaining stable between Years 1–5, with the exception of bare or debris, which decreased (Appendix C). Appendix D gives the NMDS ordination of sampling sites based on vegetation relative cover with bubble plot overlay for all groups.

Figure 3. Dendrogram of 15 sampling sites (three TAs times five years) based on cluster analysis of vegetation relative cover (Bray-Curtis) similarity at Times Beach, New York (2012–2016).

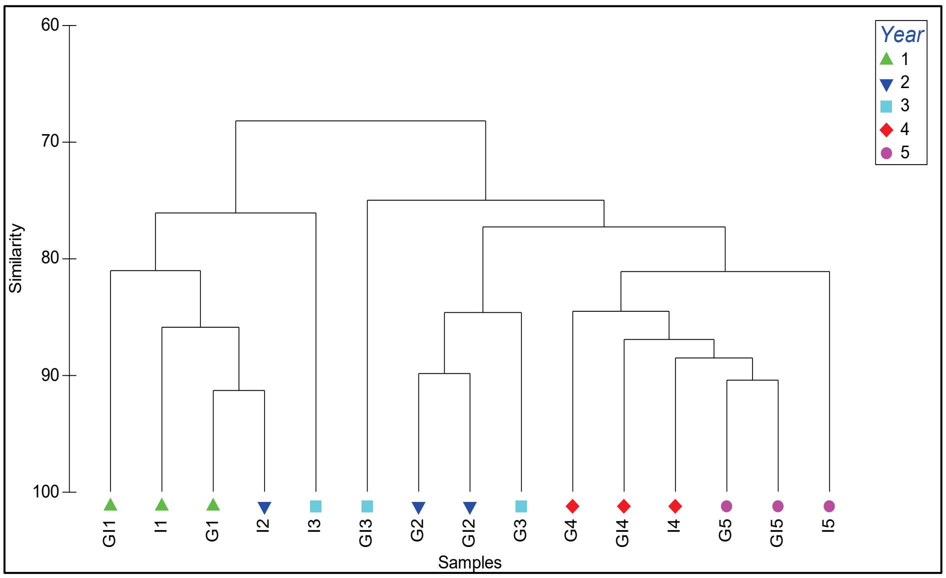
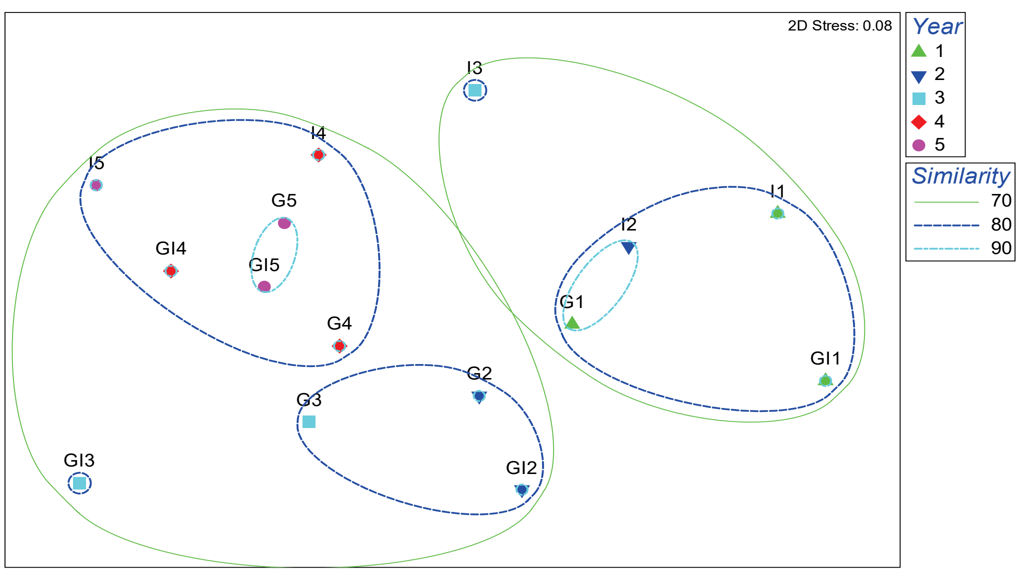


Figure 4. Relative cover of 15 sampling sites (TAs × year) at Times Beach, New York, (2012–2016) on first two dimensions from nonmetric multidimensional scaling (NMDS). Bray-Curtis similarity of 70, 80, and 90% resemblance similarity levels are given.



Similar trends were seen in RF over time. Analysis identified 7 (>90%) similar location groupings of the 15 sampling sites (Figures 5 and 6).

Resemblance groupings of RF indicated dissimilarities between sampling years, with results between TAs similar to one another (Figure 6). Frequency of phragmites decreased over the study period, albeit to a lesser degree than that seen in RC, while other groups increased or remained stable over time.

Figure 5. Dendrogram of 15 sampling sites (three TAs times five years) based on cluster analysis of vegetation relative frequency (Bray-Curtis) similarity at Times Beach, New York (2012–2016).

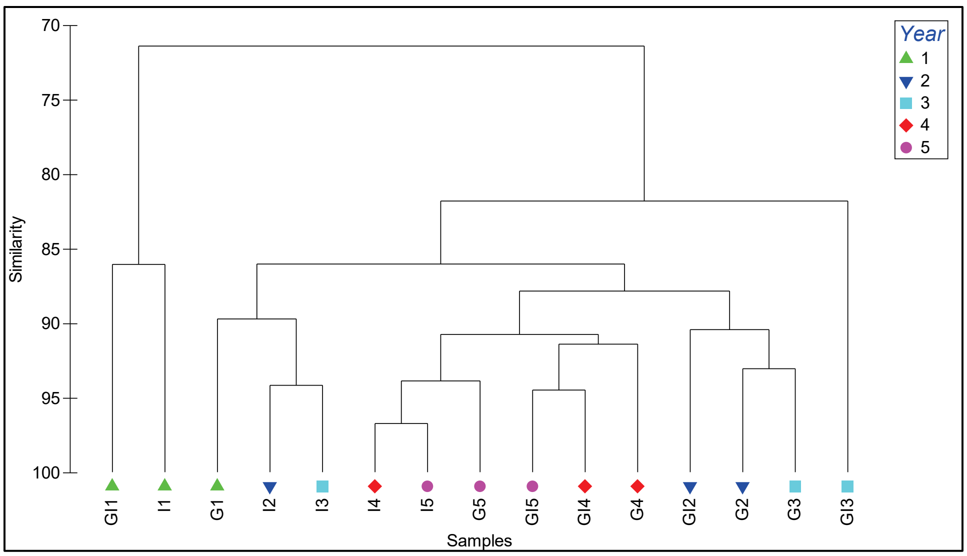
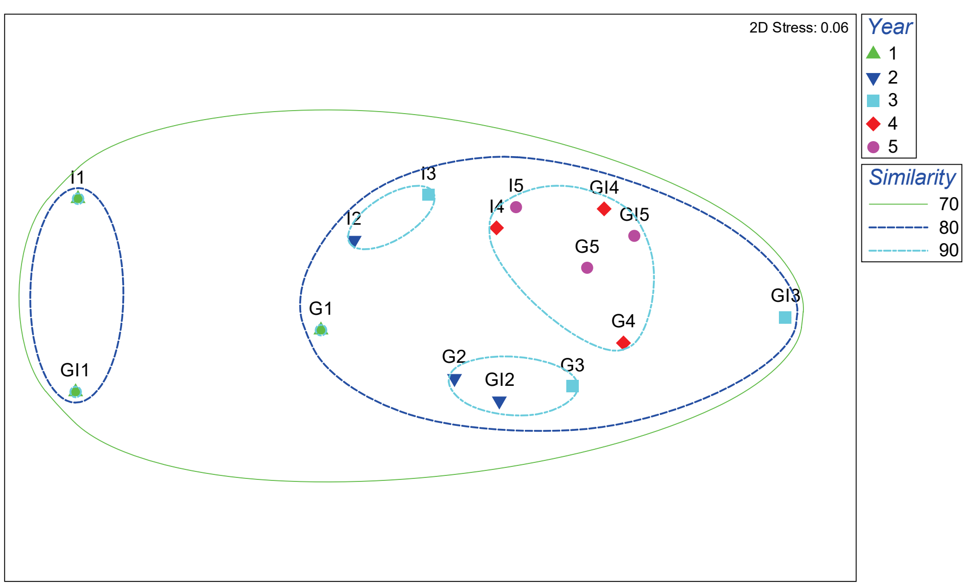


Figure 6. Relative frequency of 15 sampling sites (three TAs times five years) at Times Beach, New York, (2012–2016) on first two dimensions from NMDS. Bray-Curtis similarity of 70, 80, and 90% resemblance similarity levels are given.



Importance values (combined RC and RF) followed a similar, but stronger, trend. Analysis identified nine (>90%) similar location grouping of the 15 sampling sites (Figures 7 and 8). As in RC and RF, resemblance groupings indicated dissimilarities between sampling years due to vegetation's community structure change, primarily through decreases in phragmites and bare or debris importance and increases in other groups.

Figure 7. Dendrogram of 15 sampling sites (three TAs times five years) based on cluster analysis of vegetation importance value (Bray-Curtis) similarity at Times Beach, New York (2012–2016).

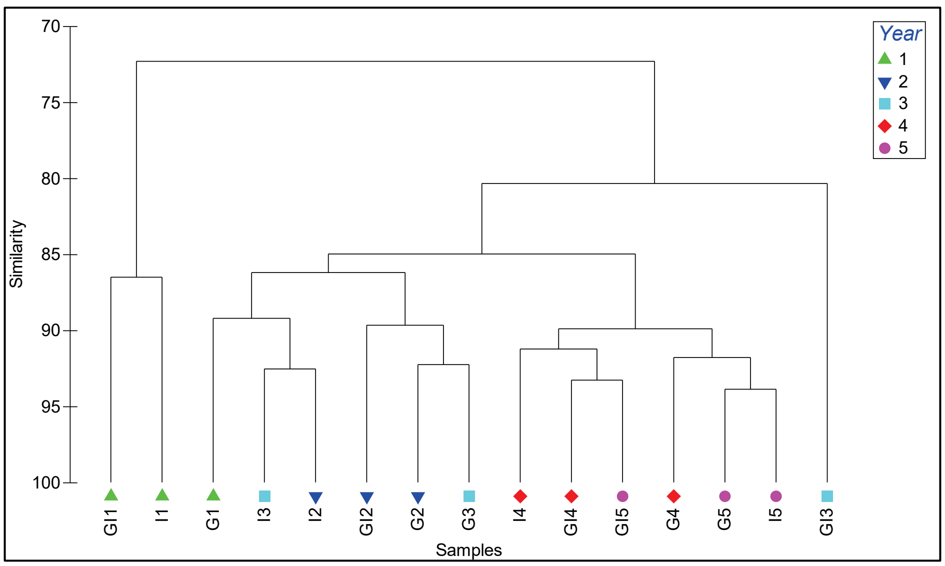
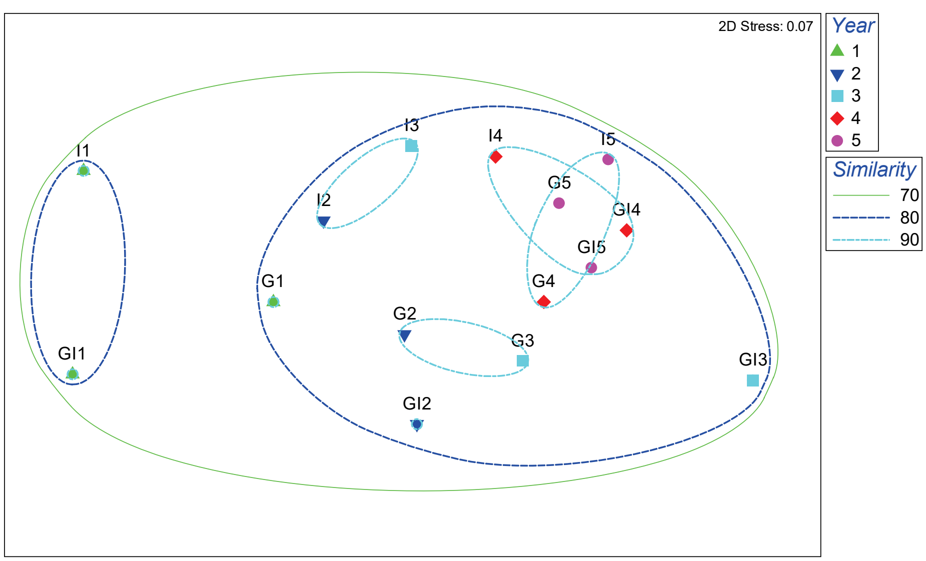
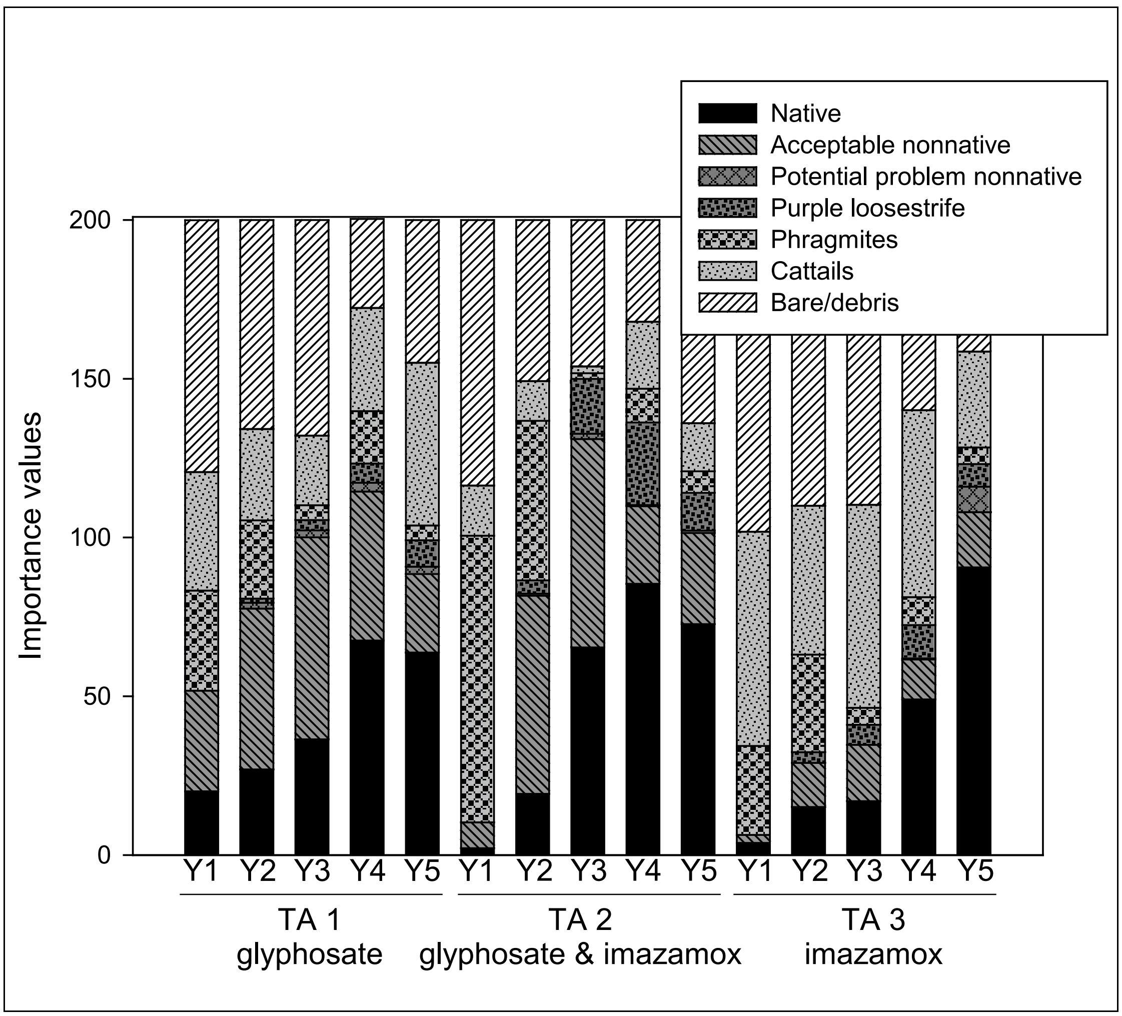


Figure 8. Importance Values of 15 sampling sites (three TAs times five years) on first two dimensions from NMDS. Bray-Curtis similarity of 70, 80, and 90% resemblance similarity levels are given.



Although unmanaged control plots were not used in the project, the results seem to suggest that management targeted at phragmites was the main effector of vegetation community changes, with herbicides having the greatest impact. Year 1 mowing and thatch removal moderately reduced phragmites across the three TAs in Year 2, from an average of 49.9 IV to 35.2 IV, but the greatest phragmites decline was recorded in Year 3, following Year 2 herbicide applications (from an average of 35.2 IV to 3.9 IV; Figure 9). Continued mowing and thatch removal coupled with herbicide suppression in subsequent years resulted in an average of 5.5 IV (and corresponding 1.2% RC, Appendix C) by Year 5.

Figure 9. Importance values (IV) for seven groups of vegetation identified along transects over a five-year period at Times Beach, New York. Year 1 was baseline.



Dense stands of phragmites are reported to suppress seed germination, and their removal can release limits on light, temperature, nutrients, and other factors required for the germination and growth of many plant species (Blossey and McCauley 2000). This change appeared to have occurred at Times Beach concurrently with reduction of phragmites at Times Beach. Figure 9 shows general trends in IV for groups of vegetation assigned in the demonstration. Bare or debris IV, along with phragmites, declined between Year 1 and Year 5, while other groups either increased (most notably native) or remained stable (most notably cattails). Project goals were met through replacement of most phragmites originally present with native and acceptable non-native plants (Figure 10). However, several groups, including purple loosestrife and potential problematic nonnatives, also increased, indicating that long-term management of the site may require not only continued suppression of phragmites but other invasive species as well.

Figure 10. Times Beach phragmites infestation in fall 2012 (top), prior to management, and in fall 2017 (bottom) following five years of management. (Photo credit: Gary Dick)

References

Blossey, B., and J. McCauley. 2000. A plan for developing biological control of *Phragmites australis* in North America. *Wetland J*. 12:23-28.

Chambers, R. M., L. A. Meyerson, and K. Saltonstall. 1999. Expansion of *Phragmites australis* into tidal wetlands of North America. *Aquat. Bot*. 64:261-273.

Clarke K. R. and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation. 2nd ed. Primer-E: Plymouth.

Cross, D. H., and K. L. Fleming. 1989. Control of phragmites or common reed. US Fish and Wildlife Leaflet 13.4.12. Washington, D.C.: US Department of the Interior, Fish and Wildlife Service. 5 pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Sci*. 33(1):43-64.

Derr, J. F. 2008. Common reed (*Phragmites australis*) response to mowing and herbicide application. *Invasive Plant Sci. Manage*. 1:12-16.

Glomski, L. M., J. F. Shearer, G. O. Dick, K. Erickson, and P. Fuhrmann. 2016. *Phragmites Management at Times Beach, Buffalo, NY*. APCRP Technical Notes Collection. ERDC/TN APCRP-CC-20. Vicksburg, MS: US Army Engineer Research and Development Center. http://ed.erdc.usace.army.mil/aqua/

Heino, J. 2000. “Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry.” *Hydrobiologia* 418:229-242.

Jackson, D. 1993. “Multivariate analysis of benthic invertebrate communities: the implication of choosing particular data standardizations, measures of association, and ordination methods.” *Hydrobiologia* 268:9-26.

Kay, S. 1995. Efficacy of wipe-on applications of glyphosate and imazapyr on common reed in aquatic sites. *J. Aquat. Plant Manage*. 33:25-26.

Kenkel, N. C., and L. Orloci L. 1986. “Applying metric and nonmetric multidimensional scaling to ecological studies: some new results.” *Ecology* 67:919-928.

Kruskal, J. B. 1964. “Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis.” *Psychometrika* 29:1-27.

Marks, M., B. Lapin, and J. Randall. 1994. *Phragmites australis* (*P. communis*): Threats, management and monitoring. *Nat. Areas J*. 14:285-294.

Martin, L. J., and B. Blossey. 2013. The runaway weed: costs and failures of *Phragmites australis* management in the USA. *Estuar. Coast*. 36:626-632.

Meyerson, L. A., and J. T. Cronin. 2013. Biol. Invasions (2013) 15: 2605. https://doi.org/10.1007/s10530-013-0491-2

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *PNAS* 99:2445-2449.

Shin, P. K. S., and K. Y. S. Fong. 1999. “Multiple discriminant analysis of marine sediment data.” *Marine Pollution Bulletin* 39:285-294.

Simmers, J. W., and C. R. Lee. 1997. Long-term evaluation of Times Beach Confined Disposal Facility, Buffalo, New York; An update. Environmental Effects of Dredging Technical Notes EEDP-02-21. US Army Engineer Waterways Experiment Station, Vicksburg, MS. http://el.erdc.usace.army.mil/dots/pdfs/eedp02-21.pdf

USDA Plant Database. 2018. https://plants.usda.gov/core/profile?symbol=PHAU7. Accessed March 2, 2018.

Appendix A: Times Beach Seed Bank Species Data Collected in 2011

Scientific Name	Common Name	Native (N) or Introduced (I)
Alliaria petiolata (M. Bieb.) Cavara & Grande	Garlic mustard	I
Althaea officinalis L.	Common marshmallow	I
Barbarea vulgaris W. T. Aiton	Yellow rocket	I
Carex spp.	Sedge	N
Chenopodium album L.	Lambsquarters	I
Chenopodium glaucum L. var. *glaucum*	Oakleaf goosefoot	I
Cirsium arvense (L.) Scop.	Canada thistle	I
Cyperus diandrus Torr	Umbrella flatsedge	N
Cyperus erythrorhizos Muhl.	Redroot flatsedge	N
Cyperus esculentus L. var. *leptostachyus*	Yellow nutsedge	I
Cyperus strigosus L.	Straw colored flatsedge	N
Eleocharis acicularis (L. Roem and Schult. var. *acicularis)*	Needle spikerush	N
Erechtites hieracifolia (L.) Raf. Ex DC. var. *hieracifolia*	American burnweed	N
Eupatorium perfoliatum L.	Common boneset	N
Eurybia divaricate (L.) G.L. Nesom	Wood aster	N
Leersia oryzoides (L.) Sw.	Rice cutgrass	N
Lindernia dubia (L.) Pennell var. *dubia*	Yellowseed false pimpernel	N
Lycopus uniflorus Michx.	Northern bugleweed	N
Lythrum salicaria L.	Purple loosestrife	I
Medicago lupulina L.	Black medick	I
Mentha arvensis L.	Wild mint	I
Mimulus ringens L. var. *ringens*	Allegheny monkeyflower	N
Panicum capillare L. ssp. *capillare*	Witchgrass	N
Persicaria hydropiperoides (Michx.) Small	Swamp smartweed	N
Persicaria lapathifolia (L.) Gray	Pale smartweed	I
Phalaris arundinacea L.	Reed canarygrass	N
Phragmites australis Trin. X Steud. ssp. *australis*	Common reed	I
Populus deltoides Bartram ex Marsh. ssp. *deltoides*	Eastern cottonwood	N
Portulaca oleracea L.	Common purslane	I
Raphanus raphanistrum L.	Wild radish	I
Rhus typhina L.	Staghorn sumac	N
Salix nigra Marsh.	Black willow	N
Schoenoplectus tabernaemontani (C. C. Gmel.) Palla	Softstem bulrush	N
Solanum ptycanthum Dunal	Black nightshade	I
Solidago altissima L.	Canada goldenrod	N
Typha sp.	Cattail	N
Urtica dioica L. ssp. *dioica*	Stinging nettle	I
Verbascum blattaria L.	Moth mullein	I
Verbascum thapsus L.	Common mullein	I
Verbena bracteata Cav. Ex Log. & Ridr	Bigbract verbena	I

Scientific Name	Common Name	Native (N) or Introduced (I)
Verbena hastata L. var. *hastata*	Swamp verbena	N
Verbena urticifolia L.	White vervain	N

Appendix B: Vegetation Species and Groupings Identified Along Six Transects at Times Beach between 2012 and 2016

Scientific Name	Common Name	Present in seed bank analysis
Group 1 (native)		
Acer sp.	Maple	N
Achillea millefolium	Common yarrow	N
Alisma subcordatum	American water plantain	N
Bidens sp.	Beggarticks	N
Brassica sp.	Mustard	N
Carex lurida	Shallow sedge	N
Carex scoparia	Broom sedge	N
Carex sp.	Sedge	Y
Cephalanthus occidentalis	Common buttonbush	N
Chenopodium sp.	Goosefoot	Y
Cirsium sp.	Thistle	Y
Conyza canadensis	Canadian horseweed	N
Cyperus sp.	Flatsedge	Y
Eleocharis obtusa	Blunt spikerush	N
Eleocharis sp.	Spike rush	Y
Epilobium sp.	Willow herb	N
Equisetum arvense	Field horsetail	N
Equisetum scirpoides	Dwarf scouring rush	N
Equisetum sp.	Horsetail	N
Galium aparine	Bedstraw	N
Impatiens capensis	Jewelweed	N
Juncus canadensis	Canadian rush	N
Juncus effusus	Common rush	N
Juncus sp.	Rush	N
Juncus tenuis	Poverty rush	N
Leersia oryzoides	Rice cut grass	Y
Lemna minor	Duckweed	N
Lindernia dubia	Yellowseed false pimpernel	Y
Lycopus uniflorus	Northern bugleweed	Y
Lycopus virginicus	Virginia bugleweed	N
Lysimachia sp.	Loosestrife	N
Morella pensylvanica	Northern bayberry	N
Oxalis sp.	Wood sorrel	N
Parthenocissus quinquefolia	Poison ivy	N
Penstemon pallidus	Eastern white beardtongue	N

Scientific Name	Common Name	Present in seed bank analysis
Persicaria hydropiperoides	Swamp smartweed	Y
Persicaria lapathifolia	Curlytop knotweed	Y
Persicaria spp.2	Smartweed/knotweed	N
Phalaris arundinacea	Reed canarygrass	Y
Populus deltoides	Eastern cottonwood	Y
Potentilla sp.	Cinquefoil	N
Salix interior	Sandbar willow	Y
Schoenoplectus sp.	Bulrush	N
Schoenoplectus americanus	Chairmaker's bulrush	N
Schoenoplectus pungens	Common threesquare	N
Schoenoplectus tabernaemontani	Softstem bulrush	Y
Scirpus atrovirens	Green bulrush	N
Scirpus sp.	Bulrush	N
Scutellaria sp.	Skullcap	N
Solidago sp.	Goldenrod	Y
Verbena hastata	Blue vervain	Y
Vernonia fasciculata	Prairie ironweed	N

Group 2 (acceptable nonnative)

Allium sativum	Garlic	N
Barbarea vulgaris	Common winter cress	Y
Brassica nigra	Black mustard	N
Capsella bursa-pastoris	Shepherd's purse	N
Cirsium arvense	Canada thistle	Y
Cyperus esculentus	Yellow nutsedge	Y
Daucus carota	Queen Anne's lace	N
Echinochloa crus-galli	Barnyard grass	N
Epilobium hirsutum	Codlins and cream	N
Hypericum perforatum	Common St. John's wort	N
Lactuca serriola	Prickly lettuce	N
Linaria vulgaris	Yellow toadflax	N
Lolium perenne	Perennial ryegrass	N
Melilotus officinalis	Sweetclover	N
Mentha arvensis	Wild mint	Y
Nepeta cataria	Catnip	N
Raphanus raphanistrum	Wild radish	Y
Rumex crispus	Curly dock	N
Sinapis arvensis	Field mustard	N
Sonchus arvensis	Field sowthistle	N
Taraxacum officinale	Common dandelion	N
Thlaspi arvense	Field pennycress	N
Trifolium repens	White clover	N

Scientific Name	Common Name	Present in seed bank analysis
Urtica dioica	Stinging nettle	N
Verbascum blattaria	Moth mullein	Y
Veronica sp.	Speedwell	N

Group 3 (Potential problem nonnative)

Alliaria petiolata	Garlic mustard	Y
Artemisia vulgaris	Mugwort	N

Group 4 (purple loosestrife)

Lythrum salicaria	Purple loosestrife	Y

Group 5 (phragmites)

Phragmites australis	Common reed	Y

Group 6 (cattails)

Typha sp.	Cattail	Y

Group 7 (bare or debris)

N/A	Bare/debris	N/A

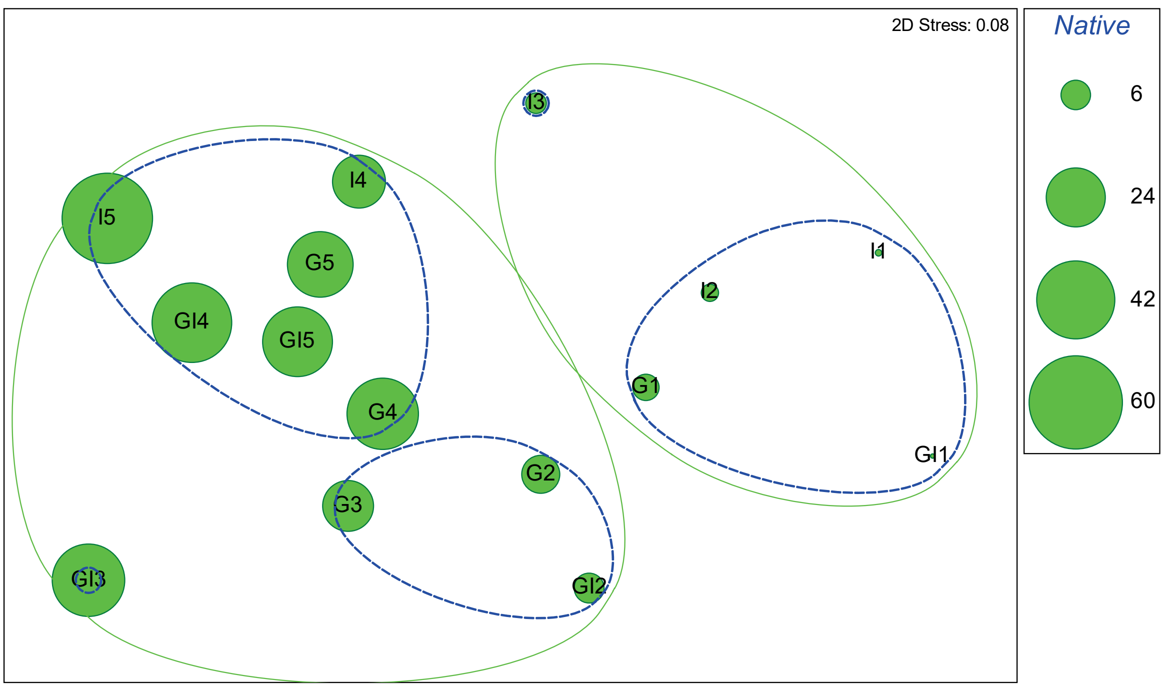
Appendix C: Relative Cover, Relative Frequency, and Importance Value Calculated for Vegetation Transects in Three Treatment Areas (TAs) at Times Beach, New York

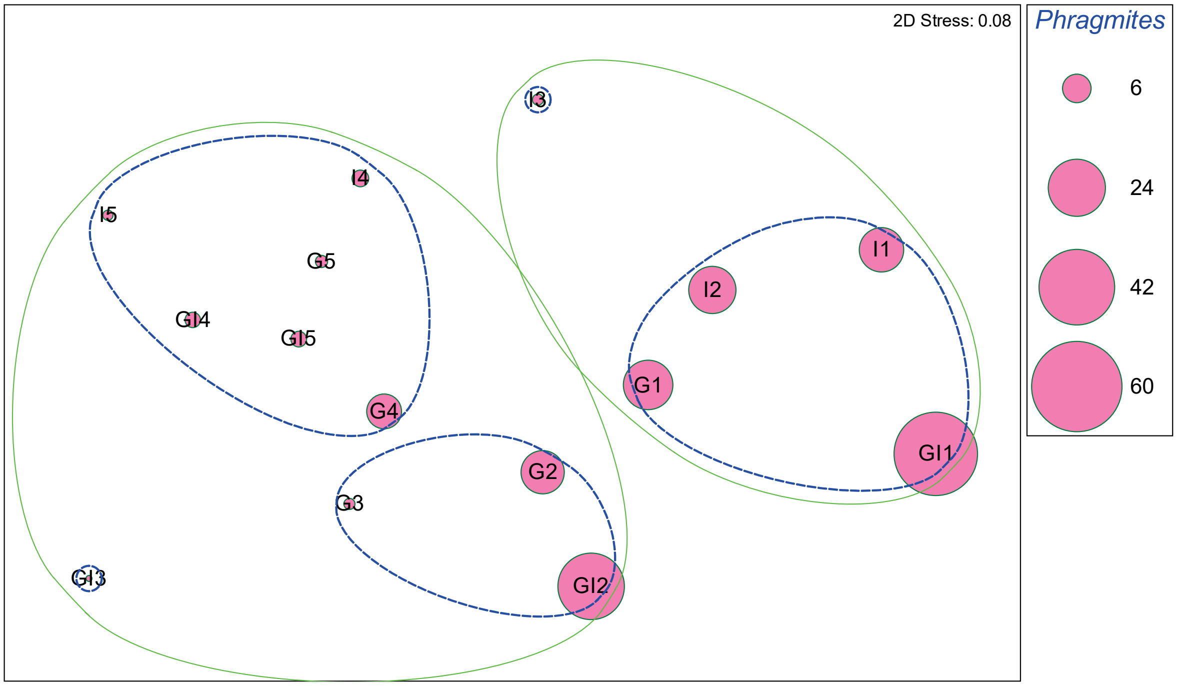
Treatment Area 1 (glyphosate)						
Metric	Group	Mean ± Standard Error				
		Year 1	Year 2	Year 3	Year 4	Year 5
Cover	Native	4.8 ± 0.3	10.0 ± 0.7	17.8 ± 2.9	35.2 ± 4.0	29.7 ± 9.0
	Acceptable nonnative	7.7 ± 4.3	17.5 ± 0.3	20.4 ± 0.6	15.0 ± 3.7	7.6 ± 1.6
	Potential problem nonnative	0.0 ± 0.0	0.4 ± 0.2	0.7 ± 0.7	0.4 ± 0.2	0.2 ± 0.1
	Purple loosestrife	0.0 ± 0.0	0.1 ± 0.1	0.4 ± 0.2	1.3 ± 0.3	1.6 ± 0.0
	Phragmites	18.0 ± 1.9	13.8 ± 4.7	0.9 ± 0.0	8.9 ± 3.6	1.1 ± 0.6
	Cattails	19.2 ± 0.9	14.2 ± 0.2	10.9 ± 7.0	25.4 ± 5.2	36.0 ± 1.1
	Bare/debris	50.3 ± 5.6	44.1 ± 5.4	48.8 ± 8.5	13.9 ± 2.4	23.7 ± 7.0
Freq	Native	15.3 ± 1.4	17.0 ± 1.8	18.6 ± 1.6	36.4 ± 3.5	34.1 ± 6.7
	Acceptable nonnative	24.0 ± 5.4	33.1 ± 1.6	43.2 ± 0.7	36.3 ± 9.9	17.2 ± 2.4
	Potential problem nonnative	0.0 ± 0.0	1.4 ± 0.6	1.5 ± 1.5	2.4 ± 1.7	2.1 ± 0.4
	Purple loosestrife	0.0 ± 0.0	1.2 ± 0.5	2.9 ± 1.1	4.8 ± 0.4	6.7 ± 0.5
	Phragmites	13.5 ± 0.7	10.9 ± 0.1	3.7 ± 0.2	7.6 ± 0.6	3.6 ± 0.8
	Cattails	18.2 ± 3.9	14.6 ± 0.2	11.0 ± 3.6	7.1 ± 1.4	15.2 ± 1.6
	Bare/debris	29.0 ± 3.6	21.8 ± 0.3	19.1 ± 0.2	14.1 ± 0.8	21.2 ± 3.3
Importance	Native	20.1 ± 1.6	27.0 ± 1.1	36.4 ± 1.3	67.6 ± 4.7	63.8 ± 15.7
	Acceptable nonnative	31.7 ± 9.6	50.7 ± 1.3	63.6 ± 0.1	46.9 ± 9.1	24.8 ± 4.0
	Potential problem nonnative	0.0 ± 0.0	1.8 ± 0.4	2.2 ± 2.2	2.7 ± 2.0	2.3 ± 0.5
	Purple loosestrife	0.0 ± 0.0	1.3 ± 0.6	3.3 ± 1.3	6.1 ± 0.7	8.3 ± 0.5
	Phragmites	31.5 ± 2.7	24.6 ± 4.8	4.6 ± 0.2	16.5 ± 3.0	4.6 ± 1.4
	Cattails	37.4 ± 4.8	28.8 ± 0.0	21.9 ± 10.6	32.5 ± 6.6	51.2 ± 2.7
	Bare/debris	79.3 ± 9.2	65.8 ± 5.1	67.9 ± 8.3	28.0 ± 1.6	45.0 ± 10.3

Treatment Area 2 (glyphosate & imazamox)						
Metric	Group	Mean ± Standard Error				
		Year 1	Year 2	Year 3	Year 4	Year 5
Cover	Native	0.1 ± 0.1	6.2 ± 2.6	36.2 ± 0.3	43.7 ± 2.8	33.6 ± 5.4
	Acceptable nonnative	1.3 ± 0.1	24.6 ± 6.0	23.8 ± 5.6	8.6 ± 4.0	7.3 ± 3.6
	Potential problem nonnative	0.0 ± 0.0	0.2 ± 0.2	0.5 ± 0.5	0.0 ± 0.0	0.1 ± 0.1
	Purple loosestrife	0.0 ± 0.0	0.4 ± 0.1	6.7 ± 1.9	15.5 ± 10.7	2.9 ± 1.9
	Phragmites	51.1 ± 0.6	32.5 ± 3.8	0.3 ± 0.1	1.7 ± 0.1	1.8 ± 0.2
	Cattails	6.1 ± 2.0	6.2 ± 1.6	0.5 ± 0.5	14.4 ± 13.6	10.6 ± 10.6
	Bare/debris	41.4 ± 2.6	30.0 ± 8.9	32.0 ± 7.8	16.1 ± 1.8	43.7 ± 21.3
Freq	Native	2.0 ± 2.0	13.1 ± 0.9	29.2 ± 3.4	41.7 ± 2.6	39.2 ± 4.1
	Acceptable nonnative	6.9 ± 1.3	37.8 ± 4.5	41.8 ± 3.4	15.9 ± 1.8	21.5 ± 2.6
	Potential problem nonnative	0.0 ± 0.0	0.4 ± 0.4	1.2 ± 1.2	0.3 ± 0.3	0.7 ± 0.7
	Purple loosestrife	0.0 ± 0.0	3.9 ± 1.4	10.7 ± 1.0	10.5 ± 0.9	9.0 ± 0.5
	Phragmites	39.2 ± 2.5	17.8 ± 1.5	1.5 ± 0.2	8.9 ± 0.1	4.9 ± 0.9
	Cattails	9.6 ± 1.5	6.3 ± 1.0	1.6 ± 1.6	6.7 ± 2.9	4.5 ± 4.5
	Bare/debris	42.3 ± 0.6	20.8 ± 2.1	14.1 ± 0.7	15.9 ± 2.0	20.3 ± 2.7
Importance	Native	2.2 ± 2.2	19.3 ± 3.5	65.4 ± 3.7	85.4 ± 0.2	72.7 ± 1.3
	Acceptable nonnative	8.1 ± 1.2	62.4 ± 10.5	65.6 ± 2.2	24.5 ± 5.8	28.7 ± 6.2
	Potential problem nonnative	0.0 ± 0.0	0.6 ± 0.6	1.6 ± 1.6	0.4 ± 0.4	0.8 ± 0.8
	Purple loosestrife	0.0 ± 0.0	4.2 ± 1.6	17.3 ± 2.8	26.0 ± 11.6	11.9 ± 1.4
	Phragmites	90.3 ± 3.1	50.2 ± 2.3	1.8 ± 0.3	10.7 ± 0.1	6.7 ± 0.7
	Cattails	15.8 ± 3.4	12.5 ± 2.6	2.1 ± 2.1	21.1 ± 16.5	15.2 ± 15.2
	Bare/debris	83.6 ± 3.2	50.7 ± 11.0	46.1 ± 8.5	32.0 ± 0.2	64.0 ± 24.0

Treatment Area 3 (imazamox)						
Metric	Group	Mean ± Standard Error				
		Year 1	Year 2	Year 3	Year 4	Year 5
Cover	Native	0.3 ± 0.0	2.1 ± 0.1	2.9 ± 0.5	19.3 ± 0.8	56.4 ± 22.1
	Acceptable nonnative	0.3 ± 0.3	2.3 ± 1.5	1.5 ± 0.9	2.4 ± 0.5	4.0 ± 1.0
	Potential problem nonnative	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	7.8 ± 7.8
	Purple loosestrife	0.0 ± 0.0	0.4 ± 0.4	1.7 ± 1.3	5.1 ± 4.6	1.7 ± 1.7
	Phragmites	14.5 ± 12.1	16.4 ± 10.3	0.9 ± 0.3	2.1 ± 0.2	0.8 ± 0.5
	Cattails	29.8 ± 10.8	20.9 ± 2.6	36.8 ± 8.2	38.5 ± 5.3	11.8 ± 11.3
	Bare/debris	55.2 ± 1.6	58.0 ± 9.6	56.2 ± 6.2	32.5 ± 1.1	17.5 ± 17.3
Freq	Native	3.5 ± 0.3	13.1 ± 0.7	14.0 ± 0.2	29.7 ± 2.2	34.2 ± 7.2
	Acceptable nonnative	2.3 ± 2.3	11.7 ± 7.3	16.2 ± 7.5	19.1 ± 11.0	13.4 ± 2.5
	Potential problem nonnative	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3	0.3 ± 0.3
	Purple loosestrife	0.0 ± 0.0	2.9 ± 2.9	4.7 ± 3.1	5.4 ± 2.0	5.4 ± 1.7
	Phragmites	13.6 ± 6.0	14.4 ± 2.0	4.4 ± 1.1	6.8 ± 0.6	4.5 ± 0.2
	Cattails	37.7 ± 6.9	26.0 ± 7.7	27.1 ± 3.9	20.3 ± 2.5	18.4 ± 4.3
	Bare/debris	43.0 ± 1.6	32.0 ± 5.2	33.5 ± 5.4	27.4 ± 3.5	23.9 ± 2.0
Importance	Native	3.8 ± 0.2	15.1 ± 0.6	17.0 ± 0.7	49.0 ± 1.4	90.6 ± 14.9
	Acceptable nonnative	2.5 ± 2.5	13.9 ± 8.8	17.7 ± 8.4	12.6 ± 2.6	17.4 ± 3.4
	Potential problem nonnative	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3	8.0 ± 8.0
	Purple loosestrife	0.0 ± 0.0	3.4 ± 3.4	6.3 ± 4.4	10.5 ± 6.6	7.1 ± 3.4
	Phragmites	28.1 ± 18.1	30.7 ± 12.3	5.3 ± 0.9	8.8 ± 0.8	5.2 ± 0.7
	Cattails	67.5 ± 17.6	46.8 ± 10.3	63.9 ± 12.1	58.9 ± 7.8	30.2 ± 7.0
	Bare/debris	98.2 ± 3.2	90.0 ± 14.8	89.7 ± 0.9	59.9 ± 2.4	41.4 ± 15.3

Appendix D: Nonmetric Multidimensional Scaling (NMDS) Ordination of Sampling Sites Based on Vegetation Relative Cover with Bubble Plot Overlay Showing Mean Vegetation Cover Class at Each Sampling Location

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Phragmites
6
24
42
60
I3
I4
I5
G5
GI4
GI5
G4
G3
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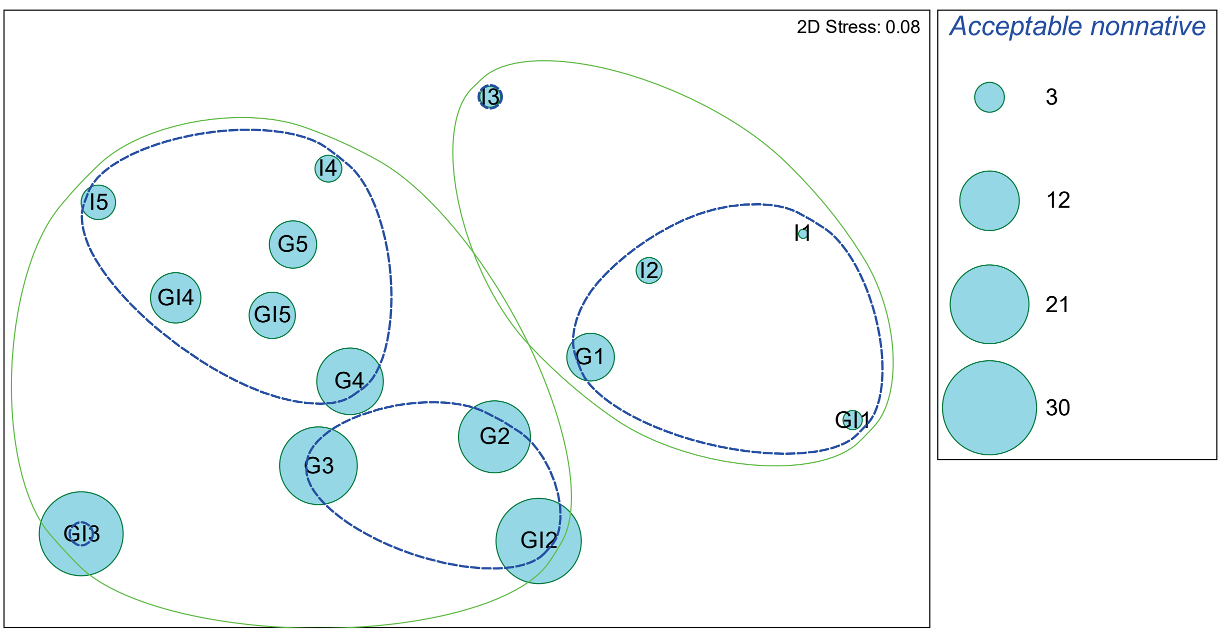
I1
I2
G1
GI1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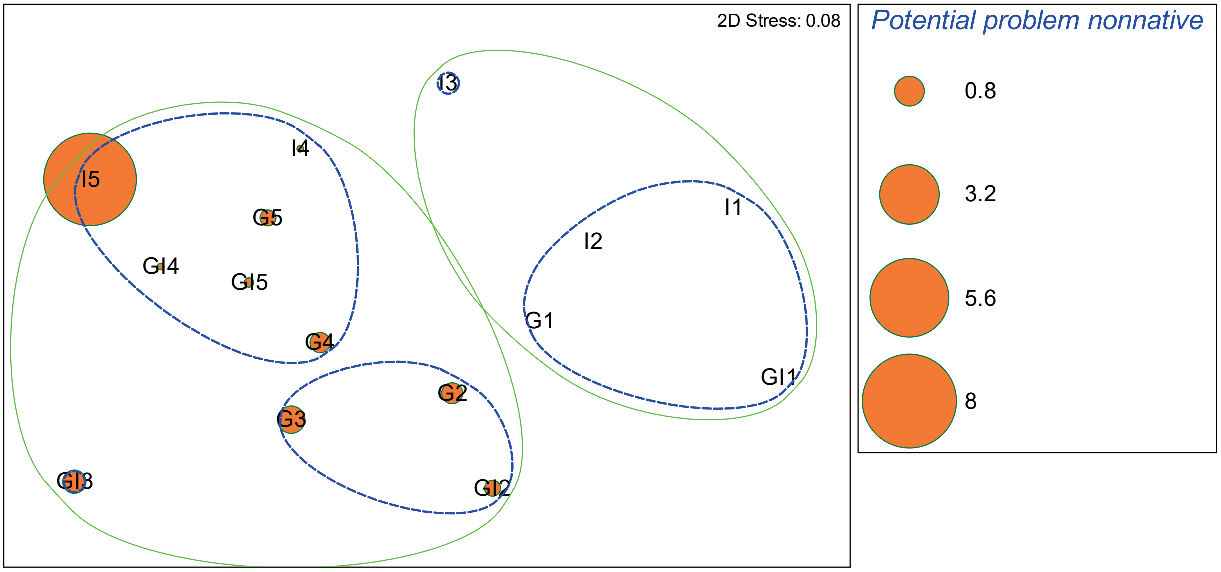
Acceptable nonnative
3
12
21
30
I3
I4
I5
G5
GI4
GI5
G4
G3
G2
GI2
GI3
I1
I2
G1
GI1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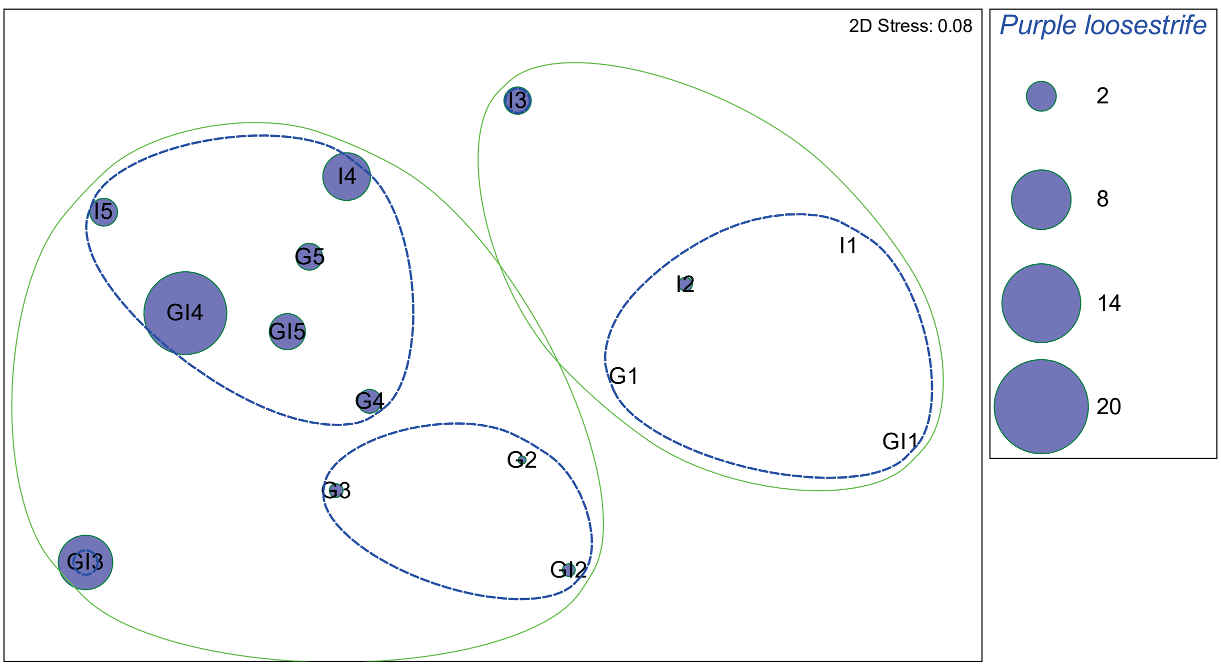
Potential problem nonnative
0.8
3.2
5.6
8
I3
I4
I5
G5
GI4
GI5
G4
G2
G3
GI3
GI2
I1
I2
G1
GI1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Purple loosestrife
2
8
14
20
I3
I4
I5
G5
GI4
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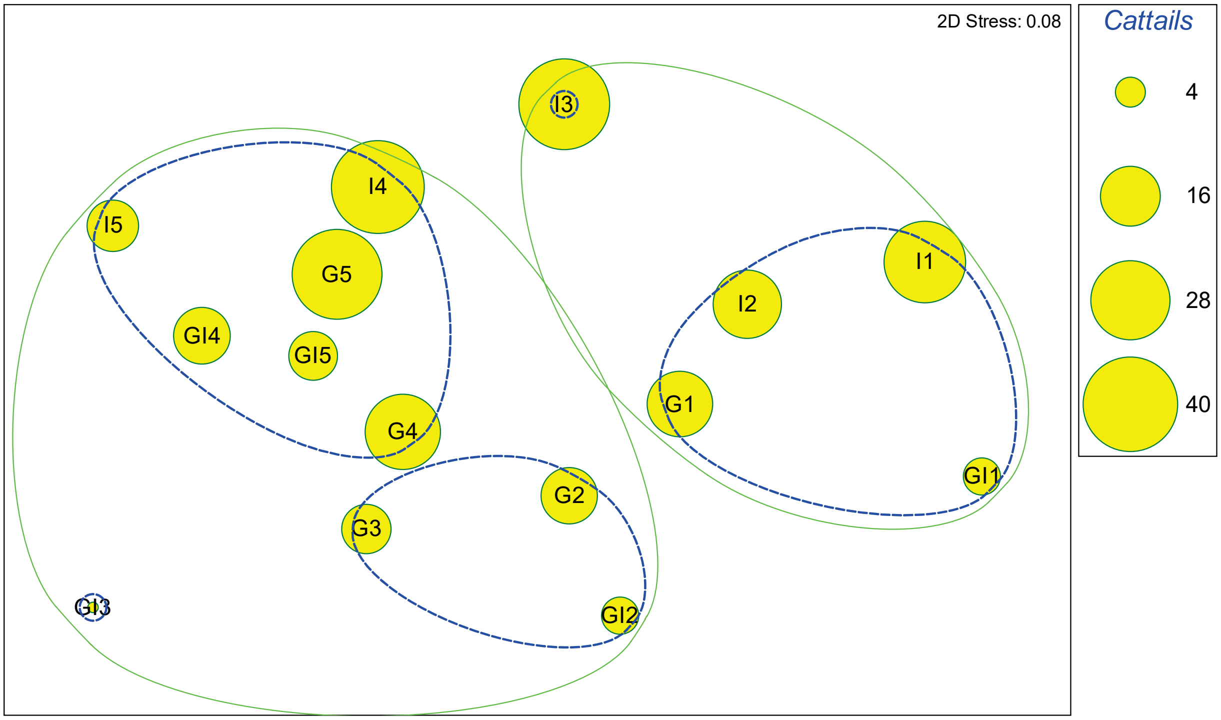
G2
G3
GI3
GI2
I1
I2
G1
GI1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Cattails
4
16
28
40
I3
I4
I5
G5
GI4
GI5
G4
I1
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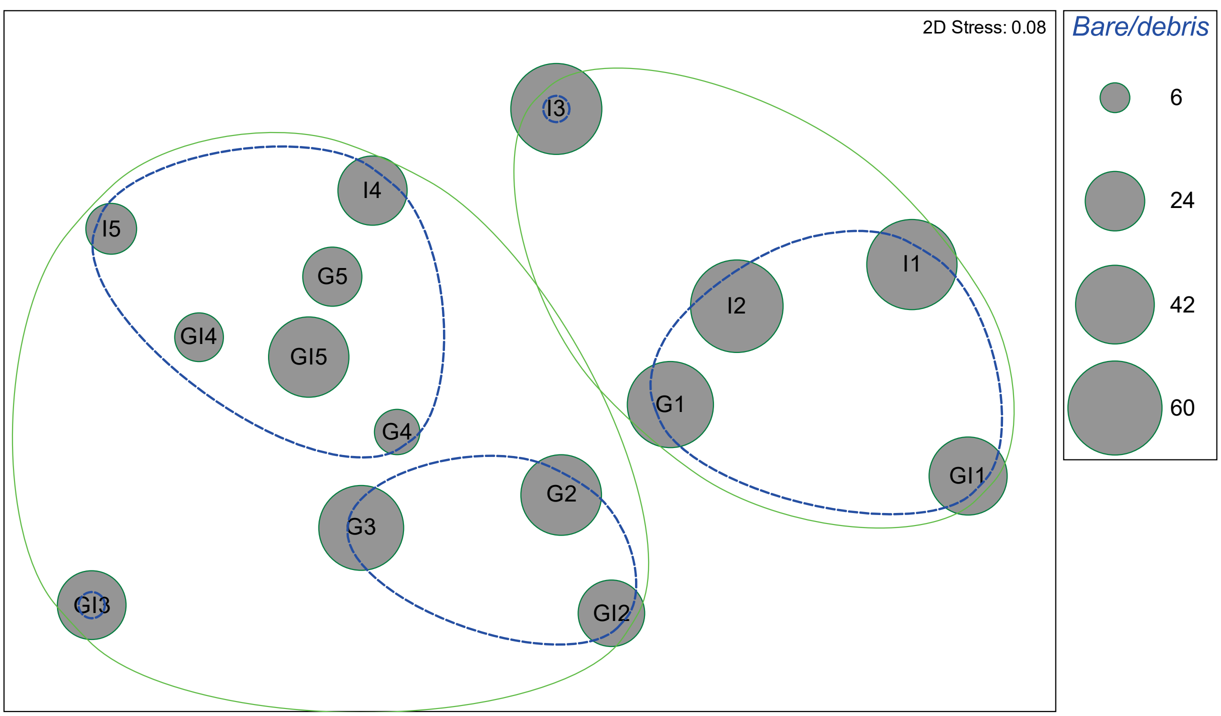
G2
G3
GI2
GI3


2D Stress: 0.08
Bare/debris
6
24
42
60
I3
I4
I5
G5
GI4
GI5
G4
I1
I2
G1
GI1
G2
G3
GI2
GI3

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14. ABSTRACT
Management of invasive phragmites (Phragmites australis [Cav.] Trin. Ex Steud.) in the United States has proven challenging over the last several decades. Various methods for control exist, but integrated approaches appear to have the most success. However, documentation of vegetation community–wide responses to these approaches remains limited.

This study monitored plant community changes at Times Beach, New York, over a five-year period. In concert with mowing and thatch removal in all areas, the study evaluated two herbicides separately and together, representing three experimental treatment areas (TAs), for control efficacy by measuring plant community structure. Phragmites was targeted for treatments, avoiding native and nonproblematic non-native species when possible, to preserve beneficial habitat during phragmites control efforts. Monitoring results showed significant drops in phragmites relative cover, relative frequency, and importance values due to integrated management, regardless of herbicide treatment, with corresponding increases in these same values for native and other plant species. This suggests that prudent removal of phragmites is compatible with beneficial plant restorative efforts to maintain and improve habitat in infested areas.

15. SUBJECT TERMS
Aquatic plants; Phragmites—Management; Beaches—Buffalo (N.Y.); Buffalo River (N.Y.)

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