TYPHA LATIFOLIA VERSUS PHRAGMITES AUSTRALIS: THE COMPETITIVE ABILITIES OF TYPHA AGAINST PHRAGMITES TO TEST WHETHER TYPHA WOULD BE A GOOD REINTRODUCTION SPECIES IN AREAS OF PHRAGMITES INVASION

By

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TYPHA LATIFOLIA VERSUS PHRAGMITES AUSTRALIS: THE COMPETITIVE ABILITIES OF TYPHA AGAINST PHRAGMITES TO TEST WHETHER TYPHA WOULD BE A GOOD REINTRODUCTION SPECIES IN AREAS OF PHRAGMITES INVASION.

ABSTRACT

Phragmites australis and *Typha latifolia* rhizomes were planted in a factorial experiment under a number of intra- and interspecific competition scenarios, two salinities and three moisture levels. *Typha* rhizome mortality was 100% and *Phragmites* rhizome mortality was 64%. *Phragmites* plants were not significantly different in final height or biomass across density, salinity or moisture treatments. *Typha* rhizomes were planted into *Phragmites* patches with five and monitored for two seasons. At Bonita Swamp all of the *Typha* rhizomes survived and sprouted. There were no clear differences in *Typha* cover, density or height between treatments. At Presque Isle all of the rhizomes in the *Phragmites* removal treatments sprouted but the rhizomes did not sprout in the plots without *Phragmites* removal At Tifft none of the *Typha* rhizomes sprouted. Also, at these three wetlands plots were monitored at the boundary between *Phragmites* and *Typha* patches and monitored for two years. Over that time little spread of the species occurred. The short duration of field observations renders conclusions difficult to make but the results do support the possibility that *Typha* rhizomes can be planted into *Phragmites* patches as part of a restoration project.

INTRODUCTION

The invasive common reed, *Phragmites australis* (Cav.) (Trin. Ex Steudel (hereafter referred to as *Phragmites*) is a perennial grass that reproduces primarily through vegetative growth, dispersal by seed is infrequent. It has spread rapidly throughout the eastern U.S. and is now increasingly abundant in both freshwater and brackish marshes and along the borders of lakes, ponds, streams and rivers. The spread is attributable to anthropogenic changes such as disturbances to wetland and riparian habitats, eutrophication, changes to hydraulic regimes, increased salinity in wetlands, and pollution (Marks et al. 1994). With an increase in nutrients, especially nitrogen, productivity of *Phragmites* increases and the ability of the species to spread is enhanced. Disturbances such as vegetation removal from construction activities also promote invasion. An example of this is highway maintenance when construction leaves areas of barren, moist soil. These areas are ideal for establishment and invasion. The spread is also attributable to the introduction of non-native genotypes from Eurasia of *Phragmites*; these non-native types have displaced the native types and expanded to regions not known to previously have had *Phragmites* (Saltonstall 2002, 2003).

Phragmites shows a high degree of adaptability to hydrological changes. *Phragmites* plants are able to increase shoot height and density with increased water depth but are also able to withstand periods of drought when water levels are far below the surface. In addition, *Phragmites* can tolerate saline conditions where native freshwater plants cannot (Galatowitsch et al. 1999, Vasquez et al. 2005). Compared to native plants *Phragmites* has an extended growing season, morphological plasticity, increased growth rates, and higher photosynthetic rates (Zedler & Kercher 2004). These traits give *Phragmites* a competitive advantage under different light, moisture and nutrient availability scenarios.

Once *Phragmites* has invaded and becomes established it can change the dynamics of the wetland areas it invades and have detrimental effects on the native flora and fauna by altering resources availability to other species. Dense *Phragmites* stands and the associated detrital accumulation combine to reduce light and air at the marsh surface. These factors inhibit establishment by other plant species and slow decomposition. The low light levels in *Phragmites* stands can delay spring thawing further reducing establishment (Meyerson et al. 2000). In invaded marshes *Phragmites* biomass is ten times higher than the native vegetation that it replaced and soil surface properties are altered by having lower soil salinity and water levels, reduced microtopographic relief, and higher redox potentials and altered patterns of nitrogen cycling (Windham & Lathrop 1999). A much reduced plant and animal diversity is generally the result of *Phragmites* invasion (Meyerson et al. 2000).

Typha latifolia L. is a rhizomatous perennial that occurs in wetlands nearly worldwide. *Typha* is found almost anywhere soil remains wet, saturated, or flooded during the growing season. It is tolerant of continuous inundation and seasonal draw-downs but it is generally restricted to areas where the water depth never exceeds 6.4 cm at establishment (Gucker 2008). *Typha* grows mostly in fresh water but also occurs in slightly brackish marshes. *Typha* is also a component of early successional wetlands with growth from seeds and extensive vegetative rhizome spread. In areas where it is native, *Typha latifolia* is potentially a good reintroduction species to replace *Phragmites* in *Phragmites* dominated freshwater wetlands. Some positive impacts of reintroducing *Typha* would be the change from a non-native dominated community to a native dominated community, increased wildlife food and cover, reduced sediment and nutrient intake into wetlands, and overall increased wetland efficiency and health (Gucker 2008). There are, however, invasive *Typha* species in the region, namely *Typha angustifolia* and *Typha x glauca* and care must be taken to exclude these species.

Springtime flooding appears to promote sprouting of *Typha* shoots from subsurface rhizomes, whereas, flooding appears to inhibit sprout emergence from *Phragmites* rhizomes (Chambers et al. 2003, Chun et al. 2009). Moderate salinity levels (18–20 ppt) negatively affects *Phragmites* establishment from rhizomes, however, mature *Phragmites* can tolerate salinity levels as high as 28-40ppt (Bart & Hartman 2002). *Typha* is less salt tolerant. Salinity experiments with rhizomes are rare, but data from an experiment using 6 month old seedlings of *Typha* varied salinity from 0 - 17.4ppm found growth decreased proportionally to increasing salinity. Salt stress on seedlings showed clear signs of vegetative tip necrosis with increasing salt concentrations (Lombardi et al. 1997).

Although there are many treatments for the control and eradication of *Phragmites* such as herbicides and mechanical controls, these must be reapplied to have any long term efficacy. With these treatments there is little mention of reintroduction of native plants that were present before *Phragmites* invasion. The reintroduction of a species, such as *Typha latifolia*, could help affected wetlands by revegetating and improving wetland functions. Since both *Phragmites* and *Typha* are rhizomatous we tested the competitive abilities of planted rhizomes, the effects of hydrology and salinity changes, and whether planting *Typha* rhizomes into *Phragmites* stands is a way to curb *Phragmites* spread.

Methods

Greenhouse Experiment

A greenhouse experiment was constructed to observe rhizome competition between *Phragmites* and *Typha*.in freshwater and brackish water. Rhizomes were collected from freshwater saturated soils. *Phragmites* rhizomes were collected from Tifft Nature Preserve, Buffalo, Erie County, NY (N 42xxxx, W 079xxxx, xxx, m asl) and *Typha* rhizomes were collected from Bonita Swamp, in Fluvanna, Chautauqua County, NY (N 0420730, W 0791709, 393 m asl) a riparian wetland located along the Chadakoin River ~0.5 km south of the outlet of Chautauqua Lake during June 2010. Tifft Nature Preserve is described in (Spiering 2009) and Bonita Swamp site is described in Blood and Titus (2009). Rhizomes 0.5-1.0 cm in diameter were cut into segments 3 cm long and contained at least one node and were weighed. Fragments <0.5cm diameter or with any sign of rot were discarded. To observe inter- and intraspecific competition under two salinity regimes and three hydrology regimes an additive series was established as follows (n=4 for each treatment):

- one *Typha* rhizome;
- one *Typha* rhizome plus one *Typha* rhizome;
- one *Typha* rhizome plus two *Typha* rhizomes;
- one *Typha* rhizome plus four *Typha* rhizomes;
- one *Typha* rhizome plus one *Phragmites* rhizome;
- one *Typha* rhizome plus two *Phragmites* rhizomes;
- one *Typha* rhizome plus four *Phragmites* rhizomes;
- one *Phragmites* rhizome;
- one *Phragmites* rhizome plus one *Phragmites* rhizomes;
- one *Phragmites* rhizome plus two *Phragmites* rhizomes.
- one *Phragmites* rhizome plus four *Phragmites* rhizomes;
- one *Phragmites* rhizome plus one *Typha* rhizomes.
- one *Phragmites* rhizome plus two *Typha* rhizomes;
- one *Phragmites* rhizome plus four *Typha* rhizomes.

The following salinity and **hydrology** treatments were established in a factorial fashion:

- fresh water and pot drainage
- fresh water and no pot drainage

- fresh water and the pot was flooded
- brackish water and pot drainage
- brackish water and no pot drainage
- brackish water and the pot was flooded

This yielded a total of 336 pots. Rhizomes were configured so the single target rhizome was planted in the center of the 10.16 cm diameter pot surrounded by the competing rhizomes. Rhizomes were planted on 26-27 July 2010 in the SUNY-Fredonia greenhouse and grown for 12 weeks. Pots were monitored and growth was measured and recorded four to five times a week.

Pots were watered five times a week with either tap water or water augmented with 20g salt/liter which achieves a 20 ppt salinity level typical for a brackish marsh environment (Odum 1988). *Typha* mortality was 100%, therefore this experiment does not have a interspecific competition element and is solely testing *Phragmites* tolerance to salinity under different intraspecific competition scenarios. Plant height was measured bi-weekly and after 50 days final plant height was measured and the wet and dry mass of the above and belowground structures determined (survivors only). Plants were dried for 48 hours at 50^{o}C.

At the beginning of the experiment the wet weight of the *Phragmites* rhizomes to be planted were compared across the following factorial treatments: initial rhizome density (1-5 *Phragmites*), hydrology (drainage, no drainage and flooded), and salinity (fresh water versus brackish), with a three-way ANOVA using SPSS to ascertain that none of the treatments were initially planted with different sized rhizomes. During the experiment *Typha* mortality was 100% and *Phragmites* mortality was high so analysis at the conclusion was based on the density of the **surviving** *Phragmites* in a pot. Pots with four *Phragmites* plants in them at the conclusion of the experiment were omitted from the analysis due to small sample sizes. A three-way MANOVA was conducted to contrast the dependent variables of final height and total dry weight across the following treatments: final density (1-3 *Phragmites*), salinity (fresh water versus brackish), and hydrology (drainage, no drainage and flooded),. All dependent variables are pot means. Initial wet rhizome mass, harvest dry biomass and final height were natural log transformed to achieve normality by the Kolmogorov-Smirnov test and homogeneous variances by Levene's test. Sample sizes for each treatment are shown in table 1.

Field Experiments

Two field experiments were set up in June 2010 in marshes at Tifft Nature Preserve, Bonita Swamp, and Presque Isle State Park in Erie PA in areas where *Typha* and *Phragmites* grow together and where *Phragmites* grows alone. A tornado destroyed the Presque Isle site in late August 2010 so this site was not used after this date.

At each site six random 1 m^2 plots were established at the boundary between patches of *Typha* and *Phragmites,* where they grow together, so each plot physically contained approximately (via % cover) half *Typha* and half *Phragmites*. Water depth varied from 5-20 cm in the plots, the substrate was uniformly muddy and other species were not present. Plots were monitored once a month through two growing seasons and percent cover and stem height and density were recorded for each species.

For the second experiment 15 0.25m^2 plots were placed in *Phragmites* patches at each of the three sites. This study was not conducted in *Typha* patches for ethical reasons and landowner wishes. Five treatments (n=3) were instituted as follows:

1. *Typha* rhizomes were planted into each plot of *Phragmites*;
2. Aboveground *Phragmites* biomass was removed and *Typha* rhizomes planted;
3. *Phragmites* rhizomes were removed and *Typha* rhizomes planted;
4. *Phragmites* rhizomes were removed with no planting occurring; and
5. Control.

In each plot (except controls) ten 3 cm long *Typha* rhizomes were planted in June 2010. These rhizomes were collected from Bonita Swamp. Plots were monitored monthly through the 2010 and 2011 growing seasons. Stem height and density were recorded for *Phragmites* and plots were assessed for *Typha* rhizome growth by measuring *Typha* shoots for height and density.

Results

<u>Salinity Greenhouse Experiment:</u>

Initial rhizome weight did not vary across treatments (data not shown). In the greenhouse *Typha* rhizome mortality was 100% (none of the rhizomes even sent up shoots) and overall *Phragmites* mortality was high at 64% thereby dramatically reducing the number of pots in the higher density *Phragmites* treatments (Tables 2 and 3). Mortality patterns indicated that survival decreased with greater *Phragmites* density and *Phragmites* in flooded pots had considerably lower survival (Table 2). *Phragmites* density, salinity level or hydrological regime did not significantly affect *Phragmites* final height or biomass nor were there any interactions between treatments.

<u>Boundary Field Experiment:</u>

In the plots placed in the boundary between *Typha* and *Phragmites* populations no clear trends were observed in cover, density or height of the two species (Figs. 1a-c, 2a-c, 3a-c). Over the short time span of this experiment both species appeared to be relatively stable.

<u>*Typha* Plantings:</u>

At Bonita Swamp all of the *Typha* rhizomes survived and sprouted (Table 4). There were no clear differences in *Typha* cover, density or height between treatments. At Presque Isle all of the rhizomes in the *Phragmites* removal treatments sprouted but the rhizomes did not sprout in the plots without *Phragmites* removal At Tifft none of the *Typha* rhizomes sprouted.

Discussion

The competition aspects of the greenhouse experiment were unsuccessful due to the complete mortality of *Typha*. A few other studies have been successful using *Typha* rhizomes although mortality remains high (e.g., Grace & Wetzel 1981) but in this study the rhizomes quickly rotted in the study even though they were carefully inspected before being planted. *Phragmites* mortality was also high at 64%. The lack of clear patterns in *Phragmites* rhizome mortality across treatments indicates that *Phragmites* is generally tolerant of a wide range of environmental conditions, except perhaps for flooding. It is difficult to determine what caused the high levels of *Phragmites* mortality. Various types of rhizome rot are well documented in rhizomatous agricultural plants. This tolerance is clearly one of the reasons why this taxa is an aggressively invasive and is supported by a variety of other studies (e.g., Bart et al. 2006). A decrease in plant biomass with increasing density is an expected result from increasing intraspecific competition.

Why *Typha* mortality was 100% in the greenhouse is difficult to determine. The rhizomes appeared to rot very quickly. However, in the wild *Typha* spreads by rhizomes fragments quite effectively (Apfelbaum 1985). This is evidenced by the successful *Typha* establishment in the wild at Presque Isle and Bonita Swamp. The three sites where *Typha* rhizome fragments were planted had very different results. No rhizomes sprouted at Tifft Nature Preserve whereas *Typha* establishment was 100% successful at Bonita Swamp, and also 100% at Presque Isle but only in the treatments which involved *Phragmites* removal. The short duration of field observations renders conclusions difficult to make but the results do support the possibility that *Typha* rhizomes can be planted into *Phragmites* patches as part of a restoration project. Additionally, the observations at the *Typha-Phragmites* interface are show that, at least over the short term, *Typha* is holding its own.

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Table 1. Percent *Phragmites* survival and final sample sizes at the conclusion of the experiment. The initial number of pots is the number of pots that contained that particular *Phragmites* density and the salinity and hydrology levels. Initial number of pots varied across densities because pots were established in an additive design with varying *Typha* rhizome density, however, *Typha* rhizome mortality was 100%. The "Treatment sample size for analysis" indicates the number of samples in the particular treatment. The majority of these pots initially had a greater number of *Phragmites* rhizomes but due to low survival the pots were relegated to a lower density treatment. Pots with four *Phragmites* plants in them at the conclusion of the experiment were omitted from the analysis due to low sample sizes. No pots contained five *Phragmites* at the conclusion of the experiment.

Treatment	Number *Phragmites* in pot	Initial number of pots	Total number *Phragmites* planted	% individual *Phragmites* surviving	Number pots remaining (trt sample size for analysis)
Fresh - drainage	1	20	20	55	22
Fresh – no drainage	1	20	20	55	17
Fresh – flooded	1	20	20	25	10
Saline – drainage	1	20	20	35	15
Saline – no drainage	1	20	20	35	10
Saline – flooded	1	20	20	15	7
Fresh – drainage	2	8	16	56	1
Fresh – no drainage	2	8	16	44	12
Fresh – flooded	2	8	16	13	0
Saline – drainage	2	8	16	31	0
Saline – no drainage	2	8	16	25	4
Saline – flooded	2	8	16	6	0
Fresh - drainage	3	4	12	33	0
Fresh – no drainage	3	4	12	50	0
Fresh – flooded	3	4	12	33	4
Saline – no drainage	3	4	12	33	3
Saline – no drainage	3	4	12	58	5
Saline – flooded	3	4	12	0	0
Fresh – drainage	4	4	16	31	0
Fresh – no drainage	4	4	16	38	2
Fresh – flooded	4	4	16	13	0
Saline – no drainage	4	4	16	63	1
Saline – no drainage	4	4	16	81	2
Saline – flooded	4	4	16	13	0
Fresh – drainage	5	4	20	45	0
Fresh – no drainage	5	4	20	55	0
Fresh – flooded	5	4	20	15	0
Saline – no drainage	5	4	20	25	0
Saline – no drainage	5	4	20	50	0
Saline – flooded	5	4	20	5	0

Table 2. Percent *Phragmites* survival under different treatments.

Treatment	Level	% Survival
Density	1	37
	2	30
	3	35
	4	16
	5	20
Salinity	Fresh	37
	Brackish	32
Hydrology	Drainage	47
	No Drainage	41
	Flooded	14

Table 3. A three-way MANOVA was conducted to contrast the dependent variables of final height and total dry weight across the following treatments: final density (1-3 *Phragmites*), salinity (fresh water versus brackish), and hydrology (drainage, no drainage and flooded). All dependent variables are pot means. Initial wet rhizome mass, harvest dry biomass and final height were natural log transformed to achieve normality by the Kolmogorov-Smirnov test and homogeneous variances by Levene's test. See table 1 for sample sizes. Significant results ($p \leq 0.05$) are in bold. See Fig. 1 for Tukey post-hoc test results.

Final Height	F	*p*
Phragmites density	0.465	0.630
Salinity	0.549	0.461
Hydrology	0.900	0.410
Density x Salinity	0.061	0.806
Density x Hydrology	0.208	0.813
Salinity x Hydrology	0.047	0.954

Final Dry Biomass	F	*p*
Phragmites density	0.488	0.615
Salinity	2.362	0.127
Hydrology	0.177	0.838
Density x Salinity	3.156	0.079
Density x Hydrology	0.200	0.819
Salinity x Hydrology	1.593	0.209

Table 4. *Typha* aboveground % cover, stem density and stem height (mean ± 1sd, n=3) of *Typha* planted into *Phragmites* patches. Ten *Typha* rhizomes 3 cm long each were planted into each of the three plots for each treatment at each site. The treatments were as follows: TP = *Phragmites* plots that received the rhizomes were unaltered; TP-AG = *Phragmites* aboveground biomass was removed and the rhizomes were planted; TP-PB = *Phragmites* above- and belowground biomass were removed from the plots and the rhizomes planted. A third site, Tifft Nature Preserve had 100% mortality of the planted *Typha* rhizomes. There were two types of controls in this experiment. These were unaltered *Phragmites* plots and plots where *Phragmites* above- and belowground biomass were removed from the plots. None of the control plots were invaded by *Typha* over the course of the experiment.

% Cover

	Presque Isle			**Bonita**				
	6 July 2010	11 Aug 2010	11 Sept 2010	11 June 2010	10 Aug 2010	18 Sept 2010	2 June 2011	27 July 2011
TP	0	0	0	0	0.3±0.6	0.3±0.6	0.7±1.2	5.0±5.0
TP-AG	0	0.3±0.6	0.7±0.6	0	0	0	1.7±2.9	5.0±8.7
TP-PB	0	0	0.7±0.6	0	0	0	1.7±2.9	3.3±5.8

Stem Density (m^2)

	Presque Isle			**Bonita**				
	6 July 2010	11 Aug 2010	11 Sept 2010	11 June 2010	10 Aug 2010	18 Sept 2010	2 June 2011	27 July 2011
TP	0	0	0	0	0.3±0.6	0.3±0.6	0.7±1.2	1.0±1.0
TP-AG	0	0.3±0.6	0.7±0.6	0	0	0	0.7±1.2	1.0±1.7
TP-PB	0	0	0.7±0.6	0	0	0	0.7±1.2	0.7±1.2

Stem Height (cm)

	Presque Isle			**Bonita**				
	6 July 2010	11 Aug 2010	11 Sept 2010	11 June 2010	10 Aug 2010	18 Sept 2010	2 June 2011	27 July 2011
TP	0	0	0	0	27±46	29±51	38±66	128±111
TP-AG	0	23±39	34±47	0	0	0	38±66	80±139
TP-PB	0	0	3±2	0	0	0	35±60	60±103

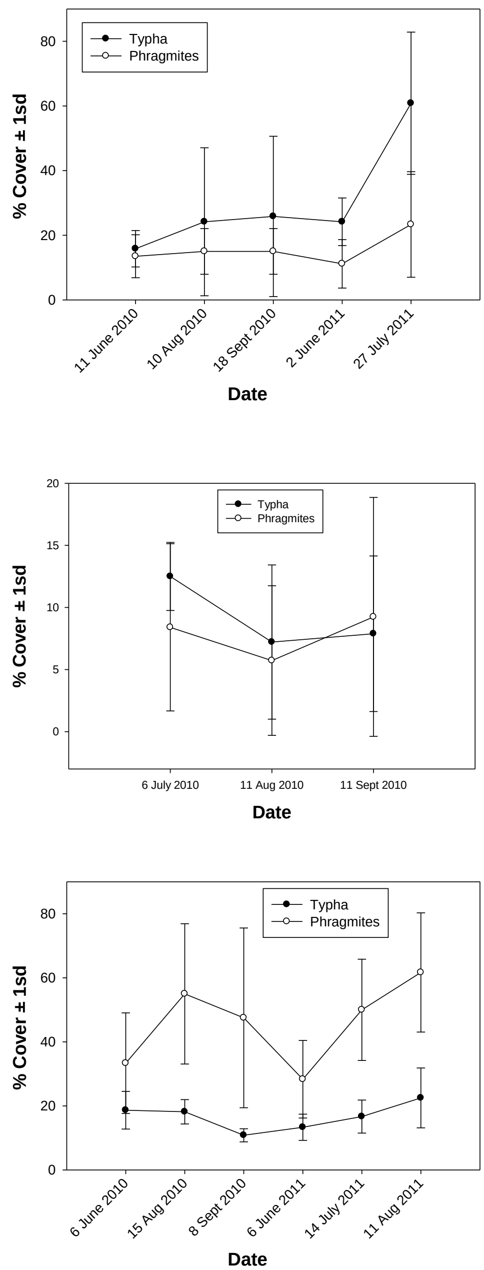

Fig. 1. Percent cover (mean ± 1sd, n=6) in m^2 plots located on the boundary between the *Phragmites autralis* portion and the *Typha latifolia* portion of a marsh. a. Bonita Swamp, b. Presque Isle State Park, c. Tifft Nature Preserve. Cover was tracked for two growing season except at Presque Isle where the plots were destroyed by a tornado.

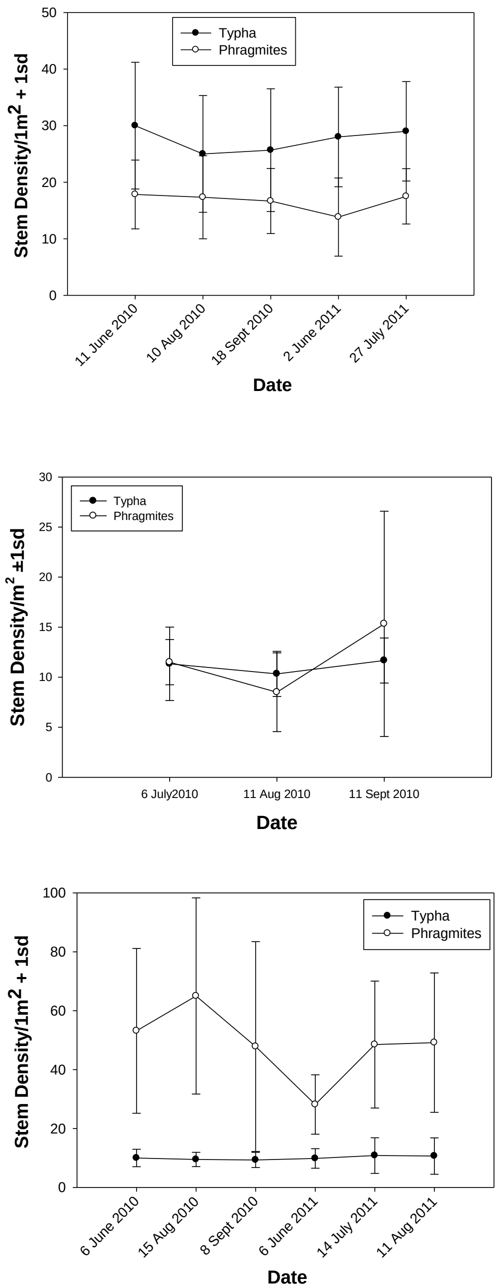

Fig. 2. Stem density/m^2 (mean $\pm$ 1sd, n=6) in plots located on the boundary between the *Phragmites autralis* portion and the *Typha latifolia* portion of a marsh. a. Bonita Swamp, b. Presque Isle State Park, c. Tifft Nature Preserve. Stem density was tracked for two growing season except at Presque Isle where the plots were destroyed by a tornado. There was no assumption that each stem was from a separate individual.

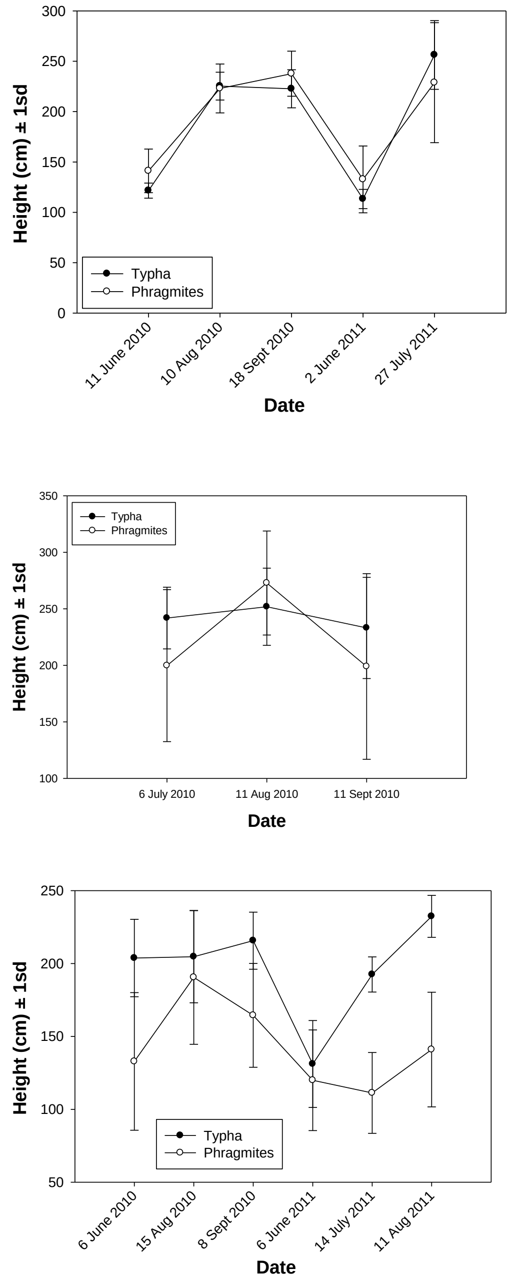

Fig. 3. Stem height (cm) (mean + 1 sd, n=6) in plots located on the boundary between the *Phragmites autralis* portion and the *Typha latifolia* portion of a marsh. a. Bonita Swamp, b. Presque Isle State Park, c. Tifft Nature Preserve. Height was tracked for two growing season except at Presque Isle where the plots were destroyed by a tornado. There was no assumption that each stem measured was from a separate individual.