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# Methods for restoring sedge/grass meadow community in a Typha-invaded Lake Ontario drowned-river-mouth wetland

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# Methods for restoring sedge/grass meadow community in a *Typha*-invaded Lake Ontario drowned-river-mouth wetland

by

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Dedication:

I dedicate this paper to my parents, Kevin and Allison Buckler, who have fully supported, guided, and encouraged me throughout my entire academic and professional career.

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I thank Dr. Doug Wilcox for his unwavering support, insight, and guidance throughout the thesis process.

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## ABSTRACT

Water-level regulation has resulted in vegetation changes in Lake Ontario coastal wetlands. The vegetation has shifted from structurally complex sedge/grass meadow communities to communities dominated by invasive *Typha*, specifically the hybrid cattail *Typha* x *glauca.* This study aims to identify control techniques for *Typha* x *glauca* to be used in wetlands hydrologically connected to Lake Ontario. The tested control techniques were implemented in a Lake Ontario drowned river-mouth wetland in 2010 and 2011 and were administered along the active invasion zone between a dense *Typha* stand and remaining sedge/grass meadow. Multiple physical and chemical treatment techniques were implemented over a two-year period at Kents Creek, in northern New York. Treatments included cutting (C), spraying (S) glyphosate (Rodeo) onto cut stalks, and wicking (W) cattail re-sprouts with glyphosate later in the growing season (August). Each treatment method had the following year options: the cut, spray, and wick treatments were applied in year 1 or in both years 1 and 2 (C1S1W1 or C12S12W12). All possible treatments yielded 12 treatment combinations, plus two control plots. Each treatment option was randomly assigned within each of five treatment replicates. All five treatment replicates were located in the invasion zone that had ~25% cover invading *Typha* and ~75% remaining sedge/grass meadow community. Vegetation sampling occurred in early summer (late June) and again in late summer (August) before treatment in both years. Cattail stem

counts and species percent cover data were collected to analyze the effects of each treatment combination. Environmental variables (soil moisture, sediment depth, water-table elevation, soil organic matter, and bulk density) were measured to assist in explaining treatment success or failure and to assess differences among replicates. In addition to looking at the effects that the treatments had on reducing *Typha* stem density and percent cover, I assessed whether the treatments had an effect on the growth and expansion of existing sedge/grass meadow species, specifically *Calamagrostis canadensis* and *Carex lacustris.* Vegetation was sampled again in August 2012 following one full growing season after the second year treatments were applied.

Seven treatment combinations: C12, C12W12, C12S, C12SW1, C1W1, C1W12, and C1SW12 significantly reduced cattail stem counts from June 2010 to August 2012. The wick (W) treatment, which was applied to the re-sprouted cattail stems in late August, was the most important treatment, when combined with other treatments (cutting and spraying). Five treatment combinations: C1SW12, C12W12, C12S, C1W12, and C12W1significantly reduced cattail percent cover from June 2010 to August 2012. Although application of the wick treatment in August was the most successful treatment method, the addition of other treatments earlier in the growing season increased *Typha* stress and led to increased reductions in *Typha* stems and percent cover. The success of cattails is strongly correlated with stable, high water levels that increase soil moisture. Four of the five replicates were statistically similar in terms of soil moisture throughout the study. Replicate 5 had significantly drier oils than the remaining replicates and had substantially fewer initial *Typha* stems and lower percent cover, which led to slightly different results in this replicate. For management practices, I suggest using the early summer cutting and late summer wicking treatments, as these two treatments (in combination) were the most effective at reducing *Typha* stems and percent cover.

# Introduction:

Water levels in the Laurentian Great Lakes have historically been affected by natural climatic variables such as precipitation, evapotranspiration, ice buildup, and seiches (Wilcox and Meeker 1995). Each of these climatic variables occurs at various frequencies, ranging from the short-term, such as seasonal variations, to long-term time-scales of years to decades to centuries. These climatic variables also vary in magnitude and duration, which have different effects on vegetation (Wilcox 2004). These natural climatic variations cause periodic hydrologic changes and water-level fluctuations that directly affect the biological communities of the Great Lakes (Wilcox et al. 2007).

The short- and long-term fluctuations in the hydrologic regime are normal in Great Lakes coastal wetlands. This dynamic hydrology plays a major role in shaping wetland plant communities because changing hydrologic conditions result in associated changes in water depth, which affects nearshore vegetation. The observed changes in species composition with water depth produce distinct zonation patterns characterized by one or more characteristic plant species, with each plant species being adapted to a particular water depth (Keddy 1983, Wilcox and Xie 2008). Water-level fluctuations have thereby caused the species composition of lakeshore vegetation to vary greatly from one point on a lakeshore to another (Keddy 1983).

Structurally complex and highly diverse coastal wetland plant communities are a direct result of lake-level fluctuations. Naturally-occurring water-level fluctuations cause intermediate levels of environmental disturbance, with species richness peaking at intermediate levels of environmental disturbance (Keddy 1983) rather than in the least disturbed areas (Sanders 1968) or in highly disturbed areas.

Water-level fluctuations result in shifting mosaics of aquatic vegetation types (Wilcox 2004). For example, periodic high lake levels eliminate dense-canopy emergent plants; receding lake levels following these highs allow the germination of emergent vegetation seeds from the dormant seed bank; and low lake levels following receding lake levels result in the resurgence of the competitively dominant emergent species. The cycle then repeats itself to prevent the establishment of a single, dominant plant community (Keddy and Reznicek 1986, Maynard and Wilcox 1997). Water-level fluctuations such as these serve to enhance the interactions of aquatic and terrestrial ecosystems, thereby resulting in higher quality habitat and increased productivity (Wilcox and Meeker 1991). The effects are greatest in shallow water, where even small changes in lake level can result in conversion of a standing water environment to an environment in which sediments are exposed to the air or *vice versa*, resulting in death by flooding or in seed bank germination (Keddy and Reznicek 1986, Wilcox 1995). Given the wide variation in lake levels and the known response of wetland plants to water-level changes, hydrology is the single most important overall factor affecting the composition and structure of wetland vegetation in the Great Lakes coastal marshes (Keddy and Reznicek 1986, Wilcox 1995).

The long-term lake-level history of Lake Michigan-Huron suggests that the hydrologic cycle behind plant community dynamics has a short-term frequency of approximately 32 years that is superimposed on a larger cycle with a frequency of 160 years, which adds further variability (Thompson and Baedke 1997, Baedke and Thompson 2000, Wilcox et al. 2007). A lake-level history spanning several thousands of years is not currently available for Lake Ontario; however, recorded lake levels for Lake Ontario from 1860 to 1960 show a pattern similar to that of Lake Michigan-Huron (Wilcox et al. 2007). This periodic cycle of long- and short-term water-level fluctuations has been suppressed since about 1960 with the opening of the St. Lawrence Seaway and the subsequent regulation of Lake Ontario (Figure 1). Water-level stabilization disrupts the historical cycle and is responsible for promoting the expansion of aggressive plant species such as cattails (Wilcox et al. 2008).

The International Joint Commission (IJC) is considering implementing a more natural regulation plan, which includes greater water-level variability that may allow native sedge/grass meadow marsh to compete with cattails. Restoring wetland ecosystems generally focuses on restoring wetland hydrology, but sedge/grass species are often slow to recolonize previously disturbed areas. Williams and Lyon (1997) found a lag time of 14 years for emergent wetlands to respond measurably to water-level declines. Therefore, this new regulation plan must be accompanied by restoration practices to reduce cattail cover and promote the restoration of sedge/grass meadow habitat (Wilcox and Xie 2007, 2008).

Therefore, prior to the restoration of native sedge/grass meadow habitat in Great Lakes coastal wetlands, an effective cattail management strategy must be in place.

To test management strategies, two nearly identical studies on controlling *Typha* were implemented in the cattail zone of Kents Creek, New York from 2010-2012. There are two distinct cattail zones in the Kents Creek coastal marsh: a dense cattail zone characterized by approximately 75% cattail cover and 25% meadow marsh plant species; and a cattail invasion zone characterized by approximately 25% cattail cover and 75% meadow marsh plant species. My study was located in the cattail invasion zone, while the congruent study, undertaken by Alex Czayka (Czayka 2012), took place in the dense cattail zone. Both studies examined various *Typha* control methods to identify a successful control technique to reduce *Typha* cover in coastal wetlands throughout Lake Ontario. My study examined the response of sedge/grass meadow species to the control techniques to determine if treatments successful at reducing *Typha* also increased the areal coverage of sedge/grass meadow species. Environmental variables (e.g., soil moisture, sediment depth, soil bulk density) were compared at the replicate level to help understand the ecology of *Typha* and meadow marsh species in a regulated hydrological system.

## Great Lakes Water Levels

Changes in Great Lakes water levels represent a change in water availability or the volume of water stored (Wilcox et al. 2007). The primary natural factors that affect lake levels are the amount of inflow received by each lake, the outflow characteristics of the outlet channels, and crustal movement (Wilcox et al. 2007). Human-induced water-level changes include diversions into or out of the basin, dredging of outlet channels, and the regulation of outflows (Wilcox et al. 2007).

Seasonal fluctuations of Great Lakes water levels reflect the annual hydrologic cycle, which is characterized by high water levels during the spring and early summer and lower water levels during the remainder of the year (Wilcox et al. 2007). The highest lake level on Lake Ontario usually occurs in June, and the lowest lake level usually occurs in December (Wilcox et al. 2007).

Fluctuations over the longer term, which represent basin-wide climate changes, are recognizable in the historical gage dataset and are preserved in geologic features and deposits throughout the Great Lakes Basin (Wilcox et al. 2007).

## Water-Level Regulation

Since 1960, the Moses-Saunders power dam on the St. Lawrence River has regulated outflow of water from Lake Ontario to "reduce the range of Lake Ontario's water levels and to provide dependable flow for hydropower, adequate navigation depths, and protection for shorelines" (International Joint Commission 2004). The International Joint Commission currently regulates Lake Ontario water levels under Regulation Plan 1958D with deviations (1958DD) (Carpentier 2003); the plan consists of a water-supply indicator, two sets of basic rule curves, seasonal adjustments, and a number of maximum and minimum outflow limitations (Final Report to the IJC 2006). Shoreline development has been able to expand under the current regulation plan, which allows more stable, predictable water levels, and year-round residences and recreational boating have increased in the decades following implementation of the current regulation plan (Final Report to the IJC 2006).

Under the current regulation plan, high summer lake levels normally experienced during high water-supply periods have been lowered, and low summer lake levels during low water-supply periods have been raised (Wilcox and Xie 2007). Therefore, the biotic communities that have adapted to periodic high and low lake-level conditions in the summer are now experiencing less hydrologic variability under the current regulation plan. Under the current regulation plan, the lake-level range has been compressed from approximately 1.5 m to 0.7 m, or half of what it was prior to regulation (Wilcox et al. 2005).

Water-level stabilization disrupts the historical water-level cycle and is responsible for promoting the expansion of aggressive plant species (Wilcox et al. 2008). When the fluctuations in water levels are reduced, shifting of vegetation types decreases, more stable plant communities develop, and species diversity and habitat value decrease (Wilcox and Meeker 1991). Hydrologic modifications that maintain constant water depths decrease plant diversity of dammed lakes (Hill et al. 1998) and promote the expansion of cattail species in the Everglades (Newman et al. 1998).

In Lake Ontario, the current regulation plan and a prolonged period of above-average water supplies resulted in an increase in emergent wetland dominated by cattails (mainly *Typha angustifolia* L. and *T.* x *glauca* Godr.) and a decrease in meadow marsh dominated by sedges (e.g., *Carex stricta,* Lam. and *C. lacustris* Willd.) and grasses (e.g., *Calamagrostis canadensis* (Mich.) P. Beauv) at slightly higher elevations (Wilcox et al. 1992, 2005, 2008; Wilcox and Meeker 1995). Photointerpretation studies along the Great Lakes have uniformly described the dynamics of *Typha* invasion into graminoid wetland vegetation and related this invasion to water-level regulation (Wilcox et al. 2008).

The current estimate of the area of coastal wetlands within Lake Ontario and the upper St. Lawrence River is approximately 26,000 ha, made up of four basic types: submerged aquatic vegetation, emergent marsh, meadow marsh, and upland vegetation (trees/shrubs) (Wilcox et al. 2005). Over 80% of the wetland area occurs in the eastern half of the Lake Ontario basin and Thousand Islands region (Wilcox et al. 2005).

Results from analyses of Lake Ontario coastal wetlands indicate that there has been a 50% reduction in meadow marsh and emergent-floating vegetation since regulation was implemented in the late 1950s (Wilcox and Ingram 2005). During that same time-period, there has been a 29% increase in cattail-dominated emergent marsh area (about 1,700 ha) (Wilcox and Ingram 2005).

## Sedge/Grass Meadow Ecology

The species that constitute sedge/grass meadow communities are considered moderately productive, can tolerate low intensity stress, and are classified as stress-tolerant competitors (Grime 1979). Sedge/grass meadows are common targets for restoration because of their disproportionately high loss relative to other wetland types (Zedler and Potter 2008) and because of their high plant diversity (Peach and Zedler 2006).

Sedges, in general, are known to have low dispersal potential and low seed viability (Reinartz and Warne 1991, Galatowitsch and van der Valk 1996), and of those species that are able to disperse, adverse conditions such as excessive drying or flooding can have a significant effect on survival (Merendino and Smith 1991). Given their low seed viability, sedges allocate resources to underground rhizomes, which results in a relatively quick expansion into surrounding areas by mature individuals (Yetka and Galatowitsch 1999). Reliance on these characteristics makes it exceedingly difficult to establish *Carex* spp. propagules in anthropogenically disturbed sites or restored wetlands.

The negative effect of stable water depth on plant survival and growth has been shown for many sedge/grass meadow species (Shipley et al. 1991). Prolonged inundation can reduce shoot growth, rhizome expansion, and seed production of newly established plants by reducing soil aeration (Mendelssohn and McKee 1988).

Sedge/grass meadow communities (dominated by *Carex* spp.) are typically located along the saturated margins of wetlands (Yetka and Galatowitsch

1999). *Carex stricta* is one of the dominant sedge species in the meadow marsh community. *Carex stricta* is a perennial graminoid that produces both long and short lateral rhizomes that cause the rapid formation of a tiller clump, or tussock (Bernard 1990). These tiller clumps are an important functional unit, in that they prevent the colonization of a site by other species (Bernard 1990). Despite the fact that *C. stricta* can comprise >90% of the cover of a sedge meadow, this species supports many other species, acting as a matrix dominant (Costello 1936, Frieswyk 2005).The soil moisture heterogeneity afforded by tussocks also provides *C. stricta* (and co-occurring species) with the ability to withstand moderate flooding (Wilcox et al. 2008).

*Calamagrostis canadensisis*, a grass species, is a common associate on *C. stricta* tussocks. *Calamagrostis canadensis* is tolerant of moist soil conditions, but it is more sensitive to flooding than *C. stricta*, so it is often found in higher and drier parts of the wetland (Wilcox 2008). Species that dominate sedge/grass meadow communities, such as *Calamagrostis canadensis* and many *Carex* species, have become less common in Lake Ontario wetlands.  Percent areal cover of meadow marsh at my study site, Kents Creek, derived from photointerpretation, decreased from 37.9% to 22.5% between the years 1959 to 2001, which represents a 40% reduction in 40 years (Wilcox et al. 2008). In the past decade, *C. canadensis* has approximately 6-12% mean cover for quadrats sampled in numerous Lake Ontario wetland sites, and *C. stricta* accounted for 3-4% mean cover (Wilcox et al. 2005).

*Carex lacustris* is another dominant sedge/grass meadow species. *Carex lacustris* is a thick-leaved sedge that produces both long and short rhizomes that form dense mats in slightly flooded areas (Yetka and Galatowitsch 1999). The growth habit of *C. lacustris,* termed "guerrilla," may allow this species to exploit open spaces quickly, whereas the growth form of *C. stricta* may make it less able to spread (Schmid and Harper 1985).

Native meadow marsh communities require periodic high lake levels to kill invading upland plants and succeeding periods of low lake levels to produce drier soils that are amenable to sedge and grass species but too dry to support cattails invading from the lower elevations (Wilcox et al. 2008). The sedge and grass species of meadow marsh communities are tolerant of dry soil conditions, and they are better competitors than *Typha* under dry soil conditions; however, many species of *Carex* are less tolerant of flooding than *Typha* (Wilcox et al. 2008).

Factors that affect the vegetation dynamics at the boundary between meadow marsh and *Typha* communities include competition for light, nutrient availability, sedimentation, and water depth/soil moisture (Wilcox et al. 2008); however, Lake Ontario studies suggest that competition driven by survival of mature plants, with moisture requirements that differ by species, is the primary factor in controlling *Typha*-meadow marsh dynamics (Wilcox et al. 2008).

In Lake Ontario wetlands, the conditions that favor meadow marsh plant communities have been replaced by conditions that favor cattail establishment and expansion. In the historical pattern of shifting plant communities, meadow marsh would expand waterward during low water-level periods and would retreat landward during high water-level periods (Frieswyk and Zedler 2007). Recently, however, emergent marsh (e.g., *Typha*-dominated habitat) has continued its landward expansion into meadow marsh even during low water-level periods (Frieswyk and Zedler 2007). This landward expansion may be because *Typha* has gained such a strong foothold in coastal wetlands that it is unaffected by seasonal or yearly water-level declines, and it continues to expand into meadow marsh even under less than ideal growing conditions.

## Ecology of *Typha*

*Typha* species have growth forms that maximize the capture of available resources in productive environments, such as those found along the shores of Lake Ontario. *Typha* is considered to be an exploiter (Grace 1989) or a competitively selected (C-selected) species, *sensu* Grime (1979).

As with many invasive species, *Typha* is favored by disturbance. It responds especially well to anthropogenic disturbances such as eutrophication and altered hydrologic regimes. For example, in the upper Midwest USA, the invasive *Typha* x *glauca* Godr., a hybrid of *Typha latifolia* L. and *Typha angustifolia* L. (Smith 1987), aggressively displaces native wetland flora under elevated nitrogen and phosphorus concentrations, expanding at rates as high as 5 m/yr (McDonald 1955, Woo and Zedler 2002, Craft et al. 2007). Similarly, *Typha* species are favored by persistently high soil moisture levels; however, they are less competitive under drought conditions. While few data are available on the drought tolerance of *Typha*, Harris and Marshall (1963) found reduced *Typha* spp. density after only one year of drawdown in a Minnesota marsh.

Cattails commonly occur in freshwater wetlands throughout North America. In high-quality natural communities, however, cattails often occur as scattered sterile plants (Apfelbaum 1985). In anthropogenically disturbed systems, such as those with altered hydrologic regimes, cattails can behave like aggressive, introduced weeds because they have adaptations that enable them to out-compete and displace endemic vegetation.  For example, *Typha* produces a dense rhizome mat and thick leaf litter, which reduce the opportunity for other plants to establish or survive (Sojda and Solberg 1993).

The superior competitive abilities displayed by *Typha* spp. may also be a result of the secretion of allelochemicals into the rhizosphere, which further inhibits the establishment and growth of competing species, resulting in *Typha* spp. easily coming to dominate many wetlands (Shih and Finkelstein 2008). In addition, because cattails can transpire significant quantities of water (2-3 m of water/ha/yr), their establishment may serve to exacerbate water-level instability and further contribute to disruptive influences supporting increased cattail cover (Apfelbaum 1985).

Cattails have become dominant in coastal marshes of Lake Ontario because of the altered hydrologic regime, which produces persistent high soil moisture conditions throughout the growing season. Wetlands around and adjacent to Lake Ontario differ in hydrologic setting and cattail dominance: bayside wetlands within large, open embayments are dominated by *Typha* species, while protected embayments that lack a direct surface water connection to the lake, such as those behind closed barrier beaches, maintain a more diverse plant community (Vaccaro et al. 2009). Hydrogeologic setting controls water-flow patterns, fluctuations, and chemistry in a wetland (Bedford 1996), which therefore influences plant competition, production, disturbance, and litter accumulation (Vaccaro et al. 2009). Hydrologic regime can affect litter dynamics by favoring growth of highly productive perennials like cattails (e.g., low disturbance, high fertility) (Wisheu and Keddy 1992).

*Typha angustifolia* and *Typha* x *glauca* are considered to be more invasive than *Typha latifolia*. *Typha* x *glauca* appeared in North America following hybridization between *Typha latifolia* and *Typha angustifolia* (Sish and Finkelstein 2008). *Typha* x *glauca* displays invasive tendencies, but because it is a combination of hybrids and backcrosses, it is also highly sterile and very rarely produces viable seeds or fertile pollen (Smith 2000). Therefore, hybrid populations are only found in regions where *T. latifolia* and *T. angustifolia* exist sympatrically (Shih and Finkelstein 2008). McDonald (1955) noted that *T. latifolia* is least tolerant of deep water, while *T. angustifolia* is most tolerant. As a hybrid, *Typha* x *glauca* has successful traits of both parents. For example, the hybrid has excessive aerenchyma tissue, making it more tolerant of high water conditions like *T. angustifolia*, but it retains a high capacity for biomass production like *T. latifolia* (Grace and Wetzel 1981). *Typha x glauca* is also capable of tolerating a wide range of salinity, a trait conferred by *T. angustifolia*, which is historically a salt-marsh species (Vail 2009). Its tall stature enables *Typha* x *glauca* to capture more light for increased primary production, while rapid nutrient uptake enables it to out-compete native species (Vail 2009). In addition, *T.* x *glauca* can stimulate rates of nitrogen-fixation that are greater than either parent species (Eckardt and Biesboer 1988).

In addition to interspecific competition between *Typha* and surrounding species, intra-generic competition occurs between *T. latifolia* and *T. angustifolia* (Shih and Finkelstein 2008). Competitive interactions between different *Typha* species suggest that *Typha angustifolia* easily out-competes and displaces *Typha latifolia*. Weisner (1993) examined the dynamics of adjacent stands of the two taxa after a 13-year period and found that, over time, an initially restricted stand of *T. angustifolia* expanded at the expense of *T. latifolia*. In addition, when *T. angustifolia* was transplanted into a natural stand of *T. latifolia*, after six years, it was found that *T. angustifolia* had expanded into the adjacent *T. latifolia* population at depths of 30 cm and greater (Weisner 1993).

Mixed stands of *T. latifolia* and *T. angustifolia* tend to be segregated by water depth, with *T. latifolia* competitively superior in water shallower than 15 cm and *T. angustifolia* dominating in deeper water (Grace and Wetzel 1981). Greater shoot densities and heights early in the growing season give *T.*

*angustifolia* competitive advantage over *T. latifolia* in disturbed habitats (Shih and Finkelstein 2008).

While *Typha angustifolia* was present in Lake Ontario wetlands long before regulation, favorable conditions related to an altered hydrologic regime, with consistently higher water levels, have allowed this species to expand its range and encroach into areas previously dominated by sedge/grass meadow (Wilcox et al. 2008). Regulated water levels and the lack of alternating flooded and dewatered conditions have produced stable, closed, monospecific communities of *Typha* that block nearly 100% of direct sunlight and prevent the establishment of other plant species.

*Typha angustifolia* and *T.* x *glauca* occur more frequently around Lake Ontario than the other Great Lakes (Johnston et al. 2007); cover of these invasive cattails has been increasing at the expense of wet meadow communities. As noted by Wilcox et al. (2008) in a study on 16 Lake Ontario coastal wetlands, when the range and amplitude of water-level fluctuations on Lake Ontario remained relatively stable and no low lake levels occurred, *Typha* invasion was mostly landward into meadow marsh. In another study (Wilcox et al. 2005), quadrat sampling in Lake Ontario wetlands found *T. angustifolia* to have its greatest mean percent cover in water deeper than for *T.* x *glauca.* The data from that study suggest that, in general, the waterward expansion of cattail is driven by *T. angustifolia* whereas the landward expansion into sedge/grass meadow communities is driven by *T.* x *glauca* (Wilcox et al. 2008). As a result, wetlands along the shorelines of the Lake Ontario have experienced vegetation shifts from sedge/grass meadow communities to *Typha*-dominated communities. This loss of meadow marsh has had detrimental effects on sedge wrens, various species of waterbirds, and northern pike (*Esox lucius*) populations (Cooper et al. 2008).

Stabilized water levels result in prolonged flooding of marsh soils. This results in the phenomenon of internal eutrophication, which directly benefits *Tyhpa.* Stabilized water levels prolong anoxic soil conditions which then causes a release of phosphorus (P) into the soil solution. This is due to the reduction of iron oxides and the solubilization of sorbed P (internal eutrophication) (Young and Ross 2001). Internal eutrophication allows plants to take up nutrients that had previously been locked up in wetland sediments (Koerselman et al. 1993). The increased uptake of P, a vital nutrient for growth and reproduction, gives *Typha* species a competitive advantage, allowing it to invade new areas (Boers and Zedler 2008).

Cattails can produce seeds and contribute to the seed bank at all marsh stages, but recruitment occurs only during the dry stages (Linde et al. 1976). During early spring, returning cattail shoots receive their energy for growth primarily from carbohydrates stored in the rhizomes (Linde et al. 1976). In summer, when the pistillate (female) spike is lime green and the staminate (male) spike is dark green, carbohydrate reserves in the rhizomes are at their minimum (Linde et al. 1976). If cattail control and management measures are planned during the period when carbohydrate reserves are at their lowest, then the chances for successful control of the plant should be greatest (Linde et al. 1976).

## Control Measures

To implement the most effective control techniques, the yearly life cycle of *Typha* must be understood. During winter, *Typha* remains dormant and stores carbohydrate reserves acquired during the previous growing season in the rhizomes (Sojda and Solberg 1993). In the early spring, carbohydrate reserves are used for shoot growth. Throughout the spring, energy reserves in the rhizomes are depleted and used by the plant to form much of the above-ground biomass (leaves, stem, and flowers). In early summer, carbohydrate reserves within the rhizome are at their lowest levels. By mid-summer, however, peak photosynthesis occurs, and energy reserves in the rhizomes begin to increase. In late summer, new *Typha* shoots form for the next growing season, and carbohydrate transport to the rhizomes begins to decrease. As fall approaches, the leaves senesce and die back, leaving a standing dead stalk that is used to maintain gas transport to the rhizomes during the winter months. *Typha* is dormant over winter, and the cycle is complete (Linde et al. 1976).

Besides this study and the congruent study that was conducted in the dense cattail zone of Kent's Creek (Czayka 2012), there are no documented reports on *Typha* control techniques in Great Lakes coastal wetlands. However, multiple control techniques have been used elsewhere for *Typha*. Stressing the rhizome is an effective approach to controlling *Typha*. This control technique involves cutting the stems in June when energy (starch) reserves in the rhizomes are at their lowest (Sojda and Solberg 1993), which stresses the plant (due to low energy reserves in the rhizome) and reduces its likelihood of resprouting. Studies by Sojda and Solberg (1993) also suggest over-winter flooding of previously cut *Typha* as a successful control technique; however, this method only works if water levels can be managed to ensure extended inundation, and such conditions cannot be met in Great Lakes coastal wetlands. Disking and tilling rhizomes (Wilcox and Ray 1989), which disconnects the rhizome network and reduces the ability of *Typha* to survive and reproduce, have also been used to control *Typha*. This technique was employed in the congruent Kents Creek *Typha* control study. Aerial spraying of herbicide with glyphosate can also control *Typha*, but time of application and follow-up treatments are important to ensure success (Sojda and Solberg 1993).

Given the relatively recent invasion of *Typha* into sedge/grass meadow habitats, my study and the congruent study by Czayka (2012) investigated numerous treatment measures to control *Typha* and restore sedge/grass meadow. Both studies hypothesized that those treatments using all possible techniques (cutting in each of two years, spraying with glyphosate Rodeo in both years, and hand-wicking with glyphosate Rodeo) would be most effective at controlling *Typha* due to the multiple stressors placed on the plants on multiple occasions. I also hypothesized that the same treatments would likely lead to the largest increases in percent cover of sedge/grass meadow species (e.g., *Calamagrostis* *canadensis*, *Carex stricta*, and *C. lacustris*) due to decreased competition from *Typha* and opening of invasion windows (Johnstone 1986, Czayka 2012).

Because of the increase in *Typha*-dominated communities in Lake Ontario wetlands, and concern for the loss of sedge/grass meadow communities, the study was designed to address the following objectives:1) observe correlations between plant communities and soil moisture and groundwater levels; 2) effectively reduce cattail invasion into sedge/grass meadow habitats; 3) recommend the preferred management strategy that will reduce the invasion of dense cattail stands along the shoreline of Lake Ontario and other coastal wetlands; 4) develop, test, and implement methods for restoring meadow marsh in Lake Ontario.

**STUDY SITE:**

Kents Creek is a Lake Ontario drowned river mouth wetland, located in the Town of Cape Vincent, Jefferson County, New York, USA (Figure 2). Kents Creek is a perennial tributary that meanders for approximately 21 km from its headwaters near the Town of Saint Lawrence, New York to its confluence with Mud Bay (Lake Ontario). Kents Creek lies in a 98,419-ha watershed that drains primarily agricultural and forested lands. Pollutants commonly associated with agricultural watersheds, such as synthetic pesticides, herbicides, and increased sediments, are likely introduced to Kents Creek and its associated wetlands.

The study site is an approximately 91-ha emergent marsh wetland located near the mouth of Kents Creek. The study site contains large areas of remaining sedge/grass meadow that has persisted because the basin morphology allows the sedge/grass meadow to exist at slightly higher elevations, which avoids the effects of long-term high lake levels that favor the establishment of *Typha*. The importance of this site for my research is that it provides an obvious transition zone between invading cattail and remaining sedge/grass meadow. The site also has uniform topography and few anthropogenic disturbances other than water-level regulation. The study site is underlain by Saprists and Auqents (Sa), which are very poorly drained organic soils. I monitored environmental conditions (e.g., soil moisture, water-table elevation, soil composition) in the transition zone to determine patterns regarding the persistence of sedge/grass meadow and controlling *Typha* on Lake Ontario.

**METHODS:**

To test *Typha* control methods and their effects on sedge/grass meadow restoration, three treatment techniques were implemented at Kents Creek over a two-year period (2010-2011). The Czayka (2012) study implemented nearly identical methods in his congruent *Typha* control study. The Czayka methods differed slightly with the inclusion of a tilling method.

The primary treatment method was cutting *Typha* using hand-held loppers; cut stems were then removed from the treatment plots. The cutting treatment included cutting in year 1 only or cutting in both years 1 and 2. The initial cutting treatment was conducted on 31 June 2010 and 11 July 2011, when energy reserves in the rhizomes were assumed to be at their lowest concentrations; both dates fell within a three-week window from one week before to one week after the pistillate spike was lime green and the staminate spike was dark green (Sojda and Solberg 1993).

The second treatment method was the spray treatment. Spraying followed the cutting treatment and was done by spraying a 2% commercial glyphosate solution on the cut *Typha* stems with a hand-held sprayer to avoid spraying other (non-target) plants. The glyphosate solution was not used over water. This spray treatment was done only in combination with cutting, in year 1 only, in both years 1 and 2, or not at all.

The third treatment technique involved wicking *Typha* stems. The wick treatment consisted of applying a 2% commercial glyphosate solution manually to the re-sprouted *Typha* plants with a cloth glove doused in the glyphosate solution worn over a rubber glove. The doused glove was run from the bottom of each leaf to the top and on both sides of the leaf to ensure complete leaf application. Again, the glyphosate solution was not used over water. Wick treatments were applied in late August, and treatments included the following: not wicking at all; wicking in year 1; or wicking in both years 1 and 2.

The different combinations of these three control techniques resulted in 12 different treatments (Table 1). The twelve treatment methods included the following: cutting in year 1 (C1); cutting in year 1 and 2 (C12); cut and spray year 1 (C1S1); cut and spray year 1 and 2 (C12S12); cut year 1, wick year 1 (C1W1); cut years 1 and 2, wick year 1 (C12W1); cut year 1, spray year 1, wick year 1 (C1S1W1); cut years 1 and 2, spray years 1 and 2, wick year 1 (C12S12W1); cut year 1, wick years 1,2 (C1W12); cut years 1 and 2, wick years 1 and 2 (C12W12); cut year 1, spray year 1, wick years 1 and 2 (C1S1W12); and cut years 1 and 2, spray years 1 and 2, wick years 1 and 2 (C12S12W12).

The 12 treatment combinations came from the 2x2x3 block design where each treatment (cutting [n=2], spraying [n=2], and wicking [n=3]) had multiple treatment options. The 12 treatment plots with two control plots were laid out in a 5 x 17 m- plot oriented parallel to the south bank of Kents Creek. In addition to the 12 different treatments, two control plots were randomly assigned to each of five treatment replicates (Figure 3).

The five treatment replicates were laid out according to visual estimation of *Typha* percent cover equality, with the goal to achieve replicates that contained 25% *Typha* cover and 75% sedge/grass meadow cover. The five replicates of the 2 x 2 x 3 design were positioned in the transition zone between invading cattail and remaining sedge/grass meadow. The congruent study positioned its five replicates in the dense cattail zone containing roughly 75% cattail and 25% sedge grass meadow species. After surveying the entire length of this transition zone, the five replicates were located at random in the zone that visually contained a ratio of 75% remaining sedge/grass meadow and 25% invading *Typha.* Each of the five replicates was also located based on similar elevation.

In late May 2010, prior to cattail sprouting, the previous year’s growth was cut with a steel-blade trimmer, and the cut material completely removed from the study areas so that sampling and treatments were not affected by the presence of dead *Typha* biomass. This cutting and removal of *Typha* was also done to lay out each treatment block accurately and to increase light availability. Treatment and control plots inside each treatment replicate consisted of 1 x 1 m plots that were staked with PVC pipe and separated from each other by a 1 x 1 m working area/buffer (Figure 3). Treatments were applied in a complete factorial, random block design. The random block design is equivalent to stratified random sampling and is constructed to reduce variance in the data. This design is appropriate because one of the objectives of this study was to identify the treatment or combination of treatments that is most effective at reducing *Typha* cover; therefore, I was testing the interaction among two or more factors (treatments) on *Typha* growth/survival.

To measure the success of treatments, I sampled vegetation twice each year, which included identifying every plant within each treatment plot to species level and estimating percent cover of each species. I identified individual *Typha* stems to species level using a combination of indicators that differentiate *Typha* x *glauca* from *Typha angustifolia* (Gertz et al. 1994). These indicators include whole-plant morphology (height), leaf blade morphology (width and cross section), and flower morphology (ovary, style, and stigma). In addition, I counted *Typha* stems to show direct effects of treatments. Primary vegetation sampling occurred on 10 July 2010 and 30 June 2011, before each round of treatments was applied. Cutting and spraying were applied immediately following primary vegetation sampling. Secondary vegetation sampling occurred on 21 August 2010 and 19 August 2011 and involved recording the same parameters as the primary vegetation sampling (species percent cover and *Typha* stem counts). Following secondary vegetation sampling, the wick treatment was applied to re-sprouting *Typha* plants in applicable treatment plots.

Following the 2010 and 2011 treatment seasons, I continued to monitor vegetation and soil moisture in the 2012 growing season, although no treatments were applied in 2012. The beginning of the growing season corresponds to leaf-out of the native plant community and, in this case, the end of the growing season corresponds to leaf senescence.

I measured environmental factors to help understand the underlying variables related to *Typha* control and sedge/grass meadow restoration. I installed water-table wells at both ends of each treatment replicate to measure the variability of ground-water elevations throughout the growing season (Figure 3). Ground water elevations were taken weekly during the growing season. I determined ground water elevations by lowering a measuring tape down into the monitoring well until the tape was observed to touch the water. I calculated the elevation by subtracting the height of the well from the overall length of tape that was lowered.

Replicate elevations were determined using laser level survey from instantaneous lake-level readings from the nearby Cape Vincent gaging station.

Soil moisture and water levels were monitored for a complete growing season, which generally is from 1 April - 30 September. Because hydrology (and soil moisture) is the main factor in determining plant assemblages, it is important to monitor soil moisture throughout the growing season of multiple sampling seasons. I monitored soil moisture to determine if there were major differences in soil moisture throughout the growing season or among sampling seasons. Percent soil moisture measurements were taken in each plot to relate treatment success to soil moisture levels.

Because soil moisture conditions in the marsh vary throughout the year as a result of human-induced water-level manipulation, I monitored soil moisture, water table, and sediment characteristics to isolate treatment effects from environmental variables. In this manner, I was able to determine if the treatments, rather than environmental variables, affected the results of the study.

I took soil moisture readings to capture the complete rise and fall of Lake Ontario water-levels through an entire growing season. According to the Detroit District USACE Monthly Bulletin of Great Lakes Water Levels (Figure 4), long-term average lake levels are at a minimum in December, rise to a peak in June (with an inflection point in mid-February), and then begin lowering again.

Percent soil moisture measurements were taken with a Dynamax TH20 Moisture Probe in each plot to relate treatment success to soil moisture levels. In 2010, soil moisture and ground-water elevation measurements were taken weekly from 7 July to 21 August; one measurement was taken on 7 September. In 2011, soil moisture and ground-water elevation measurements were taken bi-monthly from 8 April to 20 May. Due to excessive spring rains and high lake levels in

2011, all five treatment replicates were inundated, causing 100% soil moisture, so readings were not taken in June and July. Measurements continued weekly from 22 July to the end of August, and two readings were taken in September.

In the spring of 2010, organic sediment depths of each treatment and control plot were measured using a soil auger to reach the underlying clay layer. Two surface soil cores with a volume of 298.02 $cm^3$ were collected per treatment replicate in 2010 to measure bulk density and percent soil organic matter. The soil samples were collected by pushing a 7.6-cm-diameter core tube 7.6 cm into the soil. Soil cores were kept in field state (refrigerated) until ready for drying. Bulk density analysis was conducted by methods described by Grossman and Reinsch (2002). Following bulk density analysis, percent loss on ignition was used to estimate percent organic matter using methods described by Storer (1984).

**STATISTICAL ANALYSES:**

Similar to the Czayka (2012) study, treatment data from the meadow marsh zone were analyzed statistically to determine the efficacy of each treatment or combination of treatments. The Chi-Square Goodness-of-Fit test was used to determine normality. Paired T-tests were used on response variables of normal datasets (*Typha* stem counts and *Typha* percent cover) to test the significance of individual treatments or treatment combinations. Meadow marsh species percent cover datasets were non-normal so the non-parametric alternative, the Wilcoxon signed-ranks test, was used to test the response of meadow marsh species percent cover to treatments. Paired treatment techniques were run against each other (e.g., C12WS1 vs C12WS1) based on pre-treatment 2010 samples versus post-treatment 2012 samples and using mean data from all five treatment replicates. One-way ANOVAs with Tukey's multiple comparison tests were used to analyze the equality of the five treatment replicates pre-experimentation (July 2010), based on *Typha* percent cover and stem counts. A one-way ANOVA with Tukey's multiple comparisons was used to test for differences in sediment depth among all five treatment replicates. The Kruskal-Wallis non-parametric alternative to ANOVA was used to test for differences in soil moisture among the five treatment replicates within each of the sampling years (2010-2012). The same test was used to test for differences in soil moisture among each treatment throughout all three sampling years (2010-2012). One-way ANOVA with Tukey's multiple comparisons was used to test for differences among mean bulk density samples and for mean percent organic matter samples among the five treatment replicates.

The assumptions of these tests are as follows: the starting conditions (soil moisture, bulk density, elevation) in each of the five blocks are similar; the five blocks contain approximately similar plant community proportions (25% cattail and 75% SGM); and the treatments and combination of treatments are applied in the same manner for each of the five replicates. This experiment also assumes that outside factors (such as grazing or disease) will not affect the growth or survival of the cattail community.

## RESULTS

### *Typha*

Before treatment, the mean *Typha* stem count across all plots was 856 stems. Of the 856 *Typha* stems, 625 stems or 73% were *Typha* x *glauca*, whereas 231 stems were *Typha angustifolia* (~27%). The largest number of *Typha* x *glauca* stems across all years (156 stems, 18%) was recorded in treatment replicate 3, which was positioned closest to Kents Creek (Figure 3).

Results showed that treatment replicates 1 and 5 differed significantly from each other (Figure 5) at the beginning of the study ($F=2.78$, $df=4$, $p=0.034$), while treatment replicates 1, 2, 3, and 4 had statistically similar stem counts. Treatment replicate 5 had the fewest mean number of stems (Figure 5).

For this study, the success of each treatment combination was evaluated based on the ability of each combination (e.g., C1SW1) to reduce *Typha* stem counts and percent cover of *Typha* over the three-year study period (pre-treatment 2010 vs. post-treatment 2012 vegetation sampling). Seven treatment combinations significantly reduced the mean number of *Typha* stems across all plots from 2010 to 2012: cutting in years 1, 2 (C12); cutting and wicking in years 1, 2 (C12W12); cutting and spraying in years 1, 2 (C12S12); cutting and spraying in years 1, 2 and wicking in year 1 (C12S12W1); cutting and wicking in year 1 (C1W1); cutting in year 1 and wicking in year 1, 2 (C1W12); and cutting and spraying in year 1 and wicking in years 1, 2 (C1S1W12) (Table 2, Figure 6). Treatment C12S12 resulted in the greatest reduction in stem count (Table 2). Seven treatments roughly halved the mean number of stems from 2010 to 2012 (Figure 7)

The remaining treatment combinations: C1, C12W1, C12S12W12, C1S1, and C1S1W1 did not significantly reduce *Typha* stem counts. The control treatment plots lost an average of 1.2 *Typha* stems throughout the two-year study, a decrease that was not statistically significant (p=0.247). In control plots, mean *Typha* stem counts fluctuated throughout the study period and dropped slightly at the end of the study, but the fluctuation and ultimate drop in stem count was not statistically significant (p=0.190).

Five treatment combinations significantly reduced mean *Typha* percent cover across all plots from 2010 to 2012: C12W12, C12S12, C1W12, C12W1, and C1SW12 (Table 3, Figure 8). Treatments C12S12 and C12W12 yielded the greatest reduction in percent cover (Table 3, Figure 9).

Four of the seven treatments that significantly reduced *Typha* stems also significantly reduced *Typha* percent cover: C12W12, C12S12, C1W12, and C1S1W12. The treatment combination C12W1 significantly reduced *Typha* percent cover but did not significantly reduce *Typha* stem counts. The remaining treatment combinations: C1, C12, C12SW12, C1W1, C1S, C1SW1, and C12SW1 also reduced *Typha* percent cover, but the reduction was not statistically significant. Percent cover of *Typha* in control plots fluctuated slightly throughout the study and ultimately dropped at the end of the study, but this drop was not statistically significant (p=0.851).

Although all treatment plots reduced *Typha* stem counts and percent cover of *Typha* in 2010 sampling (Figures 6 and 8), both rebounded to near pre-treatment conditions by the second growing season (spring 2011). Those treatments without multiple year applications (e.g., C1) showed an increase in *Typha* percent cover and stem counts (Figures 6 and 8).

The success of the treatments, based on reduction of *Typha* stem counts and percent cover, varied among the treatment replicates, suggesting a potential for environmental differences among treatment replicates. However, statistical analysis of the most important environmental factor that was measured, soil moisture, revealed that there was no statistical difference in percent soil moisture across all treatment replicates (Table 6, 7, 8).

Treatments had widespread success at reducing *Typha* stem counts across replicates but had varied success at reducing percent cover. Treatment replicates 1, 2, 3, and 4 had significantly fewer mean *Typha* stem counts at the end of the study (August 2012) compared to the beginning (July 2010) (Figure 10). Treatment replicate 1 had the greatest mean reduction of *Typha* stem counts (9.14), while treatment replicate 5 had the smallest mean reduction of *Typha* stem counts (1 stem reduced).

## Sedge/Grass Meadow

*Carex lacustris* and *Calamagrostis canadensis* were the two most dominant sedge/grass meadow species present in all five treatment replicates at Kents Creek. These two species were widely distributed throughout the study area and occurred in abundance in all five of the treatment replicates. The median percent cover of *C. lacustris* across all sample plots was 24.9% in 2010 and was

14.2% in 2012. The median percent cover of *C. canadensis* across all sample plots was 23.9% in 2010 and was 45.7% in 2012. Neither species showed marked changes in median percent cover in any of the treatment combinations through all three years of the study. The median percent cover of these two species increased and decreased throughout the length of the study, but the fluctuations showed no observable pattern. The reductions in percent cover and stem counts of *Typha* did not have an observable or statistically significant impact on the percent cover of *C. lacustris* or *C. canadensis.*

## Water Levels

Water-table elevations were used to detect replicate-site differences in water available from Lake Ontario. Data from water-table wells closely follow Lake Ontario gauged water-level data from the National Oceanic and Atmospheric Administration (NOAA 2011). In 2010, water-table elevations peaked in July at 74.97 m (IGLD1985) and steadily decreased throughout the growing season. This decrease continued until December 2010 before levels increased again in the spring of 2011. In 2011, the water table rose sharply in the spring and stayed elevated during May, June, and July (75.23, 75.33, and 75.14 m respectively). The water fluctuated throughout the remainder of the sampling season, which ended 23 September 2011 (Table 4, 5). In 2012, the water table steadily decreased throughout the sampling period, from74.91 m in May, to74.90 in June, 74.79 m in July, and 74.76 m in August.

## Soil Moisture

There were no significant differences in mean percent soil moisture among all treatment plots across all replicates for each of the three sampling seasons (Kruskall-Wallis, 2010: H=11.46, df=12, p=0.490, 2011: H=8.11, df=12, p=0.6.18, 2012: H=16.58, df=142, p=1.66) (Table 6, 7, 8). Based on this result, any differences in *Typha* cover probably were in response to treatments and not in response to differing soil moisture regimes.

Soil moisture was also used to detect differences in water availability among replicates. If a replicate had outlier soil moisture values, that could explain outlier treatment results. During 2010, there were significant differences in the median soil moisture among the five treatment replicates (Kruskal-Wallis, 2010: H=13.61, df=4,p=0.009). Since there is no multiple comparisons test for non-parametric statistics, the Kruskal-Wallis test does not identify which treatment replicates are significantly different. However, further analysis of the 2010 data shows that the median soil moisture content of treatment replicate 5 was 78.1% and the other treatment replicates were as follows: replicate 1, 85.3%; replicate 2, 90.2%; replicate 3, 90.8%; and replicate 4, 89.7%, suggesting that the location of replicate 5 may have been drier than the rest.

The differences in soil moisture among treatment replicates were less pronounced in 2011 and 2012 than in 2010. In 2011, treatment replicate 5 had a median of 90.3%, while the remaining replicates had median of 93.7, 96.27, 95.7, and 95.1, respectively. In 2012, treatment replicate 5 had a median of 75.2%, while the remaining replicates had medians of 80.6, 76.1, 67.9, and 73%, respectively. The average soil moisture for all three years, throughout the sampling year, provides a better overview of the soil moisture trends and the differences among each of the replicates (Figure 13).

There were no significant differences in soil moisture among the five treatment replicates during the 2011 and 2012 sampling seasons (Kruskal-Wallis, 2011: H=8.01, df=4, p=0.88, 2012: H=0.42, df=4, p=0.980). Despite the lack of statistically significant differences among treatment replicates during the 2011 and 2012 sampling seasons, further analysis suggests that there were differences in soil moisture between 2011 and 2012. The second field season (2011) was substantially wetter than both 2010 and 2012; the entire month of June 2011 had 100% soil moisture, and standing water was present in about half of the treatment plots in each of the five replicates. From 2010 to 2011, soil moisture increased by 8.4% for replicate 1, 6.1% for replicate 2, 4.8% for replicate 3, 5.4% for replicate 4, and 12.2% for replicate 5.

The third field season (2012) was substantially drier than the two previous years. From 2011 to 2012, soil moisture decreased by 13% for replicate 1, 20% for replicate 2, 27.8% for replicate 3, 22% for replicate 4, and 15% for replicate 5. In 2010 and 2011, replicate 5 was the driest by a substantial amount, and in 2012, replicate 5 was the third driest behind replicates 3 and 4.

There were significant differences in mean soil moisture in each of the three sampling seasons (2010-2012) (ANOVA: F=26.48, df=4, p=0.000). Tukey's multiple comparisons test showed that all three years were significantly different from each other (Table 12). The 2012 growing season had the lowest soil moisture levels.

## Sediment Depth

Sediment depth to clay differed significantly (ANOVA: F=3.50, df=4, p-value=0.012) among replicates. Treatment replicate 3 had significantly shallower sediment depth (32.64 cm) than the remaining replicates. The remaining replicates has sediment depths of 35.14 cm for replicate 1; 36.29 cm for replicate 2; 38.29 cm for replicate 4; and 38.29 cm for replicate 5.

## Soils

Mean soil bulk density across all plots (Figure 11) differed statistically (ANOVA: F=7.96, df=4, p-value=0.0214) among all five treatment replicates. Replicate 5 had statistically greater bulk density. This difference may further explain unexpected treatment outliers. For the five treatment replicates, differences among means for percent organic matter content were not significant (ANOVA: F=4.80, df=4, p=0.08). However, there were observable differences among the means. Treatment replicate 5 had the lowest percent organic matter with 18.7% organics, while replicate 1 contained 19.6%, replicate 2 contained 56.3%, replicate 3 contained 25.3%, and replicate 4 contained 46.7% organic matter.

# DISCUSSION

Cattails are R-selected strategists that have several life-history traits commonly observed in invasive species (Apfelbaum 1985). They have combinations of traits that allow them to outcompete and displace native species.

For example, cattails reproduce both sexually and asexually; they have rapid growth, reproduce rapidly, have high dispersal ability, are phenotypically plastic, and tolerate a wide range of environmental conditions. Furthermore, vast amounts of energy are stored in the belowground structures or rhizomes, so treatment efforts that do not target rhizomes are often ineffective. These combinations of traits make cattails exceedingly difficult to control in large-scale applications.

## Most Effective Treatments

The results of my study in a Lake Ontario drowned river-mouth wetland indicate that the success of controlling *Typha*, specifically *Typha* x *glauca*, depends on the combination of treatments applied and the time of year in which the treatments are applied. The most successful treatments involved a combination of cutting (C), spraying (S), and wicking (W) applied more than once during the two-year study. Specifically, the treatments that involved the wicking treatment in both years 1 and 2 were the most successful at reducing both *Typha* percent cover and stem counts. This wicking treatment was applied in late summer and was done by applying glyphosate (Rodeo) to re-sprouting *Typha,* thereby allowing the herbicide to be absorbed by the plant and eventually into the rhizomes. These results mirror the Czayka study, which found that the most important technique in the dense cattail zone was the late-season wick (W) treatment in combination with early summer cutting. This treatment combination was included in every successful treatment for reducing cattails (Czayka 2012).

The Czayka study also found that the tilling treatment, combined with cutting and wicking, led to increased cattail stem reductions.

Other studies have illustrated the impracticality of mechanical treatment methods for cattails, such as mowing, burning, and disking. Those techniques are labor-intensive, costly, and ineffective because the stands quickly reestablish themselves through vigorous rhizome growth (Beule 1979). Studies by Cole (1985), Franz et al. (1997), and Alibhai and Stallings (2001) further show the importance of applying herbicides later in the year to control *Typha* effectively. These studies have shown that glyphosate application is most effective in late summer when cattails are actively metabolizing and transporting carbohydrates to their rhizomes. Also, studies have shown a similar invasive species, *Phragmites australis,* to be highly sensitive to glyphosate, particularly to late summer application of the herbicide, and that mowing alone does little to decrease the dominance of *Phragmites* (Warren et al. 2001). In fact, mowing alone doubled the stem density (Warren et al. 2001).

## Less Effective Treatments

The results of my study seem to mirror the results of *Phragmites* control efforts in a *Phragmites*-dominated Great Lakes coastal wetland (Carlston, et al. 2009). For example, the single treatment of cutting in year 1 (a treatment similar to mowing *Phragmites* but on a much smaller scale) was unsuccessful at reducing both *Typha* percent cover and stem counts. Furthermore, those treatment plots that received the C1 treatment saw the largest rebound in cattail percent cover immediately following this treatment. This rebound is likely because cutting treatments do not stress the rhizome enough to affect *Typha*'s resprouting abilities and may only serve to increase sunlight penetration, thereby increasing the ability of *Typha* to resprout. Treatments that did not include herbicide application were generally unsuccessful at reducing percent cover and stem density of *Typha*. This result may be because those treatments do not target the rhizome, the organ that conveys much of the competitive advantages of *Typha*. There are no known studies that investigate the spatial dynamics of an individual *Typha* genet; it is possible that an individual *Typha* genet may be several square meters in size (Travis et al. 2010). Therefore, any treatment method that targets only individual *Typha* ramets, and not the rhizome itself, is likely to be ineffective. In this study, the C1 and C12 treatments, for example, involved cutting a few dozen cattail stems, which likely affected a very small fraction of the larger *Typha* organism that may have extended many more meters beyond the treatment replicates. The ramets that were cut were possibly connected, via the extensive rhizome mat, to other cattail ramets growing outside the treatment replicates. These uncut stems, located outside the treatment replicates, are part of the larger *Typha* genet and are supplying carbohydrates to the rhizome system. Therefore, the results of this study suggest that, for cutting treatments to be successful, cutting/mowing should take place on a much larger scale to reduce the vigor of the entire *Typha* genet.

The treatment combination involving a single cutting and spraying application was also not successful at reducing both *Typha* percent cover and stem counts. The spray treatment was conducted by applying glyphosate (Rodeo) to the cut *Typha* stalk during the initial treatment applications in late June and early July. The spray treatment is ineffective because, during early summer, *Typha* is not re-establishing carbohydrate reserves in the rhizomes, so herbicide does little to affect the root system. Personal observation of the cut and sprayed stems showed that the cut/spray treatment inflicted little biological stress on *Typha*, as the cut stems showed 10-15 cm of vigorous regrowth within just 1-2 days following the treatment application. The plants were able to resprout with little damage done to the rhizome, and the lack of late-season follow-up allowed *Typha* to rebound to near pre-treatment conditions. Observation of these cut and sprayed stems later in the growing season showed stunted growth; however, the plants did not die.

The spray treatment applied to the cut cattail stem was not as effective as wicking at reducing percent cover or stem counts. Of the five treatments that were effective at reducing *Typha* percent cover, two of them included the spray treatment. Of the six treatments that were not effective at reducing *Typha* percent cover, four of them included the spray treatment, and two of them included only cutting (cutting is similar to a mowing treatment, which has been previously shown to be ineffective at reducing similar invasive species) (Beule 1979).

## Outlier Treatments

Seven treatment combinations were effective at reducing *Typha* stem counts. Five of those treatments contained the wick treatment; the outliers were the C12 treatment and the C12S12 treatment, which were also significant despite lacking the wick treatment (Table 2). Some outliers might be explained by looking at variable environmental conditions, some at the replicate level. The C12S12 outlier may be explained by weather conditions during treatment application. Spray treatments had variable success at reducing *Typha* percent cover and stem counts. These variable results do not seem to follow a pattern with regard to environmental conditions at the replicate level. Instead, these results may be attributable to weather conditions experienced in 2011. The 2011 growing season saw an excessive amount of rainfall early in the summer. This excessive moisture was reflected in the marsh, as there was up to 16cm of standing water in the lower-elevation replicates (replicates 1-4). The spray treatment was administered to the *Typha* stump, which was cut just above the water level. Since lake levels continued to rise through the end of June during the 2011 sampling season, water levels in the marsh may have risen subsequent to cutting and spraying, which may have induced a flooding treatment to the cut and sprayed stem. This possible flooding event could explain the variable results with regard to treatments containing the spray treatment. Weather conditions are explained in greater detail in the next section.

Environmental conditions in replicate 5 cannot explain the success of the C12 treatment, since those environmental conditions such as drier soils, higher bulk density, and higher elevation impede *Typha* expansion. Looking at C12 across all replicates shows that this treatment had higher initial stem counts than 8 of the 12 treatment combinations. Since the initial stem counts were higher for this treatment combination, we would expect the stem count reductions to also be higher. The C12 treatment was not successful at reducing *Typha* percent cover, which also indicates that replicate environmental conditions did not affect this result.

Despite expectations, the C12S12W12 and C1S1W1 treatments were not effective at reducing percent cover or stem counts. The inclusion of more treatments and multiple applications of each treatment should have (negatively) affected *Typha* percent cover and stem counts, but surprisingly, these treatment combinations were not effective. This result is perhaps attributable to starting conditions and to environmental differences among replicates. For example, the mean starting percent cover for the C12S12W12 treatment across all replicates was 12.4% of *Typha* cover, which was the lowest initial percent cover of all treatment combinations. Also, this treatment had the lowest initial stem counts, 8.2 *Typha* stems, of all the treatments. The low starting percent cover and stem counts of this treatment combination may explain why the treatment was not successful at further reducing *Typha* percent cover or stem counts—there was less *Typha* there to effect a change in percent cover or stem count. These initial conditions of low stem counts and percent cover may be attributable to differences in environmental conditions at the replicate scale, such as drier soil conditions in replicate 5 and the higher elevation of replicate 3. Results show that replicates 1-4 significantly reduced stem counts by 9, 6, 8, and 6, respectively, but replicate 5 saw a reduction of only 2 stems (Figure 10). An analysis of replicate environmental conditions shows that replicate 5 may be an outlier replicate. This replicate occurred at a higher elevation, had the greatest soil bulk density, had drier soils throughout the study, and had the fewest initial *Typha* stem counts and percent cover. Replicate 3 was also located at a higher elevation than the remaining replicates and had low initial *Typha* percent cover at the start of the study. These outlier replicate and starting conditions may explain why treatments C12S12W12 and C1S1W1 should have worked, but did not.

Not surprisingly, if treatments were successful at reducing *Typha* stem counts, they were likely to be successful at reducing *Typha* percent cover. Four of the seven treatment combinations that reduced *Typha* stems also were significant for reducing *Typha* percent cover, but there were outliers.

Five treatment combinations were effective at reducing *Typha* percent cover. Four of the five treatments contained the wick application. Again, the outlier was the C12S12 treatment.

The C12S12W1 treatment was not successful at reducing *Typha* percent cover. This result may be attributable to starting conditions also. This treatment combination had an initial starting *Typha* percent cover of 13.4%. This starting percent cover is the second lowest starting percent cover, after the C12S12W12 treatment, and may explain the similar lack of success at further reducing *Typha* percent cover.

Percent cover may not always be an adequate representation of treatment success because plots may have a very low percent cover of *Typha* but a high stem count of very small *Typha* individuals. Personal observations of *Typha* stands revealed sprouts of *Typha* that were stressed by the initial treatment but were not killed. When follow-up treatments were applied, small, thin, low-cover *Typha* sprouts were present. Therefore, even though the data show decreases in percent cover, it is likely that those stressed plants lived and re-emerged the following year. Also, shoot and leaf loss does not necessarily indicate plant mortality because the extensive below-ground rhizomes are likely sending up shoots elsewhere in the cattail marsh. Asamoah et al. (2010) documented prompt shoot regrowth following re-flooding of cattails, which suggests that even 4-6 weeks of excessive drying treatments were insufficient to change large-scale *Typha* abundance.

## Additional Ecological Insights Gained from Replicate Analyses

Replicate conditions were compared to assess outlier treatments. These assessments provided some insights that were outside the intended purpose of this study. Although soil moisture did not differ significantly among treatment combinations, other environmental variables that I studied (sediment depth, elevation, soil bulk density) varied among the five treatment replicates. Most importantly, variable soil moisture conditions among replicates can explain treatment outliers, such as the lack of treatment C12S12W12 to produce significant results.

Sediment depth and elevation were not studied at the treatment level because differences in these variables would not show up at such a fine scale. Sediment depth and elevation would not be found to differ measurably at the meter or sub-meter scale; therefore, differences in these variables are explained at the replicate level.

All five treatment replicates had the same 14 randomly assigned treatments. Soil moisture was recorded for each treatment, so it is possible to assess the effect of percent soil moisture on individual treatments. While it is not possible to assess the effect of all other possible environmental variables on individual treatments, it is possible to analyze how the environmental variables that were studied affected *Typha* reduction at the replicate level. Such an analysis is not capable of pinpointing the effects that environmental variables had on each treatment technique (e.g., cut, wick, spray), but it can give insights on broader techniques for controlling *Typha.*

Percent soil moisture is an important variable when considering altered water levels in Lake Ontario. While percent soil moisture was not statistically different at the treatment level, soil moisture may have had an effect on the success of treatments among the five replicates. Treatment replicates 1, 2, 3, and 4 significantly reduced *Typha* stems replicate-wide (Figure 10), whereas replicate five was the only replicate that did not significantly lower *Typha* stems replicate-wide. Replicates 1-4 had significantly wetter soils throughout the three-year study than replicate 5. Replicate 5 also had less initial *Typha* percent cover and lower initial *Typha* stem counts (Figures 8 and 9). Replicate 5 was also located in the narrowest part of Kents Creek marsh (Figure 1 and 3). Location in the narrowest part of the marsh indicates that replicate 5 was not situated in the broad flat basin of the marsh, but rather at the edge of the marsh, where elevations begin to increase markedly. The position of replicate 5 may explain why replicate 5 had less initial cattail cover and stem numbers. These environmental conditions also may explain the lack of cattail control for the C12S12W12 and C1S1W1 treatments.

There was also observed variability in soil moisture within each replicate. Each of the five replicates was oriented parallel to the shoreline of Kents Creek. Because of this orientation, the first seven treatment plots were located slightly closer to the shore, and therefore slightly lower in elevation, than the last seven plots. Personal observation of soil moisture trends throughout the study period indicated that plots 1-7 usually had slightly higher percent soil moisture throughout the growing season, whereas plots 8-14 typically had lower percent soil moisture. I did not study the differences in *Typha* percent cover and stem counts between each half of the study plot; however, personal observation indicated that the higher-elevation plots (plots 8-14) showed slightly greater success at reducing *Typha* percent cover and stem counts. This trend was particularly evident within replicate 5.

Differences in soil moisture among the five treatment replicates were tied to the elevation of each replicate. Treatment replicates 3 and 5 were slightly higher in elevation on average than the remaining replicates (Table 5). This elevation and soil moisture difference can be observed in the pre-treatment conditions: treatment replicates 3 and 5 had fewer *Typha* stems and less overall cattail percent cover of *Typha* at the beginning of the study (Figures 8 and 9).

Water chemistry also affects the success of *Typha*. Increased soil moisture and prolonged inundation can release phosphorus (P) through internal eutrophication from wetland soils; *Typha* x *glauca* growth rate is known to increase with added P (Boers and Zedler 2008). Water chemistry explains how, through vegetative reproduction alone, *Typha* x *glauca* can invade and dominate new areas at the expense of other wetland species. Further, Boers and Zedler (2008) did not find any areas dominated by *Typha* x *glauca* where water levels fluctuated. Fluctuating water levels and soil moisture levels may explain why *Typha* has not fully dominated areas like replicate 5 and was generally easier to control in the replicates that had lower soil moisture; these areas experienced greater fluctuations in soil moisture and likely experienced dry soil conditions during at least part of the growing season. In all three years of this study, soil moisture decreased near the end of the growing season (late August – September). This drying period also corresponds to the time at which *Typha* is re-establishing carbohydrate reserves in the rhizome. If a more natural hydrologic cycle is implemented for Lake Ontario and water-levels are altered in such a manner as to begin the late-season drawdown period earlier, the conditions may reduce soil moisture, phosphorous availability, and stress the landward cattail rhizomes enough to prevent its further expansion into native sedge/grass meadow.

Weather conditions also had an impact on this study and on how the treatments were applied. According to the Palmer Drought Severity Index (NOAA National Weather Center Climate Prediction Center), the 2010 growing season had a near normal amount of rainfall for the year. The local drought conditions were reflected in the conditions of Kents Creek marsh, as the soil moisture readings showed average conditions throughout the growing season when compared to the 2011 and 2012 soil moisture readings (Figure 14).

However, the 2011 growing season saw an excessive amount of rainfall early in the summer. The Palmer Drought Severity Index showed very moist to extremely moist conditions in the region. As a result, regulated lake levels were elevated slightly. This excessive moisture was strongly reflected in the marsh. During the initial treatment application in late June, there was up to 16 cm of standing water in the lower-elevation replicates (replicates 1-4). This standing water had an effect on how the treatments were applied. In 2010, the cattail stems that received the C1 or C12 treatment were cut as close as possible to the soil surface, and the spray treatment was administered to a very short cattail stump. In 2011, however, the stems that received the C12 treatment had to be cut above the water level, which meant that there was about 16 cm of remaining stem following the cutting treatment. If the stems were cut near the soil surface, as they were in 2010, then we would have introduced a fourth treatment —– flooding. Also, if the stems had been cut below the water, then I would not have been able to apply the spray treatment to the cut stem. The lake levels continued to rise following application of the cut and spray treatment, which may have flooded some of the cut and sprayed stems.

It is unclear whether the spray treatment applied to a lower or higher-cut stem and whether flooding occurred sufficiently to affect the statistical outcomes; however, these anomalous conditions may explain why the spray treatments had a variable effect on cattail reduction. To confound the results further, the 2012 sampling season included one of the driest summers on record. The Palmer Drought Severity Index showed the study area to be in an extreme drought condition in July 2012. As a result, regulated lake levels were slightly lower. The control plots showed reductions in both *Typha* percent cover and stem counts in 2012, which suggests that *Typha* was water-stressed during the 2012 growing season; however, these reductions were not statistically significant. It is important to note that these reductions may be biologically significant, as it has already been demonstrated that cattail cover and soil moisture are closely correlated and that *Typha* loses vigor under drying conditions.

The bulk density analysis showed a similar pattern with regard to the significant differences of treatment replicates 3 and 5 as compared to the other replicates. This pattern may also explain the C12S12W12 and C1S1W1 treatment outliers. Soil bulk density is a measure of the ratio of the mass of the mineral grains to the total volume (Dadey et al. 1992). In this study, replicate 5 had the highest ratio of mineral matter among the five replicates. *Typha* produces large amounts of litter that decay slowly to form organic matter. The high bulk density seen in replicate 5 may be evidence that *Typha* has recently invaded replicate 5 and the area had not had time to accumulate litter and increase soil organic matter, in turn decreasing the bulk density of the soil. Higher bulk densities indicate that there is less pore space available in the soil, which means that the soil has lower moisture-holding capacity. Higher bulk density soil could be a contributor to the lower soil moisture found in replicate 5 and a reason why this replicate had less initial cattail cover and stem density.

Replicate 3 was located at a higher elevation, yet had some of the highest soil moisture readings of all the replicates. Replicate 3 also had relatively low soil bulk density and a statistically shallower sediment layer atop the underlying clay. The low bulk density indicates that replicate 3 was located on a low mound of soil that had high levels of organic matter. Soils with high organic matter content also have high water-holding capacities, due to large pore spaces between the individual soil particles (Adams and Froehlich 1981). High soil organic matter explains why replicate 3, although higher in elevation than the remaining replicates, has some of the highest soil moisture readings. The high levels of organic matter in this area also indicate that *Typha* has been in this area long enough to overlay the mineral-based soil with a more organic-based soil.

The trend in bulk density of soils among the five treatment replicates was confirmed by measurements of percent organic matter for each replicate.

Treatment replicate 5 had the lowest percent organic matter (~20%), which provides further evidence that the *Typha* in replicate 5 may have invaded that area more recently. Because the time since invasion was less, it is possible that the soil has not yet had time to transition into a more organic-based substrate. In addition, replicate 5 had lower soil moisture (higher elevation) compared to the other replicates; drier areas undergo faster decomposition rates thereby decreasing the rate of organic matter build-up.

Based on the results of this and the congruent Czayka study, the ability of *Typha* to invade into and dominate an area is due mainly to the area's hydrology and soil moisture. Since regulation of Lake Ontario began in the 1960s, stable water levels and consistently high lake levels during the growing season have allowed *Typha* to become the dominant plant species in wetlands that are hydrologically connected to the lake. Prior to water-level regulation, *Typha* was relegated to small pockets in coastal wetlands and sedge/grass meadow was the dominant vegetation community. Wilcox et al. (2008) documented a two-fold increase in percent cover of *Typha* and a 40% decline in percent areal coverage of meadow marsh at Kents Creek from 1960 to 2001.

In this study, those replicates at lower elevations (replicates 1, 2, and 4) experienced comparatively higher soil moistures that allowed for the expansion of *Typha*. Replicate 3, with its high percentage of soil organic matter and higher water-holding capacity, also experienced higher soil moistures throughout the growing season. The results of this study indicate that the soil moisture regime at

Kents Creek does not experience drying conditions for long enough during the growing season to diminish the ability of a *Typha* stand to survive and expand landward. A study using controlled hydrologic treatments showed that *Typha latifolia* must experience soil moisture less than 5% to cause complete root mortality (Asamoah and Bork 2010).

There is a chance that lake levels will never be regulated with variability sufficient to accommodate robust wetland communities; there are too may stakeholders in the debate. Without periodic low lake levels, *Typha* will never experience sufficient drying conditions to keep this plant from expanding further landward, and as a consequence, high quality sedge/grass meadow communities will continue to be lost to the expanding *Typha* stands. However, if a more environmentally sensitive hydrologic cycle is not implemented, methods tested in this study may be able to reduce *Typha* on Lake Ontario if applied on a multi-year basis, and on a modest scale. Despite consistent high lake levels in 2010 and 2011 and corresponding high soil moisture, treatments that involved a combination of cutting and wicking were successful at reducing both *Typha* stem counts and percent cover. With a combination of treatments, most importantly cutting in late spring/early summer and wicking in late summer, reduction of *Typha* on an individual wetland community scale is still a feasible option for reducing the overall cover of a *Typha* stand and allowing the continued existence of sedge/grass meadow.

Sedge/grass meadow species are being out-competed by *Typha* because the loss of periodic low lake levels has eliminated the sedge/grass species' competitive advantage under dry conditions. Sedge/grass meadow species are better competitors than *Typha* under dry soil conditions, but these conditions have not been seen in Lake Ontario since the late 1960s. The high soil moisture regime that has been in place since the 1960s has allowed *Typha* to expand into ranges previously dominated by sedge/grass meadow species and has led to a concomitant decline in sedge/grass meadow species. Successful techniques for controlling *Typha* will likely lead to increases in percent cover of sedge/grass meadow species with time if the species dominated before the *Typha* invasion. *Carex lacustris* and *C. canadensis* were the two primary sedge/grass meadow species sampled in the five treatment replicates. *Carex stricta* was also a co-dominant in most treatment plots.

The percent cover of *C. canadensis* and *C. stricta* fluctuated throughout the three-year study. This fluctuation in percent cover did not seem to mirror the fluctuations in percent cover of the *Typha* within the control plots. *Calamagrostis canadensis* and *C. lacustris* were present in abundance in almost every plot within each of the five treatment replicates. In addition, the random placement of treatment combination resulted in the presence of these two sedge/grass meadow species in almost every treatment combination among the five treatment replicates. Therefore, the evaluation of the percent cover of these two species based on each individual treatment combination was difficult.

It is unlikely that treatments administered upon individual *Typha* stems had a direct effect on these two dominant sedge/grass meadow species for the following reasons. 1) The sedge/grass meadow species that were abundant in all five treatment replicates were mature individuals, and there was little bare ground on which sedge/grass meadow species propagules could germinate. Further, the reduction of *Typha* percent cover and stem density, although statistically significant in some cases, did not provide enough bare ground on which a new sedge/grass meadow species propagule could germinate. 2) The sedge/grass meadow species grow and expand too slowly to be measured accurately within a three-year study. 3) *Carex stricta*, a tussock sedge, devotes a majority of its reserves to underground structures, so any increase in the vigor of this species may not have been observed by only looking at the above-ground structures (stems and leaves).

The pre-study cutting and removal of live and dead *Typha* material before vegetation sampling may have had an effect on the germination rates of some sedge/grass meadow species; however, since a majority of the sedge/grass meadow species sampled in the plots were comprised of perennial grasses and sedges, most of the growth of any germinated propagules would have occurred underground and would not have been observed.

In a *Carex* revegetation study, (Yetka and Galatowitsch 1999), *C. lacustris* had the highest rates of survival and germination at or near the water’s edge. Since the five treatment replicates were located along the landward edge of the invading *Typha*, it is unlikely that any sedge propagules germinated or survived to reach maturity during the course of this three-year study. Reduction in *Typha* stems/percent cover can directly influence the response of graminoid species (Hall and Zedler 2010). Reducing the amount of *Typha* increases light availability and reduces competition, both of which favor growth and expansion of sedge/grass meadow species, particularly annuals. Hall and Zedler (2010) showed that native graminoids responded to *Typha* harvest by increasing cover by 230% and 170% in experimental plots that had *Typha* cut and removed at least twice a year. Although the response was slow, graminoid vegetation expanded measurably in 4 x 8 m plots by the end of a two-year *Typha*-manipulation study (Hall and Zedler 2010). The relatively low initial percent cover and stem density of *Typha* in this study likely did not reach a threshold high enough to affect the survivability of mature sedge/grass meadow species, particularly the perennial graminoids such as *C. lacustris* and *C. stricta*. The species that most likely filled the void left by the cut cattail stems were low-stature annuals such as *Impatiens capensis* or *Bidens* spp. Quinlan and Mulamoottil (1987) and Wilcox et al. (2008) showed that decreases in soil moisture (low water periods) increase cover of sedge/grass meadow species, so if water-levels are regulated in such a manner as to produce low water levels during the growing season, sedge/grass meadow species such as *C. lacustris* and *C. canadensis* will likely increase in cover, especially if cattails are actively managed.

**Treatment Recommendations**

Based on the findings of this study and the Czayka study the most effective treatment for *Typha* control in Lake Ontario wetlands is cutting in late June followed by late-season wicking of the resprouted stems in August. This treatment combination should be implemented for at least two consecutive years. This treatment combination was best at reducing *Typha* stem counts and percent cover over the two-year study period at Kents Creek. The spray treatment had variable results; therefore, I would not recommend this treatment even if resources are available. If time and resources are limited, I recommend implementing cutting and wicking, as these two treatments were the most effective at reducing *Typha* stems.

Treatments performed on small scales, such as in this study, are feasible with a small group of workers; however, all *Typha* stems must be treated to ensure that the entire genet is targeted, rather than just a few ramets of the larger organism. Cutting with a steel-blade trimmer is labor- and time-intensive, but it is the most effective way to cut cattails without heavy machinery that is often impractical in saturated/inundated conditions. The Marshmaster ©, a tracked amphibious vehicle that can be equipped with a brush hog, can mow *Typha* in places a conventional tractor cannot go. Similarly, boats designed to shred aquatic vegetation can be used to cut *Typha.* Wicking *Typha* with glyphosate (Rodeo) can only be done by hand, if native vegetation is present.

The most commonly used herbicide Roundup® should not be used because the surfactant, polyethoxylated tallowamine (POEA), persists in the environment and has been found to be toxic to amphibians (Mann and Bidwell 1999). The acute lethal concentration estimations for some eastern North American amphibian species are very low (King and Wagner, 2010), and therefore Roundup® is not recommended for over-water use.

Alternatively, herbicide could be applied aerially to dense *Typha* stands with backpack sprayers. For large monocultures of *Typha*, the Marshmaster© can be equipped with spraying equipment to apply herbicide to large areas quickly. Other options include the use of airplanes to apply herbicide to large monocultures of invasive species; however, follow-up, on-the-ground spot treatment should be used to ensure that the entire *Typha* genet receives herbicide. For areas that contain native vegetation to be preserved for the purpose of re-colonizing the marsh, more labor-intensive herbicide application techniques, such as hand-wicking, should be used.

Herbicides with surfactant were once commonly used to control invasive species (Havey 1999); however, surfactants can be harmful to aquatic life such as amphibians (King and Wagner 2010). Rodeo is free of surfactants; therefore, upon contact with water, glyphosate's herbicidal activity decreases rapidly through adsorption to suspended soil particles, microbial degradation, and photolysis (Linz and Homan 2011).

Whether the current water-level regulation plan persists or a new regulation plan is implemented, the two-year *Typha* control plan should be performed during lower than average summer water levels, as lower water levels decrease soil moisture and further stresses *Typha* stands, thereby leading to an effective *Typha* management plan.

The Great Lakes wetland ecosystems are immensely sensitive to environmental and anthropogenic disturbances, and the health of these systems has been noticeably declining in recent decades. The plight of the Great Lakes has gained the attention of various state and federal agencies, such as the NYS Department of Environmental Conservation (DEC), the U.S. Environmental Protection Agency (EPA), and the U.S. Army Corps of Engineers. The Great Lakes Restoration Initiative (GLRI) is a federal restoration program that targets the most significant problems in the Great Lakes region. The GLRI includes the alteration of natural lake-level fluctuations and flow regimes as one of the five major threats to the health of Great Lakes habitats and wildlife, as this alteration in Lake Ontario has led to an altered food web, a loss of biodiversity, and poorly functioning ecosystems (Great Lakes Restoration Initiative Proposed 2010 Funding Plan 2009). The GLRI also emphasizes the need for better information to guide decision-making. This project provides necessary information on cattail management techniques for Great Lakes wetlands, which is a crucial step in implementing Great Lakes restoration actions under future GLRI programs.

The results derived from this study can lead to effective cattail control among smaller (2-5 ha) Great Lakes wetlands, where necessary. The work is feasible on small scales with a small group of workers working in teams. Through the Great Lakes Restoration Initiative, Ducks Unlimited and the US EPA are working to restore Great Lakes wetlands by implementing invasive species control methods to dense cattail stands. In addition, data from this study will provide land managers with a cattail management strategy that will effectively reduce the size and density of cattail stands and will aid in sedge/grass meadow restoration efforts throughout the Great Lakes. Successful restoration of native sedge/grass meadow vegetation communities will directly increase biodiversity in Great Lakes wetlands, and it will help to improve the overall health and vigor of the Great Lakes.

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## Treatment Options

| | |
|---|---|
| **C1** | cut year 1 |
| **C12** | cut years 1,2 |
| **C1S1** | cut and spray year 1 |
| **C12S12** | cut and spray year 1 and 2 |
| **C1W1** | cut year 1; wick year 1 |
| **C12W1** | cut years 1,2; wick year 1 |
| **C1S1W1** | cut year 1; spray year 1; wick year 1 |
| **C12S12W1** | cut years 1,2; spray years 1,2; wick year 1 |
| **C1W12** | cut year 1; wick years 1,2 |
| **C12W12** | cut years 1,2; wick years 1,2 |
| **C1S1W12** | cut year 1; spray year 1; wick years 1,2 |
| **C12S12W12** | cut years 1,2; spray years 1,2; wick years 1,2 |

Table 1. Treatment combinations devised for the two-year *Typha* control and sedge/grass meadow restoration study at Kents Creek (2010 and 2011).

Table 2. Treatment significance based on paired t-tests run on *Typha* stem counts for pre-treatment 2010 vs. post-treatment 2012 samples. *Treatments with p-values less than 0.05 significantly reduced *Typha* stem counts. Both control plots from all five treatment replicates were averaged together. Paired t-test statistics: C12, n=4, T-value=2.23; C12W12, n=4, T-value=3.33; C12S12, n=4, T-value=2.83; C12S12W1, n=4, T-value=4.25; C1W1, n=4, T-value=2.35; C1W12, n=4, T-value=3.21; C1S1W12, n=4, T-value=2.85.

| Treatment | P-value | Mean Stems before | Mean Stems after | Mean Stems reduced |
|---|---|---|---|---|
| **C1** | 0.217 | 17.2 | 13.2 | 4.0 |
| **C12** | 0.026* | 13.8 | 6.4 | 7.4 |
| **C12W1** | 0.074 | 14.8 | 6.0 | 8.8 |
| **C12W12** | 0.007* | 12.4 | 3.8 | 8.6 |
| **C12S12** | 0.002* | 16.0 | 4.2 | 11.8 |
| **C12S12W1** | 0.036* | 9.8 | 5.4 | 4.4 |
| **C12S12W12** | 0.067 | 8.2 | 2.6 | 5.6 |
| **C1W1** | 0.031* | 13.6 | 5.0 | 8.6 |
| **C1W12** | 0.003* | 12.6 | 5.2 | 7.4 |
| **C1S1** | 0.129 | 10.8 | 7.0 | 3.8 |
| **C1S1W1** | 0.179 | 12.0 | 8.2 | 3.8 |
| **C1S1W12** | 0.040* | 10.4 | 4.6 | 5.8 |
| **CNTRL** | 0.247 | 9.8 | 8.6 | 1.2 |

Table 3. Treatment significance based on paired t-tests run between *Typha* percent cover of pre-treatment 2010 vs. post-treatment 2012 samples. *Treatments with p-values less than 0.05 significantly reduced *Typha* percent cover. Both control plots from all five treatment replicates were averaged together. Paired t-test statistics: C12W1, n=4, T-value= 2.65; C12W12, n=4, T-value=3.54; C12S12, n=4, T-value=2.81; C1W12, n=4, T-value=4.05; C1S1W12, n=4, T-value=2.54.

| Treatment | P-value | Mean Percent cover before | Mean Percent cover after | Mean Percent cover reduced |
|---|---|---|---|---|
| **C1** | 0.214 | 21.4 | 17.0 | -4.4 |
| **C12** | 0.071 | 18.0 | 13.0 | -5.0 |
| **C12W1** | 0.011* | 17.0 | 8.0 | -9.0 |
| **C12W12** | 0.003* | 19.0 | 6.0 | -13.0 |
| **C12S12** | 0.020* | 21.0 | 8.0 | -13.0 |
| **C12S12W1** | 0.115 | 13.4 | 7.0 | -6.4 |
| **C12S12W12** | 0.117 | 12.4 | 5.4 | -7.0 |
| **C1W1** | 0.158 | 17.0 | 11.2 | -5.8 |
| **C1W12** | 0.037* | 17.4 | 6.4 | -11.0 |
| **C1S1** | 0.085 | 21.0 | 10.0 | -11.0 |
| **C1S1W1** | 0.440 | 15.0 | 14.0 | -1.0 |
| **C1S1W12** | 0.020* | 17.0 | 6.0 | -11.0 |
| **CNTRL** | 0.487 | 14.9 | 15.0 | 0.1 |

Table 4. The mean, maximum, and minimum ground-water elevation for five treatment replicates at Kents Creek in 2011 (IGLD 1985).

| 2011 ground water elevation | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|
| **Mean (m)** | 74.924 | 74.98 | 75.12 | 74.99 | 74.977 |
| **Max (m)** | 75.196 | 75.167 | 75.395 | 75.422 | 75.195 |
| **Min (m)** | 74.84 | 74.96 | 74.922 | 74.752 | 74.43 |

Table 5. The elevations of the ground surface at each treatment replicate at Kents Creek (IGLD 1985), two elevations surveyed at well sites were used to represent each replicate (east and west ends of the replicate).

| | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 4 | Rep. 5 |
|---|---|---|---|---|---|
| **East well (m)** | 75.107 | 74.998 | 75.199 | 75.08 | 75.155 |
| **West well (m)** | 75.126 | 74.983 | 75.202 | 75.07 | 75.136 |
| **Mean (m)** | 75.1165 | 74.9905 | 75.2005 | 75.075 | 75.1455 |

Table 6. Kruskall-Wallis Test showing no significant differences based on median percent soil moisture among the treatments at Kents Creek in 2010.

**Kruskal-Wallis Test: soil moisture versus treatment 2010**

| Treatment | N | Median | Ave Rank | Z |
|---|---|---|---|---|
| C1 | 15 | 94.60 | 107.9 | 0.16 |
| C12 | 15 | 95.70 | 122.9 | 1.15 |
| C12S12 | 15 | 95.70 | 122.9 | 1.15 |
| C12S12W1 | 15 | 78.80 | 85.6 | -1.32 |
| C12S12W12 | 15 | 92.70 | 95.5 | -0.66 |
| C12W1 | 15 | 88.60 | 99.1 | -0.43 |
| C12W12 | 15 | 95.90 | 128.7 | 1.53 |
| C1S1 | 15 | 92.50 | 92.7 | -0.85 |
| C1S1W1 | 15 | 94.70 | 118.5 | 0.86 |
| C1S1W12 | 15 | 88.60 | 77.7 | -1.84 |
| C1W1 | 15 | 92.10 | 105.9 | 0.03 |
| C1W12 | 15 | 92.70 | 109.4 | 0.26 |
| CNTRL | 30 | 93.20 | 105.1 | -0.04 |
| Overall | 210 | | 105.5 | |

H = 11.41 DF = 12 P = 0.494
H = 11.46 DF = 12 P = 0.490 (adjusted for ties)

Table 7. Kruskall-Wallis Test showing no significant differences based on median soil percent moisture among the treatments at Kents Creek in 2011.

**Kruskal-Wallis Test: soil moisture versus treatment 2011**

| Treatment | N | Median | Ave Rank | Z |
|---|---|---|---|---|
| C1 | 55 | 98.10 | 322.6 | -0.32 |
| C12 | 55 | 100.00 | 352.9 | 0.91 |
| C12S12 | 55 | 100.00 | 358.5 | 1.14 |
| C12S12W1 | 55 | 100.00 | 331.5 | 0.04 |
| C12S12W12 | 55 | 98.50 | 309.4 | -0.86 |
| C1S1 | 55 | 96.40 | 294.4 | -1.47 |
| C1S1W1 | 55 | 98.20 | 334.8 | 0.17 |
| C1S12W12 | 55 | 97.10 | 314.9 | -0.63 |
| C1W1 | 55 | 98.40 | 333.3 | 0.12 |
| C1W12 | 55 | 100.00 | 366.5 | 1.46 |
| CNTRL | 110 | 98.55 | 323.6 | -0.41 |
| Overall | 660 | | 330.5 | |

H = 7.20  DF = 10  P = 0.707
H = 8.11  DF = 10  P = 0.618  (adjusted for ties)

Table 8. Kruskall-Wallis Test showing no significant differences based on median percent soil moisture among the treatments at Kents Creek in 2012.

**Kruskal-Wallis Test: soil moisture versus treatment 2012**

| Treatment | N | Median | Ave Rank | Z |
|---|---|---|---|---|
| C1 | 35 | 78.30 | 221.8 | -1.03 |
| C12 | 35 | 83.70 | 249.4 | 0.17 |
| C12S12 | 35 | 82.50 | 251.4 | 0.25 |
| C12S12W1 | 35 | 79.90 | 221.2 | -1.05 |
| C12S12W12 | 35 | 80.50 | 228.5 | -0.74 |
| C12W1 | 35 | 85.40 | 285.0 | 1.71 |
| C12W12 | 35 | 83.60 | 261.3 | 0.68 |
| C1S1 | 35 | 80.10 | 209.7 | -1.55 |
| C1S1W1 | 35 | 84.30 | 267.5 | 0.95 |
| C1S12W12 | 35 | 78.60 | 221.3 | -1.05 |
| C1W1 | 35 | 87.30 | 304.2 | 2.55 |
| C1W12 | 35 | 82.70 | 251.8 | 0.27 |
| CNTRL | 70 | 76.30 | 232.1 | -0.86 |
| Overall | 490 | | 245.5 | |

H = 16.58  DF = 12  P = 0.166
H = 16.58  DF = 12  P = 0.166  (adjusted for ties)

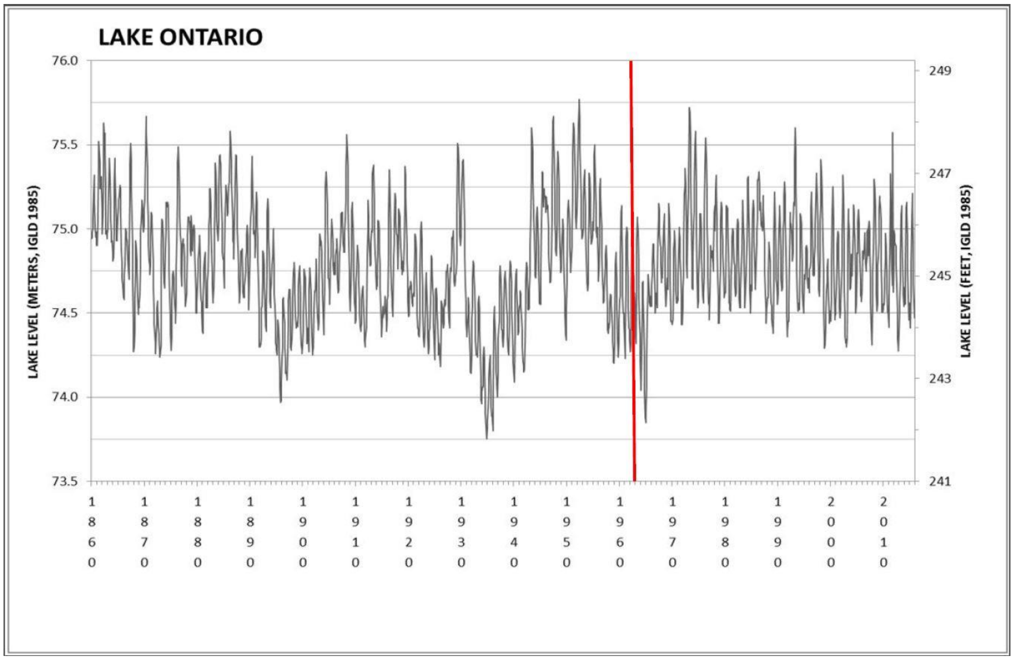


Figure 1. A hydrograph of Lake Ontario showing water levels (meters) from 1860 to 2011. Notice the periodic cycling nature until the early 1970s. Lake-level regulation stabilized water levels and allowed no low lake levels following the mid-1960s. Vertical line denotes the start of lake-level regulation. Source: NOAA monthly mean Lake Ontario data.

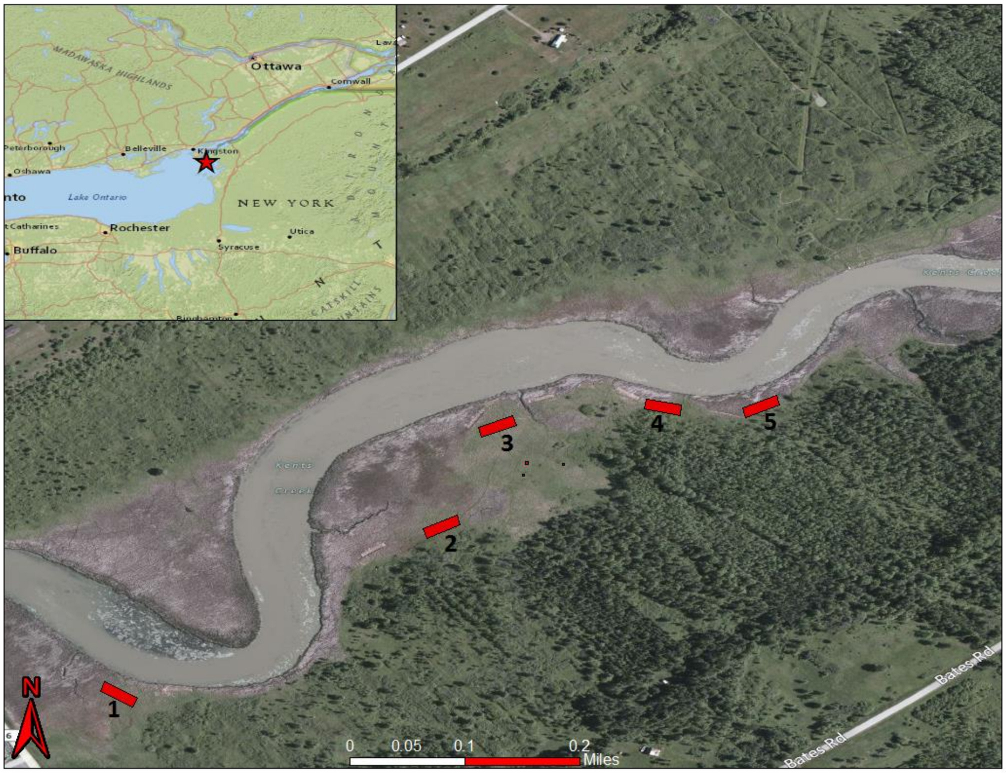


Figure 2. Location and alignment (approx.) of the five treatment replicates at Kents Creek, a drowned-river-mouth tributary to Lake Ontario.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | | **2** | | **3** | | **4** | | **5** | | **6** | | **7** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8** | | **9** | | **10** | | **11** | | **12** | | **13** | | **14** |

Figure 3. The random placement of each treatment combination within treatment replicate 3. The circles at each end of the table represent the placement of the water-table wells for each treatment replicate. Soil core samples were taken near the water-table wells in each replicate. Soil moisture readings were taken in the southeast corner of each treatment plot. The space between each treatment plot represents the 1m working buffer. Treatment layout for replica 1: 1=C1S1W12, 2=CIW1, 3=C1S1, 4=C12W12, 5=C12, 6=C1, 7=CNTRL, 8=C12S12W1, 9=C12S12, 10=C1WS1, 11=C1S12, 12=C12S1, 13=CNTRL, 14=C12S12W12.

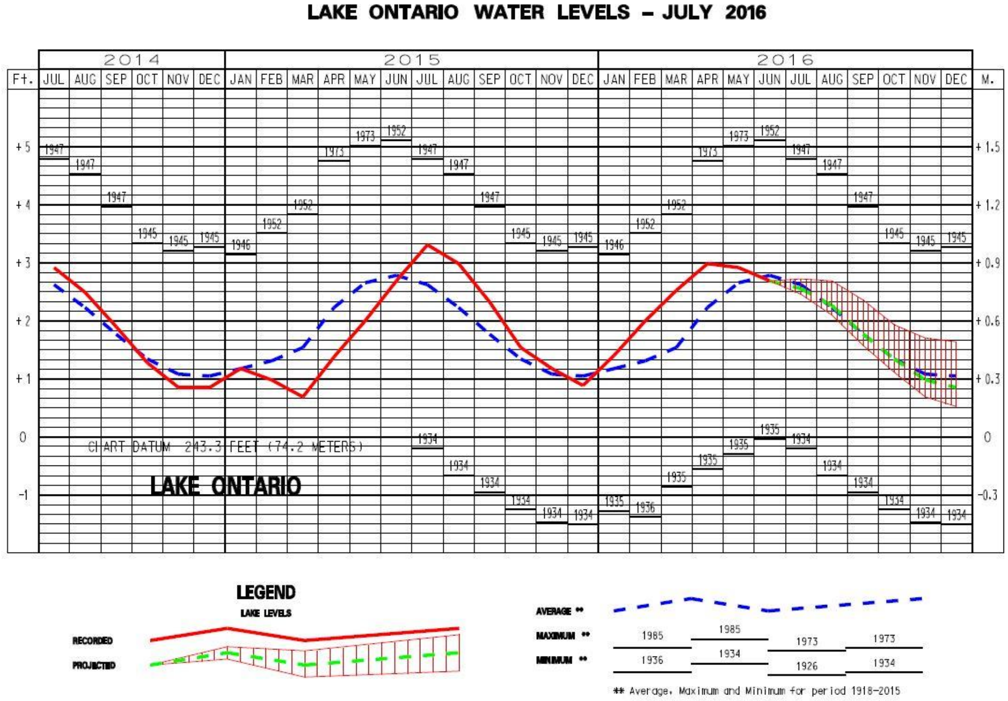


Figure 4. United States Army Corps of Engineers Detroit District Monthly Bulletin of Great Lakes Water Levels.

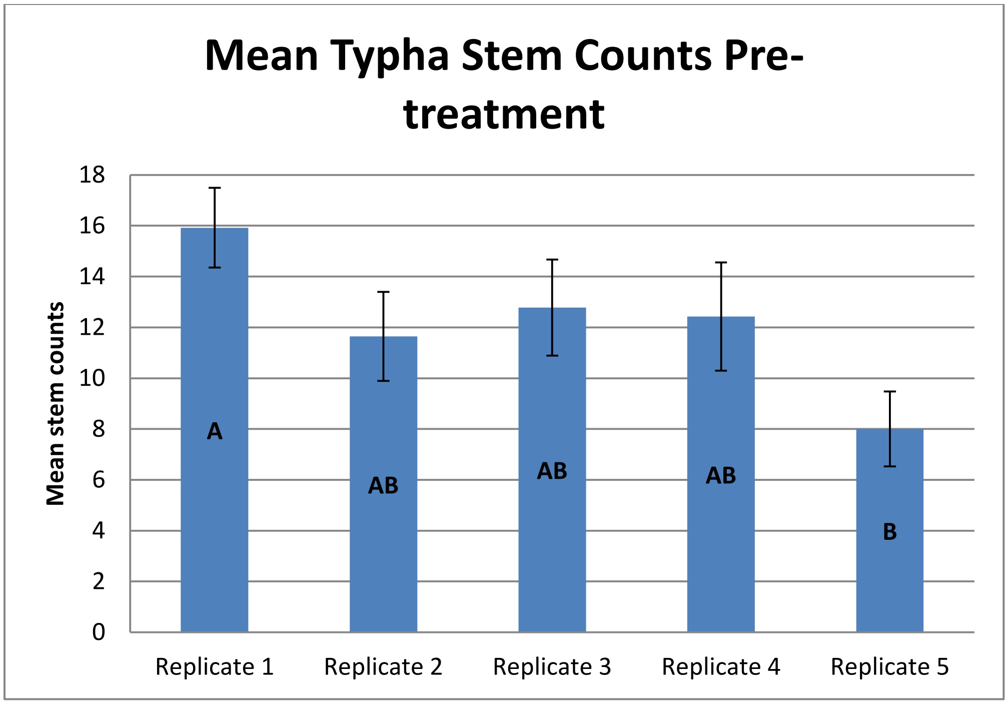


Figure 5. Mean stem counts of *Typha* across all five replicates at the start of the study (July 2010). (ANOVA: F=2.78, df=4, p=0.034). Means that do not share a letter are statistically different.

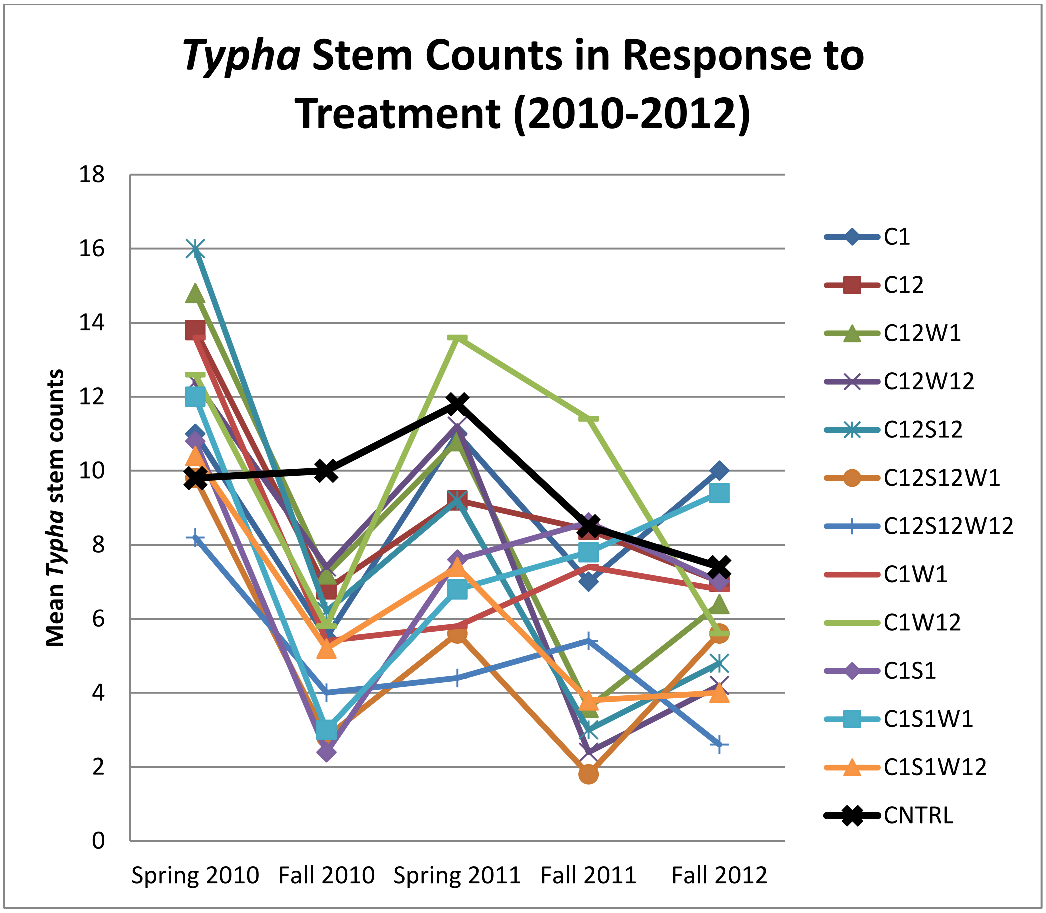


Figure 6. Mean *Typha* stem counts (averaged over all five replicas) for each treatment at each sampling date. Spring 2010 values represent pre-treatment conditions and fall 2012 values represent a full growing season following the last round of treatments. See Table 1 for treatment abbreviations.

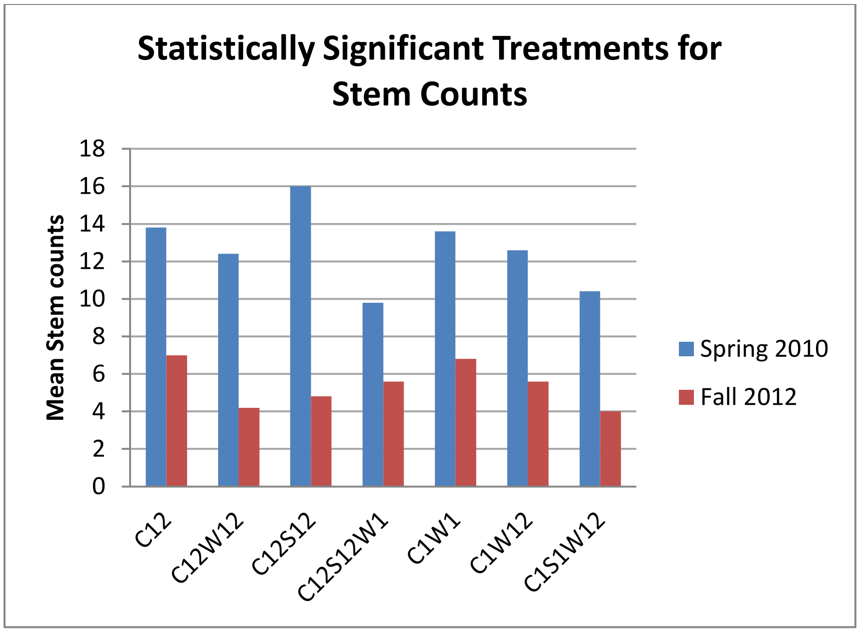


Figure 7. Treatment combinations that significantly reduced mean *Typha* stem counts. (P-values: C12: 0.026; C12W12: 0.007; C12S12: 0.002; C12S12W1: 0.036; C1W1: 0.031; C1W12: 0.003; C1S1W12: 0.04). See Table 1 for treatment abbreviations.

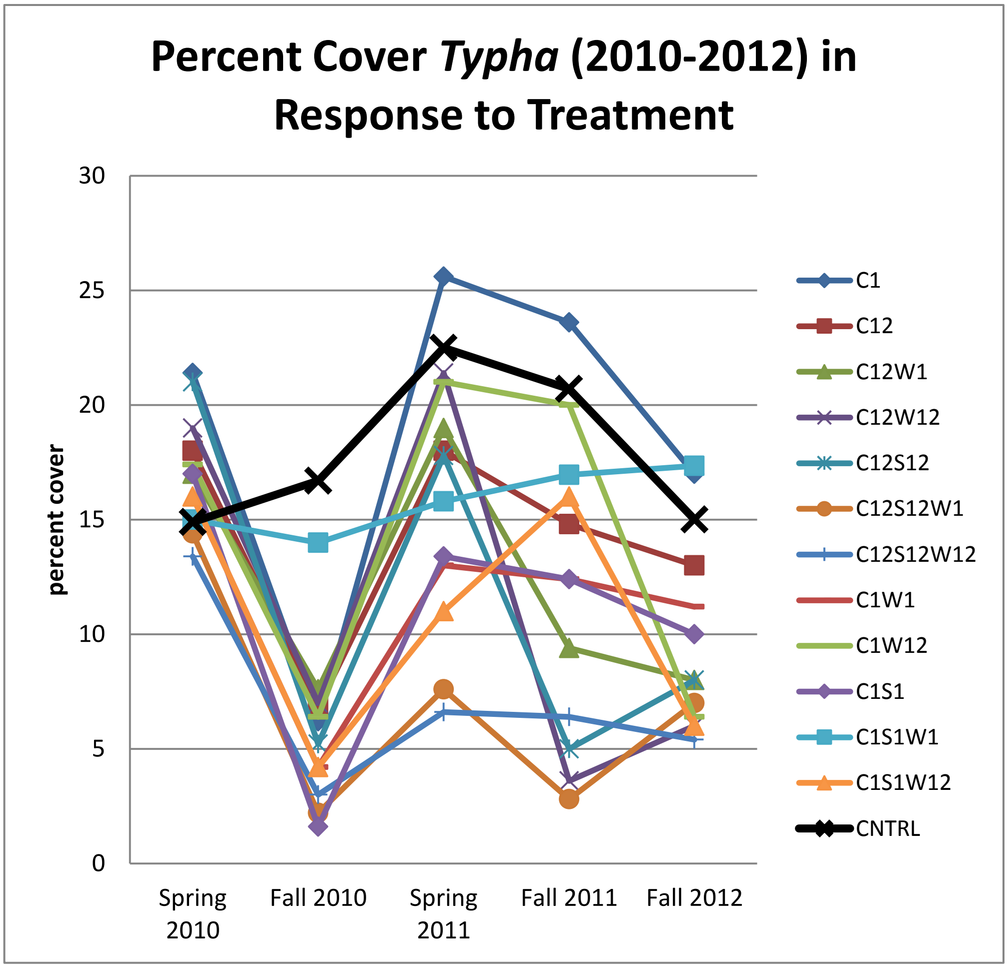


Figure 8. *Typha* percent cover (averaged over all five replicates) for each treatment at each sampling date. Spring 2010 values represent one full growing season following the last treatment. See Table 1 for treatment abbreviations.

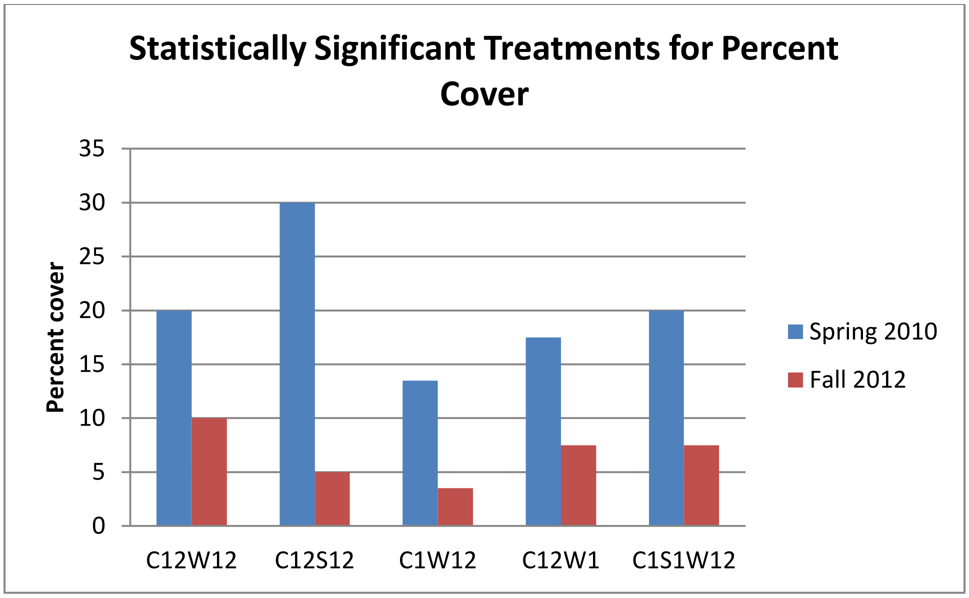


Figure 8. Treatments that significantly reduced mean percent cover *Typha*. (P-values: C12W12: 0.003; C12S12: 0.02; C1W12: 0.037; C12W1: 0.011; C1S1W12: 0.02). See Table 1 for treatment abbreviations.

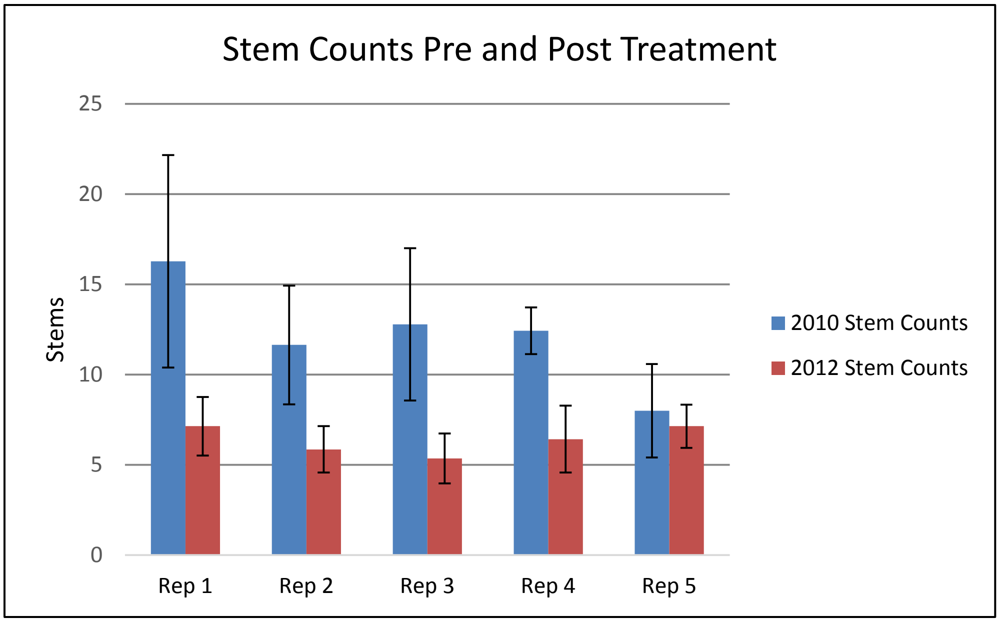

Figure 9. Mean Typha stem counts pre-treatment (2010) and post-treatment (2012). Replicates 1, 2, 3, and 4 all saw significant reductions in Typha stems. (ANOVA: F=4.19, df=3, p=0.013).

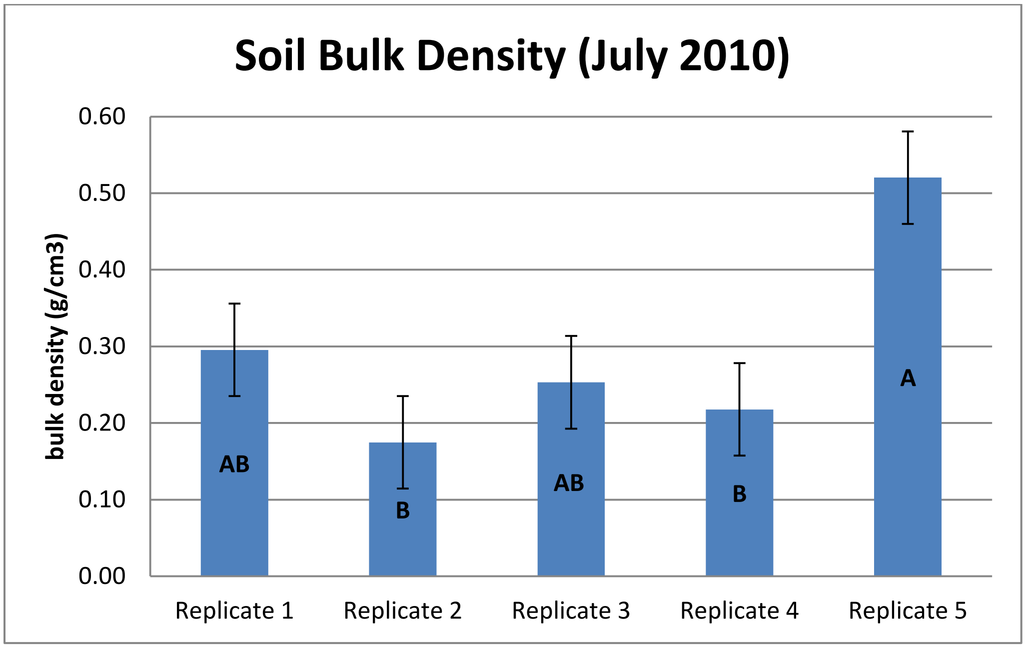


Figure 10. Mean soil bulk density (g/cm3) (±1 S.E) at the start of the study. Replicate 5 had statistically greater bulk density. (ANOVA: F=7.96, df=4, p-value=0.0214). Means that do not share a letter are significantly different.

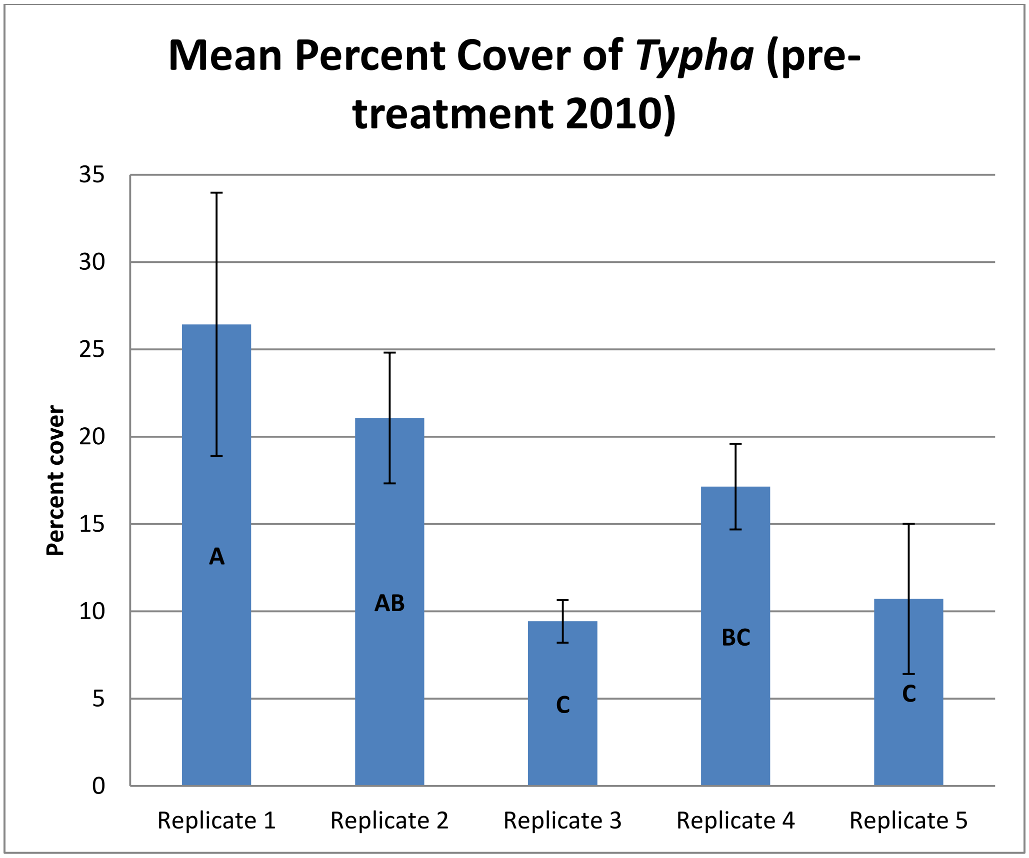


Figure 11. Mean percent cover of *Typha* across all five replicates at the start of the study. (ANOVA: F=12.09, df=4, p=0.000). Means that do not share a letter are statistically different.

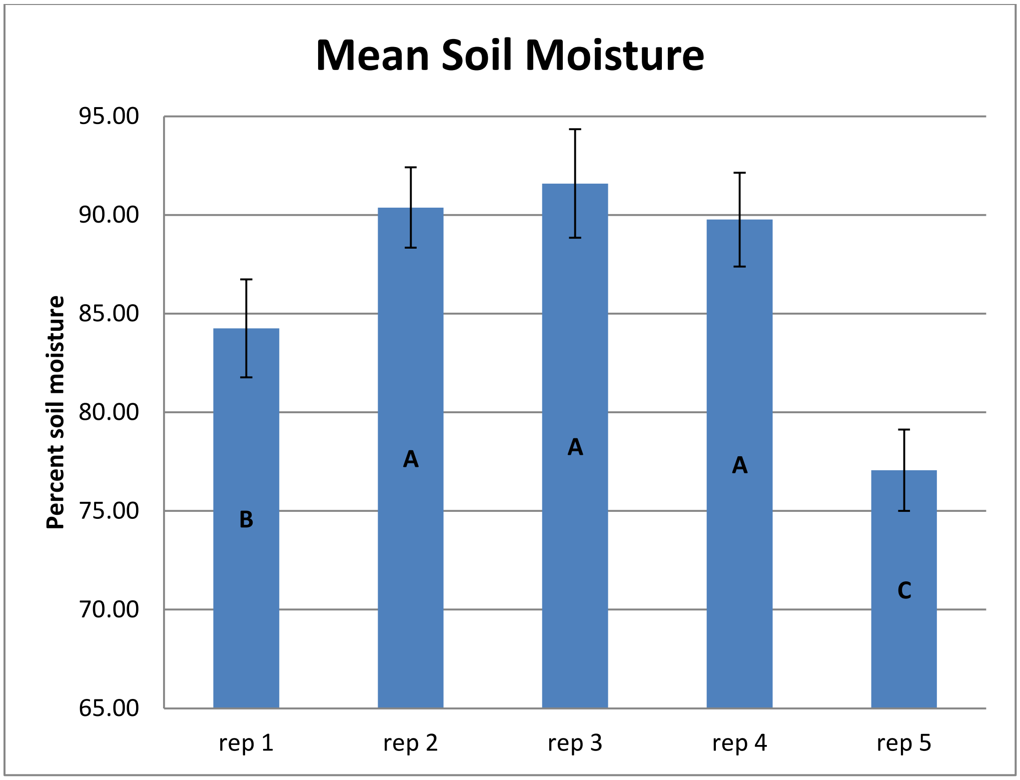


Figure 12. Mean soil moisture of each replicate. Replicate five was statistically drier than the remaining replicates (ANOVA: F=32.17, df=4, p=0.000). Means that do not share a letter are significantly different.

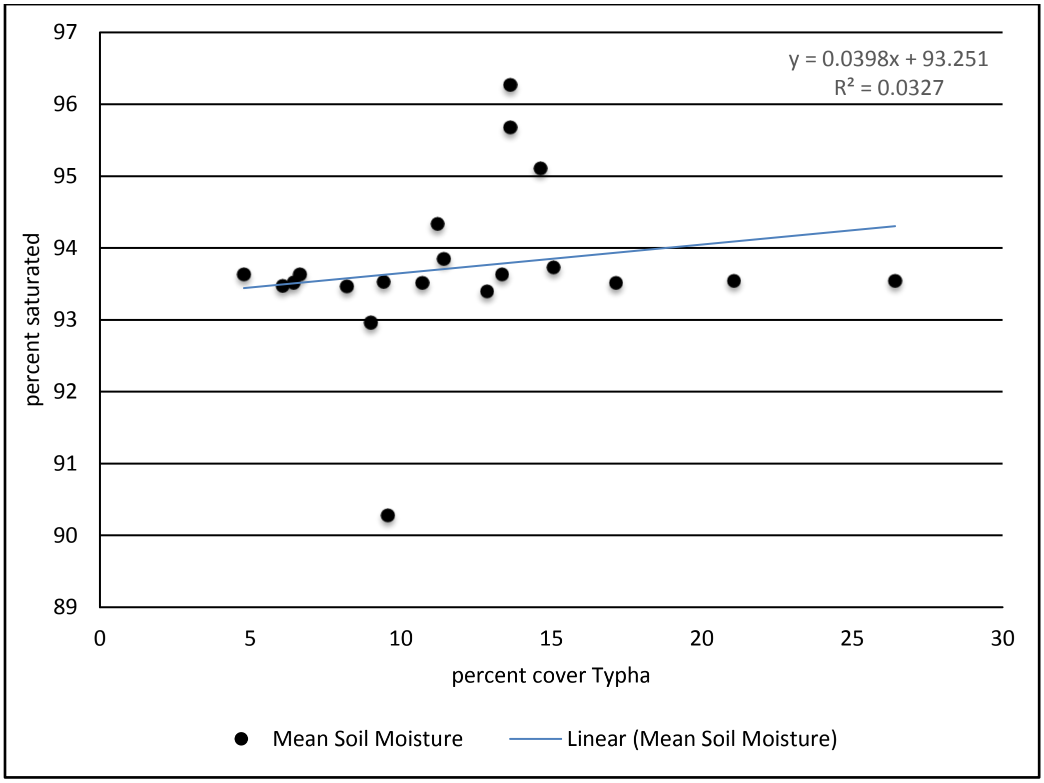


Figure 13. Percent cover vs. soil moisture regression across all replicates across all three years (May 2010 – September 2012).

**Appendix A.**
Kents Creek Species List:

Nomenclature according to: Kartesz, J.T., The Biota of North America Program (BONAP). 2015. *Taxonomic Data Center*. (http://www.bonap.net/tdc). Chapel Hill, N.C.

*Anemone canadensis* L.

*Aster* spp. *(smooth)*

*Bolboshoenus fluviatilis* (Torr.) Sojak

*Calamagrostis canadensis* (Michx) P. Beauv

*Calystegia sepium* L.

*Campanula aparanoides* Pursh

*Carex atherodes* Spreng.

*Carex blanda* Dewey

*Carex lacustris* Willd

*Carex stricta* Lam.

*Cicuta maculata* L.

*Cirsium arvense* L.

*Convolvulus arvensis* L.

*Galium trifidum* L.

*Impatiens capensis* Meerb.

*Lathyrus palustris* L.

*Lycopus americanus* W. P. C. Barton

*Lycopus unifloris* Michx.

*Lysimachia ciliata* L.

*Lysimachia terrestris* L.

*Lysimachia thyrisifolia* L.

*Mentha arvensis* L.

*Phalaris arundinacea* L.

*Phragmites australis* (Cav.) Trin. ex Steudel

*Persicaria amphibia* L.

*Satureja vulgaris* L.

*Scutellaria galericulata* L.

*Solanum dulcamara* L.

*Solidago gigantea* Aiton

*Solidago rugosa* Mill.

*Solidago* spp.

*Stachys palustris* L.

*Teucrium canadense* L.

*Typha angustifolia* L.

*Typha* x *glauca* Godr.

*Vicia cracca* L.

## Appendix B

Kents Creek vegetation data (2010-2012)

| **Replicate 1: 11 July 2010** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1W12** | **C1S1** | **C1W1** | **C12S12** | **C12** | **C1** | **CNTRL** | **C12S12W1** | **C12W12** | **C1S1W1** | **C1W12** | **C12W1** | **CNTRL** | **C12S12W12** | |
| **Sediment depth (cm)** | 40 | 35 | 34 | 40 | 35 | 35 | 35 | 40 | 35 | 30 | 30 | 30 | 35 | 38 | 35.14 |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 3.00 | 7.00 | 8.00 | 10.00 | 8.00 | 8.00 | 6.00 | 7.00 | 4.00 | 1.00 | 5.00 | 4.00 | 6.00 | 3.00 | 5.71 |
| Typha x glauca stem count | 18.00 | 12.00 | 16.00 | 12.00 | 14.00 | 13.00 | 12.00 | 10.00 | 6.00 | 4.00 | 6.00 | 11.00 | 8.00 | 6.00 | 10.57 |
| Total Typha stem count | 21.00 | 19.00 | 24.00 | 22.00 | 22.00 | 21.00 | 18.00 | 17.00 | 10.00 | 5.00 | 11.00 | 15.00 | 14.00 | 9.00 | 16.29 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 4.29 | 14.74 | 10.00 | 15.91 | 9.09 | 11.43 | 10.00 | 12.35 | 8.00 | 2.00 | 11.36 | 5.33 | 8.57 | 8.33 | 9.39 |
| Typha x glauca | 25.71 | 25.26 | 20.00 | 19.09 | 15.91 | 18.57 | 20.00 | 17.65 | 12.00 | 8.00 | 13.64 | 14.67 | 11.43 | 16.67 | 17.04 |
| Total Typha | 30.00 | 40.00 | 30.00 | 35.00 | 25.00 | 30.00 | 30.00 | 30.00 | 20.00 | 10.00 | 25.00 | 20.00 | 20.00 | 25.00 | 26.43 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 10.00 | 5.00 | 15.00 | 20.00 | 15.00 | 15.00 | 50.00 | 5.00 | 10.00 | 10.00 | 15.00 | 20.00 | 10.00 | 5.00 | 14.64 |
| Carex stricta | 15.00 | 10.00 | 15.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 5.00 | 15.00 | 10.00 | 10.00 | 10.00 | 5.00 | 9.29 |
| Calamagrostis canadensis | 35.00 | 50.00 | 35.00 | 20.00 | 25.00 | 25.00 | 10.00 | 45.00 | 35.00 | 30.00 | 35.00 | 25.00 | 10.00 | 15.00 | 28.21 |
| Phalaris arundinacea | 15.00 | 2.00 | 5.00 | 15.00 | 0.00 | 5.00 | 15.00 | 5.00 | 15.00 | 35.00 | 10.00 | 10.00 | 30.00 | 35.00 | 14.07 |
| Teucrium canadense | 10.00 | 1.00 | 20.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 20.00 | 10.00 | 15.00 | 1.00 | 8.36 |
| Lysimachia thyrisiflora | 1.00 | 15.00 | 5.00 | 10.00 | 3.00 | 2.00 | 5.00 | 5.00 | 10.00 | 10.00 | 1.00 | 1.00 | 5.00 | 2.00 | 5.36 |
| Impatiens capensis | 1.00 | 3.00 | 0.00 | 5.00 | 25.00 | 5.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.00 | 1.00 | 0.00 | 1.00 | 3.29 |
| Lathyrus palustris | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 2.00 | 0.50 |
| Anenome canadensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 0.00 | 1.50 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 | 0.00 | 5.00 | 1.79 |
| Solidago rugosa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.14 |
| Galium trifidum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |

| Replicate 2 -7/10/2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1** | **C12S12** | **C1S1W1** | **C1** | **C12** | **C1W12** | **C1S1W12** | **CNTRL** | **C12W12** | **CNTRL** | **C12S12W12** | **C12W1** | **C12S12W1** | **C1W1** | |
| **Sediment depth (cm)** | 43 | 40 | 40 | 35 | 35 | 35 | 40 | 35 | 35 | 40 | 30 | 30 | 35 | 35 | 36.29 |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 8.00 | 2.00 | 9.00 | 8.00 | 2.00 | 3.00 | 2.00 | 3.00 | 2.00 | 4.00 | 2.00 | 3.00 | 3.00 | 1.00 | 3.71 |
| Typha x glauca stem count | 11.00 | 5.00 | 18.00 | 13.00 | 11.00 | 11.00 | 8.00 | 5.00 | 7.00 | 5.00 | 3.00 | 6.00 | 5.00 | 3.00 | 7.93 |
| Total Typha stem count | 19.00 | 7.00 | 27.00 | 21.00 | 13.00 | 14.00 | 10.00 | 8.00 | 9.00 | 9.00 | 5.00 | 9.00 | 8.00 | 4.00 | 11.64 |
| ***Typha*** **Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 12.63 | 4.29 | 11.67 | 11.43 | 3.85 | 5.36 | 4.00 | 7.50 | 4.44 | 8.89 | 4.00 | 6.67 | 5.63 | 2.50 | 6.63 |
| Typha x glauca | 17.37 | 10.71 | 23.33 | 18.57 | 21.15 | 19.64 | 16.00 | 12.50 | 15.56 | 11.11 | 6.00 | 13.33 | 9.38 | 7.50 | 14.44 |
| Total Typha | 30.00 | 15.00 | 35.00 | 30.00 | 25.00 | 25.00 | 20.00 | 20.00 | 20.00 | 20.00 | 10.00 | 20.00 | 15.00 | 10.00 | 21.07 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 35.00 | 25.00 | 25.00 | 30.00 | 30.00 | 40.00 | 15.00 | 50.00 | 50.00 | 45.00 | 45.00 | 45.00 | 35.00 | 10.00 | 34.29 |
| Carex stricta | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 5.00 | 10.00 | 15.00 | 15.00 | 5.00 | 10.00 | 5.00 | 10.00 | 10.00 | 8.57 |
| Lysimachia thyrisiflora | 10.00 | 5.00 | 10.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 15.00 | 5.00 | 10.00 | 10.00 | 15.00 | 2.00 | 8.36 |
| Impatiens capensis | 5.00 | 5.00 | 1.00 | 10.00 | 5.00 | 15.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 3.14 |
| Teucrium canadense | 5.00 | 15.00 | 0.00 | 10.00 | 10.00 | 10.00 | 1.00 | 10.00 | 30.00 | 20.00 | 15.00 | 0.00 | 10.00 | 10.00 | 10.43 |
| Calamagrostis canadensis | 1.00 | 0.00 | 5.00 | 0.00 | 15.00 | 30.00 | 5.00 | 5.00 | 15.00 | 20.00 | 15.00 | 20.00 | 30.00 | 15.00 | 12.57 |
| Phragmits australis | 0.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 2.14 |
| Campanula arapanoides | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.50 |
| Phalaris arundinacea | 0.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 10.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 15.00 | 3.57 |
| Calystegia sepium | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 5.00 | 2.00 | 0.00 | 0.00 | 1.57 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Persicaria amphibia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 5.00 | 5.00 | 0.00 | 1.00 |
| Anemone canadensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.36 |
| Stachys palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.71 |
| Solidago rugosa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.14 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.71 |

| Replicate 3 - 7-09-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W1** | **C1W12** | **C12** | **CNTRL** | **C12S12W12** | **C1W1** | **C1** | **C12W12** | **C12S12W1** | **C1S1** | **C1S1W12** | **CNTRL** | **C1S1W1** | |
| **sediment depth** | 30.00 | 39.00 | 30.00 | 35.00 | 39.00 | 35.00 | 39.00 | 30.00 | 20.00 | 35.00 | 28.00 | 35.00 | 32.00 | 30.00 | 32.64 |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 6.00 | 2.00 | 3.00 | 2.00 | 4.00 | 1.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 1.00 | 2.00 | 0.00 | 1.64 |
| Typha x glauca stem count | 12.00 | 29.00 | 12.00 | 18.00 | 6.00 | 15.00 | 7.00 | 8.00 | 12.00 | 13.00 | 9.00 | 4.00 | 6.00 | 5.00 | 11.14 |
| Total Typha stem count | 18.00 | 31.00 | 15.00 | 20.00 | 10.00 | 16.00 | 7.00 | 8.00 | 14.00 | 13.00 | 9.00 | 5.00 | 8.00 | 5.00 | 12.79 |
| ***Typha* Percent cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 3.33 | 0.97 | 2.00 | 2.00 | 4.00 | 0.94 | 0.00 | 0.00 | 1.43 | 0.00 | 0.00 | 1.00 | 1.75 | 0.00 | |
| Typha x glauca | 6.67 | 14.03 | 8.00 | 18.00 | 6.00 | 14.06 | 5.00 | 5.00 | 8.57 | 10.00 | 5.00 | 4.00 | 5.25 | 5.00 | |
| Totatl Typha | 10.00 | 15.00 | 10.00 | 20.00 | 10.00 | 15.00 | 5.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 7.00 | 5.00 | 9.43 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 5.00 | 7.00 | 10.00 | 15.00 | 20.00 | 30.00 | 35.00 | 5.00 | 10.00 | 15.00 | 25.00 | 60.00 | 60.00 | 20.00 | 22.64 |
| Carex stricta | 10.00 | 10.00 | 5.00 | 10.00 | 15.00 | 15.00 | 10.00 | 5.00 | 10.00 | 10.00 | 15.00 | 5.00 | 5.00 | 15.00 | 10.00 |
| Calamagrostis canadensis | 60.00 | 30.00 | 15.00 | 5.00 | 15.00 | 10.00 | 20.00 | 60.00 | 50.00 | 30.00 | 35.00 | 10.00 | 30.00 | 10.00 | 27.14 |
| Teucrium canadense | 5.00 | 15.00 | 20.00 | 20.00 | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 | 15.00 | 15.00 | 15.00 | 1.00 | 20.00 | 10.43 |
| Persicaria amphibia | 2.00 | 2.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 5.00 | 1.79 |
| Impatiens capensis | 1.00 | 2.00 | 1.00 | 1.00 | 20.00 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 5.00 | 2.71 |
| Lysimachia thyrisiflora | 2.00 | 2.00 | 1.00 | 1.00 | 5.00 | 10.00 | 2.00 | 1.00 | 0.00 | 1.00 | 2.00 | 1.00 | 0.00 | 0.00 | 2.00 |
| Lathyrus palustris | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 2.00 | 1.00 | 1.00 | 0.00 | 0.00 | 5.00 | 5.00 | 2.00 | 5.00 | 3.00 | 8.00 | 2.29 |
| Carex blanda | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.14 |

| Repliate 4 - 7-09-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1** | **C1W12** | **C12W12** | **CNTRL** | **C1S1W1** | **CNTRL** | **C12W1** | **C12S12** | **C1W1** | **C12S12W12** | **C1S1W12** | **C12S12W1** | **C1S1** | **C12** | |
| **sediment depth** | 40 | 40 | 40 | 32 | 39 | 35 | 35 | 45 | 45 | 40 | 40 | 35 | 35 | 35 | 38.29 |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 2.00 | 3.00 | 5.00 | 3.00 | 2.00 | 3.00 | 4.00 | 5.00 | 8.00 | 4.00 | 3.00 | 3.00 | 0.00 | 1.00 | 3.29 |
| Typha x glauca stem count | 33.00 | 15.00 | 11.00 | 10.00 | 8.00 | 6.00 | 7.00 | 9.00 | 9.00 | 6.00 | 5.00 | 3.00 | 3.00 | 3.00 | 9.14 |
| Total Typha stem count | 35.00 | 18.00 | 16.00 | 13.00 | 10.00 | 9.00 | 11.00 | 14.00 | 17.00 | 10.00 | 8.00 | 6.00 | 3.00 | 4.00 | 12.43 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Typha x glauca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total Typha | 40.00 | 25.00 | 25.00 | 20.00 | 20.00 | 15.00 | 15.00 | 20.00 | 10.00 | 15.00 | 15.00 | 10.00 | 5.00 | 5.00 | 17.14 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 10.00 | 50.00 | 30.00 | 50.00 | 60.00 | 55.00 | 15.00 | 10.00 | 15.00 | 65.00 | 30.00 | 65.00 | 20.00 | 10.00 | 34.64 |
| Carex stricta | 5.00 | 10.00 | 5.00 | 5.00 | 15.00 | 10.00 | 10.00 | 5.00 | 10.00 | 15.00 | 10.00 | 5.00 | 5.00 | 10.00 | 8.57 |
| Calamagrostis canadensis | 15.00 | 10.00 | 25.00 | 25.00 | 20.00 | 20.00 | 10.00 | 40.00 | 20.00 | 10.00 | 30.00 | 20.00 | 45.00 | 35.00 | 23.21 |
| Impatiens capensis | 5.00 | 5.00 | 3.00 | 2.00 | 1.00 | 1.00 | 1.00 | 1.00 | 5.00 | 5.00 | 1.00 | 1.00 | 1.00 | 5.00 | 2.64 |
| Persicaria amphibia | 1.00 | 5.00 | 2.00 | 0.00 | 10.00 | 5.00 | 5.00 | 1.00 | 1.00 | 0.00 | 5.00 | 5.00 | 2.00 | 5.00 | 3.36 |
| Lysimachia thyrisiflora | 2.00 | 2.00 | 1.00 | 5.00 | 2.00 | 2.00 | | 5.00 | 5.00 | 5.00 | 2.00 | | 5.00 | 5.00 | 3.42 |
| Calystegia sepium | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 5.00 | 5.00 | 5.00 | 2.00 | 0.00 | 5.00 | 5.00 | 3.00 |
| Teucrium canadense | 5.00 | 5.00 | 10.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 5.00 | 5.00 | 2.00 | 2.00 | 3.29 |
| Lathyrus palustris | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.43 |
| Carex blanda | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.29 |
| Lysimachia terrestris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.43 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 5.00 | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.79 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.14 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Vicia cracca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 | 0.21 |

| Replicate 5 - 7-10-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W12** | **C12** | **C12W1** | **C1W1** | **C1S1W1** | **CNTRL** | **C1W12** | **C1S1W12** | **C12S12W1** | **C1** | **C1S1** | **C12S12W12** | **CNTRL** | |
| **sediment depth** | 40.00 | 50.00 | 26.00 | 45.00 | 45.00 | 45.00 | 40.00 | 35.00 | 35.00 | 35.00 | 30.00 | 40.00 | 35.00 | 35.00 | 38.29 |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 8.00 | 3.00 | 4.00 | 1.00 | 5.00 | 3.00 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 2.14 |
| Typha x glauca stem count | 11.00 | 10.00 | 6.00 | 7.00 | 11.00 | 10.00 | 3.00 | 5.00 | 7.00 | 4.00 | 0.00 | 3.00 | 0.00 | 5.00 | 5.86 |
| Total Typha stem count | 19.00 | 13.00 | 10.00 | 8.00 | 16.00 | 13.00 | 4.00 | 5.00 | 8.00 | 5.00 | 1.00 | 4.00 | 1.00 | 5.00 | 8.00 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 10.53 | 4.62 | 6.00 | 1.88 | 7.81 | 4.62 | 0.50 | 0.00 | 1.25 | 0.40 | 2.00 | 1.25 | 2.00 | 0.00 | 3.06 |
| Typha x glauca | 14.47 | 15.38 | 9.00 | 13.13 | 17.19 | 15.38 | 1.50 | 2.00 | 8.75 | 1.60 | 0.00 | 3.75 | 0.00 | 5.00 | 7.65 |
| Total Typha | 25.00 | 20.00 | 15.00 | 15.00 | 25.00 | 20.00 | 2.00 | 2.00 | 10.00 | 2.00 | 2.00 | 5.00 | 2.00 | 5.00 | 10.71 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 25.00 | 30.00 | 25.00 | 15.00 | 30.00 | 25.00 | 20.00 | 15.00 | 15.00 | 20.00 | 5.00 | 15.00 | 10.00 | 10.00 | 18.57 |
| Carex stricta | 10.00 | 10.00 | 0.00 | 0.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 4.64 |
| Calamagrostis canadensis | 35.00 | 20.00 | 15.00 | 20.00 | 10.00 | 40.00 | 40.00 | 35.00 | 25.00 | 30.00 | 40.00 | 35.00 | 35.00 | 20.00 | 28.57 |
| Persicaria amphibia | 5.00 | 10.00 | 10.00 | 15.00 | 15.00 | 15.00 | 10.00 | 15.00 | 5.00 | 15.00 | 15.00 | 10.00 | 5.00 | 15.00 | 11.43 |
| Teucrium canadense | 10.00 | 0.00 | 0.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 10.00 | 1.00 | 0.00 | 5.00 | 10.00 | 5.00 | 5.43 |
| Lysimachia thyrisiflora | 5.00 | 1.00 | 5.00 | 5.00 | 10.00 | 15.00 | 1.00 | 5.00 | 10.00 | 0.00 | 10.00 | 2.00 | 5.00 | 1.00 | 5.36 |
| Carex atherodes | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 5.00 | 1.00 | 5.00 | 0.00 | 0.00 | 5.00 | 10.00 | 1.00 | 4.43 |
| Calystegia sepium | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Lathyrus palustris | 1.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 10.00 | 5.00 | 0.00 | 5.00 | 5.00 | 2.71 |
| Impatiens capensis | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Lysimachia terrestris | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Phalaris arundinacea | 0.00 | 0.00 | 5.00 | 1.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 1.86 |
| Carex blanda | 0.00 | 0.00 | 1.00 | 5.00 | 5.00 | 1.00 | 0.00 | 0.00 | 10.00 | 0.00 | 15.00 | 0.00 | 0.00 | 0.00 | 2.64 |
| Scutellaria epilobiifolia | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Aster spp. (smooth, lance leaves) | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.50 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Vicia cracca | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 5.00 | 0.00 | 2.00 | 0.00 | 0.00 | 1.00 | 2.00 | 0.00 | 0.86 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 10.00 | 10.00 | 10.00 | 0.00 | 5.00 | 10.00 | 3.57 |
| Solidago spp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.71 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.71 |
| Cicuta maculata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.79 |

| Replicate 1: 8-23-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1W12** | **C1S1** | **C1W1** | **C12S12** | **C12** | **C1** | **CNTRL** | **C12S12W1** | **C12W12** | **C1S1W1** | **C1W12** | **C12W1** | **CNTRL** | **C12S12W12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 3.00 | 0.00 | 4.00 | 2.00 | 0.00 | 0.00 | 5.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 2.00 | 1.29 |
| Typha x glauca stem count | 8.00 | 3.00 | 7.00 | 6.00 | 8.00 | 9.00 | 11.00 | 6.00 | 6.00 | 3.00 | 4.00 | 5.00 | 4.00 | 7.00 | 6.21 |
| Total Typha stem count | 11.00 | 3.00 | 11.00 | 8.00 | 8.00 | 9.00 | 16.00 | 7.00 | 6.00 | 3.00 | 4.00 | 6.00 | 4.00 | 9.00 | 7.50 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 2.73 | 0.00 | 3.64 | 1.25 | 0.00 | 0.00 | 7.81 | 0.71 | 0.00 | 0.00 | 0.00 | 0.83 | 0.00 | 1.11 | 1.29 |
| Typha x glauca | 7.27 | 2.00 | 6.36 | 3.75 | 5.00 | 10.00 | 17.19 | 4.29 | 5.00 | 2.00 | 2.00 | 4.17 | 2.00 | 3.89 | 5.35 |
| Total Typha | 10.00 | 2.00 | 10.00 | 5.00 | 5.00 | 10.00 | 25.00 | 5.00 | 5.00 | 2.00 | 2.00 | 5.00 | 2.00 | 5.00 | 6.64 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 15.00 | 15.00 | 10.00 | 15.00 | 10.00 | 35.00 | 30.00 | 5.00 | 25.00 | 15.00 | 15.00 | 15.00 | 10.00 | 5.00 | 15.71 |
| Carex stricta | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 15.00 | 5.00 | 10.00 | 5.00 | 15.00 | 10.00 | 5.00 | 10.00 | 10.00 | 8.21 |
| Calamagrostis canadensis | 50.00 | 55.00 | 45.00 | 40.00 | 30.00 | 25.00 | 20.00 | 75.00 | 30.00 | 35.00 | 40.00 | 35.00 | 30.00 | 5.00 | 36.79 |
| Phalaris arundinacea | 10.00 | 5.00 | 6.00 | 30.00 | 35.00 | 0.00 | 10.00 | 10.00 | 20.00 | 20.00 | 25.00 | 30.00 | 55.00 | 75.00 | 23.64 |
| Impatiens capensis | 2.00 | 5.00 | 10.00 | 5.00 | 25.00 | 5.00 | 10.00 | 5.00 | 10.00 | 5.00 | 0.00 | 10.00 | 0.00 | 1.00 | 6.64 |
| Teucrium canadense | 2.00 | 5.00 | 15.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 2.00 | 5.00 | 10.00 | 2.00 | 1.00 | 5.00 | 5.14 |
| Lysimachia thyrisiflora | 1.00 | 2.00 | 5.00 | 1.00 | 2.00 | 2.00 | 0.00 | 2.00 | 1.00 | 1.00 | 1.00 | 2.00 | 5.00 | 0.00 | 1.79 |
| Lathyrus palustris | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 1.36 |
| Solidago gigantea | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.29 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 2.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 10.00 | 5.00 | 0.00 | 10.00 | 3.00 |
| Galium trifidum | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 |
| Cicuta maculata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Persicaria amphibia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 10.00 | 8.00 | 0.00 | 0.00 | 15.00 | 5.00 | 8.00 | 0.00 | 4.36 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.50 |
| Campanula aparanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.43 |

| Replicate 2: 8-23-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1** | **C12S12** | **C1S1W1** | **C1** | **C12** | **C1W12** | **C1S1W12** | **CNTRL** | **C12W12** | **CNTRL** | **C12S12W12** | **C12W1** | **C12S12W1** | **C1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem coun | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Typha x glauca stem count | 3.00 | 4.00 | 3.00 | 5.00 | 4.00 | 4.00 | 6.00 | 8.00 | 2.00 | 12.00 | 2.00 | 4.00 | 2.00 | 4.00 | 4.50 |
| Total Typha stem count | 3.00 | 4.00 | 3.00 | 6.00 | 4.00 | 4.00 | 6.00 | 10.00 | 2.00 | 14.00 | 2.00 | 4.00 | 2.00 | 4.00 | 4.86 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 2.86 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 |
| Typha x glauca | 2.00 | 2.00 | 2.00 | 2.50 | 3.00 | 3.00 | 5.00 | 12.00 | 2.00 | 17.14 | 2.00 | 3.00 | 2.00 | 3.00 | 4.33 |
| Total Typha | 2.00 | 2.00 | 2.00 | 3.00 | 3.00 | 3.00 | 5.00 | 15.00 | 2.00 | 20.00 | 2.00 | 3.00 | 2.00 | 3.00 | 4.79 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 30.00 | 25.00 | 30.00 | 45.00 | 60.00 | 40.00 | 15.00 | 75.00 | 55.00 | 65.00 | 65.00 | 65.00 | 65.00 | 20.00 | 46.79 |
| Carex stricta | 5.00 | 15.00 | 10.00 | 10.00 | 10.00 | 5.00 | 15.00 | 10.00 | 10.00 | 15.00 | 15.00 | 5.00 | 15.00 | 15.00 | 11.07 |
| Calamagrostis canadensis | 10.00 | 15.00 | 10.00 | 15.00 | 10.00 | 25.00 | 10.00 | 20.00 | 20.00 | 25.00 | 40.00 | 30.00 | 35.00 | 30.00 | 21.07 |
| Impatiens capensis | 0.00 | 5.00 | 0.00 | 25.00 | 8.00 | 25.00 | 2.00 | 1.00 | 2.00 | 5.00 | 1.00 | 0.00 | 0.00 | 2.00 | 5.43 |
| Polygonum amphibium | 0.00 | 1.00 | 5.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 5.00 | 10.00 | 5.00 | 5.00 | 4.00 |
| Lysimachia thyrisiflora | 1.00 | 5.00 | 3.00 | 1.00 | 2.00 | 5.00 | 3.00 | 5.00 | 5.00 | 0.00 | 5.00 | 8.00 | 10.00 | 0.00 | 3.79 |
| Phragmites australis | 5.00 | 0.00 | 5.00 | 0.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 1.79 |
| Scutellaria galericulata | 1.00 | 1.00 | 0.00 | 2.00 | 0.00 | 2.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| Teucrium canadense | 0.00 | 15.00 | 8.00 | 10.00 | 15.00 | 10.00 | 0.00 | 10.00 | 20.00 | 10.00 | 10.00 | 5.00 | 5.00 | 5.00 | 8.79 |
| Campanula arapanoides | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 10.00 | 5.00 | 3.00 | 0.00 | 0.00 | 5.00 | 1.93 |
| Calystegia sepium | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.00 | 0.00 | 8.00 | 3.00 | 2.00 | 2.00 | 0.00 | 2.00 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Galium trifidum | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 50.00 | 5.00 |
| Mentha arvensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 3.00 | 0.57 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 1.00 | 0.43 |
| Solidago gigantea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.36 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.36 |

| Replicate 3: 8-22-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W1** | **C1W12** | **C12** | **CNTRL** | **C12S12W12** | **C1W1** | **C1** | **C12W12** | **C12S12W1** | **C1S1** | **C1S1W12** | **CNTRL** | **C1S1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 3.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.57 |
| Typha x glauca stem count | 0.00 | 6.00 | 7.00 | 8.00 | 12.00 | 2.00 | 1.00 | 2.00 | 5.00 | 3.00 | 1.00 | 0.00 | 10.00 | 1.00 | 4.14 |
| Total Typha stem count | 0.00 | 9.00 | 9.00 | 8.00 | 12.00 | 2.00 | 1.00 | 3.00 | 6.00 | 3.00 | 1.00 | 0.00 | 12.00 | 1.00 | 4.79 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 3.33 | 3.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.00 | 4.17 | 0.00 | 0.83 |
| Typha x glauca | 0.00 | 6.67 | 11.67 | 8.00 | 20.00 | 1.00 | 1.00 | 1.00 | 4.17 | 2.00 | 1.00 | 0.00 | 20.83 | 1.00 | 5.60 |
| Total Typha | 0.00 | 10.00 | 15.00 | 8.00 | 20.00 | 1.00 | 1.00 | 1.00 | 5.00 | 2.00 | 1.00 | 0.00 | 25.00 | 1.00 | 6.43 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 5.00 | 15.00 | 10.00 | 30.00 | 45.00 | 30.00 | 60.00 | 5.00 | 10.00 | 15.00 | 20.00 | 80.00 | 75.00 | 25.00 | 30.36 |
| Carex stricta | 20.00 | 5.00 | 10.00 | 15.00 | 10.00 | 5.00 | 15.00 | 10.00 | 15.00 | 10.00 | 5.00 | 10.00 | 10.00 | 10.00 | 10.71 |
| Calamagrostis canadensis | 75.00 | 35.00 | 30.00 | 35.00 | 30.00 | 25.00 | 25.00 | 45.00 | 65.00 | 75.00 | 75.00 | 15.00 | 10.00 | 55.00 | 42.50 |
| Impatiens capensis | 1.00 | 2.00 | 1.00 | 0.00 | 20.00 | 0.00 | 5.00 | 3.00 | 0.00 | 1.00 | 0.00 | 3.00 | 5.00 | 10.00 | 3.64 |
| Persicaria amphibia | 15.00 | 10.00 | 15.00 | 15.00 | 2.00 | 5.00 | 2.00 | 0.00 | 20.00 | 8.00 | 25.00 | 10.00 | 10.00 | 20.00 | 11.21 |
| Teucrium canadense | 3.00 | 15.00 | 15.00 | 20.00 | 0.00 | 0.00 | 15.00 | 5.00 | 5.00 | 5.00 | 3.00 | 3.00 | 0.00 | 8.00 | 6.93 |
| Lysimachia thyrisiflora | 0.00 | 3.00 | 3.00 | 0.00 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.79 |
| Calystegia sepium | 0.00 | 0.00 | 3.00 | 5.00 | 1.00 | 1.00 | 0.00 | 2.00 | 0.00 | 5.00 | 3.00 | 0.00 | 3.00 | 1.00 | 1.71 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 2.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.64 |
| Vicia cracca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Galium trifidum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.00 | 0.00 | 0.50 |

| Replicate 4: 8-22-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1** | **C1W12** | **C12W12** | **CNTRL** | **C1S1W1** | **CNTRL** | **C12W1** | **C12S12** | **C1W1** | **C12S12W12** | **C1S1W12** | **C12S12W1** | **C1S1** | **C12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 8.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 |
| Typha x glauca stem count | 10.00 | 9.00 | 8.00 | 11.00 | 1.00 | 10.00 | 10.00 | 8.00 | 2.00 | 5.00 | 1.00 | 0.00 | 2.00 | 7.00 | 6.00 |
| Total Typha stem count | 18.00 | 9.00 | 9.00 | 12.00 | 1.00 | 10.00 | 10.00 | 9.00 | 2.00 | 6.00 | 1.00 | 0.00 | 2.00 | 7.00 | 6.86 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 6.67 | 0.00 | 0.89 | 1.67 | 0.00 | 0.00 | 0.00 | 0.44 | 0.00 | 0.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.75 |
| Typha x glauca | 8.33 | 10.00 | 7.11 | 18.33 | 1.00 | 25.00 | 15.00 | 3.56 | 2.00 | 4.17 | 1.00 | 0.00 | 1.00 | 8.00 | 7.46 |
| Total Typha | 15.00 | 10.00 | 8.00 | 20.00 | 1.00 | 25.00 | 15.00 | 4.00 | 2.00 | 5.00 | 1.00 | 0.00 | 1.00 | 8.00 | 8.21 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 25.00 | 35.00 | 50.00 | 60.00 | 50.00 | 75.00 | 50.00 | 20.00 | 25.00 | 35.00 | 50.00 | 85.00 | 75.00 | 30.00 | 47.50 |
| Carex stricta | 10.00 | 5.00 | 5.00 | 10.00 | 10.00 | 10.00 | 5.00 | 5.00 | 10.00 | 10.00 | 15.00 | 10.00 | 10.00 | 5.00 | 8.57 |
| Calamagrostis canadensis | 35.00 | 30.00 | 15.00 | 30.00 | 25.00 | 10.00 | 30.00 | 65.00 | 65.00 | 55.00 | 55.00 | 15.00 | 20.00 | 55.00 | 36.07 |
| Impatiens capensis | 20.00 | 25.00 | 15.00 | 20.00 | 3.00 | 0.00 | 5.00 | 2.00 | 10.00 | 8.00 | 5.00 | 0.00 | 0.00 | 5.00 | 8.43 |
| Convolvulus arvensis | 5.00 | 2.00 | 2.00 | 5.00 | 0.00 | 5.00 | 0.00 | 10.00 | 8.00 | 2.00 | 0.00 | 2.00 | 5.00 | 3.00 | 3.50 |
| Persicaria amphibia | 3.00 | 5.00 | 3.00 | 0.00 | 25.00 | 15.00 | 6.00 | 3.00 | 5.00 | 10.00 | 8.00 | 2.00 | 8.00 | 20.00 | 8.07 |
| Teucrium canadense | 2.00 | 0.00 | 8.00 | 8.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 15.00 | 8.00 | 0.00 | 5.00 | 3.64 |
| Lysimachia thyrisiflora | 2.00 | 2.00 | 3.00 | 5.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 3.00 | 2.00 | 1.00 | 7.00 | 2.00 | 2.64 |
| Scutellaria galericulata | 3.00 | 2.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.00 | 0.00 | 6.00 | 0.00 | 0.00 | 1.50 |
| Lathyrus palustris | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.71 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 1.00 | 5.00 | 0.00 | 2.00 | 1.00 | 0.93 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 1.00 | 1.50 |
| Vicia cracca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |

| Replicate 5: 8-22-2010 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W12** | **C12** | **C12W1** | **C1W1** | **C1S1W1** | **CNTRL** | **C1W12** | **C1S1W12** | **C12S12W1** | **C1** | **C1S1** | **C12S12W12** | **CNTRL** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 1.00 | 6.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.79 |
| Typha x glauca stem count | 9.00 | 8.00 | 7.00 | 7.00 | 8.00 | 6.00 | 4.00 | 3.00 | 7.00 | 2.00 | 2.00 | 3.00 | 1.00 | 5.00 | 5.14 |
| Total Typha stem count | 10.00 | 14.00 | 7.00 | 7.00 | 9.00 | 7.00 | 4.00 | 3.00 | 8.00 | 2.00 | 2.00 | 3.00 | 1.00 | 6.00 | 5.93 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 1.50 | 6.43 | 0.00 | 0.00 | 0.56 | 0.71 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 1.67 | 0.82 |
| Typha x glauca | 13.50 | 8.57 | 10.00 | 5.00 | 4.44 | 4.29 | 5.00 | 2.00 | 4.38 | 2.00 | 2.00 | 2.00 | 2.00 | 8.33 | 5.25 |
| Total Typha | 15.00 | 15.00 | 10.00 | 5.00 | 5.00 | 5.00 | 5.00 | 2.00 | 5.00 | 2.00 | 2.00 | 2.00 | 2.00 | 10.00 | 6.07 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 55.00 | 45.00 | 65.00 | 55.00 | 60.00 | 50.00 | 25.00 | 10.00 | 10.00 | 25.00 | 5.00 | 15.00 | 15.00 | 20.00 | 32.50 |
| Carex stricta | 10.00 | 10.00 | 10.00 | 5.00 | 10.00 | 5.00 | 15.00 | 15.00 | 10.00 | 15.00 | 10.00 | 15.00 | 15.00 | 5.00 | 10.71 |
| Impatiens capensis | 6.00 | 2.00 | 2.00 | 2.00 | 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 2.00 | 5.00 | 1.86 |
| Convolvulus arvensis | 3.00 | 0.00 | 2.00 | 3.00 | 2.00 | 0.00 | 5.00 | 25.00 | 2.00 | 10.00 | 6.00 | 0.00 | 3.00 | 2.00 | 4.50 |
| Teucrium canadense | 3.00 | 6.00 | 5.00 | 1.00 | 3.00 | 10.00 | 5.00 | 2.00 | 5.00 | 2.00 | 5.00 | 5.00 | 5.00 | 2.00 | 4.21 |
| Persicaria amphibia | 3.00 | 10.00 | 0.00 | 3.00 | 5.00 | 10.00 | 10.00 | 20.00 | 3.00 | 5.00 | 2.00 | 6.00 | 15.00 | 3.00 | 6.79 |
| Calamagrostis canadensis | 25.00 | 20.00 | 30.00 | 30.00 | 20.00 | 55.00 | 60.00 | 65.00 | 65.00 | 35.00 | 70.00 | 65.00 | 55.00 | 65.00 | 47.14 |
| Lysimachia ciliata | 2.00 | 2.00 | 5.00 | 3.00 | 1.00 | 3.00 | 5.00 | 0.00 | 3.00 | 0.00 | 0.00 | 2.00 | 0.00 | 1.00 | 1.93 |
| Lathyrus palustris | 0.00 | 0.00 | 6.00 | 2.00 | 0.00 | 0.00 | 0.00 | 3.00 | 2.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 1.14 |
| Lysimachia thyrisiflora | 0.00 | 0.00 | 3.00 | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.79 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 0.00 | 3.00 | 0.00 | 0.00 | 5.00 | 15.00 | 5.00 | 0.00 | 0.00 | 2.71 |
| Epilobium leptophyllum | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Vicia cracca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 10.00 | 15.00 | 25.00 | 7.00 | 3.00 | 15.00 | 10.00 | 6.29 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 1.00 | 0.00 | 0.00 | 3.00 | 6.00 | 2.00 | 5.00 | 1.57 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 8.00 | 0.93 |
| Solidago gigantea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 0.43 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 5.00 | 10.00 | 8.00 | 0.00 | 2.00 | 1.93 |
| Galium spp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.14 |

| Replicate 1: 7-02-2011 | | Up to 10cm standing water in plots | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treaement** | **C1S1W12** | **C1S1** | **C1W1** | **C12S12** | **C12** | **C1** | **CNTRL** | **C12S12W1** | **C12W12** | **C1S1W1** | **C1W12** | **C12W1** | **CNTRL** | **C12S12W12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 2.00 | 12.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.36 |
| Typha x glauca stem count | 13.00 | 8.00 | 7.00 | 12.00 | 8.00 | 18.00 | 3.00 | 2.00 | 3.00 | 1.00 | 7.00 | 7.00 | 2.00 | 0.00 | 6.50 |
| Total Typha stem count | 13.00 | 8.00 | 7.00 | 15.00 | 8.00 | 16.00 | 15.00 | 2.00 | 3.00 | 1.00 | 9.00 | 7.00 | 2.00 | 0.00 | 7.57 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 3.50 | 24.00 | 0.00 | 0.00 | 0.00 | 2.22 | 0.00 | 0.00 | 0.00 | 2.48 |
| Typha x glauca | 25.00 | 20.00 | 15.00 | 20.00 | 20.00 | 31.50 | 6.00 | 5.00 | 5.00 | 2.00 | 7.78 | 10.00 | 5.00 | 0.00 | 12.31 |
| Total Typha | 25.00 | 20.00 | 15.00 | 25.00 | 20.00 | 35.00 | 30.00 | 5.00 | 5.00 | 2.00 | 10.00 | 10.00 | 5.00 | 0.00 | 14.79 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 0.00 | 5.00 | 5.00 | 0.00 | 5.00 | 5.00 | 2.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.29 |
| Carex stricta | 30.00 | 20.00 | 20.00 | 10.00 | 20.00 | 15.00 | 10.00 | 10.00 | 10.00 | 20.00 | 15.00 | 15.00 | 10.00 | 10.00 | 15.36 |
| Phalaris arundinacea | 35.00 | 35.00 | 15.00 | 40.00 | 45.00 | 30.00 | 30.00 | 50.00 | 45.00 | 50.00 | 35.00 | 55.00 | 55.00 | 65.00 | 41.79 |
| Calamagrostis canadensis | 15.00 | 0.00 | 35.00 | 5.00 | 5.00 | 15.00 | 10.00 | 10.00 | 5.00 | 5.00 | 15.00 | 2.00 | 0.00 | 0.00 | 8.71 |
| Teucrium canadense | 5.00 | 15.00 | 5.00 | 15.00 | 15.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 10.00 | 10.00 | 0.00 | 2.00 | 6.21 |
| Lysimachia thyrisiflora | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.79 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.00 | 0.00 | 2.00 | 0.00 | 5.00 | 2.29 |
| Cicuta maculata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.71 |
| Persicaria amphibia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 1.79 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.29 |
| Phragmites australis | 3.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.93 |
| Galium spp. | 0.00 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 1.29 |
| Impatiens capensis | 0.00 | 2.00 | 2.00 | 0.00 | 5.00 | 2.00 | 5.00 | 0.00 | 5.00 | 10.00 | 0.00 | 5.00 | 10.00 | 0.00 | 3.29 |

| Replicate 2: 7-02-2011 | | Up to 10cm standing water in plots | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S** | **C12S** | **C1SW1** | **C1** | **C12** | **C1W12** | **C1SW12** | **CNTRL** | **C12W12** | **CNTRL** | **C12SW12** | **C12W1** | **C12SW1** | **C1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 |
| Typha x glauca stem count | 11.00 | 1.00 | 11.00 | 12.00 | 8.00 | 10.00 | 7.00 | 10.00 | 1.00 | 14.00 | 2.00 | 6.00 | 3.00 | 2.00 | 7.00 |
| Total Typha stem count | 11.00 | 1.00 | 11.00 | 13.00 | 8.00 | 10.00 | 7.00 | 10.00 | 1.00 | 16.00 | 2.00 | 6.00 | 3.00 | 2.00 | 7.21 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 0.00 | 1.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 |
| Typha x glauca | 20.00 | 2.00 | 20.00 | 23.08 | 10.00 | 15.00 | 10.00 | 20.00 | 2.00 | 17.50 | 5.00 | 10.00 | 5.00 | 5.00 | 11.76 |
| Total Typha | 20.00 | 2.00 | 20.00 | 25.00 | 10.00 | 15.00 | 10.00 | 20.00 | 2.00 | 20.00 | 5.00 | 10.00 | 5.00 | 5.00 | 12.07 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 35.00 | 30.00 | 40.00 | 55.00 | 50.00 | 55.00 | 50.00 | 45.00 | 55.00 | 50.00 | 50.00 | 55.00 | 45.00 | 50.00 | 47.50 |
| Carex stricta | 10.00 | 15.00 | 10.00 | 10.00 | 10.00 | 10.00 | 15.00 | 20.00 | 20.00 | 10.00 | 15.00 | 10.00 | 10.00 | 10.00 | 12.50 |
| Calamagrostis canadensis | 25.00 | 0.00 | 5.00 | 5.00 | 10.00 | 10.00 | 5.00 | 15.00 | 5.00 | 0.00 | 2.00 | 0.00 | 5.00 | 2.00 | 6.36 |
| Phragmites australis | 10.00 | 15.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.93 |
| Teucrium canadense | 5.00 | 10.00 | 8.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 0.00 | 5.00 | 5.00 | 5.93 |
| Standing water | 30.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 0.00 | 55.00 | 0.00 | 40.00 | 40.00 | 30.00 | 20.00 | 36.79 |
| Lysimachia thyrisiflora | 5.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.36 |
| Lathyrus palustris | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 |
| Persicaria amphibia | 0.00 | 0.00 | 0.00 | 5.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 2.14 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 40.00 | 0.00 | 20.00 | 40.00 | 7.50 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Campanula arapanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.14 |

| Replicat 3: 7-02-2011 | | Up to 16 cm standing water in plots | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W1** | **C1W12** | **C12** | **CNTRL** | **C12S12W12** | **C1W1** | **C1** | **C12W12** | **C12S12W1** | **C1S1** | **C1S1W12** | **CNTRL** | **C1S1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 8.00 | 5.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.21 |
| Typha x glauca stem count | 2.00 | 10.00 | 10.00 | 13.00 | 10.00 | 5.00 | 5.00 | 10.00 | 10.00 | 12.00 | 13.00 | 3.00 | 12.00 | 0.00 | 8.21 |
| Total Typha stem count | 2.00 | 18.00 | 15.00 | 14.00 | 10.00 | 5.00 | 5.00 | 10.00 | 12.00 | 12.00 | 13.00 | 3.00 | 13.00 | 0.00 | 9.43 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 11.11 | 8.33 | 1.79 | 0.00 | 0.00 | 0.00 | 0.00 | 3.33 | 0.00 | 0.00 | 0.00 | 1.92 | 0.00 | 2.04 |
| Typha x glauca | 2.00 | 13.89 | 16.67 | 23.21 | 20.00 | 10.00 | 15.00 | 20.00 | 16.67 | 15.00 | 20.00 | 5.00 | 23.08 | 0.00 | 15.27 |
| Total Typha | 2.00 | 25.00 | 25.00 | 25.00 | 20.00 | 10.00 | 15.00 | 20.00 | 20.00 | 15.00 | 20.00 | 5.00 | 25.00 | 0.00 | 17.31 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 10.00 | 5.00 | 10.00 | 5.00 | 5.00 | 15.00 | 45.00 | 0.00 | 10.00 | 5.00 | 5.00 | 25.00 | 30.00 | 40.00 | 15.00 |
| Carex stricta | 5.00 | 2.00 | 0.00 | 2.00 | 0.00 | 5.00 | 5.00 | 5.00 | 0.00 | 5.00 | 10.00 | 5.00 | 15.00 | 10.00 | 4.93 |
| Calamagrostis canadensis | 35.00 | 40.00 | 35.00 | 40.00 | 40.00 | 25.00 | 15.00 | 65.00 | 55.00 | 45.00 | 35.00 | 10.00 | 0.00 | 25.00 | 33.21 |
| Persicaria amphibia | 5.00 | 5.00 | 10.00 | 10.00 | 15.00 | 10.00 | 0.00 | 0.00 | 10.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.71 |
| Lysimachia thyrisiflora | 2.00 | 2.00 | 5.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 1.71 |
| Phalaris arundinacea | 10.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 |
| Teucrium canadense | 0.00 | 10.00 | 0.00 | 5.00 | 0.00 | 10.00 | 0.00 | 10.00 | 5.00 | 5.00 | 0.00 | 0.00 | 5.00 | 10.00 | 4.29 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.14 |
| Cirsium canadense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Campanula aparanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.14 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.36 |
| standing water % cover | 55.00 | 10.00 | 10.00 | 10.00 | 5.00 | 60.00 | 10.00 | 0.00 | 0.00 | 0.00 | 2.00 | 15.00 | 0.00 | 15.00 | 13.71 |

| Replicate 4: 7-02-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1** | **C1W12** | **C12W12** | **CNTRL** | **C1S1W1** | **CNTRL** | **C12W1** | **C12S12** | **C1W1** | **C12S12W12** | **C1S1W12** | **C12S12W1** | **C1S1** | **C12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha Angustifolia stem count | 2.00 | 2.00 | 0.00 | 1.00 | 4.00 | 7.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29 |
| Typha x glauca count | 19.00 | 24.00 | 19.00 | 15.00 | 10.00 | 10.00 | 13.00 | 15.00 | 4.00 | 10.00 | 8.00 | 8.00 | 3.00 | 8.00 | 11.86 |
| Total Typha stem count | 21.00 | 26.00 | 19.00 | 16.00 | 14.00 | 17.00 | 13.00 | 15.00 | 4.00 | 12.00 | 8.00 | 8.00 | 3.00 | 8.00 | 13.14 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 4.29 | 3.46 | 0.00 | 2.19 | 10.00 | 16.47 | 0.00 | 0.00 | 0.00 | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 | 2.78 |
| Typha x glauca | 40.71 | 41.54 | 40.00 | 32.81 | 25.00 | 23.53 | 30.00 | 25.00 | 10.00 | 12.50 | 10.00 | 10.00 | 5.00 | 15.00 | 22.94 |
| total typha | 45.00 | 45.00 | 40.00 | 35.00 | 35.00 | 40.00 | 30.00 | 25.00 | 10.00 | 15.00 | 10.00 | 10.00 | 5.00 | 15.00 | 25.71 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 10.00 | 15.00 | 20.00 | 25.00 | 25.00 | 30.00 | 30.00 | 15.00 | 35.00 | 25.00 | 25.00 | 25.00 | 15.00 | 15.00 | 22.14 |
| Carex stricta | 5.00 | 0.00 | 10.00 | 5.00 | 5.00 | 2.00 | 15.00 | 0.00 | 10.00 | 5.00 | 5.00 | 15.00 | 10.00 | 10.00 | 6.93 |
| Calamagrostis canadensis | 20.00 | 10.00 | 5.00 | 15.00 | 10.00 | 15.00 | 10.00 | 10.00 | 5.00 | 5.00 | 5.00 | 0.00 | 30.00 | 45.00 | 13.21 |
| Phalaris arundinacea | 10.00 | 5.00 | 0.00 | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 15.00 | 15.00 | 5.00 |
| Teucrium canadense | 5.00 | 8.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 8.00 | 0.00 | 5.00 | 0.00 | 5.00 | 3.29 |
| Lysimachia thyrisiflora | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 3.00 | 1.50 |
| open/standing water | 45.00 | 0.00 | 40.00 | 30.00 | 25.00 | 15.00 | 30.00 | 35.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16.43 |
| Calystegia sepium | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Persicaria amphibia | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 0.00 | 10.00 | 5.00 | 3.57 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Lysimachia terrestris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.50 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.64 |
| Campanula aparanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.29 |

| Replicate 5: 7-02-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S** | **C12W12** | **C12** | **C12W1** | **C1W1** | **C1SW1** | **CNTRL** | **C1W12** | **C1SW12** | **C12SW1** | **C1** | **C1S** | **C12SW12** | **CNTRL** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 2.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 2.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| Typha x glauca stem count | 11.00 | 21.00 | 8.00 | 9.00 | 11.00 | 8.00 | 10.00 | 7.00 | 6.00 | 3.00 | 5.00 | 3.00 | 3.00 | 7.00 | 8.00 |
| Total Typha stem count | 13.00 | 21.00 | 8.00 | 10.00 | 11.00 | 8.00 | 12.00 | 8.00 | 6.00 | 3.00 | 6.00 | 3.00 | 3.00 | 7.00 | 8.50 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 5.38 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 4.17 | 1.25 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.95 |
| Typha x glauca | 29.62 | 40.00 | 20.00 | 18.00 | 20.00 | 10.00 | 20.83 | 8.75 | 5.00 | 3.00 | 2.50 | 2.00 | 3.00 | 5.00 | 13.41 |
| total typha | 35.00 | 40.00 | 20.00 | 20.00 | 20.00 | 10.00 | 25.00 | 10.00 | 5.00 | 3.00 | 3.00 | 2.00 | 3.00 | 5.00 | 14.36 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 15.00 | 25.00 | 15.00 | 20.00 | 20.00 | 15.00 | 35.00 | 30.00 | 20.00 | 25.00 | 15.00 | 15.00 | 25.00 | 25.00 | 21.43 |
| Carex stricta | 5.00 | 0.00 | 2.00 | 5.00 | 5.00 | 15.00 | 0.00 | 5.00 | 2.00 | 0.00 | 5.00 | 5.00 | 10.00 | 5.00 | 4.57 |
| Calamagrostis canadensis | 40.00 | 5.00 | 30.00 | 30.00 | 15.00 | 25.00 | 20.00 | 50.00 | 45.00 | 40.00 | 50.00 | 55.00 | 40.00 | 35.00 | 34.29 |
| Persicaria amphibia | 8.00 | 0.00 | 0.00 | 5.00 | 5.00 | 0.00 | 5.00 | 10.00 | 3.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.93 |
| Lysimachia thyrisiflora | 5.00 | 5.00 | 10.00 | 0.00 | 1.00 | 3.00 | 3.00 | 2.00 | 2.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 4.00 |
| Duff | 10.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 15.00 | 10.00 | 10.00 | 0.00 | 4.29 |
| Open water | 10.00 | 35.00 | 35.00 | 10.00 | 15.00 | 40.00 | 10.00 | 0.00 | 10.00 | 5.00 | 10.00 | 0.00 | 0.00 | 10.00 | 13.57 |
| Teucrium canadense | 0.00 | 5.00 | 5.00 | 2.00 | 3.00 | 0.00 | 5.00 | 5.00 | 10.00 | 15.00 | 10.00 | 5.00 | 10.00 | 5.00 | 5.71 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.14 |
| Lysimachia terrestris | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 1.00 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 3.00 | 2.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.00 | 3.00 | 2.21 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.29 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Campanula aparinoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 1.00 | 1.00 | 0.00 | 1.00 | 0.36 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.14 |
| Solidago spp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.14 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.36 |

| Replicate 1: 8-25-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1W12** | **C1W1** | **C1S1** | **C12W1** | **C12** | **C1** | **CNTRL** | **C12S12W1** | **C12S12** | **C1S1W1** | **C12W12** | **C1W12** | **CNTRL** | **C12S12W12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 3.00 | 1.00 | 3.00 | 0.00 | 0.00 | 6.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 1.36 |
| Typha x glauca stem count | 12.00 | 5.00 | 5.00 | 6.00 | 11.00 | 14.00 | 17.00 | 2.00 | 1.00 | 1.00 | 9.00 | 9.00 | 6.00 | 2.00 | 7.14 |
| Total Typha stem count | 15.00 | 6.00 | 8.00 | 6.00 | 11.00 | 21.00 | 20.00 | 2.00 | 1.00 | 1.00 | 9.00 | 12.00 | 6.00 | 2.00 | 8.57 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 5.00 | 0.83 | 5.63 | 0.00 | 0.00 | 12.00 | 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 2.46 |
| Typha x glauca | 20.00 | 4.17 | 9.38 | 5.00 | 25.00 | 28.00 | 34.00 | 5.00 | 2.00 | 2.00 | 15.00 | 15.00 | 10.00 | 2.00 | 12.61 |
| Total Typha | 25.00 | 5.00 | 15.00 | 5.00 | 25.00 | 40.00 | 40.00 | 5.00 | 2.00 | 2.00 | 15.00 | 20.00 | 10.00 | 2.00 | 15.07 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Phalaris arundinacea | 55.00 | 65.00 | 25.00 | 35.00 | 20.00 | 10.00 | 10.00 | 30.00 | 55.00 | 50.00 | 35.00 | 20.00 | 30.00 | 55.00 | 35.36 |
| Carex stricta | 10.00 | 10.00 | 2.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 0.00 | 0.00 | 5.00 | 10.00 | 5.00 | 5.50 |
| Calamagrostis canadensis | 40.00 | 35.00 | 55.00 | 55.00 | 40.00 | 30.00 | 40.00 | 70.00 | 40.00 | 35.00 | 30.00 | 30.00 | 15.00 | 20.00 | 38.21 |
| Teucrium canadense | 2.00 | 5.00 | 2.00 | 10.00 | 5.00 | 15.00 | 10.00 | 5.00 | 15.00 | 10.00 | 5.00 | 15.00 | 10.00 | 5.00 | 8.14 |
| Persicaria amphibia | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 15.00 | 5.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 10.00 | 0.00 | 3.57 |
| Phragmites australis | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Lysimachia thyrisiflora | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 2.00 | 0.00 | 2.00 | 0.00 | 1.14 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 |
| Lysimachia terrestris | 0.00 | 0.00 | 0.00 | 5.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.00 | 0.00 | 2.00 | 1.50 |
| Carex lacustris | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 5.00 | 1.79 |
| Cicuta macula | 0.00 | 5.00 | 0.00 | 5.00 | 15.00 | 0.00 | 10.00 | 5.00 | 0.00 | 15.00 | 0.00 | 15.00 | 15.00 | 0.00 | 6.07 |
| Anemone canadensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.71 |
| Satureja vulgaris | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 4.00 | 0.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 1.64 |

| Replicate 2: 8-25-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1** | **C12S12** | **C1S1W1** | **C1** | **C12** | **C1W12** | **C1S1W12** | **CNTRL** | **C12W12** | **CNTRL** | **C12S12W12** | **C12W1** | **C12S12W1** | **C1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 1.00 | 0.00 | 8.00 | 5.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 |
| Typha x glauca stem count | 11.00 | 2.00 | 10.00 | 11.00 | 1.00 | 16.00 | 11.00 | 11.00 | 1.00 | 10.00 | 3.00 | 3.00 | 0.00 | 1.00 | 6.50 |
| Total Typha stem count | 12.00 | 2.00 | 18.00 | 16.00 | 1.00 | 16.00 | 11.00 | 12.00 | 1.00 | 10.00 | 3.00 | 3.00 | 0.00 | 1.00 | 7.57 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 2.50 | 0.00 | 11.11 | 7.81 | 0.00 | 0.00 | 0.00 | 2.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.68 |
| Typha x glauca | 27.50 | 5.00 | 13.89 | 17.19 | 2.00 | 25.00 | 20.00 | 22.92 | 2.00 | 20.00 | 5.00 | 5.00 | 0.00 | 2.00 | 11.96 |
| Total Typha | 30.00 | 5.00 | 25.00 | 25.00 | 2.00 | 25.00 | 20.00 | 25.00 | 2.00 | 20.00 | 5.00 | 5.00 | 0.00 | 2.00 | 13.64 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 50.00 | 40.00 | 65.00 | 65.00 | 75.00 | 70.00 | 65.00 | 75.00 | 85.00 | 75.00 | 80.00 | 65.00 | 80.00 | 60.00 | 67.86 |
| Calamagrostis canadensis | 20.00 | 10.00 | 15.00 | 10.00 | 10.00 | 15.00 | 20.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 5.00 | 15.00 | 11.07 |
| Carex stricta | 5.00 | 0.00 | 0.00 | 5.00 | 10.00 | 5.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 3.57 |
| Teucrium canadense | 5.00 | 5.00 | 5.00 | 10.00 | 15.00 | 5.00 | 5.00 | 5.00 | 10.00 | 15.00 | 10.00 | 0.00 | 5.00 | 0.00 | 6.79 |
| Phragmites australis | 2.00 | 5.00 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 1.43 |
| Persicaria amphibia | 5.00 | 5.00 | 5.00 | 5.00 | 8.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.00 | 10.00 | 0.00 | 0.00 | 4.14 |
| Lysimachia thyrisiflora | 2.00 | 5.00 | 0.00 | 0.00 | 2.00 | 2.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 5.00 | 1.57 |
| Scutellaria galericulata | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.29 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 1.43 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| Mentha arvensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 5.00 | 2.00 | 0.64 |

| Replicate 3: 8-25-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W1** | **C1W12** | **C12** | **CNTRL** | **C12S12W12** | **C1W1** | **C1** | **C12W12** | **C12S12W1** | **C1S1** | **C1S1W12** | **CNTRL** | **C1S1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 0.00 | 2.00 | 3.00 | 0.00 | 1.00 | 2.00 | 0.00 | 0.00 | 0.00 | 4.00 | 0.00 | 2.00 | 0.00 | 1.00 |
| Typha x glauca stem count | 2.00 | 2.00 | 10.00 | 15.00 | 2.00 | 7.00 | 8.00 | 11.00 | 4.00 | 2.00 | 19.00 | 2.00 | 13.00 | 0.00 | 6.93 |
| Total Typha stem count | 2.00 | 2.00 | 12.00 | 18.00 | 2.00 | 8.00 | 10.00 | 11.00 | 4.00 | 2.00 | 23.00 | 2.00 | 15.00 | 0.00 | 7.93 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 3.33 | 4.17 | 0.00 | 1.25 | 2.00 | 0.00 | 0.00 | 0.00 | 3.48 | 0.00 | 4.00 | 0.00 | 1.30 |
| Typha x glauca | 5.00 | 5.00 | 16.67 | 20.83 | 5.00 | 8.75 | 8.00 | 15.00 | 10.00 | 5.00 | 16.52 | 5.00 | 26.00 | 0.00 | 10.48 |
| Total Typha | 5.00 | 5.00 | 20.00 | 25.00 | 5.00 | 10.00 | 10.00 | 15.00 | 10.00 | 5.00 | 20.00 | 5.00 | 30.00 | 0.00 | 11.79 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex stricta | 25.00 | 20.00 | 15.00 | 10.00 | 10.00 | 20.00 | 20.00 | 15.00 | 10.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.43 |
| Carex lacustris | 5.00 | 15.00 | 15.00 | 25.00 | 60.00 | 35.00 | 50.00 | 5.00 | 15.00 | 10.00 | 5.00 | 45.00 | 50.00 | 30.00 | 26.07 |
| Lysimachia thyrisiflora | 3.00 | 5.00 | 5.00 | 5.00 | 10.00 | 3.00 | 5.00 | 10.00 | 1.00 | 5.00 | 2.00 | 0.00 | 5.00 | 0.00 | 4.21 |
| Bolboschoenus fluviatilis | 10.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43 |
| Calamagrostis canadensis | 60.00 | 30.00 | 15.00 | 30.00 | 10.00 | 10.00 | 20.00 | 60.00 | 40.00 | 60.00 | 55.00 | 20.00 | 5.00 | 15.00 | 30.71 |
| Persicaria amphibia | 10.00 | 15.00 | 5.00 | 0.00 | 10.00 | 10.00 | 15.00 | 5.00 | 5.00 | 10.00 | 20.00 | 5.00 | 10.00 | 15.00 | 9.64 |
| Teucrium canadense | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 10.00 | 2.00 | 5.00 | 10.00 | 5.00 | 2.00 | 10.00 | 4.93 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 5.00 | 3.00 | 5.00 | 5.00 | 5.00 | 10.00 | 5.00 | 2.86 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Cirsium arvensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.14 |

| Replicate 4: 8-25-2011 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1** | **C1W12** | **C12W12** | **CNTRL** | **C1S1W1** | **CNTRL** | **C12W1** | **C12S12** | **C1W1** | **C12S12W12** | **C1S1W12** | **C12S12W1** | **C1S1** | **C12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 1.00 | 0.00 | 0.00 | 2.00 | 2.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.64 |
| Typha x glauca stem count | 17.00 | 17.00 | 1.00 | 14.00 | 11.00 | 10.00 | 1.00 | 5.00 | 5.00 | 4.00 | 10.00 | 1.00 | 1.00 | 1.00 | 7.00 |
| Total Typha stem count | 18.00 | 17.00 | 1.00 | 16.00 | 13.00 | 11.00 | 1.00 | 5.00 | 5.00 | 4.00 | 13.00 | 1.00 | 1.00 | 1.00 | 7.64 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 1.67 | 0.00 | 0.00 | 4.38 | 3.85 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 4.62 | 0.00 | 0.00 | 0.00 | 1.20 |
| Typha x glauca | 28.33 | 30.00 | 2.00 | 30.63 | 21.15 | 22.73 | 2.00 | 10.00 | 10.00 | 10.00 | 15.38 | 2.00 | 2.00 | 2.00 | 13.44 |
| Total Typha | 30.00 | 30.00 | 2.00 | 35.00 | 25.00 | 25.00 | 2.00 | 10.00 | 10.00 | 10.00 | 20.00 | 2.00 | 2.00 | 2.00 | 14.64 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 10.00 | 35.00 | 75.00 | 45.00 | 45.00 | 50.00 | 30.00 | 15.00 | 30.00 | 35.00 | 35.00 | 35.00 | 15.00 | 30.00 | 34.64 |
| Calamagrostis canadensis | 5.00 | 15.00 | 10.00 | 10.00 | 15.00 | 10.00 | 10.00 | 30.00 | 15.00 | 10.00 | 10.00 | 15.00 | 10.00 | 15.00 | 12.86 |
| Persicaria amphibia | 5.00 | 10.00 | 5.00 | 0.00 | 30.00 | 15.00 | 5.00 | 10.00 | 15.00 | 30.00 | 10.00 | 25.00 | 30.00 | 30.00 | 15.71 |
| Calystegia sepium | 3.00 | 10.00 | 5.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 2.00 | 5.00 | 5.00 | 2.79 |
| Lysimachia thyrisiflora | 3.00 | 5.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.86 |
| Teucrium canadensis | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 5.00 | 10.00 | 0.00 | 5.00 | 0.00 | 0.00 | 2.21 |
| Phalaris arundinace | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 2.00 | 0.50 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.79 |
| Carex stricta | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 20.00 | 15.00 | 20.00 | 25.00 | 6.43 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.71 |

| Replicate 1: 8-28-2012 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1W12** | **C1S1** | **C1W1** | **C12S12** | **C12** | **C1** | **CNTRL** | **C12S12W1** | **C12W12** | **C1S1W1** | **C1W12** | **C12W1** | **CNTRL** | **C12S12W12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 2.00 | 1.00 | 0.00 | 2.00 | 2.00 | 0.00 | 1.00 | 3.00 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 1.00 |
| Typha x glauca stem count | 4.00 | 9.00 | 4.00 | 6.00 | 7.00 | 12.00 | 10.00 | 4.00 | 3.00 | 5.00 | 6.00 | 7.00 | 8.00 | 1.00 | 6.14 |
| Total Typha stem count | 6.00 | 10.00 | 4.00 | 8.00 | 9.00 | 12.00 | 11.00 | 7.00 | 3.00 | 5.00 | 6.00 | 10.00 | 8.00 | 1.00 | 7.14 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 3.33 | 2.00 | 0.00 | 3.75 | 5.56 | 0.00 | 2.27 | 6.43 | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 0.00 | 1.88 |
| Typha x glauca | 6.67 | 18.00 | 10.00 | 11.25 | 19.44 | 20.00 | 22.73 | 8.57 | 5.00 | 10.00 | 5.00 | 7.00 | 15.00 | 2.00 | 11.48 |
| Total Typha | 10.00 | 20.00 | 10.00 | 15.00 | 25.00 | 20.00 | 25.00 | 15.00 | 5.00 | 10.00 | 5.00 | 10.00 | 15.00 | 2.00 | 13.36 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Calamagrostis canadensis | 55.00 | 85.00 | 75.00 | 50.00 | 25.00 | 25.00 | 35.00 | 20.00 | 55.00 | 75.00 | 50.00 | 15.00 | 0.00 | 0.00 | 40.36 |
| Phalaris arundinacea | 15.00 | 20.00 | 15.00 | 25.00 | 25.00 | 0.00 | 15.00 | 50.00 | 15.00 | 10.00 | 30.00 | 70.00 | 75.00 | 90.00 | 32.50 |
| Persicaria amphibia | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 30.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.71 |
| Phragmites australis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Carex stricta | 0.00 | 0.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.14 |
| Carex lacustris | 5.00 | 15.00 | 10.00 | 0.00 | 10.00 | 10.00 | 0.00 | 15.00 | 0.00 | 5.00 | 25.00 | 20.00 | 25.00 | 0.00 | 10.00 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 1.43 |
| Scutellaria galericulata | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Impatiens capensis | 10.00 | 0.00 | 5.00 | 5.00 | 0.00 | 2.00 | 10.00 | 5.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 2.00 | 3.86 |
| Teucrium canadense | 0.00 | 10.00 | 0.00 | 20.00 | 10.00 | 15.00 | 5.00 | 10.00 | 10.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 7.86 |
| Lysimachia thyrisiflora | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 5.00 | 5.00 | 5.00 | 15.00 | 15.00 | 10.00 | 5.00 | 5.00 | 5.00 | 6.07 |
| Cicuta maculata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |

| Replicate 2: 8-28-2012 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1S1** | **C12S12** | **C1S1W1** | **C1** | **C12** | **C1W12** | **C1S1W12** | **CNTRL** | **C12W12** | **CNTRL** | **C12S12W12** | **C12W1** | **C12S12W1** | **C1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 0.00 | 3.00 | 3.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 |
| Typha x glauca stem count | 7.00 | 2.00 | 6.00 | 11.00 | 6.00 | 5.00 | 3.00 | 7.00 | 1.00 | 13.00 | 2.00 | 3.00 | 6.00 | 1.00 | 5.21 |
| Total Typha stem count | 7.00 | 2.00 | 9.00 | 14.00 | 6.00 | 5.00 | 3.00 | 8.00 | 1.00 | 15.00 | 2.00 | 3.00 | 6.00 | 1.00 | 5.86 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 5.00 | 4.29 | 0.00 | 0.00 | 0.00 | 1.88 | 0.00 | 2.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 |
| Typha x glauca | 5.00 | 5.00 | 10.00 | 15.71 | 10.00 | 5.00 | 5.00 | 13.13 | 5.00 | 17.33 | 5.00 | 5.00 | 10.00 | 1.00 | 8.01 |
| Total Typha | 5.00 | 5.00 | 15.00 | 20.00 | 10.00 | 5.00 | 5.00 | 15.00 | 5.00 | 20.00 | 5.00 | 5.00 | 10.00 | 1.00 | 9.00 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Calamagrostis canadensis | 25.00 | 35.00 | 35.00 | 25.00 | 0.00 | 40.00 | 0.00 | 20.00 | 0.00 | 15.00 | 30.00 | 20.00 | 0.00 | 10.00 | 18.21 |
| Carex lacustris | 25.00 | 25.00 | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 0.00 | 10.00 | 20.00 | 15.00 | 15.00 | 10.00 | 0.00 | 9.29 |
| Carex stricta | 30.00 | 10.00 | 30.00 | 35.00 | 50.00 | 35.00 | 55.00 | 65.00 | 75.00 | 60.00 | 70.00 | 55.00 | 60.00 | 10.00 | 45.71 |
| Persicaria amphibia | 10.00 | 10.00 | 15.00 | 5.00 | 10.00 | 0.00 | 10.00 | 20.00 | 10.00 | 15.00 | 10.00 | 10.00 | 0.00 | 15.00 | 10.00 |
| Impatiens capensis | 5.00 | 5.00 | 10.00 | 0.00 | 10.00 | 20.00 | 5.00 | 0.00 | 5.00 | 0.00 | 2.00 | 2.00 | 0.00 | 0.00 | 4.57 |
| Teucrium canadense | 0.00 | 20.00 | 20.00 | 15.00 | 25.00 | 10.00 | 10.00 | 10.00 | 15.00 | 15.00 | 15.00 | 10.00 | 15.00 | 5.00 | 13.21 |
| Calystegia sepium | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 2.00 | 15.00 | 10.00 | 5.00 | 0.00 | 5.00 | 4.07 |
| Phragmites australis | 5.00 | 15.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 20.00 | 3.57 |
| Scutellaria galericulata | 0.00 | 10.00 | 0.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.79 |
| Cirsium arvense | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.50 |
| Iris versicolor | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.14 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 5.00 | 0.00 | 5.00 | 5.00 | 5.00 | 10.00 | 0.00 | 2.86 |
| Aster spp. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Lycopus uniflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 25.00 | 3.93 |
| Campanula aparinoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Thelypteris palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Lysimachia terrestris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Mentha arvensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 2.00 | 0.50 |

| Replicate 3: 8-28-2012 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W1** | **C1W12** | **C12** | **CNTRL** | **C12S12W12** | **C1W1** | **C1** | **C12W12** | **C12S12W1** | **C1S1** | **C1S1W12** | **CNTRL** | **C1S1W1** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 0.00 | 0.00 | 1.00 | 2.00 | 1.00 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 3.00 | 0.00 | 0.86 |
| Typha x glauca stem count | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 | 2.00 | 7.00 | 3.00 | 3.00 | 3.00 | 5.00 | 2.00 | 8.00 | 9.00 | 5.14 |
| Total Typha stem count | 4.00 | 5.00 | 7.00 | 9.00 | 9.00 | 2.00 | 10.00 | 3.00 | 3.00 | 3.00 | 7.00 | 2.00 | 11.00 | 9.00 | 6.00 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 0.00 | 0.00 | 1.43 | 4.44 | 1.67 | 0.00 | 4.50 | 0.00 | 0.00 | 0.00 | 4.29 | 0.00 | 6.82 | 0.00 | 1.65 |
| Typha x glauca | 15.00 | 5.00 | 8.57 | 15.56 | 13.33 | 10.00 | 10.50 | 5.00 | 5.00 | 5.00 | 10.71 | 5.00 | 18.18 | 30.00 | 11.20 |
| Total Typha | 15.00 | 5.00 | 10.00 | 20.00 | 15.00 | 10.00 | 15.00 | 5.00 | 5.00 | 5.00 | 15.00 | 5.00 | 25.00 | 30.00 | 12.86 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Calamagrostis canadensis | 80.00 | 50.00 | 60.00 | 70.00 | 50.00 | 25.00 | 40.00 | 65.00 | 80.00 | 75.00 | 70.00 | 50.00 | 0.00 | 0.00 | 51.07 |
| Carex lacustris | 0.00 | 15.00 | 0.00 | 5.00 | 30.00 | 30.00 | 10.00 | 20.00 | 0.00 | 25.00 | 10.00 | 25.00 | 25.00 | 60.00 | 18.21 |
| Carex stricta | 0.00 | 10.00 | 0.00 | 0.00 | 25.00 | 10.00 | 25.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 30.00 | 25.00 | 10.00 |
| Persicaria amphibia | 5.00 | 10.00 | 15.00 | 10.00 | 15.00 | 15.00 | 5.00 | 10.00 | 10.00 | 5.00 | 10.00 | 10.00 | 15.00 | 15.00 | 10.71 |
| Teucrium canadense | 5.00 | 5.00 | 5.00 | 10.00 | 0.00 | 10.00 | 10.00 | 5.00 | 5.00 | 0.00 | 10.00 | 0.00 | 5.00 | 5.00 | 5.36 |
| Imatiens capensis | 2.00 | 15.00 | 15.00 | 0.00 | 0.00 | 15.00 | 15.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 10.00 | 0.00 | 5.86 |
| Calystegia sepium | 0.00 | 0.00 | 0.00 | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 5.00 | 10.00 | 5.00 | 5.00 | 5.00 | 5.00 | 3.21 |
| Lysimachia thyrisiflora | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.64 |
| Phalaris arundinacea | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15.00 | 15.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.21 |
| Bolboshoenus flufiatilis | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Lysimachis terrestris | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| Scutellaria galericulata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 10.00 | 0.00 | 0.00 | 1.07 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |

| Replicate 4: 8-28-2012 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C1** | **C1W12** | **C12W12** | **CNTRL** | **C1S1W1** | **CNTRL** | **C12W1** | **C12S12** | **C1W1** | **C12S12W12** | **C1S1W12** | **C12S12W1** | **C1S1** | **C12** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 3.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.64 |
| Typha x glauca stem count | 15.00 | 8.00 | 3.00 | 8.00 | 11.00 | 6.00 | 5.00 | 3.00 | 5.00 | 3.00 | 6.00 | 6.00 | 4.00 | 2.00 | 6.07 |
| Total Typha stem count | 18.00 | 8.00 | 3.00 | 8.00 | 13.00 | 8.00 | 6.00 | 3.00 | 5.00 | 3.00 | 6.00 | 7.00 | 4.00 | 2.00 | 6.71 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 4.17 | 0.00 | 0.00 | 0.00 | 2.31 | 3.75 | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43 | 0.00 | 0.00 | 1.01 |
| Typha x glauca | 20.83 | 10.00 | 5.00 | 25.00 | 12.69 | 11.25 | 12.50 | 10.00 | 10.00 | 5.00 | 5.00 | 8.57 | 5.00 | 5.00 | 10.42 |
| Total Typha | 25.00 | 10.00 | 5.00 | 25.00 | 15.00 | 15.00 | 15.00 | 10.00 | 10.00 | 5.00 | 5.00 | 10.00 | 5.00 | 5.00 | 11.43 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 5.00 | 10.00 | 30.00 | 10.00 | 5.00 | 25.00 | 10.00 | 10.00 | 5.00 | 10.00 | 5.00 | 10.00 | 30.00 | 50.00 | 15.36 |
| Carex Stricta | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 50.00 | 5.00 |
| Persicaria amphibia | 25.00 | 20.00 | 10.00 | 5.00 | 15.00 | 30.00 | 25.00 | 10.00 | 15.00 | 10.00 | 15.00 | 10.00 | 10.00 | 35.00 | 16.79 |
| Teucrium canadense | 0.00 | 10.00 | 15.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 10.00 | 5.00 | 5.00 | 0.00 | 20.00 | 5.36 |
| Impatiens capensis | 15.00 | 25.00 | 30.00 | 15.00 | 15.00 | 0.00 | 20.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 0.00 | 9.00 |
| Scutellaria galeric | 10.00 | 0.00 | 0.00 | 0.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 5.00 | 0.00 | 0.00 | 1.93 |
| Calamagrostis canadensis | 70.00 | 65.00 | 55.00 | 65.00 | 75.00 | 55.00 | 60.00 | 70.00 | 70.00 | 70.00 | 65.00 | 60.00 | 0.00 | 30.00 | 57.86 |
| Calystegia sepium | 10.00 | 5.00 | 10.00 | 10.00 | 0.00 | 2.00 | 0.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 2.00 | 4.93 |
| Lathyrus palustris | 5.00 | 0.00 | 0.00 | 2.00 | 5.00 | 5.00 | 0.00 | 2.00 | 10.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 2.43 |
| Lysimachia thyrisifolia | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 1.07 |
| Campanula aparanoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.29 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | 5.00 | 2.50 |
| Solanum dulcamara | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.07 |

| Replicate 5: 8-28-2012 | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quadrat** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Mean** |
| **Treatment** | **C12S12** | **C12W12** | **C12** | **C12W1** | **C1W1** | **C1S1W1** | **CNTRL** | **C1W12** | **C1S1W12** | **C12S12W1** | **C1** | **C1S1** | **C12S12W12** | **CNTRL** | |
| **Stem Counts** | | | | | | | | | | | | | | | |
| Typha angustifolia stem count | 2.00 | 3.00 | 1.00 | 0.00 | 4.00 | 3.00 | 2.00 | 0.00 | 0.00 | 0.00 | 2.00 | 1.00 | 0.00 | 0.00 | 1.29 |
| Typha x glauca stem count | 4.00 | 8.00 | 8.00 | 8.00 | 10.00 | 8.00 | 5.00 | 2.00 | 6.00 | 5.00 | 6.00 | 6.00 | 5.00 | 1.00 | 5.86 |
| Total Typha stem count | 6.00 | 11.00 | 9.00 | 8.00 | 14.00 | 11.00 | 7.00 | 2.00 | 6.00 | 5.00 | 8.00 | 7.00 | 5.00 | 1.00 | 7.14 |
| ***Typha* Percent Cover** | | | | | | | | | | | | | | | |
| Typha angustifolia | 1.67 | 4.09 | 1.11 | 0.00 | 7.14 | 6.82 | 2.86 | 0.00 | 0.00 | 0.00 | 3.75 | 1.43 | 0.00 | 0.00 | 2.06 |
| Typha x glauca | 3.33 | 10.91 | 8.89 | 5.00 | 17.86 | 18.18 | 7.14 | 2.00 | 5.00 | 10.00 | 11.25 | 8.57 | 15.00 | 5.00 | 9.15 |
| Total Typha | 5.00 | 15.00 | 10.00 | 5.00 | 25.00 | 25.00 | 10.00 | 2.00 | 5.00 | 10.00 | 15.00 | 10.00 | 15.00 | 5.00 | 11.21 |
| **Grass/Forb Percent Cover** | | | | | | | | | | | | | | | |
| Carex lacustris | 65.00 | 25.00 | 30.00 | 25.00 | 25.00 | 0.00 | 5.00 | 5.00 | 15.00 | 25.00 | 5.00 | 15.00 | 2.00 | 15.00 | 18.36 |
| Carex stricta | 20.00 | 0.00 | 20.00 | 10.00 | 10.00 | 25.00 | 0.00 | 0.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 30.00 | 8.93 |
| Calamagrostis canadensis | 30.00 | 50.00 | 50.00 | 65.00 | 45.00 | 75.00 | 70.00 | 75.00 | 75.00 | 60.00 | 60.00 | 65.00 | 85.00 | 50.00 | 61.07 |
| Persicaria amphibia | 25.00 | 5.00 | 0.00 | 5.00 | 15.00 | 15.00 | 15.00 | 10.00 | 5.00 | 0.00 | 20.00 | 20.00 | 10.00 | 5.00 | 10.71 |
| Teucrium canadense | 2.00 | 0.00 | 5.00 | 5.00 | 5.00 | 10.00 | 10.00 | 5.00 | 5.00 | 10.00 | 5.00 | 10.00 | 15.00 | 15.00 | 7.29 |
| Calystegia sepium | 3.00 | 1.00 | 5.00 | 3.00 | 0.00 | 0.00 | 5.00 | 5.00 | 10.00 | 2.00 | 2.00 | 1.00 | 1.00 | 2.00 | 2.86 |
| Lysimachia terrestris | 1.00 | 1.00 | 5.00 | 5.00 | 2.00 | 2.00 | 5.00 | 0.00 | 0.00 | 5.00 | 2.00 | 5.00 | 5.00 | 5.00 | 3.07 |
| Impatiens capensis | 0.00 | 0.00 | 1.00 | 0.00 | 2.00 | 2.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.00 | 1.00 | 0.71 |
| Phalaris arundinacea | 0.00 | 0.00 | 0.00 | 5.00 | 0.00 | 0.00 | 25.00 | 2.00 | 0.00 | 0.00 | 30.00 | 0.00 | 0.00 | 0.00 | 4.43 |
| Lathyrus palustris | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 2.00 | 0.00 | 0.00 | 2.00 | 2.00 | 2.00 | 0.00 | 0.00 | 2.00 | 0.86 |
| Mentha arvensis | 0.00 | 0.00 | 0.00 | 3.00 | 0.00 | 2.00 | 5.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 3.00 | 5.00 | 2.00 |
| Campanula aparinoides | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.07 |
| Solidago rugosa | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 | 5.00 | 0.00 | 0.00 | 5.00 | 5.00 | 1.21 |
| Cirsium arvense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 | 10.00 | 1.00 | 0.00 | 1.00 | 1.21 |

**Appendix C**

Mean percent soil moisture for each treatment replicate during the sampling years 2010 to 2012.

| | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 |
|---|---|---|---|---|---|
| 11-Jul-10 | 87.48 | 83.97 | 74.35 | 77.97 | 86.31 |
| 15-Jul-10 | 80.10 | 84.91 | 90.85 | 90.35 | 72.24 |
| 23-Jul-10 | 93.53 | 98.91 | 97.18 | 96.16 | 77.57 |
| 29-Jul-10 | 96.56 | 97.21 | 97.80 | 96.27 | 87.14 |
| 6-Aug-10 | 84.69 | 90.77 | 96.36 | 95.79 | 77.88 |
| 13-Aug-10 | 84.75 | 93.11 | 94.43 | 91.75 | 77.51 |
| 21-Aug-10 | 77.61 | 85.71 | 87.96 | 86.24 | 71.70 |
| 7-Sep-10 | 77.65 | 86.66 | 87.68 | 83.31 | 74.36 |
| **Mean** | **85.30** | **90.16** | **90.83** | **89.73** | **78.09** |
| Max | 96.56 | 98.91 | 97.80 | 96.27 | 87.14 |
| Min | 80.10 | 83.97 | 74.35 | 77.97 | 71.70 |
| Range | 9.83 | 2.69 | 13.33 | 5.34 | 11.95 |
| | | | | | |
| 8-Apr-11 | 98.4 | 100 | 100 | 100 | 96.8 |
| 22-Apr-11 | 95.3 | 96.3 | 91.2 | 100 | 97.1 |
| 6-May-11 | 99.72 | 100 | 100 | 100 | 95.67 |
| 20-May-11 | 100 | 100 | 100 | 100 | 100 |
| 22-Jul-11 | 90.23 | 92.43 | 93.96 | 94.46 | 85.17 |
| 30-Jul-11 | 92.32 | 96.34 | 98.27 | 95.9 | 87.56 |
| 5-Aug-11 | 92.83 | 95.21 | 95.95 | 93.34 | 84.67 |
| 12-Aug-11 | 92.91 | 89.58 | 95.2 | 94.32 | 89.24 |
| 19-Aug-11 | 91.05 | 96.23 | 96.01 | 95.94 | 82.68 |
| 10-Sep-11 | 87.09 | 95.06 | 90.46 | 85.73 | 84.37 |
| 23-Sep-11 | 91.19 | 97.85 | 91.41 | 86.51 | 89.82 |
| **Mean** | **93.73** | **96.27** | **95.68** | **95.11** | **90.28** |
| Max | 100 | 100 | 100 | 100 | 100 |
| Min | 87.09 | 89.58 | 90.46 | 85.73 | 82.68 |
| Range | 7.21 | 2.15 | 8.59 | 13.49 | 6.98 |
| | | | | | |
| 2-Jun-12 | 93.35 | 96.8 | 91.8 | 83.62 | 87.28 |
| 16-Jun-12 | 85.26 | 86.48 | 88.63 | 89.25 | 85.83 |
| 30-Jun-12 | 82.41 | 85.67 | 86.72 | 89.78 | 82.51 |
| 14-Jul-12 | 80.92 | 78.1 | 59.13 | 76.34 | 71.05 |
| 28-Jul-12 | 78.35 | 51.23 | 32.8 | 49.78 | 59.94 |
| 11-Aug-12 | 63.31 | 58.15 | 48.05 | 49.51 | 64.45 |
| **Mean** | **80.60** | **76.07** | **67.86** | **73.05** | **75.18** |
| Max | 93.35 | 96.8 | 91.8 | 89.78 | 87.28 |
| Min | 63.31 | 51.23 | 32.8 | 49.51 | 59.94 |
| Range | 30.04 | 38.65 | 43.75 | 34.11 | 22.83 |