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Research Article

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Enhancing Biodiversity by Restoring Wetland Vegetation Communities in Irrigation Ponds

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Abstract

The survival and establishment rates of five different densities and compositions of *Scirpus atrovirens, Carex lacustris* and *Sagittaria latifolia* were tested in a pilot study at two irrigation ponds in the Niagara Region, Ontario, Canada. Robust emergent wetland species were monitored to determine community assembly principles for water quality and biodiversity improvement in irrigation ponds. Growth trait and survival measurements were taken every two weeks in the growing season of 2011. A vegetation inventory occurred four times throughout the growing season. Using multivariate repeated measures analysis of variance (MANOVAR) we found that *S. latifolia* is capable of interspecific competition when planted in mixed plot plantings in semi-naturalized ponds. We found that *S. atrovirens* was more competitive in monoculture plantings in a pond community comprised of agricultural weed species. It is more difficult to establish *C. lacustris* making it a less suitable choice for restoration plantings in irrigation ponds. The findings suggest pre-restoration community composition will influence the survival establishment rates of some wetland plant species. Pond age may be an important determinant in the vegetative community composition in irrigation ponds.

Keywords

Ecological assembly; Ecosystem functioning; Habitat fragmentation; Interspecific competition; Intraspecific competition; Survival; Water quality improvements; Wetland vegetation

Introduction

On a global-scale, agriculture is a prevalent land-use [1]. In North America, agriculture and urban development have reduced the gross area of wetlands and wetland associated species [2]. The estimated loss of wetlands is close to one hundred percent in urban and agricultural areas like Southern Ontario [3]. Wetland loss has been mitigated to some degree by the creation of farm ponds. Irrigation ponds, for instance, now provide colonization sites for obligate and facultative wetland species in many farming regions [4]. Constructed wetlands can be effective for managing agricultural pesticide runoff [5]. When properly vegetated, agricultural ponds can ameliorate water quality issues and increase biological diversity [5-8]. The potential for irrigation ponds to connect fragmented wetland communities and restore the biodiversity of these ecosystems is significant. In order to use irrigation ponds as wetland ecosystem analogues effectively, there are important fundamental traits that need to be understood. The existing vegetative structure and composition should be examined in order to determine the potential effects from interspecific competition. It is also important to examine the composition and structure of natural wetlands and compare community membership to irrigation ponds to determine if particular plant-types are absent.

We felt it was important to look at the potential differences in species assemblages and colonization of ponds of different age structure to appeal to a broad audience of land managers. This study is one of the first that examines community establishment of native species in irrigation ponds and is designed as a pilot study to clarify some fundamental issues before larger studies can occur. The study is limited to two ponds and three species with the intention that the findings from this research can later be applied on a wider basis to incorporate more variables. The ponds were examined as separate case studies, but received identical treatments and sampling regimen. They were compared using meta-analytical techniques due to differences in age and adjacent land-uses. Ecological succession studies the process of ecological change over time. Succession theory would suggest that the younger pond should support pioneer-type species. The older pond would be characterized by an arguably more stable climax community. We were interested if this was in fact true for recently excavated ponds as compared to older ponds.

A key component in the maintenance of diverse wetland communities at regional scales is related to the protection of propagule sources. Analogue wetland habitats can be used as vectors of dispersal for the provision of seed sources [9]. Although ponds are different from wetlands in terms of hydrology (length of inundation), soil type and some types of vegetation, constructed ponds can benefit from and provide benefits to other existing wetland ecosystems [9]. If wetland communities are established in ponds these habitats could act as “stepping stones” to connect wetland ecosystems [10].

Submersed aquatics rapidly colonize restored wetlands because waterfowl distribute the seeds by ingestion and excretion [9]. However, other types of wetland vegetation reproduce more frequently by clonal reproduction. For instance, robust emergent species reproduce more effectively via rhizomes. This can limit dispersal to other wetlands or ponds [9]. As wetlands become isolated from one another, regional species richness decreases [10]. The closer that restored habitats are to other intact habitats and populations the more opportunity there will be for dispersal, colonization, establishment and persistence of native species. For instance, total species richness is higher for non-isolated islands than for isolated forest island patches [11].

Assembling a functionally beneficial robust emergent community is an important basis for this study for three main reasons. First, emergent species provide sites for microbes to attach. This increases nutrient and contaminant breakdown in the water body; nutrients are also taken up through their roots [12,13]. Microbes remove inorganic nutrients, heavy metals, dissolved organic carbon, particulate matter and suspended solids [14]. Wetlands are useful for the treatment of

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non-point source (NPS) pollution because they can deal with pulses of pesticides from fields in modern agriculture [15].

Second, rhizomatic vegetation in particular, provides areas for sedimentation, seed collection and seed germination while also leaking oxygen from rhizomes that stimulates aerobic decomposition of organic matter and the growth of nitrifying bacteria [6]. Oxygen leakage from rhizomes serves to oxidize and detoxify potentially harmful reducing substances in the rhizosphere [6].

Third, clonally reproducing vegetation is capable of rapid establishment and can function as a nurse crop for other more sensitive species [16]. Planting two grass species in a recently restored depressional wetland was found to improve native vegetation cover [16]. By planting species that reproduce clonally, the wetland increased in native coverage and also provided safe sites for other native plants to establish [17].

In this study, we examined the establishment, survival and competition of a matrix of three robust emergent vegetation species. Specifically, our aims were: (1) to determine the capacity of five different treatments (combinations of planted species) for survival and establishment, and (2) to study the relationship between the planted species and agricultural weeds in terms of competition and coverage over time. Ultimately, the question is whether mixed plantings of robust emergent species will be more successful in establishing and surviving in irrigation ponds as compared to monoculture plantings.

Methods

Study sites

We chose two sites in the Niagara region, both on privately owned farmland. The first site is located on a tender fruit farm that has been in cultivation for at least fifty years in Virgil, Ontario (http://goo.gl/LO2LG). The other site is also on a tender fruit farm located in Winger, Ontario (http://goo.gl/iCKMA), adjacent on one side to a field cash-crop farm. On the other side the farm borders a forested lot used recreationally for hunting. The cultivation history for this property was unknown. The irrigation pond in Virgil (Pond A) was dug in 1980, is spring fed and is approximately 700-m^2. The pond in Winger (Pond B) was dug in 2007 by expanding an existing pond on the property and is about 600-m^2. The Four Mile Creek Wetland, a provincially significant wetland is in the same watershed as the Virgil pond and is about 55 km away from Pond B. The wetland was used as a reference site to examine the vegetation composition in comparison to the two study sites.

2010 Baseline vegetation studies

In 2010, baseline vegetation studies were performed at each of the sites to characterize the two study sites. These findings were then compared to the reference site. We used the Wetland Macrophyte Index (WMI) to characterize the sites. The WMI is a specific wetland vegetation presence/absence inventory system used to characterize water quality [18]. Because macrophytes are directly influenced by changes in water quality, the taxonomic makeup of the aquatic community is a reflection of the wetland water chemistry [18]. The method delineates wetlands into different zones of growth based on water depth to ensure that all specific zones are sampled during the inventory [18].

The WMI findings were consistent with other studies that found robust emergent species are often absent from passively restored wetlands [9]. The irrigation pond in Virgil (Pond A) is devoid of robust emergent wetland species in comparison to the reference site and Pond B, and possesses some characteristic wetland species, particularly in the end that was the original pond. Submersed aquatics were present at all three sites [9].

Experimental design

For this experiment, plugs were used as opposed to direct seeding. Direct seeding of wetland vegetation is often ineffective due to very specific light, heat and water requirements [19,20]. The plug cells were 3.81-cm wide by 5.08-cm deep in trays of 72. The planting material was purchased from St. Williams Nursery & Ecology Centre, Long Point, Ontario that specializes in seed-zone specific genetics. The plants were transported to both sites in the Niagara Region on the same day (September 22nd 2010). The plugs were planted within the plots on September 26th 2010. Monitoring of the plant species continued biweekly until the end of November 2010. The timing of the plantings was based on the normative seasonal decline in herbicide application on the farms [21]. This was also the time in the growing season when water levels are the lowest in the ponds helped to protect the plants from desiccation since young plants have not yet developed the aerenchymous material necessary for them to survive in anaerobic soils [21]. The water height on the banks was used to guide planting [22].

Vegetation selection and planting design: The species that were chosen for planting were *Scirpus atrovirens* Willd., *Carex lacustris* Willd., *Sagittaria latifolia* Willd. One of the reasons these species were chosen was because they were absent from the species inventory at both study locations. This reduced possible contamination from local seed sources or the rhizomatic spread of the species within the ponds [23] with the potential for considerable vegetative coverage [16]. Other additional considerations included access to planting materials (including the capacity for the nursery to germinate certain species) and precedence from screening tests [15,22,23]. The three species were chosen because they reproduce clonally, two of them (*Carex lacustris* and *Scirpus atrovirens*) are important contributors to above ground biomass with considerable above ground canopy growth. *Sagittaria latifolia* can also reach heights of 80-cm providing it a competitive edge for light requirements [24]. All three species are tolerant of variable soil type with the capacity to adapt to degraded wetland habitats [24].

We tested the effects of the five treatments on growth, regeneration, abundance of planted species as well as species diversity and abundance and community composition (wetland species guilds, natives versus non-native) at the two different ponds. Of interest was the potential variability of species competition and establishment between the two different age structures [25,26] and the influence that the monocultures and polycultures have on other naturally occurring species in the robust emergent wetland vegetation zone [27,28].

In total 156 50-cm^2 plots were established (seventy-eight at each of the ponds). Sixty of the plots received one of five planting treatments and 18 were left alone and used as control (1 through 5 listed below). On August 23rd, 2010 a plot-based vegetation inventory was taken prior to hand-weeding during site preparation for planting

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to outline the characteristic community members [20]. The control plots were not weeded and received no plants. The planting design used was based on four treatments and the pattern is consistent around the perimeter of each pond. The planting density was three plugs per 50-cm^2 plot.

The five planting treatments created at each site are as follows:

1) Mixed Plot: includes one plant each of *Sagittaria latifolia, Scirpus atrovirens* and *Carex lacustris.*

2) Monoculture: *Sagittaria latifolia* – Each plot contained three plant plugs of *S. latifolia* (plugs were planted approximately 5-cm from one another).

3) Monoculture: *Scirpus atrovirens* – Each plot contained three plant plugs of *S. atrovirens* (plugs were planted approximately 5-cm from one another).

4) Monoculture: *Carex lacustris* – Each plot contained three plant plugs of *C. lacustris* (plugs were planted approximately 5-cm from one another).

5) Control: No plant plugs were planted in these plots

This planting pattern is repeated twelve times at each site location, resulting in a total of 15 replicates of each treatment at each site. In total 180 plugs were planted at each site, 60 of each species.

Variables measured

Two types of non-destructive monitoring occurred during the growing season of 2011. A monthly vegetation inventory was executed in May, June, July and August to gather information on plant abundance and diversity. During these inventories the maximum height of the canopy with the associated species was recorded, in addition to the percent cover of plants, water, rocks, detritus, bryophytes, and soil for each plot (including the control plots).

The survival and establishment measurements were executed every two weeks beginning when the planted species were first visible (June 13th) [29,30]. The variables measured included presence/absence of the planted species, diameter of the stem at the base of the plant (three measurements were taken and averaged) using a digital caliper, diameter of the entire canopy (taken in two measurements as North to South and East to West using a ruler), maximum plant height, leaf length (three measurements taken and averaged) and leaf width (taken as three measurements and averaged), the total number of leaves per plot (this includes the mother plant and the clones that establish from that original plant), and the total number of ramets per mother plant (i.e. the number of clones that occur) . The measurements taken for the flowers included number of bolts, mean flower height, and mean number of flowers. For the plants that survived the first winter, these measurements were taken seven times during the growing season in 2011 at two-week intervals.

Statistical analysis

The purpose of the experiment was to examine the interaction of time and treatment, therefore, repeated measures design was suitable for statistical analysis. The design reduces the variance of estimates of treatment-effects and allows for statistical inferences to be made using fewer subjects [30]. The data was analyzed using the program R.

Following the Shapiro-Wilks test for normality, it was determined that the survivorship data sets were normally distributed, therefore, multivariate repeated measures analysis of variance (MANOVAR) was used for analysis.

The measures were repeated over time on a per-plot basis, and interactions were expected to occur on an individual basis. However, the response variables were expected to be non-independent as well. For all the repeated measures, there was one within-subjects factor (time, measured in weeks; measurements were taken every two weeks from June until September). Seven sets of measurements were collected and recorded. There were six between-subjects factors for the survivorship analysis. One: *Sagittaria latifolia* in the mixed plot, Two: *Scirpus atrovirens* in the mixed plot, Three: *Carex lacustris* in the mixed plot, Four: *Sagittaria latifolia* monoculture planting, Five: *Scirpus atrovirens* monoculture planting, and Six: *Carex lacustris* monoculture planting.

There were five between-subjects factors for the vegetation inventory analysis. One: is a mixed plot (one plant each of *S. latifolia, S. atrovirens* and *C. lacustris*), Two: *S. latifolia* monoculture, Three: *S. atrovirens* monoculture, Four: *C. lacustris* monoculture, and last, Five: a control (no plants were planted). The analysis was concerned with examining whether or not time and/or treatment influences the seven particular response variables.

In this study, the F value refers to the influence that treatment and/or time have on the response variables (e.g. plant height, number of ramets, and stem diameter). The Pillai's Trace Test was used to assess the statistical significance between the groups of independent variables. Data are reported using F, p ($p < 0.05$) and Pillai's trace.

Results

Survivorship analysis

Pond A: Virgil, Ontario: The monoculture of *Scirpus atrovirens* differed significantly as compared to the other treatments. The second most successful treatment consistently for each measured trait was Treatment Two and refers to the *Scirpus atrovirens* in the mixed plot. For Mean Leaf Surface Area, Treatment One, *Sagittaria latifolia* in the mixed plot was not different than Treatment Two (*Scirpus atrovirens* in the mixed plot) (Table 1).

Pond B: Winger Ontario- Treatment One, *S. latifolia* in a mixed plot, differed significantly than of the other treatments including the monoculture planting of *S. latifolia* in mean survival traits measured. The monoculture of *S. latifolia* was second to *Sagittaria latifolia* in the mixed plot. *Carex lacustris* had a zero percent survival rate after winter at this pond (Table 2).

Pond A compared to Pond B: Flowering only occurred at Pond B for one species: *Sagittaria latifolia.* For the traits pertaining to flowering, the means of Treatment One, *S. latifolia* in a mixed plot, differed significantly than all of the other treatments. Since *S. latifolia* was the only species that flowered, Treatment Four (the monoculture of *S. latifolia*) was second in trait means (Figures 1-5).

Vegetation inventory

Pond A: The analyses revealed that Treatment One (the mixed plot treatment) was consistently the most influential treatment for all seven response variables over time for Pond A. Treatment Three

Table 1: MANOVAR testing responses of Survival for Pond A.

Variable	Treatment		Time			Time x Treatment		
	F	P	Pillai	F	P	Pillai	F	P
Stem Diameter	21.11	***	0.91	85.61	***	0.22	16.78	***
Max Plant Height	10.89	***	0.95	89.89	***	0.25	18.99	***
Spread	54.32	***	0.78	61.45	***	0.20	15.21	***
Mean Leaf Surface Area	59.87	***	0.86	76.08	***	0.34	31.87	***
# of Leaves	64.51	***	0.81	71.33	***	0.27	22.94	***
# of Ramets	35.41	***	0.58	62.04	***	0.39	34.16	***

Tests were based on data collected from 60 plots observed during the first week of June through the last week of September 2011. For time and time X treatment (within-subjects effects), data are reported using F, p, and Pillai's Trace because the latter is the actual test for significant differences of the repeated factor of time (and time x treatment) within subjects. Three asterisks (***) next the reported p-value indicates p-value <0.001, two asterisks (**) indicating that 0.001 < p-value <0.01, and one asterisk (*) indicating 0.01<p-value <0.05.

Table 2: MANOVAR testing responses for survival for Pond B.

Variable	Treatment		Time			Time x Treatment		
	F	P	Pillai	F	P	Pillai	F	P
Stem Diameter	41.18	***	0.87	79.01	***	0.21	16.11	***
Max Plant Height	45.67	***	0.84	75.22	***	0.19	14.27	***
Spread	57.61	***	0.80	72.74	***	0.23	18.33	***
Mean Leaf Surface Area	71.14	***	0.89	83.14	***	0.45	40.13	***
# of Leaves	68.79	***	0.83	73.57	***	0.17	13.50	***
# of Ramets	39.12	***	0.48	44.38	***	0.25	21.22	***
# of Bolts	66.77	***	0.44	40.85	***	0.16	12.41	***
Mean Flower Height	71.32	***	0.61	57.81	***	0.18	13.86	***
Mean # of Flowers	54.98	***	0.64	59.26	***	0.22	16.49	***

Tests were based on data collected from 60 plots observed during the first week of June through the last week of September 2011. For time and time X treatment (within-subjects effects), data are reported using F, p, and Pillai's Trace because the latter is the actual test for significant differences of the repeated factor of time (and time x treatment) within subjects. Three asterisks (***) next the reported p-value indicates p-value <0.001, two asterisks (**) indicating that 0.001 < p-value <0.01, and one asterisk (*) indicating 0.01<p-value <0.05.

was the next most influential treatment on the response variables over time. This is consistent with the survivorship analyses where Treatment Three was the most influential Treatment for survivorship (Table 3).

Pond B: The analyses revealed that Treatment One (the mixed plot treatment) was consistently the most influential treatment for all seven response variables over time for Pond B (Figures 6-8). Treatment Two was the next most influential treatment on the response variables over time. This is consistent with the survivorship analyses where *S. latifolia* was most successful in the mixed plot planting. Treatment Two was the second most influential treatment on the seven response variables. This is also consistent with the survivorship findings where

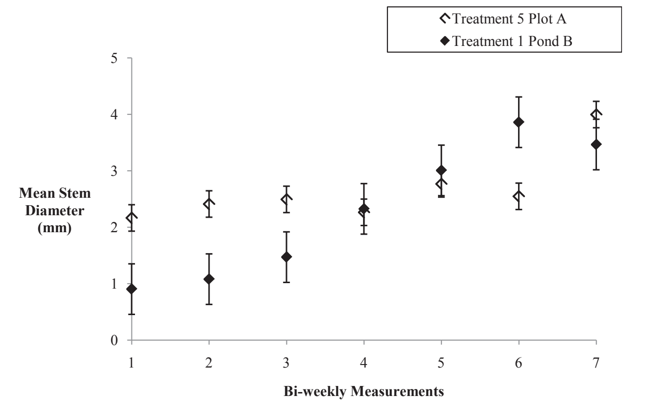

Figure 1: Mean stem diameter for the significant treatments from both sites from June to September 2011. Data are reported as the means and standard errors across all bi-weekly measurements. Absent plants, recorded as zeroes in the data set, were excluded from graphing; N= 7 for Treatment 5 from Pond A and N=8 for Treatment 1 from Pond B.

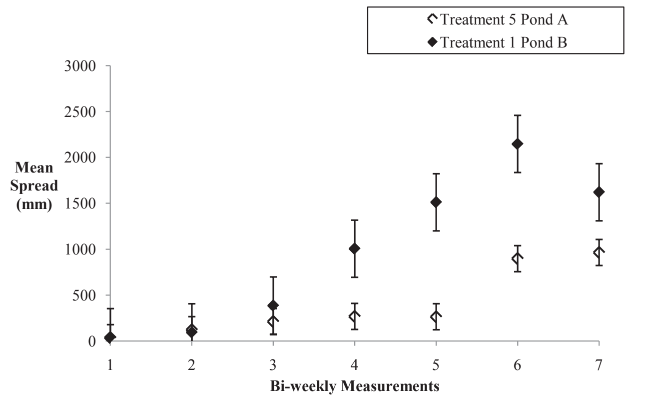

Figure 2: Mean plant spread for the significant treatments from both sites from June to September 2011. Data are reported as the means and standard errors across all bi-weekly measurements.

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S. latifolia in a monoculture was the second most influential treatment for survivorship in Pond B (Table 4).

Discussion

For ecological restoration on agricultural lands, the results suggest that planting plugs of *S. latifolia* (at a spacing of 50-cm) is an effective strategy for establishing a dominant plant community in semi-naturalized irrigation ponds. The findings suggest that *S. latifolia* is better suited to competing with existing agricultural weeds and wetland species (interspecific competition) rather than intraspecific competition. *Sagittaria latifolia* provides important

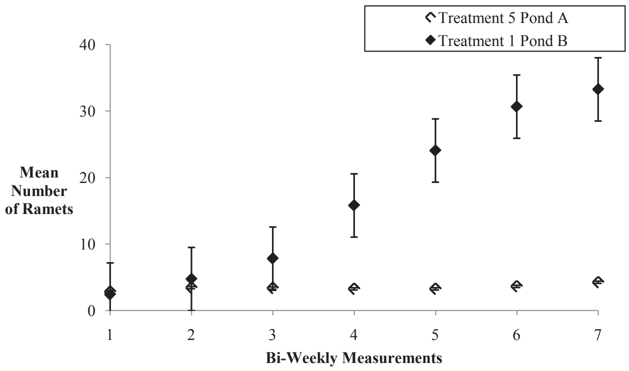

Figure 3: Mean number of ramets for the significant treatments from both sites from June to September 2011. Data are reported as the means and standard errors across all bi-weekly measurements.

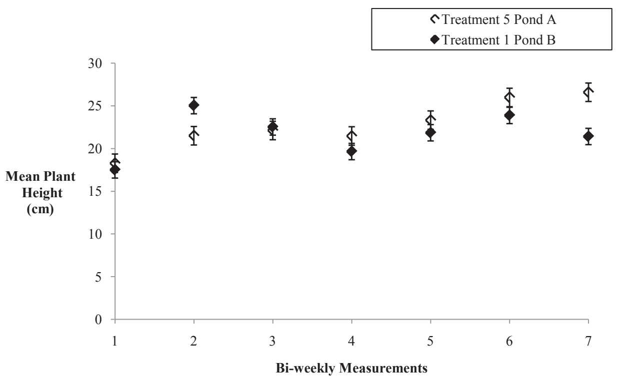

Figure 4: Mean plant height for the significant treatments from both sites from June to September 2011. Data are reported as the means and standard errors across all bi-weekly measurements. Absent plants, recorded as zeroes in the data set, were excluded from graphing; N= 7 for Treatment 5 from Pond A and N=8 for Treatment 1 from Pond B.

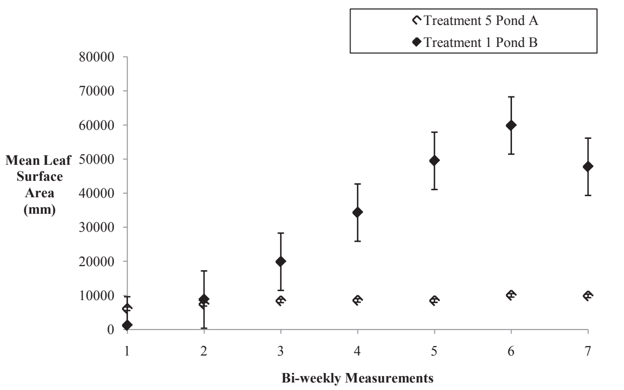

Figure 5: Mean leaf surface area for the significant treatments from both sites from June to September 2011. Data are reported as the means and standard errors across all bi-weekly measurements. Absent plants, recorded as zeroes in the data set, were excluded from graphing; N= 7 for Treatment 5 from Pond A and N=8 for Treatment 1 from Pond B.

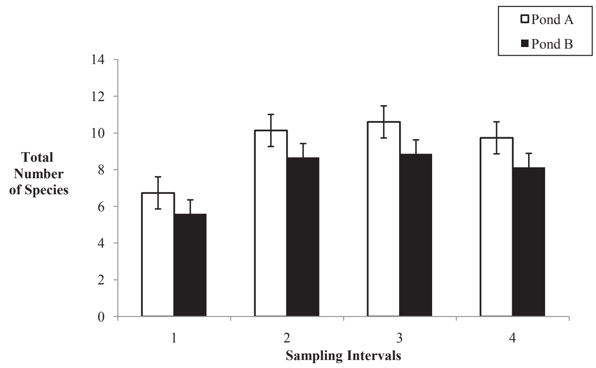

Figure 6: Total number of species for the significant treatments (Treatment 1) from both sites from June to September 2011. Data are reported as the means and standard errors across all the four growing season vegetation inventories.

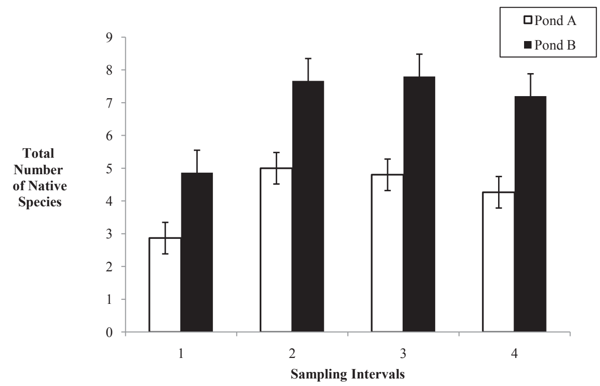

Figure 7: Total number of native species for the significant treatments (Treatment 1) from both sites from June to September 2011. Data are reported as the means and standard errors across all the four growing season vegetation inventories.

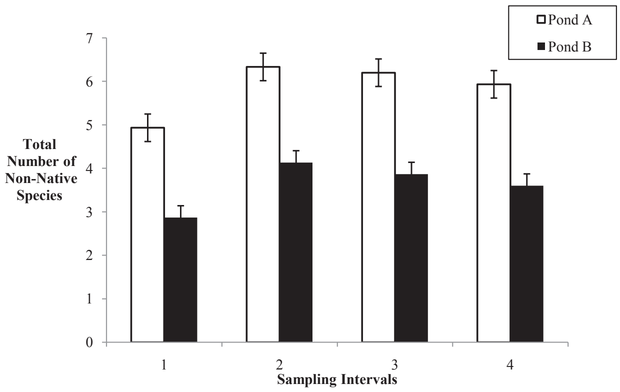

Figure 8: Total number of non-native species for the significant treatments (Treatment 1) from both sites from June to September 2011. Data are reported as the means and standard errors across all the four growing season vegetation inventories.

Table 3: Tests for vegetation inventory data for Pond A.

Variable	Treatment		Time			Time * Treatment		
	F	P	Pillai	F	P	Pillai	F	P
Total # species	14.23	***	0.84	72.13	***	0.19	13.15	***
# of native species	11.16	***	0.72	56.19	***	0.16	11.20	***
# of exotic species	16.77	***	0.85	74.98	***	0.18	12.56	***
canopy height	10.24	***	0.89	79.46	***	0.25	20.23	***
% cover treatment	12.66	***	0.74	59.08	***	0.20	13.86	***
% cover native	10.33	***	0.43	33.75	***	0.15	10.54	***
% cover exotic	11.57	***	0.48	38.69	***	0.14	10.01	***
% cover remainder	6.12	*	0.39	31.18	***	0.17	11.94	***

Tests were based on data collected from 78 plots observed during the first week of June through the last week of September 2011. For time and time X treatment (within-subjects effects), data are reported using F, p, and Pillai's Trace because the latter is the actual test for significant differences of the repeated factor of time (and time x treatment) within subjects. Three asterisks (***) next the reported p-value indicates p-value <0.001, two asterisks (**) indicating that 0.001 < p-value <0.01, and one asterisk (*) indicating 0.01<p-value <0.05.

Table 4: Tests for vegetation inventory data for Pond B.

Variable	Treatment		Time			Time * Treatment		
	F	P	Pillai	F	P	Pillai	F	P
Total # species	16.48	***	0.86	77.27	***	0.22	14.88	***
# of native species	12.96	***	0.79	63.54	***	0.23	15.31	***
# of exotic species	15.22	***	0.81	67.21	***	0.26	22.24	***
canopy height	10.80	***	0.82	70.44	***	0.28	23.07	***
% cover treatment	11.56	***	0.77	60.37	***	0.31	24.93	***
% cover native	11.79	***	0.49	39.96	***	0.30	23.47	***
% cover exotic	12.54	***	0.51	42.41	***	0.37	26.85	***
% cover remainder	7.71	**	0.36	28.67	***	0.14	10.13	***

Tests were based on data collected from 78 plots observed during the first week of June through the last week of September 2011. For time and time X treatment (within-subjects effects), data are reported using F, p, and Pillai's Trace because the latter is the actual test for significant differences of the repeated factor of time (and time x treatment) within subjects. Three asterisks (***) next the reported p-value indicates p-value <0.001, two asterisks (**) indicating that 0.001 < p-value <0.01, and one asterisk (*) indicating 0.01<p-value <0.05.

benefits to organisms dependent on wetlands for food including waterfowl, muskrats, porcupines and habitat including usage as cover and for fish and macroinvertebrates.

For ecological restoration of irrigation ponds on agricultural lands devoid of facultative wetland species planting *S. atrovirens* in monocultures (at a density of three plugs per 50 cm^2) is a good strategy in establishing a dominant emergent vegetation community and is presumably capable of managing field run-off [15]. Intraspecific competition is less of an issue for *S. atrovirens'* survival and dominance; rather interspecific competition is improved with at least three plants per 50-cm^2 plot.

At both sites, the survivorship of *C. lacustris* was limited. Although plugs were used for planting, this research may confirm findings from Yetka and Galatowitsch [31], who suggest rhizome planting is most successful when executed in the spring. More likely, however, is that the low seasonal water levels influenced survival. Budelsky and Galatowitsch [32] observed that seedling survival of *Carex lacustris* was highly dependent on water levels during the first growing season. During the growing season of 2011, precipitation was extremely low and the landowners irrigated regularly. Percent cover from the vegetation surveys indicated that by June some plots at both sites were entirely dry and by July all of them were devoid of contact with water. The drawn down of the ponds may have influenced the survival of *C. lacustris*. The variable water level of irrigation ponds during the growing season makes *C. lacustris* and unsuitable species for these habitats.

Our study has also determined that planting mixed plots of facultative wetland species is the most effective way to influence the native and exotic species community composition of agricultural irrigation ponds. Land managers must clearly identify their particular goal for restoration to determine the most appropriate type of planting to execute. *Scirpus atrovirens* in a monoculture differs significantly in its capability to establish and dominate the planted plots adjacent to weedy agricultural fields. Therefore, a monoculture planting of this species may be preferable for some land managers if the goal is to create a dominant community capable of managing agricultural pollutants. If the goal is to establish a more biodiverse and "natural" ecosystem in the irrigation pond, planting a mixed plot would help to influence the community by increasing the total number of species colonizing each plot.

The vegetation survey indicated many more agricultural weeds in the plots in Pond A. It may be more difficult for introduced native plants to become established into the communities of highly resistant agricultural weeds. For the duration of the vegetation inventory,

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Pond B supported thirteen facultative wetlands species whereas Pond A supported only four before planting.

Conclusions

The findings suggest that the pre-existing vegetative community, the density of the planted species, and the capacity for clonal reproduction influences community establishment and dominance. The species chosen for the study have the ability to reproduce clonally and offers them a chance to maximize their spread and coverage within the first growing season.

Due to the potential constraints of competing with the pre-existing community (interspecific) and within species (intraspecific), this research demonstrates that land managers looking to improve water quality and habitat in irrigation ponds need to investigate species existing in/around the community prior to plant and density selection. Additionally one needs to consider the age of the pond to maximize the success of plant survival and dominance. This study is the initial phase in determining how best to assemble ecological functional and biologically diverse communities in irrigation ponds. Based on these findings, a full-scale restoration study should first determine whether the site is well-suited to monoculture or polyculture plantings as the first stage of ecological community assembly in irrigation ponds.

The next phase of this study should look at incorporating more species, particularly rarer or more sensitive species that are largely absent from regional landscapes. Although this study was not focused on the spatial linkages between scales explicitly, there is an implied recognition that improving the delivery of ecosystem services at the farm-scale can enhance biodiversity at the regional scale. The question then becomes one of trying to determine how best to introduce the suitable species. More explicit research into the spatial dynamics of wetland fragmentation and species loss would help to create targeted species restoration plans for irrigation ponds throughout farming regions.

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References

1. Devine GJ, Furlong MJ (2007) Insecticide use: Contexts and ecological consequences. Agr Hum Val 24: 281-306.
2. Donnan JA (2008) Economic implications and consequences of population growth, land use trends and urban sprawl in southern Ontario. Final Report to the Environmental Commissioner of Ontario.
3. Daigle JM, Havinga D (1996) Restoring nature's place: a guide to naturalizing Ontario parks and greenspace. Ecological Outlook, Schomberg, Ontario.
4. Knutson MG, Richardson WB, Reineke DM, Gray BR, Parmelee JR, Weick SE (2004) Agricultural ponds support amphibian populations. Ecol Appl 14: 669-684.
5. Schulz R, Peall SKC (2001) Effectiveness of a constructed wetland for retention of nonpoint-source pesticide pollution in the Lourens River catchment, South Africa. Envir Sci Technol 35: 422-426.
6. Brix H (1999) How 'green' are aquaculture, constructed wetlands and conventional wastewater treatment systems? Water Sci Technol 40: 45-50.
7. Kantawanichkul S, Pilaila S, Tanapiyawanich W, Tikampornpittaya W, Kamkrua S (1999) Wastewater treatment by tropical plants in vertical-flow constructed wetlands. Water Sci Technol 40:173-178.
8. Houlahan JE, Keddy PA, Makkay K, Findlay CS (2006) The effects of adjacent land use on wetland species richness and community composition. Wetlands 26:79-96.
9. Galatowitsch SM, Vandervalk AG (1995) Natural revegetation during restoration of wetlands in the southern prairie pothole region of North America. Restor Temp Wetlands 126: 129-142.
10. Loehle C (2007) Effect of ephemeral stepping stones on metapopulations on fragmented landscapes. Eco Comp 4:42-47.
11. Jacquemyn H, Butaye J Hermy M (2003) Impacts of restored patch density and distance from natural forests on colonization success. Restor Ecol 11: 417-423.
12. Bastian RK Hammer DA (1993) The use of Constructed Wetlands for Waste-Water Treatment and Recycling. Adv Ecol Sci 59-68.
13. Gottschall N, Boutin C, Crolla A, Kinsley C, Champagne P (2007) The role of plants in the removal of nutrients at a constructed wetland treating agricultural (dairy) wastewater, Ontario, Canada. Ecol Eng 29: 154-163.
14. Adamus P, Danielson TJ, Gonyaw A (2001) Indicators for Monitoring Biological Integrity of Inland, Freshwater Wetlands: A Survey of North American Technical Literature (1990-2000), United States Environmental Protection Agency, Office of Water, Wetlands Division, Washington, D.C.
15. Kadlec RH, Wallace SD (2008) Treatment Wetlands (2ndedn), CRC Press, Boca Raton.
16. De Steven D, Sharitz RR (2007) Transplanting native dominant plants to facilitate community development in restored Coastal Plain wetlands. Wetlands 27: 972-978.
17. Temperton VM, Kirr K (2004) Order of arrival and availability of safe sites: an example of their importance for plant community assembly in stressed ecosystems. In: Assembly rules and restoration ecology: Bridging the gap between theory and practice. Island Press, Washington, 285-303.
18. Croft MV, Chow-Fraser P (2009) Non-random sampling and its role in habitat conservation: a comparison of three wetland macrophyte sampling protocols. Biodivers Conserv 18: 2283-2306.
19. Hoag JC (2000) Constructed wetland systems in the arid and semi-arid west to treat irrigation wastewater. Wetlands Remed 295-300.
20. Fraser A, Kindscher K (2001) Tree spade transplanting of *Spartina pectinata* (Link) and *Eleocharis macrostachya* (Britt.) in a prairie wetland restoration site. Aquat Bot 71: 297-304.
21. Griffith AB, Forseth IN (2003) Establishment and reproduction of *Aeschynomene virginica* (L.) (*Fabaceae*) a rare, annual, wetland species in relation to vegetation removal and water level. Plant Ecol 167: 117-125.
22. Weiher E, Keddy PA (1995) The assembly of experimental wetland plant communities. Nordic Soc Oikos 73: 323-335.
23. Keddy P (1999) Wetland restoration: The potential for assembly rules in the service of conservation. Wetlands 19: 716-732.
24. Newmaster SG, Harris AG, Kershaw LJ (1997) Wetland Plants of Ontario. Lone Pine Publishing, Edmonton.
25. Grace JB, Wetzel RG (1998) Long-term dynamics of *Typha* populations. Aquat Bot 61: 137-146.
26. DeBerry DA, Perry JE (2004) Primary succession in a created freshwater wetland. Castanea 69: 185-193.
27. Naeem S (2006) Biodiversity and ecosystem functioning in restored ecosystems: Extracting principles for a synthetic perspective, In: Foundations of restoration ecology. Island Press, Washington, 210-237.
28. Murphy SD (2005) Concurrent management of an exotic species and initial restoration efforts in forests. Restor Ecol 13: 584-593.
29. Shipley B, Keddy PA, Moore DRJ, Lemky K (1989) Regeneration and establishment strategies of emergent macrophytes. J Ecol 77: 1093-1110.

30. Minke A (1997) Conducting repeated measures analyses: experimental design considerations. Ericae

31. Yetka LA, Galatowitsch SM (1999) Revegetation of *Carex lacustris* and *Carex stricta* from rhizomes. Restor Ecol 7: 162-171.

32. Budelsky RA, Galatowitsch SM (2000) Effects of water regime and competition on the establishment of a native sedge in restored wetlands. J Appl Ecol 37: 971-985.

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