Green Infrastructure for Texas

Texas Commission of Environmental Quality (TCEQ) Project 528-18-80237

9/1/2017 - 2/28/2020

FINAL REPORT

Texas A&M AgriLife Extension Service

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Executive Summary

Green Infrastructure for Texas (GIFT) is a program of the Texas A&M AgriLife Extension Service (AgriLife) with the Texas Community Watershed Partners. The GIFT program works to demonstrate a range of green infrastructure (GI) practices, aimed at reaching individual property owners, large scale undeveloped lands, and decision makers in the Galveston Bay watershed. The activities funded by this contract have helped to advance the knowledge and usage of ecological restoration and stormwater wetlands as GI practices. This project consisted of two primary components, 1. Vegetation Monitoring at the Sheldon Lake State Park (SLSP) restored freshwater wetland project site; and 2. Stormwater wetland demonstration sites and project development.

Stormwater wetlands are gaining traction as a best management practice in the Lower Galveston Bay watershed and throughout Texas. This contract allowed AgriLife staff to increase the knowledge base, establish new partnerships, and empower more entities to begin using stormwater wetlands in their communities.

Quarterly vegetation monitoring for the SLSP project allowed for additional data collection. This data, combined with previously collected data, suggests the SLSP restoration is on a successful trajectory. The data presented will better inform management of ongoing and future wetland restorations in the Galveston Bay watershed.

Introduction

GI is an approach to managing stormwater that uses nature-based solutions and is applicable on a variety of scales, from a lot with an individual home, to a thousand-acre park, and every scale in between.

As communities in the lower Galveston Bay watershed, and across the State of Texas struggle to manage increasing populations, increasing impervious surface cover, and large rain fall events, GI is a solution that is gaining ground. Success of projects like Exploration Green that protected homes from flooding during Hurricane Harvey, and the Sheldon Lake State Park freshwater wetland restoration that re-created over 400 acres of lost wetland habitat and replaced countless ecological services, continue to draw interest from communities both large and small.

The activities funded by this contract have helped to advance the knowledge and usage of ecological restoration and stormwater wetlands as GI practices. Building partnerships to advance current and develop future projects, managing and expanding an educated and committed volunteer base, establishing on the ground demonstration projects, and collecting vital data long-term data on projects, were all activities funded under this contract.

Project Significance and Background

Freshwater wetland restoration began at SLSP in 2003. Since that time, four additional phases have been restored with the completion of Phase 5 in 2018. Altogether, 410 acres of agriculture land have been restored to the coastal prairie – freshwater wetland complex that existed there some 100 years ago. In 2013, in partnership with the Texas Parks and Wildlife Department (TPWD), AgriLife Extension staff developed a vegetation monitoring protocol for Phases II and III of the SLSP project. This contract continued quarterly data collection for Phases II and III, and established data collection for Phases IV and V which were completed during the contract timeframe. Coastal Prairie wetlands such as the ones at SLSP are disappearing at an alarming rate due to development pressure. Restoration is one key strategy in reclaiming this lost resource, however we must be able to measure the success of these projects and adjust the methods for future projects to ensure we are using the best possible restoration protocols. Studies such as the one funded by this contract are essential to assessing the wetland plant community and creating long-term data sets to help understand community change over time.

Another method of creating wetland habitat is through the construction of stormwater wetlands. While the design and intent of these two wetlands are different, at the most basic level they have the same components: wetland soils, hydrology, and vegetation. The TCEQ identifies those water bodies that do not meet assigned water quality standards as impaired. The majority of the bayous and streams in the Houston-Galveston region are considered impaired for high levels of bacteria. Studies have shown that stormwater wetlands are effective at removing nuisance bacteria as well as other pollutants including nutrients, hydrocarbons, and sediment. A well-designed stormwater wetland can also mitigate flooding by holding stormwater and releasing it downstream over time. As interest in this best management practice grows, so does the need for educational and science backed design criteria including plant selection, residence time, outfall design, and flood mitigation value. This contract supported development of stormwater wetland demonstration projects, which included partnership development, outreach, education, wetland plant propagation, and volunteer coordination.

METHODS

Vegetation Monitoring

The vegetation monitoring protocol was updated using the initial 2013 AgriLife-TPWD design. A Trimble Geo5T Handheld with a navigational accuracy of ±3 inches was purchased for this update. The additional accuracy of the global positional system (GPS) device allowed for easier discernment of vegetation plots within the geodatabase. The Trimble unit also allowed for digital data collection, as paper data collection sheets were not used for this project.

Quality assurance (QA) was performed in the field to ensure that field staff (both paid and volunteer) were executing the protocol correctly. Field duplicates were performed for a subset of plots, where two separate individuals assessed vegetative cover classes. This ensured accuracy of all data collected. Finally, in office quality control was executed on data, assessing both the digital data and paper duplicates.

Wetland restoration phases 1, 4, and 5 at SLSP were monitored seasonally from Winter 2018 to Fall 2019. Within each $1x1m^2$ plot, individual species were identified and assigned one of six cover classes (0 – 4%, 5 – 29%, 30 – 69%, 70 – 94%, 95 – 99%, and 100%). A volunteer botanist identified any unknown species encountered. Data were analyzed for species constancy to assess species distribution within the plant community; species abundance to understand how plentiful individual species are within the wetland; and species richness, or the number of individual species in an area of interest. These three indicators allowed AgriLife staff to assess restoration success across all phases of the restored wetland.

The full field sampling methods can be found in the Comparative Study in Appendix 1.

Stormwater Wetlands

A variety of methods were used to complete the stormwater wetland project development and demonstration tasks.

One on one meetings were held with prospective partner organizations, these frequently included site visits to completed projects or to potential project sites. For projects like Houston Botanic Garden and Exploration Green that progressed into the design and construction phases, AgriLife staff worked to coordinate with project partners through additional meetings and site visits. At these meetings AgriLife staff worked to ensure proper design and construction of the wetlands including water depths, flow patterns, wetland planning areas, and outflow structures.

Educational programs non-technical groups and the general public were held to foster community knowledge and buy into the purpose and benefits of stormwater wetlands. Power point presentations, hands-on activities, fact sheets, flyers, and site tours were all tools used to engage stakeholders.

Finally, investing in volunteers was essential to maintain and expanding the educated volunteer base for the stormwater wetland program. Workdays were held regularly on Thursdays throughout the project period where AgriLife staff worked with volunteers to complete a variety of tasks at the established wetland plant nurseries at EG and GCBO including weeding existing potted plants, splitting and re-potting plants that had outgrown their containers, and preparing for planting events. In addition, volunteers collected new plant material from local sites, removed invasive species and litter from completed projects, and served as mentors for youth and one-time volunteers at larger planting days. A majority of the regular stormwater wetland team volunteers are certified Texas Master Naturalists; therefore AgriLife staff gave presentations about ongoing projects at chapter meetings and training classes to foster the partnership with these groups.

Results and Observations

This project furthered the understanding of the vegetative progress of restored freshwater wetlands in Texas. Studying the different project phases at SLSP allowed a snapshot in time for each restoration stage. During the same growing season, data collected across the phases represents a time span of 14 years (Phase 1 was planted in 2005 and Phase 5 in 2019) giving a unique perspective of the progression of restoration and insight into changes in freshwater wetland plant communities over time.

This project also served to expand the use of stormwater wetlands as a best management practice in the Lower Galveston Bay watershed. Five partnerships were formed or continued during the course of this project, and new audiences reached. Two stormwater wetland projects were designed but not completed due to changes in leadership and priorities in the partner communities. Volunteers were engaged throughout the course of the project, providing a valuable labor force to maintain wetland plant nursery stock as well as plant the constructed wetlands.

TASK 1: PROJECT ADMINISTRATION

Objective: To effectively administer, coordinate, and monitor all work performed under this Contract including technical and financial supervision and preparation of status reports.

Output:

- Project Work;
- QPRs;
- Reimbursement forms;
- Contract communication meeting minutes; and
- Project Article

Outcome: Project completed on time and on budget, and all deliverables were accomplished with benefits to many communities and stakeholders in the Lower Galveston Bay watershed.

TASK 2: QUALITY ASSURANCE

Objective: To refine, document, and implement data quality objectives and Quality Assurance/Quality Control (QA/QC) activities that ensure data of known and acceptable quality are generated by this project.

Output:

- Draft and Final Approved QAPP
- QAPP Annual updates
- QAPP amendments
- QAPP con-conformances reports

Outcome: A comprehensive quality assurance plan was developed and executed for wetland vegetation data collection and analysis at the SLSP project site.

Task 3. Proposed monitoring regime for Sheldon Lake State Park freshwater wetland restoration sites

Objective: To collect vegetation cover data from designated areas within restoration sites and a control area (no construction) to evaluate the success of plant establishment.

Output:

- Monitoring protocol
- Comparative study report
- Collected data

Outcome: Vegetative monitoring was completed for state fiscal quarters 3 and 4 during FY2019 and quarter 1 of FY2020. Results are provided in the Comparative study provided in Appendix 1.

Task 4. Stormwater wetland demonstration and project development

Objective: Development and implementation of stormwater wetland projects in the GIFT program area.

Outputs:

- Project Partner MOUs, Engineering, Design and Site Documents
- Outreach materials
- Wetland plant nursery propagule counts

Outcome: AgriLife staff worked with partners to develop stormwater wetland projects within the 5-county GIFT program area in both new and retrofitted detention basins, community parks, and local governmentally owned property. Table 1 overviews the five projects that were developed during the grant period, including the current project status. Copies of the Memorandums of Understanding developed with project partners are included in Appendix 2.

Figure *1*. Newly excavated stormwater wetland ponds at Houston Botanic Garden, November 2019.

Table 1. GIFT Stormwater Wetland Projects, Partners, and Current Project status

Project Name	Partner Organization	Current Status
Exploration Green Phase 1	Clear Lake City Water Authority and Exploration Green Conservancy	Completed
Exploration Green Phase 2	Clear Lake City Water Authority and Exploration Green Conservancy	Excavation Complete Repairs to Sand Pockets to be complete early 2020 Planting to begin late Feb. 2020
Exploration Green Phase 3	Clear Lake City Water Authority and Exploration Green Conservancy	Excavation 18% complete Planting to begin Fall 2020
Brazosport College	Brazosport College	Partnership ended by new leadership at Brazosport College
Alvin Kost Pond	City of Alvin	Partnership/ Project cancelled by new leadership at City of Alvin
Houston Botanic Garden	Houston Botanic Garden	Excavation Complete Waiting on installation of Outfall Structures and final grading Planting Estimated to start in March 2020
MD Anderson Houston Campus	MD Anderson	Proton Therapy Wetland Completed planting in June 2019 Ongoing photo monitoring

Education and outreach is an essential effort to adoption of new practices such as stormwater wetlands. For this project, outreach focus areas were volunteer workdays, email newsletters, presentations, publications, and consultations with interested entities or landowners.

Volunteer workdays were held on a weekly basis, with additional dates added during times of intense planting, such as the spring of 2018 for Exploration Green Phase 1. Over the course of the project 84 workdays were held, engaging 672 volunteers, who provided 2,326 hours of service.

Figure 2 Volunteers planting at Exploration Green, June 2018.

A **weekly email newsletter** was sent throughout the course of the project, with few exceptions. This regular contact is integral to keeping volunteers engaged and informed. Not only does it convey information about upcoming workdays, but it also includes project updates so a volunteer can stay up engaged and be more likely to return. The number of subscribers grew from 165 to 199 over the course of the contract period. These weekly email newsletters will continue after the close of this project. Links to archived newsletters are in Appendix 3.

Presentations and publications were conducted and produced as needed throughout the project. Ten presentations (including wetland tours) were given over the course of the project and three publications (volunteer flyer, GIFT informational postcard, and a press release) produced. Copies of the press releases are included in Appendix 4.

The final piece of the contract is wetland **plant propagation**. The vegetation component of stormwater wetlands is often a barrier for success. There are only two for profit companies in the Houston area that source and install native wetland plants. Though this contract, AgriLife staff along with volunteers worked to increase stocks of plant species particularly appropriate for regional stormwater wetlands, producing quantities needed for large-scale planting at stormwater wetland projects. Current plant inventories for both the Exploration Green and Gulf Coast Bird Observatory nurseries are include in Appendix 5.

Discussion and Summary

Through this project, AgriLife staff were able to move the needle on GI projects in the Lower Galveston Bay Watershed. Important vegetation data for the SLSP wetland project is now available in a report to share with other agencies and entities that are restoring wetlands and measuring the success of those projects. This data has also allowed AgriLife staff to assess the current status of the SLSP project. Our data shows that older wetland ponds are as expected, further along the vegetation successional gradient for a maturing wetland, however these ponds do not show an overwhelming higher species diversity. The close proximity of all five restoration phases may be contributing to younger ponds recruiting new species at a faster rate, thereby helping them to mature faster. Overall, data collected through this contract, combined with previously collected data suggest the SLSP restoration is on a successful trajectory. The SLSP restoration model can be used as benchmark for similar projects in the Lower Galveston Bay Watershed.

Stormwater wetlands are gaining traction as a best management practice in the Lower Galveston Bay watershed and throughout Texas. Projects like this one that build partnerships and create on the ground demonstrations of this technology are essential to the continued adoption of these practices. The success of Exploration Green Phase 1 was seen during Hurricane Harvey when despite unprecedented rainfall, homes that had previously flooded multiple times in smaller rainfall events did not flood during Harvey. More and more entities are seeing stormwater wetlands as a flood mitigation practice and water quality benefit. This combination, as well as the aesthetic and recreation value of these projects, create a unique and attractive stormwater management practice. This contract has allowed AgriLife to increase the knowledge base, establish new partnerships, and empower more entities to begin using stormwater wetlands in their communities.

Next steps

A new ecological restoration project has begun at the Anahuac National Wildlife Refuge. Moving on from SLSP has been an important next step to engage additional partners and further the reach of GIFT. Additional restoration sites and partners will be pursued. In addition, additional data on the SLSP project should be collected to strengthen the long-term data set and to follow the succession of wetland vegetation over time. This information will continue to inform restoration protocols at other sites.

Immediate next steps for stormwater wetlands include planting the project sites at Exploration Green Phases 2 & 3 and Houston Botanic Garden. In addition, water quality sampling (funded by a Texas General Land Office Coastal Management Program grant) will continue at MD Anderson and Exploration Green Phase 1 during 2020. Extension staff will continue to engage new project partners and seek additional on the ground projects. Extension staff are also looking to fund a how-to guide for stormwater wetlands with specific recommendations for the various regions of Texas. Resources such as this would go far in empowering additional entities to embrace this GI practice.

Finally, for both programs, a wetland plant nursery how-to guide that includes pond design and maintenance, vegetation growing information, and best practices would be beneficial for other groups who want to cultivate wetland plants for their projects.

APPENDICES

Appendix 1 – Sheldon Lake State Park Freshwater Wetland Vegetation Monitoring Comparative Study. (Task 3.3)

Monitoring Vegetation Indicators to Assess the Success of Wetland Restoration

Colleen Ulibarri, Rosemary Kline, Andy Rydzak, Paul Roling,

Marissa Llosa, Christie Taylor, and Charriss York

ABSTRACT

Wetland restoration varies greatly with no single method working seamlessly across geographic locations or even different types of wetlands. Thus, measuring the progress of restoration toward an anticipated state is also difficult as outcomes are more like moving targets on a continuum. Given the wide range of approaches to restoring this ecotype and site-specific influences such as a climate, hydrology, previous land-use, or elapsed time since restoration, land managers are challenged to interpret the changes observed and discern if they on the right trajectory. This study aids to advance the knowledge base for freshwater wetland restoration by (1) developing a method to monitor the condition of a wetland; and (2) analyzing responses of the plant community to the age and success of restoration. In this study, percent cover was monitored as an indicator for species distribution, abundance and diversity in restored wetlands of varying ages in Sheldon Lake State Park from 2013 to 2019. Based on high relative richness and even distribution of species throughout the monitoring period, it was concluded that the restoration is on a manageable and expected successional trajectory. Species constancy and abundance showed the wetland was shifting in composition and abundance as expected, with new species appearing confirming that natural colonization was taking place. The study also found that the age of restoration between the Phases had less than the expected influence on species richness. The data presented will better inform management of ongoing and future wetland restorations.

INTRODUCTION

Freshwater wetlands are highly productive and ecologically valuable ecosystems that are being degraded at alarming rates due to human disturbance and changing climate. Ecological restoration is a method to increase the number of quality aces of this unique system on the landscape. Wetlands provide a disproportionately high number of ecosystem services compared to their surface area because they are transition zones – encompassing characteristics from both upland terrestrial and aquatic environments. Therefore, high species richness and diversity can be used as a goal for restoration projects.

Restoration can be thought of as assisted changes in a plant community toward a desired successional state (Luken 1990, Young et al. 2001). Progress toward the target ecosystem has been used to measure the success of restoration efforts (Holl 2002, McLachlan & Bazely 2003). Therefore, routine monitoring of a wetland's condition is critical to understanding the trajectory of succession and thus the progress of restoration. Given the high diversity of natural wetlands, we monitored species distribution, abundance and richness of wetland vegetation as a proxy to assess the condition of a restored wetland complex and the success of the restoration methods.

Restoration managers are interested in observed changes after restoration and how quickly they occur (Newbold et al. 2019). This study looks at the changes observed in vegetation due to seasonality and the age of restoration, or unattributed variability due to the stochastic nature of succession. Also, the monitoring protocol developed can be used as a template and offer lessons learned to improve future restoration monitoring regimes.

Site Description

The study site is 410 acres of restored freshwater wetland and coastal prairie located within Sheldon Lake State Park in Houston, Texas. Historically, the area was a complex of native prairie-pothole wetlands that were drained and leveled for farming St. Augustine grass (*Stenotaphrum secundatum*) and Bermudagrass (*Cynodon dactylon*) among others through time. The area was acquired by Texas Parks and Wildlife in 1952, becoming a public state park in 1984. Restoration of the tall grass prairie and freshwater wetlands began in 2003. The historic location of the prairie-pothole wetlands was identified by reading soil signatures on 1930's aerial photography. Basins were then excavated where hydric soils were confirmed by sampling soil cores. Restoration occurred in five phases over 16 years in different parts of the park. Thus, active restoration (i.e. planting) was completed at different times for each Phase (Table 1).

METHODS

Seasonal vegetation monitoring was conducted between 2013 and 2019 to assess changes in plant species distribution, abundance and diversity. Phases 2 and 3 were monitored annually in the Spring between 2013 and 2019 (Table 2). Phases 1, 4, and 5 were monitored seasonally from Winter 2018 to Fall 2019 (Table 2).

Study Design

One pond was selected from each of the five phases for monitoring based on its size and depth. Only those ponds with water depths exceeding 12 inches were selected. A map of the selected ponds is provided in Appendix A. A stratified random design was used to select meter-square plots within ponds for monitoring. Approximately eight plots per acre per depth were selected (Table 1). The sample density was derived by analyzing preliminary data from Phase 1 in 2003 to determine variance and the necessary number of samples to detect significant changes with an error rate of 30%. This method was then applied to the remaining phases.

ArcGIS 9.2 was used to overlay a 1x1 m^2 grid on aerial images of each pond using its surveyed boundary when water level was at its fullest extent. Plots were assigned *xy* coordinates, stratified by water depth and then randomly selected.

Table 1. The five phases of wetland restoration at Sheldon Lake State Park in Houston, Texas. Pond No. is the pond within each phase that was selected for monitoring with associated number of plots as determined by sample density of 8 per acre. Restoration completed is the year that active planting concluded for that Phase.

	Pond No.	Size (acres)	No. of Plots Monitored	Restoration Completed
Phase 1	2	3.1	24	2005
Phase 2	11	7.3	58	2011
Phase 3	17	12.4	98	2013
Phase 4	24	3.4	29	2016
Phase 5	2	6.1	50	2019

The depth zones were determined assuming maximum water level for each pond. This assumption was also used when determining the planting location for each species during active restoration. Phase 2 had three depth zones (0-6”, 6-12”, >12”), all other Phases had four zones (0-4”, 4-8”, 8-12”, >12”).

Data Collection

Within each 1x1m^2 plot, individual species were identified and assigned one of six cover classes (0 – 4%, 5 – 29%, 30 – 69%, 70 – 94%, 95 – 99%, and 100%). Ocular estimation of percent cover is the most frequently used method for determining abundance due to its cost-effective, noninvasive, quick and efficient nature (McCune and Grace 2002). Staff were accompanied each time by the same experienced botanist for the life of the project to assist in plant identification. If a species was not identifiable in the field, it was recorded to the closest taxonomic rank known (e.g. Genus spp.) and confirmed upon return. Unidentifiable species were regarded as a unique individual and were labeled as “Unknown”.

Methods of data recording and navigation varied from 2013-2015 to 2015-2019. Between 2013-2015 data were recorded on paper sheets and plots were navigated to using a Garmin eTrex Venture HC GPS. After 2015, the team navigated with and recorded all percent cover data directly into a Trimble Geo5T Handheld with a navigational accuracy of ±3 inches. Percent cover data recorded between 2015-2019 was therefore georeferenced.

Data Analysis

For the purpose of this study, two temporally different data sets were used: Dataset A, collected seasonally between 2018-2019 for Phases 1 – 5; Dataset B, collected in the Spring of 2013-2019 for Phases 2 and 3 (Table 2). Seasonal data reflects the four seasons (winter, spring, summer and fall) within a three-month window (e.g. Winter monitoring was conducted between December and February).

Table 2. The two subsets of data analyzed including phases monitored, data collection periods, and annual frequency of monitoring events.

	Phase	Collection Period	Collection Frequency

Dataset A	1,2,3,4,5	2018-2019	4 – winter, spring, summer, fall
Dataset B	2,3	2013-2019	1 - spring

Species Constancy

Constancy can be used an indicator to assess species distribution within a plant community (i.e. DeVelice et al. 1999, Johnson and Swanson 2005, Tart et al. 2005). It is a population attribute used to express an individual species' frequency. To account for varying sizes of ponds, constancy has been defined as the proportion of plots in a pond where a species was recorded (*p*) out of the total number of plots sampled in that pond (*n*).

$$C_{species} = \frac{p_{occupied}}{n_{total}} * 100$$

Constancy was calculated for each pond in Dataset A and then change was graphed over seasons. Ten species were selected from each pond as a subset of the total amount analyzed. The species selected were among the highest occurring within a one-year period. A comprehensive list of species detected within the wetland complex between 2018 and 2019 is provided (Appendix B).

Species Abundance

Species percent cover was used as an indicator for abundance in the population (Tart et al. 2005). Given that individual species were assigned to a cover class (i.e. range of percentages) and not an actual estimated percent, weighted averages were calculated to account for greater contribution of higher cover classes to total cover. The same subset of species from the constancy analysis was used. Seasonal change was analyzed in average cover by species for each pond in Dataset A.

Table 3. Weighted factors used to calculate average percent cover for top ten most frequent species in Dataset A, collected between 2018 and 2019.

Cover Class	% Cover Range	Weight
1	0% - 4%	0.04
2	5% - 29%	0.29
3	30% - 69%	0.69
4	70% - 94%	0.94
5	95% - 99%	0.99
6	100%	1.00

For Dataset B, species presence and percent cover were analyzed from the Spring of 2013, 2014, 2015, and 2019. A representative plot from each pond and from each depth zone was chosen (e.g. three plots from Phase 2, and four plots from Phase 3). Within each plot, the six most consistently occurring species throughout the years were selected to analyze.

Species Richness

Richness is the number of individual species in an area of interest. The statistic is fundamental to measuring diversity of a population (Schulz et al. 2009). Richness was calculated for Dataset A (2018-2019) at two different spatial scales: alpha (α) and gamma (γ).

Alpha richness was calculated as the total species encountered within a season within a pond (α_{Season}); and separately calculated as the sum of species observed at the pond level within 2018-2019 (α_{Pond}). Gamma richness (γ_{Complex}) is the sum of all individual species detected between 2018 to 2019 across all the ponds – the complex as a whole.

$$\alpha_{\text{Season}} = Total\ species\ recorded\ in\ plots\ in\ a\ single\ season\ within\ a\ pond$$

$$\alpha_{\text{Pond}} = Total\ species\ recorded\ within\ a\ pond\ between\ 2018 - 2019$$

$$\gamma_{\text{Complex}} = All\ species\ recorded\ within\ monitored\ ponds\ between\ 2018 - 2019$$

RESULTS

Dataset A: Phases 1 - 5, 2018-2019

Species constancy and abundance by pond

For Phase 1 Pond 2, species constancy was relatively consistent between the seasons with little variability of presence (Figure 1A). *Panicum hemitomon, Eleocharis quadrangulata, Pontedaria cordata,* and *Leersia hexandra* were the most frequently occurring species within the pond between 2018 and 2019 (Figure 1A). However, this trend was not true for each species' abundance in the plots (Figure 1B). *P. hemitomon* and *P. cordata* (peaking at 7.5% and 4.8% respectively) had the highest average percent cover, while *E. quadrangulata* and *L. hexandra* had proportionally lower abundance (peaking at 2.3% and 3.2% respectively) compared to their constancy (70% and 50% respectively).

In Phase 2 Pond 11, *E. quadrangulata, Cyperus virens, Juncus acuminatus, Azolla caroliniana,* and *Utricularia gibba* were the most frequently encountered species across the seasons (Figure 2A). The other five species had lower constancies that were similar to one another (ranging from 15-35%; Figure 2A). *E. quadrangulata* had the highest abundance of any species (17% of total cover) within the monitoring plots (*n* = 58) during Summer 2019 (Figure 2B). *A. caroliniana* and *Lemna aequinoctialis* accounted for the lowest amount of coverage of the ten species. *U. gibba* spiked in abundance during Summer 2019 with 9% total cover within the plots.

Within Phase 3 Pond 17, a majority of the ten species selected had similar constancy, averaging between 35% and 45% (Figure 3A). *Alternanthera philoxeroides* was the most constant species across the seasons while *C. virens* had the highest constancy in a single season (70% of the plots in Summer 2019; Figure 3A). *E. quadrangualata* was consistently present in 40-45% of monitoring plots; however, when abundance was accounted for, the species had the highest contribution to total cover compared to any other species in the pond (15% average cover in plots in Summer 2019; Figure 3AB). *Andropogon glomeratus* contributed the least to overall pond cover.

Constancy varied between the two most frequent species and the other eight in Phase 4 Pond 24. *P. cordata* and *Sagittaria platyphylla* occupied the highest proportion of the 29 monitoring plots (peaking at 69%, 69%, respectively; Figure 4A). The other species were present in relatively low proportions, not exceeding 34% but majority not more than 20% constancy (Figure 4A). The species abundance for the pond followed a similar trend, with the four most frequent species accounting for the majority of vegetation cover within plots and relative to other species (with the exception of open water and thatch). No single species provided more than 7% of total cover within the monitoring plots (Figure 4B).

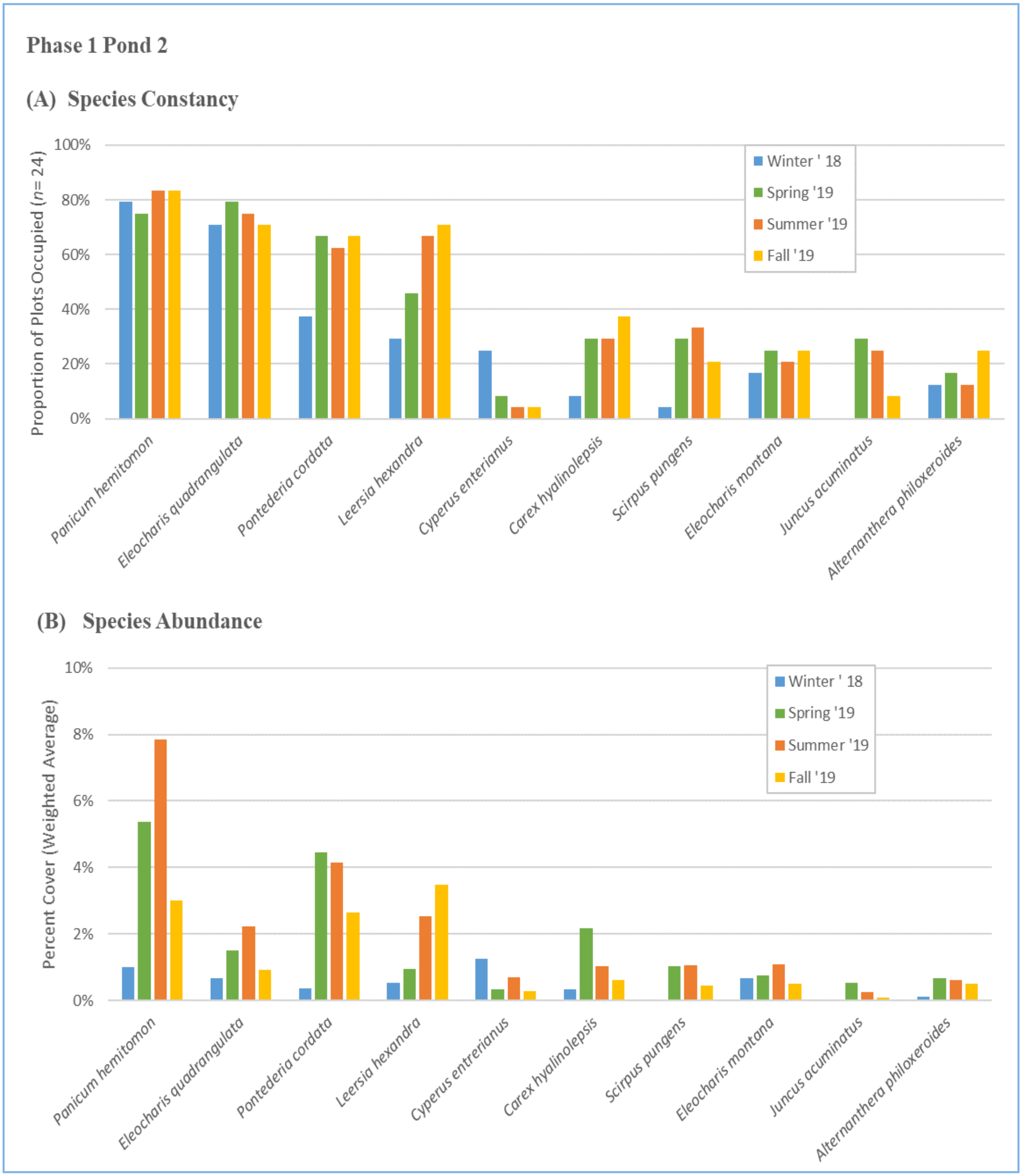


Figure 1 – Phase 1, Pond 2 –Species constancy and abundance shown for a subset of species that were among the top ten most frequent across the seasons. (A) Species constancy is the proportion of plots where a species was recorded. (B) A weighted average percent cover calculated an indicator for species abundance.

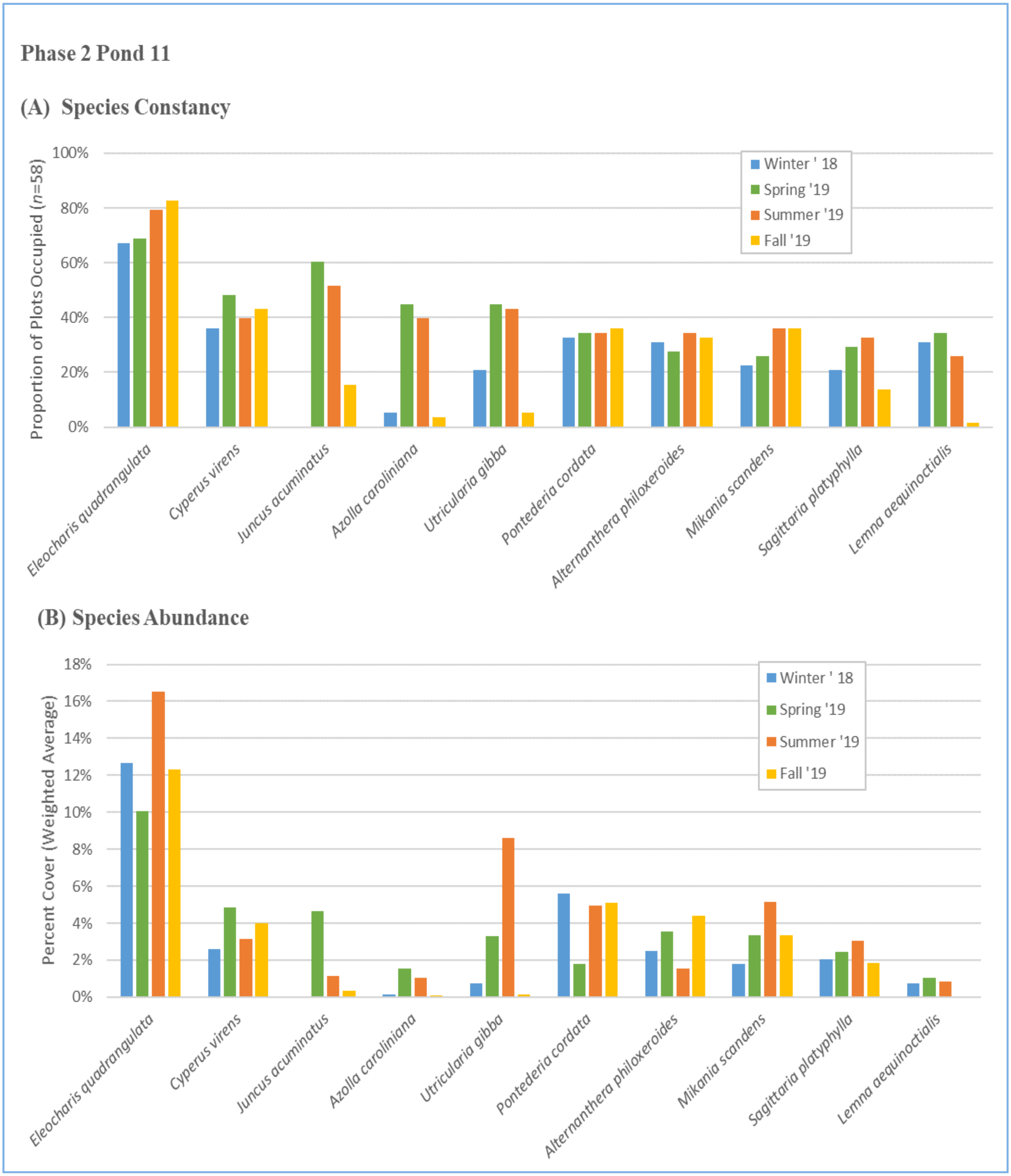


Figure 2 – Phase 2, Pond 11 – Species constancy and abundance shown for a subset of species that were among the top ten most frequent across the seasons. (A) Species constancy is the proportion of plots where a species was recorded. (B) A weighted average percent cover calculated an indicator for species abundance.

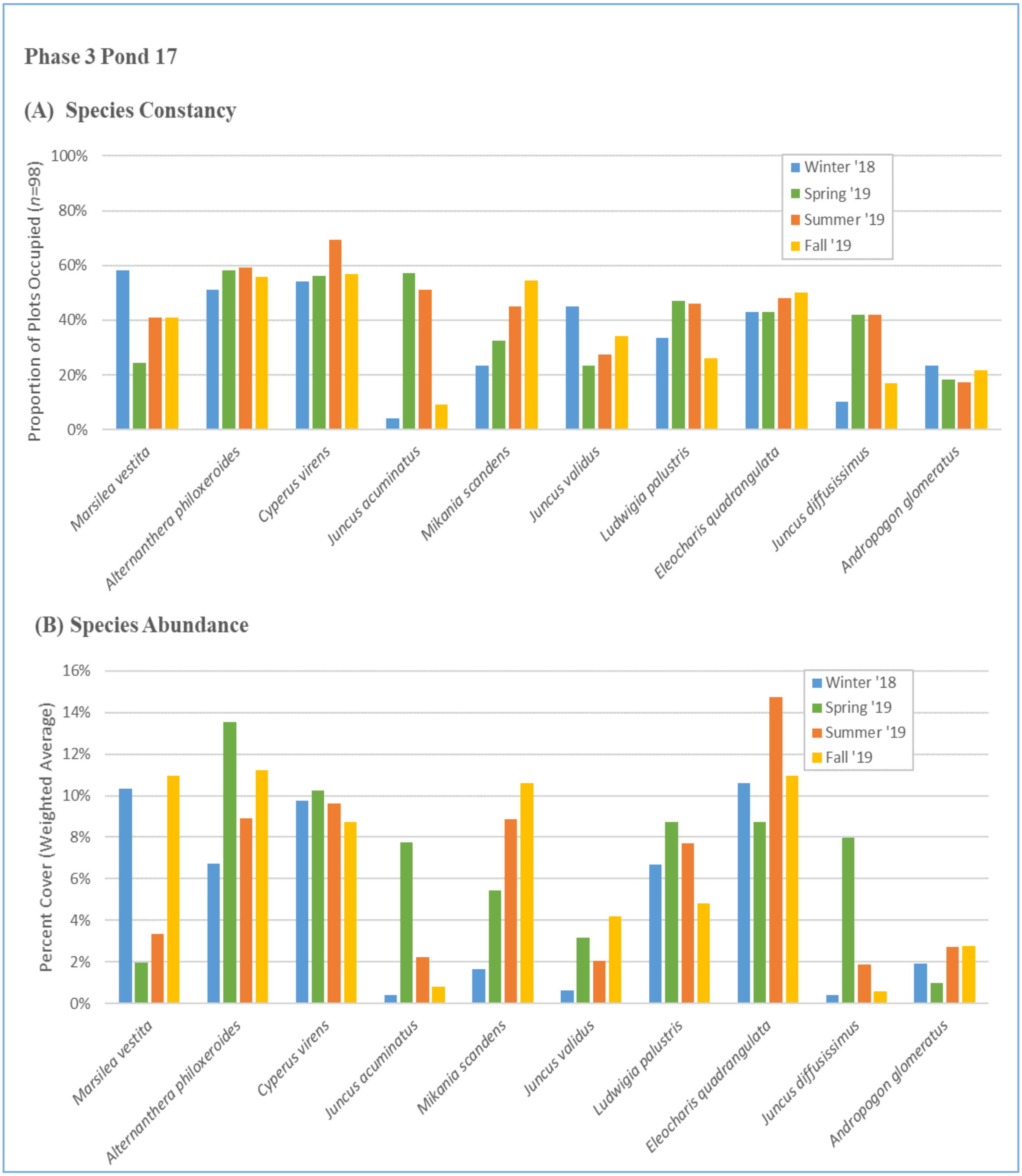


Figure 3 – Phase 3, Pond 17 – Species constancy and abundance shown for a subset of species that were among the top ten most frequent across the seasons. (A) Species constancy is the proportion of plots where a species was recorded. (B) A weighted average percent cover calculated an indicator for species abundance

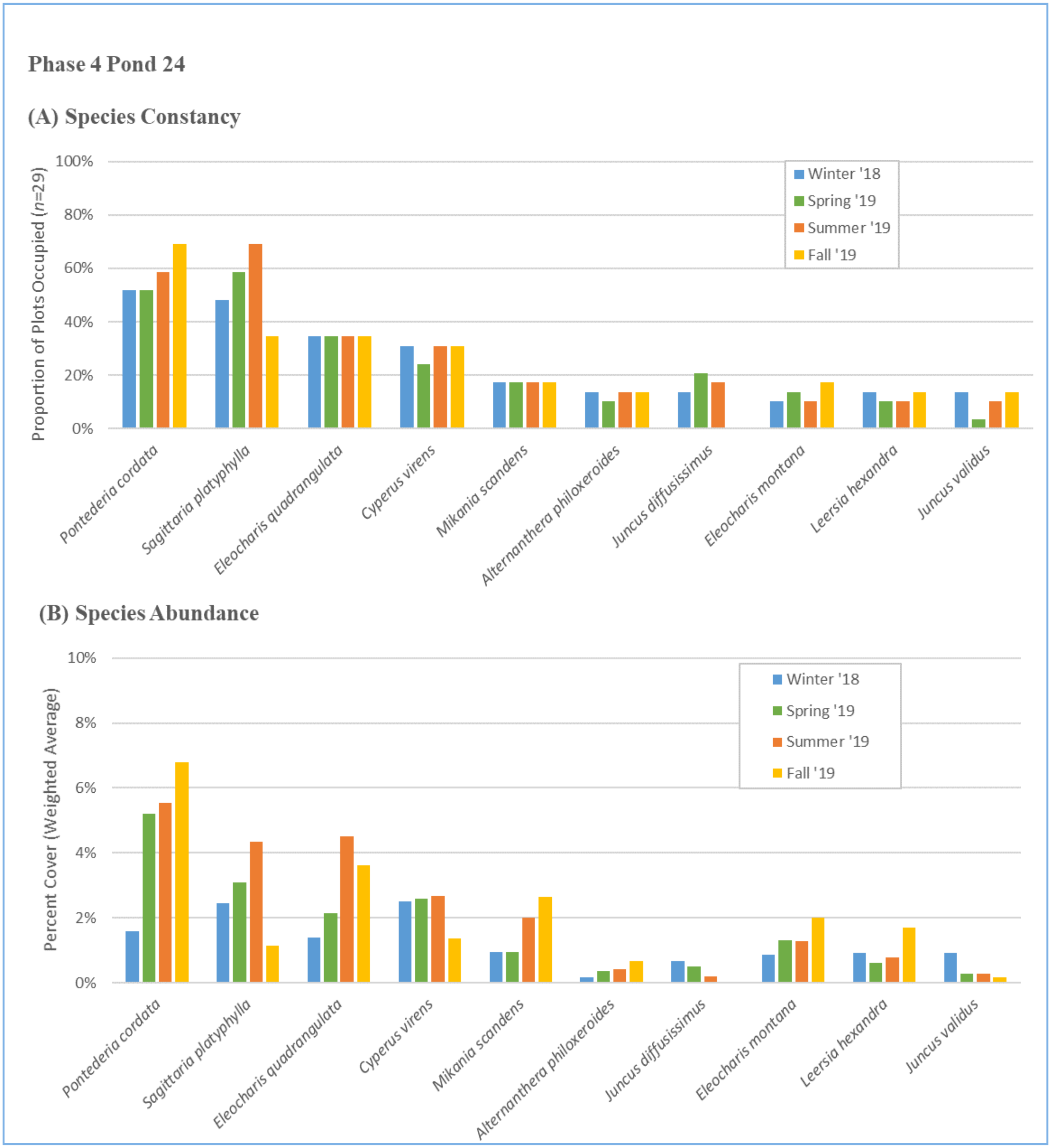


Figure 4 – Phase 4, Pond 24 – Species constancy and abundance shown for a subset of species that were among the top ten most frequent across the seasons. (A) Species constancy is the proportion of plots where a species was recorded. (B) A weighted average percent cover calculated an indicator for species abundance

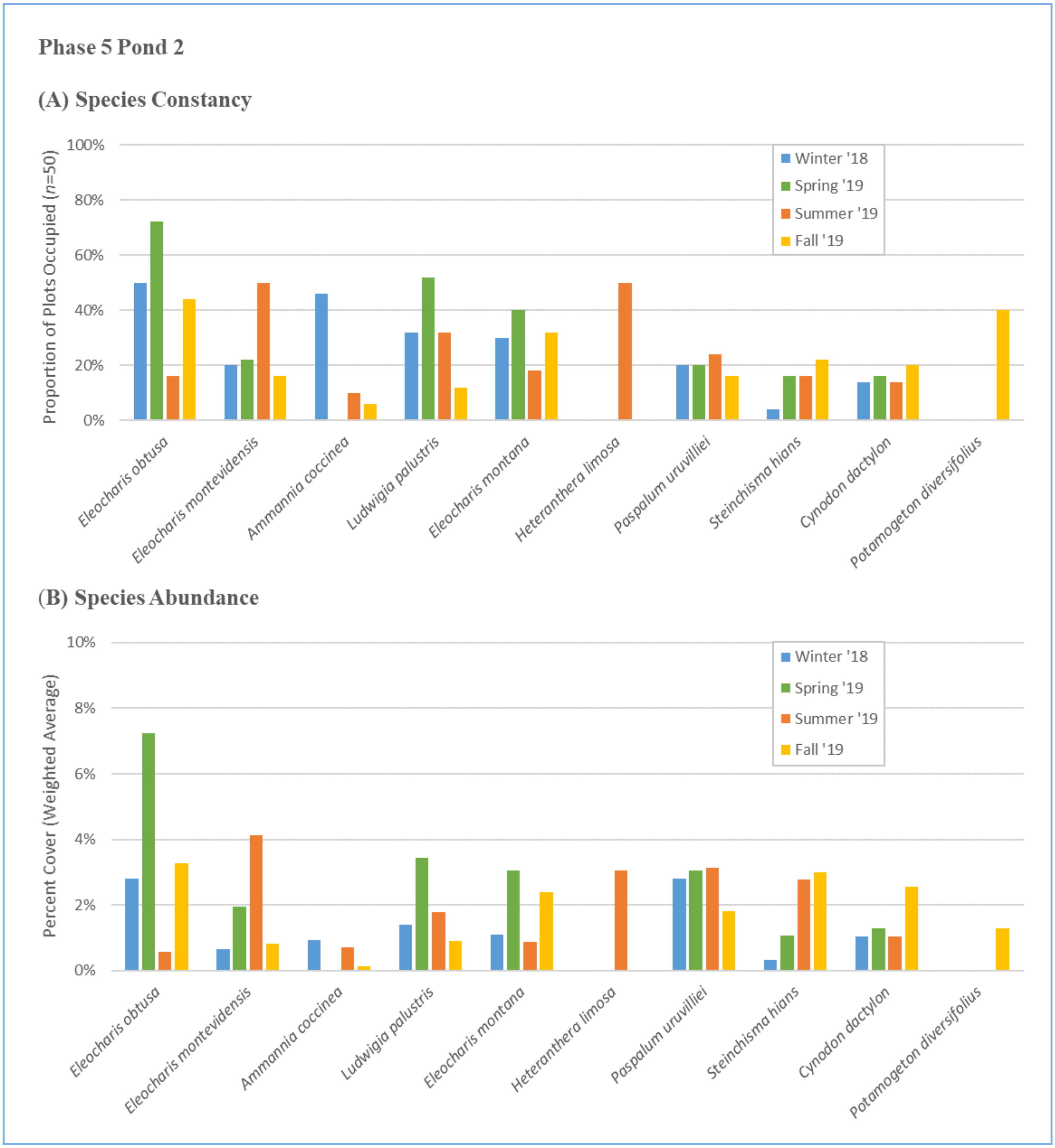


Figure 5 – Phase 5, Pond 2 – Species constancy and abundance shown for a subset of species that were among the top ten most frequent across the seasons. (A) Species constancy is the proportion of plots where a species was recorded. (B) A weighted average percent cover calculated an indicator for species abundance

Phase 5 Pond 2 had the highest number of inconsistencies in species present across the seasons in comparison to the other ponds. For example, *Ammania coccinea* was detected in plots during the Winter, Summer and Fall but absent in the Spring; *Heteranthera limosa* and *Potomogeton diversifolius* were only present in a single season (Figure 5). There is also high seasonal variability for individual species' constancy and abundance. To demonstrate, the constancy of *Eleocharis obtusa* ranged seasonally between 16% and 72% (Figure 5A). The seasonal abundance of *E. obtusa* varied from 0.5% to 7.2% (Figure 5B), a greater differential than any other species detected.

Species richness within ponds and across wetland complex

Species richness, or the number of individual species detected within a pond between 2018 and 2019 ranged from 44 species in Phase 4 to 112 species in Phase 3 (Table 4). Variation in pond richness between the seasons was relatively low: Phase 1 had the highest differential throughout the year (20 from Winter 2018 to Fall 2019) and Phase 2 had the lowest differential of 7 species. Total species richness across all ponds for the entire monitoring period was 174 unique species ($\gamma_{Complex}$; Table 4).

Table 4 – Species richness by season (α_{Season}) for each pond with associated number of monitoring plots (*n*); total species richness for each pond during Winter 2018 to Fall 2019 (α_{Pond}). Species richness ($\gamma_{Complex}$), or any species recorded in any pond making up the complex between Winter 2018 to Fall 2019.

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
n	24	58	98	29	50
α_{Winter}	31	52	67	21	24
α_{Spring}	40	59	72	25	34
α_{Summer}	49	59	63	30	42
α_{Fall}	51	54	75	28	41
α_{Pond}	103	87	112	44	76
$\gamma_{Complex}$	174				
$\alpha_{Pond}/\gamma_{Complex}$	59%	50%	64%	25%	44%

Phase 3 had the highest richness of 112 species detected in plots within the year; however, it was the largest pond sampled. Phase 1 was second highest, but when tempered for its size (24 plots compared to 98 in Phase 3), the pond had the highest richness of all the Phases. The average number of species per plot in Phase 1 was 4.29 compared to 1.5, 1.14, 1.52, and 1.52 respectively for Phases 2 through 5.

There was not a very distinct difference in species richness of younger versus older Phases when looking at richness alone (Table 4). In analyzing the proportion of species detected within a pond, out of the total number of species in the complex ($\alpha_{Pond}/\gamma_{Complex}$), the older Phases 1, 2, and 3 had higher percentages (59%, 50% and 64%, respectively) than the younger Phases 4 and 5 (25% and 44% of all species detected).

Dataset B: Phases 2 & 3, 2013-2019

Species composition, abundance & richness within representative plots

Overall, species composition shifted in both ponds over the six-year period (Figures 6,7). The most dominant species observed within plots early on (i.e. 2013 and 2014) typically became less frequent in the later years, and species absent early on increased in frequency over time.

Phase 2

In the shallowest plot (depth 0” – 6”), *Ambrosia psilostachya*, *Iva annua,* and *C. virens* were present (0% – 4%) or covered up to 30% of the plot between 2013-2015, but were absent in 2019. *Limnosciadium pumilum* increased in abundance during 2013-2015 but was also not detected in 2019. *Ludwigia palustris* and *E. quadrangulata* were newly detected species within the plot in 2015 and 2019. *L. palustris* reached the highest cover class (94% - 99%) in 2015 of any species at any depth for the entire pond (Figure 6A). Richness was fairly consistent with little variation.

The species richness of the 6” to 12” deep plot increased annually over the monitoring period from six species observed to ten (Figure 6B). Generally, any species present in 2015 and 2019 occurred in higher abundance than in 2013 and 2014.

The species present in the deep-water plot (> 12”) had the lowest constancy from year to year compared to other plots (Figure 6C). The exception was *E. quadrangulata*, which occurred in four out of five years with varying abundance, while all other species were detected in a single year with relatively low abundance. The highest cover class for a single species within selected plots was 30% - 69% for the monitoring period.

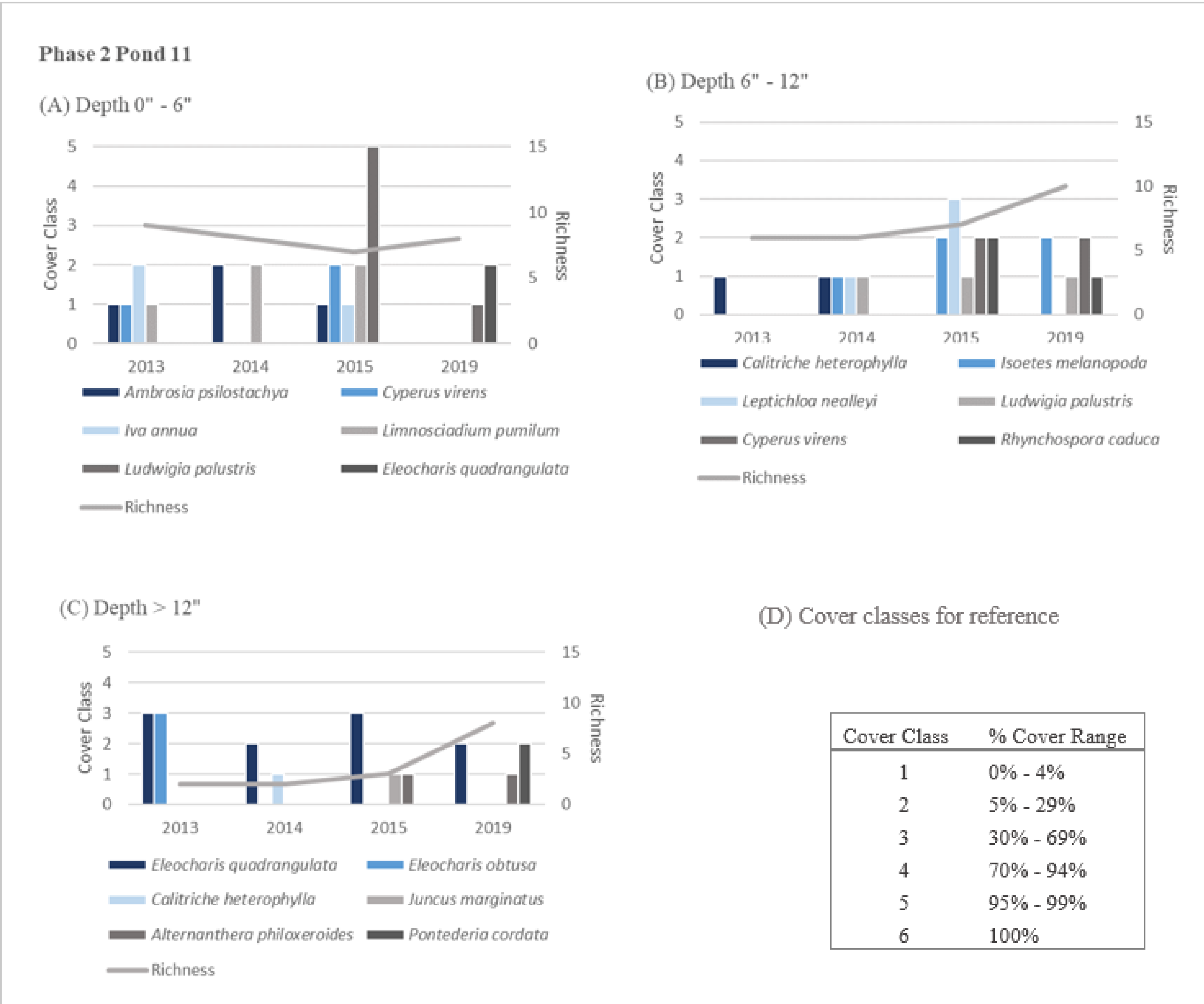
Phase 3

Within the shallowest plot selected for Phase 3, four out of the six selected species were first detected in 2015 and 2019. *L. pumilum* and *Anagallis minima* were the only two recurring species between 2013 and 2015 (Figure 7A)

At the next depth zone of 4” to 8”, species provided fairly consistent coverage during the monitoring period, but richness spiked in 2014 (Figure 7B). *C. virens* was detected in 2013 and then not again until 2019. *L. pumilum* was present in the plot every year, with peak abundance in 2014 at 5% to 29% coverage. Species richness spiked in the plot in 2014 (15 species) but was consistent at 6 species in the other years.

For the plot representative of depth zone 8” to 12”, the highly invasive alligatorweed, *Alternanthera philoxeroides* was present between 2013 to 2015 (Figure 7C). It was not detected in 2019, however another aggressive-growing species broadleaf cattail, *Typha latifolia,* was. Species richness gradually declined over the period.

Within the deepest plot, species that were present in 2013 and 2014 were absent in later years (Figure 7D). Conversely, species detected in 2015 and 2019 were absent from the earlier two years. Richness remained consistent, dropping to its lowest (3 species detected; Figure 7D) in 2019



Cover Class	% Cover Range
1	0% - 4%
2	5% - 29%
3	30% - 69%
4	70% - 94%
5	95% - 99%
6	100%

Figure 6 – Phase 2, Pond 11 – Change in percent cover class by species over monitoring period (annually in the spring, 2013 - 2019). (A-C) are single plots selected to represent each of the three depths zones in Phase 2. Percent cover is represented by cover class and as defined in (D). Species richness is the third axis defined as total number of species detected in the representative plot.

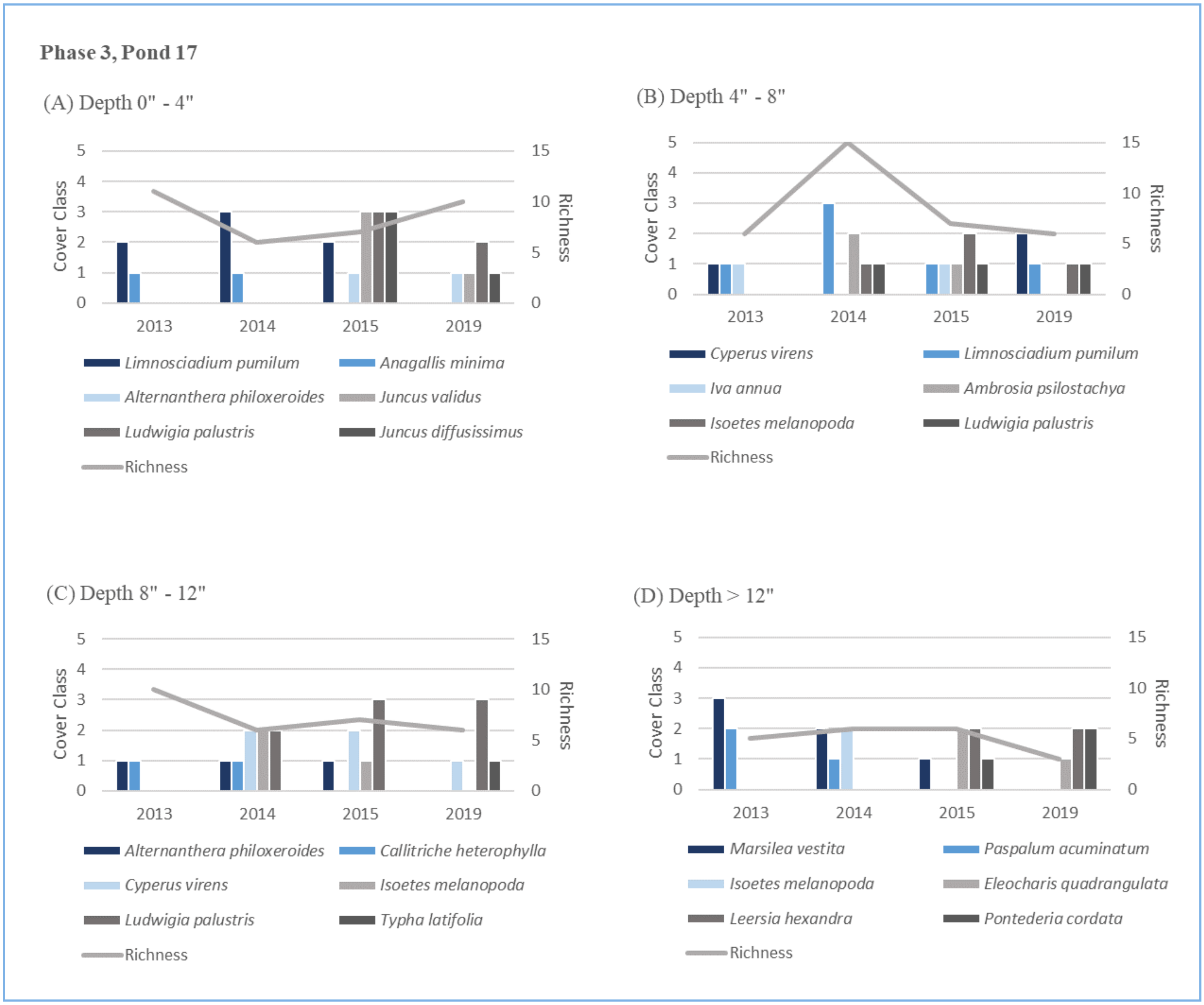


Figure 7 – Phase 3, Pond 17 – Change in percent cover class by species over monitoring period (annually in the Spring, 2013 - 2019). (A-D) are single plots selected to represent each of the four depths zones in Phase 3. Percent cover is represented by cover class and as defined in (Figure 6D). Species richness is the third axis defined as total number of species detected in the representative plot.

DISCUSSION

A vegetation monitoring protocol was developed to understand how the condition of a restored freshwater wetland changes through time. This study measured percent cover as an indicator for species distribution, abundance, and diversity to track progress of the restoration. We interpreted the condition of the restored wetland using indicator attributes, and explore possible explanations for the variability seen in restored sites.

Constancy and Abundance

For Dataset A, constancy was a good indicator of species distribution throughout the monitoring plots, but could be misleading for a species' overall presence in the pond. When paired with species abundance, the weighted average for percent cover provided a more accurate interpretation of a species' ecological contribution to the pond. With the example of *E. quadrangulata* in Phase 1, the species appeared to be dominant based on its average constancy of 75% (Figure 1A) making it fairly prolific. However, its abundance did not exceed 2% average cover among all plots (Figure 1B). Therefore, the species' contribution to wildlife habitat or nitrogen fixation for example could be overstated if only the distribution variable (constancy) were considered. Restoration monitoring regimes should collect data that allows for analysis of species abundance to maximize the understanding of an individual species' impact in the ecosystem (Ehrlen & Morris 2015).

The data further suggest our restoration is on a successful trajectory as depicted by the constancy and abundance of Phase 3. This Phase, completed in 2013, had a very even species distribution with no single species dominating constancy within the plots (Figure 3A). The highest abundance also shifted among species from season to season making for diverse habitat throughout the year, but could also increase soil health because different microbes are associated with different plant species – thus the higher diversity of species leads to higher diversity of microbes performing various functions.

Species Richness

We used species richness as an indicator for population diversity to understand progress toward our restoration goal. The size of an area has been shown to have little relationship with species richness (Matthews & Endress 2010) which related to our results. We found that the size of the pond had no influence on the number of species observed when comparing richness of Phase 1 to the large Phase 3. (Table 4). Nor was there a distinct relationship of age of the restoration to species richness. This likely has to do with effects of colonization within the ponds. Phase 5, for instance, having been planted most recently had a higher richness than Phase 4, which was completed in 2016. Because a diverse array of species was planted, many of those were likely still present and detectable during monitoring. It is expected that not all species will survive as early colonizers move in and push certain species out thus lowering diversity – the effects of which may have begun to be apparent in Phase 4.

Influence of Age of Restoration

The variability in species composition, distribution and abundance over time can be attributed to numerous external factors such as the age of restoration of each pond (i.e. when the active planting ended). The rate of change observed in the plant community is higher in the earlier stages of succession than the later ones (Matthews and Endress 2010); therefore, higher rates of change in species composition, abundance and diversity would be expected in younger Phases. Our data demonstrated this in Phase 5 – the youngest pond completed in 2019. It had the fewest number of species consistently present in all four seasons (Figure 5A). Some species were only detected in a single season. Individual abundance of species also varied greatly between the seasons relative to other phases (Figure 5B) – consistent with the expectation that species composition and presence is highly unstable and variable in newly restored sites.

Site Context

Site context can play a large role in determining the rate of succession following restoration (Matthews and Endress 2010). Factors such as distance to propagule source can influence colonization and succession. It is possible that colonization rates in later Phases of the study were influenced by the earlier Phases having already been completed nearby.

Another factor to consider is viability of the seedbank that existed after basin excavation. Dataset B demonstrated that species composition consistently shifted over the six-year period. The plots showed that species present in the beginning of the monitoring period, reduced in abundance or disappeared completely by 2015 and 2019 (Figures 6,7). Many of the new species detected within plots over time were not actively planted during restoration. This likely means that the seed bank was still viable and natural colonization was expedited because of the re-excavation of basins to their original boundaries – reaffirming this as a successful restoration. Where possible, restoring wetlands should take place as close to their historic location as possible.

Lessons Learned

To improve the development of future monitoring protocols, this study's data suggests there should be a way to account for a species whose maximum cover is extremely small when estimating overall abundance within a plot. For example, constancy data from Phase 2 shows *A. caroliniana* and *L. aequinoctialis* among the top ten most frequently encountered species within plots between 2018 and 2019 (Figure 2A). These species are extremely small, floating aquatic plants no more than 6-10 mm long. The presence of a single individual therefore does not contribute much to the overall vegetative cover. The abundance data adequately reflected this; average percent cover in the 58 plots across the seasons did not exceed 2% (Figure 2B). However, the presence of these micro-species is a strong indicator of ecosystem maturity and stability; yet that is not apparent from abundance data alone. The life history of species needs to be adequately integrated with data analysis to properly interpret species' ecological contribution to the site.

Secondly, there is a potential conflict of multiple canopy layers that can convolute percent cover data interpretation. To illustrate, in Phase 2, *U. gibba* peaked in relatively high abundance (7% in Summer 2019; Figure 2B) compared to its constancy and to species with similar constancies (Figure 2). The species is a small floating plant often occurring in mats. During monitoring, it was observed beneath the water and often underneath the leaves of the other plants. Thus, total cover was often estimated greater than 100% because of the two tiers of canopies. Monitoring protocols for forests often include methods to account for multiple layers, and wetland monitoring can benefit from utilizing similar strategies despite having a low differential between canopy heights compared to forests.

Next Steps

Given the comprehensive analysis of species richness for the pond, this study would benefit from additional data collection and analysis to compute a species diversity index such as the Shannon-Weiner or Simson's Index. These indices account for evenness and abundance of a species in study area and would allow for an easy comparison between ponds and to data from other studies.

Additionally, grouping the recorded species by life history strategies (i.e. perennial forb, annual graminoid) would allow for deeper analysis of the shifts in species composition as related to restoration age. The increasing or decreasing of particular categories over time returns a more accurate interpretation of the successional state that the pond is in. Secondly, analyzing the abundance of each category would also provide more information about the quality of habit available for wildlife.

Lastly, continuing monitoring and expanding the regime to include all ponds over a greater period of time would yield more patterns and trends, furthering our understanding of the restoration's trajectory. This is especially important to curtail invasive species expansions and thus inform necessary management.

CONCLUSION

Restoration managers are tasked with returning an area to what it once looked like – often one of higher ecological productivity with vastly different plant species composition. More information is required to better understand the rates of change observed in a restored landscape and potential causes for the variation, recognizing that monitoring is a necessary part of restoration. This study contributed a monitoring protocol that can be used to track percent cover as an indicator for species distribution, abundance and richness. These proxies were used to assess diversity in the wetland to evaluate the progress of restoration. The results of the study demonstrated that constancy is a good indicator for distribution but should be analyzed with species abundance (e.g. percent cover) to fully understand a species' impact in the ecosystem. The data confirmed the commonly recognized trend that younger restored sites exhibit high rates of change in species turnover and abundance. Older ponds in the study, whose restoration had been completed between 2005 and 2011, did not have an overwhelmingly higher diversity (as recognized by species richness) compared to younger ponds, and exhibited lower species turnover as expected. Monitoring data ideally should be collected in a way to analyze both distribution and abundance, and should be interpreted with an understanding of species' life history and phenology to best understand their individual ecological importance to the wetland ecosystem.

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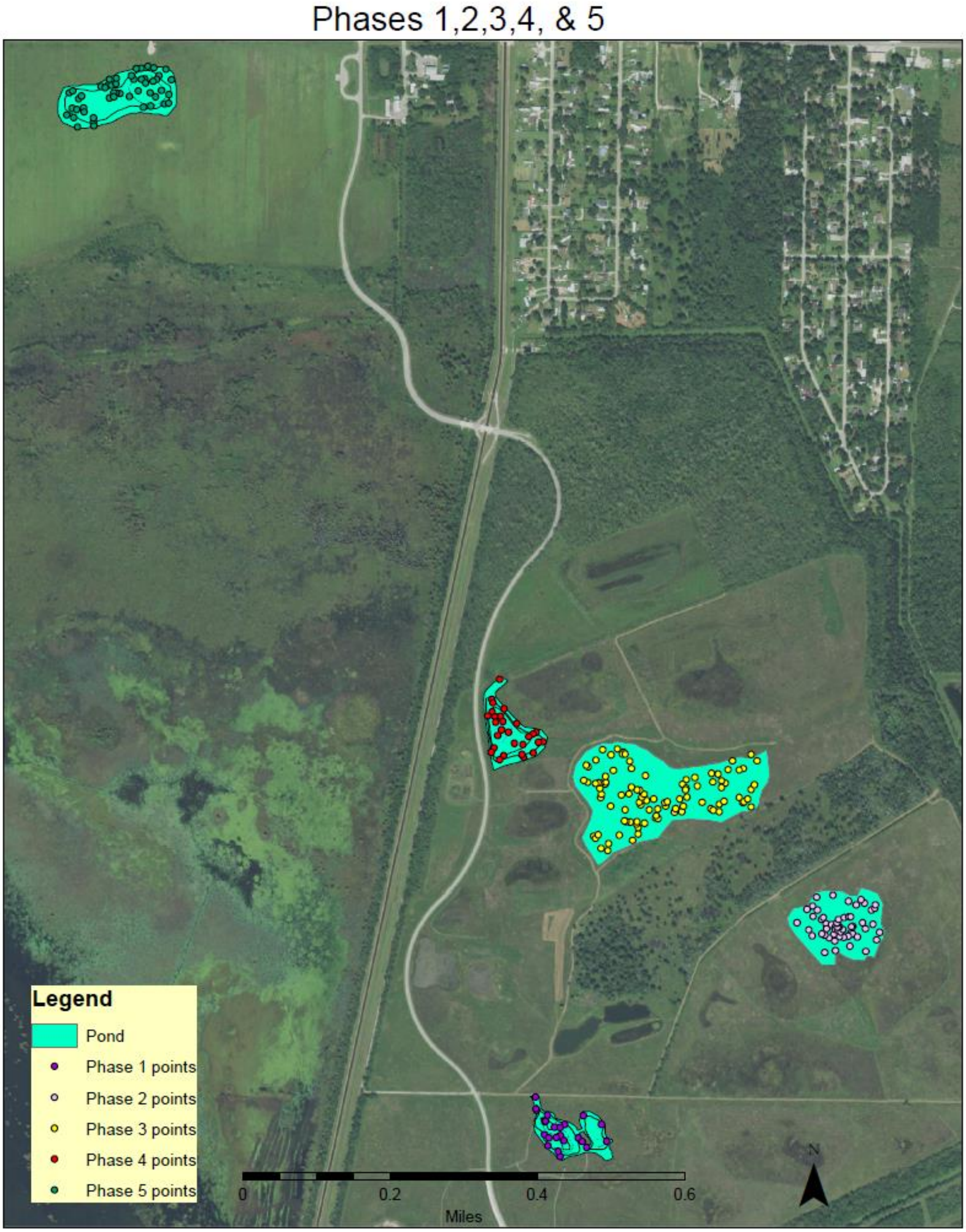
APPENDICIES

Appendix A – Map of wetland restoration Phases 1-5 at Sheldon Lake State Park, Houston, Texas. Only the ponds selected for monitoring are shown with sampling plot density.



Appendix B – Plant species encountered with common name recorded within a plot between Winter 2018 to Fall 2019 in monitored ponds in Sheldon Lake State Park, Houston, Texas.

Species	Common Name
Acer rubrum drummondii	Drummond's maple
Acmella oppositifolia	oppositeleaf spotflower
Agalinis heterophylla	prairie false foxglove
Algae	
Alopecurus carolinianus	Carolina foxtail
Alternanthera philoxeroides	alligatorweed
Ambrosia psilostachya	Cuman ragweed
Ammannia coccinea	valley redstem
Ampelopsis arborea	peppervine
Anagallis arvensis	scarlet pimpernel
Anagallis minima	chaffweed
Andropogon glomeratus	bushy bluestem
Andropogon virginicus	broomsedge bluestem
Aster subulatum	eastern annual saltmarsh aster
Azolla caroliniana	Carolina mosquitofern
Baccharis halimifolia	eastern baccharis
Bacopa monnieri	herb of grace
Bothriochloa ischaemum	yellow bluestem
Callitriche heterophylla	twoheaded water-starwort
Callitriche peploides	matted water-starwort
Canna glauca	maraca amarilla
Cardamine hirsuta	hairy bittercress
Carex hyalinolepis	shoreline sedge
Carex longii	Long's sedge
Carex triangularis	eastern fox sedge
Centella erecta	erect centella
Chara fibrosa	muskgrass
Chara zeylanica	muskgrass
Cladium jamaicense	Jamaica swamp sawgrass
Commelina caroliniana	Carolina dayflower
Commelina erecta	whitemouth dayflower
Crinum americanum	seven sisters
*Croton capitatus**	hogwort
Cyclospermum leptophyllum	marsh parsley
Cynodon dactylon	Bermudagrass
Cyperus acuminatus	tapertip flatsedge
Cyperus entrerianus	woodrush flatsedge
Cyperus esculentus	yellow nutsedge

Cyperus haspan	haspan flatsedge
Cyperus iria	ricefield flatsedge
Cyperus odoratus	fragrant flatsedge
Cyperus virens	green flatsedge
Diodia teres	poorjoe
Diodia virginiana	Virginia buttonweed
Diospyros virginiana	common persimmon
Echinochloa colona	jungle rice
Eclipta prostrata	false daisy
Elatine brachysperma	shortseed waterwort
Eleocharis montana	mountain spikerush
Eleocharis montevidensis	sand spikerush
Eleocharis obtusa	blunt spikerush
Eleocharis quadrangulata	squarestem spikerush
Eragrostis elliottii	field lovegrass
Eryngium hookeri	Hooker's eryngo
Eupatorium capillifolium	dogfennel
Eupatorium serotinum	lateflowering thoroughwort
Euthamia leptocephala	bushy goldentop
Fimbristylis annua	annual fimbry
Fimbristylis autumnalis	slender fimbry
Fimbristylis miliacea	fimbry
Galium tinctorium	stiff marsh bedstraw
Gratiola neglecta	clammy hedgehyssop
Gratiola virginiana	roundfruit hedgehyssop
Haplocladium microphyllum	bryohaplocladium moss
Helianthus angustifolius	swamp sunflower
Heteranthera limosa	blue mudplantain
Hibiscus moscheutos	crimsoneyed rosemallow
Hydrolea ovata	ovate false fiddleleaf
Hymenocallis liriosome	spring spiderlily
Ipomoea wrightii	Wright's morning-glory
Iris virginica var. shrevei	Shreve's iris
Isoetes melanopoda	blackfoot quillwort
Isolepis carinata	keeled bulrush
Iva angustifolia	narrowleaf marsh elder
Iva annua	annual marsh elder
Juncus acuminatus	tapertip rush
Juncus brachycarpus	whiteroot rush
Juncus diffusissimus	slimpod rush
Juncus effusus	common rush
Juncus marginatus	grassleaf rush
Juncus nodatus	stout rush

Juncus repens	lesser creeping rush
Juncus scirpoides	needlepod rush
Juncus tenuis	poverty rush
Juncus validus	roundhead rush
Krigia cespitosa	weedy dwarfdandelion
Landoltia punctata	dotted duckmeat
Leersia hexandra	southern cutgrass
Lemna aequinoctialis	lesser duckweed
Leptochloa fascicularis	bearded sprangletop
Leptochloa nealleyi	Nealley's sprangletop
Ligustrum sinense	Chinese privet
Limnosciadium pumilum	prairie dogshade
Lindernia dubia	yellowseed false pimpernel
Ludwigia decurrens	wingleaf primrose-willow
Ludwigia glandulosa	cylindricfruit primrose-willow
Ludwigia palustris	marsh seedbox
Ludwigia peploides	floating primrose-willow
Marsilea vestita	hairy waterclover
Medicago polymorpha	burclover
Melilotus indicus	annual yellow sweetclover
Melochia corchorifolia	chocolateweed
Mikania scandens	climbing hempvine
Najas guadalupensis	southern waternymph
Nitella tenuissima	dwarf stonewort
Nymphaea odorata	American white waterlily
Oxalis dillenii	slender yellow woodsorrel
Panicum dichotomiflorum	fall panicgrass
Panicum hemitomon	maidencane
Panicum repens	torpedo grass
Panicum ridigulum	redtop panicgrass
Paspalum acuminatum	brook crowngrass
Paspalum dilatatum	dallisgrass
Paspalum lividum	longtom
Paspalum plicatulum	brownseed paspalum
Paspalum urvillei	Vasey's grass
Phyla nodiflora	turkey tangle fogfruit
Plantago virginica	Virginia plantain
Pluchea camphorata	camphor pluchea
Polygonum hydropiperoides	swamp smartweed
Polygonum lapathifolium	curlytop knotweed
Polygonum punctatum	dotted smartweed
Polypogon monspeliensis	annual rabbitsfoot grass
Polypremum procumbens	juniper leaf

Pontederia cordata	pickerelweed
Portulaca oleracea	little hogweed
Potamogeton diversifolius	waterthread pondweed
Ptilimnium capillaceum	herbwilliam
Pyrrhopappus pauciflorus	smallflower desert-chicory
Ranunculus pusillus	low spearwort
Rhynchospora caduca	anglestem beaksedge
Rhynchospora corniculata	shortbristle horned beaksedge
Riccia stenophylla	not listed
Richardia sp	Mexican clover
Rorippa teres	southern marsh yellowcress
Rotala ramosior	lowland rotala
Rubus trivialis	southern dewberry
Rudbeckia texana	Texas coneflower
Rumex crispus	curly dock
Saccharum giganteum	sugarcane plumegrass
Sagittaria graminea	grassy arrowhead
Sagittaria longiloba	longbarb arrowhead
Sagittaria papillosa	nipplebract arrowhead
Sagittaria platyphylla	delta arrowhead
Salvia lyrata	lyreleaf sage
Salvinia minima lyrata	water spangles
Samolus valerandi	seaside brookweed
Sapium sebiferum	Chinese tallow
Schizachyrium scoparium	little bluestem
Schizophyllum commune	split gill
Schoenoplectus tabernaemontani	softstem bulrush
Scirpus pungens	common threesquare
Scirpus validus	softstem bulrush
Sesbania drummondii	poisonbean
Sesbania herbacea	bigpod sesbania
Setaria parviflora	marsh bristlegrass
Solidago altissima	Canada goldenrod
Solidago sempervirens	seaside goldenrod
Spartina patens	saltmeadow cordgrass
Sphenoclea zeylanica	chickenspike
Spirodela polyrrhiza	common duckmeat
Steinchisma hians	gaping grass
Stellaria parva	pygmy starwort
Stenotaphrum secundatum	St. Augustine grass
Strophostyles sp.	fuzzybean
Symphiotrichum subulatum	eastern annual saltmarsh aster
Symphyotrichum divaricatum	southern annual saltmarsh aster

Symphyotrichum lateriflorum	calico aster
Typha domingensis	southern cattail
Typha latifolia	broadleaf cattail
Utricularia gibba	humped bladderwort
Utricularia radiata	little floating bladderwort
Valerianella radiata	beaked cornsalad
Veronica peregrina	neckweed

Appendix 2. Stormwater Wetland Project Memorandums of Understanding with Project Partners (Task 4.1)

Texas A&M University Sponsored Research Services
Subaward Agreement

Institution/Organization ("RECIPIENT") Name: Houston Botanic Garden Address: 3701 Kirby Drive, Suite 992 Houston, TX 77098	Institution/Organization ("SUBRECIPIENT") Name: Texas A&M AgriLife Extension Service Address: 400 Harvey Mitchell Parkway South, Suite 300 College Station, TX 77845-4375
Recipient Principal Investigator: Joy Columbus	Subrecipient Principal Investigator: Charris York
Sponsor Award #:19-056-000-M090, NA18NOS4190153	Maestro#: M1901086
Prime Award #: 19-056-000-M090, NA18NOS4190153	
Prime Sponsor: General Land Office	
Project Title: Houston Botanic Garden Stormwater Wetlands	
Subaward Period of Performance: October 1, 2018 – March 31, 2020	Amount Funded this Action: $80,000
	Total Amount Funded to Date: $80,000
Reporting Requirements: See Attachment 4	Cost Share Amount: $0

Terms and Conditions

1) Recipient hereby awards a **cost reimbursable** Subaward Agreement, as described above, to Subrecipient. The statement of work and budget for this Subaward Agreement are (check one): ☐ as specified in Subrecipient's proposal dated Click here to enter a date. ; or ☒ as shown in **Attachment 5**. In its performance of subaward work, Subrecipient shall be an independent entity and not an employee or agent of Recipient.

2) Recipient shall reimburse Subrecipient not more often than monthly for allowable costs. Invoices can be submitted using Subrecipient's standard invoice. Invoices *that do not reference current and cumulative costs, subaward number, and certification as to truth and accuracy of invoice shall be returned to* Subrecipient. Payment of invoices shall be contingent upon approval by Recipient Principal Investigator. Invoices and questions concerning invoice receipt or payments should be directed to the appropriate party's Financial Contact, as shown in **Attachment 3**.

3) A final statement of cumulative costs incurred, including cost sharing, marked "FINAL," must be submitted to Recipient's Financial Contact NOT LATER THAN thirty (30) days after subaward end date. The final statement of costs shall constitute Subrecipient's final financial report.

4) All payments shall be considered provisional and subject to adjustment within the total estimated cost in the event such adjustment is necessary as a result of an adverse audit finding against the Subrecipient.

5) Matters concerning the technical performance of this Subaward Agreement should be directed to the appropriate party's Principal Investigator, as shown in **Attachment 3**. Technical reports are required as shown in **Attachment 4**.

6) Matters concerning the request or negotiation of any changes in the terms, conditions, or amounts cited in this Subaward Agreement, and any changes requiring prior approval, should be directed to the appropriate party's Administrative Contact, as shown in **Attachment 3**. Any such changes made to this Subaward Agreement require the written approval of each party's Authorized Official, as shown in **Attachment 3**.

7) Each party shall be responsible for its negligent acts or omissions and the negligent acts or omissions of its employees, officers, or directors, to the extent allowed by law.

8) Either party may terminate this Subaward Agreement with thirty days written notice to the appropriate party's Administrative Contact, as shown in **Attachment 3.**

9) No-cost extensions require the approval of the Recipient. Any requests for a no-cost extension should be addressed to and received by the Financial Contact, as shown in **Attachment 3**, not less than thirty days prior to the desired effective date of the requested change.

10) The Subaward Agreement is subject to the terms and conditions of the Prime Sponsor Award and other special terms and conditions, as identified in **Attachment 2**.

11) By signing below Subrecipient makes the certifications and assurances shown in **Attachment 1**.

By an Authorized Official of RECIPIENT:	By an Authorized Official of SUBRECIPIENT: 2·07·19
Name: Claudia Gee Vassar Date Title: President and General Counsel	Name: Julie Bishop Date Title: Associate Executive Director TG

MEMORANDUM OF UNDERSTANDING

BETWEEN

TEXAS COMMUNITY WATERSHED PARTNERS

AND

M. D. ANDERSON CANCER CENTER FACILITIES MANAGEMENT/SITE OPERATIONS

This Memorandum of Understanding ("MOU") is by and between Texas Community Watershed Partners ("TCWP"), and The M. D. Anderson Cancer Center Facilities Management—Site Operations division ("MD Anderson"), referred to as "Party" or collectively "Parties".

Both parties share a mutual interest in working together to develop a stormwater wetland demonstration project ("Project") for a new stormwater detention basin on MD Anderson property in the Texas Medical Center, Houston Texas. The location of the proposed stormwater wetland is near the intersection of Fannin Street and Old Spanish Trail, at the site of the proposed expansion of the MD Anderson Proton Therapy Center (1840 Old Spanish Trail, Houston TX 77054).

The purpose of this MOU is to recognize the mutual benefit of collaboration and defines the roles of the above mentioned parties. The function of the proposed stormwater wetlands is to demonstrate a technique for improving the stormwater quality flowing from the Texas Medical Center to Brays Bayou, while providing a wetland area with native plantings for MD Anderson staff and visitors to enjoy.

The Project is part of the larger effort to improve non-point source (i.e. stormwater runoff) water quality in Harris, Galveston and Brazoria Counties by demonstrating the use of engineered wetlands as a stormwater Best Management Practice. The Project is grant funded through the Texas Commission on Environmental Quality and the Galveston Bay Estuary Program. This MOU shall become effective when executed by all parties and shall remain in effect through March 31, 2020.

RESPONSIBILITIES OF TEXAS COMMUNITY WATERSHED PARTNERS

TCWP will provide consultation with a wetland specialist on matters concerning the design and planning of the proposed stormwater wetland, including but not limited to plant selection, sourcing, propagation, and installation; volunteer coordination, wetland maintenance, interpretive signage, educational outreach and funding opportunities. The wetland specialist will be available to discuss the stormwater wetland design, engineering and planning with MD Anderson as needed.

TCWP will provide regionally native wetland plants as needed.

25374-2

TCWP will provide planting of the stormwater wetland, by volunteers and/or subcontractors.

RESPONSIBILITY OF MD ANDERSON FACILITES MANAGEMENT/SITE OPERATIONS

MD Anderson will share site plans with TCWP, project schedules, and facilitate project communication with MD Anderson contractors.

MD Anderson will provide access to the site for TCWP and TCWP subcontractors at pre-arranged times.

M. D. ANDERSON CANCER CENTER SITE OPERATIONS	**TEXAS COASTAL WATERSHED PARTNERS**
By:	By:
Name: James E. Power, P.E.	Name: John Jacob
Title: Chief Engineer, RAF Site Operations	Title: Director
Date: 10/5/2018	Date: 10-5-2018

25374-2

MEMORANDUM OF UNDERSTANDING

BETWEEN

TEXAS COMMUNITY WATERSHED PARTNERSHIP

AND THE

CLEAR LAKE CITY WATER AUTHORITY

This Memorandum of Understanding ("MOU") is by and between Texas Community Watershed Partners (TCWP), a program of Texas A&M AgriLife Extension Service ("AgriLife"), an agency of the State of Texas, and the Clear Lake City Water Authority, a political subdivision of the State of Texas ("CLCWA"), each referred to individually as a "Party" or collectively as the "Parties". Although none of the below is binding upon the Parties, the Parties agree to act in good faith with respect to the terms provided herein.

The Parties share a mutual interest in partnering to develop the stormwater wetland component ("Project") of the Exploration Green Nature Park located in Clear Lake City, Houston, Texas.

The purpose of this MOU is to recognize the mutual benefit of collaborative partnering and serves as an indication of continued interest in cooperation of the Parties. The goal of the Project is to provide plants for the stormwater wetland by operating a wetland plant nursery onsite. The function of the proposed stormwater wetland is to demonstrate a technique for improving the water quality flowing from Exploration Green, while providing a natural wetland habitat and opportunities for Clear Lake City residents to observe and enjoy wildlife in a wetland setting.

The Project is part of the larger effort to improve non-point source (i.e. stormwater runoff) water quality in Harris, Galveston and Brazoria Counties by demonstrating the use of engineered wetlands as a stormwater Best Management Practice. Past and present funding sources for the Project include the Galveston Bay Estuary Program, the Texas Commission on Environmental Quality, the Texas General Land Office Coastal Management Program, the National Oceanic and Atmospheric Administration (NOAA), and the National Sea Grant Office.

This MOU sets forth the intentions of the Parties for increased collaboration, cooperation and interaction, but does not create any legally binding commitments with regard to such continued or future collaboration, cooperation and interaction.

RESPONSIBILITIES OF TEXAS COMMUNITY WATERSHED PARTNERSHIP

The TCWP engineering consultant will be available to discuss the stormwater wetland design and parameters with the CLCWA as needed in future Phases.

TCWP will operate the existing onsite wetland plant nursery to provide native planting material for the stormwater wetlands at all phases of Exploration Green.

TCWP will provide plant sourcing and propagation in the wetland plant nursery, while increasing stocks of healthy and appropriate wetland species.

TCWP will perform community outreach including compiling and distributing a weekly stormwater wetland newsletter for volunteers and friends of the TWP stormwater wetland program; coordinating event announcements with CLCWA and the Exploration Green Conservancy and others; and presentations and tours to community groups, elected officials, and students.

TCWP will coordinate volunteers for planting of the stormwater wetland, including weekly volunteer workdays (generally Thursday mornings), monthly weekend workdays (generally fourth Saturdays) and community volunteer events as needed to plant Exploration Green stormwater wetlands.

TCWP will monitor the wetland as it establishes for invasive species and beneficial species recruitment, and will provide assistance on establishing a healthy wetland for water quality and habitat. Future monitoring of the wetland for water quality improvements will depend on funding availability for equipment.

TCWP will provide consultation with a wetland specialist on matters concerning the design and planning of the proposed stormwater wetland, including but not limited to plant selection, sourcing, propagation, and installation; volunteer coordination, wetland maintenance, interpretive signage, educational outreach and funding opportunities. The wetland specialist will be available to discuss the stormwater wetland design and planning with the CLCWA as needed.

TCWP will coordinate design and activities with CLCWA, CLCWA's consultants, CLCW's engineer, as authorized, and Exploration Green conservancy.

RESPONSIBILITY OF THE CLEAR LAKE CITY WATER AUTHORITY

CLCWA will provide access to the site for TCWP and TCWP subcontractors as needed.

CLCWA will provide and maintain TCWP with a connection to the water supply for the wetland plant nursery.

CLCWA will facilitate coordination with CLCWA subcontractors and TCWP on an as needed basis.

TCWP will submit invoices quarterly to CLCWA for payment in the amount of $6,500.00 and such invoices will include a list of dates and activities performed. Quarters will run January – March, April – June, July – September, and October – December.

MISCELLANEOUS ITEMS

1. Entire MOU. This MOU contains the entire understanding of the parties with respect to the installation of the Study and supersedes all other written and oral MOUs between the parties with respect to the Study.

2. Governing Law. This MOU is construed under the laws of Texas.

3. Independent Contractor Status. This MOU will not be construed as creating an employer/employee relationship between any of the Parties. Each Party will maintain in force worker's compensation insurance, professional liability insurance and comprehensive general liability insurance policies; proof of such policies will be presented upon request of the other party. As an agency of the State of Texas, AgriLife is self-insured to the extent required by the State of Texas. All Parties will cooperate, as needed, with defense of claims in which students, staff, or employees were involved or of which they had knowledge related to the claim. Each Party assumes full responsibility for the actions of their own employees and each shall remain solely responsible for their own employees' supervision, daily direction, and control of payment of salary and benefits.

4. Liability and Immunity. The Parties recognize that in the event of an accident causing damage or injury, liability would be determined under the Texas Tort Claims Act. The Parties do not waive or relinquish any immunities or defenses on behalf of themselves, their trustees, officers, employees, and agents, as a result of the execution of this MOU and performance of the understandings described herein.

5. Headings. Headings appear solely for convenience of reference. Such headings are not part of this MOU and shall not be used to construe it.

6. Notice. Any notices required by this MOU shall be delivered to the following address:

TCWP: Texas Community Watershed Partnership
1335 Regents Park Drive, Suite 260
Houston, TX 77058
Attn: John Jacobs
(Phone) 832-671-8171
jjacob@tamu.edu

CLCWA: Jennifer Morrow, General Manager
Clear Lake City Water Authority
900 Bay Area Blvd, Houston, TX 77058
(Phone) (281) 488-1164
j.morrow@clcwa.org

If the above accurately reflects the terms of understanding between the Parties with respect to the Project, please execute.

Clear Lake City Water Authority

By Jennifer Morrow
Jennifer Morrow, General Manager

Date 3/21/2019

Texas Community Watershed Partners

By
John Jacob, Director

Date 3-18-19

4833-9531-7642.v1

Appendix 3. Stormwater Wetland Program E-Newsletters (Task 4.2)

2017

Sept 5: http://mailchi.mp/a36f6f574345/this-week-in-stormwater-wetland-volunteering-969513

Sept 11: http://mailchi.mp/1cee3d970ce3/this-week-in-stormwater-wetland-volunteering-976377

Sept 19: http://mailchi.mp/dadee43acbd7/this-week-in-stormwater-wetland-volunteering-986621

Sept 26: http://mailchi.mp/845750242248/this-week-in-stormwater-wetland-volunteering-994173

Oct 3: http://mailchi.mp/b8775cce3512/this-week-in-stormwater-wetland-volunteering-1002729

Oct 11: http://mailchi.mp/4d112c16c0bc/this-week-in-stormwater-wetland-volunteering-1012633

Oct 17: http://mailchi.mp/35c3e9817c4b/this-week-in-stormwater-wetland-volunteering-1019685

Oct 25: http://mailchi.mp/04883bac4c54/this-week-in-stormwater-wetland-volunteering-1028041

Oct 31: http://mailchi.mp/ab06c8b8f7a3/this-week-in-stormwater-wetland-volunteering-1033893

Nov 6: http://mailchi.mp/749912999385/this-week-in-stormwater-wetland-volunteering-1040429

Nov 13: http://mailchi.mp/f715fd267dbf/this-week-in-stormwater-wetland-volunteering-1040629

Nov 21: http://mailchi.mp/d9f968259453/this-week-in-stormwater-wetland-volunteering-1058849

Nov 28: http://mailchi.mp/8c68f22eadb3/this-week-in-stormwater-wetland-volunteering-1067677

Dec 11: https://mailchi.mp/55cdf9fe3f4f/this-week-in-stormwater-wetland-volunteering-1082225

Dec 18: https://mailchi.mp/cf09445be6a3/this-week-in-stormwater-wetland-volunteering-1089833

Dec 27: https://mailchi.mp/e8208f1eda59/this-week-in-stormwater-wetland-volunteering-1099505

2018

Jan 2: https://mailchi.mp/bc2c41df6276/this-week-in-stormwater-wetland-volunteering-1103877

Jan 8: https://mailchi.mp/6af5daebadab/this-week-in-stormwater-wetland-volunteering-1107177

Jan 16: https://mailchi.mp/f44aa66a7a41/this-week-in-stormwater-wetland-volunteering-1118289

Jan 22: https://mailchi.mp/52619b65d405/this-week-in-stormwater-wetland-volunteering-1124710

Jan 29: https://mailchi.mp/31203ffe925e/this-week-in-stormwater-wetland-volunteering-1131549

Feb 6: https://mailchi.mp/666c1c25a581/this-week-in-stormwater-wetland-volunteering-1141293

Feb 12: https://mailchi.mp/a520a5905086/this-week-in-stormwater-wetland-volunteering-1147917

Feb 19: https://mailchi.mp/b907a66a08b9/this-week-in-stormwater-wetland-volunteering-1157653

Feb 27: https://mailchi.mp/71fcd0dba8d2/this-week-in-stormwater-wetland-volunteering-1175321

Mar 6: https://mailchi.mp/377bda22746d/this-week-in-stormwater-wetland-volunteering-1190841

Mar 13: https://mailchi.mp/9a953e434e18/this-week-in-stormwater-wetland-volunteering-1208049

Mar 20: https://mailchi.mp/345ff824037e/this-week-in-stormwater-wetland-volunteering-1223513

Mar 26: https://mailchi.mp/6666bf166822/this-week-in-stormwater-wetland-volunteering-1238529

Apr 3: https://mailchi.mp/2181d749d588/this-week-in-stormwater-wetland-volunteering-1258337

Apr 9: https://mailchi.mp/0de2c131920e/this-week-in-stormwater-wetland-volunteering-1267773

Apr 16: https://mailchi.mp/83dc59532cf7/this-week-in-stormwater-wetland-volunteering-1278701

Apr 25: https://mailchi.mp/e43a5ec22c9f/this-week-in-stormwater-wetland-volunteering-1292337

May 1: https://mailchi.mp/f4cb02ae8e5a/this-week-in-stormwater-wetland-volunteering-1298329

May 7: https://mailchi.mp/27d878e16b02/this-week-in-stormwater-wetland-volunteering-1300005

May 15: https://mailchi.mp/5ac28491031c/this-week-in-stormwater-wetland-volunteering-1315557

May 23: https://mailchi.mp/1ff9f2d95c55/this-week-in-stormwater-wetland-volunteering-1326817

May 29: https://mailchi.mp/4ccd409f09c2/this-week-in-stormwater-wetland-volunteering-1335909

June 4: https://mailchi.mp/d6bd6144fc39/this-week-in-stormwater-wetland-volunteering-1343541

June 12: https://mailchi.mp/b105d0f5df56/this-week-in-stormwater-wetland-volunteering-1353209

June 18: https://mailchi.mp/4e443f52b70b/this-week-in-stormwater-wetland-volunteering-1358029

July 2: https://mailchi.mp/6544f7dfe907/this-week-in-stormwater-wetland-volunteering-1374645

July 8: https://mailchi.mp/e42bdcf2c45a/this-week-in-stormwater-wetland-volunteering-1383209

July 16: https://mailchi.mp/beaff4fb7721/this-week-in-stormwater-wetland-volunteering-1391373

July 23: https://mailchi.mp/5b81f2f3d31f/this-week-in-stormwater-wetland-volunteering-1398317

July 31: https://mailchi.mp/49ce1acfb3fd/this-week-in-stormwater-wetland-volunteering-1409341

Aug 7: https://mailchi.mp/fa52d7b9954f/this-week-in-stormwater-wetland-volunteering-1417849

Aug 13: https://mailchi.mp/ef61d623c42c/this-week-in-stormwater-wetland-volunteering-1424321

Aug 21: https://mailchi.mp/411ea7299fb7/this-week-in-stormwater-wetland-volunteering-1432353

Aug 29: https://mailchi.mp/a57551a48efd/this-week-in-stormwater-wetland-volunteering-1441269

2019

March 5: This week in stormwater wetland volunteering

March 11: This week in stormwater wetland volunteering

March 18: This week in stormwater wetland volunteering

March 26: This week in stormwater wetland volunteering

April 1: This week in stormwater wetland volunteering

April 8: This week in stormwater wetland volunteering

April 15: This week in stormwater wetland volunteering

April 22: This week in stormwater wetland volunteering

April 29: This week in stormwater wetland volunteering

May 6: This week in stormwater wetland volunteering

May 13: This week in stormwater wetland volunteering

May 20: This week in stormwater wetland volunteering

May 28: This week in stormwater wetland volunteering

June 11: This week in stormwater wetland volunteering

June 19: This week in stormwater wetland volunteering

June 24: This week in stormwater wetland volunteering

July 1: This week in stormwater wetland volunteering

July 8:This week in stormwater wetland volunteering

July 15: This week in stormwater wetland volunteering

July 22: This week in stormwater wetland volunteering

July 29: This week in stormwater wetland volunteering

August 5: This week in stormwater wetland volunteering

August 12: This week in stormwater wetland volunteering

August 19: This week in stormwater wetland volunteering

August 26: This week in stormwater wetland volunteering

September 2: This week in stormwater wetland volunteering

September 9: This week in stormwater wetland volunteering

September 16: This week in stormwater wetland volunteering

September 16: This week in stormwater wetland volunteering

September 18: This week in stormwater wetland volunteering

September 23: This week in stormwater wetland volunteering

September 30: This week in stormwater wetland volunteering

October 7: This week in stormwater wetland volunteering

October 14: This week in stormwater wetland volunteering

October 22: This week in stormwater wetland volunteering

October 28: This week in stormwater wetland volunteering

November 4: This week in stormwater wetland volunteering

November 13: This week in stormwater wetland volunteering

November 18: This week in stormwater wetland volunteering

Appendix 4. Stormwater Wetland Publications (Task 4.2)


GIFT
Green Infrastructure For Texas
Ghirardi Family WaterSmart Park, League City, TX
MD Anderson, Houston, TX
Sheldon Lake State Park, Houston, TX
Texas A&M AgriLife Extension
RECREATION, PARK & TOURISM SCIENCES
TEXAS A&M UNIVERSITY
TEXAS COMMUNITY WATERSHED PARTNERS
A Program Of Texas A&M AgriLife Extension

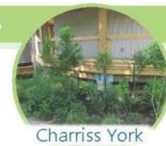
GIFT is a multi-level approach to water quality and quantity that creates a series of living landscape features, from individual properties to large-scale undeveloped lands.

GIFT enables citizens of Texas **to build resilient cities adaptable to economic, social, and environmental change; to more efficiently use their resources by minimizing losses due to misguided design, construction and planning practices;** and **to minimize impact to natural resources.** We provide on-the-ground demonstration projects, applied research, and education.

Green Infrastructure

- **Utilizes knowledge and design solutions based on local strengths and context**
- **Addresses current and emerging community needs with a unified approach**
- **Protects the quality of local water resources**
- **Reduces the quantity of water running off our land**

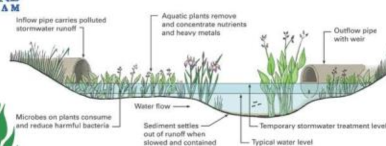
Green Stormwater Infrastructure



Charriss York
Extension Program Specialist
cyork@tamu.edu
(281) 694-5508

Stormwater Treatment Wetlands

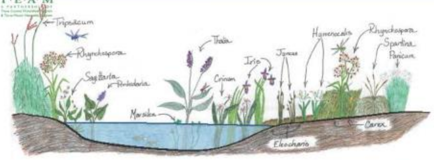
STORMWATER WETLAND PROGRAM



Mary Carol Edwards
Extension Program Specialist
mcedwards@tamu.edu
(281) 989-5517

Wetland Restoration

WETLAND RESTORATION T·E·A·M



Marissa Llosa
Extension Program Specialist
mllosa@tamu.edu
(281) 450-9674

1335 Regents Park Dr., Suite 260, Houston, TX 77058 | agrilife.org/gift

HEALTH & ENVIRONMENT (HTTPS://TODAY.TAMU.EDU/CATEGORY/HEALTH-ENVIRONMENT/)

AgriLife Extension Partners With Houston Residents To Create 'Harvey-Proof' Community

May 22, 2018

SHARE

Volunteers put in wetland plants at one of the project's water detention ponds. The project's five detention ponds will help protect area homes from flooding. (Jerry Hamby/Exploration Green Conservancy)

By Paul Schattenberg, Texas A&M University Marketing & Communications

The Texas A&M AgriLife Extension Service, working in collaboration with area residents, the Clear Lake City Water Authority, or CLCWA, and Exploration Green Conservancy, have been collaborating to transform an about-to-be paved golf course into a new kind of nature park that provides recreation while protecting thousands of homes from flooding caused by natural disasters such as Hurricane Harvey.

"We were involved in an innovative overhaul of a slated-for-development golf course in Clear Lake City, helping repurpose it into a green space with water detention areas and places for recreational activities," said Dr. John Jacob, AgriLife Extension specialist with the recreation, park and tourism sciences department of Texas A&M University.

Jacob, a Houston resident, lived in a neighborhood near the golf course when it was sold to a developer in the early 2000s.

"Area residents were very concerned about the possibility of additional flooding resulting from the new development, and they were also worried about increased runoff pollution," Jacob said. "We participated in a push-back effort against the removal of a green space that virtually everyone in the area wanted to keep."

Developing a master plan

The CLCWA eventually condemned the property for flood impact reduction and asked for residents' input on other uses of the old golf course that would be compatible with floodwater detention. An oversight committee was formed and Jacob was named co-chair.

"We formed citizen committees to explore aspects such as athletic and ball fields, walking trails, native vegetation, stormwater wetlands and other possibilities," Jacob said. "Local residents were intensely involved in this process and were diligent in exploring the many options for use of this green space. Their contributions formed the basis for a master plan developed by SWA Group Houston."

He said the resulting plan was for a new nature park, Exploration Green, designed to detain and slow floodwaters and clean the runoff from 95 percent of the storms that occur in the area. Additional provisions were added for a walking trail, lake, wetlands areas and other features.

Jacob said the 178-acre golf course ran alongside large drainage ditches constructed by the original developer, providing a perfect setting for accommodating additional floodwater detention volume.

The Exploration Green walking trail is popular with area residents. (Mary Carol

"Almost as soon as the master plan was completed there was additional resident participation. An Exploration Green conservancy was formed to oversee all facilities over and above floodwater detention," he said. "The first phase of Exploration Green was about 80 percent completed when Hurricane Harvey hit and the detention area held enough stormwater runoff that even houses that habitually flooded with 5-inch to 10-inch storms didn't flood with the 45 or so inches that came with Harvey."

AgriLife Extension continued to participate by leading the way in the design and integration of stormwater wetlands into the overall plan, he said.

"The Texas Community Watershed Partners program of Texas A&M AgriLife was instrumental in this effort," he said. "Texas Community Watershed Partners provides education and outreach to local governments and citizens on the impacts of land use on watershed health and water quality. It operates on the land-grant model of integrated university research, education and extension to help make Texas' coastal communities more sustainable and resilient."

Additionally, AgriLife Extension is participating in a statewide effort to help Texans recover from Hurricane Harvey. Last September, Gov. Greg Abbott asked Texas A&M University System Chancellor John Sharp to coordinate state and local recovery efforts of the Governor's Commission to Rebuild Texas. Sharp then tasked employees of AgriLife Extension with serving as his local liaisons with the impacted communities, reporting on local recovery needs and providing a pipeline for information and recovery resources.

Protecting a community

Dr. Monty Dozier, AgriLife Extension special assistant for Rebuild Texas, said the agency will continue to be involved in a variety of recovery efforts throughout the Rebuild Texas effort.

"AgriLife Extension personnel will continue to serve as liaisons between local jurisdictions and state and federal agencies," he said. "And we will help communities recover from Harvey and work to be more resilient for future events. Our involvement in the Exploration Green project will certainly help protect that community from flooding brought on by future storms."

Mary Carol Edwards, AgriLife Extension program specialist with Texas A&M's Texas Community Watershed Partners, or TCWP, is a Houston native who grew up in the Clear Lake area and has been working on the stormwater wetlands portion of Exploration Green.

"This will be one of the largest stormwater wetlands initiatives ever undertaken by the TCWP, with nearly 40 acres of wetlands when all five phases of the initiative are completed," she said.

Phase 1 of the Exploration Green project. The multi-phase project is slated for completion in 2022. (Joe Bibby)

According to the Clear Lake City Water Authority, the project's five detention ponds are expected to help keep potentially 2,000 area homes from flooding through a collective water-holding capacity of a half-billion gallons, providing protection against a significant amount of rainfall and runoff.

Edwards also has been promoting the incorporation of constructed stormwater wetlands into urban drainage systems elsewhere along the Gulf Coast of Texas. Stormwater wetlands clean the stormwater that flows through them, including removing 99.99 percent of the nitrates that make their way into the runoff.

"Properly designed stormwater wetlands are beautiful and also attract a diversity of wildlife, including water and song birds," she said.

For Exploration Green, Edwards develops planting plans and educational materials, leads a Texas Master Naturalist-based volunteer program, manages the wetland plant nursery and coordinates stormwater wetlands design and implementation with the Exploration Green Conservancy and other agencies involved in creating the park.

Gaining national interest

"Planting of the trees and wetlands in Phase 1 began in 2016, even while the detention pond was under construction," she said. "As a result, about an acre of wetland is already approaching maturity and delighting visitors with displays of native water lilies and irises, and attracting wading birds and turtles."

Edwards said an on-site wetland nursery supplies the aquatic plants for Exploration Green. The nursery has an approximately 30,000-plant capacity — enough to plant 5 acres at a time.

"During weekly workdays, plus special workdays for students, native plants are collected and propagated in the nursery," she explained. "Over 300 volunteers assisted in the 2018 spring wetland planting events, which created 1.25 acres of new wetland. Over a dozen organizations, from the Girl Scouts of America to the NASA Sustainability group, have participated in this effort."

A 1.1 mile concrete hike-and-bike trail loops the lake in Phase 1 and is proving to be popular with area residents, Edwards said. Each of the five phases will be connected by trails, providing approximately 6 miles of off-road recreational trails through a natural environment.

Water quality studies, funded by a grant from the Texas General Land Office Coastal Management Program, will begin in October 2018 to monitor and document water quality changes provided by the stormwater wetlands. A groundbreaking for Phase 2 of the stormwater wetlands portion of the project is slated for May 2018. All phases of the project are expected to be completed in 2022.

"This is a great example of residents, water management agencies, and others working together to save an important green space for recreation and to do so in such a way that it serves a vital environmental purpose that also helps improve the quality of life within that community," Jacob said. "Other flood-prone communities in the metropolitan Houston area have shown interest in implementing this type of project, and we have also had inquiries from other states."

###

This story by Paul Schattenberg originally appeared in AgriLife Today ***(https://today.agrilife.org/2018/05/18/residents-agrilife-extension-others-work-to-change-course-of-houston-area-community/)*** .

SHARE

Appendix 5. Stormwater Wetland Plant Nursery Inventories (Task 4.3)

Gulf Coast Bird Observatory Wetland Plant Nursery Inventory		
Name	**Common Name**	**Number as of December 2019**
Asclepias perrenis		3
Crinum americanum		27
Cyperus articulatus	Jointed Flatsedge	3
Cyperus hyalinolepis	thinscale sedge	16
Eleocharis montana	Mountain Spikerush	10
Eleocharis montevidensis	sand spikerush	22
Eleocharis quadrangulata	Square-stem spikerush	10
Equisetum hymale		17
Hibiscus coccineus	Texas star hibiscus	17
Hydrolea ovata		
Hymenocalis liriosome	spider lily	2
Iris brevicaulis	Zigzag iris	61
Iris fulva	copper iris	48
Iris hexagona	Dixie iris	68
Iris virginica	Southern blue flag iris	540
Juncus polycephalus	many headed rush	17
Leersia hexandra		80
Ludwigia peploides		5
Panicum virgatum	Switchgrass	78
Physostegia intermedia		11
Polygonum hydropiperoides	Swamp Smartweed	118
Rhyncospora caduca		10
Helianthus angustifolius	swamp sunflower	55
Canna glauca	canna	8
Saccharum giganteum	sugar cane plum grass	12
Echinodorus berteroi	upright burhead	14
Sagittaria lancifolia	bulltongue	3
Total		**1255**

Houston Botanic Garden Stormwater Wetland Plant Inventory			
Species	**Common name**	**Location**	**Number as of December 2019**
Schoenoplectus pungens	common three-square bullrush	EG nursery	442
Spartina spartinae	gulf cordgrass	EG nursery	56
Spartina patens	marshhay	EG nursery	
Panicum hemitomon	maidencane	EG nursery	80
Eleocharis quadrangulata	square spikerush	EG nurserey	
Eleocharis montana	montana spikerush	GCBO nursery	20
Eleocharis montvidensis	sand spikerush	GCBO nursery	40
Equisetum hymenale	scouring horsetail	GCBO nursery	15
Ludwigia peploides	floating seedbox	EG/GCBO	54
Iris hexagona	Dixie iris	EG nursery	61
Iris virginica	blue flag iris	GCBO nursery	180
Iris brevicalis	zig zag iris	GCBO nursery	33
Sagittaria graminae		EG nursery	21
Sagittaria lancifolia		EG nursery	
Sagittaria longiloba		GCBO nursery	70
Sagitarria platyphylla		EG nursery	60
Saururus cernus	lizard tail	EG nursery	64
Crinum americana	swamp lily	GCBO nursery	25
Pontederia cordata	pickerelweed	EG nursery	34
Bacopa monerii	coastal water hyssop	EG nursery	220
Bacopa caroliniana	lemon bacopa/ blue water hyssop	EG nursery	1000
Heteranthera limosa	blue mudplantain	EG nursery (volunteer)	54
Hibiscus lasiocarpus	wooly swamp mallow	GCBO nursery	53
Hydrolea ovata	blue water leaf	GCBO nursery	6
Hymenocallis liriosme	spider lily		60
Setaria geniculata	foxtail	EG nursery	25
Carex hyalinolepsis	thinscale sedge	GCBO nursery	20
Cephalanthus occidentalis	buttonbush	EG nursery	20
Nymphea mexicana	yellow water lily	EG nursery	10
Nymhea odorata	white water lily	EG nursery	10

Thalia dealbata	powdery alligator flag	GCBO nursery	2
Rhynocospora corniculata	horned beakrush	EG/GCBO	
Total			**2735**