MANAGING CATTAIL (*Typha latifolia*) GROWTH IN WETLAND SYSTEMS

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Nutrient availability, water depth, competition, and soil management effects on cattail (*Typha latifolia*) growth in wetland systems were examined. Soluble reactive phosphorous (SRP), nitrate-nitrogen (NO_3-N), and ammonia-nitrogen (NH_3–N) removals were tested at a constructed wetland receiving municipal wastewater effluent. Over all, no significant differences in nutrients occurred between diverse planted and cattail areas. *T. latifolia* seeds, under the canopy of *Eleochoris macrostachya*, had low seed germination. Established stands of emergent vegetation can prevent cattail colonization and spread. Germination of *T. latifolia* at various water depths was tested, and depth impacts on cattail seedling growth and survival were ascertained using various moist soil management techniques in three ponds. Water levels at 0cm and >40cm can adversely impact cattail establishment.

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INTRODUCTION

Cattail (*Typha*) species are considered important wetland plants of littoral zones in temperate and boreal North America (Smith 1986). Cattails exist in a wide range of habitats, from mineral poor to mineral rich soils, basic to acidic waters, and tolerate many levels of salinity (Fasset and Calhoun, 1952). In particular, *Typha latifolia* also exists in a wide range of climates and photoperiods (Smith 1986).

Cattails are often abundant wetland species, and perhaps the most common cattail species in North Texas is *Typha latifolia*. This species out-competes other *Typha* species in shallow waters and is more shade tolerant. *T. latifolia* produces relatively long rhizomes and colonies spread rapidly (Smith 1986). Seeds are small, one-seeded fruits that have many perigonial hairs (Stewart et al., 1997). *T. latifolia* has a "flattened stigma and curb-shaped aborted pistils" (Fassett and Calhoun, 1952). If one compares seeds per pistillate spike, *T. latifolia* has greater seed production than *T. domingensis,* even though it has a smaller seed mass. *T. latifolia* has a greater ability to spread (compared with other *Typha*) based on the number of seeds produced (Stewart et al., 1997).

Cattails are aggressive species that quickly inhabit disturbed areas, ultimately reducing diversity and productivity of wetland systems. They disperse seeds over a wide area and pre-empt spaces rapidly following a disturbance. They are mainly self-pollinators, but can also cross-fertilize (Krattinger, 1975). Seeds of *T. latifolia*, when floating or submerged under water, adjust to changes in temperature more successfully than when seeds find land (Thompson, 1974).

Normally, *T. latifolia* seeds germinate during the spring, when temperatures are mild, water levels are adequate, and day light hours are longer (Lombardi et al., 1997). Physical characteristics, such as these, may result in *T. latifolia* stands that are oligo-specific, partly due to extensive rhizome growth that precludes other species (Lombardi et al., 1997). In the absence of heavy vegetation in an area, cattails can spread rapidly by vegetative propagation (Gopal and Goel, 1993).

The success of cattail growth in ponds across North America has been partly attributed to changes in nutrients in freshwater, resulting in eutrophication (Weller 1994). In an Everglades nutrient study, *T. latifolia* germinated faster in field water than *T. domingensis* under high nutrient concentrations, including phosphorous (Stewart et al., 1997). Cattails thriving in an area indicate that the wetland area is nutrient rich and has been disturbed (DyKyjova and Kvet, 1978; Grace and Harrison, 1986; Keddy, 1990). Higher nutrient levels have resulted in rapid growth of cattails in freshwater systems, decreasing diversity of other wetland species, and affecting other ecosystem components, such as duck populations. Decreases in vegetation diversity in waterfowl marshes can result in a decrease in food resources and nesting habitat (ter Heerdt and Drost, 1994).

Wetland management strategies today may influence cattail establishment. Moist soil management strategies and the created wetland “dig it, fill it, and they will come” philosophy contribute to conditions conducive to rapid cattail establishment. Wetland management strategies for cattails focus on water

fluctuation to drown plants, herbicides, and burning, etc. This study focuses on water fluctuations as a management strategy.

To reduce cattail expansion rates, reduced water depths and hydro-periods should be studied more in depth (Newman et al., 1998). Management strategies for cattails should focus on preemptive establishment of less aggressive and more beneficial native species and/or water management that inhibits cattail germination or growth. Complete draining or maintaining constant water levels are commonly practiced wetland soil management techniques used for waterfowl habitat, although partial drawdowns may be beneficial (Polasek, 1994).

Objectives:

Four research objectives are presented below:

A. Measure soluble reactive phosphorous (SRP), nitrate-nitrogen (NO_3-N), and ammonia-nitrogen (NH_3–N) at various points in a constructed wetland for one year to evaluate whether nutrient levels differ between planted areas (diverse wetland plants) and unplanted areas (cattail stands).
B. Examine cattail seedling germination and growth as influenced by competitive effects of other wetland species.
C. Determine cattail seedling germination rates, seedling survival, and growth at multiple water depths.

D. Ascertain cattail establishment under different conditions associated with three moist soil management strategies.

In this study, comparisons were made in a constructed wetland between areas occupied by cattails (disturbed areas that were quickly overrun by cattails) and areas purposely planted with a diversity of wetland species. These comparisons were conducted to ascertain nutrient abatement of nitrogen, phosphorous, and ammonia. Recent studies have shown that large aquatic plants, especially cattails, contribute to the removal of human disease-causing microorganisms and pollutants (Kadlec and Knight, 1996).

Establishment of cattails from seed under competitive conditions, the influence of water depth on cattail seed germination, and seedling survival and growth at different water depths were examined experimentally. It is hypothesized that *T. latifolia* has greater biomass production at low water depths with high percent-light transmission than areas of high water depths and low percent-light transmission. Finally, cattail seedling survival, using three moist soil management techniques, was investigated to determine cattail establishment under various water fluctuation conditions.

2. NUTRIENT ANALYSIS OF A WETLAND

A wetland was constructed in 1992 by the city of Denton, Texas to receive de-chlorinated wastewater from the Pecan Creek Wastewater Treatment Plant. This is a type of surface flow wetland, similar to marshes, where shallow channels and basins resulting in water flowing at low velocities above and within the substrate (Shutes, 2001). The wetland has a clay liner that restricts movement of groundwater inflow or outflow and has a maximum volume of 567,812 liters. Approximately 642,000 liters per day enter this wetland (Baerenklau, 1996).

The constructed wetland measures approximately 45 .7m². Depths range from a few inches at the inflow of the wetland to depths up to 2 feet at the outflow. Three earthen barriers were built to create a channel in the wetland (Baerenklau, 1996). Three wetland plant species, bulltongue (*Sagittaria graminea*), pickerelweed (*Pontederia cordata*), and bulrush (*Scirpus validus*), obtained from the Lewisville Aquatic Environmental Research Facility, in Lewisville, Texas, were planted in the wetland between stations 1 and 2-3 (Figure 1). Duckweed (*Lemna* spp.), hydrilla (*Hydrilla verticillata*), coontail (*Ceratophyllum demersum*), flatstem spikerush (*Eleocharis macrostachya*) , and cattails (*T. latifolia*) have inhabited this area as well. Figure 1 shows the diversity of wetland plants between stations 1 and 2 with the cattails in the rest of the wetland.

Methods

Grab samples of water were collected at stations 1, 3, and 5 periodically between February 2001 and January 2002. Station 1 was the inflow area, station 3 was located at the middle of the wetland flow, and station 5 was located towards the end of the flow. Samples were filtered using a 47mm glass fiber filter, and alkalinity and pH values were ascertained. Samples were analyzed for SRP, NO_3^--N and NH_3-N per water sampling at the University of North Texas using standard methods for the SRP analysis and the LaMotte water testing kits for NO_3–N and NH_3–N (Eaton, 1995).

SRP is the measure of biologically available phosphorous (Mitsch and Gasselink 2000). For the SRP analysis, a standard phosphate solution was made (Eaton et all, 1994). 219.5 mg anhydrous KH_2PO_4 was dissolved in distilled water and diluted to 1000ml (1.0ml = 50.0μg of PO_4^{3-}-P). From this stock solution, three replicates of 0.0, 0.25, 0.5, 0.75, and 1.0 standards were made. A combined reagent stock solution was made from 500ml 5N H_2SO_4, 50ml potassium antimony solution (1.3715g of $K(SbO)C_4H_4O_6 \cdot 1/2H_2O$ dissolved in 500ml distilled water), and 150ml ammonium molybdate solution (20g of $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$ dissolved in 500ml distilled water). 1.76g of ascorbic acid (0.1M) were dissolved in 100ml of distilled water. To make the final reagent working solution, 70ml of combined stock reagent and 30ml of ascorbic acid were mixed.

Wetland water samples were diluted with distilled water from 25ml to 100ml as a 1:4 ratio. Two ml of final reagent working solution was added to

12.5ml of sample/standard. After 10 minutes, and no more than 30 minutes, absorbance readings were recorded from the sample/standard using a Beckman DU - spectrophotometer at 880nm.

For the NO_3-N analysis, LaMotte NO_3-N water testing kits were used. 0.7218g of potassium nitrate (anhydrous) was dried at 105°C for 24 hours and diluted to 1000ml with distilled water (1.0ml = 100ug NO_3-N). From this stock solution, three replicates of 0.0, 1.0, 2.0, 3.5, and 5.0 standards were made. Wetland samples were diluted to a 1:4 ratio. Five ml of each sample or standard was mixed with 5ml of mixed acid reagent (included in kit), and after two minutes, 0.2g of nitrate reducing reagent (in kit) was added. Each test tube of sample/standard was inverted 50-60 times/minute for four minutes. After 20 minutes, samples/standards absorbance readings were recorded at 543nm from the spectrophotometer.

NH_3-N analysis was conducted by first making an NH_4Cl standard solution (3.819g anhydrous NH_4Cl dried at 100°C and diluted to 1000ml with distilled water). Three replicates of 0.0, 0.25, 0.5, 0.75, and 1.0 standards were used for each analysis. The concentration of the standards varied throughout the year depending on sample absorbance readings. An NH_3-N water testing kit from LaMotte Co. was used to analyze the samples. Eight drops of NH_3-N reagent #1 (in kit) were added to 10ml of each sample/standard, and each sample was mixed. 1.0ml of NH_3-N reagent #2 (from kit) was added and mixed. After 5 minutes, samples/standards absorbance readings were recorded at 430nm from the spectrophotometer.

Concentrations were ascertained from these absorbance values from each analysis throughout the year. Statistical analyses were conducted between the individual sampling dates for all three chemical analyses using two-sample independent *t*-tests. Line graphs showed trends between stations of chemical concentrations of SRP, NH_3-N, and NO_3-N during the months tested.

Results

SRP concentrations (from the inflow water) had means plus or minus the standard deviations (±SD) at stations 1, 3, and 5 of 1.64 ± 0.02, 1.58 ± 0.01, and 1.65 ± 0.05 mg/L respectively. Figure 2 shows the mean SRP concentrations for the entire sampling period. In order to test differences between the concentrations from station 1 (inflow) to station 3 comparing it to concentrations from station 3 to station 5 (outflow), a *t*-test was used. There were no significant differences between concentrations from stations 3 to 1 and stations 5 to 3 (Independent *t*-test, p =0.07, alpha = 0.05).

NO_3-N concentrations decreased from stations 1 to 5 for all sample periods. Between February 27, 2001 and January 8, 2002, stations 1, 3, and 5 had mean and SD of 12.66 ± 0.37, 6.66 ± 0.14, and 2.33 ± 0.04 mg/L, respectively (Figure 3). In order to test differences between the concentrations from station 1 (inflow) to station 3 comparing it to concentrations from station 3 to station 5 (outflow), a *t*-test was used. Significant differences occurred between concentrations in stations 3 and 1 and stations 5 and 3 (Mann Whitney U test, p =0.0215, alpha = 0.05).

NH_3-N concentrations at stations 1, 3, and 5, were 1.02 ± 1.89, 0.39 ± 0.256, and 0.66 ± 0.37 mg/L, respectively. However, the only concentrations above 1.5 mg/L occurred in November 2001, with a maximum of 6.61 mg/L. A Grubb's outlier test showed that this value of 6.61 was a statistically significant outlier. This value was removed from the data when statistical analyses were conducted. In order to test differences between the concentrations from station 1 (inflow) to station 3 comparing it to concentrations from station 3 to station 5 (outflow), a Mann Whitney U test was used since the data were non-normal. There were significant differences between stations 3 and 1 and stations 5 and 3 (two-sided Mann Whitney U test, p =0.0064, alpha = 0.05).

Discussion

There was no significant difference in SRP concentrations between stations 1 (inflow) to 5 (outflow) in the Pecan Creek Wastewater wetland, indicating that neither cattails nor wetland plants contributed to the reduction of SRP in this system. A constructed wetland made to treat secondary runoff from a wastewater treatment plant was studied by Geiger et al. (1993). SRP amounts ranged from 0.0 – 0.3 mg/L, with unusually high amounts of SRP reaching between 1 – 4 mg/L (Geiger et al. 1993). The concentrations in this Denton constructed wetland are therefore considered nutrient rich in SRP, since the average was 1.65 mg/L, and this could be a reason for the large cattail growth. However, flow rates vary between wetlands. Craft and Richardson (1997) showed phosphorous enrichment to be correlated with the expansion of cattail populations. Evidently, cattails and other wetland plants in the Denton wetland had reached some peak biomass and were no longer expanding.

The NO_3-N results indicated that NO_3-N was lost as N_2 gas or reduced to some other form, such as NH_3-N, as water moved through the wetland system, with concentrations greater at station 1 and lowest at station 5. There was a significant difference between the cattail area and other wetland species area, indicating that reduction rates of NO_3-N concentrations were different between the two areas (Figure 3). High concentrations (mg/L) in municipal wastewater wetlands have been reported between 5.46 mg/L (inflow) and 1.55 mg/L (outflow) on average (Newman et al. 2000). This is in contrast to the Denton's constructed wetland concentration amounts. Denton concentrations were much higher at the

inflow (12.66 mg/L average), and the outflow, averaging 2.33 mg/L. The Pecan Creek wastewater laboratory tests for nitrates once a year. In January of 2001 the effluent concentration was 12.19 mg/L. The nitrate concentrations are high in de-chlorinated treated water initially before the water reaches the wetland. Decreasing NO_3-N 10mg/L between the inflow to outflow area of the constructed wetland showed that organisms living in the system decrease nitrates effectively by converting it into N_2 gas, NH_3-N, or biomass for plants and microorganisms.

NH_3-N concentrations ranged from 0 - 1.5 mg/L (Figure 4), with significant differences between concentrations at stations 3 and 1 and stations 5 and 3. The cattail area contained higher concentrations of NH_3-N than the other wetland plant area. However, concentrations throughout the wetland area were moderately low on average. Municipal wastewater wetlands usually contain concentrations of NH_3-N between 4.08 (inflow) and 1.6 (outflow) (Newman et al. 2000). The constructed wetland had 1.02mg/L average at the inflow, decreased to .39 mg/L on average at station 3, and then increased to 0.66 mg/L at the outflow. This indicated that the Denton constructed wetland had NH_3-N in low amounts in the water column. A possible explanation for this low amount could be that most of the $N0_3$-N in the wetland converted to N_2 gas by denitrification from microorganisms instead of a reduction to NH_3-N.

Wetland plants themselves are not the only means by which nutrients are removed from wastewater. The root structure of wetland plants supplies oxygen to soil microorganisms. The effectiveness of wetlands to remove nitrogen, phosphorous, and trace organics is generally due to both microbial interactions

on contaminants and uptake by vegetation (Watson et al., 1989). Soil microorganisms also nitrify NH_3-N (Trautmann et al., 1989). In large part, vegetation provides the surface area for microbial growth on rhizomes and roots, filters solids, and transfers oxygen to create an aerobic environment for microorganisms, like nitrifiers (Steiner and Freeman, 1989). Phosphorous and nitrogen removal varies from wetland to wetland (Watson et al., 1989). Cattails have been known to be a particularly effective substrate in removing nutrients from wastewater because of relatively high biomass above and below ground, providing potentially greater surface area for the uptake of nutrients and ions (Shutes, 2001).

Many terrestrial ecosystems are becoming enriched with nutrients from transported wastewater, increased amounts of nitrogen in the atmosphere, and eutrophication (Verhoeven et al., 1983). Decreasing the amount of nitrogen and phosphorous in freshwater systems reduces algal growth and other problems that occur with eutrophication. The results of this study indicate that there is no significant difference in SRP, but there was a significant difference with NO_3^- concentrations between areas with diverse wetland plants and areas of only cattails in a constructed wetland. NH_3-N concentrations were too low throughout the wetland to have an ecological significance between the diverse planted area and the cattail area.

Where cattails contribute to decreasing nitrates, their occurrence may help decrease problems with eutrophication. However, many other wetland species

provide the same benefit, and in cases where diversity is greater, a more optimal environment for soil microorganisms than cattails alone may provide.

3. EFFECTS OF COMPETITION ON CATTAIL GERMINATION, SURVIVAL, AND GROWTH

Methods

The competition study was conducted in a small pool at the Lewisville Aquatic Environmental Research Facility (LAERF) beginning August 3, 2001. Soil from LAERF ponds was heat-sterilized at 90°C for 24 hours then mixed with water at a 9:4 ratio in a gasoline-powered cement mixer. Fourteen 10cm height X 7cm diameter pots were filled up to 9cm depth with the mud mixture, and approximately 100 *T. latifolia* seeds were spread on top of the sediment in each pot. Seven *T. latifolia* pots were placed in a 3m diameter X 0.76m deep pool with six pots of established *E. macrostachya* (approx. 0.61m high). The remaining seven *T. latifolia* pots were used as controls and not surrounded by *E. macrostachya* pots, exposing them to full sunlight during the entire study. *T. latifolia* seeds (approximately 100) were also introduced to seven *E. macrostachya* pots, each of which was positioned within the colony of *E. macrostachya/T. latifolia* pots (Figure 5).

The pool was filled with 12.5 cm depth of alum treated water. This water was treated to precipitate phosphorous (Dick et al., 1993), thereby reducing algal growth. A 12.5cm pool depth provided a depth of 2.5cm above the soil of the pots. This depth was ascertained by evaluating the literature, which indicated such a depth to be ideal for cattail germination and survival (Stewart et al., 1997).

Seeds were allowed to germinate and grow beginning August 3, 2001 and seedlings were harvested on November 30, 2001. Plants were counted, dried,

and weighed for above and below ground biomass (g). A one-way ANOVA was conducted to determine plant survival and percent seed germination.

Results

Mean percent seed germination of *T. latifolia* between the control, *T. latifolia* pots, and *E. macrostachya* pots were found to be non-normal (p <0.0001, Shapiro-Wilks). Rank percent seed germination was significantly different (alpha = 0.05, one-way parametric ANOVA on ranked data, p =0.0085). Ranked percent seed germination of *T. latifolia* was separated into three significantly distinct groups: mean percent seed germination of control > *T. latifolia* pots > *E. macrostachya* pots.

Total biomass (above and below ground) for the control pots ranged from 0.01g to 26.88g, with a mean and standard deviation (g±SD) of 9g± 11.47. The seven *T. latifolia* pots had a total biomass ranging from 0.0g to .09g, with a mean and SD of .028g ± .036, and the *E. macrostachya* pots had a mean cattail biomass of 0±0g in all pots. Mean total, above, and below ground biomass (g) of *T. latifolia* were each significantly different among the control group, the *T. latifolia* pots, and the *E. macrostachya* pots (one-way parametric ANOVA on ranked data, p < 0.0001 with mean total and above ground biomass (g) and p = 0.0002 for below ground biomass (g)). Mean total, above, and below ground biomass (g) of *T. latifolia* were each separated into three significantly distinct

groups: mean biomass of control > biomass of the *T. latifolia* pots > biomass of the *E. macrostachya* pots (SNK, alpha = 0.05).

Discussion

The *E. macrostachya* shade apparently resulted in low percent seed germination by *T. latifolia.* The absence of germination in *E. macrostachya* pots was possibly due to shading and most likely combined with an additional issue of a lack of space and possibly nutrients. Competition, defined by Begon et al. (1986), is an interaction between individuals that share a limited supply that causes a decrease in survivorship, growth, and/or reproduction. Firbank and Watkinson (1990) explained the plant that has emerged first in an area suppresses competing plants' growth by also having the fastest growing rate. This plant suppresses competing plants' growth by decreasing light, water, and nutrients available. *E. macrostachya* was well-established in pots and was situated in the pool to simulate a colony surrounding an open, non-vegetated spot (*T. latifolia* pots). Because separate pots were used, nutrients and spatial limitations should not have played a role in low germination rates and growth in *T. latifolia* pots. Therefore, low germination rates and growth appeared to be most attributable to shading by the mature *E. macrostachya* pots. Germination by seeds introduced directly into *E. macrostachya* pots may have been further inhibited by the absence of adequate space for seeds. Although allelopathic effects may have played a role in both cases, the control pots (in the same water as other pots) exhibited higher germination rates and growth, implying that germination was not inhibited by factors other than those previously mentioned. The *T. latifolia* seeds that grew best and had the greatest biomass were in the control group. This group had no colony shade and did not have any vegetation

cover from *E. macrostachya*. Lombardii et al. (1997) discussed that *T. latifolia* seeds do not germinate under areas already shaded by vegetation because there is a risk that no seeds will grow, since light intensity and the number of light hours in an area regulate *T. latifolia* seed germination. This explains a way to manage cattails. When other shady wetland plants are established in an area first, cattail seed germination and seedling survival decreases because of vegetation cover and lack of space for them to be able to grow.

4. EFFECTS OF WATER DEPTH ON CATTAIL GERMINATION, SURVIVAL, AND GROWTH

Methods

The water depth study was conducted in a 2000 L (1.3m tall X 2.3m diameter) tank at the LAERF, beginning August 3, 2001. Shelves were constructed at target depths by using cinder blocks (19.5cm tall) and 0.5cm PVC plastic sheet material. Four PVC plastic squares were placed above each cinder block before the next block was added, producing 20cm increments. On top of the last cinder block for each depth was a 48.26cm X 33.02cm PVC plastic piece placed to hold the ten 10cm tall X 7cm diameter pots. The seven depth levels used were: 120cm, 100cm, 80cm, 60cm, 40cm, 20cm, and 0cm. The maximum growth depth reported for *T. latifolia* is approximately 1.2m (Nichols, 1999).

Soil from a LAERF pond bottom was heat-sterilized at 90°C for 24 hours and then mixed with water at a 9:4 ratio in a cement mixer. Ten pots filled with 9cm of sediment were placed at each of the 7 depths. Approximately 100 *T. latifolia* seeds were mixed with 15ml of sand and spread on top of each pot. Alum-treated water was used to fill up the tank to 120cm, with each shelf maintained at target depths.

Germinated seeds in each pot were counted two, three, and six weeks after planting. Percent seed germination was compared at different depths using a two-factor ANOVA. Light readings were taken after one, three, five, and seven weeks from seed planting at each depth using a “Li-Cor 100” light

meter. Light readings were taken to ascertain the amount of light that was received at each depth during the growth period.

After six weeks, three seedlings were left in each pot for evaluation of seedling survival. This was to reduce competitive effects of growth on seedlings. The seedlings pulled were harvested and dried to ascertain biomass.

After ten weeks, remaining plants were harvested and dried. Above ground, below ground, and total biomass (g) were measured, also using the six weeks biomass results. One-way and two-way ANOVAs on ranked data was conducted on percent seed germination data and biomass (g).

Results

Average tank temperature was 19.72°C. Light readings were measured throughout the water depth study and calculated as an average percent transmission (Figure 6). Seed germination occurred at each water depth.

Percent seed germination after two weeks ranged from 6.6% (0 cm depth) to 39.5% (40 cm depth) for all the depth levels. Total percent seed germination at each water depth after two, three, and six weeks are shown in Figure 8. Initial percent seed germination was normally distributed after two and six weeks respectively (alpha = 0.05, $p = 0.27$, $p = .05$, Shapiro-Wilks). After three weeks, percent seed germination rates were not normally distributed (alpha = 0.05, $p = 0.03$, Shapiro-Wilks). A two-factor ANOVA was performed on all three periods to ascertain whether seed germination rates were significantly different from one

another. The time the percent seed germination was recorded (alpha = 0.05, p = 0.1731, on ranked data) was not a factor relative to depth.

Mean total biomass, including above and below ground, are shown in Figure 7. Mean total, above, and below ground biomass of *T. latifolia* were individually tested for normality, and all three were non-normal (alpha = 0.05, p >0.05, Shapiro-Wilks). Mean total, above, and below ground biomass of *T. latifolia* were highly significantly different among the seven water depths (one-way parametric ANOVA on ranked data, $p < 0.0001$). Mean total biomass was separated into five significantly distinct groups: 20cm depth > 40 cm depth > 0 cm depth > 60, 80, and 100 cm depths > 120 cm depth (SNK, alpha = .05). When above and below ground biomass were compared by a two-way ANOVA on ranked data, the means were significantly different at all depths (alpha = 0.05, $p < 0.0001$). SNK was conducted, and below ground biomass for 0 and 20 cm depths and the 20 cm above ground biomass were statistically greater (SNK, alpha = 0.05) than the biomass at other depths.

Discussion

Seed germination and survival were optimal at 20cm. Most *T. latifolia* germinated and grew at depths of 20 and 40cm, indicating that lower depths were more optimal for cattail establishment. Above these depths, germination appeared to be somewhat inhibited, possibly due to partial desiccation, although growth of established seedlings was fair. Below these depths, an environmental stress, such as lessened percent-light transmission, could have inhibited growth and root structure development of the plants, causing a decrease in survival. Mooney (1972) explained that plants that grow in deeper areas allocate more of their biomass to respiration and a less proportion to photosynthesis resulting in less biomass production and potentially weaker plants. The above to below ground biomass ratio (Figure 7) indicated that more biomass was above ground in deeper water. Root structure was not as prominent at depths lower than 40 cm. Grace (1989) stated that there is a decrease in root allocation, flowering, and reproduction for plants in deep water and an increase in biomass of leaves and stems. These results supported Grace's observations.

The light reading results (Figure 6) showed a low amount of light transmission penetrating the deeper water depths. The 80, 100, and 120cm depths had less than 40% transmission the entire growth period. These lower light levels apparently contributed to lower germination and biomass production at greater depths. The 120cm depth had 25.9% seed germination after two weeks, and then decreased to 16.7% after 5 weeks.

The percent seed germination average of 39.5% indicates a good percent compared with other studies. For example, Stewart and his colleagues (1997) studied germination of *T. latifolia*, where 22% to 40% of the seeds germinated in seven days.

Lombardi (1997) claimed that there has been no detailed study on seed germination trends and the early growth of seedlings of *T. latifolia*. This study showed depths of seed germination and how the plants allocated their biomass as they grew from seeds at different depths.

Further testing should be conducted by increasing the water depths to a level where seeds do not germinate. Seeds germinated in all seven water depths in this study, implying that germination may occur at greater depths. Although seed germination occurred in depths up to 120cm, survival was lowest in the greatest depths. Further study would possibly reveal at what depths *T. latifolia* seedlings would not survive.

The objective of this study was to ascertain at which depths *T. latifolia* could germinate and grow. Both germination rates and growth of cattails were reduced as depth increased, indicating that deeper water (that greater than 40cm) may not be suitable for establishment of cattails. Conversely, low germination (or very early seedling survival) was reduced at a depth of 0cm (saturated soil), indicating that exposure to desiccation also affected cattail establishment. Therefore, depths greater than 40cm, or so shallow as to be exposed to desiccation in a wetland or pond, might minimize seedling germination, survival and growth, and therefore limit establishment of cattails.

5. EFFECTS OF MOIST SOIL MANAGEMENT TECHNIQUES ON CATTAIL SEEDLING SURVIVAL AND GROWTH

Methods

Several moist soil management techniques were employed to ascertain effects on cattail seedling survival and growth. Three 0.125ha earthen ponds infested with cattails were drained and rototilled to a soil depth of 15 cm, in order to kill rootstalks and rhizomes. The ponds had similar operational histories, and a seed bank assay (ter Heerdt and Drost, 1994) indicated no differences in viable cattail seeds in the ponds. Ponds were filled to a maximum (full pool) depth of 1 m during the 2000-2001 winter. In March 2001, one pond was completely drained (dry), one pond was lowered by 0.3 m (low pool), and one pond was left at full pool (Figures 9, 10, and 11). These water levels were maintained throughout the growing season.

Each pond was divided into quadrants, two in the deep end (0-1 m at full pool) and two in the shallow end (0-0.6 m at full pool). One deep and one shallow quadrant from each pond were randomly selected to provide counts of cattail seedlings. The remaining quadrants were left undisturbed.

T. latifolia seedling counts were made periodically beginning in early June 2001 and continued through October 2001. Seedlings that had grown to 50 cm in height were counted as those likely to survive in the LAERF ponds (Dick, pers.comm., 2002). Plants were destructively harvested by hand pulling, and depth of each was recorded. Mann-Whitney U tests were performed to compare

seedling survival and depths between treatments by using the SAS statistical program (SAS Institute, 1999).

GIS mapping of the plant communities that had developed in each pond was conducted, with species' occurrence and dominance visually estimated using a global positioning system (GPS) Trimble Asset Surveyor 5.0 version. No statistical analysis was performed on these data. Ponds were refilled to full pool in October 2002. Duck species were counted at each of the three ponds approximately once per week to ascertain preferences by duck species between October 2001 and February 2002 (Dick, 2002).

Results

From June 13 to October 1, 3,062 *T. latifolia* plants were harvested from the full pool pond. Sixty-seven plants were harvested from the low pool pond through August 1, 2001. No plants were harvested from the dry pond the entire growing season (three seedlings were found growing in association with the pond's drainage structure, which was excluded from the study area). For this reason, statistical analyses performed did not include the dry pond. The depth range for *T. latifolia* germination in plot 1 in the full pool pond was 0 to 45 cm. The depth range for plot 3 in the full pool pond was 0 to 40 cm in depth. The average plant depth for the full pool pond in plot 1 was 4.76 cm, and the average depth for plot 3 was 7.38 cm. Harvests were not conducted in plots 2 and 4, and cattails had almost over-grown both by August. In the low pool plot 1 area, plants were harvested from depths between 0.5cm to 18cm with an average

depth of 4.52cm. In plot 2 the depths ranged from 0cm to10 cm, and had an average of 4.28cm.

Statistical analyses on depth and mean data of *T. latifolia* were collected over four months. Plant depth analyses revealed the full pool pond depths were normal (p = 0.2458, Shapiro-Wilks) and were not normal in the low pool pond (p = 0.0047, Shapiro-Wilks). Therefore, the Mann-Whitney U-test was used to analyze the data, and the mean depths of *T. latifolia* between the low pool and full pool pond were determined to be significantly different from one another (2-sided Mann Whitney U test, p = 0.0404, alpha = 0.05).

The mean number of *T. latifolia* found in each plot of the full pool and low pool ponds are shown in Figure 12. The full pool and low pool ponds were both normal (p = 0.7084, p = 0.6587, Shapiro-Wilks) and variances of the number of *T. latifolia* plants were equal, so a *t*-test was conducted. Mean number of *T. latifolia* plants was not significantly different between the two ponds (p = 0.2453, alpha = 0.05). Sample size used, comparing the two ponds, was small, making variances extremely large.

Plant distributions in the three ponds are shown in Figure 13. Percentages of dominant plants in each pond are shown in Table 1. The dry pond had not developed a wetland plant community and was dominated by terrestrial forbs and grasses. Although cattails did not establish in this pond, the community of plants supported by conducting full drawdown was not desirable in terms of wetland habitat development. The low pool pond developed a diverse wetland plant community, with cattails present, but not dominant. Overall, this pond exhibited

the most desirable wetland habitat in terms of species diversity. The full pool pond exhibited some diversity of wetland species but was dominated by cattails.

In terms of habitat value, the low pool pond plant community was apparently the most attractive to ducks. During winter 2001, after all three ponds were flooded again to full pool, the dry pond had only twelve mallard ducks (*Anas platyrhynchos*) visit in the months the pond was observed. In the full pool pond, 46 ducks total were observed. These consisted of two species, and included 25 mallards and 21 green-winged teals (*Anas carolinensis*). One hundred and twenty-nine ducks visited the low pool pond, consisting of 117 mallards, 9 green-winged teals, and 3 northern shovelers (*Spatula clypeata)* (Gary, 2002).

Discussion

Even though statistical ANOVA showed no significant different because of small sample size and large variance, the two ponds had a large difference in the number of cattails found between the low pool and the full pool pond. Cattails established most heavily in the full pool pond, where it became the dominant species. The species also established in the low pool pond, but at lower numbers. Cattails did not establish in the dry pond.

The low pool and dry ponds were drawn down in March. Drawdown may have interrupted germination and/or reduced seedling survival by exposing seeds and seedlings to desiccation, implying that timing of drawdowns may be effective in lowering cattail establishment.

Gerittsen and Greening (1989) stated water depth had a direct affect on seed germination of certain wetland plants, and it had an indirect effect on seedling growth and recruitment through nutrient dynamics. Welling et al. (1988) showed that no *Typha* seeds or seedlings were found above shoreline heights in the seedbanks during drawdown periods, but seeds were found in those same heights during the non-drawdown periods. Welling's results suggested that this differential germination was primarily due to the variation in soil moisture along the height gradient. Flooded wetland areas can inhibit wetland species' seed germination (Moore and Keddy, 1988). However, mature cattails may increase in growth from flooded conditions (Miao et al., 2001). During a drawdown in Minnesota, recruitment of emergents, including *Typha* spp. and *Scirpus* spp., was greatest where moisture levels were favorable (Harris and Marshall, 1963).

This supports the low pool and dry pond's results of lower cattail establishment. When moisture levels are higher, cattail growth increases. In a *T. latifolia* study by Boyd and Hess (1970), most growth occurred during the short growing season (Grace and Wetzel, 1981). The optimal depth for cattail survival was approximately 40cm, determined by the water depth study and the moist soil management technique study. At this depth, cattails had a high germination rate and a high survival rate. By lowering the water levels during the optimal growing season for cattails, cattail growth and establishment could decrease.

The low pool pond was lowered by 0.3 meters and the dry pond was lowered entirely. Perennial emergents survived after re-flooding, and the mud-flat annuals and meadow perennials died. The zonation patterns, characterizing these wetlands, were likely re-established by vegetative propagation of these perennial emergents (Stewart and Kanturd, 1972; Millar, 1976). Reduction of cattail establishment in the low pool pond allowed establishment of other wetland and aquatic species, such as American pondweed (*Potamogeton nodosus*), *Paspalum spp.*, *Najas guadalupensis* , bulltongue (*Sagittaria graminea*), and flatstem spikerush (*E. macrostachya*). Interestingly, a similar community of plants established in the full pond plots from which *T. latifolia* was harvested for counts: cattails never established in the harvested plots, so the aquatic plant diversity increased compared to the undisturbed plots that grew rapidly with cattails. So, a more desirable community of plants resulted both from water level manipulation (low pool pond) and physical removal of the cattail plants (full pool pond).

In contrast to what was learned in this study, Van der Valk and Davis (1978) revealed that plant species recruitment in prairie wetlands occurs in areas of low water depth, which are referred to as drawdowns. They define a drawdown as a marsh substratum that is free of standing water. Their study included the perennial emergents *T. latifolia, Scirpus lacustris,* and *Carex atherodes*. Welling (1988) also showed that most emergent vegetation did not survive when the drawdown was proceeded by two years in which the water levels were maintained at 1 m higher than normal. Water is fluctuated to reduce cattail germination (and thus establishment), allowing less aggressive species to establish. This may or may not lead to greater diversity.

The duck populations preferred to visit the low pool pond (129 ducks) over the full pool pond (46) and dry pond (12). The most common species to utilize the ponds were mallard ducks. Flooded terrestrial plants dominating the dry pond were apparently the least attractive to waterfowl, followed by the cattail-dominated full pond. Cattails had been removed from two plots (or approximately ½ of the pond), providing some more preferred habitat. Ducks were not observed in the un-harvested plots of this pond. The low pool pond attracted the greatest number of waterfowl, presumably due to the diversity of wetland species throughout. Managing to minimize cattail establishment while at the same time maximizing wetland species community development (partial drawdowns) may be an effective tool in producing habitat beneficial to waterfowl, and presumably other wetland wildlife.

CONCLUSIONS

The research conducted at the Pecan Creek Wastewater Treatment Plant in Denton, Texas and the LAERF in Lewisville, Texas examined four issues concerning *T. latifolia*. First, the study assessed the concentrations of SRP, NO_3-N, and NH_3-N at the beginning, middle, and end of the constructed wetland for one year. This was done to determine any differences between an area occupied by a diverse community of wetland plants and an area dominated by cattails. Next, effects of competition by *E. macrostachya*, another wetland emergent, on *T. latifolia* seedling germination and growth were ascertained. Third, cattail germination rates and seedling survival were ascertained at different water depths up to 120cm. Finally, cattail establishment in ponds was ascertained under three hydroperiods, during the cattail-growing season, to determine if moist soil management techniques can control or reduce cattail establishment in a pond ecosystem.

The research conducted on the constructed wetland at the wastewater treatment plant showed that SRP and NH_3–N (low values) concentrations were not affected by either cattails or the diverse community of plants, probably because the colonies were no longer expanding. However, NO_3–N decreased from the beginning to the end of the wetland, with significant differences in the nutrient decreases associated with the diverse community of plants or cattails. Essentially, cattails and the diverse community of plants of this wetland had the same effectiveness in reducing nutrients, except for NO_3–N. Because of other problems associated with cattails, particularly those concerning habitat value for

wetland and aquatic wildlife, a diverse community of plants in constructed wetlands is more desirable and its development and maintenance should be the goal of wetland managers. However, this depends on the designed use of the wetland.

The competition study revealed that an established plant colony surrounding cattail seeds reduced or prevented seed germination and survival (at a depth of 2.5cm above soil). This implies that when other aquatic emergents are established in a wetland colony, cattails may have difficulty establishing from seed. This information is also related to the constructed wetland at the treatment plant where a diversity of plants was manually established in 1992. Cattails have not become a problem, whereas they have colonized the rest of the (unplanted portion of the) wetland. Cattails have not over-grown the diverse area, indicating that established stands of emergent vegetation can prevent cattail colonization and spread.

Fluctuating water levels reduce cattail expansion. Reducing the water depth during *T. latifolia*'s growing season can reduce germination and seedling survival through desiccation, and may allow less aggressive species to establish. Reducing cattail establishment can result in diverse wetlands that are of greater value to wetland wildlife than oligospecific stands of cattails.

Both the water depth study and the soil management technique study showed that the most optimal depth for cattail establishment was between 0cm and 40cm depths. If the soil is dry or if a pond is flooded at depths deeper than 40cm, cattail seeds have a harder time germinating. Additionally, seedlings in

water depths greater than 40cm show a larger allocation to shoots and less to *T. latifolia* roots, decreasing survival rates. Flooding cattails during critical times may reduce establishment. Newman et al. (1998) argue that maybe altered hydrology techniques should be focused on more than just working on decreasing phosphorous loading into wetlands to help problems of eutrophication. The results from this study suggest that manipulating water levels can interrupt cattail establishment, and may be a useful and effective tool in managing wetlands to their greatest functionality.

Table 1. Percent plant distribution in the low pool, full pool, and dry ponds in the moist soil management techniques study at the LAERF, October 2001.

Common Names	Low Pool (%)	Full Pool	Dry Pool
Panicum spp.	12.8	0	5.3
Sorghum halepense	16.1	0	17.9
Amaranthus spp.	6.7	3.9	1.8
Aster spp.	17.1	0	4.8
Paspalum spp.	20.4	24.4	9.5
Eleocharis macrostachya	14	6.2	0
Pnod/Najas/Paspalum spp.	0	23.3	0
Pnod/najas	5.8	7.7	0
Potomogeton nodosus	0	8.1	0
Najas spp.	0	7.7	0
Typha latifolia	3.3	11.2	0
Hordeum jubatum L.	3.7	0	0
Sagittaria lancifolia	0	7.4	0
Populus fremontii	0	0	4.1
Ammannia coccinea	0	0	2.8
Iva spp.	0	0	3.5
Alismataceae spp.	0	0	6.7
Sesbania spp.	0	0	43.5

Figure 1. Constructed wetland at the Pecan Creek wastewater treatment plant in Denton, Texas at Station 1 to 2. The diversity of aquatic plants is shown here with cattails established between stations 2 to 5.

Figure 2. Mean SRP (soluble reactive phosphorous) concentrations (mg/L) for stations 1, 3, and 5 at the Pecan Creek Wastewater Treatment Plant constructed wetland in Denton, Texas from April 2001 – January 2002

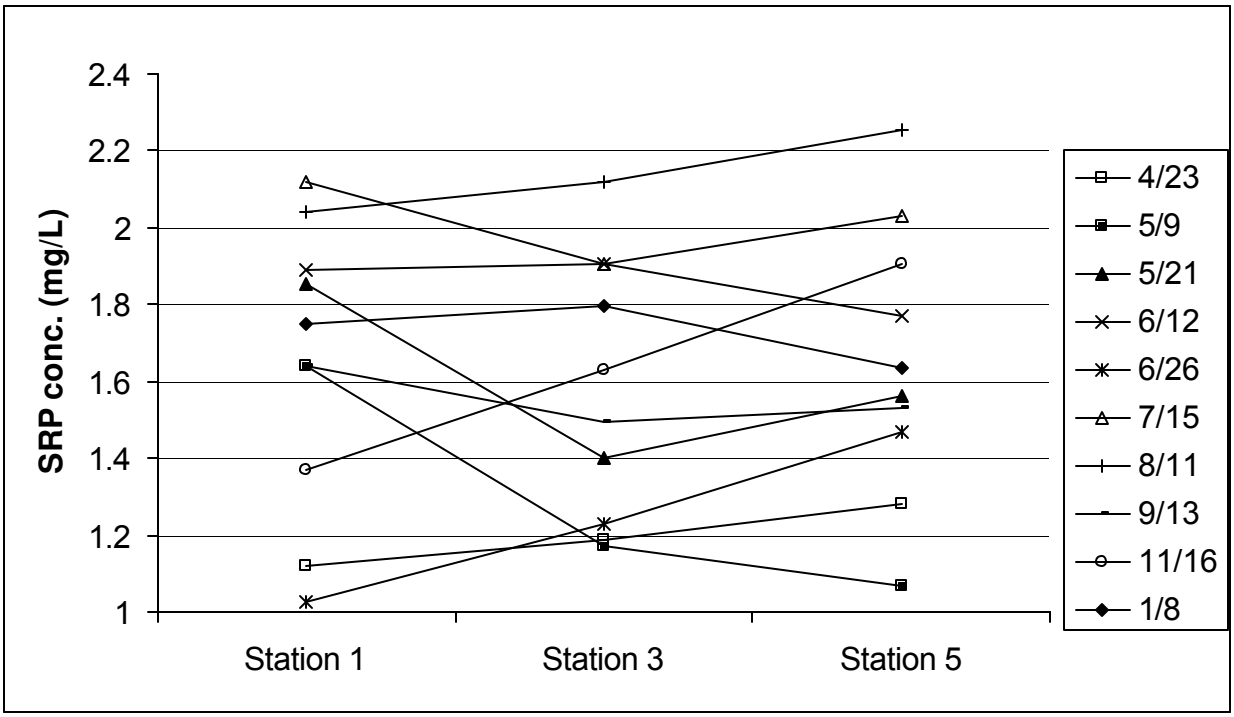


Figure 3. Mean NO_3-N concentrations (mg/L) for stations 1, 3, and 5 at the Pecan Creek Wastewater Treatment Plant constructed wetland in Denton, Texas from February 2001- January 2002

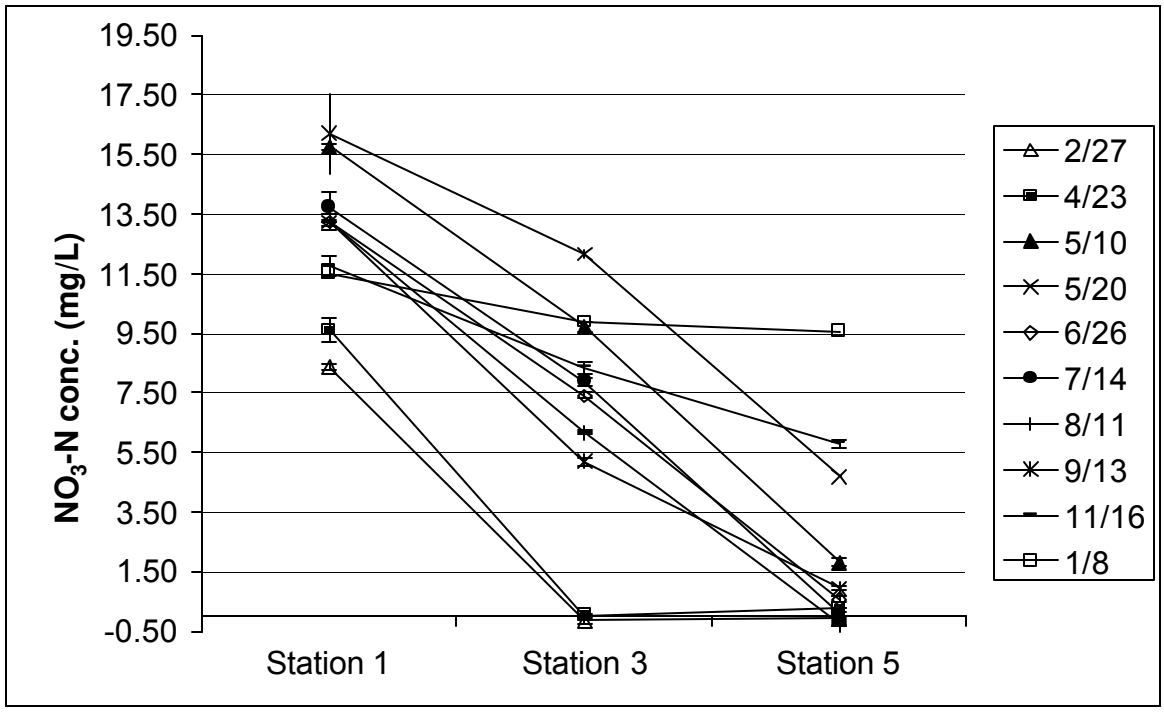


Figure 4. Mean NH_3-N concentrations (mg/L) for stations 1, 3, and 5 at the Pecan Creek Wastewater Treatment Plant constructed wetland from February 2001 – January 2002.

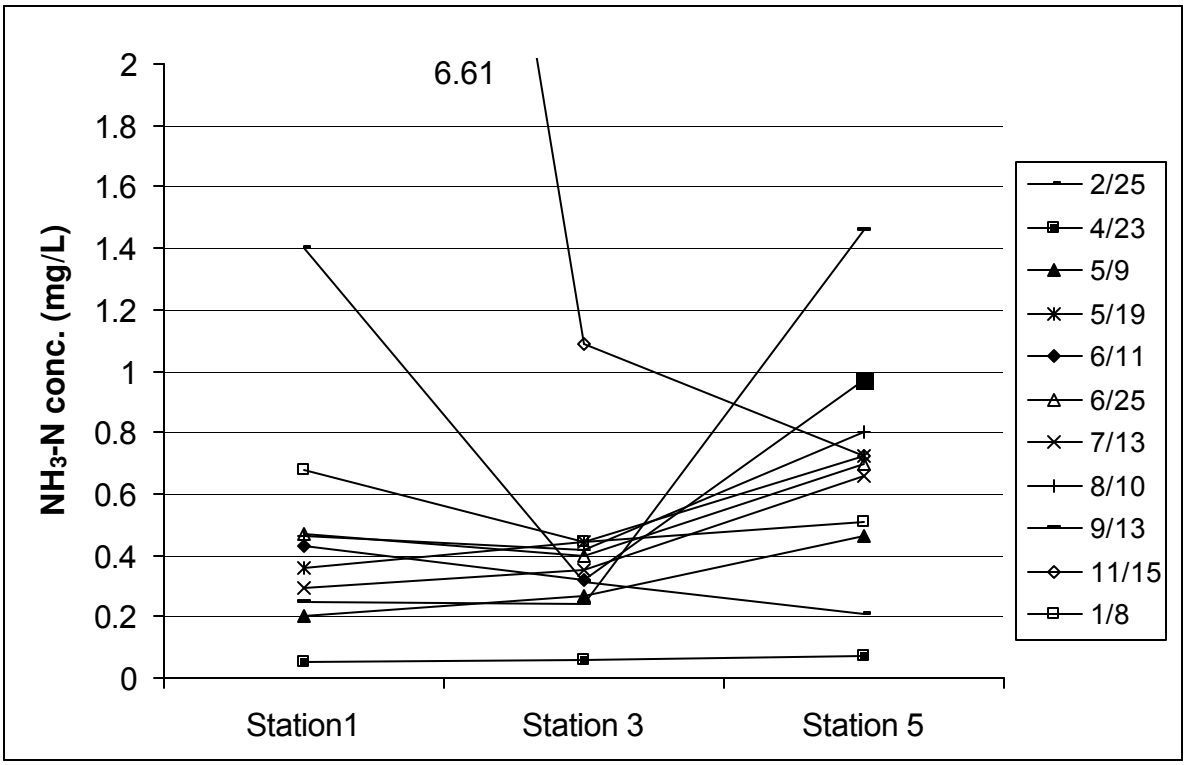


Figure 5. Seven micro wetland colonies, each with one *T. latifolia* pot, and one *E. macrostachya* pot all surrounded by an *E. macrostachya* canopy. The seven control pots are in the middle of the pool.

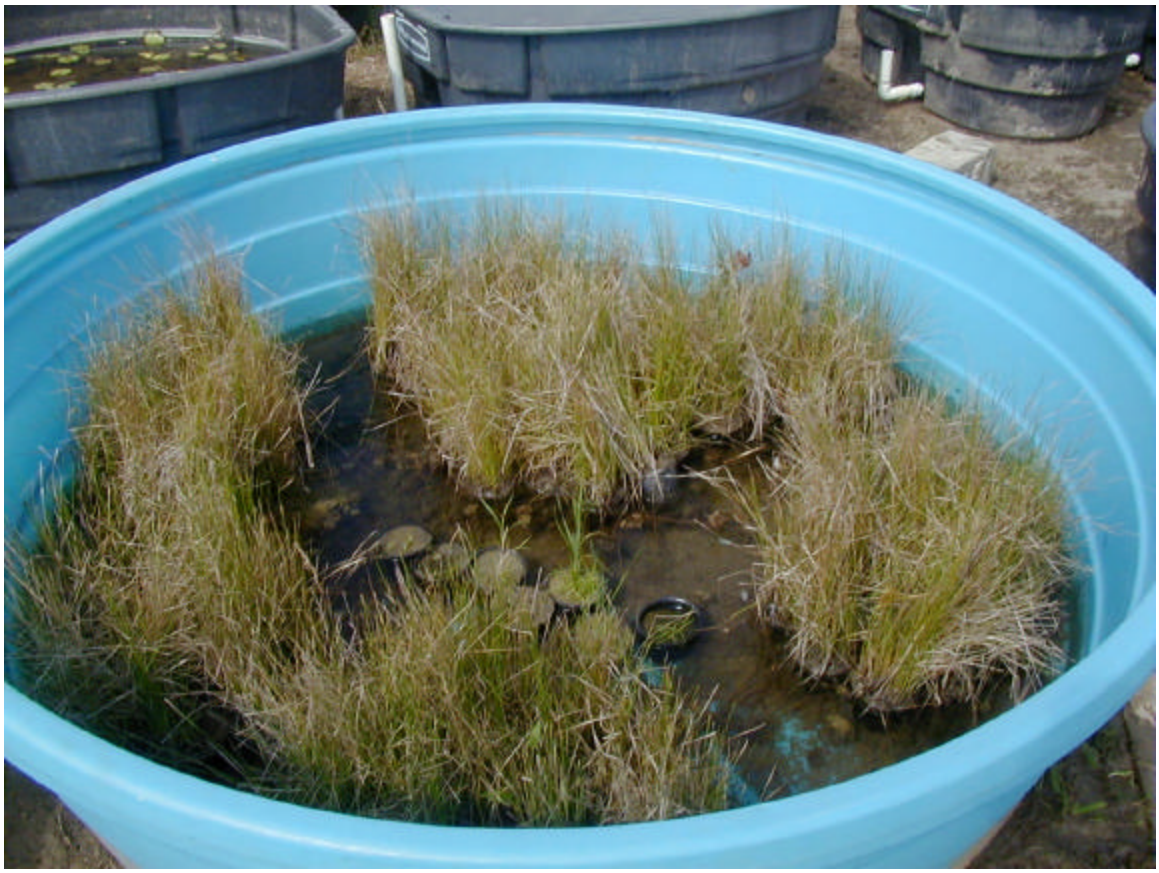


Figure 6. Average percent light transmission for the seven water depths after one, three, five, and seven weeks of seed germination

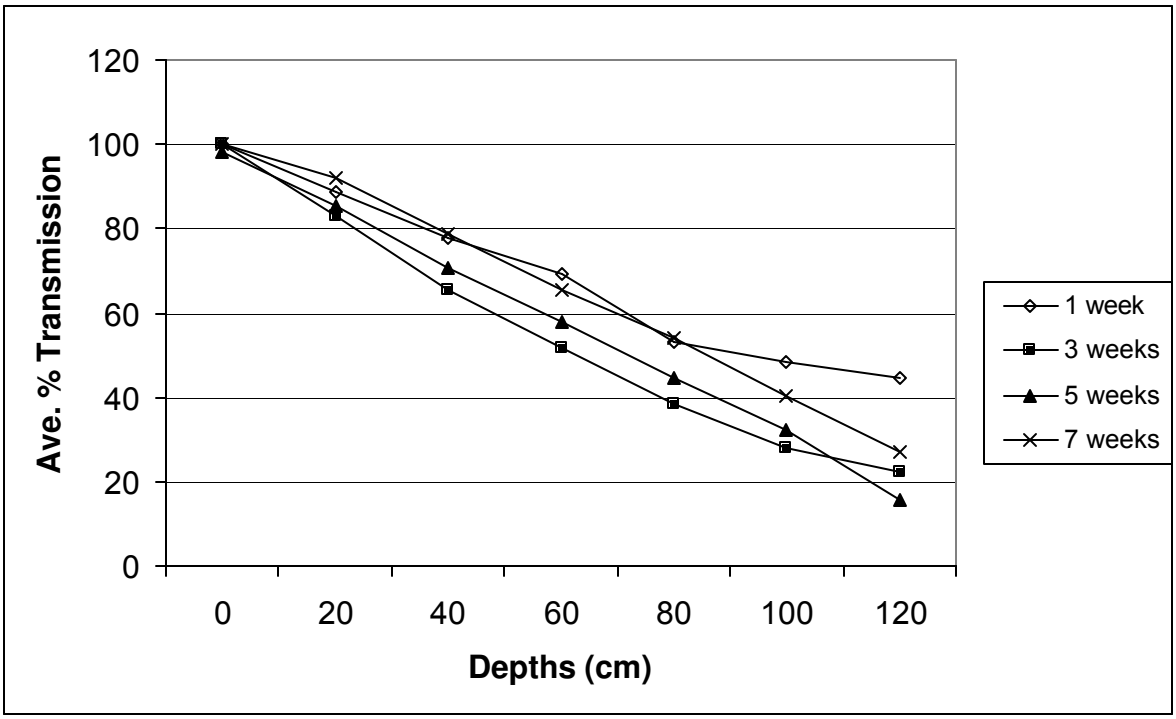


Figure 7. Final above, below, and total mean biomass of *T. latifolia* for seven water depths

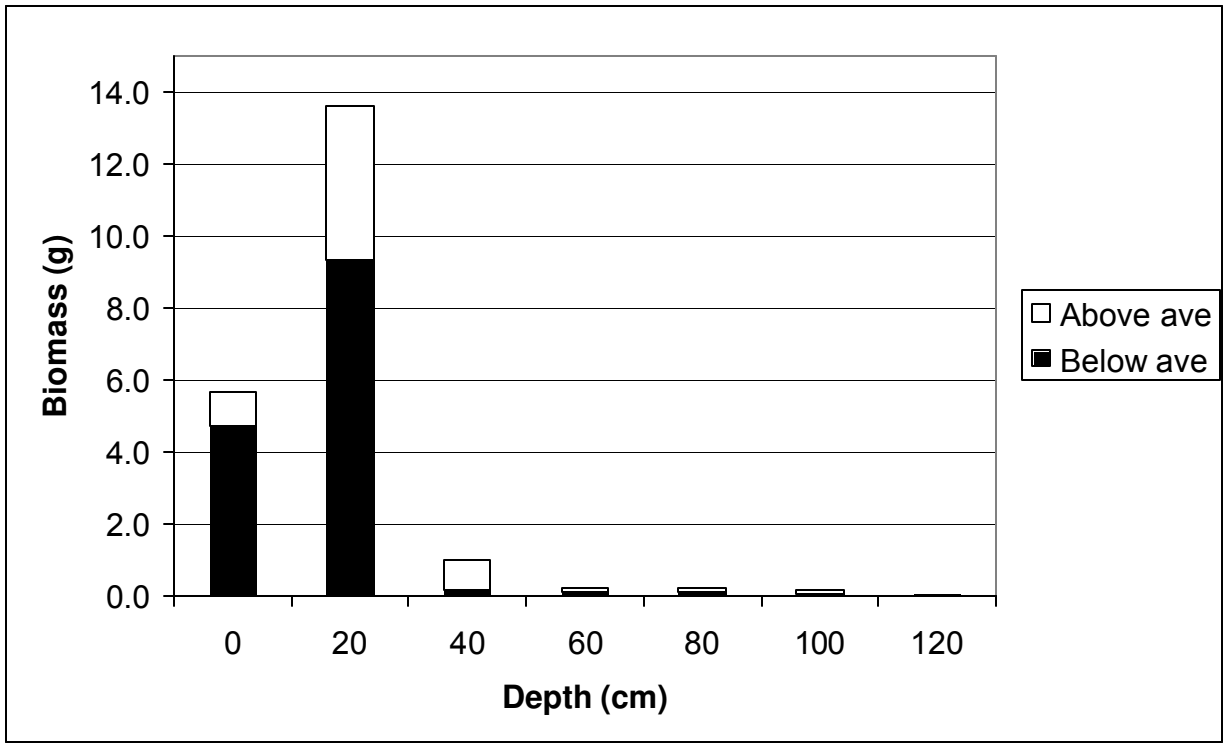


Figure 8. Total percent seed germination at each water depth after two, three, and six weeks

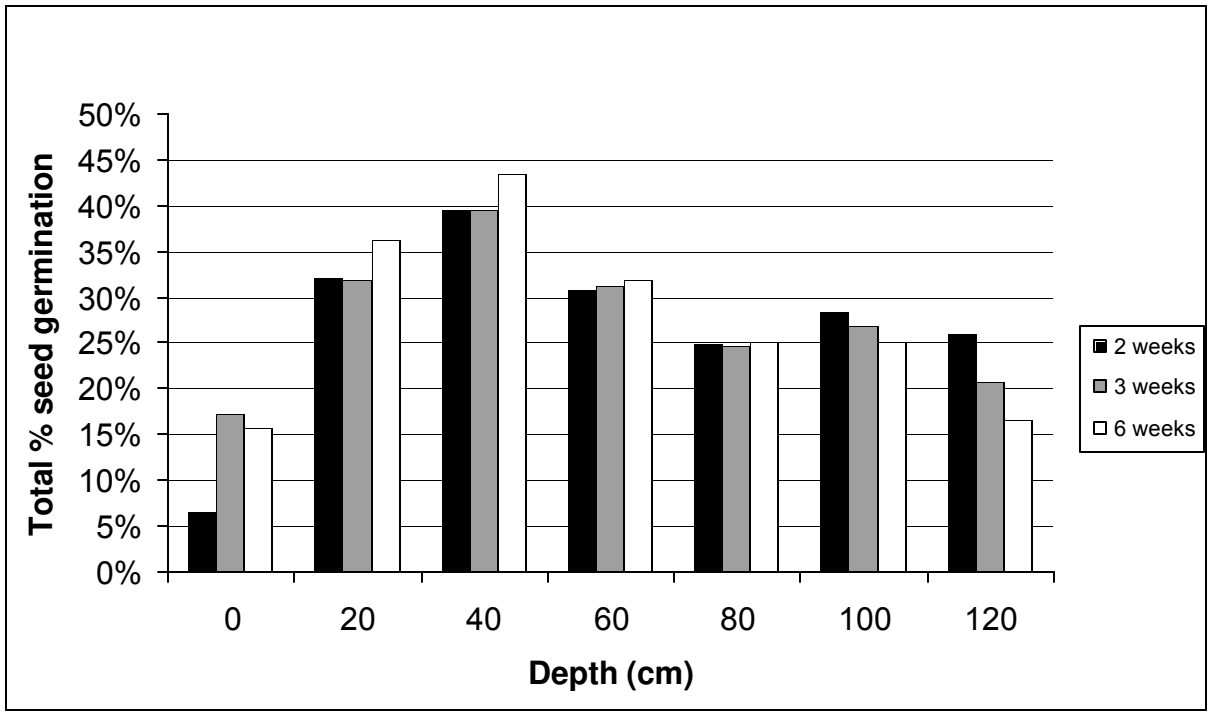


Figure 9. Dry pond at the LAERF for the moist soil management study from May to October 2002

Figure 10. Low pool pond at the LAERF for the moist soil management study from May to October 2002

Figure 11. Full pool pond at the LAERF for the moist soil management study from May to October 2002

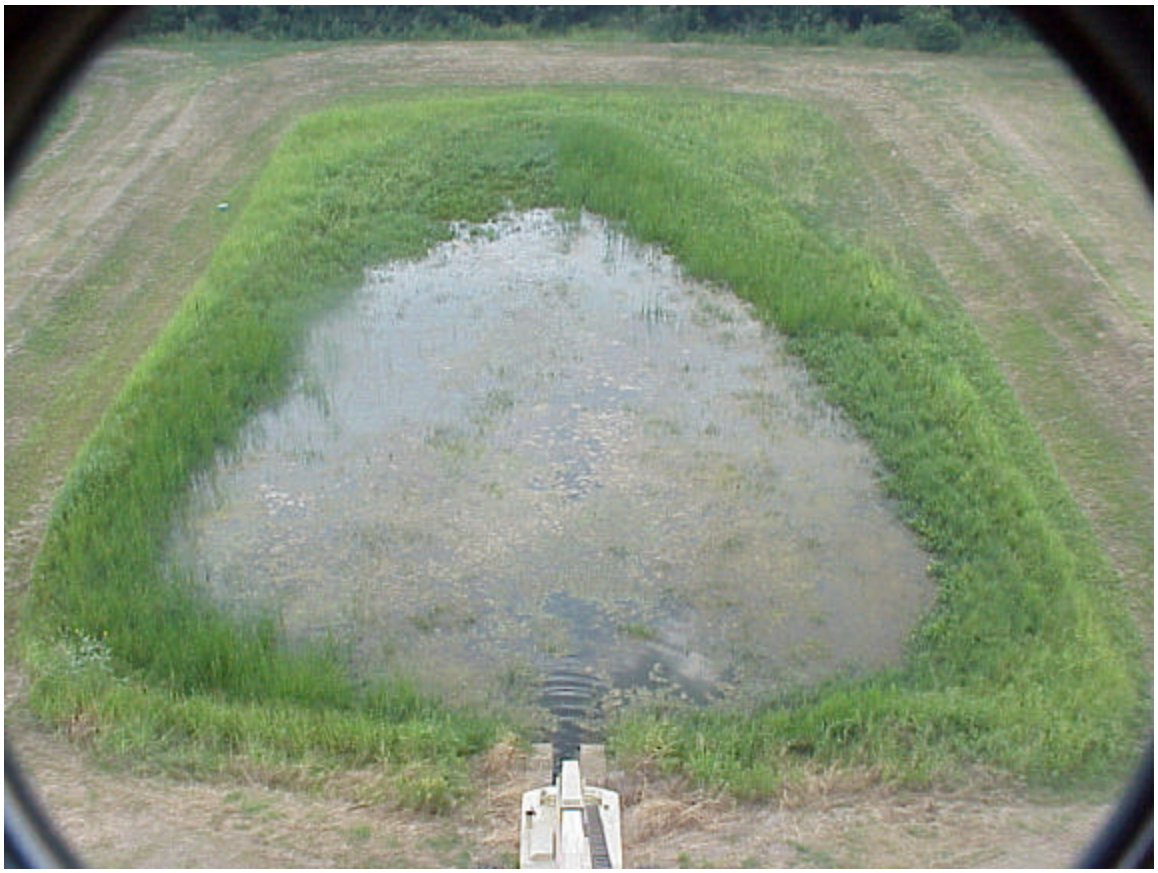


Figure 12. Total cattail seedlings harvested during the moist soil management study from June to October 2001

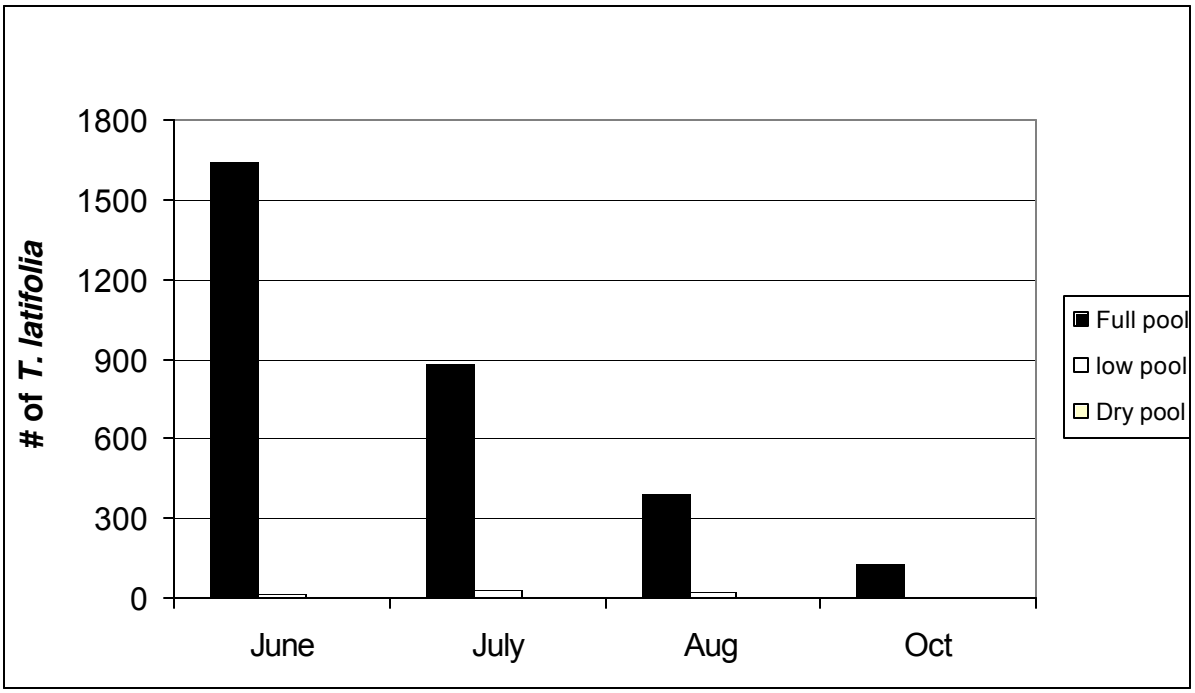
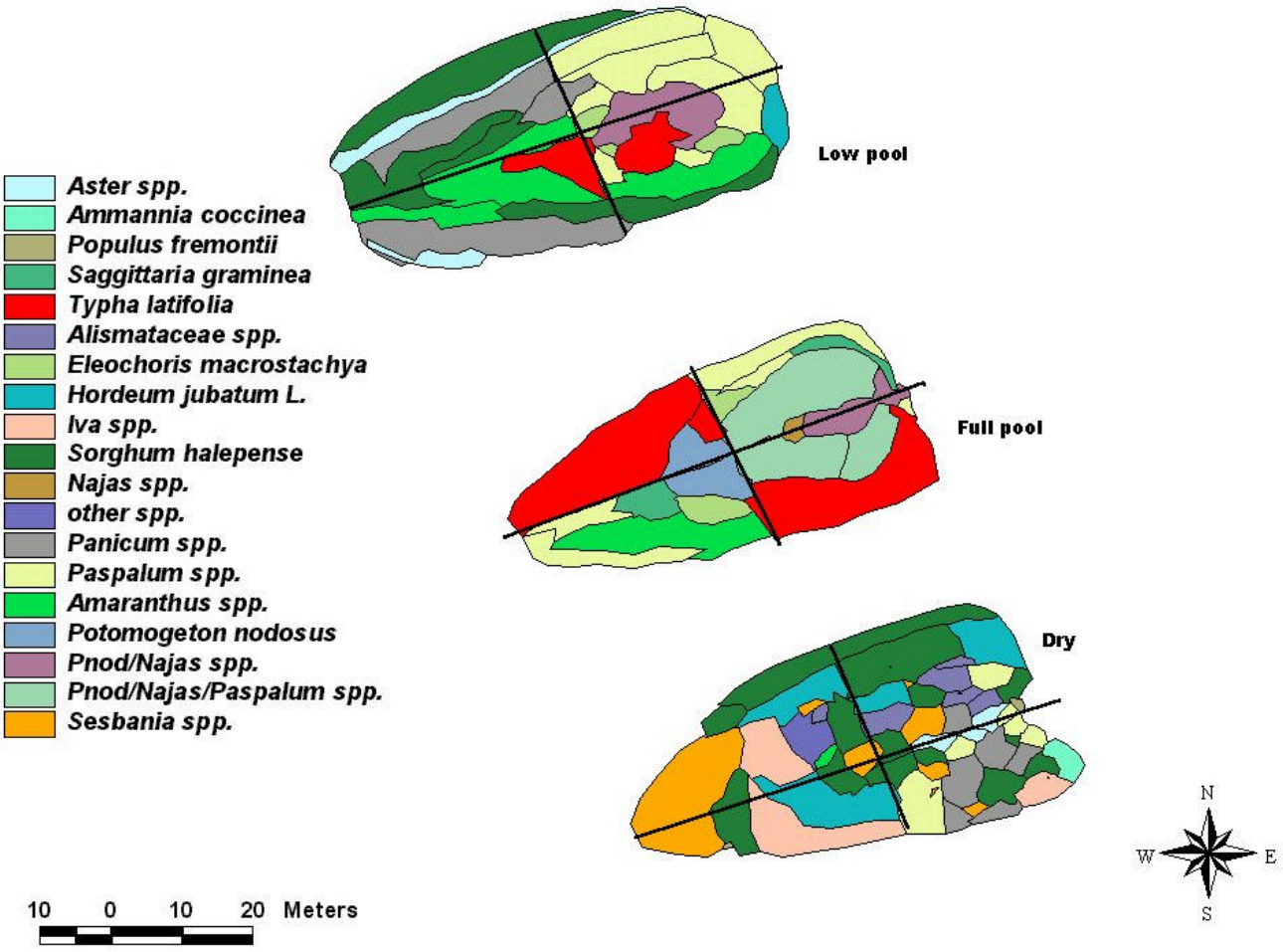


Figure 13. Plant distributions of a dry, full pool, and low pool pond at the Lewisville Aquatic Environmental Research Facility



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