Appendix 5C-5: Evaluation of Inundation Depth and Duration Threshold for Cattail Sustainability: In Situ Study

Orlando A. Diaz

INTRODUCTION

Cattail species (*Typha domingensis* and *Typha latifolia*) are flood tolerant plants that can be found under a wide range of hydrological regimes. When grown in monocultures under controlled water depths such as in the stormwater treatment areas (STAs), *T. domingensis* and *T. latifolia* both grow optimally at 22 ± 5 centimeters (cm) depth (Redwine 2008, Chen et al. 2010). However, other studies suggest that the optimal water depth for *T. domingensis* is 30 to 60 cm (Newman et al. 1996, Grace and Wetzel 1998, White et al. 2007). Miao and Zou (2012) reported that *T. domingensis* plants grown in 20-cm water depth produced significantly greater biomass than those grown in 60-cm water depth after a year. A mesocosm study conducted in STA-1 West (STA-1W) reported that, after three years, *T. domingensis* communities grown in 40-cm water depths were healthy and maintained their high productivity and ecological functions (Miao 2014). Fluctuating water levels are a common occurrence in wetlands, which, depending on the amplitude of cyclic water level fluctuations, can influence growth and productivity of emergent macrophytes (Edwards et al. 2003, Deegan et al. 2007). Harris and Marshall (1963) reported that cattail plants died after they were continuously flooded for 2 to 4 years at water depths ranging from 30 to 100 cm. Deegan et al. (2007) reported that *T. domingensis* responded negatively to water level fluctuations around an initial water depth of 60 cm. Biomass of *T. domingensis* did not change at three water fluctuations treatments (static, ± 15, and ± 30 cm, each cycling over a 40-day period). However, biomass decreased by 52% when the amplitude of water fluctuation increased to ± 45 cm.

Inundation exceeding the optimal depth and duration causes increasing physiological stress to cattail plants, reducing growth and anchorage capacity by decreasing biomass allocation to rhizomes and roots (Grace and Wetzel 1982). Several studies have suggested that *T. domingensis* is stressed at water depth greater than 60-cm with an inundation duration ranging from a few weeks to more than a year (Grace 1989, Miao and Zou 2012). Grace (1989) reported that the density of *T. domingensis* plants decreased at water depths greater than 58 cm. Miao and Zou (2012) reported that *T. domingensis* plants in a mesocosm study using a flow-through system, with low phosphorus (P) water from STA-1W, showed approximately 50% mortality after one year when subjected to an inundation depth of 60 cm. Other studies (Chen et al. 2010, 2013) in the Everglades STAs showed that increasing inundation depths from 40 to 137 cm for six weeks significantly decreased growth, biomass, photosynthesis, and belowground non-structural carbohydrate storage of *T. domingensis*. When water depths from different treatments returned to 40 cm for a 4-week recovery period, damage to roots and belowground biomass to cattail plants stressed at water depths < 90 cm was reversed, however, damage to cattail plants stressed at 137-cm water depth was not reversed. Increasing inundation also reduces the anchorage capacity of cattails, sometimes resulting in floating cattail mats as plants respond to deep inundation by decreasing biomass allocation to rhizomes and roots and increasing allocation to shoots (Grace 1989, Chen et al. 2010, Miao and Zou 2012).

The primary objective of the in situ study was to identify field conditions such as water depth, duration, and frequency of inundation as primary factors affecting the health of cattail populations in the selected STAs. Results from the in situ study will serve as a basis in the experimental design of the next phase of this study (the Test Cell Study), aimed at establishing an inundation depth and duration threshold, which is expected to start in late 2018. The overall hypotheses that will be evaluated by the cattail study are (1) there is an inundation duration threshold for cattail sustainability at a specific inundation depth, in terms of survival, growth, and propagation, (2) the inundation duration depth threshold is longer at relatively shallow inundation depth than at deep inundation conditions, and (3) longer inundation durations than the threshold results in a decline in cattail growth, in terms of plant density, the ability to propagate, and biomass. The results of these studies will help identify the depth and duration threshold for cattail sustainability that will assist in the development of water level management strategies in the STAs. Data presented in this report correspond to the first year (2015) wet season cattail monitoring of the in situ study. Field monitoring and data collection for the in situ portion of the study are continuing until December 2017. Additional data and further interpretation will be included in next year's report.

METHODS

STA-1W Cell 2A and STA-3/4 Cell 2A, both emergent aquatic vegetation (EAV) cells were selected for the in situ study (**Figure 1**). STA-1W Cell 2A is a cell with an effective treatment area of 284 hectares dominated by *T. domingensis*. The cattail population in this cell has been in decline during the last few years, even though the cell was rehabilitated in 2006–2007. Aerial observations from helicopter flights in WY2015 reported that cattail density was poor and a large portion of the cell had floating mats and primrose willow (*Ludwigia* spp.), with cattail coverage progressively declining due to the expansion of pennywort (*Hydrocotyle* spp.) mats (Pietro 2016).

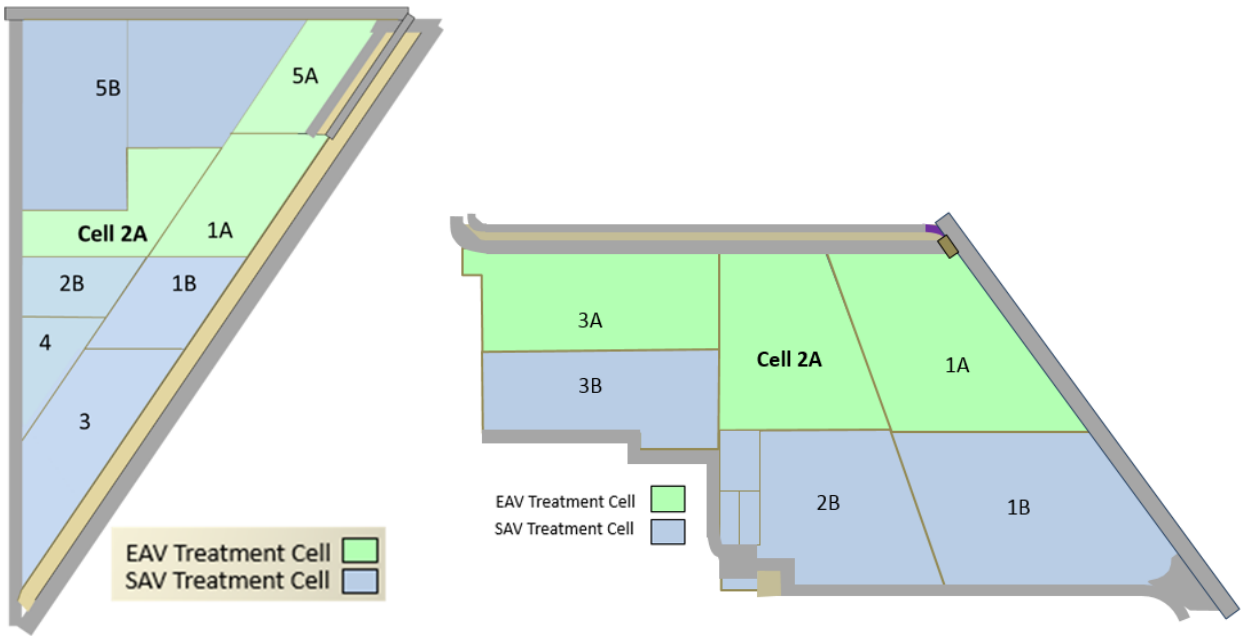

Figure 1. Schematic maps of STA-1W (left) and STA-3/4 (right). In situ monitoring and measurements for the Cattail Study were conducted in STA-1W Cell 2A and STA-3/4 Cell 2A, where widespread cattail losses have been observed in the past.

STA-3/4 Cell 2A has an effective treatment area of 1,014 hectares with a healthy *T. domingensis* population during the first year of the study (2015 wet season). However, this cell has previously experienced a decline in cattail coverage and density, particularly in the inflow region, requiring a drawdown and rehabilitation in 2011 and 2013, with an improved cattail coverage after the drawdown of 2013. One of the operational issues in this STA, historically, was the inability to regulate the magnitude and durations of inflows. During heavy rain events and resulting runoff, the EAV cells (Cells 1A, 2A, and 3A) in this STA were exposed to high water depths for extended periods of time, negatively affecting cattail communities particularly in the inflow region of the cells. To alleviate this issue, the A-1 Flow Equalization Basin (FEB), a 15,000-acre aboveground storage reservoir, was constructed immediately north of STA-3/4 and started operations in Water Year 2016 (WY2016; May 1, 2015–April 30, 2016). The primary objective of this reservoir is to temporarily store stormwater runoff and reduce peak inflows to this STA during the wet season and to provide a source of water during the dry season to decrease the frequency of dryout conditions in this STA.

Twenty 2-meter (m) x 3-m plots were established in STA-1W Cell 2A (**Figure 2**) and fifteen plots of the same size were established in STA-3/4 Cell 2A (**Figure 3**) during summer 2014. Monitoring was conducted in July, September, and November 2015 in STA-1W Cell 2A, and in June, August, and October 2015 in STA-3/4 Cell 2A, representing wet season conditions. Findings from these events are included in this report. Monitoring continued in 2016 and 2017 for plots in STA-3/4 Cell 2A; data for those events will be reported in next year's South Florida Environmental Report (SFER). Field observations and parameters measured during each monitoring event included: plant density (adult and juvenile), photosynthesis, foliage area index (LAI), leaf elongation, and water depth using a graduated polyvinyl chloride (PVC) pole. Field observations included cattail damage and presence of floating mats, presence of other emergent or floating aquatic plants within the plots, and photo documentation of each plot. Photosynthesis, LAI, and leaf elongation monitoring data will be reported in next year's SFER.

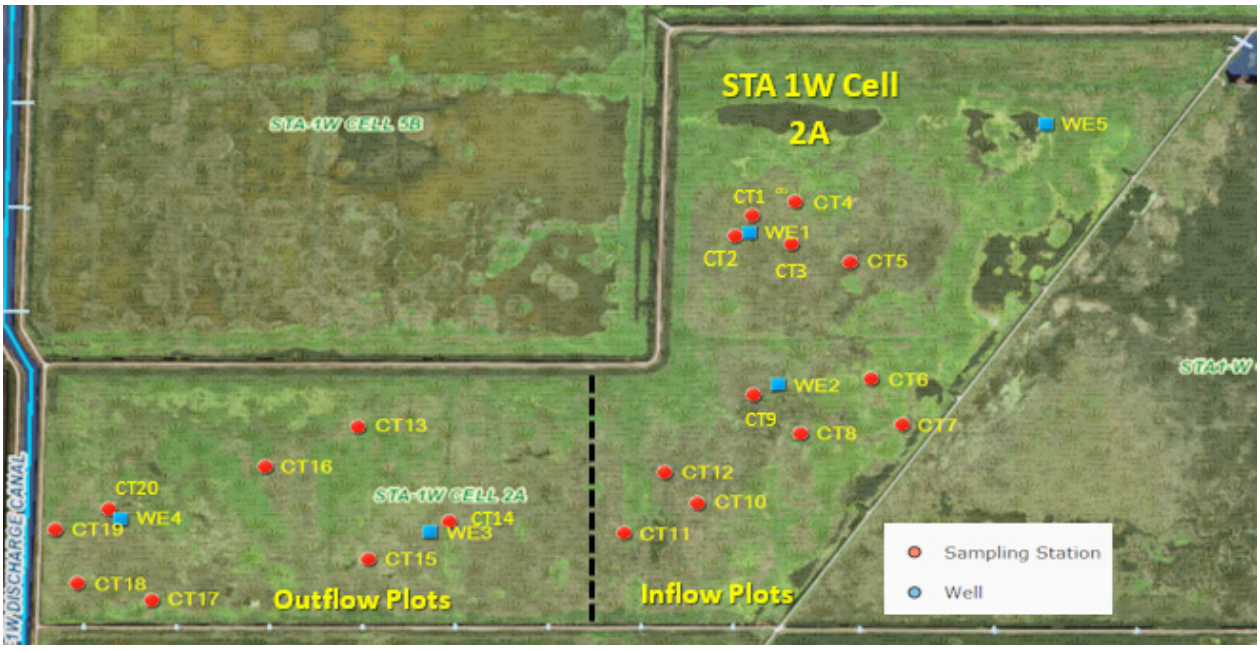

Figure 2. STA-1W Cell 2A survey plot (red) and water level logger (blue) locations.

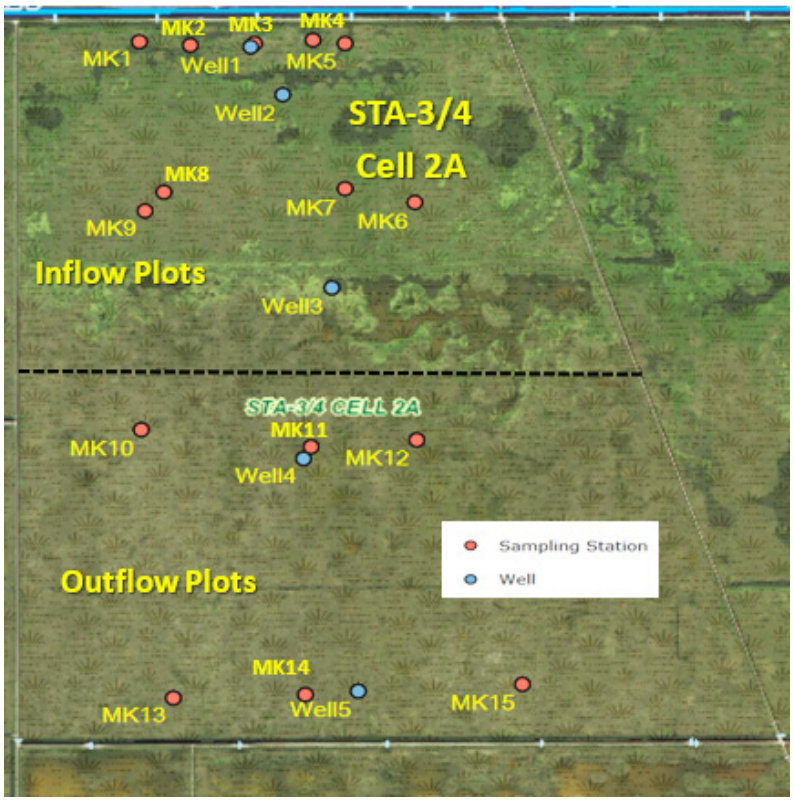

Figure 3. STA-3/4 Cell 2A survey plot (red) and water level logger (blue) locations.

The number of cattail plants within each plot was categorized into four groups: (1) live adults (> 1.5 m in height), (2) live juveniles (< 1.5 m in height), (3) live adults with flower or seed stalk, and (4) dead plants. Cattail shoot density was estimated as the number of plant shoots per square meter (m^2). Leaf elongation was measured on five recently emerged leaves from five healthy rooted cattail plants in each plot. After the cattail plants were selected, the selected young leaves were tagged with a brightly colored flagging tape. The length of the labeled leaves was measured at day 0 and remeasured between 7 to 10 days after the initial measurement. Leaf elongation rate was calculated by dividing the change in height by the number of days between measurements. Photosynthesis was measured using a LI-6400 XT Portable Photosynthesis System (Li-COR, Lincoln, Nebraska). LAI was measured using a LAI-2200C Plant Canopy Analyzer (Li-COR, Lincoln, Nebraska).

Samples were also collected for plant biomass, including aboveground and belowground, and live and dead materials from a 0.25-m^2 quadrat (0.5 m x 0.5 m) in an area adjacent to the experimental plot. Baseline or initial biomass samples of plots from STA-3/4 Cell 2A and STA-1W Cell 2A were collected in November and December 2014, respectively. A second and final biomass sampling was conducted in September and October 2015 in plots in STA-1W Cell 2A and STA-3/4 Cell 2A, respectively.

Daily stages from WY2011 to WY2016 for STA-1W Cell 2A and STA-3/4 Cell 2A were estimated from the South Florida Water Management District's (SFWMD's or District's) corporate environmental database, DBHYDRO, by averaging the daily average stage at the inflow (tailwater [TW]) of structure G-255 and outflow (headwater [HW]) of structure G-249 for STA-1W Cell 2A and daily inflow TW stages of structure G-377 and outflow HW stages of structure G-378 for STA-3/4 Cell 2A. Daily average water depths (cm) for each cell were calculated by subtracting the average ground elevation in National Geodetic Vertical Datum of 1929 (NGVD29, Piccone et al. 2014) from the daily stage values. In addition, continuous water depths at 30-minute intervals were monitored using water level loggers. Five *Solinst* water level

logger stations were deployed across STA-1W Cell 2A on April 30, 2015. Five *Solinst* water level logger stations were deployed in STA-3/4 Cell 2A on July 18, 2015.

Statistical data analysis was performed using JMP® statistical software (Version 12.1.0, SAS Institute Inc. 2015, Cary, North Carolina). Experimental plots in Cells 2A of STA-1W and STA-3/4 were grouped into inflow and outflow regions for statistical analysis purposes, due to general observation of deeper water depths in the inflow region of many EAV cells. Summary statistics and frequency distribution for water depth were calculated. Plant biomass and cattail density data were tested for normality of distribution and for equal variances to determine the proper test to compare means. Parameters that met the assumptions for parametric analysis were compared using the pooled t-test. Parameters that did not meet the assumptions for parametric analysis were compared using the non-parametric Wilcoxon Rank Sum Test. Due to the small number of observations in the first year of monitoring, the results of the statistical analysis must be used with caution.

RESULTS AND DISCUSSION

STA-1W CELL 2A

Daily Water Depths

The annual average of daily water depths in STA-1W Cell 2A from WY2011 to WY2016 (May 1, 2010, to April 30, 2016) were 60, 56, 60, 57, 57, and 53 cm, respectively (**Table 1**). Generally, water depths in this cell consistently exceeded the target stage, except in early June to early July 2011 due to a regional drought and from early March to mid-July 2015, when water levels were lowered for vegetation rehabilitation in the Eastern Flow-way. Calculated daily water depths from this cell were very similar, suggesting that water depths across the cell were uniform (**Figure 4**). More than 60% of the time, the daily water depths ranged from 38 to 61 cm, while water depths above 76 cm accounted for less than 12% of the total number of days (**Table 2**). Daily water depths > 91 cm were rare, accounting for only 3.5% of the total number of days, occurring primarily during high flow events such as those associated with the Tropical Storms Isaac and Andrea.

Average daily water depths during the 2015 cattail monitoring wet season in this cell were also monitored using *Solinst* water level loggers with the objective of monitoring in-field water depth variability in the different regions of the cell. Daily average water depths from the five water level loggers matched closely with each other (**Figure 5**) and with the inflow and outflow water depths calculated with DBHYDRO, corroborating that water depths across the entire cell were uniform. Daily water depths from all water level loggers were averaged to represent a daily average water depth across the entire cell. Water depths of water-level loggers from May 1, 2015, to December 31, 2015, indicated that 47% of the daily water depths in that cell ranged from 38 to 61 cm, with only 9.3% of the monitored days showing water depths > 76 cm.

Table 1. Summary statistic from inflow and outflow water depths from STA-1W Cell 2A.

Water Year [a]	Inflow Water Depth (cm)				Outflow Water Depth (cm)			
	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
WY2011	60	15	41	104	59	13	42	96
WY2012	56	14	31	105	55	12	30	87
WY2013	61	18	38	125	58	15	41	116
WY2014	59	17	37	111	55	16	37	109
WY2015	58	15	32	105	56	14	32	95
WY2016	52	19	17	126	53	15	30	120

a. Data range: May 1, 2010–April 30, 2016.

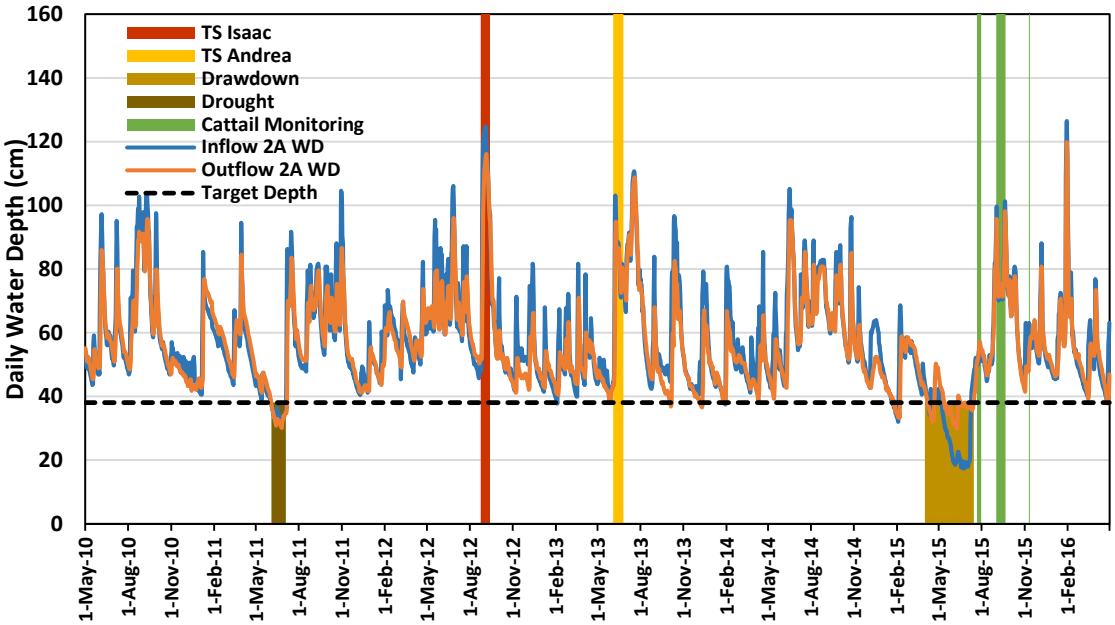

Figure 4. Daily water depths in STA-1W Cell 2A from WY2011 to WY2016, showing hydrologic events and cattail monitoring periods.

Table 2. Water depths ranges from STA-1W Cell 2A from WY2011-WY2016.

Water Year	Water Depth Range Categories (cm)				
	<38	38–61	61–76	76–91	> 91
	Days within the Depth Range Category [a]				
WY2011	0 (0.0%)	327 (64.9%)	82 (22.5%)	28 (7.7%)	18 (4.9%)
WY2012	32 (8.7%)	210 (57.4%)	99 (27.0%)	22 (6.0%)	3 (0.8%)
WY2013	0 (0.0%)	231 (63.3%)	87 (23.8%)	25 (6.8%)	22 (6.0%)
WY2014	1 (0.3%)	256 (70.1%)	55 (15.1%)	40 (11.0%)	13 (3.6%)
WY2015	24 (6.6%)	218 (59.7%)	74 (20.3%)	41 (11.2%)	8 (2.2%)
WY2016	61 (16.7%)	217 (59.3%)	57 (15.6%)	18 (4.9%)	13 (3.6%)

a. Number of days per range category with their respective percentage in parentheses.

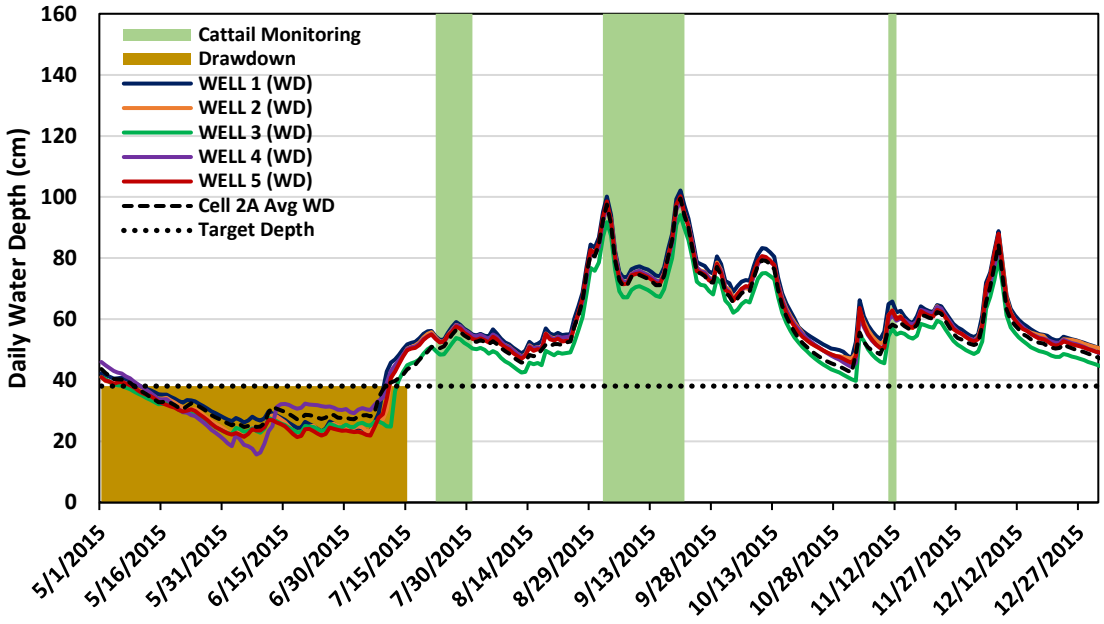

Figure 5. Daily average water depths from water level loggers deployed within STA-1W Cell 2A for the 2015 cattail monitoring season.

Cattail Density

Results from the first monitoring event from STA-1W Cell 2A indicate that cattail density in plots from the outflow region were significantly higher (probability [p] < 0.05) than cattail density from plots from the inflow region (**Figure 6**). The same significant results were observed with the number of live adult shoots and the number of dead shoots per square meter (shoots/m^2). Average total shoot densities during the first monitoring event from this cell were 3.6 and 6.1 shoots/m^2 from plots in the inflow and outflow regions, respectively, which are low compared to other studies. Toth and Galloway (2009) reported cattail densities of 5.7 to 13.6 shoots/m^2 in a study of cattail expansion in the STAs, while Chen and Vaughn (2014) reported a density of 6 to 15 cattail shoots/m^2 in a cattail study in STA-1 East (STA-1E). Average total shoot densities from the inflow and outflow regions during the second monitoring event were not significantly different ($p > 0.05$), averaging 5.2 and 6.1 shoots/m^2, respectively, which are also considered low. Dead shoots/m^2 was the only measured cattail parameter that showed significant differences between the inflow and outflow regions ($p < 0.05$). This significant difference may be due to the presence of cattail floating mats and the overall decline of the cattail population in the entire cell. Floating mats are macrophytes and/or substrates held together by live and dead roots that float within the water column that lack connectivity with bottom sediments to restrict vertical movement in response to fluctuations in water level or changes in buoyancy (Clark 2000). The total number of cattail shoots/m^2 from plots in the inflow and outflow regions were also not significantly different ($p > 0.05$) during the third monitoring event. Dead shoots/m^2 was the only cattail measured parameter that showed significant differences between the inflow and outflow regions, with the number of dead shoots from plots in the outflow region significantly higher ($p < 0.05$) than dead shoots from plots in the inflow region. This difference in dead shoots may be due to higher average water depths in the plots in the outflow region due to microtopography in the cell or the presence of higher percentage of cattail floating mats in the outflow region and the overall decline in cattail population in this cell. Average shoot densities during the third monitoring event from this cell were 4.5 and 5.5 total shoots/m^2 from the plots in the inflow and outflow regions, respectively, which are also considered low compared to the studies cited above.

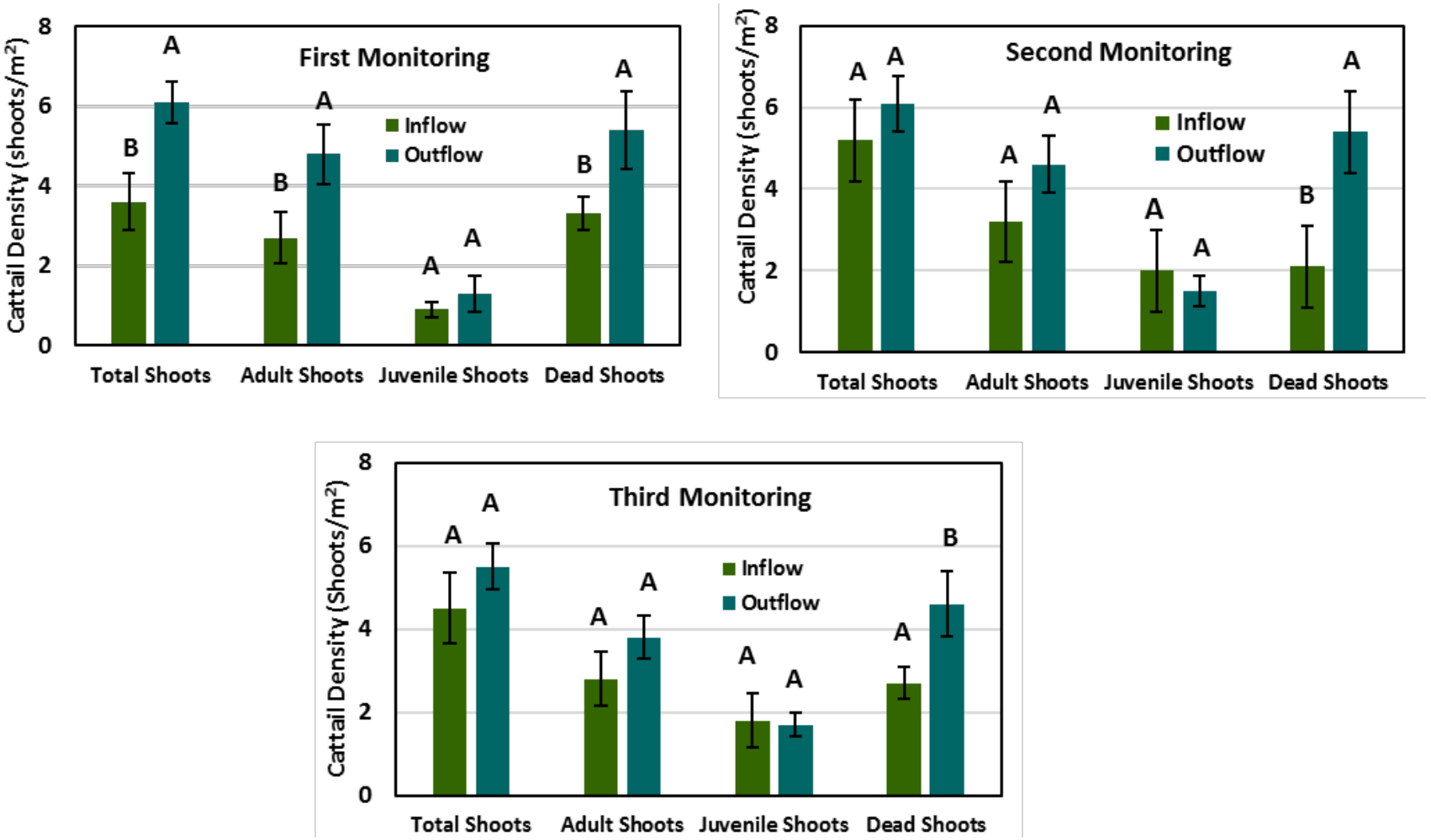

Figure 6. Cattail density parameters (mean ± standard error) in STA-1W Cell 2A from monitoring events in July, September, and November 2015. Mean differences with the same letter are not significantly different at the 0.05 probability level.

Cattail Biomass

In STA-1W Cell 2A, total biomass of the different plant components in the initial sampling in December 2014 were slightly higher in the plots from the outflow region compared to the inflow region; however, the differences were not significantly different at the 0.05 probability level (**Figure 7**). In contrast, results from the final sampling in September 2015 showed that the total biomass from plots in the inflow region were slightly higher than the total biomass from plots in the outflow region, but the differences were not significantly different at the 0.05 probability level, except for root biomass. There was no change in the below ground biomass/leaf ratio from the inflow (1.36) and outflow (1.35) regions in the first sampling, and a slight decrease in the second biomass sampling from the inflow (0.40) to the outflow (0.24). Flooding depth has been reported to affect total live aboveground and belowground biomass in cattail plants (Grace 1989, Chen et al. 2010). However, based on the daily water depths from WY2011 to WY2016 calculated using stage data from the DBHYDRO database and the average ground elevation, all plots in this cell have been exposed to the same water depths, assuming minimal variation in the topography across the cell.

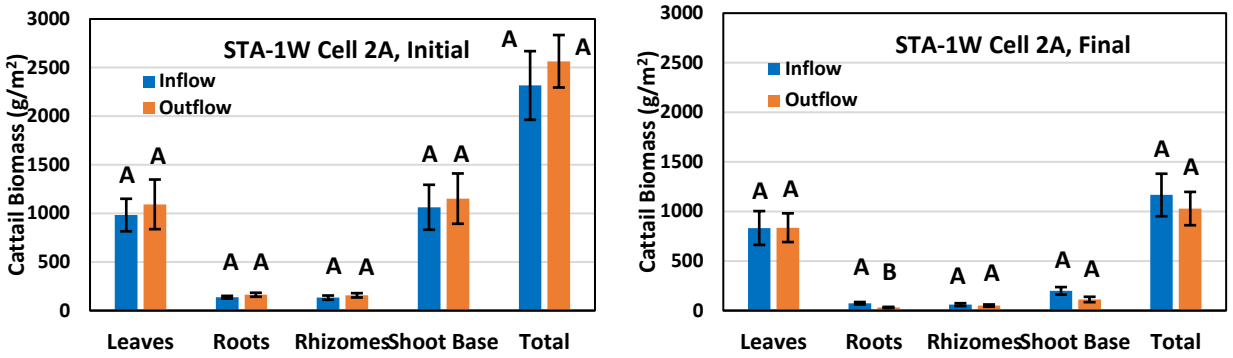

Figure 7. Cattail biomass (mean ± standard error) from the inflow and outflow regions of the in situ study, collected in December 2014 and September 2015 in STA-1W Cell 2A. Means with the same letter are not significantly different at the 0.05 probability level.

Comparison of total plant biomass from the initial and final biomass samplings showed that biomass from the different plant components of the initial sampling were significantly higher ($p < 0.05$) than biomass from the final sampling (**Figure 8**). The average total live biomass from the initial sampling in December 2014 (2,416 grams per square meter [g/m^2]) was significantly higher than total live biomass from the final sampling in September 2015 (1,111 g/m^2). There was also a notable change in biomass distribution in terms of aboveground and belowground biomass with the initial sampling consisting of 42.5% leaves and 57.5% belowground biomass. In contrast, total biomass from the final sampling consisted of 75% leaves and 25% belowground biomass. Total biomass from the initial sampling was slightly lower than the total biomass reported in a cattail study in STA-1E (Chen and Vaughan 2014), and slightly higher than total biomass in a cattail study in Water Conservation Area 2A (Miao and Sklar 1998). Since water depth was assumed to be generally uniform across the STA-1W Cell 2A, one of the possible factors responsible for the difference in plant biomass from both sampling events is the continuous inundation of the cell above the target depth without rest periods (or depths below target depth) and the presence of floating cattail mats or floating tussocks that may have contributed to the overall decline in cattail population in this cell. Cattail plants growing in this cell appear to be healthy without any visible signs of diseases.

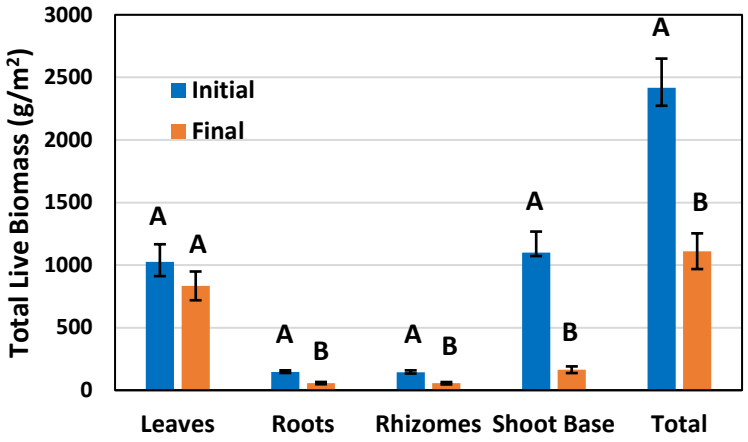

Figure 8. Total biomass (mean ± standard error) of samples collected in December 2014 (initial) and September 2015 (final) biomass from STA-1W Cell 2A. Mean differences with the same letter are not significantly different at the 0.05 probability level.

STA-3/4 CELL 2A

Daily Water Depths

Daily average water depths in the inflow region of STA-3/4 Cell 2A were consistently higher at the inflow region, compared to water depths in the outflow region of the cell (**Figure 9**). During high flow events, vegetation density, plant architecture, and microtopography are important parameters contributing to flow resistance, which in EAV cells with dense cattail stands can result in increased water depths at the inflow region of the cells (Lal 2017). Annual average water depths from WY2011 to WY2016 in the inflow region were 68, 60, 67, 50, 67, and 77 cm, respectively, and 52, 42, 51, 41, 48, and 54 cm in the outflow region, respectively (**Table 3**). Daily average water depths during this period were generally greater than the target depth of 38 cm for EAV cells, except from October 2010 to June 2011 during a regional drought during which all cells dried out (Ivanoff et al. 2013), and from January to June 2013, because of a drawdown for vegetation rehabilitation (Chimney 2014).

In the inflow region, 42% of the daily average water depths ranged from 38 to 61 cm, while daily average water depths > 91 cm accounted for 13.3% of the total number of days in the period of record (POR) studied (**Table 4**). In contrast, in the outflow, region 61% of the daily average water depths ranged from 38 to 61 cm, while daily average water depths > 91 cm accounted for only 3.2% of the total number of days in this POR (**Table 5**). Average daily water depths during the 2015 cattail monitoring season period in STA-3/4 Cell 2A were also monitored using *Solinst* water level loggers to evaluate in field water depth variability in the cell. Daily average water depths from five water level loggers deployed within the cell showed the same pattern with greater depths in the inflow region compared to the outflow region of the cell (**Figure 10**). To calculate water depth ranges, data from water level loggers 1, 2, and 3 (Wells 1, 2, and 3) were averaged to represent average water depths for the inflow region of the cell, and water level loggers 4 and 5 (Wells 4 and 5) were averaged to represent average water depths for the outflow region of the cell. Water level logger data from July 7, 2015, to February 23, 2016, showed that daily average water depths from the inflow region of the cell were > 61 cm and 62% of the total days were > 76 cm. In contrast, 81% of the daily water depths in the outflow region of the cell were between 38 to 76 cm and 19% were > 76 cm.

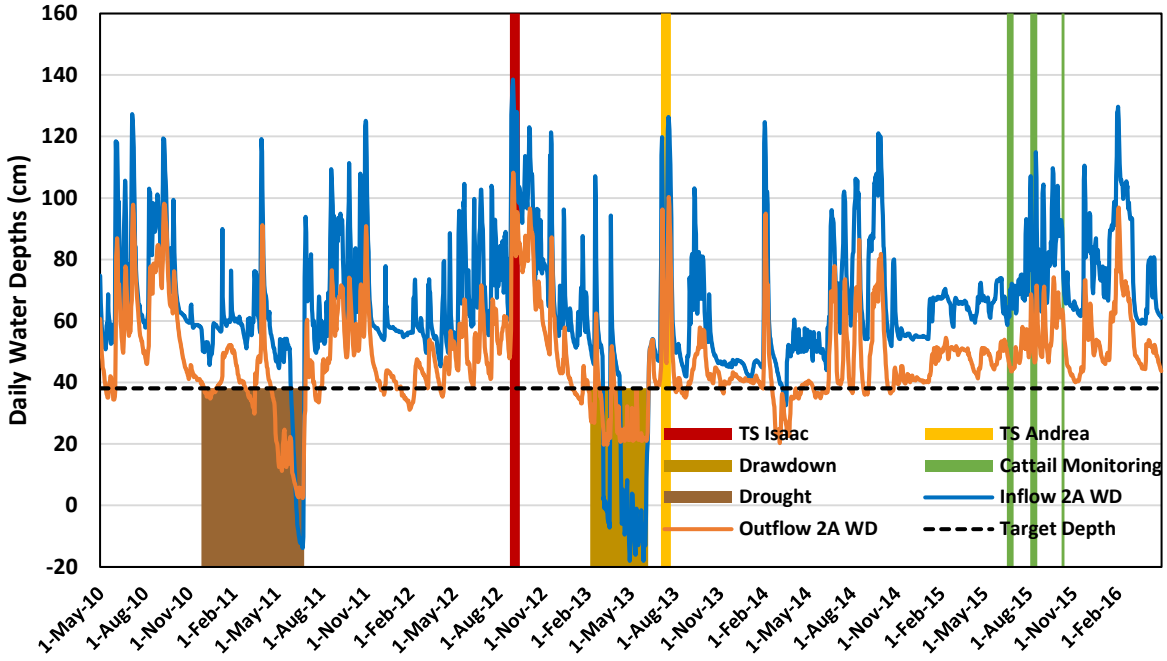

Figure 9. Daily water depths in STA-3/4 Cell 2A from WY2011 to WY2016, showing hydrologic events and cattail monitoring periods.

Table 3. Summary statistic from inflow and outflow water depths from STA-3/4 Cell 2A.

Water Year [a]	Inflow Water Depth (cm)				Outflow Water Depth (cm)			
	Mean	Standard Deviation	Minimum	Maximum	Mean	Standard Deviation	Minimum	Maximum
WY2011	68	17	46	127	52	17	21	98
WY2012	60	22	-14	125	42	17	2	91
WY2013	67	31	-18	139	51	19	20	108
WY2014	50	25	-18	126	41	14	20	100
WY2015	67	15	44	121	48	11	35	86
WY2016	77	15	59	130	54	10	40	97

a. Data range: May 1, 2010–April 30, 2016.

Table 4. Water depth ranges from the inflow region of STA-3/4 Cell 2A for WY2011–WY2016.

Water Year	Inflow Water Depth Range Categories (cm) [a]				
	< 38	38–61	61–76	76–91	> 91
	Days within the Depth Range Category [b]				
WY2011	0 (0.0%)†	184 (50.4%)	93 (25.5%)	35 (9.6%)	53 (14.5%)
WY2012	28 (7.7%)	204 (55.7%)	71 (19.4%)	36 (9.8%)	27 (7.4%)
WY2013	37 (10.1%)	101 (27.7%)	83 (22.7%)	65 (17.8%)	79 (21.6%)
WY2014	45 (12.3%)	254 (69.6%)	27 (7.4%)	17 (4.7%)	22 (6.0%)
WY2015	0 (0.0%)	155 (42.5%)	135 (37.0%)	33 (9.0%)	42 (11.5%)
WY2016	0 (0.0%)	22 (6.0%)	189 (51.6%)	85 (23.2%)	70 (19.1%)

a. Water depth ranges are based on stages from inflow structures.
b. Number of days per range category with their respective percentage in parentheses.

Table 5. Water depth ranges from the outflow region of STA-3/4 Cell 2A for WY2011–WY2016.

Water Year	Outflow Water Depth Range Categories (cm) [a]				
	< 38	38–61	61–76	76–91	> 91
	Days within the Depth Range Category [b]				
WY2011	68 (18.6%)†	198 (54.2%)	51 (14.0%)	33 (9.0%)	15 (4.1%)
WY2012	114 (31.1%)	202 (55.2%)	36 (9.8%)	6 (1.6%)	8 (2.2%)
WY2013	92 (25.2%)	173 (47.4%)	46 (12.6%)	37 (10.1%)	17 (4.7%)
WY2014	117 (32.1%)	220 (60.3)	9 (2.5%)	7 (1.9)	12 (3.3%)
WY2015	53 (14.5%)	258 (70.7%)	42 (11.5%)	7 (1.9%)	12 (3.3%)
WY2016	0 (0.0%)	286 (78.1%)	69 (18.9%)	5 (1.4%)	6 (1.6%)

a. Water depth ranges are based on stages from outflow structures.
b. Number of days per range category with their respective percentage in parentheses.

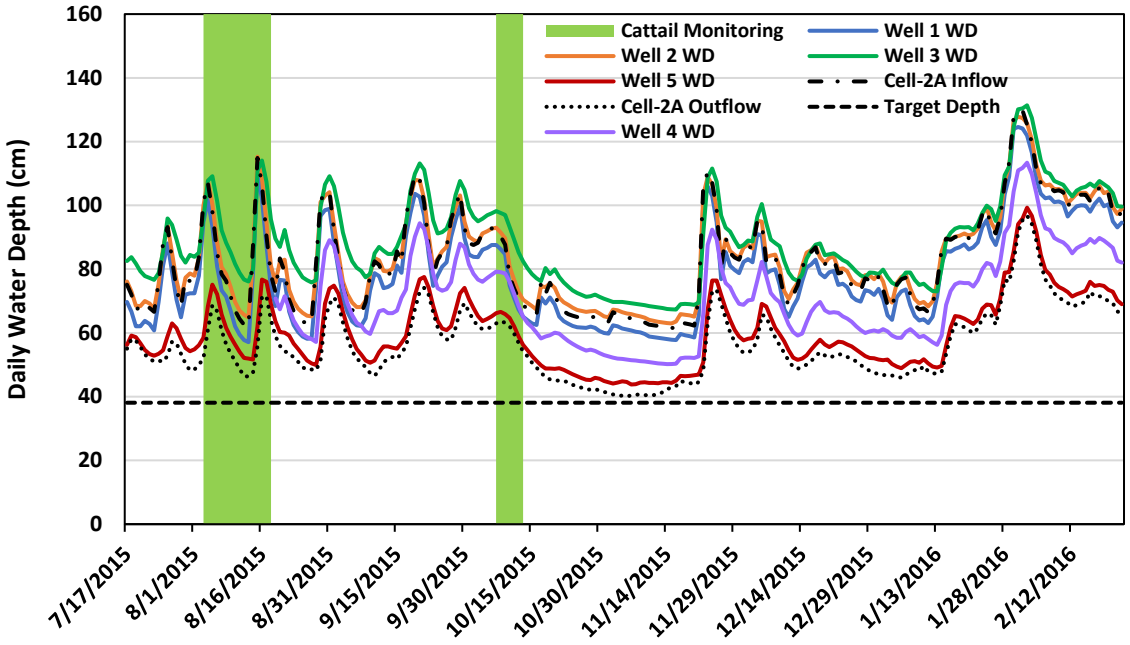

Figure 10. Daily average depths from water level loggers deployed within STA-3/4 Cell 2A for the 2015 cattail monitoring season.

Cattail Density

Cattail densities of monitoring plots from STA-3/4 Cell 2A were consistently higher than densities reported from STA-1W Cell 2A, and remained constant throughout the entire 2015 wet monitoring season. The cell had recently undergone a rehabilitation that involved drawdown to encourage regrowth of cattails. Results from the first monitoring event showed that the total number of shoots/m^2 from plots in the inflow and outflow regions were not significantly different ($p > 0.05$, **Figure 11)**. Density of adult shoots/m^2 was the only measured cattail parameter significantly different, with plots from the inflow region indicating a higher density ($p < 0.05$) than the outflow region. Total cattail shoot density during the first monitoring event from this cell averaged 9.3 and 7.6 total number of shoots/m^2 for plots in the inflow and outflow regions, respectively, which are higher than those reported in STA-1W Cell 2A but within the range of values reported by Toth and Galloway (2009) and Chen and Vaughn (2014). The higher daily average water depths in the inflow region did not have an observed negative effect on cattail density, although this event was completed at the beginning of the wet season when water depths from plots in the inflow and outflow regions averaged 50 and 42 cm, respectively.

The total cattail density from plots in the inflow and outflow regions were not significantly different ($p > 0.05$, **Figure 11**) during the second monitoring event. Dead shoot density was significantly higher in plots from the outflow region than in the inflow region ($p < 0.05$). None of the other measured cattail parameters were significantly different between the inflow and outflow regions. Average shoot densities during the second monitoring event were 9.6 and 9.3 cattail shoots/m^2 in plots from the inflow and outflow regions, respectively. Consistent with the results from the first two monitoring events, total shoot density of plots from the inflow and outflow regions during the third monitoring event were not significantly different at the 0.05 probability level. Average shoot densities during the third monitoring event were 9.0 and 9.7 shoots/m^2 from the inflow and outflow plots, respectively (**Figure 11**).

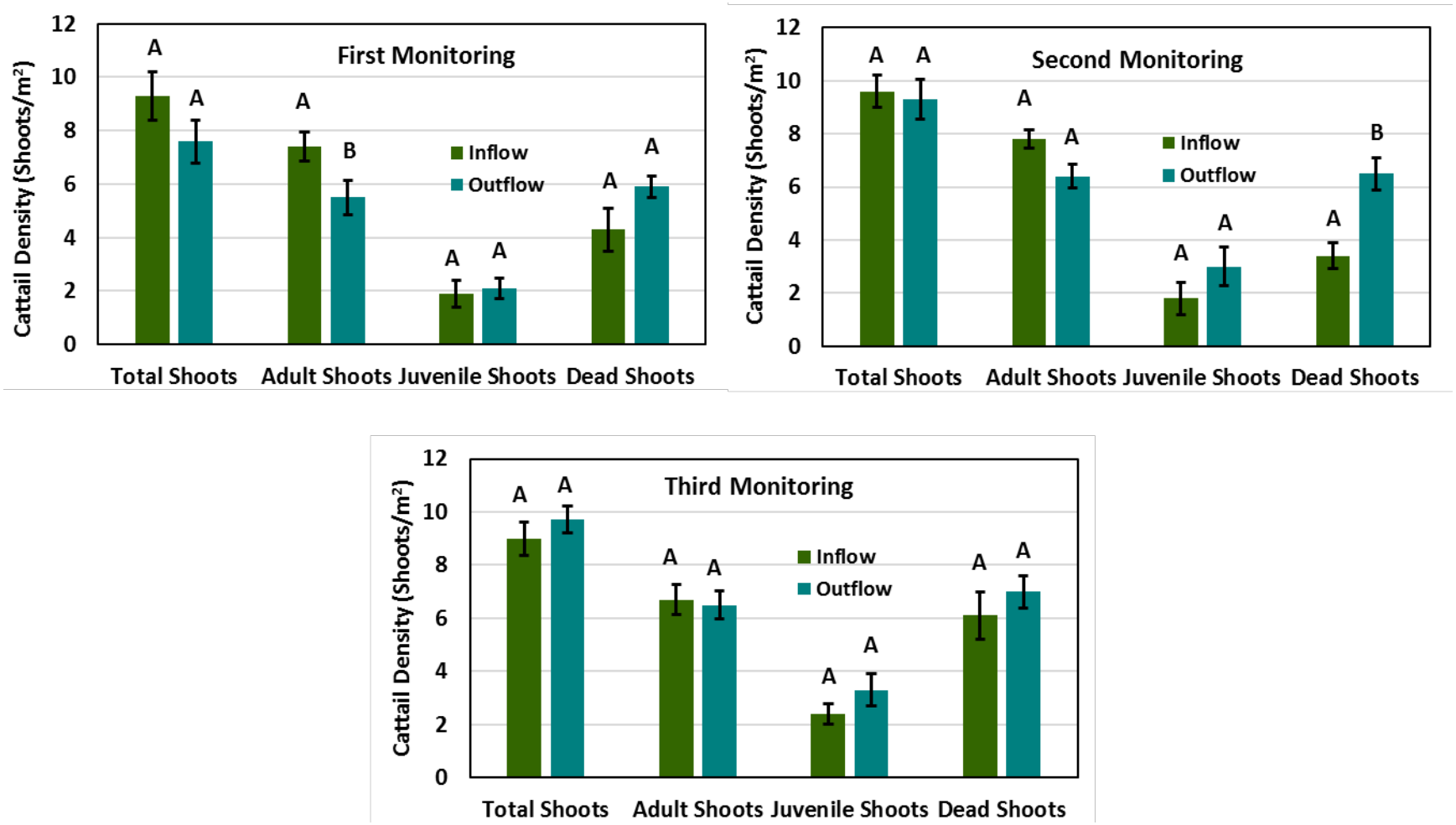

Figure 11. Cattail density parameters (mean ± standard error) in STA-3/4 Cell 2A from monitoring events in June, August, and October 2015. Mean differences with the same letter are not significantly different at the 0.05 probability level.

Cattail Biomass

Total biomass from the different plant components of samples collected in the initial sampling of November 2014 were slightly higher in the outflow region compared to the inflow region, except leaf biomass. However, the differences were not significant ($p > 0.05$). Similar results were observed in the biomass samples collected in the final sampling of October 2015, with total biomass from the outflow region slightly higher than total biomass from the inflow region. However, the differences were not significant ($p > 0.05$), except for root biomass ($p < 0.05$, **Figure 12**). The belowground biomass:leaf ratio in both sampling events were higher in the outflow than the inflow region; the initial sampling was 1.20 and 0.78 the final sampling was 0.51 and 0.28, at the outflow and inflow regions, respectively. A decrease in the belowground biomass:leaf ratio suggests that the roots and rhizomes of *T domingensis* were stressed more substantially than shoots in the inflow region of this cell. The daily water depths from STA-3/4 Cell 2A were consistently higher in the inflow region, with depths decreasing toward the outflow region of the cell (**Figure 9**). Chen et al. (2010) reported a decrease of approximately 80% of root and rhizome biomass on cattail plants flooded for six weeks at 137 cm.

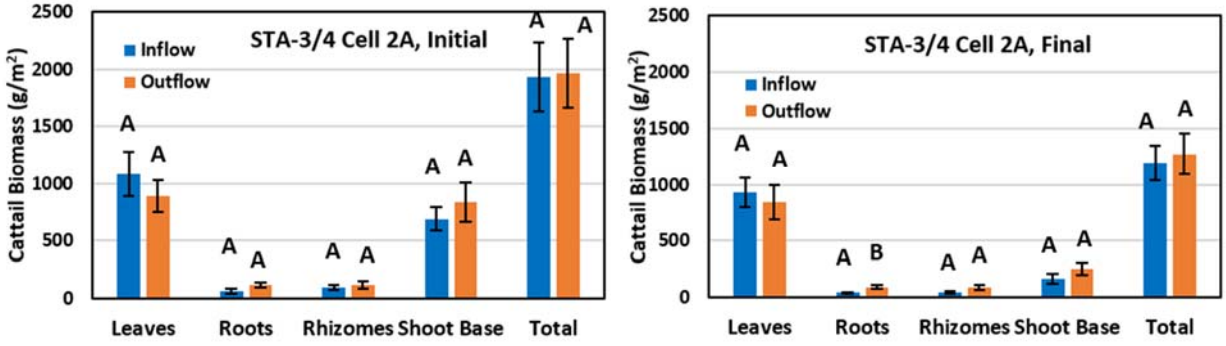

Figure 12. Initial and final plant biomass (mean ± standard error) from the in situ study in STA-3/4 Cell 2A. Mean differences with the same letter are not significantly different at the 0.05 probability level.

Comparison of total plant biomass from the initial and final biomass samplings showed that shoot base and total biomass from the initial sampling were significantly higher ($p < 0.05$) than biomass from the final sampling (**Figure 13**). There a was significant decline in total live biomass from the initial sampling in November 2014 (1,947 g/m^2) compared with the final sampling in October 2015 (1,224 g/m^2). There was also a notable change in biomass distribution in terms of aboveground and belowground biomass with the November 2014 sampling consisting of 51.7% leaf and 48.3% belowground biomass. In contrast, total biomass from the October 2015 sampling consisted of 73.2% leaf and only 26.8% belowground biomass.

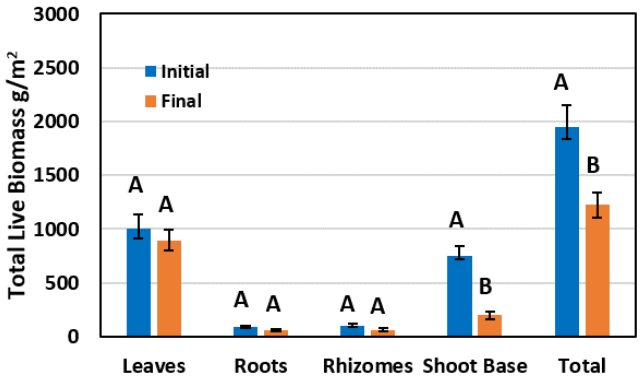

Figure 13. Total biomass (mean ± standard error) of samples collected November 2014 (initial) and October 2015 (final) biomass from STA-3/4 Cell 2A. Mean differences with the same letter are not significantly different at the 0.05 probability level.

SUMMARY

Typha species are currently the dominant emergent macrophyte in the EAV cells of the STAs. High flows during the wet season can result in excessive inundation conditions that can stress the cattail population of these cells. Uneven topography within treatment cells can also create deep areas even when target depths (32–46 cm) are maintained. Chronic and large-scale losses of cattails have been observed historically in both cells investigated in this study (STA-1W Cell 2A and STA-3/4 Cell 2A). Measurements from WY2011 to WY2017 in STA-1W Cell 2A showed that water depths were generally uniform across the cell, and ranged from 17 to 61 cm a majority of the time, which is ideal for optimal growth of *T. domingensis*. However, about 32% of the daily water depths were > 61 cm, which, depending on the duration of inundation (consecutive days) can cause physiological stress to *T. domingensis.* STA-1W Cell 2A experienced two periods of 24 and 28 days at a water depth range of 61 to 76 cm and one period of 17 days at a depth > 91 cm. In contrast, POR water depths from STA-3/4 Cell 2A were consistently higher in the inflow region than in the outflow region of the cell, with 53% of the daily water depths > 6 cm. The inflow region of this cell experienced periods at a water depth range of 61 to 76 cm for an average of 37 consecutive days and periods at a depth > 91 cm for up to 47 days. The outflow region also experienced deep water conditions, but at a lesser extent than in the inflow region.

During the first year, wet season monitoring, no significant differences were observed in cattail shoot density between the inflow and outflow regions of either cell. However, in STA-1W Cell 2A, there had been a notable decline in the cattail density and coverage, and presence of floating mats prior to initiation of this study. This resulted in the proliferation of other species in the floating mats and further decline of the cattail population of this cell during the course of this study. Additional plant density data have been collected since and a more comprehensive data analysis will be included in the next year's report.

Significant declines in total biomass were observed in the first year of the study in both study cells, and were primarily attributed to a decline in shoot base biomass. Biomass decline was observed in both the inflow and outflow regions of these cells. However, the plant biomass from this study is limited by the small size of the data set and the high variability of this type of field data. A third biomass sampling scheduled for STA-3/4 Cell 2A at the end of the 2017 wet season will be useful to corroborate these initial results.

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