Mill River Freshwater Tidal Marshes:
2011 Vegetation Monitoring

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Prepared by

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INTRODUCTION

As part of the ongoing evaluation of the lower Mill River corridor and the potential environmental effects of public water supply withdrawals, the South Central Connecticut Regional Water Authority (RWA) has been conducting annual monitoring of plant communities in the freshwater tidal marsh. This marsh, created in part by downstream tide gates belonging to the City of New Haven, is an unusual wetland habitat that contributes significantly to the biological diversity and wildlife populations in the lower Mill River and East Rock Park.

The Water Authority's Environmental Study Team (EST), in its 1999 assessment of potential impacts of the proposed treatment plant, recommended that vegetation in the marsh be monitored annually or biennially, both prior to construction of the plant to provide baseline data and after the plant is placed in operation. Data from these vegetation studies, along with monitoring of soil salinity, river flow, water quality, and aquatic life in the lower Mill River, will be used to evaluate environmental impacts of treatment plant operation.

The new treatment plant was placed in operation on April 20, 2005. Prior to the operation of this plant, baseline data were collected from 1998 through 2004 (J. L. Rogers and P. Sharp 2005: "2004 Vegetation Monitoring in the Mill River Freshwater Tidal Marshes: A Summary of Six Years of Baseline Data Collection," prepared for the South Central Connecticut Regional Water Authority). The baseline sampling provided information on variations in plant communities in the marsh during six years (no monitoring was performed in 1999) when there were no withdrawals for water-supply use. Vegetation sampling was repeated in September 2005 following the initiation of treatment plant operation, and has continued to be performed annually in late summer. Soil water salinity measurements were made from 2000 through 2009 in spring and again in the summer from three monitoring wells on each transect, installed in September 2000. Beginning in 2010, the wells have been sampled annually during the summer only.

VEGETATION SAMPLING METHODS

Penni Sharp and Vincent Kay conducted quantitative vegetation sampling of the Mill River marshes on September 15 and 16, 2011. Monitoring in most previous years has been performed between September 7 and September 25, except in 2000 when the site was sampled in mid-August. Sampling dates for each year are listed in Table 1 on page 6.

Vegetation sampling is conducted along two permanent transects. The upstream or northern transect, MR-N, is about 2,000 feet below the Whitney dam, just south of the East Rock Park footbridge and about 700 feet north of the East Rock Road bridge. This transect passes through one of the largest and most varied parts of the marsh. The downstream transect, MR-S, passes through a narrower and less varied marsh community about 300 feet south of the East Rock Road bridge.

The permanent transect at each site is approximately perpendicular to the river with permanent marker stakes placed every 5 meters along the transect. Transect MR-N is 100 m in length, but only 18 of the surveyed stakes are sampled regularly; the stake at the upland origin of the transect is outside the tidal area, while the two stakes closest to the river are typically inundated and can be sampled only during unusually low flow or low tidal conditions. Transect MR-S is 55 m long and ends at a low levee at the river; since it does not extend into the typically inundated low marsh along the river's edge, all 12 stakes are sampled regularly. Vegetation sampling is performed by extending 5-meter sampling chains south from each stake, perpendicular to the permanent transect. A dowel rod is inserted into the vegetation at 0.5 m. intervals along the sampling chain, for a total of 10 sampling points per chain, and all species touching the rod (or an imaginary upward extension of it) are recorded. Maps of these transects, and a detailed description of the methodology, appear in the report by Lee Rogers included in the *Lake Whitney Water Treatment Plant Environmental Evaluation: Volume Two* (January 1999).

RESULTS

Precipitation and Soil Conditions

Precipitation as measured by the RWA at the Lake Whitney dam during the 2011 growing season (April-October) was high in comparison to 2010 and rainfall for the year was well above average (see Table 1). During the growing season, monthly rainfall totals ranged from a low of 1.93 inches in July to a high of 11.53 inches in August. A significant portion of the August rainfall came at the end of the month with the arrival of Tropical Storm Irene. A total of 37.18 inches of precipitation fell during this period compared to 19.08 inches for the same period in 2010. The annual total of 60.84 inches of precipitation ranks among the highest on record during the 100 years that the RWA has measured rainfall, with only 10 of those years exceeding the 2011 yearly total. However, annual rainfall in 2011 was lower than 2008 and 2009, which totaled 72 and 66 inches, respectively. Month-by-month precipitation data for the last ten years since sampling began appear in Table A-1 on page 4 of this report.

Withdrawals from Lake Whitney, guided by the Management Plan, are intended to protect downstream and upstream environmental resources. Due to declines in water demand and in an effort to cut operating costs, the treatment plant began operating on a "once per week" basis for about 8 hours on October 22, 2008 and continued this mode of operation throughout 2009, 2010, and 2011 with some minor exceptions of short duration. This withdrawal is negligible and has had little to no effect upon the natural conditions and the rates of water flowing over the Lake Whitney spillway.

Groundwater Salinity

Groundwater in the transect monitoring wells was sampled on July 14, 2011, during both high and low tide conditions. Monitoring well data for 2011 and for the six preceding years are included in Table A2, pages 5 and 6. As indicated, the groundwater salinity is now measured only during the summer, as agreed upon by the study team. The 2011 groundwater salinity measurements in the marsh were within 0.10 to 0.20 parts per thousand (ppt). In 2010,

salinity levels of 0.30 ppt were recorded in the Mill River adjacent to transect MRN for both low and high tide readings, and 0.70 ppt and 2.60 ppt adjacent to transect MRS at low and high tide, respectively. In some years, during late summer or early fall low freshwater flow conditions, surface salinities in the adjacent river ranging from about 2 to 12 ppt have been observed. These higher salinities are due to tidal waters extending further upstream during seasonal low freshwater flows. Because of the low water surface elevations in the river relative to the marsh during these flow conditions, it is highly unlikely that this more saline water will inundate the marsh and increase soil water salinities. Annual vegetation within the marsh is well established prior to the timing of the seasonal low flows. Therefore, even with the potential for higher salinity levels during the low flow periods, vegetation is unlikely to be negatively affected. From the long-term monitoring record it can be inferred that soil-water salinity has consistently remained below 0.50 ppt as an annual average, considered the limit of tolerance for freshwater marsh plants.

Precipitation and Salinity in the Mill River Marshes

Table A1
Lake Whitney Precipitation, 2000-2011**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	G.S.*
2000	2.44	1.89	4.14	4.68	3.31	5.95	7.04	2.72	4.29	0.44	4.45	2.41	43.76	27.99
2001	1.62	2.05	7.29	1.53	5.32	4.26	2.87	3.43	2.84	1.18	1.03	2.18	35.60	20.25
2002	1.67	1.27	4.09	3.45	5.56	3.35	1.90	3.16	6.73	4.20	4.15	4.06	43.59	24.15
2003	1.47	2.48	4.13	2.92	4.11	6.57	1.57	5.47	6.94	5.36	2.18	3.62	46.82	27.58
2004	1.38	2.09	3.08	5.77	2.69	0.88	2.95	4.52	7.48	1.97	3.19	3.27	39.27	24.29
2005	3.61	2.31	3.16	6.14	1.31	2.68	2.83	1.35	2.48	14.03	3.90	4.25	48.05	16.79
2006	5.70	2.42	0.55	6.46	6.35	5.87	3.54	5.08	2.20	6.58	4.73	2.88	52.36	29.50
2007	3.64	1.28	5.71	10.17	1.47	3.39	3.54	2.36	1.58	3.80	2.79	5.79	45.52	22.51
2008	2.44	11.16	7.23	6.06	3.67	4.23	3.98	5.89	11.06	3.67	4.58	8.02	71.99	34.89
2009	3.13	1.66	2.63	5.88	3.82	8.86	10.63	2.13	4.17	9.73	4.95	8.55	66.14	35.49
2010	3.36	7.04	13.02	2.01	2.80	3.31	4.14	3.82	3.00	5.15	3.84	4.73	56.22	19.08
2011	3.11	4.04	4.08	5.60	4.09	6.39	1.93	11.53	7.64	4.55	3.86	4.02	60.74	37.18
10-yr Aver.	***3.36***	***3.97***	***5.91***	***6.07***	***4.45***	***5.57***	***4.69***	***5.15***	***6.04***	***6.07***	***4.29***	***5.33***	***60.90***	***31.97***
100-yr Aver.	**3.62**	**3.33**	**4.43**	**4.25**	**3.92**	**3.68**	**3.68**	**4.03**	**3.82**	**3.80**	**4.03**	**4.08**	**46.67**	**23.38**

* Growing season precipitation, April through September.
** RWA rain gauge at Lake Whitney dam

Table A2
Groundwater Monitoring Well Data, 2005-2011

	2011	
	7/14/11 (high flow)	
Monitor well	**Low tide**	**High Tide**
MRN-1	0.1	0.2
MRN-2	0.1	0.1
MRN-3	0.1	0.1
River@ MR-N	0.1	0.1
MRS-1	0.2	0.1
MRS-2	0.1	0.1
MRS-3	†	†
River@ MR-S	0.1	0.1

	2005				2006				2007			
	4/8/05 (high flow)		7/21/05 (low flow)		4/27/06 (high flow)		7/12/06 (low flow)		5/11/07 (high flow)		7/12/07 (low flow)	
Monitor well	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low Tide**	**High tide**	**Low tide**	**High tide**
MRN-1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1
MRN-2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2
MRN-3	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
River@ MR-N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
MRS-1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1
MRS-2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1
MRS-3	0.1	0.1	0.3	0.1	0.1	0.4	0.2	0.1	0.2	0.1	0.4	0.4
River@ MR-S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3

† Monitoring Well missing
*** New Monitoring Well installed; now known as MRN-MW3B**
+ Well dislodged and broken; not sampled

Table A2
Groundwater Monitoring Well Data, 2005-2011, cont.

	2008				2009				2010	
	4/7/08 (high flow)		7/9/08 (low flow)		4/8/09 (high flow)		7/28/09 (low flow)		7/12/07 (low flow)	
Monitor well	**Low tide**	**High tide**	**Low tide**	**High Tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**
MRN-1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MRN-2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1
MRN-3	0.4	0.3	0.2	0.2	--†	0.3*	0.2*	0.2*	0.2*	0.2*
River@ MR-N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3
MRS-1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MRS-2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
MRS-3	0.2	0.1	0.2	0.2	0.2	0.1	--+	--+	0.2	0.2
River@ MR-S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.7	2.6

† Monitoring Well missing
*** New Monitoring Well installed; now known as MRN-MW3B**
+ Well dislodged and broken; not sampled

2011 VEGETATION MONITORING RESULTS

Vegetation monitoring results in 2011, along with those obtained during the baseline years, are summarized in the tables below. Table 1 shows the total number of species and total percent cover measured on each transect during the twelve years of sampling. Percent cover is the percentage of all points sampled at which a species occurred. Total percent cover, obtained by adding the percent cover for all species, is generally more than 100 percent, due to the fact that several species are encountered at a single sampling point. Table 1 also shows growing-season precipitation conditions. For purposes of this table, rainfall more than 2 inches below the long-term growing-season average of 23 inches was considered "low," 21-25 inches "normal," and above 25 inches "high." Since the time of sampling could also affect species distribution, the sampling dates are also included in the table.

Table 1
Mill River Freshwater Tidal Marsh
Total Cover and Number of Species on Each Transect, 1998-2011

Year	Sampling date	Growing-season Rainfall (Apr.-Sept.)	Transect MR-N			Transect MR-S		
			Total Cover		Total # spp.	Total Cover		Total # spp.
			Percent	Rank		Percent	Rank	
2000	8/18	27.99" – high	259.4	11	29	244.2	11	17
2001	9/24	20.25" – low	359.4	2	40	258.3	9	27
2002	9/24	24.15" – average	315.0	4	28	279.0	7	23
2003	9/25	27.58" – high	290.0	9	31	256.7	10	21
2004	9/7	24.29" – average	366.7	1	26	338.3	2	17
2005	9/20	16.79" - low	348.3	3	32	359.2	1	27
2006	9/18-19	29.50" – high	314.4	5	32	291.6	6	35
2007	9/19-20	22.51" – average	306.1	7	33	322.5	3	25
2008	9/8-9	34.89" – high	300.5	8	36	299.2	5	26
2009	9/8 - 10	35.49" – high	283.4	10	31	265.8	8	31
2010	9/1 - 14	19.08" - low	307.2	6	36	317.5	4	31
2011	9/15 – 16	37.18" - high	221.7	12	32	186.6	12	27

Changes in cover by selected plant species over the past nine years of sampling are shown in Table 2 for site MR-N and Table 3 for site MR-S. These tables indicate the dominant species of the herb and shrub strata in 2011. Dominants are those species that collectively make up

more than half the total percent cover for that stratum of the community. Percent cover by several other common species that may have been dominant or subdominant in past years' samples are also included in these tables.

The sampling in 2011 showed the lowest in percent cover of species at both transects since sampling began. This was due in large part to tropical storm Irene which occurred in late August. It was evident that the marshes at both MR-N and MR-S had been inundated and many of the more tender herbaceous species were likely washed away or buried in mud.

The large decrease in the climbing composite *Mikania scandens* observed in 2007 persisted during 2008 at MR-N. However, since 2009, this vine has been relatively robust and in 2011 appeared as it had in years past with a percent cover measured at 27.2, close to its all time high. This annual vine, generally found clambering over narrow-leaved cattails (*Typha angustifolia*) in the marshes, reached a near-peak in 2006, but in 2007 it fell to the lowest percent cover that has been observed during the study, less than a fifth of its previous year cover (see Tables 2 and 3). Although there was a slight increase in 2008 at MR-N, it remained in very low numbers when compared to previous years. During 2009, it was measured at 27.8 percent cover which is the highest level observed at this transect since 2006. In 2010, the species remained relatively stable at 26.7 percent cover. At MR-N, cattail cover of 36.7 percent was below the average for the study most likely due to the aforementioned storm.

At MR-S, *Mikania* reached 54.2 percent cover in 2009; however in 2010, it retreated to 37.5 percent cover. In 2011 percent cover was measured at 28.3, down from the previous year, but within a normal range overall. This plant is closely associated with the cattails. During 2007, the cattail cover of 55.8 percent at MR-S was the lowest observed in this study until this year. Cattail cover at MR-S increased somewhat during the 2008 monitoring and was tallied at 63.3 percent. During 2009, cattail coverage was measured at 61.7 percent and in 2010 it was identical at 61.7 percent cover. In 2011, cover for cattails at MR-S was 53.3 percent, the lowest yet sampled, again likely due to the storm event.

In past years, spotted jewelweed (*Impatiens capensis*) has shown a trend of continued dominance at both sites. However, in 2009, this species showed a dramatic drop at both MR-N where it was measured at 28.3 percent cover and at MR-S where percent cover was 27.5. This trend continued into 2010 with percent cover at MR-N at 29.4 percent and at MR-S 32.5 percent. In 2011, percent cover was 11.7 at MR-N and 5.8 at MR-S. Spotted jewelweed is a tender plant and its numbers were likely reduced dramatically by the storm. This annual is extremely variable from year to year at all the sites we have studied, thus the tally for this year is not considered to be indicative of any significant shifts in overall vegetation composition. The parasitic vine dodder (*Cuscuta gronovii*), which favors the succulent jewelweed as a host plant, showed an decrease in cover in 2011 when compared with the previous year.

Purple loosestrife (*Lythrum salicaria*), which has shown a steady increase at MR-N from its 1998 cover of 7.2 percent to its 35.6 percent cover in 2007, showed a decline in 2008 to 28.3 percent. It was up very slightly in 2009 to 29.4 percent cover and rose again in 2010 to 33.3 percent cover. In 2011, its percent cover was the lowest since 1998 at 12.2. Although one

would be glad to note a downward trend for this species, it is likely that the lower number is a reflection of the tropical storm. This species measured 15.0 percent cover at MR-S. Although on the low side, it is within the range of past recordings for the species at MR-S. Despite 2011 being somewhat of an anomaly due to the effects of the storm, overall, the marsh vegetation remains relatively stable with no statistically significant changes from year to year.

Table 2[1]
Percent Cover of Principal Species – Transect MR-N

Species (* dominant in 2011)	2011 (high)	2010 (low)	2009 (high)	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)
HERBS									
**Typha angustifolia*	36.7	48.3	50.0	46.7	50.0	51.7	57.2	46.7	44.4
**Lythrum salicaria*	12.2	33.3	29.4	28.3	35.6	31.7	31.7	30.6	15.6
**Impatiens capensis*	11.7	29.4	28.3	55.6	33.9	10.6	34.4	66.7	40.6
Thelypteris palustris	7.8	11.1	9.4	13.9	15.6	12.2	20.0	14.4	16.7
Leersia oryzoides	1.7	1.7	2.2	1.7	13.3	21.7	30.6	22.2	11.1
Polygonum sagittatum	3.9	5.6	5.6	17.2	12.8	6.7	13.9	20.0	1.7
Polygonum hydropiper	0.0	1.1	1.1	2.2	10.6	3.3	4.4	12.2	3.9
Onoclea sensibilis	8.3	11.1	10.0	8.3	10.0	11.1	8.9	6.1	8.3
Cuscuta gronovii	0.6	4.4	2.2	4.4	7.6	0.0	4.4	8.9	5.0
Bohemeria cylindrica	4.4	6.7	3.9	7.8	6.1	9.4	6.1	15.6	6.7
Pilea pumila	0.6	8.3	2.8	1.7	5.8	1.7	1.1	5.0	0.0
Peltandra viginica	1.7	3.3	3.9	5.0	5.0	4.4	6.7	7.2	6.1
*Mikania scandens**	27.2	26.7	27.8	6.7	4.4	47.8	24.4	15.6	30.6
Polygonum arifolium	1.1	1.7	5.0	5.0	1.7	6.1	2.8	2.2	2.2
Bidens connata	0.0	1.1	0.6	0.6	0.6	2.8	6.7	0.0	0.0
SHRUBS									
**Cornus amomum*	49.4	47.8	50.0	52.2	45.6	41.7	37.8	46.1	40.6
Hibiscus moscheutos	4.4	10.6	9.4	5.6	8.9	10.6	9.4	6.1	7.8
**Viburnum dentatum*	13.9	16.1	15.0	5.6	7.2	11.7	14.4	8.3	20.0
Cephalanthus occidentalis	5.0	1.7	1.7	1.7	2.8	2.8	3.3	0.0	5.6

[1] 1998, 2000, 2001,and 2002 data has been omitted from Table 2 and Table 3 due to lack of space. All data is included in the tables in the Appendices

Table 3
Percent Cover of Principal Species – Transect MR-S

Species (* dominant in 2011)	2011 (high)	2010 (low)	2009 (high)	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)
HERBS									
**Impatiens capensis*	5.8	32.5	27.5	57.5	64.2	21.7	48.3	74.2	56.7
**Typha angustifolia*	53.3	61.7	61.7	63.3	55.8	61.7	76.7	83.3	75.0
**Pilea pumila*	5.8	19.2	11.7	10.8	17.5	9.2	9.2	14.2	0.0
Polygonum arifolium	2.5	4.2	2.5	6.7	17.5	6.7	15.8	21.7	12.5
Polygonum sagittatum	0.0	10.0	0.8	28.3	17.5	0.8	11.7	12.5	5.8
**Lythrum salicaria*	15.0	20.0	15.8	15.0	16.7	20.8	23.3	11.7	14.2
Cuscuta gronovii	3.3	10.8	1.7	0.0	16.7	0.0	11.7	2.5	0.0
**Peltandra viginica*	10.0	16.7	8.3	6.7	15.0	11.7	10.0	13.3	12.5
Leersia oryzoides	1.7	0.0	0.8	9.2	11.7	9.2	2.5	0.0	2.5
**Mikania scandens*	28.3	37.5	54.2	25.0	10.0	50.0	45.8	33.3	21.7
Bohemeria cylindrica	3.3	9.2	5.0	9.2	9.2	5.8	10.0	13.3	6.7
Apios americana	1.7	7.5	1.7	4.2	2.5	5.0	1.7	0.0	0.0
Polygonum hydropiper	0.8	2.5	0.8	0.8	1.5	5.0	0.8	0.0	0.0
SHRUBS									
**Viburnum dentatum*	14.2	16.7	22.5	12.5	18.3	20.8	15.0	11.7	12.5
**Cornus amomum*	5.0	17.5	12.5	5.8	10.0	10.8	12.5	12.5	9.2
Lindera benzoin	1.7	4.2	3.3	0.8	4.2	5.0	5.8	5.8	4.2
Hibiscus moscheutos	5.8	0.0	3.3	1.7	1.7	2.5	5.0	6.7	3.3

At transect MR-S purple loosestrife cover at 15.0 in 2011 was down from that observed in 2010, but remains less than the high measure of 23.3 in 2005 (see Table 3). One species, swamp rosemallow (*Hibiscus moscheutos*) which had decreased in cover over the past few years, from 6.7 percent in 2004 to a low of 1.7 percent in both 2007 and 2008 showed a slight increase to 3.3 percent cover in 2009. Although observed within the marsh, the species was not encountered on any of the transect points in 2010; however in 2011, it was measured at 5.8, higher than most of the previous years.

Shrub cover at MR-N has shown steady increase since the study was initiated, in particular silky dogwood (*Cornus amomum*), which showed its highest percent cover on record in 2008 and comparable levels in 2009. In 2010, there was a slight decline in percent cover at MR-N; however, it was up slightly in 2011, remaining well within the range of previous observations. As noted above, the species reached its highest recorded level at MR-S in 2010. It declined from its high of 17.5 at this site to 5.0 percent cover in 2011. It appeared that a large clump of the dogwood near the distal end of the transect was washed out. Similarly, a large silver maple (*Acer saccharinum*) that grew at the water's edge, was uprooted, thus no longer covering the transect. At both sites, northern arrowwood (*Viburnum dentatum*), remained within the previously observed range.

Figures 1 and 2, and Tables 1, 2, and 3 illustrate the variability in the structure of the marsh communities from year to year. As shown in Table 1, the transect at MR-N, the more complex of our two marsh sites, has yielded 26 to 40 plant species in 1998-2008; 32 species sampled in 2011 is slightly below average for this range. At MR-S, the number of species from 1998 through 2005 ranged from 17 to 27, but in 2006, the number of species reached 35. The 31 species observed in 2009 and again in 2010 is the second highest observed on this transect. The number was down to 27 in 2011, but remained well within the range observed in the past.

Figure 1 - Lower Mill River Marsh Vegetation Survey - North Transect (MRN)

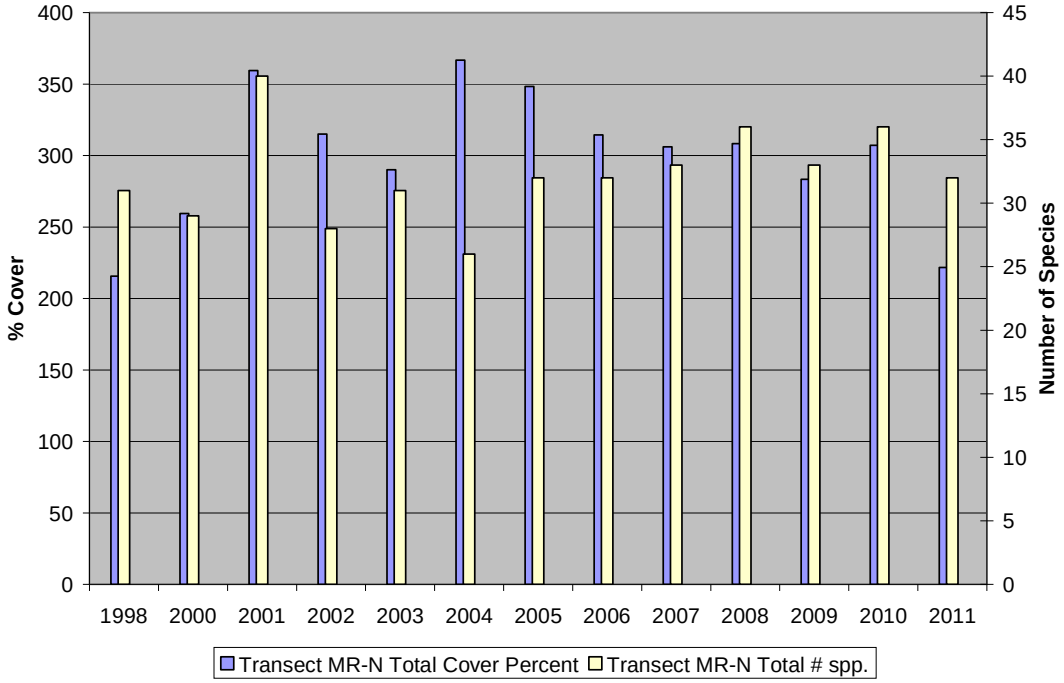
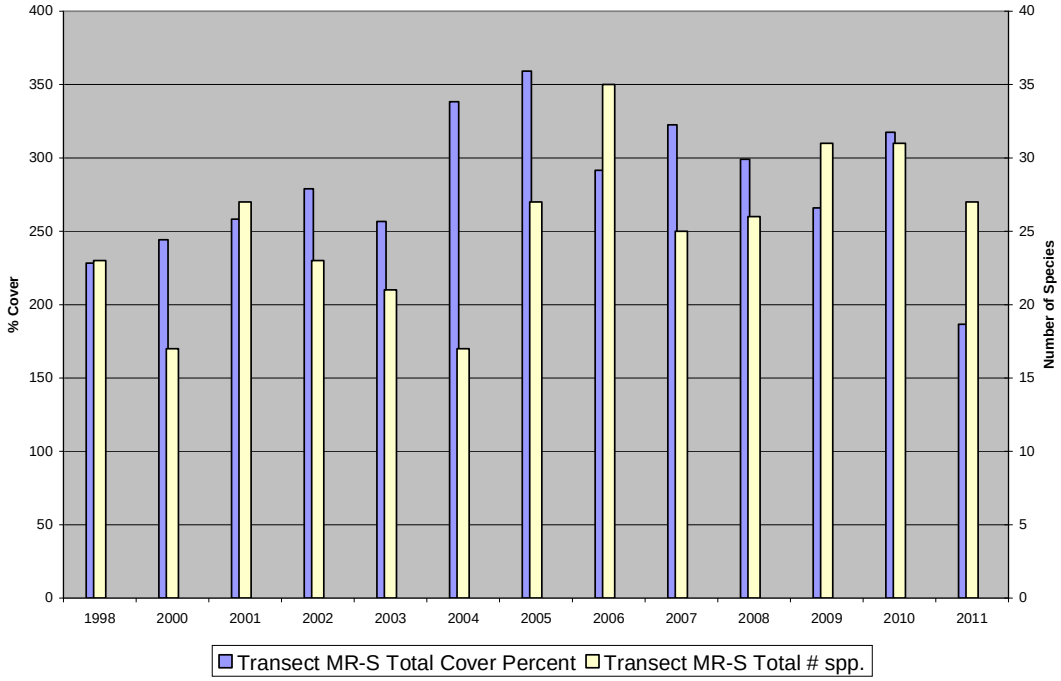


Figure 2 - Lower Mill River Vegetation Survey - South Transect (MRS)



DISCUSSION

Species Diversity and Total Plant Cover

The total number of species in a plant community is an indication of its structure and complexity. A complex, diverse plant community generally is a richer wildlife habitat than an area with fewer species because the complex community can fill more of the requirements of a variety of animal species. The same is true for other functional values of wetlands such as groundwater retention, nutrient removal, sediment trapping, water quality effects, soil stabilization, etc.

Total plant cover is another indicator of complexity and overall health in a plant community since it reflects the presence of multiple species at each sampling point. Cover by each individual species is the percentage of total sampling points along the transect at which the species is found. These typically sum to more than 100 percent cover because several species are usually found at a sampling point. As Table 1 shows, total cover was generally highest in years of low to normal rainfall and lower in the years when growing-season precipitation was above normal. However, 2006, one of the wet years, was anomalous in having both higher

cover and greater species diversity than are typical in a year of high rainfall. Generally, diversity and cover are higher in relatively dry growing season because species that prefer dryer conditions can move deeper into the marsh while more hydric species persevere in the wettest areas. In 2011, cover and diversity at both transects were low as might be expected in a growing season characterized by above average precipitation. Furthermore, the storm inundation in late August likely removed a number of the herbaceous species.

Herbaceous and Shrub Cover

The upper and middle marsh communities at both of the Mill River marsh sites are mosaics of herbaceous emergent marsh species intermixed with shrub thickets; intermittently submerged herbaceous species are dominant in the lower marsh zone which is more frequently inundated by tides. Shrubs tend to occur in drier portions of the marsh that are rarely flooded. The wetter parts of the Mill River marsh are dominated by narrow-leaved cattails (*Typha angustifolia*), but include a mixture of many other herbaceous species. The principal thicket-forming shrub species are silky dogwood (*Cornus amomum*) and northern arrowwood (*Viburnum dentatum*). Because the shrub areas support very little species diversity due to the dense cover of the shrubs, a long-term increase in shrub areas at the expense of herbaceous area could indicate not only that the marsh is becoming drier, but that its complexity and diversity are reduced.

In the Mill River marshes, cattail cover at both sites has fluctuated over the years. At MR-N (Table 2), cattails in 2010 remained within the range observed during the baseline period before the water treatment plant was placed in service. In 2011, cattail cover was lower than previously observed at MR-N; however, no conclusions can be drawn due to the anomalous year. At MR-S (Table 3), however, cattail cover reached new lows in both 2006 and 2007. There was an increase in cattail cover during both 2009 and 2010; however, cover remained slightly below the highest baseline levels. In 2011, cover was lower than many previous years, but not the lowest ever observed. At present, the fluctuations do not appear to be significant, particularly in view of recent weather events.

Cover by Introduced Wetland Species

Invasion by non-native species has become a serious problem in some wetland areas. Two of the most widespread invasive species are the common reed (*Phragmites australis*) and the showy perennial, purple loosestrife (*Lythrum salicaria*). These species can spread extensively in a marsh community, especially one that has been disturbed or stressed, replacing most of the native vegetation. This produces a much less complex and varied marsh that is unable to support diverse wildlife.

Purple loosestrife has show a long-term increase at both sites. At MR-N, this species had an initial baseline cover of 7.2 percent in 1998 and reached a high of 35.6 percent in 2007. Fortunately, its percent cover in 2008 was reduced to 28.3 percent and in 2009, was up only slightly to 29.4 percent cover. During 2010, percent cover was tallied at 33.3 percent, less that its all time high, but increased from the previous few years. However, 2011 showed a decline to 12.2 percent cover, the lowest since 1998. At MR-S, loosestrife cover was 0.8 percent in 1998 and reached a peak of 23.3 percent in 2005. During the next two years, it declined to 16.7 percent and declined further in 2008 to 15.0 percent. In 2009, percent cover for loosestrife at MR-S was 15.8 percent, a marginal increase. Percent cover in 2010 was 20.0 percent and in 2011 dropped to 15.0 percent cover. The trend of increasing loosestrife cover was evident during the baseline period (1998-2004) and does not appear to have accelerated to any greater extent than is to be expected for this invasive species since the water treatment plant was placed in service. Biological control of purple loosestrife has been initiated in Connecticut by the release of leaf-feeding beetles (*Galerucella* spp). These beetles reduce the growth and reproduction of purple loosestrife and were released at wetlands adjacent to Mather Street which crosses Lake Whitney a number of years ago.

No common reed (*Phragmites australis*) occurs on the Mill River transects. There are isolated patches of this species between the two transect areas, primarily where dredging, draining, or pollution by storm sewer outfalls has occurred. We have found no evidence that these areas are expanding following annual qualitative surveys of the patches.

CONCLUSIONS

There is some evidence from several years of vegetation sampling that freshwater tidal marshes in the lower Mill River are undergoing gradual changes. The increase in shrub cover, could eventually result in an overall loss of diversity and wildlife habitat value of these marshes. Such an increase would be considered a change attributable to natural succession and unlikely to be caused by treatment plant operation. Since the Whitney water treatment plant has only been in operation since 2005 and the changes in the plant communities have been occurring at least since 1998, these changes do not appear to indicate environmental impacts due to treatment plant operation, particularly since the plant has not operated at capacity for an extended period of time. This is further supported by the fact that downstream flows have not been seriously affected and average groundwater salinities remain well below 0.5 ppt.

To date, the study team has gathered considerable data, spanning thirteen years, regarding the marshes and has noted gradual changes that appear due to natural phenomena such as weather events and plant succession. Although, the treatment plant has not operated at normal capacity since October of 2008, the summers of 2005 and 2007 were reasonably representative of seasonally low river flows during operating conditions. As documented in the report entitled "*Lake Whitney Water Treatment Plant Environmental Evaluation, Volume 1*" (January 1999), sustained soil salinities exceeding 0.5 ppt have the potential to negatively impact a freshwater tidal marsh. The terms of the Management Plan governing water withdrawals and minimum flows coupled with the hydrology of the Mill River system make it highly unlikely that this salinity threshold will be exceeded for a significant duration. During the years of data gathering, changes in the marshes have been observed. These are due to either a lack or a surfeit of rainfall, to extreme weather events such as hurricanes and unseasonable snow storms, and to natural succession. For example, the increase in shrub cover at MR-N is due primarily to the natural growth of the shrubs and not attributable to water withdrawal influences. While changes are likely to continue within the marshes, including those documented in this report, these are not viewed as being attributable to current or future water withdrawals for public drinking water supply as guided by the Management Plan. Therefore, the suspension of the annual monitoring program is something to consider at this time.