Mill River Freshwater Tidal Marshes:
2009 Vegetation Monitoring

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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) conducts 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 variation 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 continues to be performed annually in late summer. Soil water salinity measurements are made in spring and again in the summer from three monitoring wells on each transect, installed in September 2000.

Vegetation Sampling Methods

Penni Sharp and Vincent Kay conducted quantitative vegetation sampling of the Mill River marshes on September 8 and 10, 2009. Monitoring in most previous years was 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 7.

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 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 in the lower Mill River during the 2009 growing season (April-October) was unusually high overall (see Table 1). In fact, it was the highest on record to date. During the growing season, monthly rainfall totals ranged from a low of 2.13 inches in August to a high of 10.63 inches in July. A total of 35.49 inches of precipitation fell during this period, topping the 2008 record of 34.89 inches. The annual total of 66 inches of precipitation ranks among the highest on record during the 97 years that the RWA has measured rainfall although it is less than last year's all time high of 72 inches. Month-by-month precipitation data for the last ten years since sampling began are shown in Table A-1 on page 4.

Withdrawals from Lake Whitney, guided by the Management Plan, are intended to balance water needs with protection of 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. 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 April 8 and July 28, 2009, during both high and low tide conditions. Monitoring well data for 2009 and for the four preceding years (2005 was a very dry year whereas 2006, 2007, and 2008 had high rainfall) are included in Table A2 found on page 5. The well data this year is incomplete due to the fact that MRN-MW3 was missing on the low tide sampling in April. The well was replaced the same day for the high tide reading and is now known as MRN-MW3B. Data is also missing for MRS-MW3 for the July sampling, as a result of the monitoring well becoming dislodged, presumably by storm flows. 2009 groundwater salinity measurements in the marsh were generally around 0.1 parts per thousand (ppt). Exceptions to the 0.1 salinity levels occurred at MRN-MW3B where salinity levels of 0.3 ppt were recorded at the April high tide reading and in the same well, 0.2 ppt was recorded at the July low tide reading. MRS-MR3 also had 0.2 ppt salinity levels during the April low tide sample. In previous years, peak soil-water salinity measurements reached 0.4-0.5 ppt in 2001 and as high as 0.7 ppt in 2002. In late summer low freshwater flow conditions, surface salinities in the adjacent river have exceeded 10 ppt on occasion, but even under these conditions are usually less than 7 ppt. These higher salinities are generally due to seasonal low flows that are unlikely to inundate the marsh, and they therefore have little or no effect on soil water salinities. Throughout the study, however, soil-water salinity has remained below 0.5 ppt as an annual average, considered the limit of tolerance for freshwater marsh plants. The groundwater salinity levels have remained stable over the years and there has been little variation between seasons in any given year. To that end, the Study Team plans to discontinue the spring measurements in future years.

Precipitation and Salinity in the Mill River Marshes

Table A1
Precipitation at Lake Whitney (inches), 1998-2009

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	G.S.*
1999	6.85	4.76	3.90	1.50	2.75	0.32	1.22	3.42	7.05	3.86	2.91	2.41	40.95	16.26
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	2.00	N/A	N/A	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
10-yr Aver.	***3.40***	***3.34***	***4.59***	***5.46***	***4.04***	***4.64***	***4.21***	***3.95***	***5.68***	***5.48***	***3.81***	***4.63***	***54.28***	***24.42***
95-yr Aver.	**3.62**	**3.28**	**4.35**	**4.26**	**3.92**	**3.65**	**3.70**	**3.96**	**3.78**	**3.78**	**4.03**	**4.07**	**46.40**	**23.27**

* Growing season precipitation, April through September.

Table A2
Groundwater Monitoring Well Data, 2005-2009

	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

Table A2, cont.
Groundwater Monitoring Well Data, 2005-2009

	2008				2009			
	4/7/08 (high flow)		7/9/08 (low flow)		4/8/09 (high flow)		7/28/09 (low flow)	
Monitor well	**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
MRN-2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1
MRN-3	0.4	0.3	0.2	0.2	--†	0.3*	0.2*	0.2*
River@ MR-N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
MRS-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
MRS-3	0.2	0.1	0.2	0.2	0.2	0.1	--+	--+
River@ MR-S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

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

Table A3
Baseline Groundwater Monitoring Well Data, 2001-2004

	2001				2002				2003			
	4/20/01` (high flow)		7/21/05 (low flow)		4/6/02 (high flow)		7/24/02 (low flow)		4/16/03 (high flow)		7/31/03 (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	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2
MRN-2	0.2	0.1	0.2	0.2	0.1	0.1	0.7	0.7	0.2	0.2	0.2	0.3
MRN-3	0.2	0.2	0.4	0.1	0.2	0.2	0.3	0.2	0.2	0.3	0.3	0.2
River@ MR-N	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
MRS-1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2
MRS-2	0.1	0.1	0.3	0.2	0.1	0.1	0.3	0.4	0.1	0.1	0.2	0.1
MRS-3	0.1	0.1	0.4	0.5	0.1	0.1	0.7	0.5	0.2	0.2	0.2	0.1
River@ MR-S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

	2004			
	4/6/04 (high flow)		7/29/04 (low flow)	
Monitor well	**Low tide**	**High tide**	**Low tide**	**High tide**
MRN-1	0.3	0.3	0.2	0.3
MRN-2	0.1	0.1	0.2	0.2
MRN-3	0.1	0.1	0.1	0.2
River@ MR-N	0.1	0.1	0.1	0.1
MRS-1	0.2	0.2	0.2	0.2
MRS-2	0.1	0.1	0.1	0.2
MRS-3	0.1	0.1	0.1	0.1
River@ MR-S	0.1	0.1	0.1	0.1

2009 Vegetation Monitoring Results

Vegetation monitoring results in 2009, 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 ten 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, because 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 approximate sampling dates are also included in the table.

Table 1
Mill River Freshwater Tidal Marsh
Total Cover and Number of Species on Each Transect, 1998-2008

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	
1998	9/21	26.18” – high	215.6	11	31	228.3	11	23
2000	8/18	27.99” – high	259.4	10	29	244.2	10	17
2001	9/24	20.25” – low	359.4	2	40	258.3	8	27
2002	9/24	24.15” - average	315.0	4	28	279.0	6	23
2003	9/25	27.58” – high	290.0	8	31	256.7	9	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	5	35
2007	9/19-20	22.51” - average	306.1	6	33	322.5	3	25
2008	9/8-9	34.89” – high	300.5	7	36	299.2	4	26
2009	9/8 - 10	35.49” – high	283.4	9	31	265.8	7	31

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 2009. 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 large decrease in the climbing composite *Mikania scandens* observed in 2007 persisted during 2008 at MR-N. However, during 2009, this vine was relatively robust and appeared as it had in years past. 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. At MR-S, *Mikania* reached 54.2 percent cover more than double last year's 25 percent cover and the highest level to date on this transect. This plant is closely associated with the cattails. At MR-N, cattail cover of 50.0 percent was near the average for the study and consistent with past years of monitoring. During 2007, the cattail cover of 55.8 percent at MR-S was the lowest yet observed in this study. 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.

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. In 2008, percent cover was 55.6 at MR-N and 57.5 at MR-S. This annual is extremely variable from year to year at all the sites we have studied, thus the decline 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 a marked decrease in cover compared with previous years. At MR-S, it appeared at only two sample points and at four at MR-N. Perhaps the high rainfall during the growing season created conditions unfavorable to this parasitic species.

At transect MR-N, none of the species was outside the range observed during the baseline period (see Table 2). Purple loosestrife (*Lythrum salicaria*), which has shown a steady increase at this site 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.

At transect MR-S, percent cover of two of the species exceeded the range observed during the baseline period (see Table 3). These included climbing hempweed (*Mikania scandens*) and northern arrowwood (*Viburnum dentatum*), both of which were at the highest levels observed to date at MR-S. Purple loosestrife cover in 2009 was up very slightly from 2008, but remains less than that measured in the previous three years (see Table 3).

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. At both sites, northern arrowwood (*Viburnum dentatum*), remained within the previously observed range. However, swamp rosemallow (*Hibiscus moscheutos*) at site MR-S 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. The species had also shown a decline at MR-N where its percent cover was 5.6 in 2008, down from 8.9 in 2007 and 10.6 in 2006. In 2009 it has rebounded to 9.4 percent cover.

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; 31 species sampled in 2009 is 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 is the second highest observed on this transect.

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

Species (* dominant in 2009)	2009 (high)	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)	2002 (avg.)	2001 (low)
HERBS									
**Typha angustifolia*	50.0	46.7	50.0	51.7	57.2	46.7	44.4	47.2	51.7
**Lythrum salicaria*	29.4	28.3	35.6	31.7	31.7	30.6	15.6	20.6	17.2
**Impatiens capensis*	28.3	55.6	33.9	10.6	34.4	66.7	40.6	45.0	42.8
Thelypteris palustris	9.4	13.9	15.6	12.2	20.0	14.4	16.7	13.3	17.8
Leersia oryzoides	2.2	1.7	13.3	21.7	30.6	22.2	11.1	8.9	11.7
**Polygonum sagittatum*	5.6	17.2	12.8	6.7	13.9	20.0	1.7	0.0	10.6
Polygonum hydropiper	1.1	2.2	10.6	3.3	4.4	12.2	3.9	3.9	4.4
Onoclea sensibilis	10.0	8.3	10.0	11.1	8.9	6.1	8.3	5.6	7.2
Cuscuta gronovii	2.2	4.4	7.6	0.0	4.4	8.9	5.0	1.1	3.9
Bohemeria cylindrica	3.9	7.8	6.1	9.4	6.1	15.6	6.7	5.6	10.6
Pilea pumila	2.8	1.7	5.8	1.7	1.1	5.0	0.0	0.0	0.0
Peltandra viginica	3.9	5.0	5.0	4.4	6.7	7.2	6.1	2.8	3.9
*Mikania scandens**	27.8	6.7	4.4	47.8	24.4	15.6	30.6	48.3	28.9
Polygonum arifolium	5.0	5.0	1.7	6.1	2.8	2.2	2.2	0.6	2.8
Bidens connata	0.6	0.6	0.6	2.8	6.7	0.0	0.0	0.0	0.0
SHRUBS									
**Cornus amomum*	50.0	52.2	45.6	41.7	37.8	46.1	40.6	45.6	37.8
Hibiscus moscheutos	9.4	5.6	8.9	10.6	9.4	6.1	7.8	5.0	5.0
Viburnum dentatum	15.0	5.6	7.2	11.7	14.4	8.3	20.0	20.0	25.6
Cephlanthus occidentalis	1.7	1.7	2.8	2.8	3.3	0.0	5.6	2.8	5.0

[1] 1998 and 2000 Data has been omitted from Table 2 and Table 3 due to lack of space.

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

Species (* dominant in 2009)	2009 (high)	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)	2002 (avg.)	2001 (low)
HERBS									
**Impatiens capensis*	27.5	57.5	64.2	21.7	48.3	74.2	56.7	69.2	42.5
**Typha angustifolia*	61.7	63.3	55.8	61.7	76.7	83.3	75.0	81.7	80.0
Pilea pumila	11.7	10.8	17.5	9.2	9.2	14.2	0.0	0.0	0.0
Polygonum arifolium	2.5	6.7	17.5	6.7	15.8	21.7	12.5	0.0	8.3
**Polygonum sagittatum*	0.8	28.3	17.5	0.8	11.7	12.5	5.8	2.5	2.5
**Lythrum salicaria*	15.8	15.0	16.7	20.8	23.3	11.7	14.2	10.8	15.8
Cuscuta gronovii	1.7	0.0	16.7	0.0	11.7	2.5	0.0	4.2	8.3
Peltandra viginica	8.3	6.7	15.0	11.7	10.0	13.3	12.5	8.3	8.3
Leersia oryzoides	0.8	9.2	11.7	9.2	2.5	0.0	2.5	0.8	2.5
**Mikania scandens*	54.2	25.0	10.0	50.0	45.8	33.3	21.7	31.7	28.3
Bohemeria cylindrical	5.0	9.2	9.2	5.8	10.0	13.3	6.7	5.8	5.8
Apios Americana	1.7	4.2	2.5	5.0	1.7	0.0	0.0	0.0	0.8
Polygonum hydropiper	0.8	0.8	1.5	5.0	0.8	0.0	0.0	0.0	0.0
SHRUBS									
**Viburnum dentatum*	22.5	12.5	18.3	20.8	15.0	11.7	12.5	11.7	10.0
Cornus amomum	12.5	5.8	10.0	10.8	12.5	12.5	9.2	5.0	8.3
Lindera benzoin	3.3	0.8	4.2	5.0	5.8	5.8	4.2	4.2	4.2
Hibiscus moscheutos	3.3	1.7	1.7	2.5	5.0	6.7	3.3	5.0	4.2

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

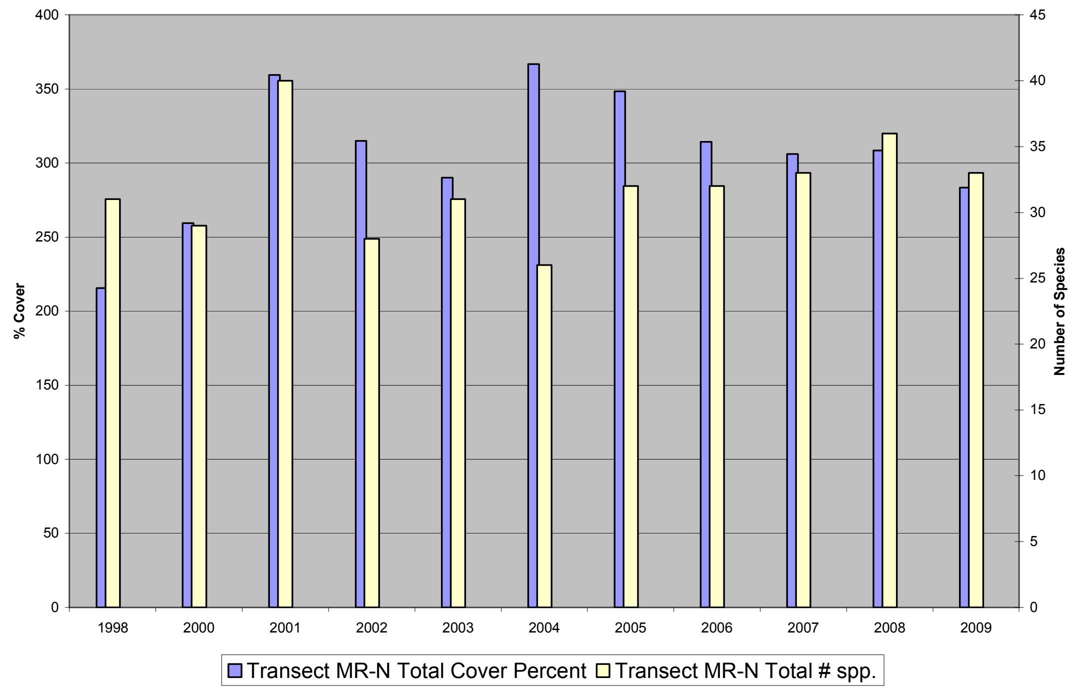
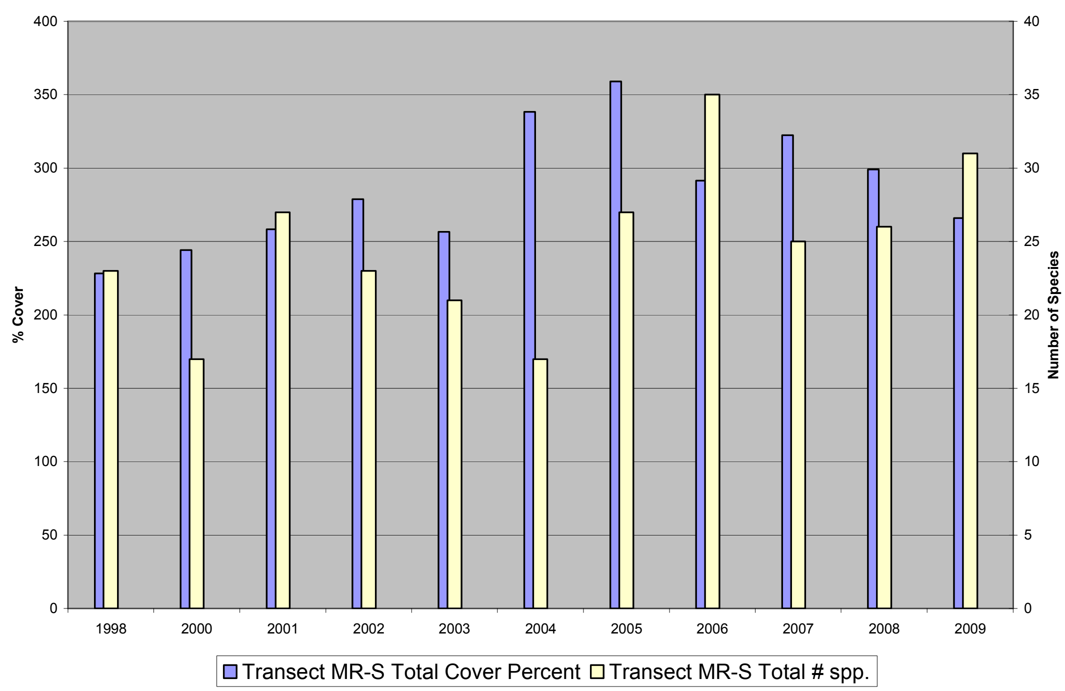


Figure 2 - Lower Mill River Vegetation Survey - South Transect (MRS)



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, 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, the wettest year, 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 2009, cover and diversity at both transects were typical of what would be expected in a season of above average precipitation.

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, 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 decreased over the past few years. At MR-N (Table 2), cattails in 2007 remained within the range observed during the baseline period before the water treatment plant was placed in service. 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 2008 and 2009, but cover remains slightly below the highest baseline levels. At present, the fluctuations do not appear to be significant. However, any future changes should be evaluated carefully as there may be a long-term decline in cattails in this part of the marsh. Slightly higher marsh elevation at MR-N and the fact that the cattail community is less well established may have contributed to the different effects on the two marsh communities.

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 this year, was up only slightly to 29.4 percent cover. 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. The trend of increasing loosestrife cover was evident during the baseline period (1998-2004) and does not appear to have accelerated 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 have been released at wetlands adjacent to Mather Street which crosses Lake Whitney. It is possible that the beetles have spread to the nearby wetlands and are responsible for the apparent loosestrife decline along the transects.

No common reed (*Phragmites australis*) occurs on the Mill River transects. There are isolated patches of this species within the marsh, primarily where dredging, draining, or pollution by storm sewer outfalls has occurred. We have found no evidence that these areas are expanding based upon 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, and the decrease in cattail cover at site MR-S could eventually result in an overall decline in diversity and wildlife habitat value of these marshes. 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. There is no indication to date that the observed changes within the vegetation community is related to the flow in the Mill River. It remains possible that future operations could play a role in accelerating changes in marsh plant communities, therefore continued monitoring is needed to ensure that withdrawal management and mitigation measures are adequate and effective.