2001 Vegetation Monitoring in Mill River Freshwater Tidal Marshes
January 2002

Prepared for
South Central Connecticut Regional Water Authority

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As part of the ongoing evaluation of the lower Mill River corridor and the potential environmental effects of the Whitney Water Treatment Plant, the South Central Connecticut Regional Water Authority is conducting annual monitoring of plant communities in the freshwater tidal marsh. This marsh, created in part by downstream tidegates belonging to the City of New Haven, is an unusual vegetation type that contributes significantly to the biological diversity and wildlife populations in the lower Mill River and East Rock Park.

The Environmental Evaluation Team (1999) assessing the impacts of the proposed treatment plant recommended that vegetation in the marsh be monitored annually or biennially prior to construction of the plant to provide baseline data, as well as after the plant is placed in operation. Data from these studies are to be evaluated against measurements of soil salinity, river flow, and water quality in the lower Mill River to evaluate environmental impacts of treatment plant operation and the possible need to implement management measures to mitigate any adverse effects.

In 2001, Penni Sharp and Vincent Kay conducted quantitative vegetation sampling of the Mill River marshes on September 24. Two permanent transects for vegetation monitoring were established in 1998, and vegetation and river water parameters were monitored in that year and in 2000 and 2001; preliminary sampling in the area of the northern transect was also performed in 1991. Soil water salinity measurements are taken in spring and fall from monitoring wells (three on each transect) installed in 2000.

The upstream, or northern, transect, MR-N, is located about 2000 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 best-developed parts of the marsh. As surveyed, the transect is about 100 meters long; approximately 75 meters of this length passes through high marsh, a mosaic of emergent marsh (primarily cattails) and shrubs, which is seasonally or occasionally flooded but not subject to daily tidal inundations. About 25 meters of low marsh bordering the river is alternately flooded by river water and exposed as a result of daily tidal fluctuations; portions of the low marsh transect are often inaccessible due to flooding by tidal action or high river flows.

The downstream transect, MR-S, passes through a narrower and less varied section of the marsh about 300' south of the East Rock Road bridge. It is about 55 meters long from upland edge to river. The high marsh, about 45 meters wide, consists primarily of cattail marsh, with shrub thickets on elevated hummocks. The remaining 10 meters of the transect is in low marsh bordering the river.

Vegetation Sampling Method

Permanent transects at both sites are approximately perpendicular to the river, with marker stakes placed every 5 meters. Maps of these transects, and a detailed description of the methodology, appear in the 1999 report by Lee Rogers included in the Water Authority's Lake Whitney Water Treatment Plant Environmental Evaluation: Volume Two (January 1999). In vegetation sampling, 5-meter sampling chains are extended to the south at right angles from each stake on 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/chain), and all species touching the rod (or, in forest communities, an imaginary upward extension of it) are recorded.

For transect MR-S, sampling begins at the origin of the permanent transect (stake 1) and extends through stake 12, for a total of 12 chains and 120 sampling points; however, stake 12 is typically inundated, and the frequencies of the sparse vegetation on the last sampling transect have been estimated rather than measured precisely. On transect MR-N, sampling begins at the origin of the permanent transect (stake 1) and extends to stake 18, for a total of 18 chains and 180 sampling points; however, a total of 21 stakes have been installed and surveyed on this transect, and, because the drop-off from stake 18 to the river is fairly gradual, it is possible that one or two additional riverward stakes may be accessible for future sampling under drier conditions.

Results and Discussion

The 2001 vegetation samples showed little change in the structure of the marsh plant community as compared with data from 2000. Specifically, there was little evidence of

successional changes that could reduce diversity, such as increasing coverage by shrubs or invasive non-native plants. While some differences were observed, they are generally of a reversible type frequently observed in wetlands due to climatic variation from year to year and were also due in part to a later sampling time than in 2000, when monitoring was performed several weeks earlier, in mid-August. Somewhat more marked changes were observed last year between the 1998 (mid-September) and 2000 data. This may be partly due to the 2-year interval, but is probably largely attriibutable to the fact that 1998 was a dry year, whereas the last two years had normal to high precipitation during the growing season.

River and Soil Conditions

Precipitation was approximately normal during the 2001 growing season, resulting in fairly typical river flows at the time of sampling. Data on Mill River salinity collected by CH2MHill in August 2001 showed that river salinities remained at essentially freshwater levels at the East Rock Park footbridge, upstream of transect MR-N. Sampling in October and November, during an extended period of low rainfall, revealed relatively high salinities, indicating brackish water, at depths of 0.6 to 1 foot as far upstream as the footbridge; however, near the surface of the river a layer of fresh water persisted. Since it is the surface water that inundates the wetland, and since the growing season was largely over by this time, it is unlikely that the elevated river salinity in the fall had a significant effect on marsh vegetation. Soil water in the transect monitoring wells was sampled on April 20 and July 25, 2001; the results are shown in Table 1. At the spring sampling, soil water salinity in all six monitoring wells and in the river adjacent to the two transects was 0.1 to 0.2 parts per thousand (ppt), well below the 0.5 ppt considered to be limiting (as an annual average) for freshwater marsh vegetation. In July, soil water in the two wells closest to the river had salinities as high as 0.4 ppt on transect MR-N and 0.5 ppt on transect MR-S.

Table 1
Soil Water Salinities in Mill River Marsh Monitoring Wells

Monitor Well No.	Soil Water Salinity (ppt)				
	8/9/00	4/20/01		7/25/01	
	1-2 hr. before low tide	0-2 hr. before high tide	2-3 hr. before low tide	1-2 hr. before low tide	1-2 hr. after low tide

MRN - MW1	0.20	0.20	0.20	0.20	0.20
MRN - MW2	0.10	0.10	0.20	0.20	0.20
MRN - MW3	0.30	0.20	0.20	0.10	0.40
River@MRN	0.20	0.10	0.10	0.10	0.10
MRS - MW1	0.20	0.10	0.10	0.20	0.10
MRS - MW2	0.20	0.10	0.10	0.20	0.30
MRS - MW3	0.20	0.10	0.10	0.50	0.40
River@MRS	0.10	0.10	0.10	0.10	0.10

Vegetation

Table 2 (MR-N) and Table 3 (MR-S) show results of the 2001 sampling and previous monitoring results, listing species in order of their 2001 dominance. Tables 2a and 3a provide an alphabetical listing of the species in the samples.

In both of the marsh communities monitored, the most abundant species is narrow-leaved cattail (*Typha angustifolia*), an emergent marsh plant tolerant of relatively high salinities. This species has gradually increased at both sites from 1998 through 2001. This increase has been more marked at site MR-S, where cattail cover has increased from 67 percent in the dry year of 1998 to 80 percent in 2001. At site MR-N, where the wetland is more varied, cattail cover has increased from 45 to 52 percent over the same period. The apparently higher cover (53 percent) in 1991 cannot be directly compared to later samples, since the transect had not yet been permanently staked and probably passed through slightly different vegetative associations.

Mikania scandens, a vine-like composite, is primarily found in close association with the cattails. Its frequency, however, has generally decreased from 1998 through 2001, from 65 to 28 percent at MR-S and from 31 to 29 percent at MR-N. This plant may have an advantage in germinating and becoming established during dry periods, such as the 1998 growing season. It is noteworthy that numerous seedlings of this annual vine were observed during sampling on September 24, 2001, during a period of low rainfall. Mikania seedlings, which had not previously been noted during August-September sampling, consituted 11 percent cover at MR-S and 16 percent cover at MR-N in 2001. Presumably these fall-germinating seedlings will not survive the winter.

Other dominant herbaceous species on transect MR-N are the ferns found as part of the cattail association, but only in the upper marsh , which is rarely subject to tidal inundation and presumably receives primarily freshwater from runoff during the growing season). Marsh fern (*Dryopteris thelypteris*), was not found on the transect until 2000, when it appeared at 11 percent cover, increasing to 18 percent in 2001. Sensitive fern (*Onoclea sensibilis*) has also increase in cover, from 2 percent in 1998 to 7 percent the last two years

Shrub thickets are the other major association in the upper and middle wetlands, especially on transect MR-N, where they form an intricate mosaic with the emergent cattail marsh, reflecting small increases in elevation. It is assumed that natural succession will gradually increase shrub cover, at the expense of emergent marsh, as will any change that decreases river flow and frequency of marsh inundation. However, rates of siltation and subsidence in these marshes are unknown, and their interplay will affect the suitablity of the habitat for the various plant associations. An earlier analysis of aerial photos (Rogers 1999 in Lake Whitney Water

Treatment Plant Environmental Evaluation, vol. 2) taken between 1980 and 1995 indicated that shrub coverage was increasing in the area which includes the lower part of transect MR-N, at the expense of herbacous marsh.

Since permanent transects were established at this site in 1998, further successional increases in shrub cover appear to be minor. On transect MR-S, where there is little shrub cover, silky dogwood (*Cornus amomum*) has remained fairly constant at 6 to 8 percent, while northern arrowwood (*Viburnum recognitum*) cover has varied from a low of 8 percent in 1998 to a high of 14 percent in 2000. At site MR-N, silky dogwood has varied from a low of 38 percent in 2001 to a high of 47 percent in 2000, declining to about 37percent in 2001, while northern arrowwood has gradually increased from 16 percent in 1998 to 26 percent in 2001.

Other, less common, shrub species at the Mill River sites, which are not part of the shrub thicket association, have also remained fairly constant. Nannyberry (*Viburnum lentago*) is found at MR-N in the transitional zone at the edge of the marsh; its cover has decreased slightly since 1998, from 4 to 2 percent; the transition zone was not included in the 1991 sample. Buttonbush (*Cephlanthus occidentalis*), an emergent tolerant shrub found in lower parts of the marsh at MR-N, varies between 2 and 5 percent cover, as does marsh mallow (*Hibiscus moscheutos*), a woody perennial with showy flowers.

Table 2
MR-N Transect - Species by Current Percent Cover
1991* - 2001

	1991*	**1998**	**2000**	**2001**
Species	% Cover	% Cover	% Cover	% Cover
Typha angustifolia	52.8	45.0	46.7	51.7
Impatiens capensis	27.2	13.9	23.3	42.8
Cornus amomum	28.9	41.1	47.2	37.8
Mikania scandens	24.4	31.1	21.7	28.9
Viburnum recognitum	4.4	15.6	17.8	25.6
Dryopteris thelypteris	0.0	0.0	11.1	17.8

Lythrum salicaria	21.1	7.2	17.8	17.2
Leersia oryzoides	3.3	2.2	3.3	11.7
#Polygonum sagittatum	0.0	0.0	0.0	10.6
Bohemeria cylindrica	1.7	8.3	5.0	10.6
Strophostylus helvola	1.1	1.1	0.0	8.3
Onoclea sensibilis	6.7	2.2	7.2	7.2
# Aster simplex	0.0	0.0	0.0	7.2
Parthenocissus quinquefolia	3.3	6.1	7.2	6.7
Acer rubrum **	0.0	0.0	8.3	6.1
Cephalanthus occidentalis	5.6	1.7	3.3	5.0
Hibiscus moscheutos	3.9	2.8	5.0	5.0
Solidago gigantea	1.1	1.7	5.0	5.0
#Helenium autumnale	0.0	0.0	0.0	4.4
Clethra alnifolia **	0.0	0.0	2.8	4.4
Polygonum hydropiper	1.7	0.0	0.0	4.4
Cuscuta gronovii	2.8	0.0	0.0	3.9
Iris pseudacorus	0.0	3.3	2.8	3.9
Peltandra virginica	5.0	2.2	3.3	3.9
Lobelia cardinalis	0.0	0.0	3.3	3.3
Smilax rotundifolia **	0.0	0.0	2.8	3.3

#Bidens frondosa	0.0	0.0	0.0	3.0
Polygonum arifolium	17.2	1.7	3.3	2.8
Ilex verticillata **	0.0	0.0	2.2	2.2
Sagittaria rigida	0.0	3.9	2.2	2.2
Apios americana	0.0	0.0	1.7	2.2
Todxicodendron radicans	3.9	2.2	0.0	2.2
Viburnum lentago	0.0	3.9	2.8	2.2
#Eupatorium perfoliatum	0.0	0.0	0.0	1.1
#Viburnum recognitum SDLG	0.0	0.0	0.0	1.1
#Scutellaria lateriflora	0.0	0.0	0.0	0.6
Bidens connata	0.0	3.3	0.0	0.6
Vernonia novaboracensis	0.0	0.0	0.6	0.6
Verbena hastata	1.1	0.6	0.0	0.6
Eupatoriadelphus maculatus	3.9	2.2	0.6	0.6
Symplocarpus foetidus	0.0	0.0	0.6	0.6
Aster umbellatus	1.1	0.0	0.0	0.0
C. amomum SDLNG	1.7	0.0	0.0	0.0
Chelone glabra	0.6	0.0	0.0	0.0
Cinna latifolia	1.7	3.3	0.0	0.0
Geum lacinatum	1.1	2.2	0.6	0.0

Lycopus uniflorus	1.1	0.0	0.0	0.0
Mimulus ringens	1.7	0.0	0.0	0.0
Nymphaea odorata	0.0	4.4	0.0	0.0
Panicum clandestinum	0.6	0.0	0.0	0.0
Pilea pumila	0.0	1.1	0.0	0.0
Polygonum scandens	4.4	0.0	0.0	0.0
Quercus sp SDLNG	0.0	0.6	0.0	0.0
Rosa multiflora	6.7	0.0	0.0	0.0
Solidago uliginosa	1.1	0.6	0.0	0.0
U.I. small grass	2.2	0.0	0.0	0.0
Urtica dioica	7.2	0.0	0.0	0.0
TOTALS	**252.2**	**215.6**	**256.1**	**342.8**

* 1991 sample location is not identical to transect surveyed in 1998 amd sampled in subsequent years.

** These species occur in an overhanding canopy and were not sampled in previous years.

Occurred in sample for first time in 2001

Table 2A

MR-N Transect - Alphabetical List of Species and Percent Cover

1991* - 2001

	1991		**1998**		**2000**		**2001**	
Species	Total	%	Total	%	Total	%	Total	%

		Cover		Cover		Cover		Cover
Acer rubrum **	0	0.0	0	0.0	15	8.3	11	6.1
Apios americana	0	0.0	0	0.0	3	1.7	4	2.2
#Aster simplex	0	0.0	0	0.0	0	0.0	13	7.2
Aster umbellatus	2	1.1	0	0.0	0	0.0	0	0.0
Bidens connata	0	0.0	6	3.3	0	0.0	1	0.6
#Bidens frondosa	0	0.0	0	0.0	0	0.0	6	3.0
Bohemeria cylindrica	3	1.7	15	8.3	9	5.0	19	10.6
C. amomum SDLNG	3	1.7	0	0.0	0	0.0	0	0.0
Cephalanthus occidentalis	10	5.6	3	1.7	6	3.3	9	5.0
Chelone glabra	1	0.6	0	0.0	0	0.0	0	0.0
Cinna latifolia	3	1.7	6	3.3	0	0.0	0	0.0
Clethra alnifolia **	0	0.0	0	0.0	5	2.8	8	4.4
Cornus amomum	52	28.9	74	41.1	85	47.2	68	37.8
Cuscuta gronovii	5	2.8	0	0.0	0	0.0	7	3.9
Dryopteris thelypteris	0	0.0	0	0.0	20	11.1	32	17.8
Eupatoriadelphus maculatus	7	3.9	4	2.2	1	0.6	1	0.6
#Eupatorium perfoliatum	0	0.0	0	0.0	0	0.0	2	1.1
Geum lacinatum	2	1.1	4	2.2	1	0.6	0	0.0
#Helenium autumnale	0	0.0	0	0.0	0	0.0	8	4.4

Hibiscus moscheutos	7	3.9	5	2.8	9	5.0	9	5.0
Ilex verticillata **	0	0.0	0	0.0	4	2.2	4	2.2
Impatiens capensis	49	27.2	25	13.9	42	23.3	77	42.8
Iris pseudacorus	0	0.0	6	3.3	5	2.8	7	3.9
Leersia oryzoides	6	3.3	4	2.2	6	3.3	21	11.7
Lobelia cardinalis	0	0.0	0	0.0	6	3.3	6	3.3
Lycopus uniflorus	2	1.1	0	0.0	0	0.0	0	0.0
Lythrum salicaria	38	21.1	13	7.2	32	17.8	31	17.2
Mikania scandens	44	24.4	56	31.1	39	21.7	52	28.9
Mimulus ringens	3	1.7	0	0.0	0	0.0	0	0.0
Nymphaea odorata	0	0.0	8	4.4	0	0.0	0	0.0
Onoclea sensibilis	12	6.7	4	2.2	13	7.2	13	7.2
Panicum clandestinum	1	0.6	0	0.0	0	0.0	0	0.0
Parthenocissus quinquefolia	6	3.3	11	6.1	13	7.2	12	6.7
Peltandra virginica	9	5.0	4	2.2	6	3.3	7	3.9
Pilea pumila	0	0.0	2	1.1	0	0.0	0	0.0
Polygonum arifolium	31	17.2	3	1.7	6	3.3	5	2.8
Polygonum hydropiper	3	1.7	0	0.0	0	0.0	8	4.4
#Polygonum sagittatum	0	0.0	0	0.0	0	0.0	19	10.6
Polygonum scandens	8	4.4	0	0.0	0	0.0	0	0.0

Quercus sp SDLNG	0	0.0	1	0.6	0	0.0	0	0.0
Rosa multiflora	12	6.7	0	0.0	0	0.0	0	0.0
Sagittaria rigida	0	0.0	7	3.9	4	2.2	4	2.2
#Scutellaria lateriflora	0	0.0	0	0.0	0	0.0	1	0.6
*Smilax rotundifolia **	0	0.0	0	0.0	5	2.8	6	3.3
Solidago gigantea	2	1.1	3	1.7	9	5.0	9	5.0
Solidago uliginosa	2	1.1	1	0.6	0	0.0	0	0.0
Strophostylus helvola	2	1.1	2	1.1	0	0.0	15	8.3
Symplocarpus foetidus	0	0.0	0	0.0	1	0.6	1	0.6
Todxicodendron radicans	7	3.9	4	2.2	0	0.0	4	2.2
Typha angustifolia	95	52.8	81	45.0	84	46.7	93	51.7
U.I. small grass	4	2.2	0	0.0	0	0.0	0	0.0
Urtica dioica	13	7.2	0	0.0	0	0.0	0	0.0
Verbena hastata	2	1.1	1	0.6	0	0.0	1	0.6
Vernonia novaboracensis	0	0.0	0	0.0	1	0.6	1	0.6
Viburnum lentago	0	0.0	7	3.9	5	2.8	4	2.2
Viburnum recognitum	8	4.4	28	15.6	32	17.8	46	25.6
#Viburnum recognitum SDLG	0	0.0	0	0.0	0	0.0	2	1.1
TOTALS	**454**	**252.2**	**388**	**215.6**	**461**	**256.1**	**617**	**342.8**

* 1991 sample location is not identical to transect surveyed in 1998 and sampled in subsequent

years.
** These species occur in an overhanding canopy and were not sampled in previous years.
# Occurred in sample for first time in 2001

Table 3
MR-S Transect - Species by Current Percent Cover
1998 - 2001

	1998	2000	2001
Species	% Cover	% Cover	% Cover
Typha angustifolia	66.7	78.3	80.0
Impatiens capensis	32.5	42.5	42.5
Mikania scandens	65.0	35.8	28.3
Lythrum salicaria	0.8	6.7	15.8
Viburnum recognitum	8.3	14.2	10.0
Acer saccharinum *	8.3	8.3	8.3
Cornus amomum	5.8	8.3	8.3
Cuscuta gronovii	3.3	0.0	8.3
Peltandra virginica	1.7	10.8	8.3
Polygonum arifolium	9.2	0.0	8.3
Bohemeria cylindrica	1.7	5.8	5.8
Onoclea sensibilis	0.8	1.7	5.0

Hibiscus moscheutos	2.5	4.2	4.2
Lindera benzoin	5.8	7.5	4.2
#Acer rubrum	0.0	0.0	3.3
#Bidens frondosa	0.0	0.0	2.5
Leersia oryzoides	3.3	8.3	2.5
Polygonum sagittatum	0.0	4.2	2.5
#Chelone glabra	0.0	0.0	1.7
Cinna latifolia	2.5	0.0	1.7
#Helenium autumnale	0.0	0.0	0.8
#Lobelia cardinalis	0.0	0.0	0.8
#Symplocarpus foetidus	0.0	0.0	0.8
#Vernonia novaboracensis	0.0	0.0	0.8
Apios americana	0.0	0.8	0.8
Cornus amomum seedling	0.0	0.8	0.8
Rosa multiflora	1.7	4.2	0.8
Sambucus canadensis	0.8	0.0	0.8
Epilobium coloratum	0.0	0.8	0.0
Geum lacinatum	0.8	0.0	0.0
Mentha arvensis	1.7	0.0	0.0
Parthenocissus quinquefolia	1.7	0.0	0.0

Solidago uliginosa	1.7	0.0	0.0
Strophostylus helvola	1.7	0.8	0.0
TOTALS	**228.3**	**244.2**	**258.3**
# Occurred in sample for first time in 2001			
* Overhanging branches of tree rooted on adjacent levee			

Table 3A
MR-S Transect - Alphabetical List of Species and Percent Cover
1998 - 2001

	1998		2000		2001	
Species	Total	% Cover	Total	% Cover	Total	% Cover
#Acer rubrum	0	0.0	0	0.0	4	3.3
Acer saccharinum *	10	8.3	10	8.3	10	8.3
Apios americana	0	0.0	1	0.8	1	0.8
#Bidens frondosa	0	0.0	0	0.0	3	2.5
Bohemeria cylindrica	2	1.7	7	5.8	7	5.8
#Chelone glabra	0	0.0	0	0.0	2	1.7
Cinna latifolia	3	2.5	0	0.0	2	1.7
Cornus amomum	7	5.8	10	8.3	10	8.3
Cornus amomum seedling	0	0.0	1	0.8	1	0.8

Cuscuta gronovii	4	3.3	0	0.0	10	8.3
Epilobium coloratum	0	0.0	1	0.8	0	0.0
Geum lacinatum	1	0.8	0	0.0	0	0.0
#Helenium autumnale	0	0.0	0	0.0	1	0.8
Hibiscus moscheutos	3	2.5	5	4.2	5	4.2
Impatiens capensis	39	32.5	51	42.5	51	42.5
Leersia oryzoides	4	3.3	10	8.3	3	2.5
Lindera benzoin	7	5.8	9	7.5	5	4.2
#Lobelia cardinalis	0	0.0	0	0.0	1	0.8
Lythrum salicaria	1	0.8	8	6.7	19	15.8
Mentha arvensis	2	1.7	0	0.0	0	0.0
Mikania scandens	78	65.0	43	35.8	34	28.3
Onoclea sensibilis	1	0.8	2	1.7	6	5.0
Parthenocissus quinquefolia	2	1.7	0	0.0	0	0.0
Peltandra virginica	2	1.7	13	10.8	10	8.3
Polygonum arifolium	11	9.2	0	0.0	10	8.3
Polygonum sagittatum	0	0.0	5	4.2	3	2.5
Rosa multiflora	2	1.7	5	4.2	1	0.8
Sambucus canadensis	1	0.8	0	0.0	1	0.8
Solidago uliginosa	2	1.7	0	0.0	0	0.0

Strophostylus helvola	2	1.7	1	0.8	0	0.0
#Symplocarpus foetidus	0	0.0	0	0.0	1	0.8
Typha angustifolia	80	66.7	94	78.3	96	80.0
#Vernonia novaboracensis	0	0.0	0	0.0	1	0.8
Viburnum recognitum	10	8.3	17	14.2	12	10.0
TOTALS	**274**	**228.3**	**293**	**244.2**	**310**	**258.3**
# Occurred in sample for first time in 2001						
* Overhanging branches of tree rooted on adjacent levee						

The third major association in the Mill River marshes is the low marsh, which is regularly inundated during the diurnal tidal cycles. Because of the difficulty of sampling this association, it is underrepresented in the monitoring protocol, with sampling generally limited to the last two chains on each transect. The dominant species in this association are arrow arum (*Peltandra virginica*) and arrowhead (*Sagittaria rigida*). The former species has remained fairly constant at MR-N, increasing from 2 percent cover in 1990 to 4 percent in 2001, but at MR-S, it went from a low of 2 percent cover in 1998 to a high of 11 percent in 2000, dropping to 8 percent in 2001. Arrowhead, which has not been observed in the MR-S sample, was most abundant at MR-N in 1998, with 4 percent cover, falling to 2 percent in subsequent years.While little can be concluded from these small numbers, these figures suggest that the two species differ in their requirements for germination and establishment, with dry springs providing better conditions for arrowhead and wetter ones favoring arrow arum.

One type of vegetative change that can reduce the diversity and habitat value of the marsh is invasion by non-native "nuisance" species. Purple loosestrife (*Lythrum salicaria*) showed a marked increase in cover from 1998 to 2000, from 7 to 18 percent at site MR-N and from 1 to 7 percent at MR-S. In 2001, however, it decreased slightly, to 17 percent cover, at MR-N, while increasing to 16 percent at MR-S but not spreading to new parts of this transect. The highest loosestrife frequency noted to date was on transect MR-N in 1991, where it had 21 percent cover. While this sample is not directly comparable to the later ones, it suggests that the low loosestrife frequency in 1998 and the subsequent increase may be due mainly to differences in precipitation. To date there has been no invasion of the study marshes by the introduced reed *Phragmites autralis*. Although this species does exist in isolated, generally disturbed, areas of

the lower Mill River marshes, this species has not invaded healthy, undisturbed parts of the marsh.

Other changes in plant cover observed in the upper and middle Mill River marshes involve mainly opportunistic annual species. We have noted in our studies of nontidal wetlands of the Quinnipiac River in Cheshire, Connecticut, that these species can vary widely from year to year, without showing any marked directional trend. These differences probably reflect minor differences in precipitation and other climatic factors, especially at the time their seeds are germinating and becoming established, as well as competition and other factors that temporarily affect habitat suitablity. Some of the most dramatic changes are seen in the transitional herb jewelweed (*Impatiens capensis*), a dominant species in many non-forested wetlands. Since 1998, cover by this species has increased at both Mill River sites, from 14 to 43 percent at MR-N and from 33 to 43 percent at MR-S; this probably results mainly from the drier conditions in 1998.

Also interesting in their variability are the two species of tearthumb, *Polygonum arifolium* and *P. sagittatum*, similar in their sprawling, vinelike habit and the grasping thorns that give theim their name, but each having a very distictive leaf shape. In the Cheshire marshes, we have seen tearthumbs go from a minor component of the vegetation in one year to a vicious and nearly impenetrable thicket in another, as well as showing inexplicable shifts in the relative frequency of the two species. In the Mill River marshes, *P. arifolium* has gone from an impressive 17 percent cover at MR-N in 1991 to only 2-3 percent in 1998 through 2001, while it had 9 percent cover on the MR-S transect in 1998, zero in 2000, and 8 percent in 2001. Its sister species, *P. sagittatum*, was not observed on the MR-N transect until 2001, when it became a dominant species with 11 percent cover; on MR-S it showed up with 4 percent cover in 2000 and 3 percent in 2001.

The other type of change noted in the 2001 sample was a larger than usual number (7 at MR-N and 5 at MR-S) of new herbaceous species, generally at less than 2 percent cover, that had not previously been sampled on these transects. Changes in transect cover by these low-frequency plants are largely random, but it is likely that the later sampling time in 2001 increased the incidence of these minor changes in species composition. The larger number of infrequent species, as well as increases in some of the dominant species, is responsible for the high total cover observed in 2001, especially on transect MR-N.

Conclusions

The results of repeated sampling along permanent transects at two sites in the lower Mill River marshes provide a range of baseline data that quantitatively describe the marsh community in terms of natural or successive changes and responses to high (2000), normal (2001), and low

(1998) precipitation conditions during the growing season. Subsequent baseline sampling, to be conducted annually prior to the construction and operation of the proposed treatment plant, will enhance this data base and help to differentiate between year-to-year phenological changes and long-term successional trends. This data base showing variations in vegetation under existing conditions will be useful in evaluating whether future changes can be attributed to the effects of treatment plant operation on river flows. Ongoing monitoring of river water and soil water chemistry will help to establish whether any such changes occur as a result of changes in water salinity that may be caused by reductions in freshwater flows.