2001 Benthic Biological Assessment of The Lower Mill River

Hamden / New Haven (CT)

FEBRUARY 2002

prepared for:

South Central Connecticut Regional Water Authority
90 Sargent Drive
New Haven CT 06511

---

prepared by:

Water Resources Group

11 Phelps Way

P O Box 506

Willington CT 06279-0506

Table of Contents

List of Tables

List of Figures

INTRODUCTION

The purpose of this study is to provide baseline information for future management decisions in conjunction with possible alterations to present stream flows. The study provides quantitative and qualitative information about general habitat characteristics and benthic macroinvertebrate community structure at five locations along the lower Mill River in Hamden and New Haven, CT. This study supplements and updates two similar surveys carried out in 1998 and 2000 (ENSR 1998, 2000). Both the 2000 and 2001 surveys included a lower number of variables than the

1998 study, but habitat and macroinvertebrate characterization was carried out with more detail than in 1998.

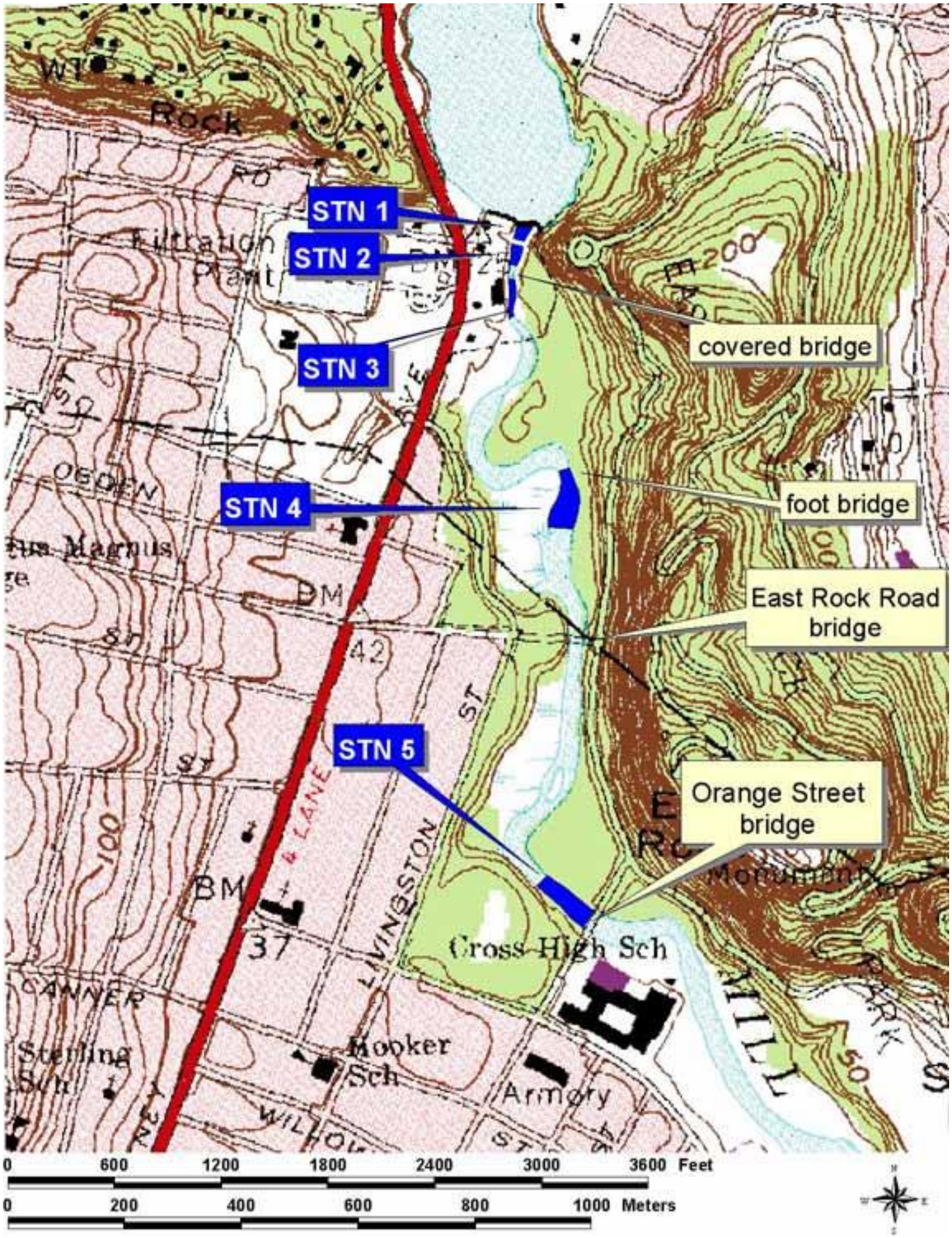
METHODS

General methods followed those applied in the 1998 and 2000 surveys (ENSR 1998, 2000), though periphyton and fish surveys were not performed in 2000 and 2001. Samples were collected in June and August 2001, at the peak of the tidal outflow (low tide). Sampling locations were the same as in the 1998 and 2000 studies (Figure 1). Sampling stations were longitudinal stretches, ranging from 85 to 300 ft in length (~25-90 m). Each sampling station was characterized for general habitat and instream water quality at representative sites. A single sample per site was used to determine water quality parameters. Macroinvertebrates were collected as duplicate D-frame dip-net samples at each station.

Aquatic habitat was evaluated in a qualitative to semiquantitative way adopting the same framework used in the 1998 and 2000 studies (ENSR 1998, 2000). This was a modified version of the USEPA Rapid Bioassessment Protocol (Physical Characterization / Water Quality Assessment) (Barbour et al. 1999). Aquatic habitat characterization included features such as surrounding land use, canopy cover, flow, and substrate composition for each sampling station. Water quality was assessed in a quantitative way with in situ determinations of water temperature, dissolved oxygen content, conductivity, turbidity, and pH at each sampling station.

Timed (two minutes) D-frame dip-net sampling was used to collect macroinvertebrates. This method is commonly used as a multihabitat rapid bioassessment technique (Barbour et al. 1999). Where present, riffle habitats were sampled. Otherwise, run habitats were selected. Macroinvertebrates were captured in the net by dislodging the substrate up to 1 ft (0.3 m) upstream of the dip-net. Two subsamples per sampling station were collected. Each subsample consisted of a two-minute collection. Subsamples were preserved in 70% ethanol for laboratory analysis. Macroinvertebrates were sorted, identified to the lowest meaningful taxonomic level, and counted. Samples were collected during the period of low tide on both sampling dates (approximately 13:30 on 13 June and 12:00 on 21 August).

Figure 1. Locations of the five sampling stations along the Lower Mill River in Hamden (stations 1-4) and New Haven (station 5) (from ENSR 2000).



[Back to top](#)

The two macroinvertebrate subsamples were analyzed separately, but combined into a single sample per station for analysis. Variability among subsamples was slight, but higher than in the 2000 survey. Numerical analysis included relative abundance and dominance patterns, species richness, diversity, and evenness. Species richness was expressed as number of taxa (S). Species diversity indices quantify the degree of dominance (or lack thereof) of taxa within a community. When one or a few taxa dominate a community, diversity is low. Species diversity was calculated as the Shannon-Wiener index (H'), which includes both distribution/dominance patterns and number of taxa (i.e, a community with a high number of taxa is more "diverse" than a community with a low number of taxa, all other things being equal). Evenness (Pielou's index J') normalizes H' in relation to number of taxa, and therefore provides the basis for a quantitative diversity comparison between communities with different S values (the scale is always 0 to 1). Mathematical descriptions of the indices can be found in Zar (1984).

RESULTS

Habitat Characterization

Predominant land use (forest and residential) and sources of watershed pollution (storm pipes discharging at several locations between stations 2 and 5) were the same as in the 1998 and 2000 surveys (Table 1). Sources of pollution to the lower Mill River also include combined sewer overflows (CSOs), one of which is located in the study area (East Rock Road). CSOs can have strong but intermittent water quality impacts. Canopy cover was maximum at station 3 and minimum at station 1, like in 1998 and 2000. Major shore or bank erosion was not noted, as in the previous surveys.

Flow (as estimated or calculated at the spillway) was comparable in June and August 2001. The spring flows were similar in 1998, 2000, and 2001, and may be considered typical for spring to early-summer discharges. The August 2001 flow was slightly higher than in August 2000, and was comparable to the 1998 observations. August 2000 and 2001 studies followed significant rain events and thus flows were higher than typically observed during late summer. Spring and summer of 1998 and 2001 were fairly typical in terms of the distribution of precipitation, while a fairly normal spring 2000 was followed by a relatively wet summer, as reflected by high flows during summer 2000 sampling. Sampling was not conducted during the very dry spring and summer of 1999. Stream flows were not considered extremely low at any time during sampling, but a wide range of flow conditions could be expected to be reflected by the aquatic community over the course of this monitoring program.

Observed instream features did not change appreciably from previous years, with some differences within and among locations. The two upstream stations were dominated by riffle habitats (Table 1). Station 2 exhibited 100% riffle habitat in June 2001, with the small amount of run habitat in August caused by a heavier presence of flow-dampening rooted macrophytes (Table 1). As in previous years, the two downstream stations (stations 4 and 5) exhibited the widest seasonal fluctuations in habitat composition. Run habitat remained more common than pool habitat in August 2001, as in August 1998, but in slight contrast with August 2000. Stations 4 and 5 were also evidently influenced by tidal activity (Table 1), with some barnacle shells observed at station 5.

Table 1. Lower Mill River habitat characterization - June and August 2000. Flow, as estimated at the Lake Whitney outlet, was 138 cfs on June 22 and 184 cfs on August 1. Watershed characteristics did not change from June to August:

	stn 1		**stn 2**		**stn 3**		**stn 4**		**stn 5**	
parameters	13 Jun	21 Aug	13 Jun	21 Aug	13 Jun	21 Aug	13 Jun	21 Aug	13 Jun	21 Aug
length of sampling segment	85 ft (26 m)		150 ft (46 m)		300 ft (91 m)		300 ft (91 m)		300 ft (91 m)	
watershed / bank features										
predominant surrounding land use	forest / residential		forest / residential		forest / residential		forest / residential		forest / residential	
local watershed pollution	some potential sources		obvious sources		obvious sources		obvious sources		obvious sources	
canopy cover	open		some shade (<40%)		mod. shade (40-80%)		some shade (<40%)		some shade (<40%)	
dominant riparian vegetation	shrubs		shrubs		trees		trees / shrubs		trees	
bank stability[(1)]	stable		stable		stable		stable		stable	
other notable features	upstream dam		upstream dam		upstream dam		upstream dam		upstream dam	
in-stream features										

general habitat type (%):										
riffle	100	100	100	90	–	5	-	-	-	-
run	-	-	–	5	100	95	50	20	90	70
pool	-	-	-	-	-	-	50	80	10	30
estimated stream width (ft):	50	50	50	50	100	100	100	100	100	100
estimated stream depth (ft):										
riffle	0.8	1.0	0.5	1.5	–	1.0	–	–	–	–
run	-	-	–	1.5	2.0	1.5	3.0	3.0	2.5	2.5
pool	-	-	-	-	-	-	3.0	3.0	4.0	4.0
inorganic substrate composition(2)										
bedrock	-	-	-	-	-	-	-	-	-	-
boulder (>256 mm)	10	10	10	10	5	5	5	5	5	5
cobble (64-256 mm)	75	80	70	70	40	45	20	10	15	15
gravel (2-64 mm)	15	10	20	20	40	50	10	5	20	25
sand (0.06-2 mm)	-	-	-	–	15	10	50	60	40	40
silt (0.004-0.006 mm)	-	-	-	-	-	-	15	20	20	15
clay (<0.004 mm)	-	-	-	-	-	-	-	-	-	-
organic substrate composition(2)										

detritus(3)	5	10	5	10	5	10	10	10	15	10
aquatic macrophytes	50	50	50	40	15	30	10	15	10	65
filamentous algae	50	20	45	10	10	5	5	-	5	30
water lilies	-	-	-	-	-	–	traces	15	-	-
Pondweeds (4)	-	-	-	15	-	25	-	–	-	25
moss	-	30	5	15	5	-	5	–	-	5
waterweed	-	-	-	-	-	traces	traces	traces	–	5
tidal influence	no	no	no	no	yes	yes	yes	yes	yes	yes
other notable features							recreation (swimming)		barnacle fragments	

(1) stable = minimal evidence of erosion or bank failure.

(2) % coverage

(3) logs, wood, coarse particulate organic matter

(4) Potamogeton richardsonii at stn 5 and narrow-leaved species at the other stations

Back to top

Average stream width and depth in 2001 broadly followed the 1998 and 2000 observations. Variability in depth among years was highest at the upstream stations (Table 1). Tide influenced stream depth at the downstream sites during sampling, with evident water level changes during data collection at stations 3, 4, and 5.

Inorganic substrates were generally coarser at the upstream sites (stations 1 and 2) in 2001 and progressively decreased in mean particle size in the downstream direction (Table 1), as in 2000. Fine-grained substrate such as silt was observed only at the most downstream stations (4 and 5). However, presence of relatively coarse substrate (large gravel, cobble) was higher in August 2001 than August 2000 at all stations except station 4, which tended to be dominated by fine sand with sparse large rocks. It is possible that station 4 represented a "collection bowl" of fine sediment washed downstream by storm-driven flows in 2001, and maintained in place by the regular, opposite tidal current. However, a more rigorous flow study would be necessary to better estimate particle transport patterns in the lower Mill River.

Quantity of detritus (e.g., logs, wood, leaf litter) remained at the relatively low levels of 2000, but tended to increase slightly from June 2001 to August 2001, except for station 5, where the combination of unstructured substrate and tidal stream flows may have prevented accumulation of detritus. The upstream stations (1 and 2) had the highest amount of fine detritus, probably originating from Lake Whitney and transported with the water current. General amounts of detritus, both fine and coarse, appeared to be sufficient to support abundant populations of macroinvertebrates at all stations.

Aquatic macrophytes rarely comprised a large portion of the organic substrate (Table 1). However, living vegetation was more abundant in 2001 than 2000. Forms tolerant of high flow such as attached moss and filamentous green algae (Chlorophyta: Chlorophyceae) comprised the majority of the vegetation at the upstream stations (1 and 2), but presence of rooted macrophytes (mostly narrow-leaved pondweeds) was heavier in 2001 than 2000. As in 1998 and 2000, abundance of green algae decreased from spring to mid-summer, except at station 5, where a relatively heavy presence of an apparently brackish-water filamentous macroalga was observed in 2001 but not in 2000. The macroalga was not identified further. Waterweed (*Elodea canadensis*) and waterlilies (*Nymphaea* spp.), two freshwater species that prefer low-flowing to lentic waters, were rarely observed in 2001. Presence of narrow-leaved pondweeds was similar in 2000 and 2001, these species adapt to a relatively wide range of water current regimes. All the taxa of vascular plants encountered in the lower Mill River were common taxa, tolerant of conditions such as low light, high nutrients, and salinity gradients (Crow and Hellquist 1980). Total plant coverage at the sites was within the typical ranges observed for temperate lotic systems (Allan 1995).

In general, habitat structure was suitable for macroinvertebrates at all stations. Substrate structural complexity (i.e., spatial heterogeneity) provides a diverse habitat for invertebrates, creating "niches" dominated by different food resources and hence invertebrate species, and/or providing crevices that protect invertebrates from predation or dislodgement by strong currents (Hixon & Menge 1991; Allan 1995). Macrophytes also contribute to increase spatial heterogeneity by providing a substrate rich in food resources (epiphytic algae and detritus covering the plants) (Diehl & Kornijów 1998). Physical substrate (cobble and gravel substrate) and/or macrophyte cover was sufficient to potentially support a rich and diverse macroinvertebrate community at all stations except station 4, where the waterlily-dominated vegetation did not appear to provide a sufficiently complex habitat to compensate for the flat, sand-dominated physical substrate.

Selected water quality parameters were assessed again in 2001 (Table 2). Water quality was comparable in the three study years (1998, 2000, and 2001). Water temperature remained within a biologically comparable ~21-26 ºC (Table 2), and varied little between stations. Water temperature in 2001 was similar to water temperature in 1998 and 2000, with the lower (~20 ºC) August 2000 temperature likely due to the high flow and runoff following the storm event that preceded that sample collection.

Dissolved oxygen was always within the life-supporting range for most lotic fauna, though it appeared relatively low at station 5 in August (Table 2). Oxygen solubility decreases non-linearly with increasing temperatures and/or with increasing salinity (Wetzel 2001a). Comparable temperature but higher salinity (as suggested by higher conductivity) at station 5 suggest that the relatively low dissolved oxygen levels at station 5 during low tide are likely due to the transient intrusion of sea water. Decreasing oxygen levels with increasing tidal influence were also observed in a separate study (CH2M Hill 2001).

Specific conductivity in all other instances was comparable between stations and between years. Specific conductivity values observed in the lower Mill River (~200-250 µS/cm) are not indicative of degraded water quality and slightly higher August values are probably a simple result of recent storm water inputs. The slight increase in specific conductivity at stations 1 – 4 from June to August 2001 was unlikely to have any influence on stream ecology.

Table 2. Water quality at the sampling locations, summer 2001:

	station 1	
parameter	**13 Jun**	**21 Aug**
water temperature (° C)	22.5	25.6
dissolved oxygen (mg/l)	9.7	8.1
dissolved oxygen (% saturation)	112	99
specific conductivity (µS/cm)	199	270
turbidity (NTU)	1.72	4.24
pH (SU)	8.5	6.8
	station 2	
	13 Jun	**21 Aug**
water temperature (° C)	22.4	25.6
dissolved oxygen (mg/l)	10.4	9.0
dissolved oxygen (% saturation)	120	111

specific conductivity (µS/cm)	199	268
turbidity (NTU)	2.04	2.57
pH (SU)	8.5	7.8
	station 3	
	13 Jun	**21 Aug**
water temperature (° C)	22.3	25.9
dissolved oxygen (mg/l)	10.2	8.8
dissolved oxygen (% saturation)	117	109
specific conductivity (µS/cm)	200	265
turbidity (NTU)	2.38	4.80
pH (SU)	8.6	8.1
	station 4	
	13 Jun	**21 Aug**
water temperature (° C)	23.5	26.1
dissolved oxygen (mg/l)	11.8	8.2
dissolved oxygen (% saturation)	134	98
specific conductivity (µS/cm)	199	270
turbidity (NTU)	1.99	2.74
pH (SU)	8.8	7.3
	station 5	
	13 Jun	**21 Aug**
water temperature (° C)	24.7	25.5
dissolved oxygen (mg/l)	11.2	6.4
dissolved oxygen (% saturation)	135	75

specific conductivity (µS/cm)	207	411
turbidity (NTU)	2.25	3.90
pH (SU)	8.6	8.5

Back to top

Likewise, a slight increase in turbidity from June to August 2001 (Table 2) is probably storm-induced and is not expected to be influential on the ecology of the lower Mill River. Turbidity remained low (with values <5 NTU) in all three survey years.

As in previous years, pH in 2001 was circumneutral to slightly basic (Table 2). However, pH was relatively high in June 2001. Such relatively high values could not be explained by sea water intrusion (sea water is typically more basic than freshwater), since stations 1 and 2, which were not influenced by tide, also exhibited high pH in June. The quantitative data and the qualitative observations were not sufficient to explain the 2001 pH patterns, but it is not unusual for photosynthesis to cause temporally fluctuating and elevated pH levels. Even so, pH remained within the life-compatible 4.5 – 9.5 range for most aquatic biota (Wetzel 2001b).

Macroinvertebrates

Total invertebrate densities in 2001 were higher than in 1998, but lower than in the 2000 survey, especially at the upstream stations (sites 1, 2 and 3) (Table 3). The 2001 vs. 2000 difference was statistically significant (with p□0.05) in June (two-tailed t-test: $n1=n2=10$, $d.f.=18$, $t=2.833$, $p=0.011$) but not in August (two-tailed t-test: $n1=n2=10$, $d.f.=18$, $t=2.056$, $p=0.055$), probably because of higher between-site variability in August in both years. Invertebrate density at station 4 was very low in August 2001. A complete taxonomic and ecological (feeding) characterization of the invertebrate taxa found in 2001 is presented in Tables 4 and 5.

General macroinvertebrate assemblage structure and patterns were similar in all three years. For example, the three upstream stations (sites 1, 2 and 3) exhibited markedly higher invertebrate density, species richness, and species diversity than the two downstream sites (stations 4 and 5) (Table 3; Figures 2 and 3), though differences were less dramatic in 2001 than 2000.

Taxonomic richness or number of species (S) was slightly lower in 2001 than 2000 (Figure 3), but the difference may be only apparent given rare taxa patchiness that influences presence/absence lists. As in 2000, species richness was higher at the upstream than downstream stations.

Species diversity (H’) at the upstream sites (stations 1, 2 and 3) was comparable in 2000 and 2001, though it tended to be higher at the downstream sites (stations 4 and 5) in 2001. Higher diversity at station 4 may be a mathematical artifact, with the observed few indivi-duals belonging to different taxa. Higher diversity at station 5 in August 2001 than 2000 may be related to denser vegetation in 2001, which increased spatial heterogeneity. Evenness (J’) remained at comparable, relatively low levels in 2000 and 2001 ([Figure 3]()). Low evenness was related to numerical dominance by a few taxa in both years, but given the relatively high species richness at most sites, may not be considered as a sign of degraded conditions. Comparison of species richness, diversity or evenness with the 1998 survey could not be carried out because of the lower taxonomic resolution adopted in 1998.

Table 3. Number of individual macroinvertebrate (by taxa) at each sampling site, June and August 2001. Sampling time is also reported. Location of sampling sites is in Figure 1.

	13 June										**21 August**									
	sites										**sites**									
	1		**2**		**3**		**4**		**5**		**1**		**2**		**3**		**4**		**5**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
taxon	**13:25**	**13:00**	**14:00**	**13:45**	**15:45**	**15:30**	**15:00**	**14:40**	**16:25**	**16:20**	**11:15**	**11:30**	**10:20**	**10:50**	**13:00**	**13:20**	**12:10**	**12:35**	**14:05**	**14:30**
Hydra	-	-	-	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-
Dugesia	3	29	13	6	28	23	2	2	-	-	14	36	21	21	24	4	-	1	1	-
Amn. limosa	1	6	13	9	41	54	-	-	-	-	2	34	58	4	135	66	-	-	-	3
Valv. tricarinata																				
Physa	2	1	1	-	-	-	1	-	-	-	-	-	16	27	-	-	-	-	-	1

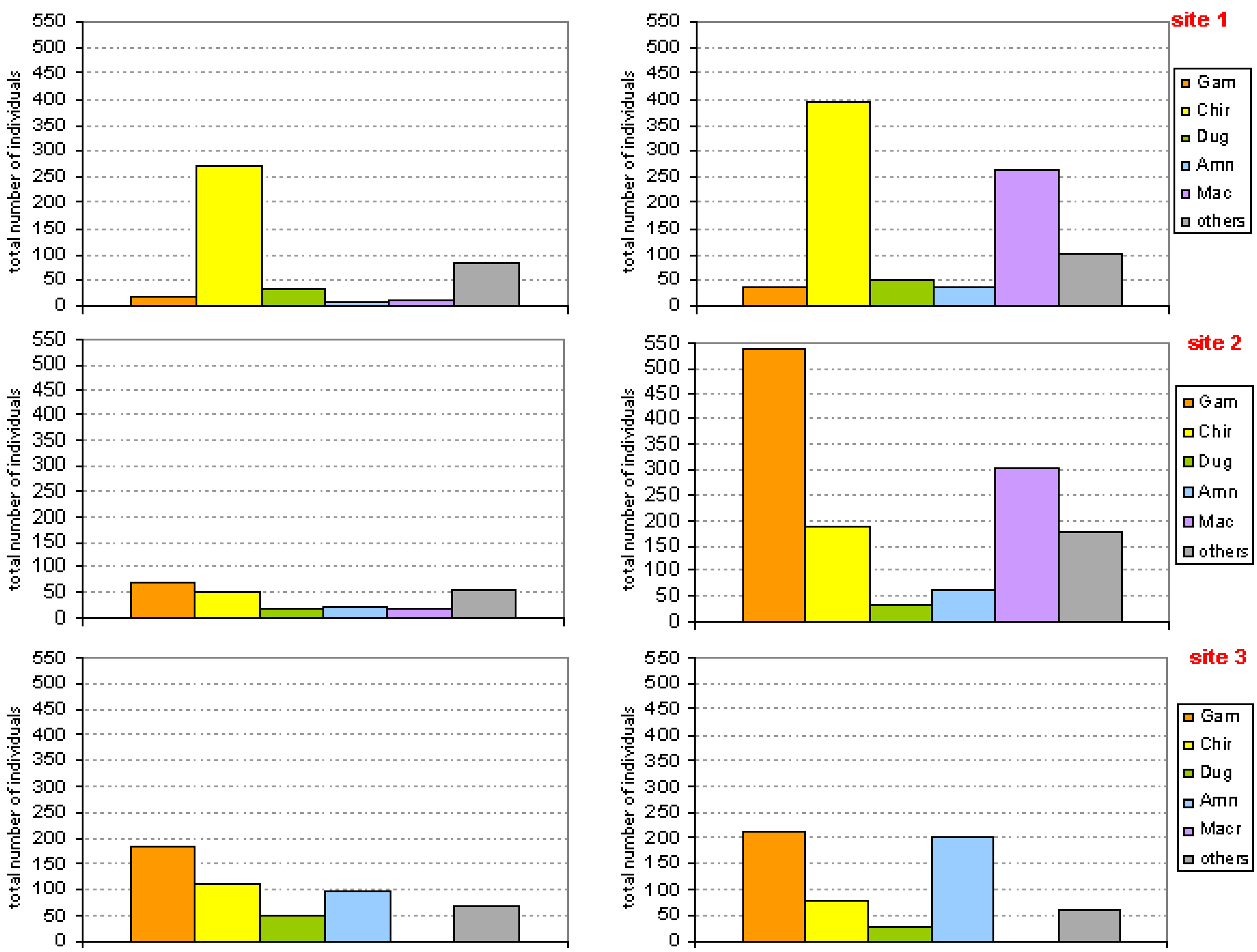
Gyr. parvus	1	2	3	-	4	5	8	9	-	-	-	4	22	4	3	16	-	-	-	2
G. circumstr.	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Lymn. colum.	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-
Pleurocera	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Pomatiopsis	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-
Ferr. rivularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
Sphaeriidae	-	-	-	-	-	5	-	2	-	-	-	-	2	-	-	-	-	-	-	-
Gl. complanata	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	4	-	-
Oligochaeta	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	1	1	-	-
Crangonyx	-	8	2	2	2	3	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Gammarus	3	16	28	41	94	91	38	54	27	37	8	28	378	162	79	133	3	-	21	67
Lirceus	1	7	2	2	1	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Ischnura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

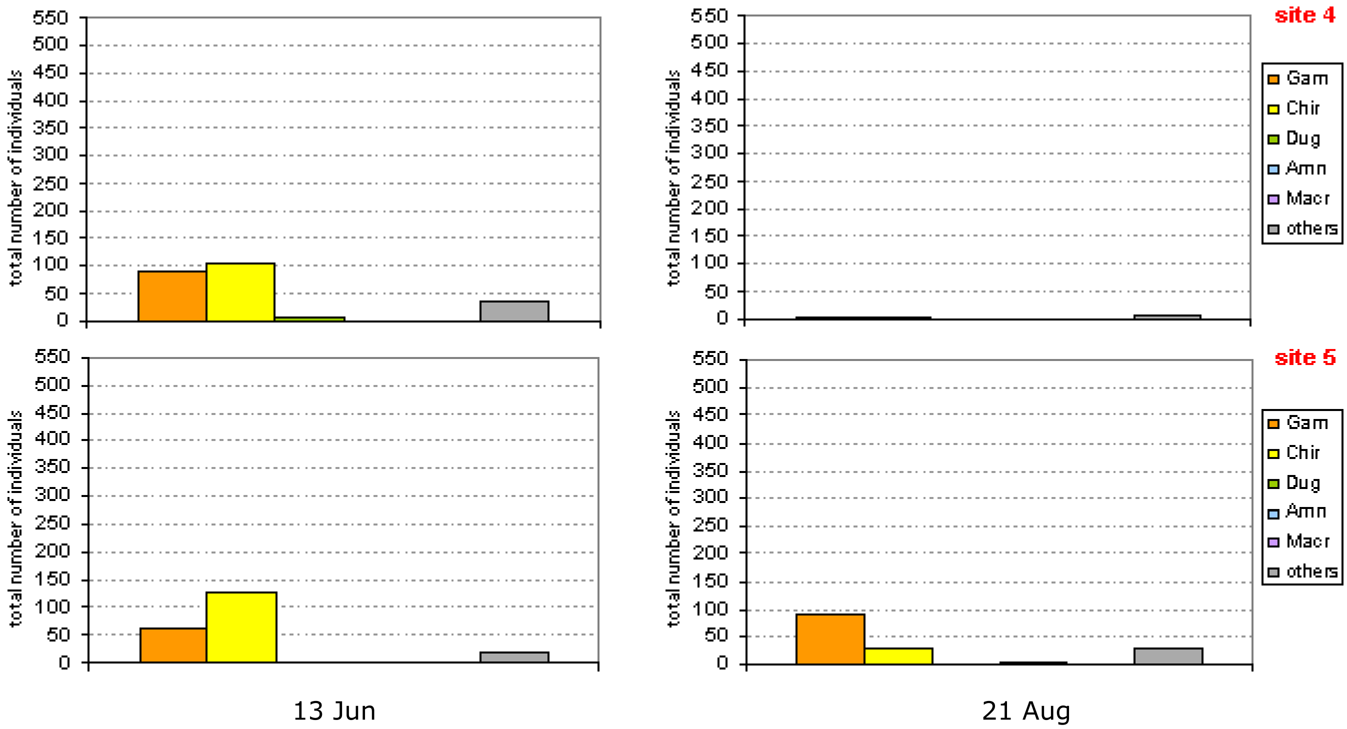
Caenis	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Isonychia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Triaenodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Ceraclea	3	8	2	5	26	19	2	3	1	4	-	8	10	2	7	4	-	-	4	1
Mystacides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	2	-	-	8	2
Macrostemum	-	9	18	-	-	-	-	-	-	-	254	10	191	112	1	-	-	-	-	-
Hydropsyche	3	11	2	30	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	-
Psychomia	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyethira	-	-	-	-	-	-	-	-	-	-	2	4	-	-	-	-	-	-	-	-
Rossiana	-	-	-	-	-	-	-	-	-	-	-	-	2	8	2	-	-	-	-	1
Brachycentrus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Limnephilidae	-	-	-	-	-	-	-	1	-	-	-	-	-	-	8	2	-	-	2	1
Berosus	-	-	-	-	-	4	-	-	-	-	-	2	-	2	-	-	-	-	-	1
Hemerodromia	-	1	-	1	-	-	-	-	-	-	30	12	30	10	-	-	-	-	-	-

Simulium	11	22	-	4	-	-	-	-	-	-	-	27	10	2	28	-	-	-	-	-	-
Chironomidae	161	112	10	40	27	85	26	77	34	92		298	96	106	82	9	69	-	2	30	-
TOTAL	**189**	**234**	**77**	**159**	**223**	**290**	**82**	**153**	**64**	**138**		**637**	**246**	**844**	**460**	**280**	**301**	**4**	**10**	**65**	**83**

Back to top

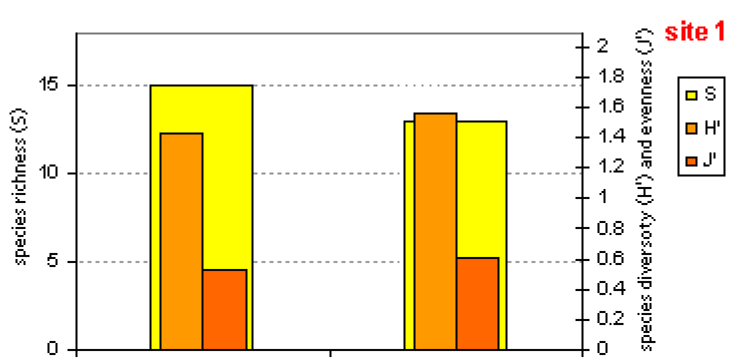
Figure 2. Number of individuals per sampling for selected common taxa in June **(left)** and August 2001 **(right)**. Gam: *Gammarus* sp.; Chir: Chironomidae; Dug: *Dugesia* sp.; Amn: *Amnicola limosa*; Macr: *Macrostemum* sp.. Location of sampling sites is in Figure 1.

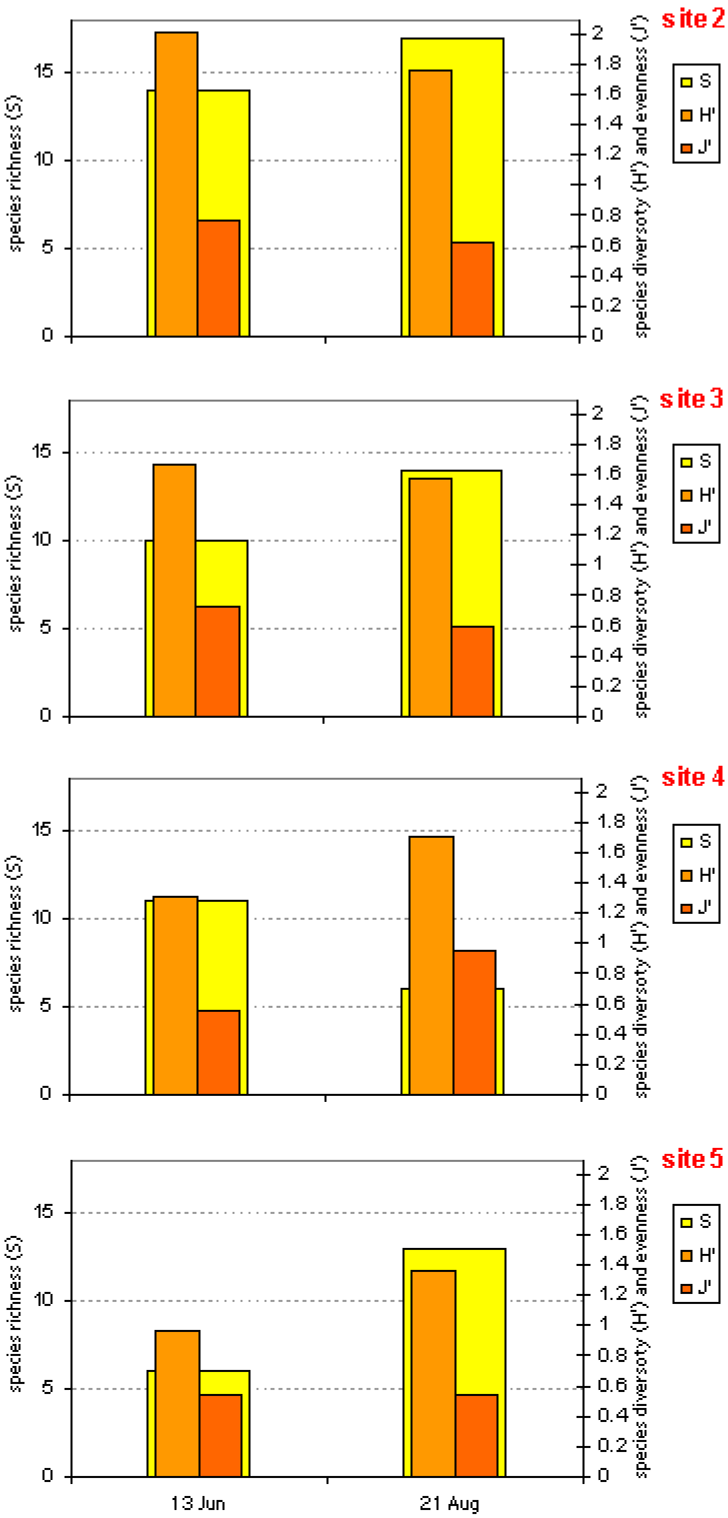




[Back to top](#)

Figure 3. Macroinvertebrate species richness (*S*), diversity (*H'*) and evenness (*J'*) in June and August 2001. Location of sampling sites is in Figure 1.





[Back to top]

Table 4. Macroinvertebrate taxonomic characterization:

phylum orsubphylum	class	order, subclass, or superfamily	family orsuperfamily	taxon	present on	
					13 Jun	21 Aug
Cnidaria	Hydrozoa			*Hydra*		x
Platyhelminthes	Turbellaria	Tricladida	Dugesiidae	*Dugesia*	x	x
Mollusca	Gastropoda	Prosobranchia	Hydrobiidae	*Amnicola limosa*	x	x
Mollusca	Gastropoda	Prosobranchia	Pleuroceridae	*Pleurocera*	x	
Mollusca	Gastropoda	Prosobranchia	Pomatiopsidae	*Pomatiopsis*	x	
Mollusca	Gastropoda	Pulmonata	Physidae	*Physa* sp.	x	x
Mollusca	Gastropoda	Pulmonata	Planorbidae	*Gyraulus parvus*	x	x
Mollusca	Gastropoda	Pulmonata	Planorbidae	*Gyr. circumstriatus*		x
Mollusca	Gastropoda	Pulmonata	Lymnaeidae	*Lymnaea columella*	x	
Mollusca	Gastropoda	Pulmonata	Ancylidae	*Ferrissia rivularis*	x	x
Mollusca	Bivalvia	Corbiculacea	Spheriidae	Sphaeriidae	x	x
Annelida	Hirudinea	Rhynchobdell.	Glossiphoniidae	*Glossiph. complanata*	x	x
Annelida	Oligochaeta	-	Tubificidae?	Oligochaeta	x	x
Crustacea	Malacostraca	Amphipoda	Crangoniyctidae	*Crangonyx*	x	x
Crustacea	Malacostraca	Amphipoda	Gammaridae	*Gammarus*	x	x
Crustacea	Malacostraca	Asellida	Asellidae	*Lirceus*	x	x
Uniramia	Insecta	Odonata	Zygoptera	*Ischnura*		x

Uniramia	Insecta	Ephemeroptera	Caenidae	*Caenis*	x	x
Uniramia	Insecta	Ephemeroptera	Oligoneuriidae	*Isonychia*		x
Uniramia	Insecta	Trichoptera	Leptoceridae	*Triaenodes*		x
Uniramia	Insecta	Trichoptera	Leptoceridae	*Ceraclea*	x	x
Uniramia	Insecta	Trichoptera	Leptoceridae	*Mystacides*		x
Uniramia	Insecta	Trichoptera	Hydropsychidae	*Macrostemum*	x	x
Uniramia	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	x	x
Uniramia	Insecta	Trichoptera	Psychomiid.	*Psychomia*	x	
Uniramia	Insecta	Trichoptera	Hydroptilidae	*Oxyethira*		x
Uniramia	Insecta	Trichoptera	Limnephilidae	*Rossiana*	x	x
Uniramia	Insecta	Trichoptera	Brachycentridae	*Brachycentrus*		x
Uniramia	Insecta	Trichoptera	Limnephilidae	Limnephilidae		x
Uniramia	Insecta	Coleoptera	Hydrophilidae	*Berosus*	x	x
Uniramia	Insecta	Coleoptera	Dryopidae	*Helichus*	x	
Uniramia	Insecta	Diptera	Empididae	*Hemerodromia*	x	x
Uniramia	Insecta	Diptera	Simuliidae	*Simulium*	x	x
Uniramia	Insecta	Diptera	Chironomidae	Chironomidae	x	x

Back to top

Table 5. Macroinvertebrate ecological (feeding) characterization. Primary (main) and secondary feeding categories are given for facultative predators and generalists (herbivores and/or detritivores). Feeding modality refers to how the animals obtain their food (see note on bottom).

Feeding information was obtained mainly from Merritt & Cummins (1996), Thorp & Covich (1991), and ENSR staff personal observations.

taxon	**general**	**primary**	**secondary**	**feeding modality**[(1)]
Hydra	predator	predator	-	engulfer
Dugesia	facult.ative predator	predator	detritivore	engulfer / scraper
Amnicola limosa	generalist	herbivore	detritivore	scraper
Pleurocera	generalist	herbivore	detritivore	scraper
Pomatiopsis	generalist	herbivore	detritivore	scraper
Physa sp.	generalist	herbivore	detritivore	scraper
Gyraulus parvus	generalist	detritivore	herbivore	scraper
Gyraulus circumstriatus	generalist	detritivore	herbivore	scraper
Lymnaea columella	generalist	herbivore	detritivore	scraper
Ferrissia rivularis	generalist	herbivore	detritivore	scraper
Sphaeriidae	detritivore	detritivore	-	filter feeder
Glossiphonia complanata	predator	predator	-	piercer
Oligochaeta	detritivore	detritivore	-	collector
Crangonyx	generalist	detritivore	herbivore	shredder
Gammarus	generalist	detritivore	herbivore	shredder
Lirceus	detritivore	detritivore	-	shredder
Ischnura	predator	predator	-	engulfer

Caenis	detritivore	detritivore	-	shredder
Isonychia	generalist	detritivore	herbivore	filter feeder / collector
Triaenodes	herbivore	herbivore	-	shredder
Ceraclea	generalist	herbivore	detritivore	shredder
Mystacides	generalist	herbivore	detritivore	shredder
Macrostemum	generalist	detritivore	herbivore	filter feeder
Hydropsyche	generalist	detritivore	herbivore	filter feeder
Psychomia	detritivore	detritivore	-	collector
Oxyethira	herbivore	herbivore	-	scraper
Rossiana	herbivore	herbivore	-	scrape
Brachycentrus	generalist	detritivore	herbivore	collector / filter feeder
Limnephilidae	generalist	detritivore	herbivore	shredder / collector
Berosus	generalist	predator	detritivore	piercer / collector
Helichus (adult)	generalist	detritivore	herbivore	scraper / collector
Hemerodromia	detritivore	detritivore	-	collector
Simulium	generalist	detritivore	herbivore	filter feeder
Chironomidae	generalist	herbivore	detritivore	shredder

(1) predator: engulfer and/or piercer scraper: coarse food scrubbed off substrate
shredder: coarse food cut into smaller particles filter feeder: suspended particles captured from water
collector: fine food particles gathered from substrate

Back to top

All the common taxa observed in 1998 were also encountered in 2000 and 2001. Some of the uncommon and rare taxa were observed only in one or two years. Taxonomic resolution was lower in 1998, but a few taxa did not appear in 2000 and 2001 (Hydracarina or water mites, Eubranchiopoda or fairy shrimps, Lepidoptera or moths, Odonata Anisoptera or dragonflies, and Diptera Tipulidae or crane flies). Taxa observed only in 2000 (the Neuropteran *Sysira*, the snails *Gyraulus deflectus* and *Helisoma*, the leech *Placobdella*, the damselfly *Argia*, and the caddisfly *Orthotrichia*) or 2001 (the snails *Valvata tricarinata*, *Pleurocera*, *Pomatiopsis*, and *Lymnaea columella*, and the caddisflies *Brachycentrus*, *Rossiana*, and other species of Limnephilidae) were uncommon to rare.

Sysira is a small-bodied predator specialized on freshwater sponges, and was collected as a single individual in August 2000. *Pleurocera*, a snail found in rivers in the Northeast United States (Peckarsky et al. 1993), also was collected as a single individual in June 2001 (Table 3). Rare taxa tend to be patchily distributed, and patchiness may be exacerbated by spatial heterogeneity. Therefore, absence of such rare taxa in some samples or years may not mean that the taxa do not occur in the lower Mill River system. A more detailed monitoring would be needed to better evaluate the presence/absence of rare taxa in specific years or sites, and is not essential to understanding general patterns of invertebrate communities.

Differences in macroinvertebrate taxonomic composition between the upstream (sites 1 through 3) and downstream stations (sites 4 and 5) may be ascribed mostly to differences in physical habitat. As in 1998, macroinvertebrate assemblages in the upstream stations were more indicative of riffle habitat and coarse substrates, and included several filter-feeding and collector taxa that feed on detritus [e.g., net-spinning caddisflies (Trichoptera Hydro-psychidae), *Isonychia* (Ephemeroptera Oligoneuridae), the dipterans *Simulium* and *Hemerodromia*]. Such taxa were rare or absent at the downstream sites, dominated by finer substrates (e.g., sand).

In general, the macroinvertebrate assemblages observed in 2001 were indicative of moderately degraded conditions, as in 1998 and 2000 (ENSR 1998, 2000). Most of the invertebrate taxa collected were either moderately or highly tolerant of organic enrichment and other forms of pollution. However, such taxa may be commonly found also in relatively unimpacted environments (e.g., scuds, prosobranch snails, caddisflies). Most taxa were typical of urban freshwater habitats (Walsh et al. 2001).

Freshwater invertebrate tolerance to salinity is not well known, but some of the taxa found in the lower Mill River in 2001 and/or 2000 (e.g., scuds, damselflies, chironomid midges, beetles, and pulmonate snails) are found in relatively high numbers in moderately saline lakes (Colburn 1988; Alcocer et al. 1998).Midges (Diptera Chironomidae) can be found in a variety of freshwater habitats (Wetzel 2001c), but their dominance in a community is often regarded as a sign of degraded conditions. Midges dominated at the downstream sites (stations 4 and 5) in 2000, but they increased in importance at site 1 in 2001 (Figure 2). At this site, density of scuds (*Gammarus*) decreased dramatically in 2001, and midges may have simply filled the niche left by scuds. The decrease in the *Gammarus* population at station 1 may be related to natural annual oscillations, since obvious flow or instream environmental changes from 2000 to 2001 were not observed. Scuds are vulnerable to vertebrate and invertebrate predation (e.g., Lombardo 1997), and predation may have played some role. However, data or observations about predation were not collected, and this possibility remains a speculation. The less common scud *Crangonyx* was still present in 2001, but at much lower density than in 2000.

Snails (Mollusca Gastropoda) were represented by several taxa, most of which are tolerant of organic pollution and degraded conditions (Brown 1991). The only exceptions were three limpet individuals (*Ferrissia rivularis*, which prefer fast-flowing and clean habitats: Pip 1986), found at the riffle/run habitat in station 3 in August (Table 3). A partial, calcified shell of *Valvata tricarinata* (Prosobranchia Valvatidae) also was found at station 3B in August, but was not included in the survey. If this species was/is present in the lower Mill River system, it would indicate a relatively unimpacted habitat rich in submerged vegetation (ENSR personnel, personal observation). Increased presence of *Amnicola limosa* and other snail species from 2000 appeared to follow the heavier macrophyte presence at most sites in August 2001 than August 2000, supporting the statements in ENSR (2000) and a number of published works (e.g., Gørtz 1998). The snail *Pomatiopsis*, observed at station 5 in June (Table 3), is a more proper inhabitant of stream banks, and may not provide much information on stream ecosystem status.

Predators (leeches, odonates, beetles) were represented by five taxa and low numbers (Table 3). Number of both predator taxa and individuals were lower in 2001 than 2000. Data from the 2000 survey suggested that food availability in the lower Mill River was sufficient to support a relatively complex invertebrate food web, even if water quality is suboptimal for invertebrates (ENSR 2000). As for scuds, low numbers of predatory invertebrates in 2001 suggest presence of larger predators in the food web, but a specific study would be needed to address this idea.

CONCLUSIONS

The macroinvertebrate assemblage in the lower Mill River is the product of several factors acting simultaneously. Flow is typically a major determinant of invertebrate assemblage structure (e.g., Brunke et al. 2001), influencing invertebrates directly or by altering physical instream habitat and physico-chemical characteristics such as temperature, oxygen, pH, and conductivity (Sabo et al. 1999). Predicted lower flow from the Lake Whitney dam as a result of increasing withdrawal for human use may affect taxa that rely on water current for food, such as filter-feeders (e.g., the mayfly *Isonychia* , the caddisfly *Hydropsyche*, and the dipteran *Simulium*) (Brunke et al. 2001). Density of the scud *Crangonyx* also may be reduced by lower flow regimes, while the closely related, but slow-water taxon *Gammarus* may increase (Beckett et al. 1998). However, effects may be highly localized in time and space and that generalization should be based on real data and not assumed ecological relationships. Any impacts relating to flow would be expected only during withdrawals that coincide with low flow periods, not from expected withdrawal during higher flows.

Reduced flow may decrease invertebrate density and diversity (Gørtz 1998; Brunke et al. 2001), but flow interacts closely with the physical structure of the habitat. Streams with relatively low flow but high degree of habitat heterogeneity (coarse detritus, rocks, submerged vegetation) may still support high invertebrate density, diversity, and taxonomic richness (Brunke et al. 2001). Increased vegetation cover may be expected at lower flow regimes, thus counterbalancing (at least in part) the potentially negative effects of decreased flow by increasing substrate heterogeneity. Though some changes in densities and relative abundances may occur, major changes in invertebrate taxa in the lower Mill River are not expected after the flow from Lake Whitney would become increasingly regulated.

Effects of increased salinity (possibly brought about by lower flow and/or any future alteration or removal of the downstream tide gates) on the lower Mill River invertebrate assemblages are difficult to predict, but would seem likely to be more severe than minor changes in flow. Most of the taxa found in the 1998, 2000, and 2001 surveys may withstand small increases in salinity, with invertebrate communities shaped more by physical habitat characteristics than fluctuations in salinity (Alcocer et al. 1998). However, effects of possible tide-related bursts in salinity, exacerbated by lower flow or removal of tide gates, could shift the community to a species-poor, low-diversity assemblage dominated by highly tolerant species (Wolfram et al. 1999). Salinity values that may lead to such drastic changes were recorded only at the tide gate area (CH2M Hill 2001). The upstream portion of the lower Mill River (e.g., stations 1 through 3) appear unlikely to be significantly affected by tide-driven salinity bursts, because of their higher elevation.

As was the conclusion from the 2000 survey, the data collected in 2001 suggest that alteration of flow associated with reactivation of Lake Whitney as a water supply appears to be only a minor potential influence on the lower Mill River. Also, and on a larger-scale basis, projected lower flow in the lower Mill River may not influence the downstream New Haven Harbor, since the lower Mill River's contribution to harbor hydrology and water chemistry is marginal (Rozan & Benoit 2001).

LITERATURE CITED

Alcocer J., E. Escobar, A. Lugo, & L. Peralta, 1998. Littoral benthos of the saline crater lakes of the basin of Oriental, Mexico. International Journal of Salt Lake Research 7: 87-108

Allan J. D., 1995. *Stream Ecology — Structure and Function of Running Waters*. Chapman & Hall, London, UK.

Barbour M. T., J. Gerritsen, B. D. Snyder, & J. B. Stribling, 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. Second edition. EPA 841-B-99-002. USEPA, Office of Water. Washington, DC.

Beckett D. C., P. A. Lewis, & J. H. Green, 1998. Where have all the *Crangonyx* gone? The disappearance of the amphipod *Crangonyx pseudogracilis*, and subsequent appearance of *Gammarus* nr. *fasciatus*, in the Ohio River. The American Midland Naturalist 139: 201-209

Brown K. M., 1991. Mollusca: Gastropoda. Pp. 285-314 in: *Ecology and Classification of North American Freshwater Invertebrates*, J. H. Thorp & A. P. Covich editors. Academic Press, San Diego, CA.

Brunke M., A. Hoffman, & M. Pusch, 2001. Use of mesohabitat specific relationships between flow velocity and river discharge to assess invertebrate minimum flow requirements. Regulated Rivers: Research & Management 17: 667-676

CH2M Hill, 2001. 2001 monitoring of Mill River dissolved oxygen and salinity — Hamden and New Haven, CT. Draft report for the SCCRWA.

Colburn E. A., 1988. Factors influencing species diversity in saline waters of Death Valley, USA. Hydrobiologia 158: 215-226

Crow G. E., and C. B. Hellquist, 1980. Aquatic Vascular Plants of New England. Part 1 through 8. Series of bulletins published by the New Hampshire Agricultural Experiment Station, University of New Hampshire. Durham, NH.

Diehl S., & R. Kornijów, 1998. Influence of submerged macrophytes on trophic interactions among fish and macroinvertebrates. Pp. 24-46 in: *The Structuring Role of Submerged Macrophytes in Lakes*; E. Jeppesen, Ma.

Søndergaard, Mo. Søndergaard, and K. Christoffersen Editors. Springer-Verlag, New York, NY.

ENSR, 1998. Aquatic biological assessment of the Lower Mill River — Hamden, Connecticut. Final Report to the SCCRWA.

ENSR, 2000. Benthic biological assessment of the Lower Mill River — Hamden / New Haven (CT). Final report to the SCCRWA.

Gørtz P., 1998. Effects of stream restoration on the macroinvertebrate community in the River Esrom, Denmark. Aquatic Conservation: Marine and Freshwater Ecosystems 8: 115-130

Hixon M. A., & B. A. Menge, 1991. Species diversity: prey refuges modify the interactive effects of predation and competiiton. Theoretical Population Biology 39: 178-200

Lombardo P., 1997. Predation by *Enallagma* nymphs (Odonata, Zygoptera) under different conditions of spatial heterogeneity. Hydrobiologia 356: 1-9

Merritt R. W., & K. W. Cummins (editors), 1996. *An Introduction to the Aquatic Insects of North America*, third Edition. Kendall/Hunt Publishing, Dubuque, IA.

Peckarsky B. K., P. R. Fraissinet, M. A. Penton, & D. J. Conklin Jr., 1993. *Freshwater Macroinvertebrates of Northeastern North America*. Cornell University Press, Itahaca, NY.

Pip E., 1986. The ecology of freshwater gastropods in the central Canadian region. Nautilus 100: 56-66

Rozan T. F., & G. Benoit, 2001. Mass balance of heavy metals in New Haven Harbor, Connecticut: predominance of nonpoint sources. Limnology and Oceanography 46: 2032-2049

Sabo M. J., C. F. Bryan, W. E. Kelso, & D. A. Rutherford, 1999. Hydrology and aquatic habitat characteristics of a riverine swamp: I. Influence of flow on temperature and water chemistry. Regulated Rivers: Research & Management 15: 505-523

Thorp J. H., & A. P. Covich (editors), 1991. *Ecology and Classification of North American Freshwater Invertebrates*. Academic Press, San Diego, CA.

Walsh C. J., A. K. Sharpe, P. F. Breen, & J. A. Sonneman, 2001. Effects of urbanization on streams of the Melbourne region, Victoria, Australia. I. Benthic macroinvertebrate communities. Freshwater Biology 46: 535-551

Wetzel R. G., 2001a. Oxygen. Chapter 9 in: *Limnology - Lake and River Ecosystems*, 3rd edition. Academic Press, San Diego, CA.

Wetzel R. G., 2001b. The inorganic carbon complex. Chapter 11 in: *Limnology - Lake and River Ecosystems*, 3rd edition. Academic Press, San Diego, CA.

Wetzel R. G., 2001c. Littoral and profundal benthic communities of lakes. Pp. 702-705 in: *Limnology - Lake and River Ecosystems*, 3rd edition. Academic Press, San Diego, CA.

Wolfram G., K. Donabaum, M. Schagerl, & V. A. Kowarc, 1999. The zoobenthic community of shallow salt pans in Austria — preliminary results on phenology and the impact of salinity on benthic invertebrates. Hydrobiologia 408/409: 193-202

Zar J. H., 1984. Indices of diversity. Pp. 32-36 in: *Biostatistical Analysis*, 2nd edition. Prentice Hall, Englewood Cliffs, NJ