COMPARISON OF BENTHIC MACROINVERTEBRATE DATA COLLECTED FROM THE MERRIMACK RIVER NEAR MERRIMACK STATION DURING 1972, 1973, AND 2011

January 2012

Comparison of Benthic Macroinvertebrate Data Collected from the Merrimack River near Merrimack Station During 1972, 1973, and 2011

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1.0 Introduction

Public Service of New Hampshire ("PSNH") owns and operates two separate generating units, Unit 1 and Unit 2, known together as Merrimack Station, in Bow, New Hampshire. Merrimack Station is located on the west bank of the Merrimack River adjacent to Hooksett Pool in freshwater, approximately 2.9 miles upstream from the Hooksett Dam and Hydroelectric Station and about 2.9 miles downstream from the Garvins Falls Dam. Merrimack Station withdraws and discharges once-through cooling water from the Merrimack River subject to and with the benefits of National Pollutant Discharge Elimination System ("NPDES") Permit No. NH001465 ("Permit"), which was last renewed by Region 1 of the United States Environmental Protection Agency ("USEPA") on 25 June 1992. Unit 1, which became operational in 1960, generates at a rated capacity of 120 MW, and withdraws once-through cooling water from the waters of the Merrimack River using a cooling water intake structure ("CWIS") located in a bulkhead at the shoreline of Hooksett Pool. Unit 2, which became operational in 1968, generates at a rated capacity of 350 MW, and withdraws once-through cooling water from the Merrimack River using a separate CWIS located in a bulkhead approximately 120 feet downstream from the Unit 1 CWIS.

The Station is seeking a renewal of its existing variance under Section 316(a) of the Clean Water Act ("CWA"), 33 U.S.C. §1326(a), as part of the renewal of its existing Permit. CWA §316(a) provides that a permit applicant may demonstrate that any effluent limitation proposed for the thermal component of any discharge is more stringent than necessary to assure the protection and propagation of a Balanced, Indigenous Population ("BIP") of shellfish, fish, and wildlife in and on the body of water into which the discharge is made. Applicants with an existing thermal discharge may demonstrate that the existing discharge is protective of the BIP by evaluating the BIP over a series of years during which the discharge occurred, and showing an absence of appreciable harm (40 C.F.R. §125.73(c); USEPA 1977). This report and certain other reports prepared by Normandeau Associates, Inc. (Normandeau) and submitted to the Merrimack Station Advisory Committee (which was established pursuant to Part I.15 of the Permit and comprises representatives of the United States Environmental Protection Agency ("USEPA"), New Hampshire Department of Environmental Services ("NHDES"), the United States Fish and Wildlife Service ("USFWS") and the New Hampshire Fish and Game Department ("NHFGD")) collectively demonstrate that the Station's past and current operations have resulted in no appreciable harm to the BIP in the segment of the Merrimack River receiving the Station's thermal discharge (Normandeau 2006a; Normandeau 2007a; Normandeau 2007b; Normandeau 2009a). These studies focused on the Merrimack River fish community due to the frequent use of fish assemblages as indicators of overall ecological condition. USEPA (2006) documented the advantages of using fish as indicators of ecological condition due to their relatively long life spans, mobility, ability to feed at every trophic level (herbivores, omnivores, predators) and relative ease of species identification.

The following report compares benthic macroinvertebrate data collected during 1972, 1973, and 2011 to document changes in the benthic macroinvertebrate community composition from the 1970s to 2011. These data include qualitative aquatic insect data collected in shallow, wadeable shoreline areas, as well as quantitative benthic invertebrate data collected from deep, non-wadeable sediment samples. Sampling locations and techniques were identical during all three years.

2.0 Methods

2.1 Habitat Assessment

The benthic habitat was assessed at each sampling station (N-10, S-0, S-4, and S-17). Latitude and longitude of each sampling station was determined with a hand held GPS and water temperature, dissolved oxygen, and specific conductance were measured with a calibrated YSI model 85 water quality meter. Five habitat assessment metrics, Epifaunal Substrate/ Available Cover, Channel Flow Status, Bank Stability, Vegetative Protection, and Riparian Vegetative Zone Width were rated at shoreline stations only (e.g., N-10-E, S-4-W) and were selected from Barbour et al (1999) to allow a comparison of habitat quality and conditions between stations. In addition, grain size analysis was performed on sediment samples collected from Ponar sampling locations to document substrate conditions.

2.2 Aquatic Insects

In October 1972, aquatic insects were collected from the east and west banks of Stations N-10, S-0, S-4, and S-17 in Hooksett Pool (Normandeau 1973); one sample was collected from each bank. Collections were made by two field personnel working for 10 minutes at each station (Normandeau 1973).

In 2011, qualitative aquatic insect samples (Kick Samples) were collected in October from the east and west banks of Stations N-10, S-0, S-4, and S-17 in Hooksett Pool. In November 2011 aquatic insect samples were collected at a Downstream Reference Station (DSR) and at an Upstream Reference Station (USR) in Garvins Pool and at Station N-10 in Hooksett Pool. Collections were made following procedures used in 1972, although in 2011, Kick Samples were collected over a 20 minute period by one biologist. In both cases, samples were collected using a standard dip net with a mesh size of 595 µm to jab, dip, and sweep along shoreline areas. At each station, a grain size sample was collected during Ponar grab sampling to document substrate conditions. Aquatic insect samples were placed in a labeled sample container and preserved with 10% buffered formalin for later identification.

2.3 Benthic Invertebrates

Quantitative samples were collected at Stations N-10, S-0, S-4, and S-17 with a 9 in by 9 in Ponar grab sampler in October 1972 (Normandeau 1973), 1973 (Normandeau 1974), and 2011. Grab samples were also collected in Garvins Pool at Stations USR and DSR and at Hooksett Pool Station N-10 in November 2011. Two replicate samples were collected from non-wadeable areas on the east and west banks and at a mid-river, deep water location at each station. Samples were sieved in the field using a 595 µm mesh sieve bucket, then placed in a labeled sample container and preserved with 10% buffered formalin, and then returned to the laboratory for identification. Grain size samples were also collected from each Ponar sampling location to document substrate conditions.

2.4 Analytical Metrics

Five analytical metrics were used to summarize benthic macroinvertebrate data. These metrics are used in EPA's Rapid Bioassessment Protocols (Plafkin et al 1989, Barbour et al 1999) to detect biological impairment in lotic ecosystems and are often used to assess and compare benthic macroinvertebrate communities at separate locations.

Taxa Richness – Taxonomic richness (taxa richness) is the number of different types (taxa) of benthic macroinvertebrates present in a sample, and is a measure of the diversity within a sample. For example, if two different types of mayfly, one type of caddisfly, and five different types of midges were found in a sample, regardless of the number of individuals in each group, the taxa richness of the sample would be 8. Higher values indicate better water quality and less stressful conditions for aquatic organisms.

Biotic Index – The biotic index is a ranking based on literature-reported values of the relative sensitivity of a taxon to organic pollution stress caused primarily by the presence of oxygen-demanding substances in the water. This index was developed by Hilsenhoff (1977) to summarize the pollution tolerances of benthic macroinvertebrates. Organisms were assigned a value ranging from sensitive (0) to tolerant (5), and the individual tolerance values were weighted by the proportion of that taxon among the total number of organisms in the sample; the weighted values were summed within the sample to calculate the biotic index. In 1987 the index was updated and expanded to a 0 (sensitive) to 10 (tolerant) scale.

Samples from degraded sites usually have mostly tolerant taxa and a high biotic index value closer to 10 while pristine sites typically have mostly intolerant taxa and a biotic index closer to 0. Low gradient sites often have moderate biotic index values (approximately 4-7), even at pristine sites, because some organisms with low biotic index values also prefer habitats with low gradients, sand/silt/mud substrates, and low flow. Biotic index values assigned to macroinvertebrate taxa in this study were based on those provided by the New Hampshire DES, Maine DEP, Massachusetts DEP, New York DEC, and the Vermont DEP.

Ratio of Ephemeroptera, Plecoptera, and Trichoptera (EPT) to Chironomidae abundance – Non-biting midges in the insect family Chironomidae are generally abundant in the benthic macroinvertebrate community and tolerant of environmental stress. The ratio of abundance of the sensitive EPT taxa to the abundance of the tolerant Chironomidae is a measure of community balance. Good biotic conditions are reflected in a relatively even distribution among all four groups and a relatively high ratio. Macroinvertebrate communities experiencing environmental stress may exhibit a low EPT/Chironomidae ratio due to a disproportionately high number of tolerant midges. Chironomids tend to become increasingly dominant along a gradient of increasing organic enrichment or heavy metals concentration.

Percent Contribution of the Dominant Taxon – The percent contribution of the most abundant taxon to the total number of organisms found in a sample is a measure of balance in the benthic community. If the dominant taxon accounts for a large percentage of the individuals present, it is an indication of stress because the community is dominated by one taxon, whereas unstressed communities typically exhibit a more evenly balanced abundance among several taxa.

EPT Index – Three groups of benthic insects are considered particularly sensitive to pollution, and the number of distinct taxa among them generally increases with increasing water quality. These groups (orders) are Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) and are collectively referred to as the EPT taxa. The EPT Index is calculated by counting the number of EPT taxa represented in each sample, similar to calculating taxa richness. Low values for this metric indicates potentially stressful conditions.

3.0 Results

3.1 Habitat

The aquatic insect and benthic invertebrate stations sampled in 2011 were at the same locations sampled in 1972 and 1973. Table 1 shows station coordinates, water quality, habitat information collected in for each station sampled in 2011. Habitat at all stations was comparable and water quality values were within normal ranges. Substrate composition, based on grain size analysis, showed that medium sand (0.25 – 0.5 mm diameter) and coarse sand (0.5 – 1.0 mm) composed the largest percentage of the substrate at most stations. However at Stations S-17-middle and S-17-east, the stations farthest downstream, fine sand (125 – 250 µm) composed a greater percentage of the substrate than coarse sand (Table 2).

3.2 Aquatic Insects

Qualitative aquatic insect samples were collected along shoreline areas on 4 October 1972 and 25 to 26 October 2011.

In 1972 along the eastern bank, the mean taxa richness value was 6.8, the mean EPT richness value was 1.7, and the mean EPT/Chironomidae abundance value was 0.05 (Table 3). Along the western bank, the mean taxa richness value was 9.2, mean EPT richness was 2.8, and mean EPT/ Chironomidae abundance value was 0.8. The numerically dominant taxon at all along the east bank stations was the non-biting midge, Chironomidae (Normandeau 1973) and along the west bank three taxa were numerically dominant Chironomidae, the riffle beetle *Dubiraphia* sp., and the caddisfly Hydroptilidae (Table 4).

In 2011, the numerically dominant taxon along the eastern bank was the amphipod *Gammarus fasciatus* (Table 4). The mean taxa richness value was 20.8, the mean EPT richness value was 5.2, and the mean EPT/Chironomidae abundance value was 32.4. Along the western bank in 2011, the numerically dominant taxon at all stations was the amphipod *Gammarus fasciatus* (Table 4). The mean taxa richness value was 22.5, mean EPT richness was 4.2, and EPT/ Chironomidae abundance value was 7.1.

Kick sample data collected from the aquatic insect community at all Hooksett Pool Stations showed dramatic improvements in the aquatic insect community composition between 1972 and 2011. The most dramatic differences between the two years was seen in Taxa Richness (the total number of taxa), EPT Richness (the number of EPT taxa), and the EPT to Chironomidae Abundance ratio.

Mean taxa richness values, from 1972 to 2011, increased 300 percent along the west bank and over 240 percent along the east bank. EPT Richness also showed large increases in 2011; mean values increased over 300 percent at stations along the east bank from 1.7 in 1972 to 5.2 in 2011 and on the west bank values increased over 150 percent from 2.8 in 1972 to 4.2 in 2011 (Table 3).

Table 1. Merrimack River benthic sampling station habitat data.

					SURFACE			5 FT DEPTH		
STATION	SAMPLE DATE	LATITUDE	LONGITUDE	DEPTH	TEMP (°C)	DO (mg/l)	SP. COND (µS/cm)	TEMP (°C)	DO (mg/l)	SP. COND (µS/cm)
USR-W	8-9 Nov11	43° 12.124	71° 31.750	11	6.9	12.7	67.4	6.8	12.7	67.6
USR-M	8-9 Nov11	43° 12.147	71° 31.729	9	6.8	12.5	67.5	6.8	12.5	67.4
USR-E	8-9 Nov11	43° 12.171	71° 31.709	7	6.9	12.4	68.6	6.9	12.4	68.8
DSR-W	8-Nov-11	43° 11.841	71° 31.371	9	6.6	12.4	68.1	6.5	12.4	68.5
DSR-M	8-Nov-11	43° 11.857	71° 31.333	9	6.8	12.0	66.6	6.5	12.0	66.8
DSR-E	7-Nov-11	43° 11.868	71° 31.299	9	6.4	13.5	66.9	6.4	13.5	67.6
N-10-W	26-Oct-11	43° 9.075	71° 28.761	7	10.4	12.0	64.6	10.4	12.0	65.2
N-10-M	26-Oct-11	43° 9.109	71° 28.718	8	10.4	12.0	65.7	10.4	12.1	65.9
N-10-E	26-Oct-11	43° 9.136	71° 28.690	8	10.3	12.0	66.7	10.3	12.0	66.8
N-10-W	7-Nov-11	43° 9.075	71° 28.761	8	6.0	10.5	70.4	5.8	10.7	69.8
N-10-M	7-Nov-11	43° 9.109	71° 28.718	10	5.9	13.4	69.3	5.9	13.5	69.4
N-10-E	7-Nov-11	43° 9.136	71° 28.690	13	6.2	12.8	68.2	6.0	12.6	69.5
S-0-W	26-Oct-11	43° 8.168	71° 27.805	11	12.7	11.2	68.6	11.2	11.7	66.6
S-0-M	26-Oct-11	43° 8.169	71° 27.745	10	10.5	12.0	64.7	10.5	12.0	64.7
S-0-E	26-Oct-11	43° 8.176	71° 27.699	10	10.3	12.1	66.7	10.3	12.0	66.7
S-4-W	25-Oct-11	43° 7.857	71° 27.845	10	12.1	10.0	64.9	12.1	10.2	64.8
S-4-M	25-Oct-11	43° 7.845	71° 27.807	13	11.7	10.1	63.7	11.5	10.3	63.5
S-4-E	26-Oct-11	43° 7.840	71° 27.779	13	10.4	12.3	66.4	10.4	12.3	66.1
S-17-W	25-Oct-11	43° 6.747	71° 27.956	10	11.7	10.1	63.4	11.7	10.2	64.5
S-17-M	25-Oct-11	43° 6.756	71° 27.907	8	11.3	10.2	62.3	11.3	10.2	63.8
S-17-E	25-Oct-11	43° 6.766	71° 27.829	10	10.9	10.7	62.5	10.9	10.7	62.6

(continued)

Table 1. (Continued)

	HABITAT ASSESSMENT						
STATION	EPIFAUNAL SUBST/COVER	CHANNEL FLOW STATUS	BANK STABILITY	VEGETATIVE PROTECTION	RIPARIAN VEG. ZONE	TOTAL SCORE[1]	HABITAT CLASS
USR-W	5	19	8	8	4	44	GOOD
USR-M	*	*	*	*	*		
USR-E	5	19	9	9	3	45	GOOD
DSR-W	5	19	8	8	10	50	GOOD
DSR-M	*	*	*	*	*		
DSR-E	5	19	8	8	10	50	GOOD
N-10-W	5	20	9	6	8	48	GOOD
N-10-M	*	*	*	*	*		
N-10-E	5	19	3	2	10	39	GOOD
S-0-W	5	19	8	6	0	38	GOOD
S-0-M	*	*	*	*	*		
S-0-E	5	19	8	8	10	50	GOOD
S-4-W	5	19	9	9	7	49	GOOD
S-4-M	*	*	*	*	*		
S-4-E	5	19	8	8	2	42	GOOD
S-17-W	5	19	7	7	10	48	GOOD
S-17-M	*	*	*	*	*		
S-17-E	5	19	9	9	10	52	GOOD

* = Habitat assessment not conducted at the mid-river stations
1 = excellent 70 - 53, good 53 - 35, fair 35 - 18, poor 18 – 0

Table 2. Merrimack Station benthic sampling station grain size percent composition.

STATION	N-10-W	N-10-M	N-10-E	S-0-W	S-0-M	S-0-E
WENTWORTH GRAIN SIZE CATEGORY						
Coarse Sand (0.5 - 1.0 mm)	12.3	28.4	9.1	39.3	15.4	31.1
Medium Sand (0.25 - 0.5 mm, 250 - 500 µm)	84.4	70.6	89.0	57.7	78.3	59.5
Fine Sand (125 - 250 µm)	2.4	1.0	1.3	2.1	5.8	5.2
Very Fine Sand (62.5 - 125 µm)	0.7	0.1	0.4	0.6	0.4	3.1
TOTAL	**99.8**	**100.1**	**99.8**	**99.7**	**99.9**	**98.9**

STATION	S-4-W	S-4-M	S-4-E	S-17-W	S-17-M	S-17-E
WENTWORTH GRAIN SIZE CATEGORY						
Coarse Sand (0.5 - 1.0 mm)	7.1	17.3	39.8	22.5	9.1	4.0
Medium Sand (0.25 - 0.5 mm, 250 - 500 µm)	85.3	74.8	59.5	74.9	74.8	78.3
Fine Sand (125 - 250 µm)	6.8	7.5	0.3	2.2	14.9	14.6
Very Fine Sand (62.5 - 125 µm)	0.8	0.4	0.2	0.2	1.1	2.9
TOTAL	**100.0**	**100.0**	**99.8**	**99.8**	**99.9**	**99.8**

STATION	DSR-W	DSR-M	DSR-E	USR-W	USR-M	USR-E
WENTWORTH GRAIN SIZE CATEGORY						
Coarse Sand (0.5 - 1.0 mm)	16.7	1.1	4.0	22.6	16.7	4.2
Medium Sand (0.25 - 0.5 mm, 250 - 500 µm)	82.6	61.4	79.8	77.1	80.9	91.0
Fine Sand (125 - 250 µm)	0.6	31.6	14.9	0.2	2.3	4.0
Very Fine Sand (62.5 - 125 µm)	0.1	5.5	1.0	0.1	0.1	0.5
TOTAL	**100.0**	**99.6**	**99.7**	**100.0**	**100.0**	**99.7**

Table 3. Summary of benthic macroinvertebrate data from the Merrimack River during 1972, 1973, and 2011.

STATION	LOCATION	SAMPLE TYPE	REP	YEAR	TOTAL ABUNDANCE	SHANNON DIVERSITY	EPT/CHIR ABUNDANCE	TAXA RICHNESS	EPT RICHNESS	HBI
N-10	EAST	KICK		1972	85	1.10	0.02	5	2	6.73
S-17	EAST	KICK		1972	156	0.87	0.01	8	1	6.14
S-4	EAST	KICK		1972	24	1.06	0	4	0	6.14
S-0	EAST	KICK		1972	69	1.82	0.12	10	2	6.02
					MEAN	**1.21**	**0.05**	**6.8**	**1.7**	**6.26**
N-10	EAST	KICK		2011	1918	0.67	36.83	19	3	5.73
S-17	EAST	KICK		2011	1279	1.11	19.60	28	7	5.71
S-4	EAST	KICK		2011	716	0.60	41.00	20	6	5.92
S-0	EAST	KICK		2011	1684	0.42	32.33	16	5	5.83
					MEAN	**0.70**	**32.44**	**20.8**	**5.2**	**5.80**
N-10	WEST	KICK		1972	103	1.76	0.11	10	3	5.75
S-17	WEST	KICK		1972	316	1.46	2.35	11	6	4.75
S-4	WEST	KICK		1972	409	1.76	0.46	10	1	5.62
S-0	WEST	KICK		1972	216	1.07	0.13	6	1	5.71
					MEAN	**1.51**	**0.76**	**9.2**	**2.8**	**5.46**
N-10	WEST	KICK		2011	1121	1.34	7.80	25	6	6.87
S-17	WEST	KICK		2011	3671	0.55	2.36	27	5	6.13
S-4	WEST	KICK		2011	947	0.68	0.19	18	3	6.21
S-0	WEST	KICK		2011	1937	0.96	18.00	20	3	6.09
					MEAN	**0.88**	**7.09**	**22.5**	**4.2**	**6.33**
N-10	EAST	PONAR	A	1972	310	0.54	0	6	0	7.95
N-10	EAST	PONAR	B	1972	279	0.50	0	6	0	7.94
S-17	EAST	PONAR	A	1972	138	2.16	0.03	16	2	6.71
S-17	EAST	PONAR	B	1972	50	2.22	0.11	12	1	6.72
S-4	EAST	PONAR	A	1972	437	1.36	0.00	13	1	7.16
S-4	EAST	PONAR	B	1972	506	1.06	0	10	0	7.54
S-0	EAST	PONAR	A	1972	433	0.68	0	4	0	7.91
S-0	EAST	PONAR	B	1972	194	0.93	0	5	0	7.92
					MEAN	**1.18**	**0.05**	**9.0**	**1.3**	**7.48**

(continued)

Table 3. (Continued)

STATION	LOCATION	SAMPLE TYPE	REP	YEAR	TOTAL ABUNDANCE	SHANNON DIVERSITY	EPT/CHIR ABUNDANCE	TAXA RICHNESS	EPT RICHNESS	HBI
N-10	EAST	PONAR	A	1973	1661	0.77	0	9	0	7.07
N-10	EAST	PONAR	B	1973	2166	0.73	0	8	0	7.07
S-17	EAST	PONAR	A	1973	726	0.84	0.12	12	3	7.71
S-17	EAST	PONAR	B	1973	624	0.73	0.10	8	1	7.73
S-4	EAST	PONAR	A	1973	1376	0.75	0	8	0	7.08
S-4	EAST	PONAR	B	1973	1858	0.83	0.00	10	1	7.14
S-0	EAST	PONAR	A	1973	717	0.80	0	7	0	7.07
S-0	EAST	PONAR	B	1973	952	0.69	0	4	0	7.33
					MEAN	**0.77**	**0.07**	**8.25**	**1.67**	**7.28**
N-10	EAST	PONAR	A	2011	35	1.15	0	6	0	7.21
N-10	EAST	PONAR	B	2011	36	0.91	0	4	0	6.53
S-17	EAST	PONAR	A	2011	190	2.78	0.35	38	8	7.14
S-17	EAST	PONAR	B	2011	63	2.20	0.10	12	2	7.49
S-4	EAST	PONAR	A	2011	151	0.52	0	8	0	5.29
S-4	EAST	PONAR	B	2011	236	0.40	0	8	0	5.32
S-0	EAST	PONAR	A	2011	21	1.30	0.12	6	2	6.75
S-0	EAST	PONAR	B	2011	16	1.25	0	6	0	5.00
					MEAN	**1.31**	**0.19**	**11.00**	**4.00**	**6.34**
N-10	MIDDLE	PONAR	A	1972	2	0.69	0	2	0	6.00
N-10	MIDDLE	PONAR	B	1972	5	1.06	0	3	0	7.00
S-17	MIDDLE	PONAR	A	1972	11	1.24	0	4	0	6.73
S-17	MIDDLE	PONAR	B	1972	16	1.84	0	8	0	7.25
S-4	MIDDLE	PONAR	A	1972	4	0.56	0	2	0	8.00
S-4	MIDDLE	PONAR	B	1972	8	1.24	0	4	0	7.75
S-0	MIDDLE	PONAR	A	1972	12	1.47	0	6	0	7.33
S-0	MIDDLE	PONAR	B	1972	8	0.90	0	3	0	7.50
					MEAN	**1.13**		**4.00**		**7.20**

(continued)

Table 3. (Continued)

STATION	LOCATION	SAMPLE TYPE	REP	YEAR	TOTAL ABUNDANCE	SHANNON DIVERSITY	EPT/CHIR ABUNDANCE	TAXA RICHNESS	EPT RICHNESS	HBI
N-10	MIDDLE	PONAR	A	1973	78	1.36	0.05	8	1	6.62
N-10	MIDDLE	PONAR	B	1973	142	1.18	0.07	7	1	6.47
S-17	MIDDLE	PONAR	A	1973	94	1.45	0	6	0	7.27
S-17	MIDDLE	PONAR	B	1973	136	1.24	0	7	0	7.54
S-4	MIDDLE	PONAR	A	1973	159	0.71	0	5	0	7.50
S-4	MIDDLE	PONAR	B	1973	129	0.84	0	7	0	7.57
S-0	MIDDLE	PONAR	A	1973	43	1.33	0.50	6	1	6.95
S-0	MIDDLE	PONAR	B	1973	38	1.12	0	5	0	7.11
					MEAN	**1.15**	**0.21**	**6.38**	**1.00**	**7.13**
N-10	MIDDLE	PONAR	A	2011	27	1.20	0	6	0	7.54
N-10	MIDDLE	PONAR	B	2011	49	0.80	0	4	0	7.43
S-17	MIDDLE	PONAR	A	2011	320	0.53	0	8	0	8.13
S-17	MIDDLE	PONAR	B	2011	152	0.66	0	6	0	7.50
S-4	MIDDLE	PONAR	A	2011	139	0.78	0	5	0	6.26
S-4	MIDDLE	PONAR	B	2011	152	0.76	0	5	0	6.73
S-0	MIDDLE	PONAR	A	2011	106	1.10	0	6	0	7.70
S-0	MIDDLE	PONAR	B	2011	158	0.89	0	6	0	8.02
					MEAN	**0.84**		**5.75**		**7.41**
N-10	WEST	PONAR	A	1972	333	0.70	0	9	0	7.91
N-10	WEST	PONAR	B	1972	261	0.80	0	7	0	6.49
S-17	WEST	PONAR	A	1972	145	1.30	0.02	9	1	7.63
S-17	WEST	PONAR	B	1972	781	1.51	0	16	0	7.43
S-4	WEST	PONAR	A	1972	379	1.08	0	7	0	7.61
S-4	WEST	PONAR	B	1972	297	0.98	0	6	0	7.71
S-0	WEST	PONAR	A	1972	168	0.79	0	4	0	7.86
S-0	WEST	PONAR	B	1972	13	1.46	0	5	0	7.15
					MEAN	**1.08**	**0.02**	**7.88**	**1.00**	**7.47**

(continued)

Table 3. (Continued)

STATION	LOCATION	SAMPLE TYPE	REP	YEAR	TOTAL ABUNDANCE	SHANNON DIVERSITY	EPT/CHIR ABUNDANCE	TAXA RICHNESS	EPT RICHNESS	HBI
N-10	W	PONAR	A	1973	3242	0.68	0	7	0	6.71
N-10	W	PONAR	B	1973	1080	0.06	0	6	0	6.01
S-17	W	PONAR	A	1973	1027	0.54	0.05	10	2	7.78
S-17	W	PONAR	B	1973	1208	0.86	0.03	11	1	7.64
S-4	W	PONAR	A	1973	610	0.51	0	6	0	7.72
S-4	W	PONAR	B	1973	798	0.49	0	5	0	7.71
S-0	W	PONAR	A	1973	338	0.52	0.03	8	1	7.79
S-0	W	PONAR	B	1973	470	0.44	0	7	0	7.85
					MEAN	**0.51**	**0.04**	**7.50**	**1.33**	**7.40**
N-10	W	PONAR	A	2011	30	1.22	0	7	0	8.04
N-10	W	PONAR	B	2011	14	1.57	0	6	0	8.31
S-17	W	PONAR	A	2011	104	0.25	0	3	0	9.00
S-17	W	PONAR	B	2011	70	0.55	0	5	0	6.86
S-4	W	PONAR	A	2011	112	1.06	0.10	8	1	9.00
S-4	W	PONAR	B	2011	135	0.80	0	5	0	9.17
S-0	W	PONAR	A	2011	109	1.29	0.13	12	2	7.18
S-0	W	PONAR	B	2011	141	0.79	0	8	0	8.26
					MEAN	**0.94**	**0.12**	**6.75**	**1.50**	**8.23**

** = no Chironomidae in sample

Table 4. Numerically dominant benthic macroinvertebrate taxa found in Merrimack River samples collected in 1972, 1973, and 2011.

STATION	LOC	SAMPLE TYPE	REP	YEAR	BIOTIC INDEX	DOMINANT TAXON	PERCENT COMP.
N-10	E	KICK		1972	6	Chironomidae	49
S-0	E	KICK		1972	6	Chironomidae	28
S-4	E	KICK		1972	6	Chironomidae	46
S-17	E	KICK		1972	6	Chironomidae	76
N-10	E	KICK		2011	6	*Gammarus fasciatus*	85
S-0	E	KICK		2011	6	*Gammarus fasciatus*	92
S-4	E	KICK		2011	6	*Gammarus fasciatus*	89
S-17	E	KICK		2011	6	*Gammarus fasciatus*	73
N-10	W	KICK		1972	6	Chironomidae	35
S-0	W	KICK		1972	6	Chironomidae	55
S-4	W	KICK		1972	6	*Dubiraphia* sp.	32
S-17	W	KICK		1972	4	Hydroptilidae	51
N-10	W	KICK		2011	6	*Gammarus fasciatus*	51
S-0	W	KICK		2011	6	*Gammarus fasciatus*	48
S-4	W	KICK		2011	6	*Gammarus fasciatus*	85
S-17	W	KICK		2011	6	*Gammarus fasciatus*	89
N-10	E	PONAR	A	1972	8	*Cryptochironomus* sp.	84
N-10	E	PONAR	B	1972	8	*Cryptochironomus* sp.	86
S-0	E	PONAR	A	1972	8	*Cryptochironomus* sp.	76
S-0	E	PONAR	B	1972	8	Oligochaeta, *Cryptochironomus* sp.	47
S-4	E	PONAR	A	1972	6	Chironomidae	39
S-4	E	PONAR	B	1972	8	*Cryptochironomus* sp.	61
S-17	E	PONAR	A	1972	6	Chironomidae	30
S-17	E	PONAR	B	1972	8	Oligochaeta	20
N-10	E	PONAR	A	1973	8	Oligochaeta	53
N-10	E	PONAR	B	1973	8	Oligochaeta	50
S-0	E	PONAR	A	1973	8	Oligochaeta	51
S-0	E	PONAR	B	1973	8	Oligochaeta	66
S-4	E	PONAR	A	1973	8	Oligochaeta	54
S-4	E	PONAR	B	1973	8	Oligochaeta	56
S-17	E	PONAR	A	1973	8	Oligochaeta	80
S-17	E	PONAR	B	1973	8	Oligochaeta	83
N-10	E	PONAR	A	2011	9	*Procladius* sp.	57
N-10	E	PONAR	B	2011	9	*Procladius* sp.	47
S-0	E	PONAR	A	2011	9	*Procladius* sp.	48
S-0	E	PONAR	B	2011	4	*Robackia demeijerei*	63
S-4	E	PONAR	A	2011	*	*Corbicula fluminea*	89
S-4	E	PONAR	B	2011	*	*Corbicula fluminea*	92
S-17	E	PONAR	A	2011	10	*Limnodrilus* sp.	21
S-17	E	PONAR	B	2011	10	Tubificidae imm. w/ caprilliform chaete	21

(continued)

Table 4. (Continued)

STATION	LOC	SAMPLE TYPE	REP	YEAR	BIOTIC INDEX	DOMINANT TAXON	PERCENT COMP.
N-10	M	PONAR	A	1972	6	Nemertea, *Campeloma decisum*	50
N-10	M	PONAR	B	1972	6	Hydracarina, Oligochaeta	40
S-0	M	PONAR	A	1972	*	Nemertea	50
S-0	M	PONAR	B	1972	8	Sphaeriidae	63
S-4	M	PONAR	A	1972	8	Oligochaeta	75
S-4	M	PONAR	B	1972	8	Oligochaeta	50
S-17	M	PONAR	A	1972	6	*Campeloma decisum*	45
S-17	M	PONAR	B	1972	8	Oligochaeta	38
N-10	M	PONAR	A	1973	6	Chironomidae	47
N-10	M	PONAR	B	1973	6	Chironomidae	58
S-0	M	PONAR	A	1973	8	Oligochaeta	51
S-0	M	PONAR	B	1973	8	Oligochaeta	55
S-4	M	PONAR	A	1973	8	Oligochaeta	74
S-4	M	PONAR	B	1973	8	Oligochaeta	74
S-17	M	PONAR	A	1973	8	Oligochaeta	37
S-17	M	PONAR	B	1973	8	Oligochaeta	60
N-10	M	PONAR	A	2011	9	*Procladius* sp.	59
N-10	M	PONAR	B	2011	9	*Procladius* sp.	65
S-0	M	PONAR	A	2011	*	*Corbicula fluminea*	58
S-0	M	PONAR	B	2011	*	*Corbicula fluminea*	71
S-4	M	PONAR	A	2011	*	*Corbicula fluminea*	78
S-4	M	PONAR	B	2011	*	*Corbicula fluminea*	78
S-17	M	PONAR	A	2011	*	*Corbicula fluminea*	88
S-17	M	PONAR	B	2011	*	*Corbicula fluminea*	85
N-10	W	PONAR	A	1972	8	*Cryptochironomus* sp.	79
N-10	W	PONAR	B	1972	6	Chironomidae	72
S-0	W	PONAR	A	1972	8	*Cryptochironomus* sp.	71
S-0	W	PONAR	B	1972	8	Oligochaeta, *Cryptochironomus* sp.	31
S-4	W	PONAR	A	1972	8	Oligochaeta	61
S-4	W	PONAR	B	1972	8	Oligochaeta	68
S-17	W	PONAR	A	1972	8	Oligochaeta	54
S-17	W	PONAR	B	1972	8	*Cryptochironomus* sp.	44
N-10	W	PONAR	A	1973	6	Chironomidae	64
N-10	W	PONAR	B	1973	6	Chironomidae	99
S-0	W	PONAR	A	1973	8	Oligochaeta	87
S-0	W	PONAR	B	1973	8	Oligochaeta	89
S-4	W	PONAR	A	1973	8	Oligochaeta	86
S-4	W	PONAR	B	1973	8	Oligochaeta	85
S-17	W	PONAR	A	1973	8	Oligochaeta	86
S-17	W	PONAR	B	1973	8	Oligochaeta	76

(continued)

Table 4. (Continued)

STATION	LOC	SAMPLE TYPE	REP	YEAR	BIOTIC INDEX	DOMINANT TAXON	PERCENT COMP.
N-10	W	PONAR	A	2011	9	*Procladius* sp.	63
N-10	W	PONAR	B	2011	9	*Procladius* sp.	36
S-0	W	PONAR	A	2011	*	*Corbicula fluminea*	63
S-0	W	PONAR	B	2011	*	*Corbicula fluminea*	78
S-4	W	PONAR	A	2011	*	*Corbicula fluminea*	67
S-4	W	PONAR	B	2011	*	*Corbicula fluminea*	73
S-17	W	PONAR	A	2011	*	*Corbicula fluminea*	94
S-17	W	PONAR	B	2011	*	*Corbicula fluminea*	87

* = Biotic Index value does not exist for these taxa

The most substantial metric value increase was seen in the EPT to Chironomidae Abundance Ratio. This metric compares the abundance of pollution sensitive EPT taxa to the pollution tolerant Chironomidae. In 1972 the mean EPT to Chironomidae Abundance Ratio of all four stations on the east bank was 0.05, whereas in 2011 the mean value for this metric was 32.44 (Table 3). Along the west bank, mean EPT to Chironomidae Abundance Ratio increased from 0.8 in 1972 to 7.1 in 2011. These aquatic insect community data indicate that water quality conditions at these stations in the Merrimack River had substantially improved in 2011 compared to 1972.

November 2011 kick samples showed that community metrics were not consistently better or worse at any station (Table 5). The numerically dominant taxon was the amphipod *Gammarus fasciatus* at all stations (Table 6). Station USR had the lowest values for total abundance, Shannon Diversity, taxa richness, and EPT richness; however it had the highest value for EPT to Chironomidae Ratio. Conversely, on the west bank, Station USR had the highest values for Shannon diversity, EPT to Chironomidae abundance ratio, taxa richness, and EPT richness. Metric values at Station N-10 were usually between values found at Garvins Pool stations.

3.3 Benthic Invertebrates

Benthic invertebrate communities also indicated that water quality improved slightly at Stations N-10, S-0, S-4 and S-17 in 2011 compared to 1972 (Normandeau 1973) and 1973 (Table 3, Normandeau 1974). Differences in data collected in 1972 and 1973, when compared to 2011 data, showed increased values in 2011 for taxa richness, EPT richness, and EPT to Chironomidae abundance ratio (Table 3), although the differences were not as large as the kick sample data. The numerically dominant taxa varied between stations and years (Table 4). Dominant taxa were, in general, composed of genera and species of Oligochaeta, Chironomidae, and Corbiculidae. In 1973, the dominant taxon at all stations except the N-10 – middle station was Oligochaeta; the dominant taxon at Station N-10 – middle was Chironomidae. In 2011, the numerically dominant taxon at middle and western stations of S-0, S-4, and S-17 was *Corbicula fluminea*, an invasive species that was introduced from Asia in the early 1900s.

Grab data from Garvins Pool Stations DSR, USR, and Hooksett Pool Station N-10 showed little difference in metric values (Table 5). Total abundance from all samples was less than 100 organisms, taxa richness was less than 10 at all stations except Station DSR, and Shannon diversity was less than 1.00 for all samples except along the east bank of Stations DSR and USR and the west

Table 5. Summary of benthic macroinvertebrate data from the Merrimack River during November 2011.

STATION	LOC	SAMPLE TYPE	REP	YEAR	TOTAL ABUNDANCE	SHANNON DIVERSITY	EPT/CHIR ABUNDANCE	TAXA RICHNESS	EPT RICHNESS	HBI
DSR	E	KICK		2011	3460	0.83	2.25	39	8	6.35
N-10	E	KICK		2011	1544	1.27	12.22	34	7	6.13
USR	E	KICK		2011	1007	0.34	4.50	11	3	6.06
DSR	W	KICK		2011	1405	0.61	0*	19	4	5.76
N-10	W	KICK		2011	1290	0.92	3.67	31	4	6.19
USR	W	KICK		2011	952	1.62	7.70	34	6	6.44
DSR	E	PONAR	A	2011	72	1.61	0	10	0	7.87
DSR	E	PONAR	B	2011	97	1.64	0	12	0	8.07
N-10	E	PONAR	A	2011	70	0.68	0	4	0	7.93
N-10	E	PONAR	B	2011	38	0.59	0	3	0	8.05
USR	E	PONAR	A	2011	80	1.17	0.01	7	1	6.51
USR	E	PONAR	B	2011	40	1.20	0	5	0	6.48
DSR	M	PONAR	A	2011	28	0.00	0	3	0	6.92
DSR	M	PONAR	B	2011	2	0.80	0	1	0	9.00
N-10	M	PONAR	A	2011	16	0.68	0	5	0	7.33
N-10	M	PONAR	B	2011	14	0.59	0	3	0	5.36
USR	M	PONAR	A	2011	25	0.69	0.04	4	1	4.76
USR	M	PONAR	B	2011	30	0.98	0	5	0	5.63
DSR	W	PONAR	A	2011	28	0.80	0	5	0	4.57
DSR	W	PONAR	B	2011	11	0.86	0	4	0	5.27
N-10	W	PONAR	A	2011	30	0.91	0	5	0	7.90
N-10	W	PONAR	B	2011	17	1.23	0	4	0	7.47
USR	W	PONAR	A	2011	18	0.88	0	4	0	4.94
USR	W	PONAR	B	2011	25	0.18	0	7	0	4.63

* = no Chironomidae in sample

bank sample at Station N-10. The numerically dominant taxa at all stations in November 2011 were three genera of Chironomidae (Table 4).

Other metrics used to analyze the benthic invertebrate data showed differences between 2011 and the 1970s; however these differences were not as consistent as the kick sample aquatic insect data. Metrics such as Hilsenhoff Biotic Index, total abundance, and percent contribution of the dominant taxon did not consistently indicate improved conditions for a specific year or station. This is somewhat expected since habitats in large river systems with sand substrates typically have benthic communities that are composed of tolerant organisms, such as oligochaetes and chironomids, even in pristine conditions. Organisms in these communities often have moderate or moderately high (4 to 8) biotic index values, may have high total abundance, and may have dominant taxa that compose a greater percentage of the benthic community than communities in smaller rivers and streams.

Therefore, qualitative aquatic insect data collected along shoreline areas probably provide the best data to compare benthic macroinvertebrate samples between the 1970s and 2011. Organisms in littoral zones are typically more pollution sensitive than organisms found in the sand substrates, and invertebrate community responses to changes in water quality conditions would be more obvious.

Table 6. Numerically dominant benthic macroinvertebrate taxa found in Merrimack River samples collected in November 2011.

STATION	LOC	SAMPLE TYPE	REP	YEAR	BIOTIC INDEX	DOMINANT TAXON	PERCENT COMP.
DSR	E	KICK		2011	6	*Gammarus fasciatus*	81
N-10	E	KICK		2011	6	*Gammarus fasciatus*	54
USR	E	KICK		2011	6	*Gammarus fasciatus*	94
DSR	W	KICK		2011	6	*Gammarus fasciatus*	87
N-10	W	KICK		2011	6	*Gammarus fasciatus*	81
USR	W	KICK		2011	6	*Gammarus fasciatus*	52
DSR	E	PONAR	A	2011	9	*Procladius* sp.	50
DSR	E	PONAR	B	2011	9	*Procladius* sp.	49
N-10	E	PONAR	A	2011	9	*Procladius* sp.	77
N-10	E	PONAR	B	2011	9	*Procladius* sp.	79
USR	E	PONAR	A	2011	9	*Procladius* sp.	45
USR	E	PONAR	B	2011	9	*Procladius* sp.	43
DSR	M	PONAR	A	2011	6	*Polypedilum halterale* gr.	65
DSR	M	PONAR	B	2011	9	*Procladius* sp.	100
N-10	M	PONAR	A	2011	9	*Procladius* sp.	50
N-10	M	PONAR	B	2011	4	*Robackia demeijerei*	71
USR	M	PONAR	A	2011	4	*Robackia demeijerei*	80
USR	M	PONAR	B	2011	4	*Robackia demeijerei*	63
DSR	W	PONAR	A	2011	4	*Robackia demeijerei*	79
DSR	W	PONAR	B	2011	4	*Robackia demeijerei*	64
N-10	W	PONAR	A	2011	4	*Robackia demeijerei*	70
N-10	W	PONAR	B	2011	9	*Procladius* sp.	41
USR	W	PONAR	A	2011	4	*Robackia demeijerei*	72
USR	W	PONAR	B	2011	4	*Robackia demeijerei*	68

4.0 References

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