WATER QUALITY DATA FOR THE NISSITISSIT RIVER: 2007-2009

Susan E. Barbaro, Ph.D,*
Associate Professor and Department Coordinator, Department of Biology, Rivier College

Abstract

This study presents water-quality data for the Nissitissit River for the period 2007-2009. Water samples were collected at five locations along the river once a month for three consecutive months in the summers of 2007, 2008, and 2009. Water was analyzed for a group of chemical and microbiological parameters typically monitored to characterize water quality. Parameters measured included water temperature, dissolved oxygen, pH, nitrate, phosphate, and the number of fecal coliforms. With the exception of one site (site #4, 2008), dissolved oxygen concentrations did not fall below 70% oxygen saturation during the 2007 and 2008 sampling periods. Dissolved oxygen concentrations did vary considerable during the 2009 sampling period. Dissolved oxygen values, measured during the second sampling event, increased to levels above 100% oxygen saturation and was associated with a rainfall event that increased flow rates to 158 ft^3/s measured at the United States Geological Survey (USGS) streamgage located at site #1, Pepperell, Mass. The increase in dissolved oxygen was followed by a substantial decrease for the following sampling event (100% down to 55% oxygen saturation) and corresponded with a 100-fold increase in the number of fecal coliforms. The number of fecal coliforms far exceeded the Massachusetts recreational water quality standards suggesting an additional input of fecal contamination and increase in microbial growth after the rainstorm event.

Introduction

The Nissitissit River basin encompasses an area of approximately 59.6 square miles in Southern New Hampshire and Northeastern Massachusetts (Figure 1). The Nissitissit River discharges into the Nashua River at Pepperell, Mass. In 1968, when it became evident that development in the Nissitissit River watershed was increasing, a group of local citizens formed the Nissitissit Land Trust and began work to ensure that the hydrology and water quality of the river remained protected (Tupper, 1991). Development has long been recognized as a primary threat to the health of river ecosystems (Klein, 1979; Paul and Meyer, 2001). Development along the banks of rivers increases the amount of impervious surface, resulting in storm runoff that can affect water quality (Paul and Meyer, 2001). A primary effect of storm runoff is degradation of water quality caused by the introduction of excessive concentrations of nutrients such as phosphorous and nitrogen (David and Gentry, 2000), input of diverse sources of organic matter (Sickman, 2007) and anthropogenic chemicals (Kolpin et al., 2002), and the introduction of pathogenic organisms (Donovan et al., 2008).

Currently, land use in the Nissitissit River basin is comprised of forest, open undeveloped land, and low density residential development. Since its conception, the Nissitissit Land Trust and cooperating organizations (Beaver Brook Association, Brookline Conservation Commission (NH) Pepperell Conservation Commision (MA), Massachusetts Department of Fisheries and Wildlife, and Nashoba Conservation Trust) have purchased approximately 667 acres of land in the watershed. Their efforts have resulted in the acquisition of 50,200 ft of river frontage (52% of the total frontage along the river) that is currently protected from development.

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This study presents water-quality data collected for the period 2007-2009. Data collected in this study includes water temperature (°C), pH, dissolved oxygen (DO) (mg/L), nitrate (NO_3^-) (mg/L), phosphate (PO_4^{3-}) (mg/L), and fecal coliforms (cfu/100ml). The presence of fecal coliforms in water is commonly used as an indicator for monitoring potable and recreational water quality. Their presence often correlates with gastrointestinal illnesses and indicates that waters have been exposed to wastewater or feces (Donovan et al., 2008; Kinzelman et al., 2003). Physical data (temperature and flow rate) and chemical data (DO, pH, nitrogen, and phosphorous) can affect microbiological data and indicate sources of contamination. By closely monitoring these parameters, activities in the watershed that may be affecting water quality can be better understood.

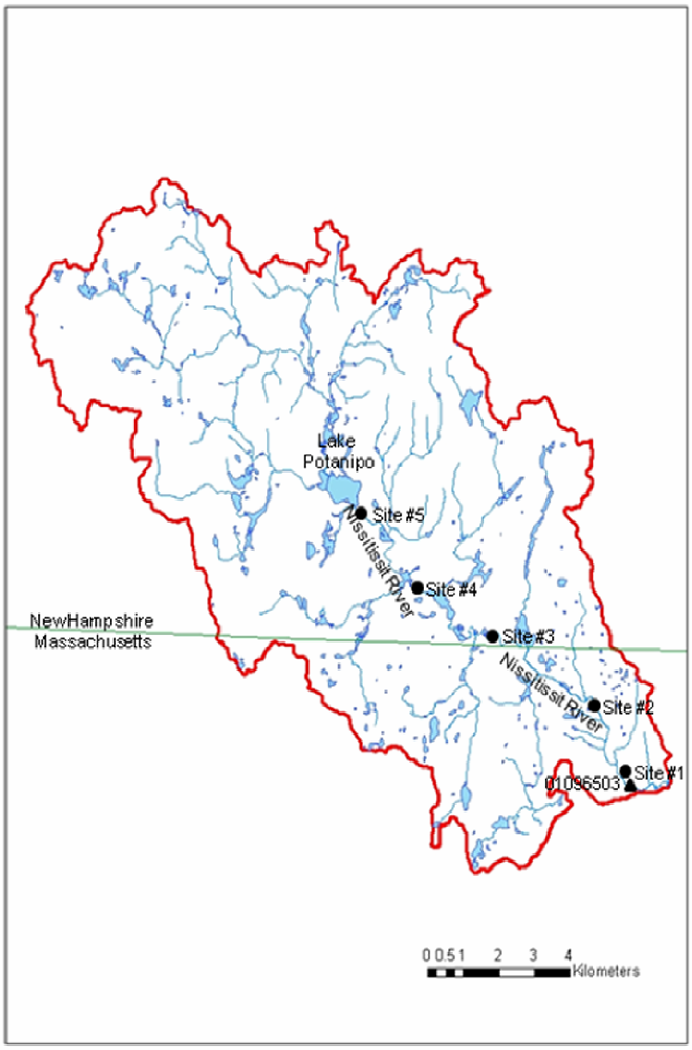


Figure 1: Nissitissit River Watershed. ▲USGS Streamgage (01096503); ● Sampling Site.

Data Collection

Sample Locations and Procedure

Five locations along the Nissitissit River were sampled three times throughout the summer months: Site #1: Mill St., Pepperell MA, Site #2: Prescott St., Pepperell, MA, Site #3: West Hollis and Worcester Rds., Hollis NH, Site #4: Bohanan Bridge Rd., Brookline NH, and Site #5: Lake Potanipo, Brookline, NH (Figure 1). The first water sampling event typically took place in late May (2008) or early June (2007 and 2009), a second sampling event in June (2008) or July (2007 and 2009), and a final sampling event conducted in July (2008), August (2007), or early September (2009) (See Table 1 for sampling dates). Procedures for sample collection have been previously described (Barbaro, 2008).

Analyses

Procedures for analyzing temperature, pH, DO, PO_4^{3-}- P, NO_3^{-}-N, and enumeration of fecal coliforms have been previously described (Barbaro, 2008).

Streamflow Rates

Daily mean streamflow rates were obtained from the USGS real time streamflow data for streamgage 01096503 (U.S. Geological Survey, 2007, 2008, and 2009).

Results

Streamflow Rates

Daily mean flows are all on the low end of the annual range of flows at this station (USGS, 2010) (Table 1). In 2007 and 2008, streamflow at the USGS streamgage at Pepperell MA (sampling Site #1) were higher during the first sampling event (132 ft^3/s and 36 ft^3/s respectively) compared to the following two sampling events in the same year (2007-21 ft^3/s, 28 ft^3/s and 2008-27 ft^3/s, 17 ft^3/s) (Table 1). In 2009, streamflow was low during the first sampling event (27 ft^3/s), followed by the highest reported flow rate (158 ft^3/s) recorded for all three years during the second sampling event. By the final sampling event of the same year flow rate decreased to 50 ft^3/s (Figure 2d).

Temperature

Water temperatures ranged between 12 ºC (June 2009, Site #1) and 28 ºC (July 2008, Site #5) (Table 1). Water temperatures were noticeably higher (above 20 ºC) during the July 2008 sampling date. Water temperatures ranged between 21 ºC at Site #4 and 28 ºC reported at Site #5. Regardless of year, water temperatures measured at Site #5 were generally higher than water temperatures measured at the other four sites (Table 1). The lowest seasonal water temperatures were reported for 2009 (ranging from 12ºC—18ºC).

pH

pH varied only slightly between sites and sampling year and remained within limits appropriate for Class B rivers (pH 6.5-8.3) (Table 1) (Massachusetts Stream Water Quality, 1990-1991; New Hampshire Stream Water Quality, 1990-1991).

Dissolved Oxygen

Percent oxygen saturation is the amount (mg/L) of oxygen dissolved in water compared to the maximum amount of oxygen that could be present at the same temperature. Percent oxygen saturation values above 75% are important for maintaining cold water fisheries and are expected for the Nissitissit River. Dissolved oxygen concentrations reported for 2007 and 2008 represent values at or above 70%

saturation (Table 1). In 2009, percent oxygen saturation varied substantially over the 3 month period. Site average percent oxygen saturation concentrations measured during the June sampling was approximately 80% saturation (8.1 mg/L-9.0 mg/L) compared to 103% oxygen percent saturation (7.4 mg/L-12.8 mg/L) for July samples, and 57% percent oxygen saturation (5.3 mg/L-6.7 mg/L) for September samples (Table 1).

Nitrate

Nitrate concentrations measured in 2007 and 2008 ranged from not detected (May, 2008-Site #5) to 0.919 mg/L (July, 2008- Site #2). In 2009, higher nitrate concentrations were reported during the second sampling event ranging from 0.693 mg/L measured at Site #1 to 1.270 mg/L measured at Site #3 (Table 1 and Figure 2b). A substantial drop in nitrate concentrations were reported for Sites #1, 2, 3, and 4 for the final sampling event, while an increase in nitrate concentration from 0.808 mg/L to 2.245 mg/L was observed at sampling Site #5 (Table 1).

Phosphate

Currently there are no specified drinking water standards for phosphate, but it has been well established that even small increases in phosphate concentrations can have substantial consequences for water quality because phosphorous is a limiting nutrient for growth. In this study, phosphate remained below 0.041 mg/L over the 2007 sampling period and remained below 0.040 mg/L over the first two sampling events in 2008 and 2009. Higher phosphates concentrations, ranging from 0.069 mg/L (Site #2, 2008) to 0.134 mg/L (Site #4, 2009), were observed during the final sampling event (Table 1).

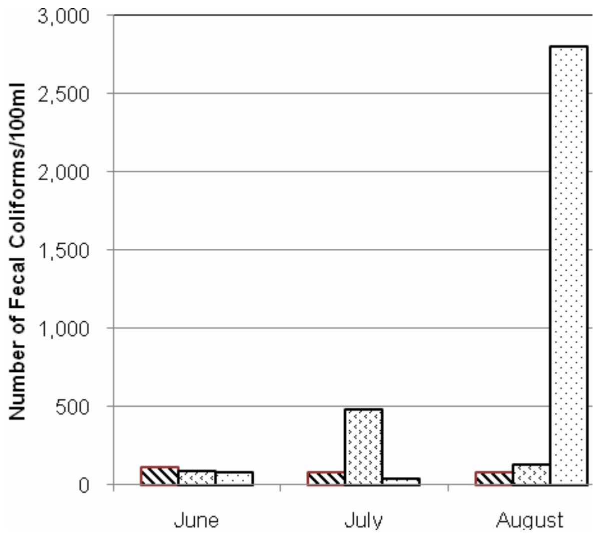
Fecal Coliforms

The presence of fecal coliforms in water indicates contamination with feces and presents a serious risk to animal and human health. The drinking water standard in terms of the number of fecal coliforms is set at 0 cfu/100ml (USEPA-SDWS, 2003). The current advisory limits for recreational use used by the state of Massachusetts for ecosystems with a class B category, is 200 cfu100/ml (USEPA-BWQS for Recreational Waters, 2003). The state of New Hampshire bases it limits specifically on the presence of Escherichia coli. For class B waters, the current limit for E. coli is 126 cfu/100ml. Based on Massachusetts water quality standards, all sites during 2007 sampling period met recreational standards except Site (#4) measured during the August sampling event (250 cfu/ml) (Table 1). In 2008,four of the five sites sampled in June failed to meet the limits (Site #1 - 485, Site #2 - 410, Site #3 - 225, and Site #4 - 460 cfu/100ml) and in 2009 none of the sites sampled in September met the limits (Table 1 and Figure 2a).

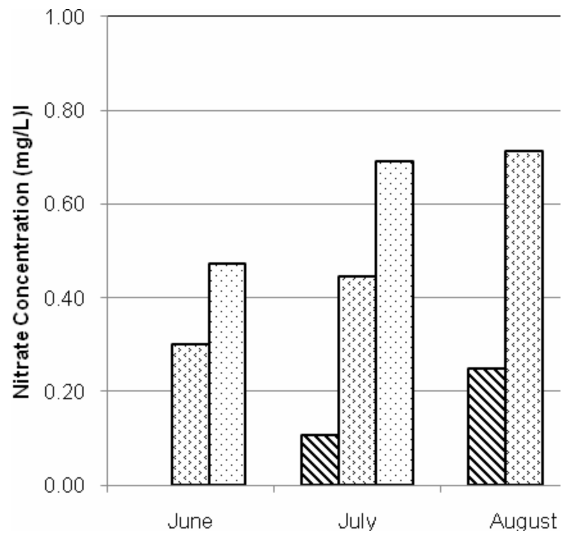
Table 1: Water quality data for five sites along the Nissitissit River: 1) 2007 data, 2) 2008 data, and 3) 2009 data.

Date	Site	Flow (ft^3/s)	Temp. (ºC)	pH	DO (mg/L)	NO_3^{-} - N (mg/L)	PO_4^{3-} - P (mg/L)	*Fecals (per 100ml)
1. 06/07/07	#1	132	17.0	7.11	8.8(98)	—	—	115
	#2		17.0	6.93	8.1(90)	—	—	110
	#3		17.5	7.73	7.6(85)	—	—	145
	#4		17.5	6.83	8.0(90)	—	—	90
	#5		19.0	7.10	6.6(73)	—	—	45
07/25/07	#1	21	20.0	7.11	6.4(72)	0.11	0.04	80
	#2		20.0	7.09	6.4(72)	0.11	0.02	75
	#3		19.5	6.90	6.7(74)	0.01	0.02	90
	#4		20.0	6.74	5.7(65)	0.11	0.02	150
	#5		24.0	6.94	7.1(80)	ND	0.01	5
08/22/07	#1	8	15.5	8.52	7.1(82)	0.25	0.02	70
	#2		15.0	8.04	7.7(85)	0.25	0.01	27
	#3		14.5	7.58	8.0(70)	0.29	0.01	95
	#4		14.5	7.24	6.7(75)	0.50	0.01	250
	#5		18.0	7.49	7.9(88)	0.14	0.01	25
2. 05/29/08	#1	36	16.5	7.12	7.3(75)	0.30	0.03	90
	#2		17.0	6.98	7.4(76)	0.15	ND	150
	#3		17.0	6.73	7.8(79)	0.90	ND	145
	#4		15.5	6.61	7.9(77)	0.75	ND	46
	#5		19.5	6.91	8.1(87)	ND	ND	25
06/17/08	#1	27	18.5	7.51	8.2(85)	0.45	0.02	485
	#2		18.5	7.35	7.9(84)	0.59	0.02	410
	#3		19.0	7.05	7.7(80)	0.74	0.01	225
	#4		19.0	6.84	7.8(82)	0.59	0.01	460
	#5		19.0	7.15	7.1(75)	0.74	0.01	23
07/16/08	#1	17	22.0	7.80	7.5(85)	0.71	0.05	134
	#2		23.0	7.46	6.3(72)	0.92	0.07	85
	#3		22.0	6.28	6.8(76)	0.89	0.05	68
	#4		21.0	6.64	5.8(65)	0.80	0.03	43
	#5		28.0	7.11	6.8(85)	0.62	0.06	40
3. 06/10/09	#1	27	12.0	6.05	9.0(84)	0.47	0.03	80
	#2		12.5	6.48	8.2(78)	0.35	0.04	175
	#3		12.5	6.40	8.9(82)	0.41	0.02	175
	#4		12.0	6.41	8.1(75)	0.47	0.02	110
	#5		15.0	6.47	8.9(88)	0.47	0.05	70
07/10/09	#1	158	14.5	6.09	10.2(100)	0.69	0.04	40
	#2		15.0	6.28	12.8(125)	1.04	0.07	40
	#3		15.0	6.28	11.8(112)	1.27	0.01	12
	#4		16.0	6.31	9.7(100)	0.81	0.01	15
	#5		18.0	6.34	7.4(77)	0.81	ND	12
09/02/09	#1	50	14.0	8.00	5.7(55)	ND	0.03	2800
	#2		14.0	8.14	5.6(54)	ND	0.09	2600
	#3		15.0	7.38	5.4(54)	ND	0.05	7400
	#4		15.0	7.44	6.7(65)	ND	0.13	9000
	#5		18.0	7.75	5.3(55)	2.24	ND	1500

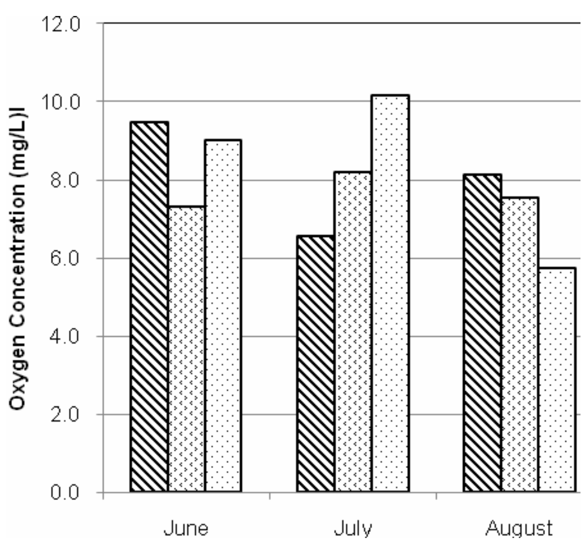
(*) = duplicate samples analyzed, (—) = analysis not done, ND = not detected, (value) = % Oxygen Saturation


3,000
2,500
2,000
1,500
1,000
500
0
Number of Fecal Coliforms/100ml
June
July
August

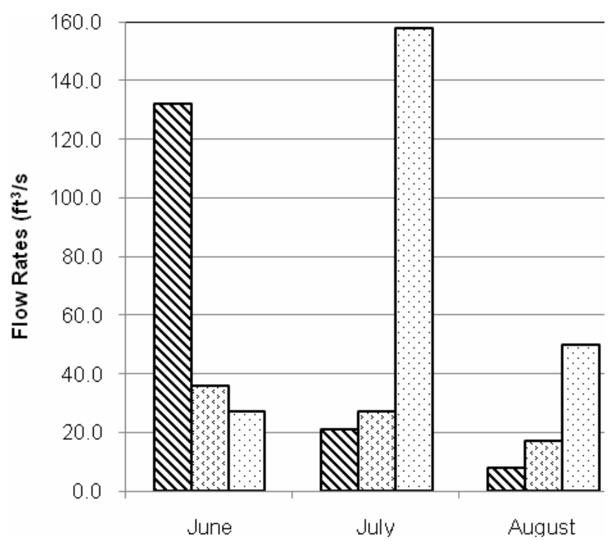
a)


1.00
0.80
0.60
0.40
0.20
0.00
Nitrate Concentration (mg/L)l
June
July
August

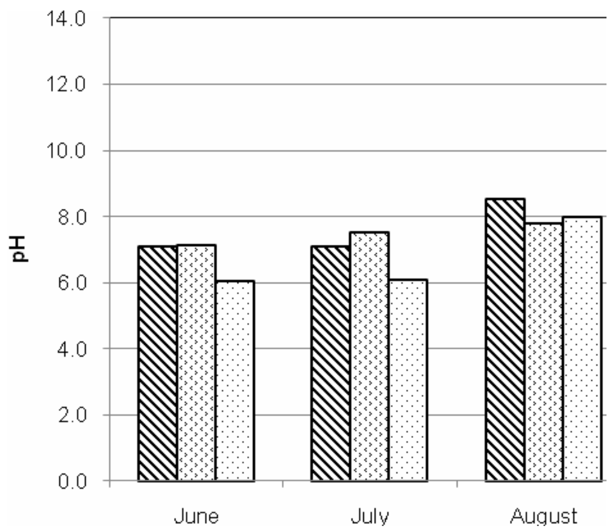
b)


12.0
10.0
8.0
6.0
4.0
2.0
0.0
Oxygen Concentration (mg/L)l
June
July
August

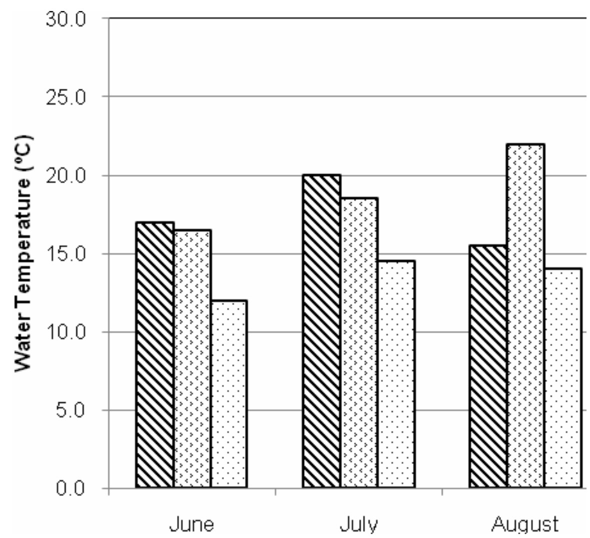
c)


160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Flow Rates (ft³/s
June
July
August

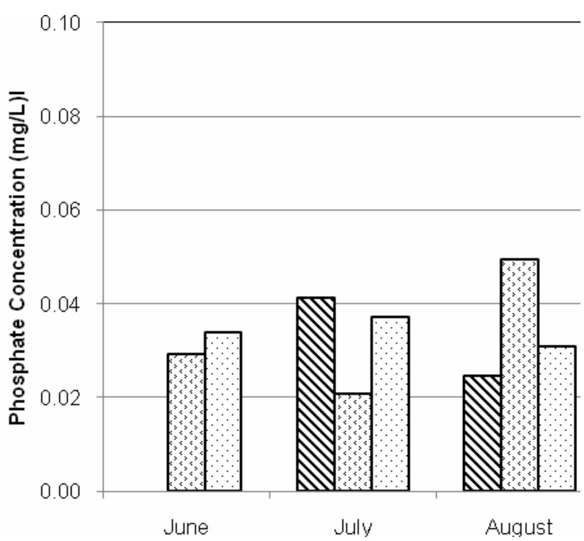
d)



e)



f)



g)

Figure 2: Water quality data for Site #1 (Mill St., Pepperell, MA) on the Nissitissit Rivier: a) number of fecal coliforms per 100ml water; b) nitrate concentrations (mg/L); c) dissolved oxygen concentrations (mg/L); d) water flow rates (ft^3/s); e) pH; f) water temperature (ºC), and g) phosphate concentrations (mg/L); represents 2007 data, represents 2008 data, and represents 2009 data.

Discussion and Conclusions

Changes in land use present a serious threat to the water quality of streams. Limiting development adjacent to stream channels is an important aspect of protecting these ecosystems. The water quality of the Nissitissit has been considered good (Class B) and acceptable for recreational purposes by the New Hampshire Water Pollution Commission. This ongoing study monitors stream water characteristics of the Nissitissit River by providing regular and long term water quality data to the Nissitissit Land Trust.

Water quality in streams is variable both spatially and temporally. Temperature is an important factor in stream ecosystems because of its effects on the growth rates and distribution of aquatic organisms in these environments (LeBlanc et al., 1997). The Nissitissit River is regarded as a cold water fishery. In order to maintain healthy cold water fish populations, water temperatures should not exceed 20 ºC. Several factors affect stream water temperatures, including the amount and type of riparian vegetation, streamflow rate, groundwater discharge into the water, surface area of the stream, and air temperatures. In urban areas average stream water temperatures tend to be higher than in undeveloped areas (Klein, 1979; LeBlanc et al., 1997). Similarly, dissolved oxygen concentrations are controlled by several factors including, water temperature, air temperature and pressure, flow-rate, photosynthetic and respiratory activity of stream biota, and the concentration of organic matter. Downward trends in DO conditions indicate deteriorating water quality commonly associated with direct and/or indirect activities of humans (Massachusetts Stream Water Quality, 1990-1991; New Hampshire Stream Water Quality, 1990-1991).

Nutrient (nitrogen and phosphorous) concentrations in streams typically increase in response to development (Paul and Meyer, 2001). Sources of nutrients include inputs of nitrogen and phosphorous due to runoff of residential and agricultural fertilizers, seepage from domestic septic systems, and direct wastewater discharge to steams. Concentrations may further increase during storm events due to disturbance of sediment-associated (particulate) nitrogen and phosphorous. In the Nissitissit River, N and P concentrations in the summer are relatively low indicating that development in the watershed has not yet led to eutrophication of the stream.

Although fecal coliform counts reported during 2007 and 2008 exceeded potable water standards, numbers usually remained below standards set for recreational use. One notable exception was the June 2008 sampling event in which fecal coliform numbers exceeded the 200 cfu/100ml standard reaching numbers as high as 485 cfu/100 ml. The Nissitissit River provides wetland habitat for diverse wildlife so it was not surprising to detect fecal coliforms because animals are a source of fecal contamination. Bacterial growth may have been further stimulated during this period due to higher water temperatures. High flow rates during a rainstorm event have been found to cause an increase in bacterial numbers. This increase is due to disturbance of stream bed sediments which serve as important reservoirs for microorganisms (McDonald and Kay, 1981). The high stream flow rates (158 ft^3/s) observed during the July sampling event in 2009 likely contributed to the 100 fold increase in the number of fecal coliforms observed for the September sampling event. High dissolved oxygen concentrations (often greater than 100% saturation) and an increase in nitrate concentrations accompanying the high flow rates likely provided additional nutrients to support the 100 fold increase in the number of fecal coliforms. Undetectable nitrate concentrations and percent oxygen concentrations at and below 55% reported during the September sampling event also suggests an increase in microbial activity.

Data presented in this study support the Class B categorization for the Nissitissit River. While there was a substantial increase in the number of fecal coliforms reported during 2009 compared to the previous two years, analyses of the samples took place relatively soon after a rainfall event. Continued water monitoring will serve to identify changes in the water quality due to normal stream ecosystem processes and will detect permanent changes that result from ongoing development in the watershed and other human activities.

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* **SUSAN E. BARBARO**, Ph.D., obtained a Bachelor of Science Degree from Concordia University, Montreal, Quebec, and Master of Science and Doctorate from the University of Waterloo, Ontario. Her desire to understand and protect the environment has always played an important role in determining Susan's research interests. In particular, she is interested in the microbial ecology of fresh water and soil ecosystems. Susan has studied and conducted research related to microbial physiology, biological control, and bioremediation. She joined the faculty at Rivier College in 2003. Dr. Barbaro is an Associate Professor and Coordinator of the Department of Biology.