A WATER QUALITY MONITORING STUDY OF THE NISSITISSIT RIVER AND SALMON BROOK: YEAR ONE DATA

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Abstract

This study evaluated water quality of the Nissitissit River and Salmon Brook, located in southeastern New Hampshire and northeastern Massachusetts. Water samples were collected once a month over three consecutive months (June, July, and August – summer of 2007) at five locations in each river and analyzed for a group of chemical and microbiological parameters typically monitored to characterize water quality. Parameters measured included water temperature, dissolved oxygen, pH, sodium, nitrate, phosphate, total coliforms, and fecal coliforms. pH, sodium, nitrate, and phosphate concentrations were measured at levels below potable water standards set by the United States Environmental Protection Agency (USEPA). Dissolved oxygen concentrations varied substantially between sites and rivers. Dissolved oxygen concentrations measured for Salmon Brook were generally lower than those for the Nissitissit River. The number of fecal coliforms also varied among sites and rivers and always exceeded potable water standards. In addition, in several samples, fecal coliform counts exceeded Massachusetts recreational water quality standards. Data collected in this study represents the first year data for an anticipated long-term water quality study conducted for the Nissitissit Land Trust and Salmon Brook Greenway Committee and will be incorporated into a companion studies designed to assess the fate of contaminants in these rivers.

INTRODUCTION

Rivers provide important habitat for aquatic species and breeding and feeding sites for other wildlife. They are also used for recreation such as swimming, canoeing, and fishing, and in some cases, are a source of drinking water. Development in watersheds replaces forested and open land with urban land such as new residential and commercial development. These land use changes increase the amount of impervious surface resulting in storm runoff events that negatively affect stream ecosystems and water quality (Paul, 2001). Rivers in watersheds with substantial agricultural and urban land use experience increased inputs and varying compositions of organic matter (Sickman, 2007) and excessive concentrations of phosphorus and other nutrients from fertilizer application and watershed releases (Howarth, 1996; David, 1997; Easton, 2007). Nutrient loading is known to stimulate primary productivity, eutrophication, and subsequent degradation of water quality (Steinman and Mulholland, 2006). Rivers in urbanized watersheds are also at greater risk of becoming contaminated with pathogenic organisms, and inorganic and anthropogenic chemicals (Kolpin et al., 2002). Natural and synthetic estrogens, other pharmaceuticals, and disease-causing bacteria are entering streams through the release of wastewater from sewage treatment plants and effluent from septic systems (Williams et al., 2003; Kinzelman, et al., 2003; Gross, et al., 2004). Methyl *tert* butyl ether (MTBE), a gasoline oxygenate, has been detected frequently in surface water as a result of leaking underground gasoline storage tanks (Carter et al., 2007), and pesticides are often intentionally released into aquatic ecosystems

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in measured applications (Kolpin et al., 2002). In watersheds with rapid development, preserving and protecting wetlands and floodplains is important for minimizing flooding, and protecting water quality.

Both the Nissitissit River and Salmon Brook watersheds are facing increasing development pressures. The Nissitissit Land Trust was first formed in 1968 by a group of local citizens after it became apparent that development along the rivers banks and in the watershed was increasing (Tupper, 1991). The Nissitissit River is approximately 9.2 miles long. Its headwaters are at Lake Potanipo, West Brookline, NH. The river flows primarily through underdeveloped and lightly developed areas before discharging into the Nashua River in Pepperell, MA. The New Hampshire Water Pollution Commission historically has granted the Nissitissit River a B-1 classification, signifying good water quality for recreational use. An important goal of the Nissitissit Land Trust is to ensure the water and stream bed of the river are protected from the effects of development. More recently, the Salmon Brook Greenway Committee was established by a group of individuals interested in improving aspects of Salmon Brook. The goal of the Greenway Committee is to improve the visibility of Salmon Brook and make better use of the potential recreational areas associated with it. Salmon Brook is approximately 10.0 miles long and its headwaters are located at Massapoag Pond, Dunstable, MA. In contrast to the Nissitissit River, in addition to flowing through undeveloped areas, Salmon Brook also flows through and under the City of Nashua, NH before discharging into the Merrimack River.

The objective of this study is to provide water quality data for the Nissitissit River and Salmon Brook so that trends in water chemistry and microbiology can be assessed both spatially (comparison among sampling sites) and temporally (trends that occur seasonally and annually). Data collected in this study will also be integrated into biodegradation studies designed to assess the fate of environmental contaminants in these rivers. Data collected in this study include daily mean streamflow rates(ft^3/s) (Nissitissit River only), temperature (°C), dissolved oxygen (DO) (mg/L), nitrate (NO_3^-) (mg/L) (July and August only), phosphate (PO_4^{2-}) (mg/L) (July and August only), sodium (Na^+) (mg/L) (July and August only), total coliforms (cfu/100ml), and fecal coliforms (cfu/100ml). The most common indicator used when monitoring potable and recreational water quality is the detection of fecal coliforms and the presence of *Escherichia coli*. The presence of these microorganisms correlates with gastrointestinal illnesses and indicate wastewater or feces as the source of contamination in the watershed (Donovan et al., 2008; Kinzelman et al., 2003). Physical data (temperature and flow rate) and chemical data (DO, nitrogen, phosphorous, and Na^+) were also collected as these parameters may affect microbiological data and indicate other sources of contamination. Water quality data for 2007 are provided in this report.

EXPERIMENTAL PROCEDURE

Sampling Sites

Five sites were identified for sampling based on accessibility and location along the river. The fives sites sampled along the Nissitissit Rivier and Salmon Brook are identified as follows:

Nissitissit Rivier Sample Sites:

#1: Mill St., Pepperell MA
#2: Prescott St., Pepperell, MA
#3: West Hollis and Worcester Roads., Hollis NH
#4: Bohanan Bridge Rd., Brookline NH
#5: Potanipo Lake, Brookline, NH

Salmon Brook Sample Sites:

#1: Dunstable Road (Rte. 113), Massapoag Pond, Dunstable, MA
#2: Searles Road, Nashua, NH
#3: Dunstable Road, Nashua, NH
#4 Fields Grove, Nashua, NH
#5 Ingals St., Nashua, NH

Sample Collection

Samples were collected from the Nissitissit River and Salmon Brook throughout the summer (June-August) of 2007. Samples were obtained using the grab method by wading out into the center of the river and collecting water samples from midway between the surface and sediment with the exception of sampling site # 5 of Salmon Brook. This site is located at an inside bend of a meander. Thick sediment has made it difficult to access the interior of the river so samples were collected approximately 1m from the bank. Water samples were collected in sterile glass screw top bottles, transported back to the laboratory in a cooler on ice packs, and analyzed. Dissolved oxygen, pH measurements, and microbiological analyses were conducted within one hour of retrieving the samples. Water samples to be tested for nitrate, phosphate, and sodium were stored at 4°C and analyzed within 24 hours of collection. Temperature measurements were determined in the field.

Physical Parameters

Flow Rates

Flow rates for the Nissitissit River were obtained from the United States Geological Survey (USGS) streamflow gaging station at Pepperell, MA (Station No. 01096503). The gage is located at the Mill Street Bridge in Pepperell (sample site #1) about 1 mile upstream from the mouth of the Nissitissit River at the Nashua River. Flow rate data were not available for Salmon Brook.

Temperature

Water temperature was measured on site using an alcohol field thermometer.

Chemical Parameters

pH

pH was measured in the laboratory using a pH specific probe (Fisher Scientific).

Dissolved Oxygen

Dissolved oxygen concentrations were determined using an oxygen specific probe (Microelectrodes, Inc. Bedford, NH). Oxygen measurements were converted from moles/L to mg/L using the following equations:

$$DO\ (moles/L) = (a/22.414) \times (760-p)/760) \times (r\%/100);$$

$$DO\ (mg/L) = ((moles/L) \times (32))/0.001$$

where: a = absorption coefficient of gas at temperature, p = vapor pressure of water at temperature, and r% = actual reading in percent oxygen.

Phosphate

Phosphate concentrations in unfiltered samples were determined using the Ascorbic Acid Method (Method adapted from the Standard Methods for the Examination of Water and Wastewater, 1992). A powder pillow (Hach Company), was added to 25 mL of water. After 5 min incubation with agitation, the resulting color change was determined by measuring the absorbance of the water sample at a

wavelength of 790nm. Results were compared to a phosphate standard curve (0.00, 0.04, 0.08, 0.16, and 0.20 mg/L) prepared with a phosphate stock solution (Hach Company) and distilled, deionized water.

Nitrate

Nitrate concentrations in unfiltered samples were determined using the Cadmium Reduction method (Method adapted from the Standard Methods for the Examination of Water and Wastewater, 1992). A reagent powder pillow (Hach Company), was added to 25 mL of water. After 5 min incubation with agitation, the resulting color change was determined by measuring the absorbance of the water sample at a wavelength of 543 nm. Results were compared to a nitrate standard curve (0.00, 0.10, 2.5, and 5.0 mg/L) prepared with nitrate stock solution (Hach Company) and distilled, deionized water.

Na^+

Sodium concentrations were determined using a Flame Ionizing Spectrophotometer (Perkin-Elmer). Prior to analysis samples were filtered passing samples through a 0.45 µm cellulose acetate filter. Concentration of Na^+ in the filtrate was determined by comparing the absorbance spectra at 589 nm of the water samples with a standard sodium curve (0.00, 1.0, 2.0, 5.0, and 10 mg/L).

Biological Parameters

Enumeration of Total and Fecal Coliforms

The membrane filter technique was used to determine the number of colony forming units per 100 mL (# cfu/100ml) of total and fecal coliforms in water. Undiluted water samples (100 ml) or 1:10 dilution of water samples (100 ml) (or as determined from previous sampling events) were filtered through a 0.45 µm pore-size membrane filter. The filter was aseptically placed onto Endo agar for the determination of total coliforms and m-FC agar for the determination of fecal coliforms. Plates for determining total coliforms were incubated for 18-24 h at 37 °C. Plates for fecal coliforms were incubated for 18-24h at 44.5°C. After incubation, colonies presenting a green metallic sheen appearance on Endo agar plates with 3-30 colonies were counted and used to determine #cfu of total coliforms /100ml. Dark blue colonies growing on mFc were counted on plates with 3-30 colonies and used to determine #cfu fecal coliforms /100ml. Data are presented as an average for two samples.

RESULTS

First year water quality data for the Nissitissit River and Salmon Brook are summarized in Tables1 and 2, respectively. Water temperatures ranged between 17-24°C in the Nissitissit River and 15-23°C in Salmon Brook over the course of the summer. Temperatures among sites typically remained within 0.5°C of each other on any given sampling date with the exception of site #1 in the Nissitissit River (Table 1). Greater variability in water temperatures was observed for Salmon Brook sites during a given sampling event (Table 2). Dissolved oxygen concentrations measured for the Nissitissit River during June and August sampling dates represent values above 80% saturation, with the exception of site #1 (June) and sites #3 and #4 (August). Concentrations measured during the July sampling event are considerably lower, dropping as low as 64.8 % saturation at site #4, suggesting an increase in microbial activity (Table 1). Dissolved oxygen concentrations measured in Salmon Brook were generally lower and more variable than those determined for the Nissitissit River, ranging from 39.4% saturation at site #1(August) to 97.3 % saturation at site #5 (August) (Table 2).

Table 1: Water Quality Data for the Nissitissit River, 2007

Date	Sampling Site	[1]Flow (ft^3/s)	Temp (°C)	[2]Dissolved Oxygen (mg/L)	NO_3^- (mg/L)	PO_4^{2-} (mg/L)	Na^+ (mg/L)	[3]Total Coliforms (cfu/100ml)	[4]FecalColiforms (cfu/100ml)
06/07/07	#1	132	17.0	9.49 (97.8)	NA	NA	NA	360	115
	#2		17.0	8.76 (89.9)	NA	NA	NA	400	110
	#3		17.5	8.06 (84.8)	NA	NA	NA	430	145
	#4		17.5	8.51 (89.6)	NA	NA	NA	275	90
	#5		19.0	6.82 (73.3)	NA	NA	NA	50	45
07/25/07	#1	21	20.0	6.56 (71.6)	0.106	0.041	8.42	750	80
	#2		20.0	6.56 (71.6)	0.113	0.019	8.61	600	75
	#3		19.5	6.82 (74.5)	0.009	0.018	8.45	2000	90
	#4		20.0	5.83 (64.8)	0.106	0.022	8.67	1450	150
	#5		24.0	6.73 (80.1)	0.000	0.012	7.88	285	5
08/22/07	#1	7.9	15.5	8.14 (82.2)	0.250	0.024	9.34	630	70
	#2		15.0	8.60 (84.8)	0.250	0.015	9.18	1150	27
	#3		14.5	7.04 (69.5)	0.286	0.011	9.26	1220	95
	#4		14.5	7.56 (74.6)	0.50	0.011	9.26	1080	250
	#5		18.0	8.33 (87.7)	0.143	0.011	8.70	1420	25

NA = Not applicable, water was not tested for these parameters.
[1] = Mean streamflow at USGS Station No. 01096503.
[2] = (value) represents % saturation.
[3] = Mean of two samples.
[4] = Mean of two samples.

Table 2: Water Quality Data for Salmon Brook, 2007

Date	Sampling Site	Temp (°C)	[1]Dissolved Oxygen (mg/L)	NO_3^- (mg/L)	PO_4^{2-} (mg/L)	Na^+ (mg/L)	[2]Total Coliforms (cfu/100ml)	[3]Fecals Coliforms (cfu/100ml)
05/31/07	#1	22.0	4.88 (55.4)	NA	NA	NA	55	2
	#2	20.0	4.63 (50.6)	NA	NA	NA	310	46
	#3	20.0	4.33 (47.3)	NA	NA	NA	490	180
	#4	20.0	5.19 (56.7)	NA	NA	NA	255	225
	#5	19.5	5.92 (64.6)	NA	NA	NA	310	210
07/17/07	#1	24.0	3.39 (40.3)	0.541	0.013	7.11	35	20
	#2	22.5	5.48 (63.7)	0.598	0.020	6.10	600	90
	#3	22.0	6.45 (73.3)	0.680	0.013	3.94	650	145
	#4	23.0	7.67 (88.7)	0.598	0.018	5.79	800	35
	#5	22.0	7.65 (86.9)	0.648	0.023	4.97	1150	130
08/21/07	#1	18.0	3.74 (39.4)	0.271	0.014	8.61	380	28
	#2	16.0	7.87 (79.5)	0.458	0.005	7.85	540	45
	#3	16.0	7.78 (78.5)	0.396	0.003	8.69	670	195
	#4	15.0	7.04 (69.4)	0.417	0.006	8.92	980	300
	#5	17.0	9.44 (97.3)	0.396	0.008	9.08	560	110

NA = Not applicable, water was not tested for these parameters.
[1] = (value) represents % saturation.
[2] = Mean of two samples.
[3] = Mean of two samples.

For both rivers, pH values fell within typical concentrations determined for rivers (6.5-8.5) (data not shown). Sodium concentrations are typical of ecosystems in areas not impacted greatly by road salt usage (30 mg/L) and are below recommended drinking water standards (20 mg/L) (USEPA, 2003).

Nitrate concentrations are below USEPA recommended drinking water standards (10 mg/L) for all sites in both rivers (USEPA, 2008). Although drinking water standards have not been set for phosphate, even small increases in phosphate concentrations can have substantial consequences for water quality. In this study, phosphate remained below 0.041 mg/L for both rivers over the entire sampling period.

The presence of fecal coliforms in water indicates contamination with feces and presents a serious risk to animal and human health; therefore the drinking water standard in terms of fecal coliforms is set at 0 cfu/100ml (USEPA-SDWS, 2008). The current advisory limits for recreational use for the State of Massachusetts (MA) is 20 cfu/100ml for freshwater ecosystems with excellent water quality (Class A) and 200 cfu100/ml in ecosystems with good quality (Class B) (USEPA-BWQS for Recreational Waters, 2003). Class distinctions for the state of NH based on the presence of *Escherichia coli* are as follows: 47 cfu/100ml class A, 126 cfu/100ml class B. All samples showed the presence of fecal coliforms, thereby failing to meet the drinking water standards. Based on MA water quality standards, Site (#4) (Nissitissit River) failed to meet recreational standards in August, with an estimated fecal coliform count of 250 cfu/100ml (Table 1). Site #4 of Salmon Brook failed to meet standards in June (255 cfu/100ml) and again in August (300 cfu/100ml) (Table 2). Site #5 (Salmon Brook) also failed to meet recreational standards during the June sampling event (210 cfu/100ml) (Table 2).

DISCUSSION AND CONCLUSIONS

Although dissolved oxygen concentrations are rarely uniform along stream reaches due to changes in flow rate, water temperature, groundwater infiltration, upwelling, and microbial activity, most unpolluted rivers contain average dissolved oxygen concentrations that are greater than 80 percent of the concentration at saturation (Hauer and Hill, 2006). Organic contaminants, for example organic carbon associated with wastewater discharge, can substantially reduce dissolved oxygen concentrations by stimulating microbial processes that consume oxygen. Reductions in oxygen have a major effect on aquatic wildlife relying on oxygen for metabolism. For example, the State of Massachusetts requires that surface waters contain 5.0 mg/L dissolved oxygen to protect warm water fisheries and 6.0 mg/L of dissolved oxygen to protect cold water fisheries (Massachusetts Department of Environmental Protection, 1996). Primary sources of dissolved nitrogen in pristine streams include inputs from mineral sources, surrounding vegetation, and the atmosphere. In pristine environments, indigenous microbial populations, particularly those associated with bioflims, may be limited by available dissolved nitrogen. As a result, bacterial numbers remain relatively low. However, an input of allochthonous nitrogen, such as ammonium in wastewater effluent and nitrate in agricultural or residential runoff, can quickly cause eutrophication of the river ecosystem, resulting in decreased oxygen concentrations, and an increase in anaerobic microbial metabolism (Tank et al., 2006). Similarly, allochtonous inputs of phosphorous, also typically a limiting nutrient in aquatic ecosystems, can lead to eutrophication and toxic algal blooms. In addition to a loss in fish populations, decreased oxygen concentrations stimulate the activity of anaerobic microbial populations which contribute to poor water quality through the production of metabolic by-products. Based on the data collected for year one of this study, the water quality of these rivers can be considered good (Class B). Chemical parameters were found to be within water quality standards with no apparent addition of excessive levels of nutrients from the watersheds.

Coliforms are bacteria that comprise the family *Enterobacteriaceae*. They are characterized as nonspore forming, gram-negative rod-shaped bacteria that ferment lactose with gas production within 48 hours at 35 °C. These bacteria are ubiquitous in nature and can be isolated from a variety of environments. A significant portion of coliforms isolated from the environment can be traced to fecal

origins, as many members of the coliform group comprise up to 10% of all bacteria found in the intestinal tracts of humans and other animals (Prescott et al., 2005). These bacteria are most often associated with gastrointestinal diseases as a result of drinking contaminated water and respiratory, skin, eye, ear, nose, and throat diseases as a result of recreational contact with contaminated water. Therefore, they are used as indicators for determining water quality of potable surface and groundwater sources as well as for recreational uses (Brenner, et al., 1993). Fecal coliforms most often find their way into freshwater systems by the unintentional release of untreated sewage (farming practices, combined sewer flows, and sanitary sewer outfalls) or through intentional releases of wastewater (Donovan, 2008). In this study, fecal coliform counts exceeded potable water standards, so water should not be consumed without pretreatment. Occasionally, fecal counts were found to exceed recreational water standards, but still remained reasonably low. Two factors contributing to the observed increase in fecal counts were increased water temperatures, indirectly increasing microbial activity and growth, and the presence of wetlands and other habitat for wildlife, particularly waterfowl, in the watersheds. Wildlife is likely the source of the fecal contamination measured in these rivers.

In addition to pathogenic organisms and excessive nutrients, rivers receiving wastewater have recently been found to contain low levels of a host of anthropogenic compounds such as hormones (estrogens), pharmaceuticals (e.g., carbamazepine and ibuprofen), and plastics (e.g. alkylphenol polyethoxylates) (Kolpin, 2002; Tixier et al., 2003; Gross et al., 2004). Although the health risks associated with exposure to pathogenic microorganisms are well known, the potential effects of these pharmaceuticals and personal care products on ecosystem and human health are not well understood. Some possible effects of exposure to these compounds include abnormal reproductive processes, increased incidence of cancer, development of antibiotic resistant bacteria, and increased toxicity due to synergistic effects (Kolpin et al., 2002). In the future, it is anticipated that this study will be expanded to provide a more comprehensive data set for the Nissitissit Land Trust and Salmon Brook Greenway Committee including some of the above mentioned wastewater constituents. Although it is not anticipated that these compounds will be present in the Nissitissit River and Salmon Brook, the ability of bacterial assemblages in uncontaminated streams to degrade environmental contaminants will be examined and later compared to the degradative abilities of bacterial assemblages in streams receiving effluent from wastewater treatment plants.

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