Annapolis River 2008 Annual Water Quality Monitoring Report

including results from the

Annapolis River Guardians Volunteer Water Quality Monitoring Program

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This report is available electronically at *www.annapolisriver.ca*

Acknowledgements

The Annapolis River Guardians is a volunteer-based program. Without the dedication of the volunteers, the program would not be the success that it is. We would therefore like to extend our thanks to the volunteers who have contributed their time and energy during the 2008 season. The Annapolis River Guardian volunteers include:

Claire Diggins

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The success of the River Guardians program is in part due to its approach of bringing together a variety of stakeholders who have an interest in the health of the Annapolis River. We would like to thank the following partners who have worked with us to deliver the Annapolis River Guardians program:

Environment Canada – Atlantic Coastal Action Program

Nova Scotia Environment

The Acadia Centre for Estuarine Research, Acadia University

Human Resources and Skills Development Canada

Executive Summary

In 2008, the Annapolis River Guardians completed their 17th year of continuous water quality monitoring on the Annapolis River. Ten volunteers monitored eight sites over the course of the season, which ran from April to November. Total suspended solids and turbidity were added to the suite of parameters monitored, which included dissolved oxygen, *E. coli* bacteria, air and water temperature, pH and conductivity, as well as local weather conditions.

E. coli bacteria levels along the Annapolis River during 2008 were roughly similar to those observed in 2007. The 2008 E.coli data exhibited a narrower range of variability than 2007, with fewer results less than 50 cfu/100 ml and few results greater than 200 cfu/100 ml. Again during 2008, E.coli counts increased markedly between the sampling stations at Aylesford Road and Victoria Road, indicating the introduction of fecal material between these two locations.

Over 17 years of monitoring, mean dissolved oxygen saturation (DOSAT) levels have remained in the range of 80-94%. In 2008, the mean DOSAT level was 89%. As a result of the regular monitoring provided by the Annapolis River Guardian program, low dissolved oxygen (DO) levels were observed in the lower river in 2005, which prompted a more in-depth examination in 2006 and 2007. In the tidal section of the Annapolis River between Bridgetown and Hebb's Landing, DO levels in the underlying saltwater fell to levels below 2 mg/L (DOSAT <25%) during the late summer and autumn of 2008. Similar observations were recorded in 2007.

The mean summer water temperature for the Annapolis River during 2008 was 20.0ºC, 1.5ºC warmer than for the same period in 2007. As in previous years, water temperatures during 2008 continued to reach levels stressful to aquatic life regularly during the summer months (>20ºC).

The pH levels at each of the River Guardians sites were consistently within the recommended range for the protection of aquatic life (6.5-9.0). Mean pH values for the eight monitoring locations along the Annapolis River ranged between 6.8 and 7.4.

Nitrogen and phosphorus levels were measured at two locations along the river in the 2006 to 2008 period. While elevated total nitrogen results were observed, phosphorus remains a significant concern. During 2006 to 2008 period, 61% of total phosphorus results exceeded the suggested guideline level of 0.030 mg/L. These elevated phosphorus concentrations are believed to have a role in excessive periphyton growth and depression of dissolved oxygen levels in the tidal portion of the river.

Working in conjunction with Environment Canada, turbidity and total suspended solids (TSS) samples were collected in 2008 as part of the regular bi-weekly sample collection as well as during high flow precipitation events. These activities were part of a two-year effort to establish a baseline for turbidity and TSS in the Annapolis watershed and develop a numerical relationship between these parameters.

CARP has collected benthic invertebrate samples in the Annapolis watershed since 2002, using the protocol developed through the Canadian Aquatic Biomonitoring Network (CABIN). There has been no significant change in the Family Biotic Index at the Paradise location over the period of 2005 to 2008. For the Wilmot location, the Family Biotic Index improved slightly over the period of 2006 to 2008.

As part of CARP's Quality Assurance Project Plan, regular quality control samples were collected. The accuracy of River Guardian dissolved oxygen readings were estimated at +/- 0.094 mg/L, compared with 0.003 mg/L recorded in 2007. Travel blank samples, collected to check for cross contamination, consistently had *E. coli* counts of 0 cfu/100ml. *E. coli* split samples had a Relative Percent Difference of 23%.

Introduction

History

The Annapolis River Guardians volunteer monitoring program began collecting water quality data in the Annapolis River watershed in 1992. The Clean Annapolis River Project (CARP) initiated the program as a public awareness project, and has had numerous volunteer sample collectors over the years. It is one of the longest running and most extensive volunteer based water quality programs in Eastern Canada. It is also CARP's longest running and only ongoing project. At least 90 volunteers from the Annapolis Valley community have participated in the program over the years, with over 3500 water samples being collected and analyzed.

The program was initiated in the early 1990's by Dr. Graham Daborn and Dr. Mike Brylinsky of the Acadia Centre for Estuarine Research (ACER). Many groups were involved in the planning process for the program, including staff with the Nova Scotia Department of Health, the Nova Scotia Department of Environment, Nova Scotia Community College, and CARP. Although the program has undergone slight changes over the last seventeen years, its core has remained the same.

The initial program design called for 11 sites to be monitored by 17 volunteers. The initial response from the community was excellent and the project was significantly expanded between 1992 and 1994. In 1994, 38 sites were monitored by 43 River Guardians from 36 households (Pittman *et al* 2001). This intensity of monitoring placed considerable strain on the capacity of CARP. While some of the initial enthusiasm surrounding the program has diminished, a core group of 8 to 15 dedicated volunteers has been maintained over the past number of years.

Program Objectives

The Annapolis River Guardians program has four objectives:

- To establish and support a regular observation system that provides an early warning of environmental problems.
- To provide a long-term record of the river's health.
- To develop interest in the Annapolis River and community stewardship to ensure a viable resource for future generations.
- To provide a knowledgeable group of local individuals who can promote the preservation, rehabilitation, and use of these aquatic resources in the future.

Overview of 2008 Monitoring Season

The first sample collection for 2008 occurred on May 4th and samples were collected on a biweekly basis until November 2nd. The parameters that were monitored were *E. coli* bacteria, dissolved oxygen content, water temperature, air temperature, pH, conductivity, total suspended solids (TSS) and turbidity. The last two parameters on the list, TSS and turbidity, were new protocols for 2008. They were added as part of a joint project between CARP and Environment Canada to determine baseline levels in the Annapolis River and to establish a mathematical relationship between the two variables. This would allow for the calculation of the water quality index (WQI) for the River, which would be useful in the annual reporting of the data.

Eight stations were sampled along the Annapolis River. Further information on these sampling locations is contained in Appendix B. Figure 1 shows the freshwater portion Annapolis Watershed and the 2008 monitoring sites. The data collected by the volunteers is stored in an in-house Microsoft Access database at the CARP office.

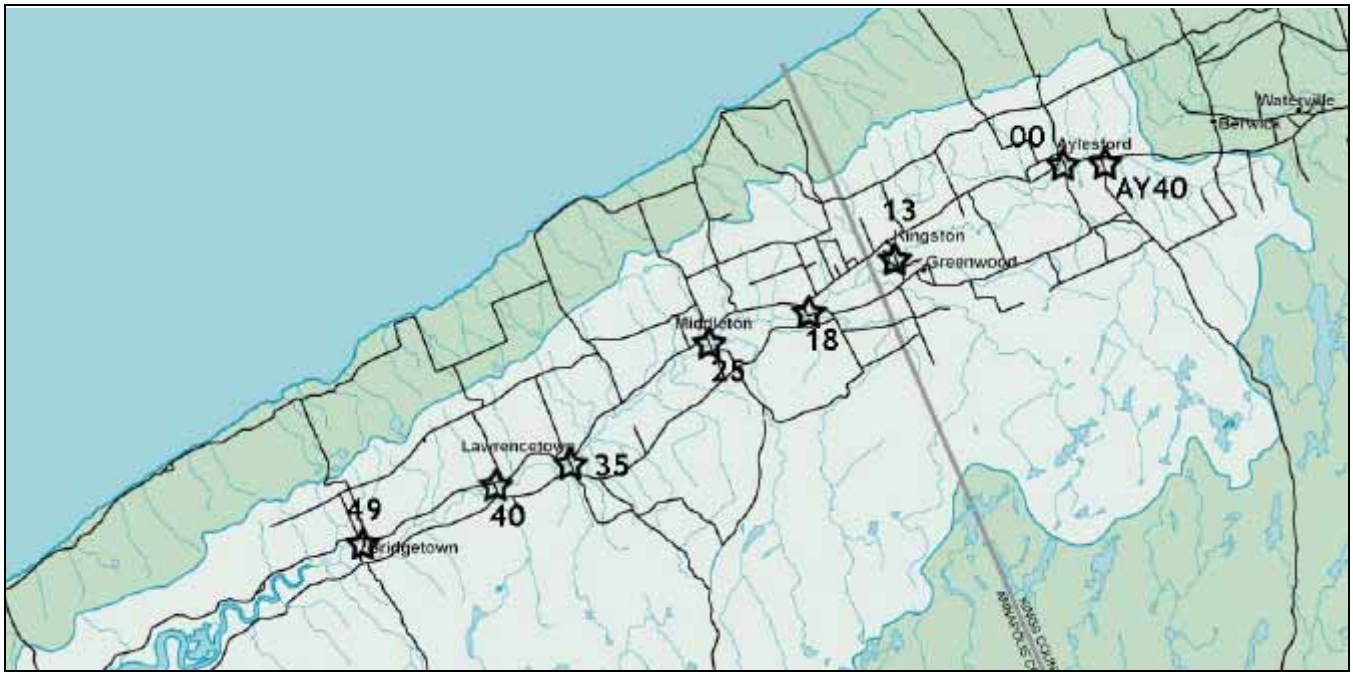

Figure 1. Annapolis watershed with 2008 River Guardian monitoring sites identified by stars.

The 2008 River Guardian sampling locations (with their identification numbers) were:

49 – Bridgetown	40 – Paradise	35 – Lawrencetown	25 – Middleton
18 – Wilmot	13 – Kingston	00 – Victoria Road, Aylesford	AY40 – Aylesford Road, Aylesford

All sample sites were located on the main stem of the Annapolis River.

In the autumn of 2005, CARP was alerted by a member of the community of foul odours in the vicinity of Middleton's Riverside Park. Subsequent investigation and collection of water samples from Lily Lake Brook, a tributary of the Annapolis River, indicated very elevated *E. coli* levels (>20,000 cfu/100 ml). The problem was traced back to limitations in the Town's sewage infrastructure. When heavy rains occurred, the water was collected through the combined sewer system and exceeded the capacity of the sewage treatment plant (STP). This resulted in the discharge of untreated waste to the Lily Lake Brook and the Annapolis River.

In the autumn of 2007, a temporary repair to the STP was made to ensure that untreated waste would not be released into the Lily Lake Brook during peak flow events. During 2008, CARP

continued to work with the Town of Middleton to address issues concerning the sewage treatment plant. With the assistance of ABL Environmental Consultants Ltd., the town has completed a full design for a new two-lagoon sewage treatment plant and made an application for federal-provincial infrastructure funding. If this application is successful, it is anticipated that construction of the new sewage treatment plant (STP) can commence in the spring of 2009.

CARP would like to acknowledge and congratulate the Town of Middleton for its persistence in pursuing a solution to its sanitary waste challenges.

This case serves as an example of how community water quality monitoring programs, such as River Guardians, can help to identify water quality issues, motivate regulators and polluters to address the problem and work with all parties to ensure the long-term health of a watershed.

2008 Monitoring Results

E. coli Bacteria

Introduction

Escherichia coli (*E. coli*) are rod-shaped, aerobic, lactose fermenting bacteria. They are Gram-stain negative, thermotolerant and appear as dark blue colonies when cultured in the laboratory. The predominant sources of *E. Coli* bacteria in the watershed include poorly maintained on-site septic systems, malfunctioning central sewage treatment plants, aquatic wildlife, domestic animals, and livestock. Because they occupy the same ecological niche as many human pathogens, such as *Cryptosporidium*, *E. coli* are used as indicators for the possible presence of other potentially dangerous pathogens. *E. coli* levels have been identified in the past as a major cause of concern in the Annapolis River watershed (Pittman *et al* 2001). The potential sources of fecal contamination in the watershed include central sewage treatment plants, malfunctioning on-site septic systems, aquatic wildlife (i.e. beavers, muskrats, waterfowl), domestic animals, and livestock.

Many factors in a particular ecosystem affect the abundance of *E. coli* in rivers. These include the type of source, the transport mechanism with which the *E. coli* is deposited, and precipitation. The result is that *E. coli* densities in surface waters can be highly variable. Their survival in surface waters is not well understood, and is dependent on many factors. These include predation by other organisms, amount of sunlight, salinity of the water, temperature, as well as composition and abundance of sediment (Davies *et al* 1995). There is a range of estimates for the survival times of the commonly monitored *E. coli* in various media:

- Cow pats: 49 days at 37°C, 70 days at 5°C (also dependent on moisture content) (Chalmers *et al* 2000)
- Drinking water: Between 28 and 84 days (Edberg *et al* 2000)
- Soil cores with grass roots: 130 days (Chalmers *et al* 2000)
- In situ freshwater sediment: 57 days (Davies *et al* 1995)

Over the period of 1992 to 2008, numerous initiatives have been undertaken which have contributed to the improvement of water quality in the Annapolis River. For example, in the winter of 1994, 14 Wing Greenwood discontinued the discharge of untreated aircraft wash-water into a tributary of the Annapolis River. In August 1998, the base discontinued the operation of its own sewage treatment plant, redirecting its waste to the Greenwood municipal facility.

While the core River Guardian monitoring program has been maintained over the period of 1992 to 2008, a number of modifications have been made. For example, in 1996, the collection of *E. coli* samples was standardized to a fortnightly basis. During the period of 1997 to 2002, fecal coliform numbers were determined using the IDEXX Colilert procedure, which specifically identifies *E. coli*. With the change to a new laboratory, the 2003 and 2004 samples were analyzed using the Membrane Filtration procedure, which enumerates fecal coliforms (see Appendix A). In 2005, the Science Advisory Committee for the Annapolis River Guardians advised that bacteria monitoring be switched from fecal coliforms to *E. coli*, to bring the program more in line with current guidance at a

national level. To ensure the continuity of the historic dataset, it was decided to collect split samples for the first two months of the season, to allow parallel testing for fecal coliform and *E. coli*. This process confirmed that the two methods do not give statistically different results. Further information on the parallel testing and statistical analysis can be found in the 2005 Annual Report for the Annapolis River Guardians (Beveridge *et al* 2006).

Canadian Water Quality Guidelines

Various government agencies have developed water quality guidelines to protect the safety of the general public. Health Canada is responsible for the guidelines for drinking and recreational waters. The Canadian Council of Ministers of the Environment (CCME) has incorporated these guidelines in the comprehensive Canadian Water Quality Guidelines (CCME 2002). There have been several different guidelines developed for different possible water uses, such as protection of aquatic life, agricultural uses, drinking or recreation. CARP has summarized some of these guidelines for fecal bacteria contamination into a single table for public awareness purposes (Table 1).

Table 1. Summary of water quality guidelines for fecal coliforms.

cfu*/100ml	Water Use	Explanation/Source
0	Acceptable for drinking	CCME/Health Canada, fecal coliforms/100ml.
<50	Acceptable for livestock watering	Interpretation of CCME narrative "high-quality water given to livestock" (total coliforms).
<100	Acceptable for food crop irrigation	Tentative Maximum Concentration. CCME Guidelines (fecal coliform bacteria/100ml).
< 200	Acceptable for recreational use	CCME/Health Canada, Geometric Mean of 5 samples taken during a period not to exceed 30 days, should not exceed 200 cfu/100 ml.
cfu = colony forming units		

Monitoring Results

The high variability of fecal bacteria measurements presents a number of challenges with respect to data analysis. Samples collected from a single site, on separate occasions, can vary by two and sometimes three orders of magnitude (e.g. 3 cfu/100 ml to 3000 cfu/100 ml). The use of standard data analysis methods, such as calculating and comparing mean values, inadequately describes the distribution of fecal bacteria results. The following analysis is therefore based on the proportion of samples analysed that exceed particular water quality thresholds. This approach was chosen as it best presents, to decision-makers and resource managers, whether the water at a site is unsuitable for particular uses.

While this approach eliminates the bias of calculating means with highly variable data, it presents another type of bias. If the majority of samples one year fall slightly below a guideline threshold (e.g. 200 cfu/100 ml), a small increase in fecal coliform concentration the next year may cause the proportion of samples above 200 cfu/100 ml to increase significantly. This would give the appearance that the water quality had worsened considerably, when in fact the mean coliform concentration may have only increased slightly. In order to ensure the differences observed in the following analysis are real, a box-whisker plot was prepared to compare the distribution of the 2007 and 2008 *E. coli* results (see Figure 2). The box plot shows the 25th and 75th percentiles as well as

the median for each site. The minimum and maximum results are also shown. The three water quality guidelines for *E. coli* discussed in the report are shown as dotted lines at 50, 100, and 200 cfu/100ml. Note that the y-axis of the graph is plotted using a logarithmic scale (Log *E. coli*) and that the data is artificially capped at 2420 cfu/100mL, as this is the maximum possible value with the IDEXX Colilert testing system. From 1992 to 2008, approximately 3% of the data have exceeded this cap value.

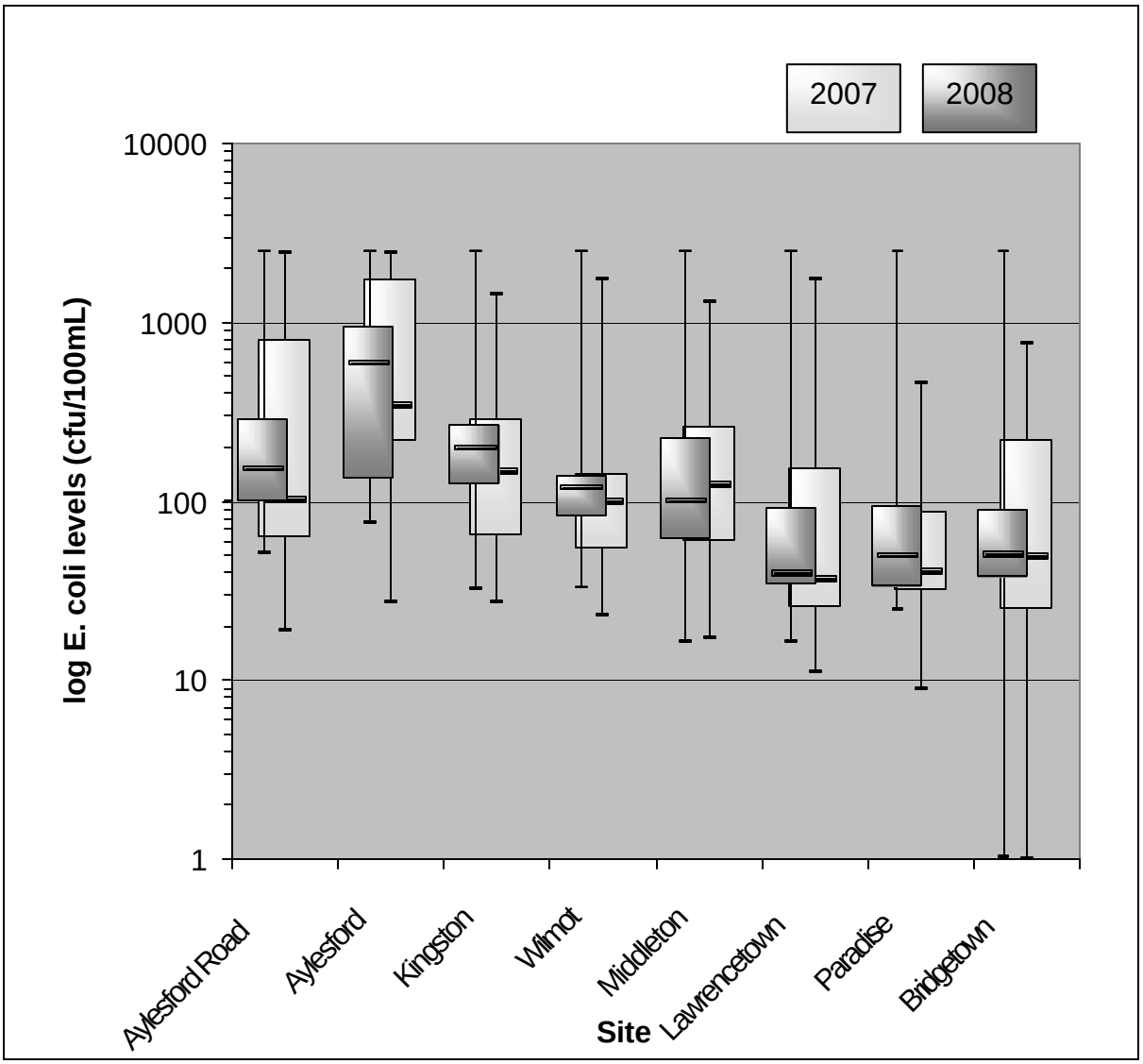

Figure 2. Box and whisker plot of Annapolis River Guardian *E. coli* bacteria results for 2007 and 2008.

In 2008, the median *E. coli* values for Aylesford Road, Aylesford, Kingston, Wilmot and Paradise were higher than their 2007 respective medians; the only 2008 median value lower than the 2007 value was recorded at Middleton. The Bridgetown and Lawrencetown medians remain unchanged from the previous year. Also in 2008, every site except Paradise showed less variability when

compared to 2007. The reason for this is not known. It is important to note that the Middleton River Guardian sample station is upriver from the discharge from the Middleton sewage treatment plant. Tables 2 through 9 present the *E. coli* data for each River Guardians location as the percentage of samples that fall within each of the ranges specified above, in table 1. This allows one to easily see how the *E. coli* readings have fluctuated and changed for each station since CARP began monitoring the Annapolis River. All of the *E. coli* ranges are in units of cfu/100mL.

Table 2. *E. coli* percentages for Aylesford Road samples.

Year	% 0 - 50	% 51 - 100	% 101 - 200	% >200
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003	20	40	20	20
2004				
2005	33	13	27	27
2006	29	6	6	59
2007	20	20	33	27
2008	8	23	38	31

Table 3. *E. coli* Percentages for Aylesford, Victoria Road.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	0	50	50
1993	9	9	27	55
1994	17	17	17	50
1995	67	0	17	17
1996	62	0	0	38
1997	14	14	29	43
1998	15	8	23	54
1999	9	18	27	45
2000	40	0	20	40
2001	25	19	31	25
2002	6	11	33	50
2003	16	16	58	11
2004	6	0	24	71
2005	29	7	7	57
2006	8	23	8	62
2007	6	6	12	76
2008	0	23	8	69

Table 4. *E. coli* percentages for Kingston.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	67	33	0	0
1993	21	21	36	21
1994	33	17	0	50
1995	86	0	0	14
1996	50	19	6	25
1997	19	38	31	13
1998	27	27	27	18
1999	35	18	18	29
2000	40	20	33	7
2001	24	29	18	29
2002	39	28	17	17
2003	13	13	40	33
2004	7	14	43	36
2005	33	7	33	27
2006	7	29	14	50
2007	14	29	14	43
2008	15	0	46	38

Table 5. *E. coli* percentages for Wilmot.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	0	67
1993	19	13	19	50
1994	13	0	31	56
1995				
1996				
1997	28	11	44	17
1998	60	30	10	0
1999	31	25	19	25
2000	50	17	17	17
2001	25	31	25	19
2002	29	35	12	24
2003	20	47	13	20
2004	0	21	57	21
2005	27	7	60	7
2006	21	36	14	29
2007	27	27	27	20
2008	23	8	54	15

Table 6. *E. coli* percentages for Middleton.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	0	67
1993	14	14	43	29
1994	9	9	27	55
1995				
1996	40	10	20	30
1997	13	25	50	13
1998	50	0	25	25
1999	50	8	25	17
2000	60	20	7	13
2001	41	18	24	18
2002	65	29	6	0
2003	36	29	14	21
2004	15	23	38	23
2005	53	20	13	13
2006	43	21	7	29
2007	20	27	27	27
2008	14	36	21	29

Table 7. *E. coli* percentages for Lawrencetown.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	33	33
1993	7	14	21	57
1994	24	6	41	29
1995	43	0	29	29
1996	13	13	33	40
1997	29	36	29	7
1998	42	25	25	8
1999	40	30	30	0
2000	53	20	7	20
2001	56	25	13	6
2002	50	11	17	22
2003	53	20	7	20
2004	21	29	21	29
2005	47	33	20	0
2006	40	7	13	40
2007	57	14	7	21
2008	54	23	8	15

Table 8. *E. coli* percentages for Paradise.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	0	67	33
1993	14	14	36	36
1994	14	29	0	57
1995	63	0	13	25
1996	29	18	12	41
1997	50	36	7	7
1998	22	44	22	11
1999	42	25	25	8
2000	33	17	8	42
2001	35	18	29	18
2002	59	6	18	18
2003	40	20	27	13
2004	14	21	21	43
2005	36	36	21	7
2006	33	7	13	47
2007	53	27	7	13
2008	54	23	15	8

Table 9. *E. coli* percentages for Bridgetown.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992				
1993				
1994	14	21	21	43
1995	44	11	22	22
1996	29	18	18	35
1997	35	12	47	6
1998	44	38	13	6
1999	33	22	28	17
2000	60	27	13	0
2001	71	18	0	12
2002	41	35	12	12
2003	33	27	13	27
2004	14	7	50	29
2005	40	47	7	7
2006	27	20	20	33
2007	53	13	0	33
2008	50	29	7	14

In 2008, five of the sampling locations, Kingston, Wilmot, Lawrencetown, Paradise and Bridgetown, had a similar proportion of samples (a difference of less than five percentage points) within the 0 – 50 cfu/100mL range compared to 2007, while Aylesford Road, Aylesford and Middleton all decreased in the number of samples falling into this range. In the 51 – 100 cfu/100mL range, sample percentages increased for Aylesford, Middleton, Lawrencetown and Bridgetown, decreased for Kingston and Wilmot and did not change significantly for Aylesford Road and Paradise. For the 101 – 200 cfu/100mL range, sample percentages for Aylesford and Middleton decreased, increased for Aylesford Road, Kingston, Wilmot, Paradise and Bridgetown while Lawrencetown's percentage of samples did not change significantly. The increase in samples falling into this range was especially pronounced in Kingston and Wilmot, where the numbers increased by 32 and 27 percentage points respectively. There were no significant increases from 2007 in the amount of samples falling into the >200 cfu/100mL range; the percentage dropped for Aylesford, Kingston, Lawrencetown, Paradise and Bridgetown and remained unchanged for Aylesford Road, Wilmot and Middleton.

These results complement the results of the box plot, Figure 2, which shows a smaller spread of the data in most locations in 2008 compared to 2007. The percentages indicate that fewer results were falling into the uppermost and lowermost categories, >200 cfu/100mL and <50 cfu/100mL, and instead tended to fall in the two central categories, 51-100 and 101-200 cfu/100mL. Figure 4 presents the percentage of data falling into each of these categories by year. The data for each location has been combined for each year and the number of samples collected in each year is presented with this figure, in table 10.

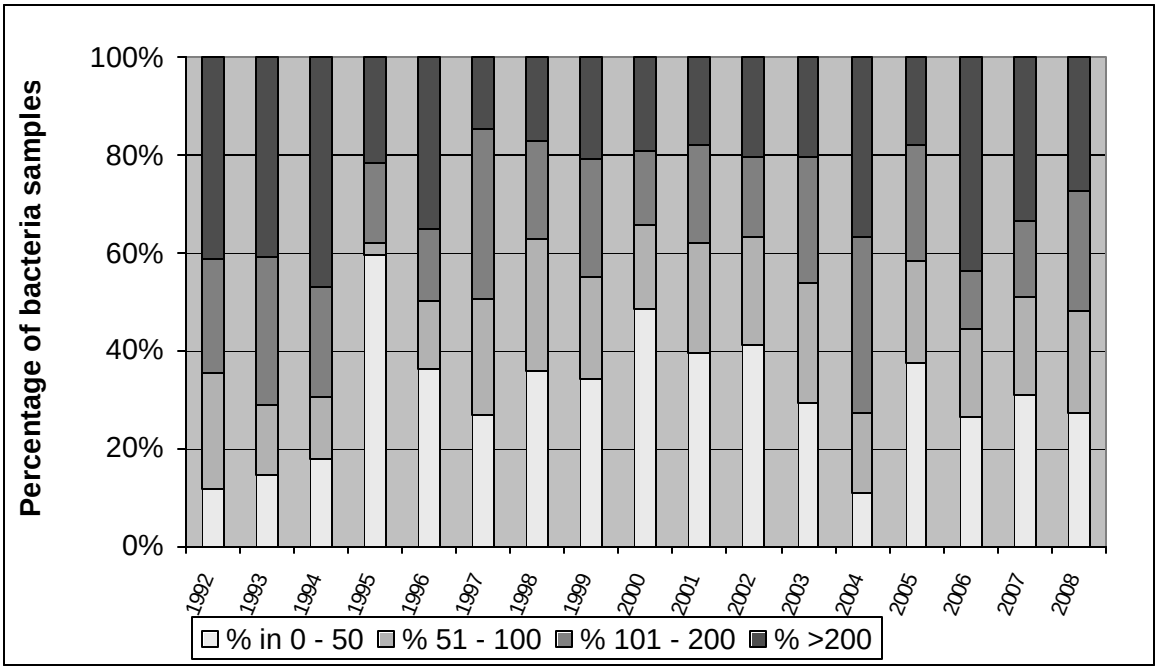

Figure 4. The percentages of fecal bacteria samples that fall in each water quality category by year.

Table 10. The number of *E. coli* or fecal coliform samples taken each year.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Sample Count	17	83	89	37	88	109	75	96	99	116	122	113	100	118	117	120	106

It is important to note that in 1992 and 1995, a relatively small number of samples were collected, meaning results for these years may not be as representative as for other years. 1992 showed an extreme low for sample proportion falling into the 0 – 50 cfu/100mL range, while 1995 showed an extreme high. However, due to the fact that there were so few samples taken in those years, the results may not reflect actual water quality for those years.

Figure 5 presents data for 2008 with the percentage of samples in each of the water quality guideline categories.

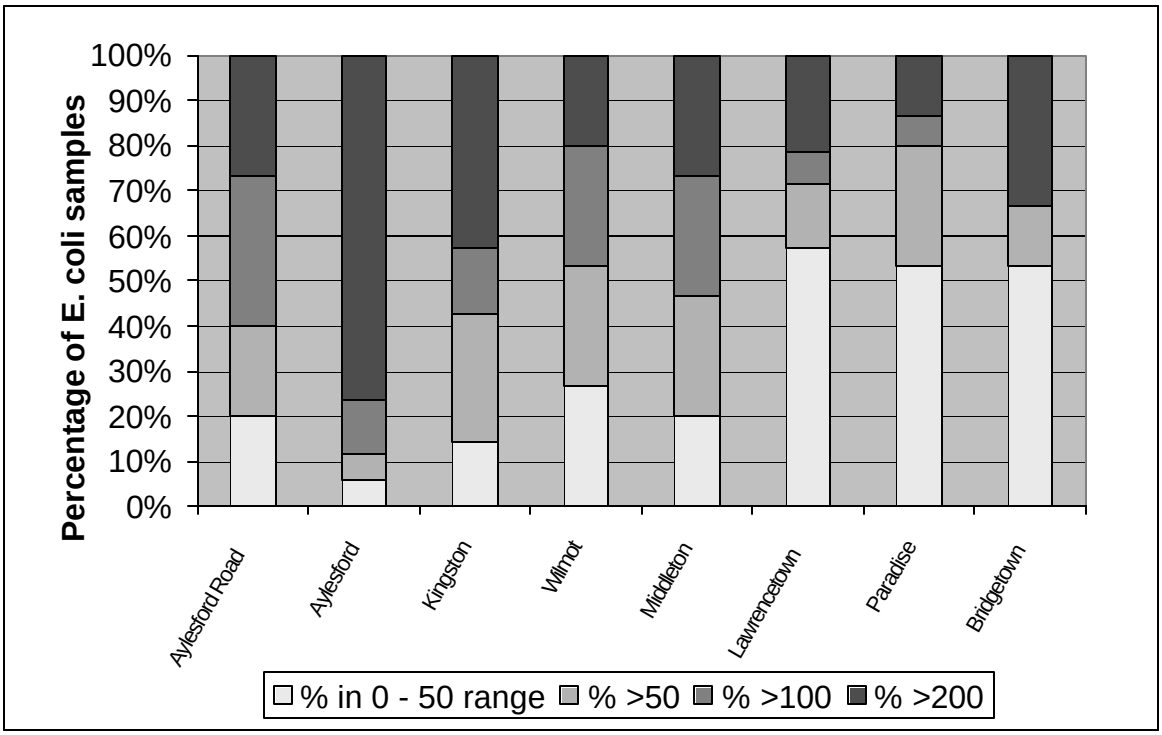

Figure 5. The percentages of 2008 samples falling into the different cfu/100mL ranges, organized by location.

As in 2007, the highest bacteria counts occurred in Aylesford on Victoria road, while the lowest occurred at the Bridgetown, Paradise and Lawrencetown locations. There seems to be a source of contamination between the Aylesford Road and Aylesford sites, which may be coming in from one of several tributaries that join the main river between these two sites.

Recommendations

- Continue regular River Guardian *E. coli* monitoring at the eight main river sample locations.
- Conduct simultaneous monitoring at Sites 00 and AY40, together with intervening tributary streams.
- Conduct a foot survey of the Annapolis River between these two sites and the intervening tributary streams to identify possible contamination sources.
- Review current and historic air photos of this area to identify land use changes and possible sources of contamination.

Dissolved Oxygen

Introduction

Dissolved oxygen (DO) is a widely used and important general indicator of the health of a river system (Addy *et al* 1997). Aquatic organisms require oxygen in solution for internal respiration. Oxygen in the atmosphere, which is readily available to terrestrial organisms, must be dissolved into the water and is present at much lower concentrations. Wind, wave action, rainfall, and photosynthesis help aerate waterways and increase dissolved oxygen levels. Sewage, lower rates of photosynthesis, eutrophication and limited diffusion from the atmosphere due to ice cover can all lead to decreased oxygen levels.

As the temperature of water decreases, a greater concentration of oxygen is able to dissolve in the water. DO levels are also dependent to a lesser degree on atmospheric pressure and water salinity. The amount of oxygen in water can be reported in two ways, either as a concentration measurement (mg/L) or as percent saturation. Water reaches its saturation point when it can no longer dissolve any additional oxygen for a given temperature. High levels of photosynthesis or turbulent conditions can "supersaturate" the water, resulting in saturation levels greater than 100%. Dissolved oxygen levels below 60% saturation are known to cause stress to aquatic life, particularly cold-water fish species (Mackie 2004).

Monitoring Results

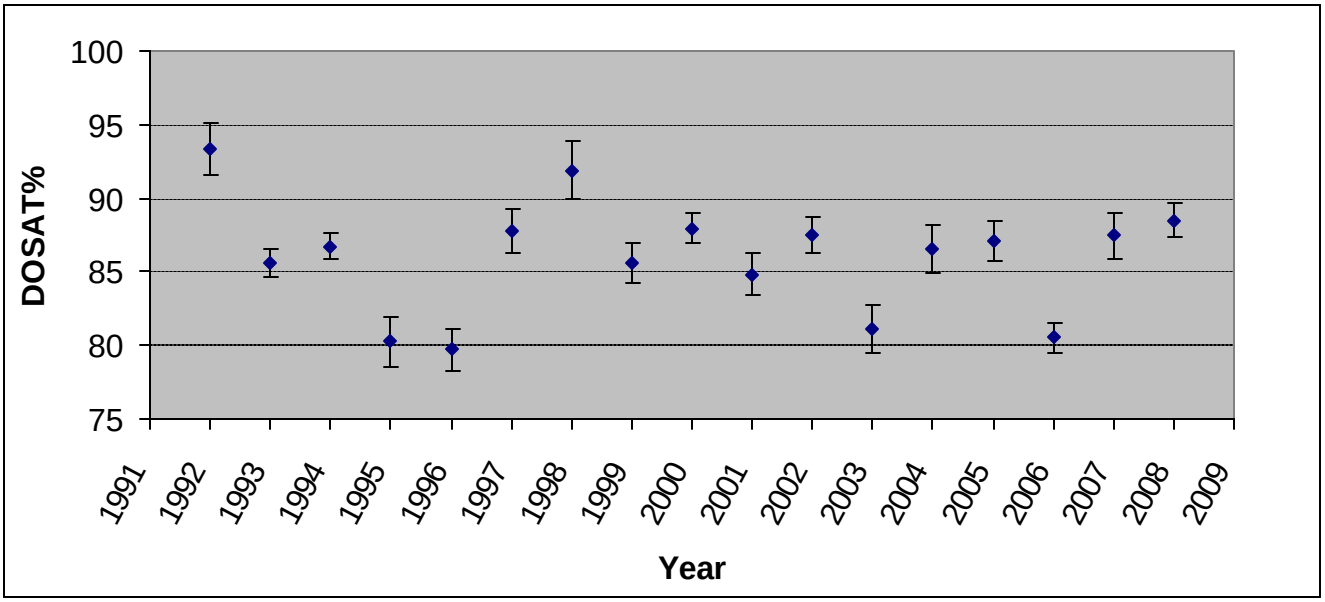

Figure 8. Mean dissolved oxygen saturation (DO SAT) by year, 1992 to 2008 (showing standard error of the mean).

Figure 8 shows that during the period of 1992 to 2008, annual mean dissolved oxygen (percent saturation) levels have varied from a high of 94% in 1992, to a low of 80% in 1996. For the values recorded during 2008, the mean dissolved oxygen saturation was 89%, compared with 87% in

2007. This value is within the normal range of variability observed for the Annapolis River. The standard error of the mean is shown with error bars.

Figure 9 presents the 15-year mean dissolved oxygen (percent saturation) values for each of the main river monitoring sites. The standard error of this mean is shown with error bars. This is overlaid with the mean values for the 2008 monitoring season. Except for Aylesford Road and Lawrencetown, each the DO readings for 2008 were higher than the 15-year average. Note that the average for Aylesford Road is only for 5 years, and that the Middleton and Wilmot averages are missing some data from1995 and 1996.

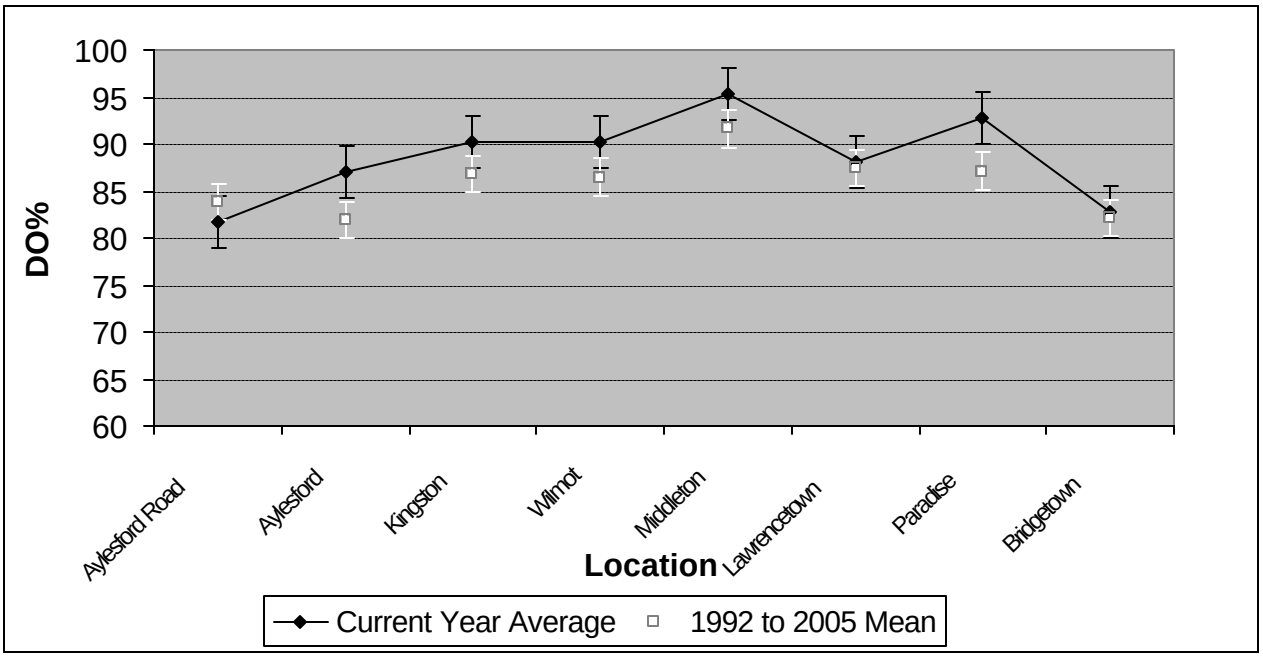

Figure 9. Mean dissolved oxygen saturation (DO SAT) by sampling site, 1992 to 2005, with means showing standard error of the mean.

The Canadian dissolved oxygen water quality guideline for the protection of freshwater aquatic life is 5.5 mg/L (CCME 2002). Only one of the 110 water samples analyzed by the Annapolis River Guardians in 2008 had a dissolved oxygen level below this guideline level (Aylesford Road, September 8th, 5.08 mg/L) (Table 8). The cause of the depressed oxygen at Aylesford is not known. The low dissolved oxygen observed at Bridgetown is believed to be associated with a wider pattern of depressed DO levels in the tidal section of the Annapolis River.

Table 8. Dissolved oxygen percent saturation (DOSAT) thresholds for Annapolis River.

Site	Samples less than 60%	Samples within 60-75%	Samples greater than 75%	Total 2008 Samples
Aylesford Road	1	2	11	14
Aylesford	0	1	12	13
Kingston	0	2	11	13
Wilmot	0	1	13	14
Middleton	0	1	13	14
Lawrencetown	0	1	13	14
Paradise	0	0	14	14
Bridgetown	0	2	12	14
Totals	1	10	99	110

Dissolved Oxygen Monitoring in the Estuary

From 2004 to 2005, low oxygen levels were observed in the Annapolis River estuary, from Bridgetown to Annapolis Royal. This prompted a further investigation in 2007, the details of which were reported by Sharpe and Sullivan (2007). This monitoring was continued in 2008. DO readings were collected at two different depths from the lower river on three separate occasions. The information gathered in 2008 is presented below, in Figure 10.

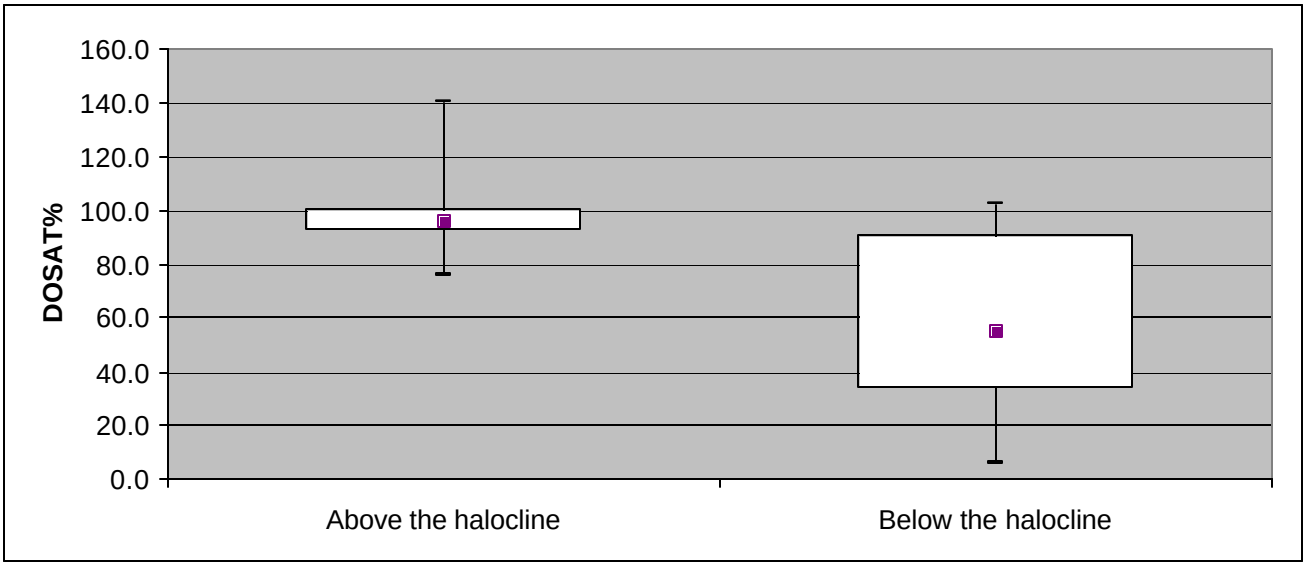

Figure 10. DO levels in the Annapolis River estuary, grouped by depth.

Samples were collected at 8 different locations on August 18th, August 27th, and October 15th, 2008. The lowest DO level observed was 0.50 mg/L, or 6.1%. This value was recorded on August 27th, 2008 at Bridgetown. It occurred at a depth of 3.5 m, below the halocline[1].

[1]Halocline – the layer of water within a river where an abrupt change in salinity occurs.

The results are similar to those obtained in 2007. DO levels above the halocline are acceptable for supporting aquatic life, while the DO levels below the halocline at times fall to levels that are stressful for aquatic life, and possibly lethal.

Recommendations

- Continue regular River Guardian DO monitoring program at eight main river sample locations.
- Undertake periodic DO monitoring of the Annapolis River estuary in the late summer and early autumn. These times are most likely to display depressed levels of DO.

Temperature

Introduction

Water temperature, like dissolved oxygen, serves as a broad indicator of water quality. The temperature of water has a direct bearing on the aquatic species present and their abundance. For example, trout and salmon species experience stress at water temperatures in excess of 20ºC, with lethality occurring after prolonged exposures to temperatures over 24ºC (MacMillan *et al* 2005).

Monitoring Results

The mean summer water temperature for the Annapolis River in 2008 was an all-time high of 20.0ºC, a full 1.5ºC warmer than for the same period in 2007. As in previous years, water temperatures during 2008 continued to reach levels stressful to aquatic life regularly during the summer months. Figure 11 presents the mean summer water temperature (July, August, September) by year for the main eight River Guardian monitoring sites. Figure 11 also includes the 1992 to 2007 mean summer water temperature (18.5 ºC).

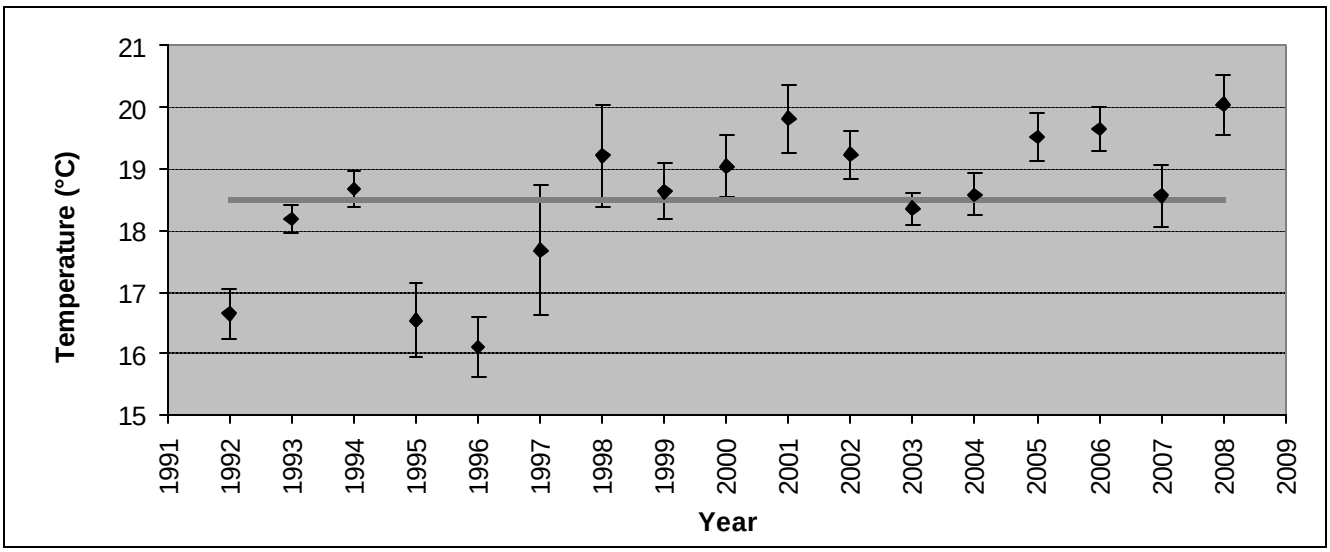

Figure 11. Mean summer water temperature by year (showing standard error of the mean) with 1992-2007 mean shown as a thick line.

The data from previous River Guardians annual reports suggested a gradual increase in temperature in the lower river sites, particularly in the summer data. Figure 12 presents the mean summer water temperature along the main Annapolis River in 2008, indicating that while the river progressively warmed from Aylesford to Lawrencetown, there was some cooling at Paradise and Bridgetown. It is unclear if the increase in temperature of water in the Annapolis River between Aylesford and Lawrencetown is due to direct warming of water within the main stem due to solar radiation, or inputs of warmer water from tributaries. Between Aylesford and Lawrencetown, a number of major tributaries (South Annapolis, Fales and Nictaux) join the Annapolis River, along with many small tributaries. Limited temperature data exists for these tributaries.

Of the 48 temperature measurements recorded during the months of July, August and September in 2008, 54% exceeded 20ºC. The maximum temperature observed was 25.9ºC, recorded at Lawrencetown on July 27th, 2008.

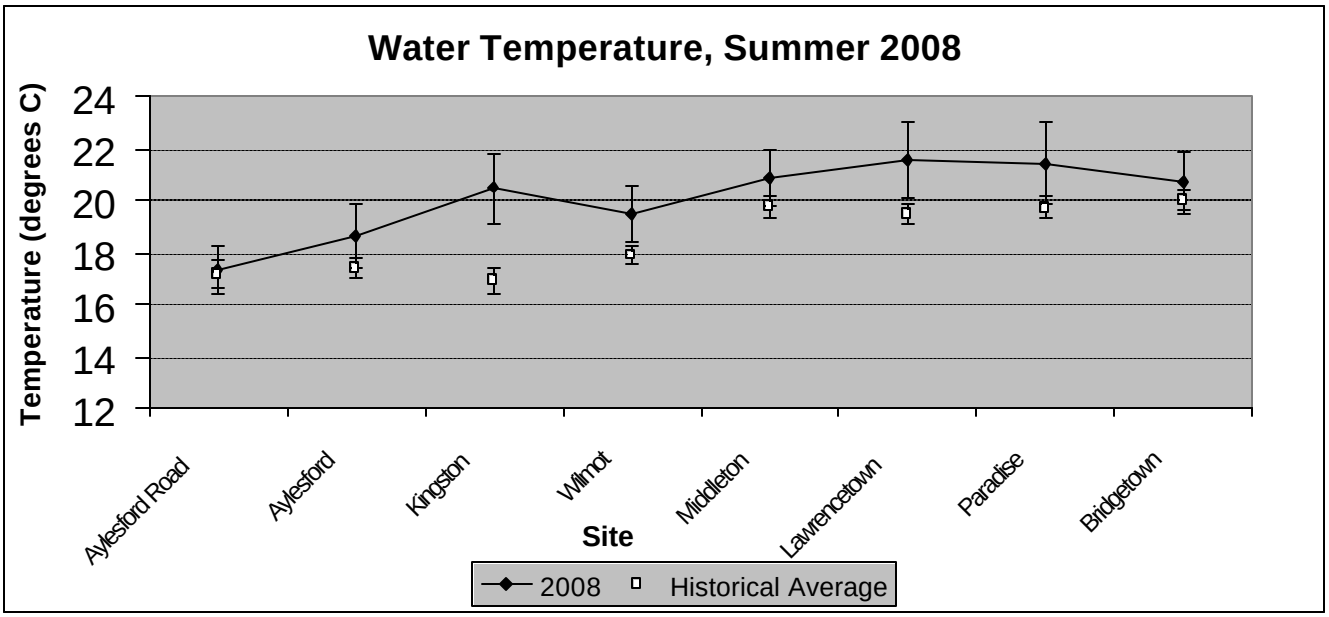

Figure 12. Mean 2008 summer water temperature and historical average temperature by site, with standard error of the mean.

Recommendations

- Continue regular River Guardian temperature monitoring program at eight main river locations.
- Install temperature loggers in candidate streams to assess for fish habitat improvements.
- Temperature data loggers should be calibrated immediately prior to deployment and at least once *in situ*. These procedures should be added to the QA/QC Project Plan.

pH

Introduction

pH is a measure of the acidic/basic nature of water and is determined by measuring the concentration of the hydrogen ion (H^+). It is expressed on a logarithmic scale from 0 to 14, with zero being the most acidic. As pH is an inverse logarithmic scale, every unit decrease in the pH scale represents a tenfold increase in acidity. To ensure the health of freshwater aquatic life, pH levels should not vary beyond the range of 6.5-9.0 (CCME, 2002). Levels below 5.0 are known to adversely affect many species of fish, including salmon and trout. pH varies naturally depending on the underlying soil type and its buffering capacity; however it can also be influenced by anthropogenic means, such as acid precipitation.

pH values are typically measured on the day following River Guardian collection by CARP staff using the portable HydroLab Quanta water meter (see Appendix A for more details on sampling procedure and meter calibration).

Monitoring Results

Figure 13 shows that pH values all along the Annapolis River are generally good, being only slightly acidic. In total, 125 individual pH measurements were made during 2007. The pH values are consistently well within the range recommended by the CCME for the protection of freshwater aquatic life. A number of the principal tributaries of the Annapolis River pass through the Torbrook geologic formation, which contains limestone that helps buffer rivers and streams in the watershed from acidification. The pH levels seem to be fairly consistent across all the locations on the main stem of the River, with a slightly elevated level at the Paradise location, although it has a large standard error range that encompasses most of the other locations' values.

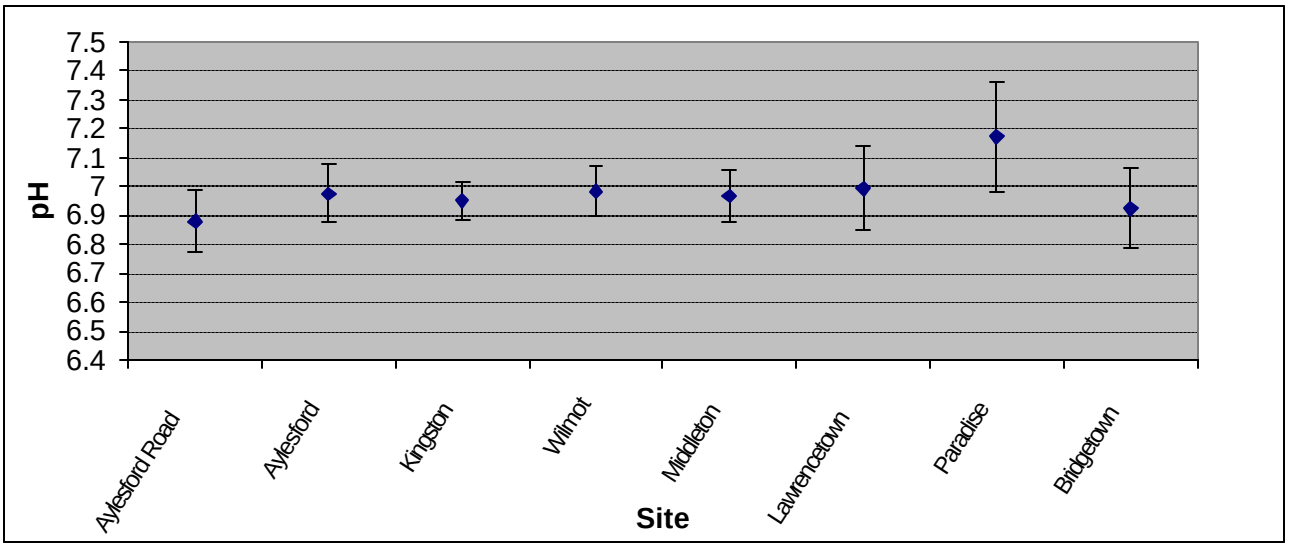

Figure 14. pH 2008 averages for the sampling locations along the Annapolis River, with standard error of the mean.

pH data collected from eight main river sites for 2003 to 2008, using the Quanta Hydrolab meter, are presented below (Figure 14). There do not appear to be any statistically significant trends in pH values in the Annapolis River between 2003 and 2008. During the early years of the Annapolis River Guardians program, pH was regularly measured at many of the main river sample locations. During this period, the mean pH was 6.9, based on 634 individual measurements. This historic pH is similar to that observed during the 2003 to 2008 period.

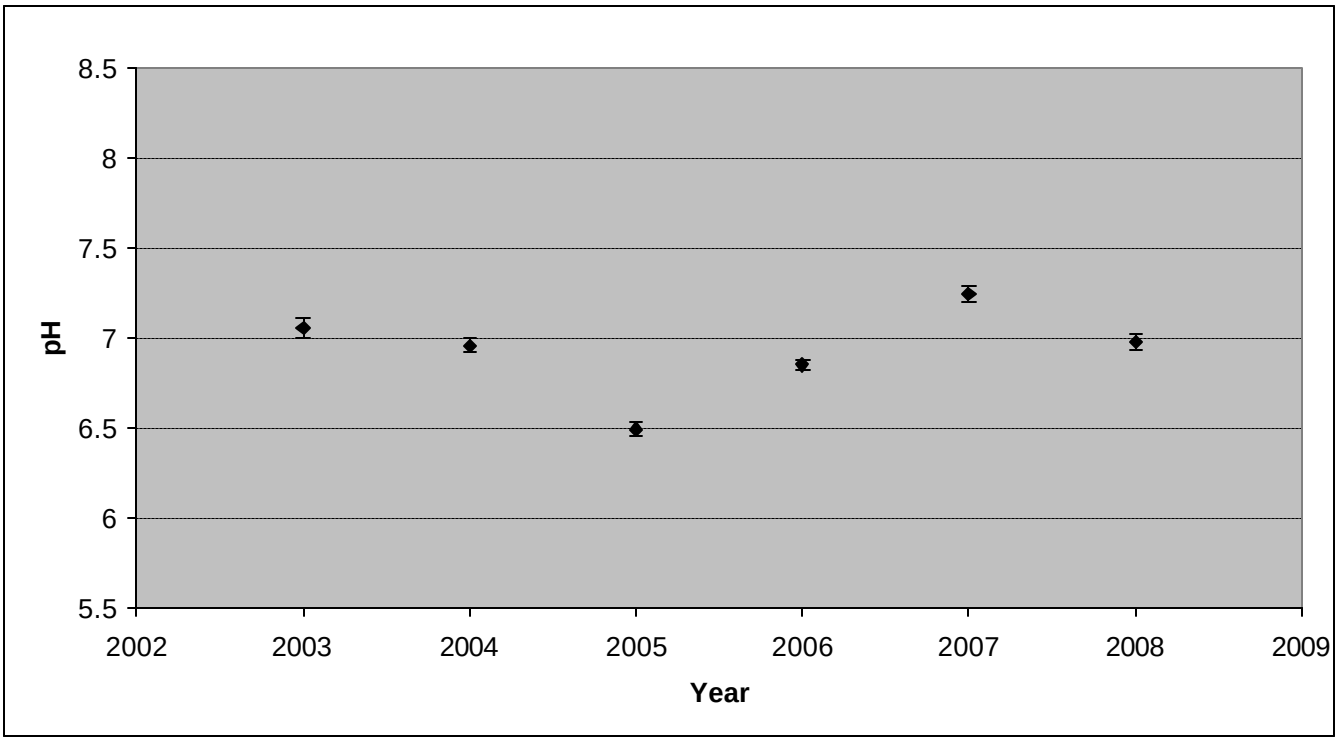

Figure 14. Average pH measurements along the Annapolis River, 2003 to 2008, with standard error of mean.

Although pH remained within the range of 6.5 to 9 for most of the sampling season, an abrupt drop in the values occurred immediately after hurricane Hanna struck the Annapolis Valley, depositing approximately 80 mm of rain. The values at each location fell below the 6.5 guideline when measured on September 8th, the day after the storm. These values are shown below, in Figure 15.

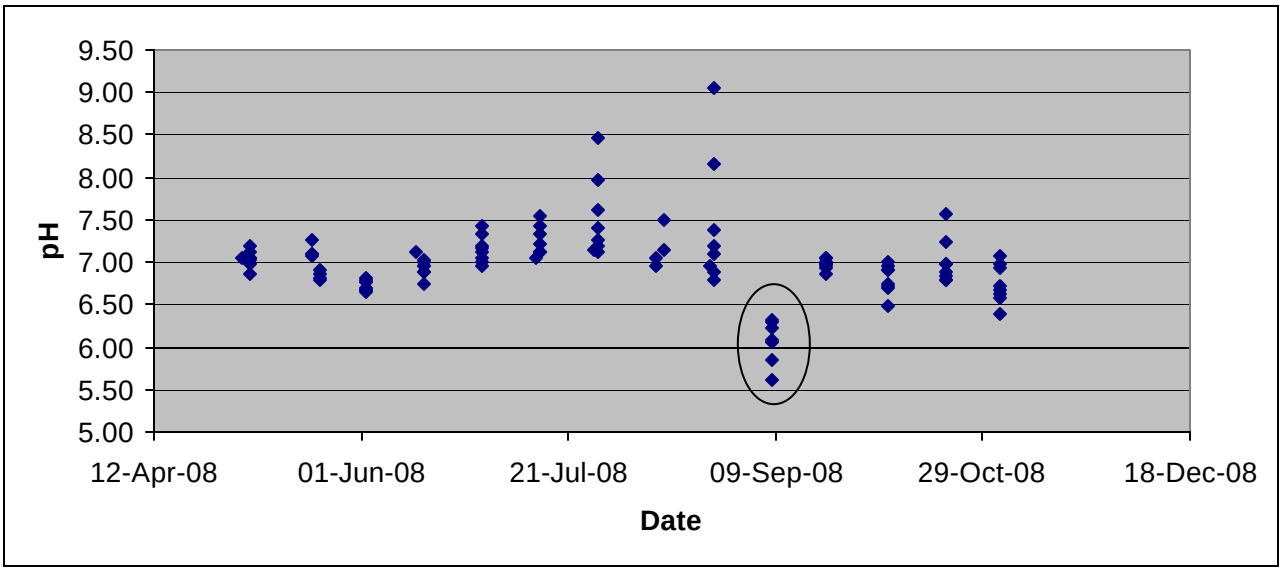

Figure 15. pH values recorded during the 2008 season. The low pH values recorded after hurricane Hanna are indicated with a circle.

Recommendations

- Regular pH monitoring should be continued at the eight Annapolis River Guardian monitoring locations.

Nutrients: Nitrogen and Phosphorus

Introduction

Nutrients are naturally occurring substances that are essential for the growth of both plant and animal life. Since 2006, Environment Canada has been monitoring two locations along the Annapolis River for a large range of water quality parameters, including nitrogen and phosphorus. Although these two elements are naturally occurring, there are many anthropogenic sources. Any kind of wastewater discharges (domestic, municipal, industrial), agricultural chemicals such as fertilizers and atmospheric deposition can all contribute to elevated nutrient levels in a river system.

Nitrogen and phosphorus occur naturally in very small amounts and thus are often the limiting factor for plant growth. When nitrogen levels rise, they can cause excessive periphyton and macrophyton growth in freshwater systems. Excess phosphorus levels can lead to large algal blooms that, upon dying and decomposing, deplete oxygen to levels that can threaten aquatic life.

There is much disparity between literature sources identifying unacceptable levels of these two nutrients. Dodds and Welch (2000) compiled many different criteria from literature sources for unacceptable levels of both nitrogen and phosphorus. For total nitrogen, depending on the water quality target, the upper limit ranged from 0.25 mg/L to 3.0 mg/L. For dissolved nitrate, the limits are defined to be anywhere from 0.02 mg/L to 1.0 mg/L. The CCME has established a guideline for dissolved nitrates at 2.9 mg/L NO_3 as N for the protection of aquatic life.

There appears to be greater consensus for guidelines for phosphorus. The Ontario Ministry of Environment and Energy (OMEE) set a guideline of 0.030 mg/L total P, above which excessive plant growth occurs. Mackie (2004) suggested that total phosphorus levels in excess of 0.030 mg/L indicate that the surface waters are eutrophic. Dodds and Welch (2000) list upper limits ranging from 0.02 mg/L to 0.07 mg/L.

Monitoring results

The nutrient results shown in this section were collected and analyzed by Environment Canada. Environment Canada collects regular water quality samples at two locations on the Annapolis River. Grab sampling is performed in Wilmot, near the bridge and gauging station on Bayard Road and in Lawrencetown, near the bridge and gauging station on Lawrencetown Lane.

The following graph, figure 16, displays the total nitrogen results for the Wilmot and Lawrencetown sites since 2006. The graphs for the two locations are very similar and display the same spikes, although the Wilmot reading is almost always higher than the Lawrencetown reading. The lowest result was 0.2 mg/L and occurred at Lawrencetown on May 21st, 2008 and the highest was 1.18 mg/L, occurring at Wilmot on August 21st, 2007. All of the results fall into a range described by Dodds and Welch (2000) that potentially causes adverse ecological effects.

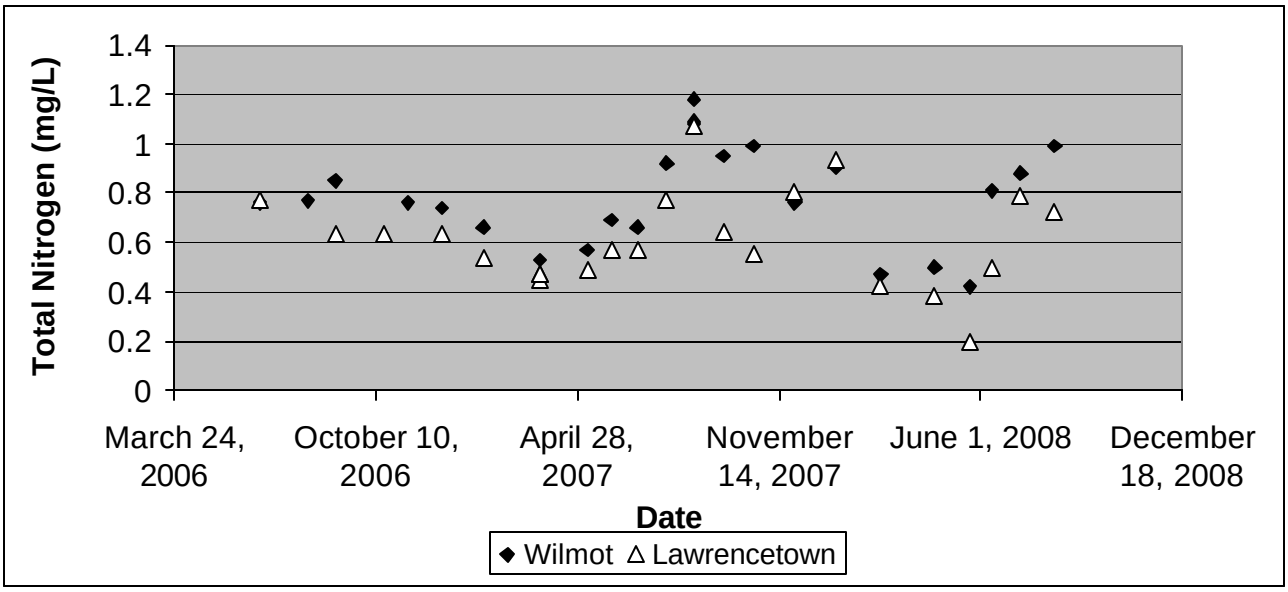

Figure 16. Total nitrogen results from 2006 to 2008 for Wilmot and Lawrencetown.

Figure 17 presents the results for dissolved nitrates at these two locations. It displays most of the same spikes as the total nitrogen graph to different magnitudes. The lowest result was 0.07 mg/L NO_3 as N and occurred at Lawrencetown on June 16th, 2006 and the highest was 0.74 mg/L NO_3 as N, occurring at Wilmot on August 21st, 2007. These levels are far below the CCME guideline of 2.9 mg/L NO_3 as N.

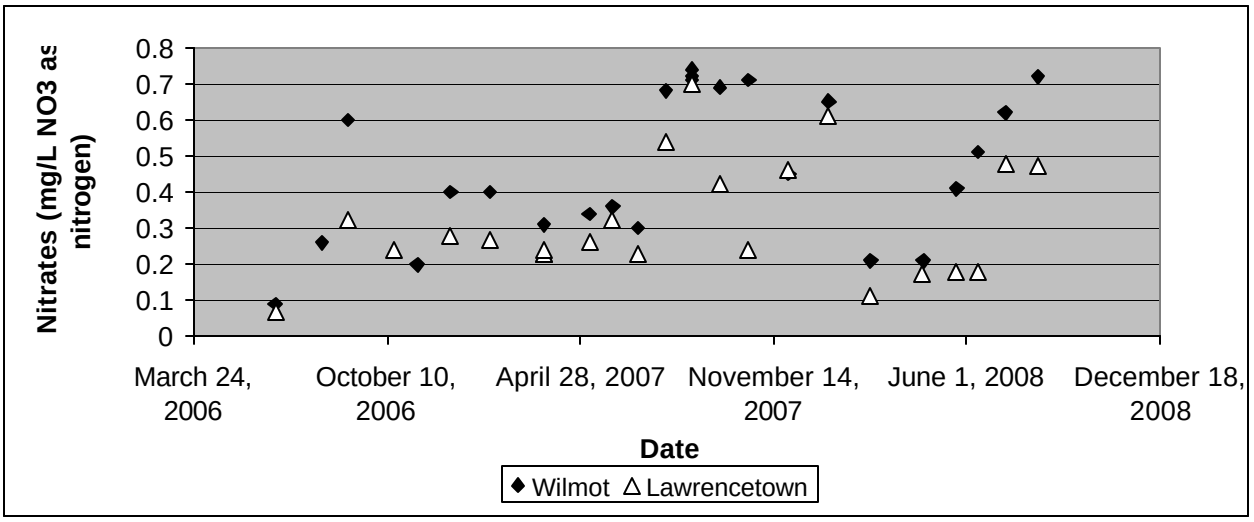

Figure 17. Dissolved nitrogen results from 2006 to 2008 for Wilmot and Lawrencetown.

The total phosphorus results for Wilmot and Lawrencetown are shown below, in Figure 18. The lowest result was 0.018 mg/L and occurred at Lawrencetown on January 24th, 2007 and the highest was 0.087 mg/L, occurring at Wilmot on July 10th, 2008. Unlike nitrogen, phosphorus has a better-defined upper limit of 0.030 mg/L. Twenty-nine out of forty-seven samples (61%) were above this limit.

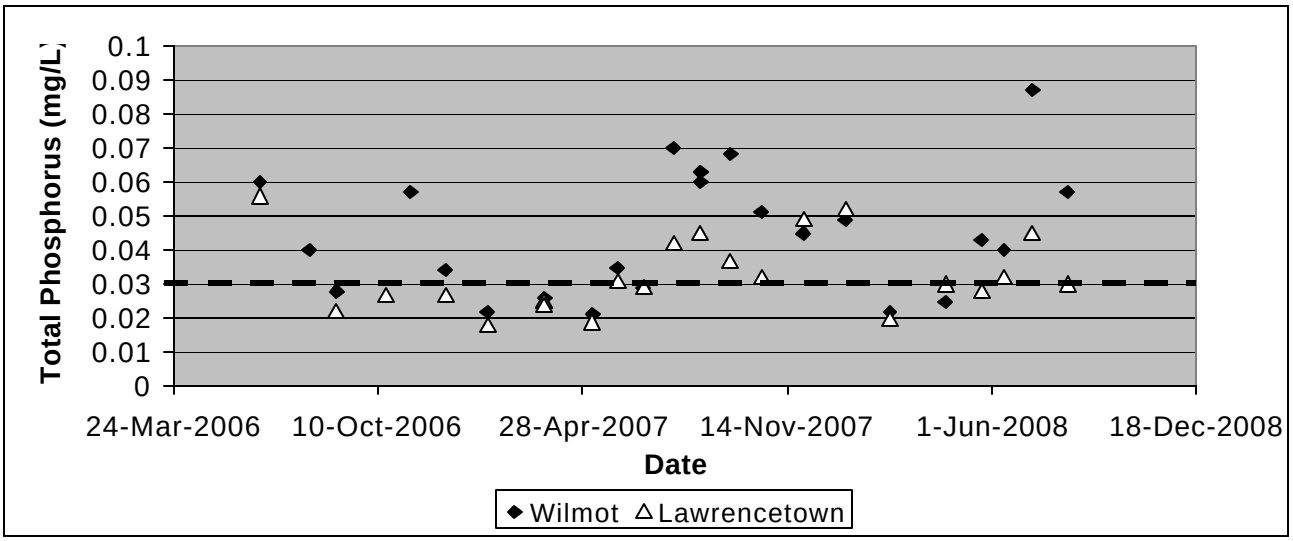

Figure 18. Total phosphorus results from 2006 to 2008 for Wilmot and Lawrencetown. The dashed line represents the phosphorus guideline of 0.030 mg/L.

On July 27th, 2008, the River Guardian volunteer for Bridgetown noted a green colour to the water. CARP staff collected a water sample on August 1st, 2008 and also observed a dark green colour to the water at this location only. This colour seems to be indicative of an algal bloom and may have been a result of excess levels of nitrogen and/or phosphorus. On the next collection day, August 10th, the green colour was no longer observable.

Beginning in May 2008, the South Annapolis River was monitored for nutrients as well. The site was at Millville, near the bridge on Victoria Road, and was chosen as a baseline, relatively unimpacted site. As a result, most of the results for nutrients were lower than the results for either Lawrencetown or Wilmot. Figure 19 shows the total phosphorus results for all three locations in 2008.

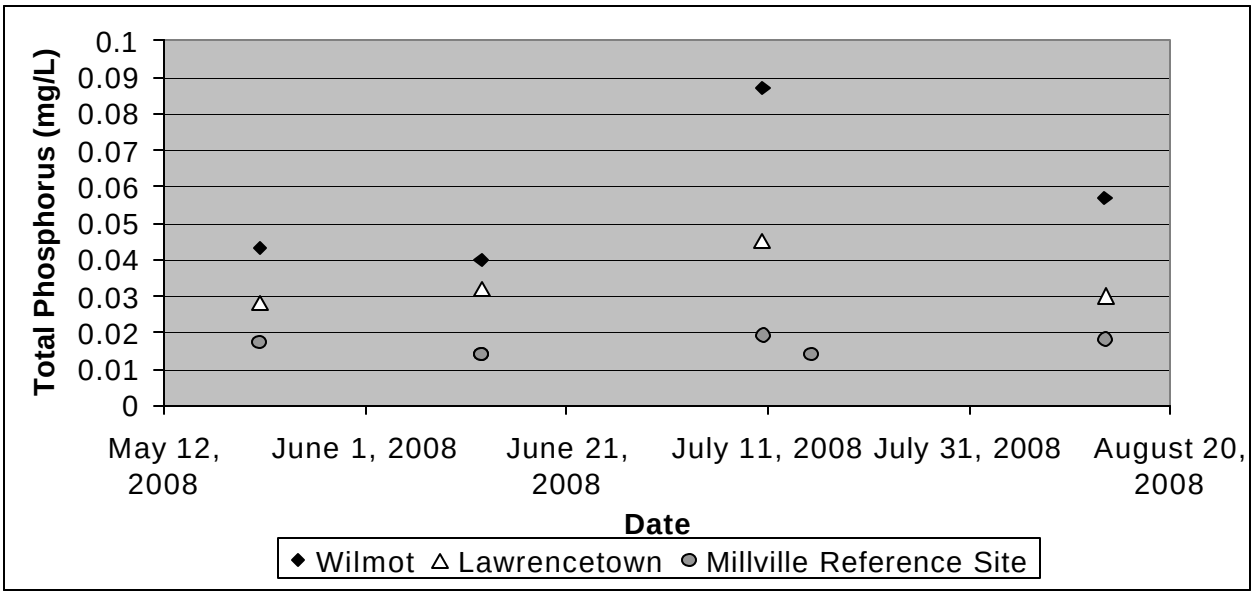

Figure 19. Total phosphorus levels for all three sampling locations in 2008.

Samples collected from Millville did not exhibit as much variability as the two sampling stations on the main Annapolis River. The average results for each parameter at each location are presented below, in Table 9.

Table 9. Average results for each location and nutrient. Lawrencetown and Wilmot data are from 2006 to 2008, Millville data are from 2008 only.

Location	Total N (mg/L)	Nitrates (mg/L NO_3 as nitrogen)	Total P (mg/L)
Wilmot	0.78	0.45	0.045
Lawrencetown	0.61	0.32	0.032
Millville	0.31	0.06	0.016

For each nutrient, the average is highest at Wilmot and lowest at Millville. The Millville site on the South Annapolis River tributary was chosen as a relatively unimpacted site for reference, and to possibly establish baseline nutrient levels, therefore the low averages are expected. The Wilmot site is downstream of the Kingston and Aylesford sites, which have recently displayed elevated *E. coli* levels. The Lawrencetown site is downstream of the Wilmot site, but its nutrient averages are less than those of the Wilmot sites. This is possibly due to dilution of the nutrients between the two sites; there are several large tributaries between the Wilmot and Lawrencetown sites, including the Nictaux River and the Black River.

Recommendations

- Work in collaboration with Environment Canada to ensure the continued collection of nitrogen and phosphorus samples at Millville, Wilmot and Lawrencetown.
- Examine flow rates in the Annapolis River near the nutrient sample collection points, as flow has a great influence on nutrient concentrations.

Benthic Invertebrates

Introduction

River systems are host to many different forms of life, and many of them can help indicate the river's water quality. Of particular interest are the benthic invertebrates that live on the streambed. These include insects (e.g. mayflies), molluscs (e.g. clams) and other organisms that spend part or all of their life cycle on the bottom of watercourses. Some invertebrates are very sensitive to pollution, while others are pollution tolerant and can thrive in a contaminated environment. The relative abundance and diversity of benthic invertebrates present at a site can provide information on the water quality.

Benthic invertebrate sampling provides a slightly different approach to ecological monitoring. While the measurement of physical and chemical parameters provides a picture of the river's health at a given time, the type of organisms existing in the system can provide a longer-term indication of its health. For example, a rainfall event can cause a river's total suspended solid count to spike for a short period and then quickly return to normal, whereas benthic life will show a greater sensitivity to long-term effects.

The sampling is ideally performed in the latter portion of the summer, late August to mid-September, during relatively low water levels. CARP makes use of the sampling and analysis procedure developed through the Canadian Biomonitoring Network (CABIN).

Benthic Invertebrate Monitoring in the Annapolis Watershed

The CABIN sampling program undertaken by CARP has pursued three objectives:

- To collect a sufficient number of samples from reference, or pristine, sites in order to allow the development of a reference condition approach model (RCA) for Nova Scotia or Atlantic Canada. The development of a RCA model is a long-term objective, requiring contributions from many partners and the collection of samples from across the region.
- To annually collect benthic invertebrate samples from water quality monitoring sites along the main Annapolis River in order to allow a time series analysis to be performed, highlighting temporal changes. This objective has been undertaken with the view that the CABIN analysis will compliment CARP's traditional chemical and physical water quality monitoring activities.
- To utilize benthic invertebrates as a tool to assess before and after changes in aquatic quality at sites undergoing habitat restoration activities.

CARP has worked with Environment Canada since 2002 to build a network of benthic invertebrate sample stations in the Annapolis watershed. Table 10 describes the location and status of CABIN samples collected in the Annapolis watershed by CARP, with CABIN samples collected by Environment Canada staff shown in Table 11. The locations of these samples are shown in Figure 20.

Table 10. CABIN samples collected by CARP

Site Code	Date Sampled	River	Number of	Reference	Comments
	dd/mm/year		Samples	or Test	
ANN0102	9/5/2002	Fales River	1	Reference	
ANN0202	9/24/2002	East Round Hill River	1	Reference	
ANN0302	9/24/2002	West Round Hill River	1	Reference	
ANN0402	9/25/2002	Black River	1	Reference	
ANN0502	10/11/2002	South Annapolis River	1	Reference	
ANN0703	10/8/2003	Skinner Brook	1	Test	
ANN0803	10/8/2003	Leonard Brook	1	Test	
ANN0903	10/8/2003	Leonard Brook	1	Test	
ANN1003	10/9/2003	Slokum Brook	1	Reference	
ANN0103	10/9/2003	Fales River	1 + 2	Reference	Repeat of 2002 Reference Site; QA/QC samples collected
ANN1104	10/18/2004	Annapolis River at Aylesford	1	Test	Long-term monitoring site
ANN1204	10/19/2004	Acacia Brook	1	Reference	
ANN1304	10/19/2004	West Branch Bear River	1	Reference	
ANN1404	10/20/2004	Annapolis River at Kingston	1	Test	Long-term monitoring site
ANN1504	10/20/2004	East Round Hill River	1	Reference	Repeat of 2002 Reference Site
ANN1604	10/21/2004	West Branch Moose River	1	Reference	
ANN1704	10/21/2004	West Branch Moose River	1	Reference	
ANN1804	10/21/2004	East Branch Moose River	1	Reference	
ANN1105	9/13/2005	Annapolis River at Aylesford	1	Test	Long-term monitoring site
ANN1405	9/13/2005	Annapolis River at Kingston	1	Test	Long-term monitoring site
ANN1905	9/13/2005	Annapolis River at Middleton	1	Test	Long-term monitoring site
ANN2005	9/14/2005	Annapolis River at Paradise	1 +2	Test	Long-term monitoring site; QA/QC samples collected
ANN2006	11/10/2006	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN2106	11/10/2006	E. Branch of S. Annapolis @ Morristown	1	Reference	
ANN2206	11/10/2006	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN2007	11/9/2007	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN2107	11/9/2007	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN2307	11/9/2007	Fash Brook	1	Test	
ANN2008	17/9/2008	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN2208	17/9/2008	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN2308	9/9/2008	S. Annapolis River at Millville	1 + 2	Reference	Co-located with EC tubidity & TSS station
ANN2408	8/9/2008	Thornes Brook at Karsdale	1	Reference	
ANN2508	8/9/2008	Fash Brook-West Branch	1	Reference	
ANN2608	9/9/2008	Shearer Brook	1	Reference	

Table 11. CABIN samples collected by Environment Canada

Site Code	Date Sampled	River	Number of	Reference
	dd/mm/year		Samples	or Test
EELBRK01	3/10/2006	Eel Weir Brook (inflows to Annapolis River near Lawrencetown)	1	Reference
ROXBRK01	3/10/2006	Roxbury Brook (inflow to Annapolis River near Paradise)	1	Reference
OAKBRK01	4/10/2006	Oakes Brook (inflow to Nictaux River near Albany	1	Reference
BLKRIV01	5/10/2006	Black River (inflow to Annapolis River)	1	Reference
SNSHBK01	6/10/2006	Snowshoe Brook south of Lawrencetown on the South Mountain	1	Reference
SANN01	7/10/2006	South Annapolis River	1	Reference

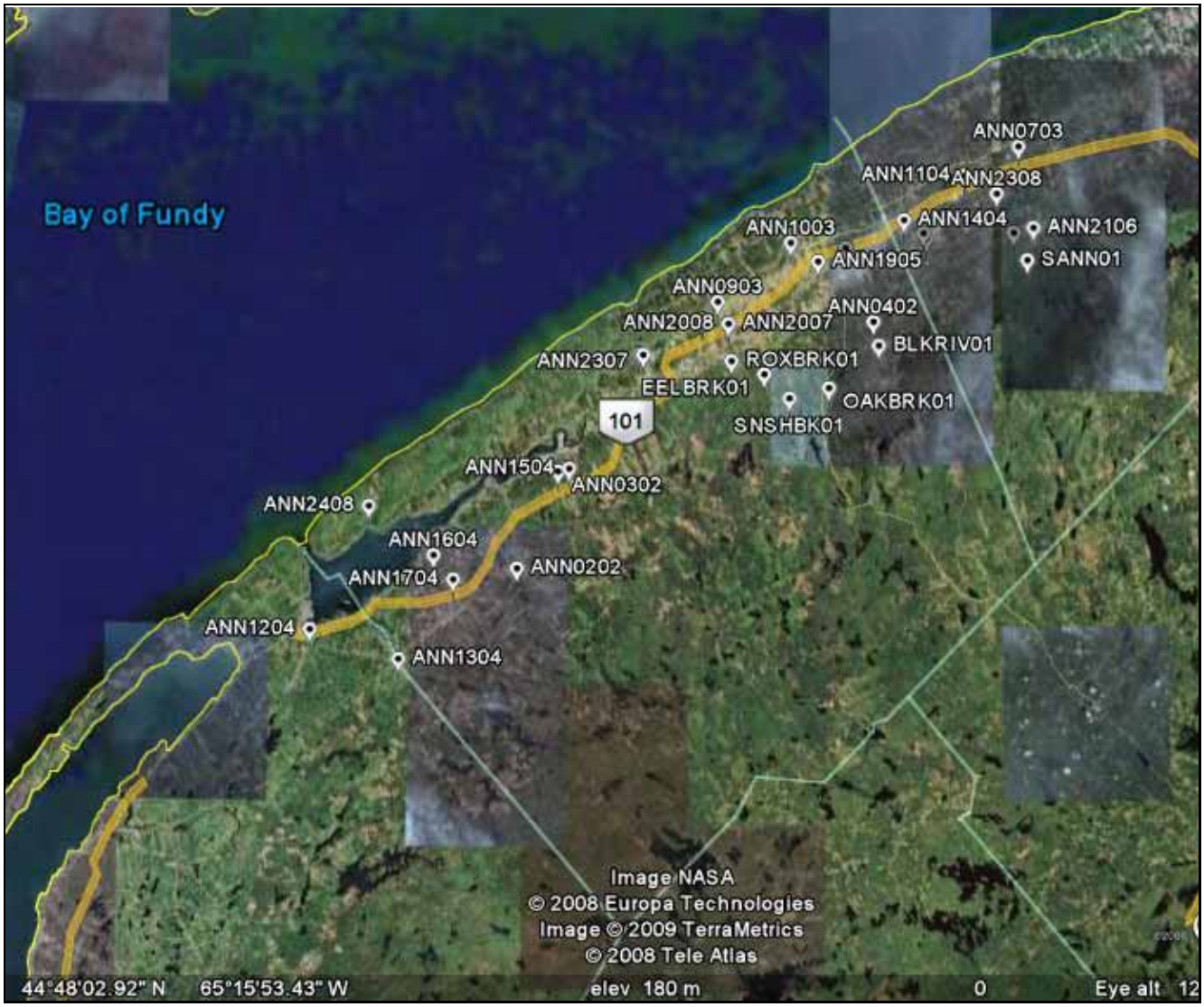

Figure 20. CABIN sample locations in the Annapolis watershed (collections by CARP and Environment Canada)

Monitoring Results

Benthic invertebrate samples have been collected from the Annapolis River at Paradise since 2005 and at Wilmot since 2006. To present these results, the Family Biotic Index has been used, as indicated by the CABIN analysis procedure. The index produces a value from 0 to 10, 0 being excellent water quality and 10 being poor water quality. The CABIN procedures outline categories for evaluation of water quality using the Family Biotic Index (Reynoldson *et al*, 2002). These categories are presented below, in Table 12.

Table 12. Evaluation of water quality using the Family Biotic Index.

Family Biotic Index Score	Stream Condition
0.00 – 3.75	Excellent
3.76 – 4.25	Very good
4.26 – 5.00	Good
5.01 – 5.75	Fair
5.76 – 6.50	Fairly poor
6.51 – 7.25	Poor
7.26 – 10.00	Very poor

The tolerance values for the Family Biotic Index calculation were taken from Applied Aquatic Ecosystem Concepts (Mackie, 2004). If they were not listed there, the values were taken from either the CABIN procedures (Reynoldson *et al*, 2004) or from the Quality Assurance Work Plan for Biological Stream Monitoring in New York State (Bode *et al*, 1991).

Figure 21 presents the results for the Family Biotic Index calculations for the Paradise site. The result for each year falls between 4.26 and 5.00, which is a 'good' score, according to the table above.

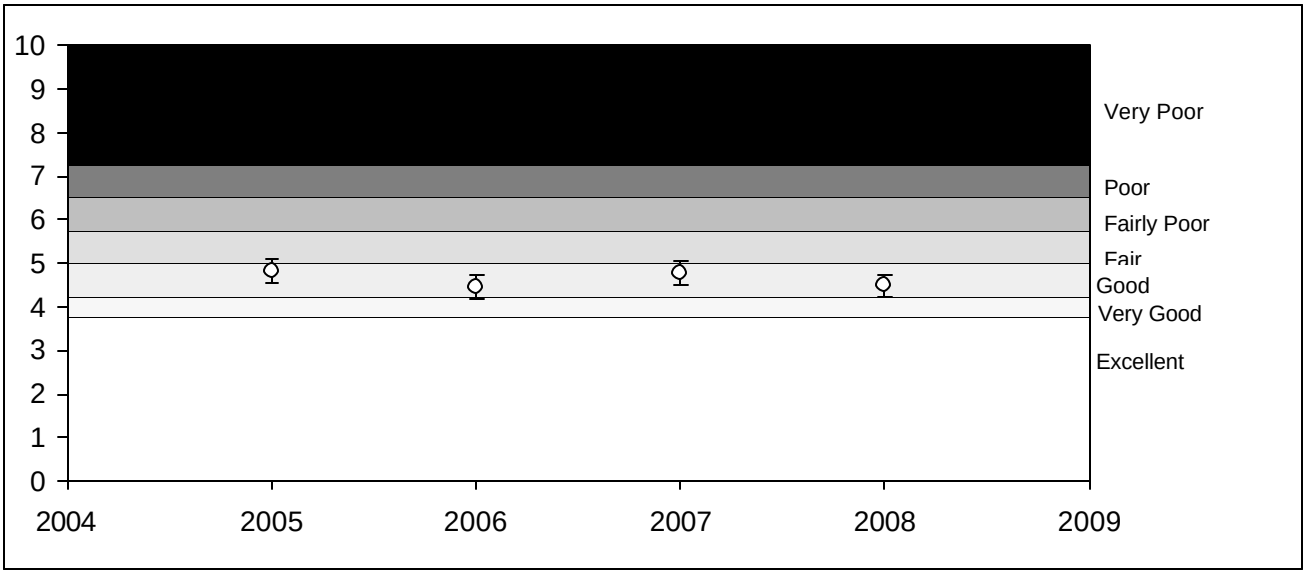

Figure 21. Family Biotic indices for 2005 – 2008 for the Paradise location. The error bars are displaying a 12% error, which was calculated using the QA/QC replicate data.

The index results for Wilmot are presented below in Figure 22. The 2006 index falls into the 'fair' category while the results for 2007 and 2008 fall into the 'good' category. There seems to be a statistically significant difference between the 2006 result and the 2007 and 2008 results.

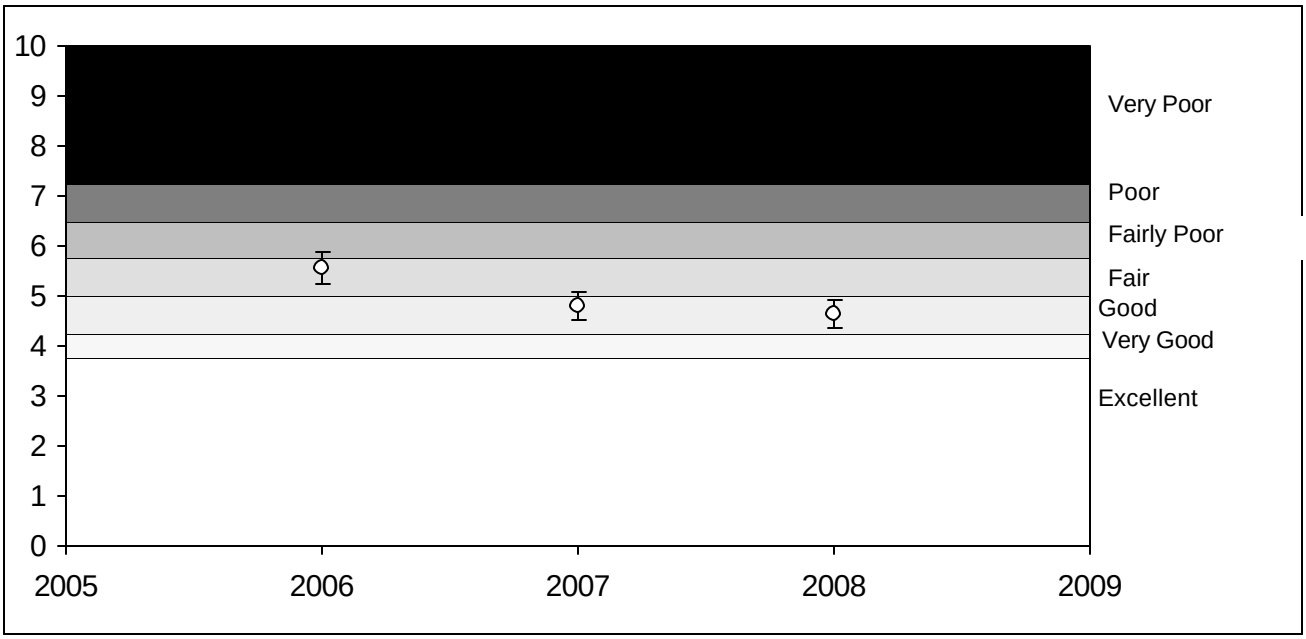

Figure 22. Family Biotic indices for 2006 – 2008 for the Wilmot location. The error bars are displaying a 12% error, which was calculated using the QA/QC replicate data.
The 2008 results for both sites were calculated using the unverified identifications performed by CARP, as the verified identifications were not yet available. The verified results were used to calculate the indices for 2005 to 2007.

In addition to the Family Biotic Index, several other measures were used to characterize the benthic invertebrate samples for Paradise and Wilmot. The tables displaying these results are below.

Table13. Benthic invertebrate results for Paradise.

Measurement Type	2005	2006	2007	2008
Family Biotic Index	4.83	4.47	4.77	4.48
Taxonomic Richness	31	23	19	33
Total EPT	293	91	211	275
Percentage EPT in sample	50.52%	31.27%	44.89%	54.13%
Diversity Index	3.21	2.99	3.11	3.31
Evenness	0.65	0.66	0.73	0.68
Intolerant Organism Count	86	58	87	68
Tolerant Organism Count	5	12	11	13
Tolerant – Intolerant Ratio	0.06	0.21	0.13	0.19

Table 14. Benthic invertebrate results for Wilmot

Measurement Type	2006	2007	2008
Family Biotic Index	5.56	4.80	4.65
Taxonomic Richness	21	21	28
Total EPT	41	61	168
Percentage EPT in sample	10.79%	21.11%	30.60%
Shannon's Diversity Index	1.65	2.51	3.24
Evenness	0.38	0.57	0.67
Intolerant Organism Count	21	51	99
Tolerant Organism Count	32	0	25
Tolerant - Intolerant Ratio	1.52	0.00	0.25

The different measurements are described below.

- Taxonomic Richness refers to the number of different types of families in the sample.
- Total EPT refers to the number of organisms in the sample that come from the orders of Ephemeroptera, Plecoptera or Trichoptera. These organisms tend to have low pollution tolerance, so larger relative numbers of them tend to indicate less contaminated waters.
- The Diversity Index measures the relative abundance of each family. Mackie (2004) describes guidelines for using the species diversity index in assessing water quality. Since the samples taken by CARP were not identified to species, the index was modified to be used at the family level. A diversity index of <1 indicates polluted water, an index result of 1-3 indicates sub-polluted water and an index of >3 indicates clean water. However, Mackie does emphasize that these results treat all organisms as identical and does not take into account the pollution sensitivity of each different taxonomic grouping. The test is also optimized for analysis at the genus level of taxonomy and loses reliability at higher levels, such as family.
- Evenness also measures how the organisms are distributed between families. The closer the sample is to an even distribution, the closer this value will be to 1. Stresses to the aquatic environment tend to cause some taxa to shrink in number or disappear while causing others to increase in population resulting in populations skewed toward a small number of taxa. Thus, evenness results close to 1 tend to indicate a relatively uncontaminated environment.
- Intolerant organism counts measure the amount of organisms that come from families with a Hilsenhoff tolerance value of 3 or less; tolerant organism counts measure the amount of organisms that come from families with a Hilsenhoff tolerance value of 7 or greater.

Recommendations

- Continue to collect annual benthic invertebrate samples from the Paradise and Wilmot locations.

Total Suspended Solids and Turbidity

Introduction

Total suspended solids (TSS) and turbidity are both terms that describe the amount of suspended particulate matter in water, although they are measured in different ways. TSS describes the physical mass of the particulate matter, while turbidity refers to the extent that light will penetrate the sample. Highly turbid waters have poor light penetration, which can hinder the growth of aquatic plants and in turn can affect the health of aquatic animals.

During 2008, CARP and Environment Canada worked together in order to establish baseline levels of TSS and turbidity for the Annapolis River, which can then be used in determining a water quality objective for these parameters. This water quality objective could then be used in the calculation of a water quality index for the Annapolis River, which would useful for annual reporting. The monitoring was also conducted to help determine the relationship between TSS and Turbidity. The two measurements are related, but this relationship is unique for every waterway and must be determined. In order to develop this relationship, for the duration of the 2008 sampling season, TSS and turbidity samples were taken simultaneously for each station along the Annapolis River.

TSS was measured by the River Guardian program from the period of 1992 to 2001. Although it was recognized that TSS was an important parameter for the Annapolis River, the variable was discontinued in early 2002 as it was felt that the biweekly River Guardian collection failed to record the inherent variability of the parameter. The revised protocol used in 2008 required biweekly sample collection. As well, samples were gathered after events of significant rainfall or snowmelt. These event readings were taken by either CARP staff or volunteers. At first, event samples were gathered after rainfall amounts of at least 5 – 10 mm, but it was found that this amount of rainfall had very little effect on the TSS and turbidity readings. The collection protocol was subsequently revised, with samples only being collected for rainfall amounts of at least 20 – 30 mm.

TSS and turbidity were both processed from the same sample. TSS was processed by taking a measured volume of sample and performing a suction filtration procedure. The mass of the leftover particles was measured and related to the volume of the sample to produce a TSS reading in mg/L. The remainder of the original sample was processed for turbidity at Acadia University. The turbidity measurement was conducted using a 2100P Hach Turbidimeter, which returned a reading in nephelometric turbidity units (NTU). These units describe the amount of light scattered by a sample compared to the amount of light shone into the sample.

Monitoring results

In addition to the regular eight sampling sites, two more sites were sampled for TSS and turbidity. The first site is on the main stem of the Annapolis River, at the bridge on Bayard Road in Wilmot. This is the site of an Environment Canada gauging station that can also measure turbidity. The other site is the baseline reference site, located in Millville on the South Annapolis River. Samples at these sites were gathered by CARP staff.

Figures 23 and 24 below display the turbidity and TSS data collected in 2008 from May through to the beginning of December for all of the sampling locations along the Annapolis River. There are several spikes in the data, most notably at the beginning of June, early September, and the end of November. Each event corresponds to high-flow events caused by very significant precipitation. At the beginning of June, there was a rain event of approximately 40 mm over a 2-day period, and on September 6th and 7th, the Annapolis River watershed was hit by the tail end of Hurricane Hanna, depositing approximately 80 mm of rain. The November and December spikes were produced by large snowfalls followed by some rainfall, melting most of the snow. For most of the summer, the turbidity and TSS levels remained around baseline, as there was there were not enough large precipitation events that would potentially have resulted in elevated levels of TSS and turbidity.

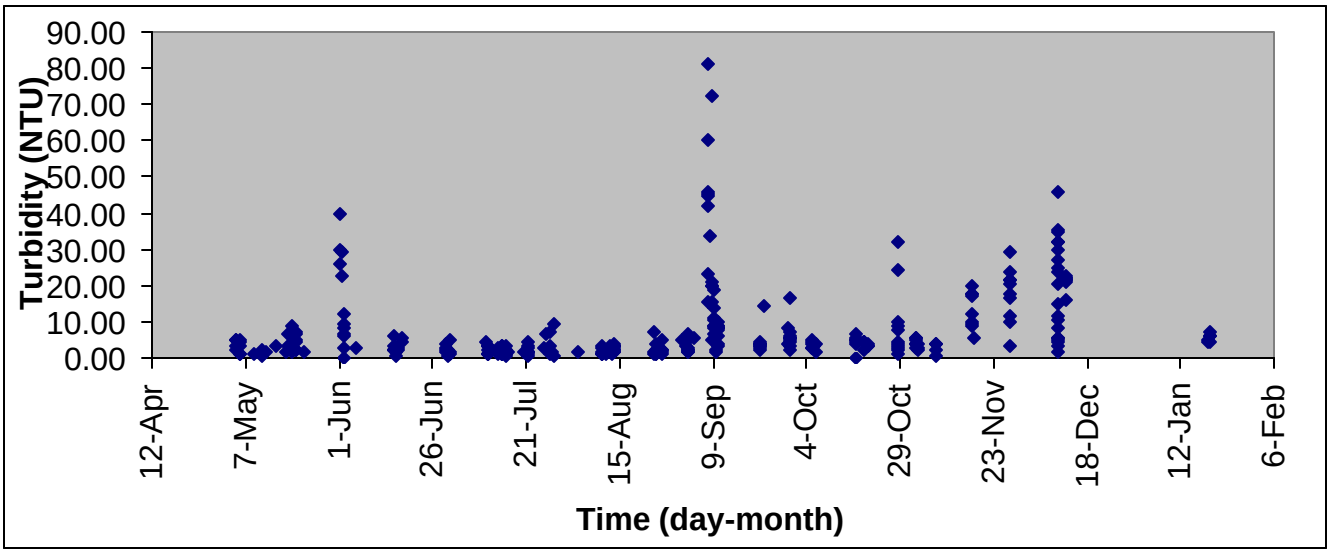

Figure 23. 2008 turbidity results in NTU by date at all sampling locations.

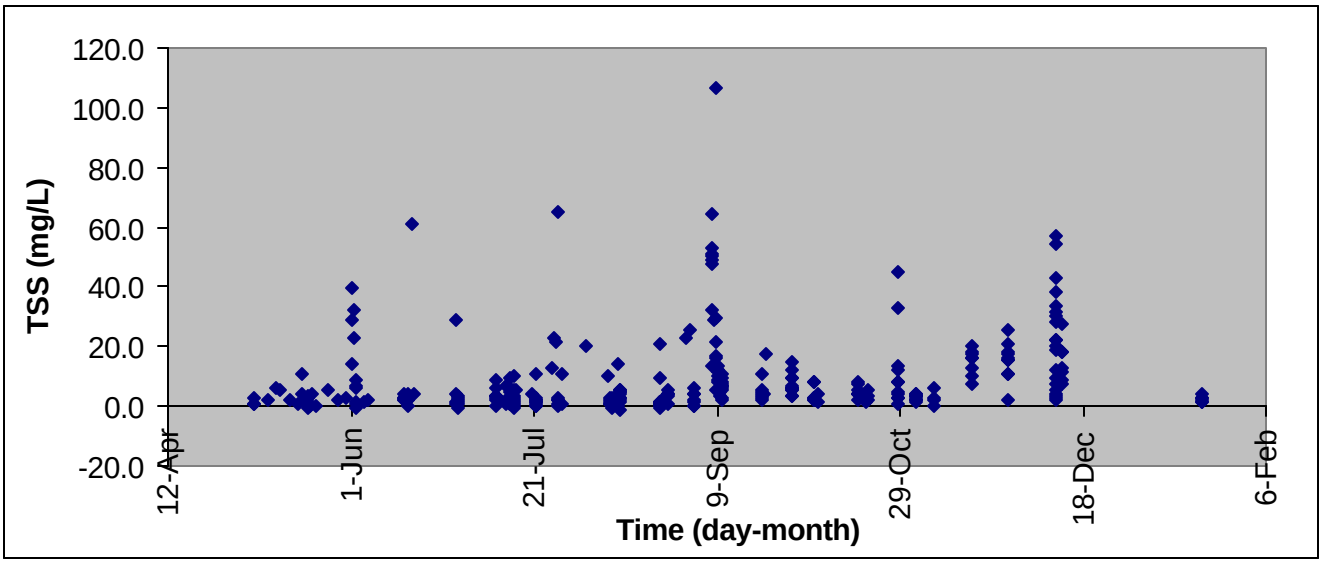

Figure 24. 2008 TSS results in mg/L by date.

The following figures, 25 and 26, present the biweekly routine grabs of the TSS and Turbidity data by station in box and whisker plots to show the variability of the parameters between stations. In addition to the regular 8 monitoring stations, the reference site in Millville was added as well as a sampling site on Bayard Road in Wilmot at which an Environment Canada water quality monitoring station is located. The results have a large range and are shown in logarithmic format.

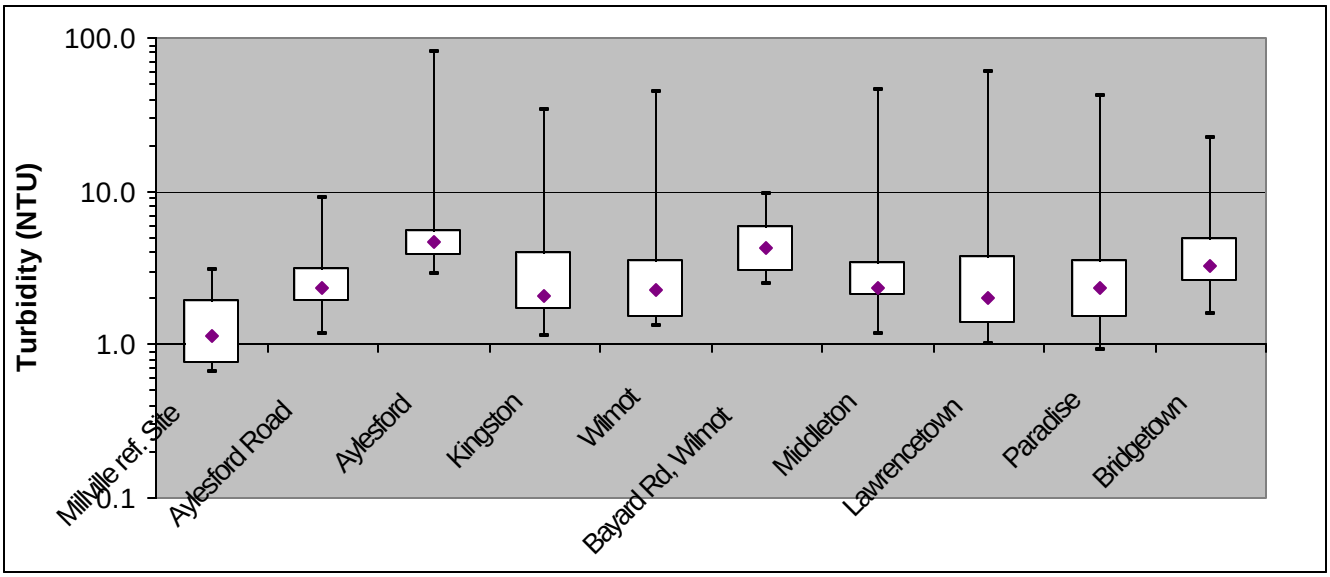

Figure 25. Turbidity results for routine sampling by location.

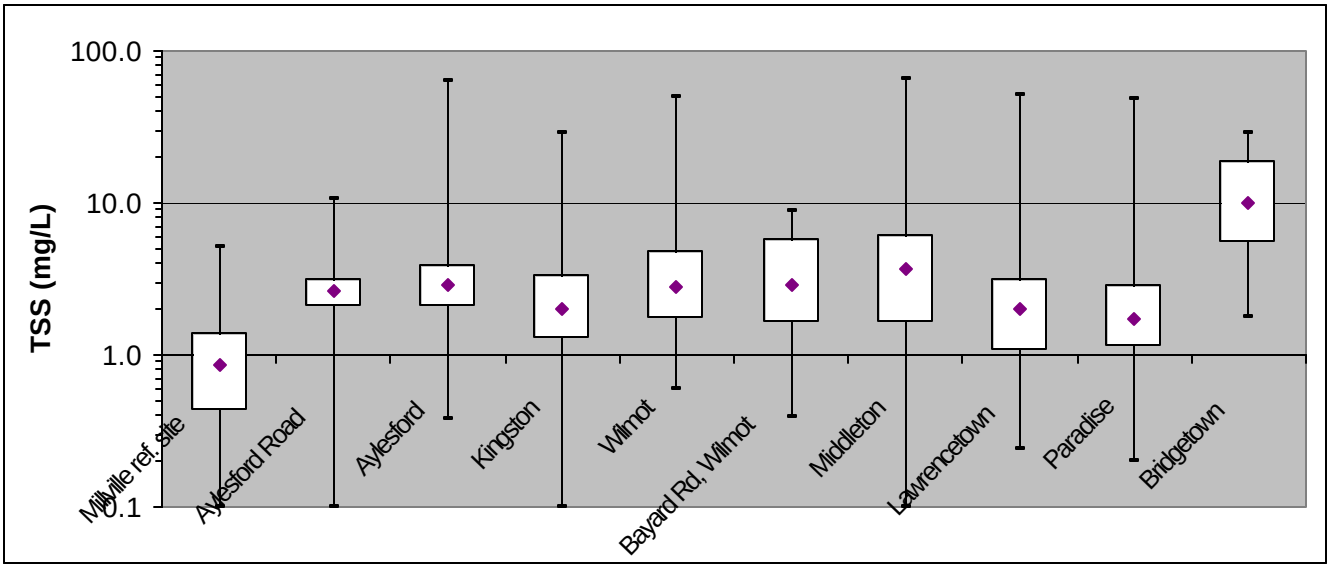

Figure 26. TSS results for routine sampling by location.

Note that the Bridgetown location shows high TSS readings when compared with the other sites, which is not reflected in the turbidity results. The Bridgetown location is the only monitored location that sometimes has salt water due to tidal influence, which may be a possible explanation for this discrepancy.

One of the purposes of measuring these two parameters was to establish a relationship between the two variables. Figure 27 below shows the TSS results as related to the turbidity results. Upon visual examination, it seems as though these two variables are directly correlated, although further analysis is required to determine exactly what that relationship is.

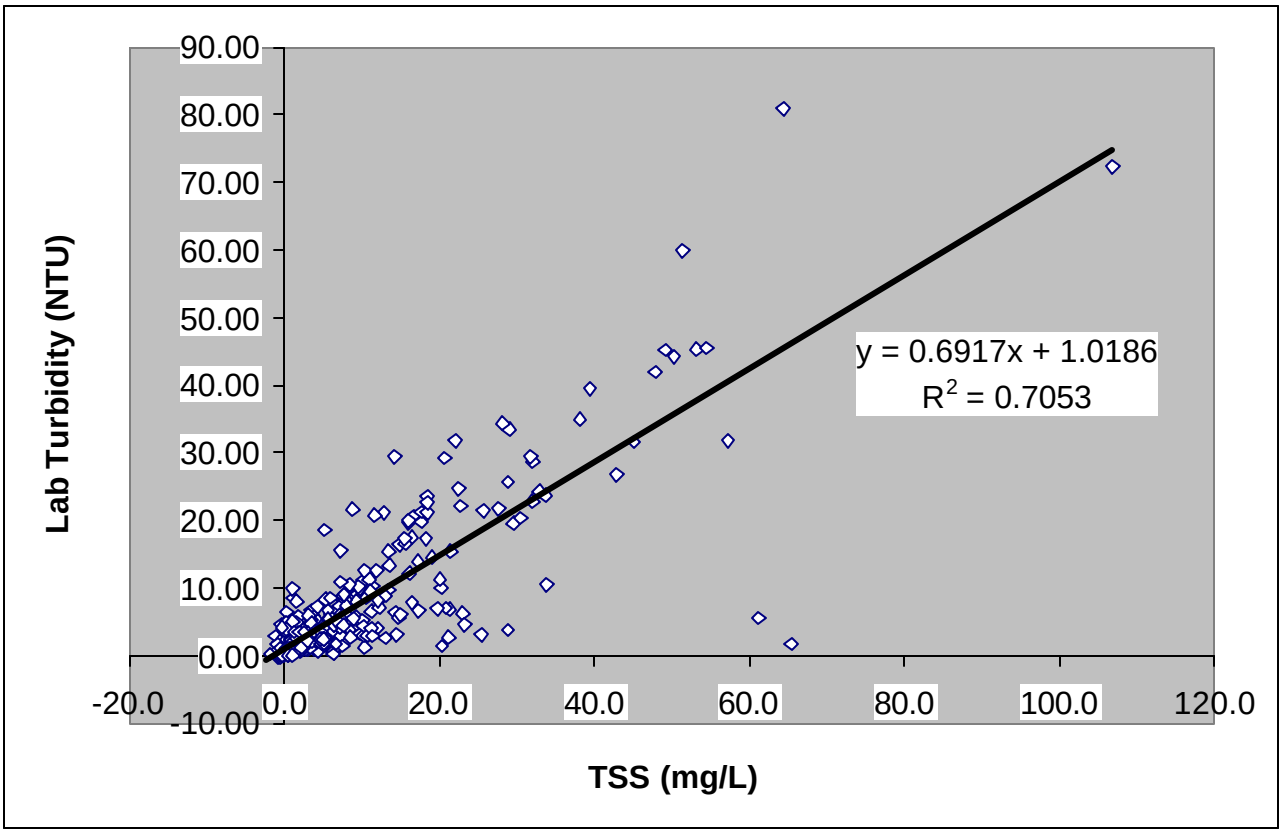

Figure 27. TSS in mg/L vs. turbidity in NTU for all sampled locations along the Annapolis River with the best-fit straight line and equation.

Although the best-fit straight line and equation are included in the chart above, this is only a preliminary estimate of what the relationship between TSS and turbidity is. More high-flow data will be gathered in the following year in order to provide a better base for assessing the relationship between these two properties. In addition, a more thorough statistical analysis will be performed once enough data has been gathered.

Figure 28 presents the historical TSS data collected from 1992 to 2002 by River Guardians volunteers and the TSS data from 2008 gathered during routine biweekly collections. The medians of the two data sets are similar, but the spread of the original data is larger and has a greater number of small values (between 0.1 and 1 mg/L). This might be due to the size of the original data set, which contains 9 years of data, whereas the 2008 data set is only for 1 year. Note that the scale of the y-axis is logarithmic.

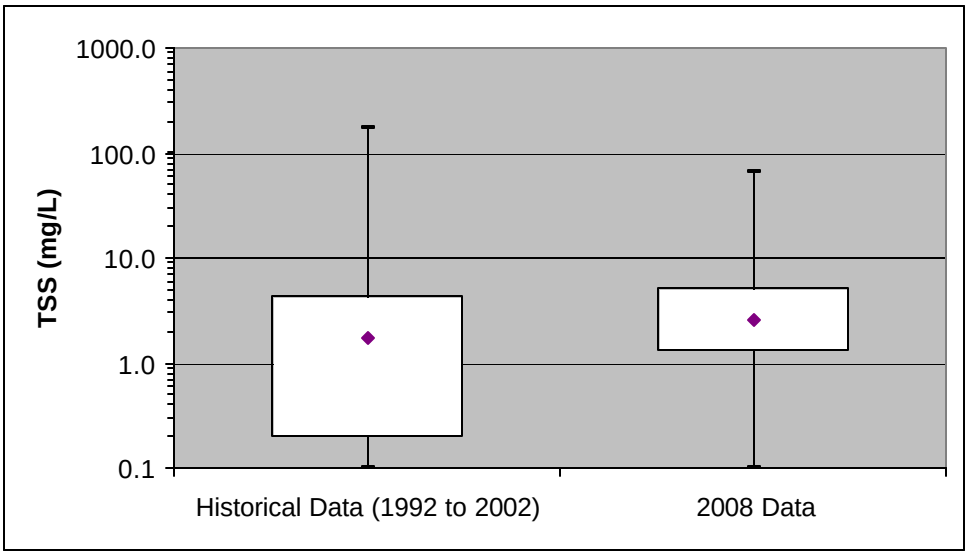

Figure 28. Comparison of the historical River Guardians TSS data (1992 – 2002) and the 2008 TSS data collected as part of the TSS/Turbidity project.

Recommendations

- Continue to monitor TSS and turbidity in 2009, especially during the high-flow periods in the springtime. When sufficient data is collected, several methods can be used to assess relationships between the two variables:
    - Separating the data by station
    - Grouping the data according to flow conditions
    - Assessing duration of rising and falling limbs on a hydrograph
    - Performing outlier assessments
- Once baseline parameters and a relationship between TSS and turbidity have been developed, add turbidity to the regular monitoring procedure.

Trend Analysis

Purpose

A trend analysis has been done for several of the water quality monitoring parameters since 2006. The results of this analysis were included as part of the annual River Guardians Report Card. These trend calculations were simple three-year rolling average comparisons, and a trend was indicated for a certain parameter if it had changed by a given percentage, which varied according to the parameter. If a trend was found, it was reported as either increasing or decreasing, otherwise it was reported to have no trend indicated.

In 2008, new methods of performing trend analyses were researched in an effort to increase the statistical validity of the results. Literature sources consulted included: Australian and New Zealand Environment and Conservation Council (2000), Helsel and Hirsch (2002), Hirsch, Alexander and Smith (1991) and Cooke (2006). Bacteria count, DO and temperature data have been collected since the inception of the River Guardians program in 1992, and pH has been collected since 2003.

Background Information

There are several different ways of reporting trends in a series of data, depending on the nature of the data set. Many of the statistical methods fall under two broad categories, parametric and non-parametric. Parametric methods are used for normally distributed data, while non-parametric methods are suited for non-normally distributed data. Methods of each type were attempted for the trend analysis of the water quality data.

The parameters that were assessed using these two methods were bacteria counts, DOSAT, temperature and pH. DOSAT was used over DO because DO values are dependent on temperature, therefore, temperature trends might cause DO trends to be masked or indicated when they are not appropriate.

The procedure used for the non-parametric analysis was based on a procedure provided by D. Parent of Environment Canada and used by Glozier, Crosley, Mottle and Donald (2004). This procedure involved:

- separation of the data by station for each parameter
- a visual assessment of the data time series, which includes dividing the data into season according to the box-plot
- checking outliers for errors in measurement
- the Kruskal-Wallis test for seasonality
- either the Seasonal Kendall test or the Mann-Kendall test depending on whether the data displayed seasonality.

The Kruskal-Wallis test was performed using Systat 8.0 and the Kendall tests were performed using a free DOS-based computer program for the Kendall family of trend tests developed by the United States Geological Survey. The program is available at http://pubs.usgs.gov/sir/2005/5275/downloads/ (Helsel, Mueller, Slack, 2006)

The parametric procedures that were performed on the data were suggested by Drs. Y. Zhang and M. Brylinsky of Acadia University (pers. comm, December 2008). This procedure involved:

- separation of the data by station for each parameter
- a visual assessment for correlations between locations using scatterplot matrices
- a check for autocorrelation for each parameter and location
- an assessment for normality using the Shapiro-Wilks test
- transformations of the data if the parameter was found to be non-normal
- a linear regression of the data to determine whether a trend was present.

Systat 8.0 was used to produce scatterplot matrices and autocorrelation plots; the Analyse-It add-on for Microsoft Excel was used to perform the Shapiro-Wilks test and regression analyses.

Methodology

Before any trend analyses were performed, outlier tests were conducted. The mean and standard deviation of a particular data set were calculated and each value was compared to the mean. If any value differed from the mean by more than twice the standard deviation, it was considered an outlier and was checked against the original data sheets. If there was reason to suspect the data point of being invalid, the data was not included in the trend analysis. If no notes or calculation errors were made on the original data sheet, the outlier value was retained in the data set. The analysis for the temperature data was performed only on data from the summer months (July, August and September), as elevated water temperatures that occur in the summer months are the principal concern. The outlier analysis was not performed on the bacteria data, as the nature of the data is not conducive to outlier analysis. The data is highly variable with a wide range of 0 to 2419 cfu/100 mL and is capped at 2419 cfu/100 mL. The cap of 2419 cfu/100 mL is due to method limitations; the IDEXX Colilert testing method will not produce a reading greater than this number. Some of the earlier data was analyzed using a different method that was not capped, so any data point above the 2419 cfu/100 mL threshold was artificially capped at 2419 cfu/100 mL for consistency purposes.

Non-Parametric Analysis

A box and whisker plot was made for each parameter, with the data grouped by month. For the temperature, bacteria and pH data, months of January through March were excluded, as very little data was recorded for those months. The box plots were then visually assessed for similarities across months. Adjacent months with similar medians and ranges were grouped together as a season. Figure 29 below shows the bacteria count box plot by month with the seasonal determinations indicated.

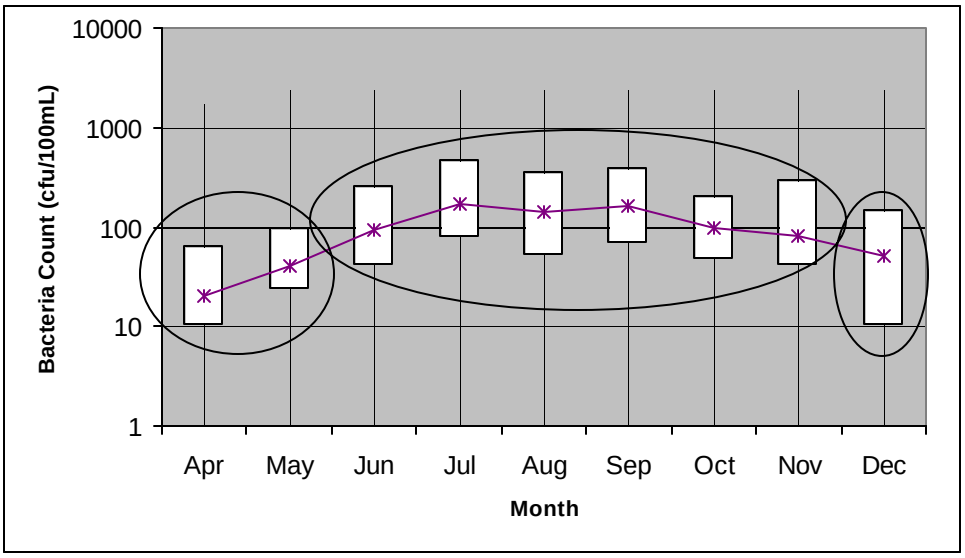

Figure 29. Bacteria count data for all years grouped by month. The circles indicate the seasons that were determined from this plot. There was very little data for the January to March period; these months were not used in the analysis. A 'dummy season' containing no data was used in the analysis to represent the January to March period.

Three seasons were indicated by the bacteria count box plot shown above and a fourth season was included in the analysis to represent the January to March months. The bacteria data was grouped according to these seasons and the Kruskal-Wallis for seasonality test was performed. A similar box plot was constructed for each other parameter using the same procedure. Bacteria count data were indicated as being seasonal, while the pH, DOSAT and summer temperature data were not. Based on this, the Seasonal Kendall test was performed on the bacteria count data and the Mann-Kendall test was performed on pH, DOSAT and temperature data. These tests produce a linear trend equation and a probability statistic (p value), which indicates whether or not the trend is statistically significant. A trend was considered significant if the p value was less than 0.05.

Parametric Analysis

The data was grouped by parameter and location, and the Shapiro-Wilks test was performed on each data set. The Shapiro-Wilks test is a test for non-normality and produces a histogram of the data overlaid with a normal distribution curve as well as some significance and probability statistics. The statistics produced are generally only useful for small data sets; for larger data sets, it is more useful to examine the histogram and determine whether the data visually resembles a normal distribution. If the data does not resemble a normal distribution (in this case, the *E. coli* data did not), the data set can be transformed until it resembles a normal distribution. CARP's *E. coli* data distribution resembled a logarithmic distribution, so the data was transformed by taking the base-10 logarithm of the bacteria results. The logarithmic transformation produced a normally distributed data set. The figure below, figure 30, displays the distribution of the bacteria data for Bridgetown, before and after transformation.

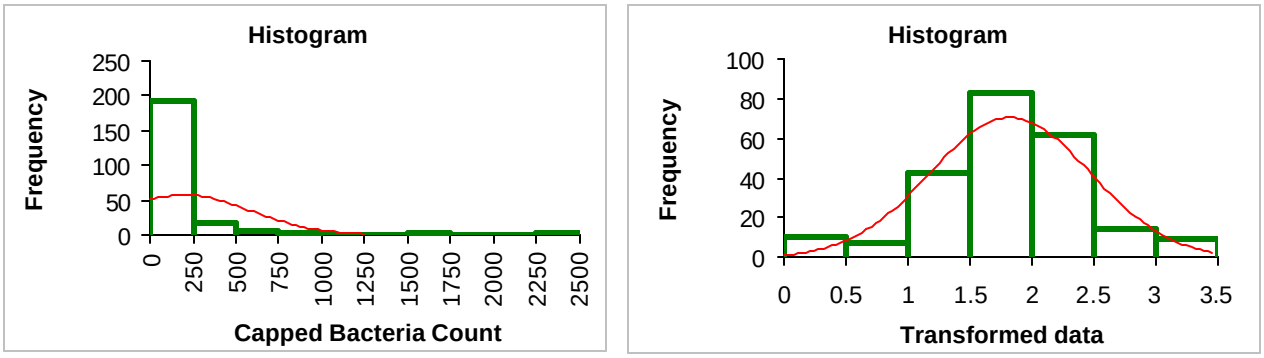

Figure 30. Bridgetown bacteria count data distribution before transformation (left) and after transformation (right).

From the figure above, the transformed data much more closely resembles a normal distribution and can be used for the regression analysis. The data for DO, temperature and pH did not require transformation to resemble a normal distribution. After the trend analysis procedure below was completed, the bacteria data trend results had to be transformed back using an inverse logarithmic function.

After normality was established for each parameter, a linear regression was performed on its data set. This produced a linear slope of the trend, as well as a confidence interval, prediction interval, probability value and residual histogram. The trend slope provides the rate of change of the variable by year, the confidence interval and probability value allow for the determination of statistical significance of the trend and the residual plot and histogram indicate whether the data set varies in a non-linear fashion, which would indicate that the linear regression calculation is not appropriate for the data set. For the determination of statistical significance, three tests were performed. If any of these tests were failed, the trend was not considered significant. The three tests included:

- verification of the slope's p value. If the value was less than 0.05, this test was passed.
- examination of the confidence intervals of the regression plot. If the confidence interval range at the beginning of the data set did not overlap with the range at the end of the data set, this test was passed. See Figure 27 for more information.
- examination of the residual plot and distribution. If the residual scatterplot was randomly distributed and the associated histogram resembled a normal distribution, this test was passed. Non-linear correlation of the data would be indicated if this test was failed. See figure 28 for more information.

As an example, the DOSAT data for the Kingston location is displayed below. The p value for the slope produced by the regression analysis was 0.0003. This value is less than the 0.05 threshold, therefore, the data passed this significance test. Figures 31 and 32 below show that the Kingston data set passed the other two significance tests as well, therefore the trend slope of –0.6 %/year was accepted as significant. This indicates that dissolved oxygen levels are decreasing at the Kingston location.

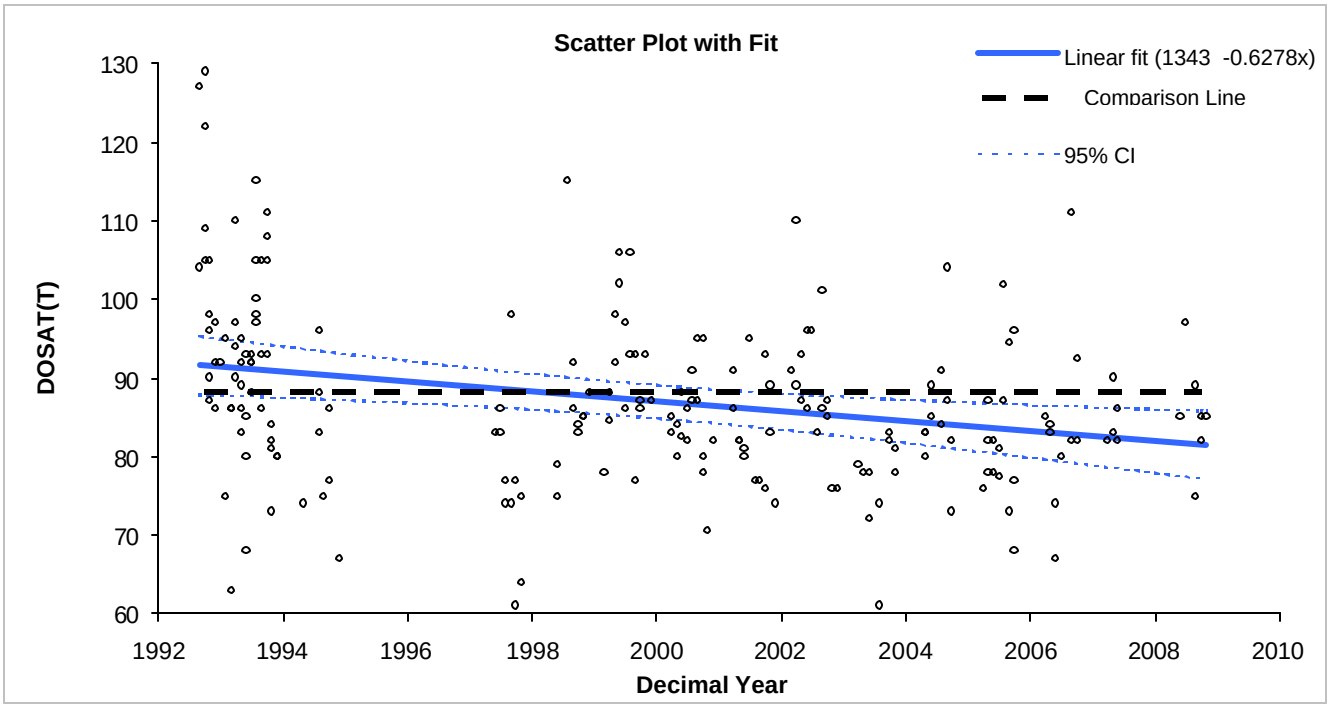

Figure 31. Linear regression for DOSAT data at the Kingston location. The thick dashed line is for the purpose of comparing the confidence interval range at the beginning of the data set. If this horizontal line had remained within the confidence interval range for the entire domain of the data set, a trend could not be concluded. This did not occur for the Kingston DO data set; this data set passes this significance test.

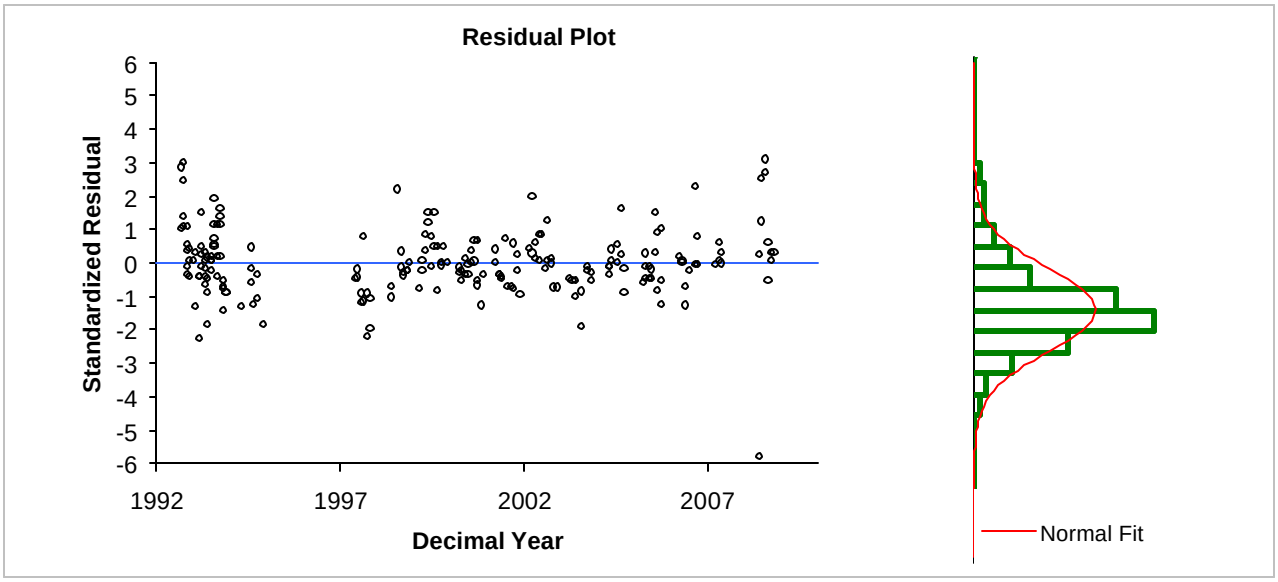

Figure 32. Residuals plot for the DOSAT regression for the Kingston location. The scatterplot does not display significant clustering and appears to be randomly distributed and though the histogram displays a small spike around the centre, it still resembles a normal distribution; therefore this test is passed for the Kingston DO data.

Autocorrelation and Serial Dependence

Autocorrelation is an important consideration for both parametric and non-parametric statistical trend analyses (Helsel and Hirsch, 2005) as its existence invalidates most statistical tests. Autocorrelation refers to serial dependence within a data set, meaning that observation pairs separated by a constant time lag are correlated (Australian and New Zealand Environment and Conservation Council, 2000). One of the assumptions of the linear regression fit is that there must be no correlation between data points (i.e. data points must be independent). In the case of water quality data, the potential existed for data points collected temporally close or along the same stretch of river to be correlated. To assess whether the data was affected by this serial dependence, an autocorrelation plot for each variable at each location was performed, as well as for the entire data set for each parameter.

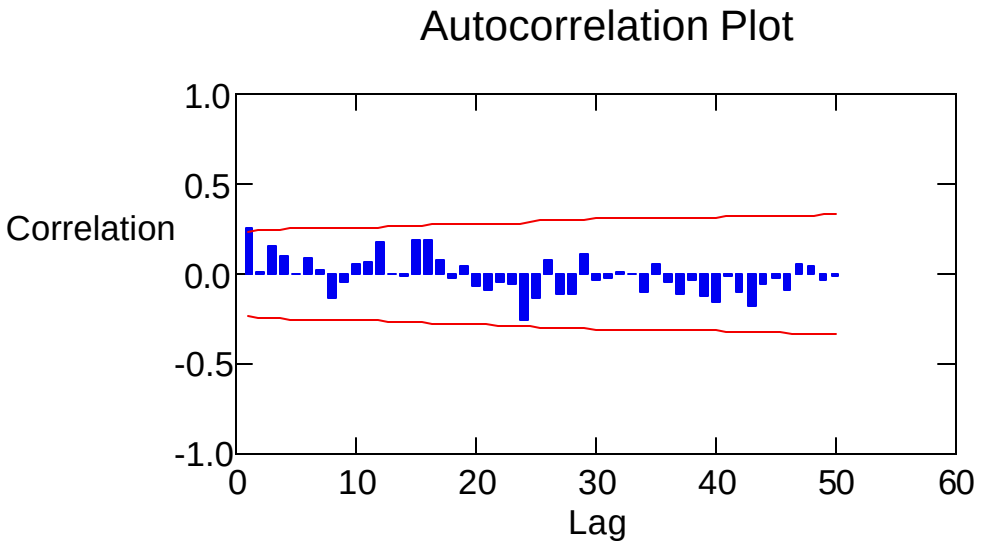

Figure 33. Autocorrelation plot for temperature at the Kingston location.

Figure 33 above shows the autocorrelation plot for temperature at the Kingston location. Significant serial dependence is indicated when the vertical bars extend beyond the 95% confidence curves. In the above plot, most of the bars do not extend beyond the confidence interval, thus serial dependence is not indicated. When an autocorrelation plot was made for all locations, significant serial dependence was displayed; therefore a trend analysis was not performed on the data for all locations. The autocorrelation plot for the entire temperature data set is displayed in Figure 34.

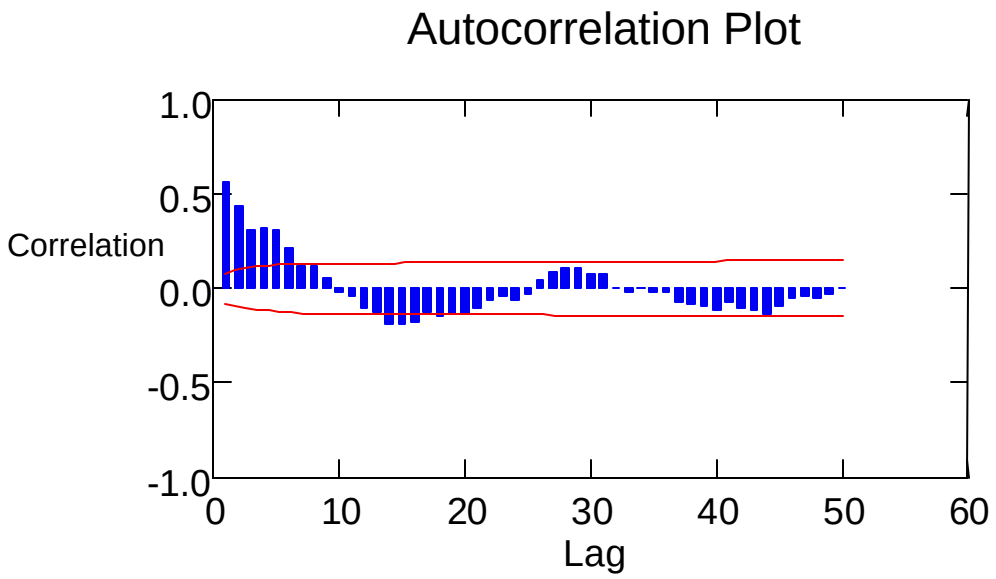

Figure 34. Autocorrelation plot for the entire temperature data set. Several of the bars extend beyond the confidence interval range; therefore significant serial dependence is indicated.

Results

The results for the non-parametric tests are shown below and the results for the parametric tests are shown in Table 16.

Table 15. Statistically significant trends* and rates of change using non-parametric procedures.

	Bacteria Count	Dissolved Oxygen	pH	Temperature
Aylesford Road	No	No	No	No
Aylesford	No	No	No	No
Kingston	Yes (+4 cfu/100mL/year)	Yes (-0.6 %/year)	No	Yes (+0.19ºC/year)
Wilmot	No	Yes (+0.3 %/year)	No	No
Middleton	No	No	No	No
Lawrencetown	Yes (-5 cfu/100mL/year)	No	No	Yes (+0.18ºC/year)
Paradise	No	No	No	No
Bridgetown	No	Yes (-0.6 %/year)	No	No

*Statistically significant trends ($p < 0.05$) using Seasonal Kendall and Mann-Kendall tests.

Table 16. Statistically significant trends* and rates of change using parametric procedures.

	Bacteria Count	Dissolved Oxygen	pH	Temperature
Aylesford Road	No	No	No	No
Aylesford	Yes (+8 cfu/100mL/year)	No	No	No
Kingston	Yes (+8 cfu/100mL/year)	Yes (-0.6 %/year)	No	No
Wilmot	No	No	No	No
Middleton	No	No	No	No
Lawrencetown	No	No	No	Yes (+0.21ºC/year)
Paradise	No	No	No	No
Bridgetown	No	Yes (-0.7 %/year)	No	No

*Statistically significant trends ($p < 0.05$, residual plot randomly distributed, initial confidence interval range does not overlap with final confidence interval range) using linear regression fit.

Values in the table indicate a statistically significant trend as a rate of change, with a positive value as an increasing trend and a negative value as a decreasing trend. The two test types generates slightly different results, but were mostly consistent. Both indicate increasing bacteria trends upriver, at Kingston, with the parametric results also producing an increasing result at Aylesford. The non-parametric tests also produced a decreasing bacteria trend at Lawrencetown. The non-parametric tests produced a result of +10 cfu/100mL/year with a p value of 0.0599 for Aylesford. This was not included in the table above because the p value is greater than 0.05, but the result may still be significant. Both methods display a decreasing DO trend at both upriver and downriver locations, especially at Kingston and Lawrencetown. No pH trends were indicated for any location by either method and an increasing temperature trend was shown at Lawrencetown by both methods. The non-parametric tests also showed an increasing temperature trend at Kingston. The Aylesford Road site has only been monitored since 2003, and was only monitored sporadically until 2006, so there is not a large amount of data for that location. The data produced confidence intervals with a wide range; therefore no trends could be concluded.

Because of the presence of the serial dependence, it was not possible to conduct trend analysis for all of the sites as a single data set.

Recommendations

Recommendations for the River Guardians Program

- Continue regular River Guardian *E. coli* monitoring at the eight main river sample locations.
- Conduct simultaneous monitoring at Sites 00 and AY40, together with intervening tributary streams.
- Conduct a foot survey of the Annapolis River between these two sites and the intervening tributary streams to identify possible contamination sources.
- Review current and historic air photos of this area to identify land use changes and possible sources of contamination.
- Continue regular River Guardian DO monitoring program at eight main river sample locations.
- Undertake periodic DO monitoring of the Annapolis River estuary in the late summer and early autumn.
- Continue regular River Guardian temperature monitoring program at eight main river locations.
- Investigate the temperature increase on the Annapolis River between Aylesford and Lawrencetown. This may include collection of thermal status data on tributaries to the Annapolis River.
- Install temperature loggers in candidate streams to assess for fish habitat improvements.
- Temperature data loggers should be calibrated immediately prior to deployment and at least once *in situ*. These procedures should be added to the QA/QC Project Plan.
- Regular pH monitoring should be continued at the eight Annapolis River Guardian monitoring locations.
- Work in collaboration with Environment Canada to ensure the continued collection of nitrogen and phosphorus samples at Millville, Wilmot and Lawrencetown.
- Continue to monitor TSS and turbidity in 2009, especially during the high-flow periods in the springtime.
- Once baseline parameters and a relationship between TSS and turbidity have been developed, add turbidity to the regular monitoring procedure.

Recommendations for CARP

- Complete the Quality Assurance Project Plan for all of CARP's Water Quality monitoring programs.

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Appendices

Appendix A – Parameters Tested and Methodologies

Parameters Analyzed in 2008	Additional Parameters Analyzed in Previous Years of the Program
E. coli bacteria densities	Salinity
Dissolved Oxygen	Chlorophyll a
Temperature (Water and Air)	Nitrate-N, Chloride, Sulphate, Total Phosphate
Weather conditions	Colour
pH, Conductivity, Total Dissolved Solids	Transparency
Nitrate, Nitrite, Ammonia, Phosphate	
Total Suspended Solids (TSS)	
Turbidity	

Water Collection for Fecal Bacteria Analysis
Following the contamination of some sampling equipment in 2003, a new collection procedure for fecal coliform samples was developed and used during the 2004 through 2008 seasons. The sample collection unit is shown in Figure A1.

Figure A1. Collection unit used for fecal coliform samples in 2008.

The open sample bottle is secured in the clamp, and lowered from the mid-span of the bridge into the river, to a depth of 1 meter. Samples are collected on the upstream side of bridges, where a safe pedestrian walkway exists. After collection, water samples are refrigerated until delivery to the lab, typically within 24 hours of collection.

Enumeration of Fecal Bacteria
Prior to the 2005 season, bacterial samples collected by Clean Annapolis River Project's Annapolis River Guardians program were tested for Fecal Coliforms (FC) using the membrane filtration

method. During the winter of 2005, the program's Science Advisory Committee suggested that the program switch to testing for *E. coli* (EC) using the Most Probable Number method, to bring testing more in line with national guidelines. In order to ensure the continuity of the dataset, a period of duplicate analysis with the two methods was conducted. Duplicate samples were analysed using both methods over a two-month period (four biweekly sample events at eight locations along the river). Analysis of the paired results indicated no significant difference between the two testing methods. Further information on the comparison of the two testing methodologies is presented in the 2005 Annapolis River Guardian Report, Appendix C, which is available at the CARP office.
All fecal bacteria samples were submitted to the Valley Regional Hospital Microbiology Laboratory in Kentville, Nova Scotia. The Valley Regional lab is recommended by Nova Scotia Environment to perform water quality analysis. From 1997 to 2003 and again since 2005, fecal bacteria densities were determined using the IDEXX Colilert procedure, to give a Most Probable Number of *E. coli* bacteria present. For the 2004 sample season, fecal coliform analysis was performed using the membrane filtration method.

Dissolved Oxygen Content

Dissolved oxygen samples are collected from the mid-span of bridges using a horizontal van Dorn sampler, at a depth of 1 meter. Dissolved oxygen in mg/L is determined using the modified Winkler titration using pre-packaged Hach reagents. The Winkler titration procedure is a widely recognized standard for determining dissolved oxygen. The procedure is reported to have an accuracy of at least +/- 1 mg/L. Dissolved oxygen as percent saturation is determined using Rawson's nomogram. Further information on the collection and analysis procedure for dissolved oxygen can be found in the Annapolis River Guardians Procedure Manual, which is available at the CARP office.

Temperature

The Annapolis River Guardians used a combination of glass/alcohol and digital thermometers during 2008. Prior to the start of the season, all thermometers were compared with the temperature reading from CARP's HydroLab Quanta water meter. This unit had recently been serviced and calibrated, with a reported accuracy of +/- 0.10 ºC. From this comparison, a correction factor was determined for each River Guardian thermometer. These correction factors were applied to all River Guardian temperature measurements.

pH and Conductivity

Water chemistry data, including pH and conductivity, was collected using CARP's portable HydroLab Quanta water quality monitoring meter. Data was collected on a fortnightly basis by CARP staff, typically the day following the volunteers' sampling day, at a set location on the riverbank at each River Guardian site. The meter was placed in the river approximately 1 to 2 meters away from the bank, and allowed to stabilize, usually for two to three minutes before a reading was taken. Once stabilized, the values were stored in the meter's memory and recorded on the data sheets upon return at the CARP office. The data is stored using an in-house Microsoft Access database. Approximately every two to three weeks, the multi-sensor water meter was calibrated for pH, conductivity and dissolved oxygen according to the directions in the Operating Manual (Hydrolab Corporation 2002).

Procedures for Investigation of Low Dissolved Oxygen in Lower River

At several points through the 2008 sampling season, from mid-August to early October, DO readings and nutrient samples were gathered in the estuarine section of the river. The DO readings were taken using the Hydrolab Quanta multi-probe unit from a boat at eight locations along the river. The Hydrolab also records temperature, conductivity, pH and salinity. Two measurements were performed for each location, one at a depth of approximately 0.5 m (above the halocline) and one at approximately 3.5 m (below the halocline). Nutrient samples (silicate, nitrate, nitrite, ammonia, phosphate) were gathered in 30 mL sample bottles and field-filtered using Millipore glass fibre filters (Cat. No. APFC02500). All samples were handled in accordance with the protocols of the Bedford Institute of Oceanography (BIO), where the final analysis was conducted. The nutrient analysis was performed using Colorimetric Segmented Flow with a Technicon II.

Procedures for TSS/Turbidity collection and processing

Samples were taken using either van Dorn Samplers or by hand from the shore near the bridge. If a van Dorn sampler was used, it was used mid-span of the bridge at a depth of approximately 30 to 60 cm. If taken from the shore, the bottle was dunked in an area where the water's flow was constant and at a depth the length of a forearm, approximately 30 to 40 cm. Occasionally, an extendible rod with the bottle attached to the end was used from the shore. The collection method was not recorded for particular samples, although any sample collected by a River Guardian was collected using a van Dorn Sampler. A collection of approximately 1 litre of water was attempted for each collection, but limited quantities of sample bottles sometimes forced a collection of only 500 millilitres. Lab Turbidity was assessed at Acadia University using a 2100P Hach Turbidimeter.

TSS data was collected through filtration. Filters were stored in a desiccator for at least 24 hours and were then weighed in a weighing boat on an analytical balance. The weight of the filter paper and the weighing boat together were recorded on the weighing boat. The filters used were Ahlstrom brand, grade 161, 4.7 cm in diameter, or Whatman brand, grade 934AH, 4.7 cm in diameter. The water sample was passed through one of the preweighed filters using a suction filtration procedure. The filter paper was carefully placed back in its weighing boat and dried in an oven at ~90 degrees Celsius before being stored back in the desiccator. After remaining in the desiccator for approximately 24 hours, the filters and boats were removed and reweighed. The new weight was subtracted from the original weight of the filter and boat, and this number was divided by the sample volume to give a g/L TSS reading. The balance used was an A&D Electronic Balance ER-120A.

Procedures for Benthic Invertebrate sampling

The procedures for collecting information on benthic macroinvertebrates are standardized across Canada by the Canadian Aquatic Biomonitoring Network (CABIN). These procedures include gathering invertebrate samples, recording stream characteristics and determining properties of the substrates as well as safety and location selection instructions.

Benthic invertebrate samples are gathered using a timed kicknet transect of the watercourse (400 µm mesh size). Samples are preserved in 70% isopropyl alcohol for later identification. Habitat information is collected onsite, including riparian vegetation, flow and hydraulic characteristics, and grain size of the benthos. Benthic invertebrate samples are later sub-sampled using a Marchant box, with a minimum of 300 organisms picked and identified to at least Family level.

For more information on the CABIN protocol, please refer to:
http://www.unb.ca/cri/cabin_criweb.html
http://cabin.cciw.ca/application/welcome.asp?Lang=en-ca

Appendix B – Sites Monitored

Water samples were collected during 2008 by the Annapolis River Guardians program at the locations shown in Table B1. Coordinates are reported in latitude and longitude, as recorded on a hand-held GPS unit.

Table B1. Coordinates and descriptions for Annapolis River Guardian and TSS/turbidity sample locations.

Site Code	Latitude	Longitude	Site Name	Site Name (Long with Reference Points)
AY40	N45 01.699	W64 48.617	Aylesford Road	Bridge at Aylesford Rd, near Hwy 1
Ref	N45 00.122	W64 49.381	Millville	Bridge on Victoria Rd, South Annapolis River
00	N45 01.606	W64 50.148	Aylesford	Bridge on Victoria Rd, near Hwy 1
13	N44 58.713	W64 56.663	Kingston	Bridge on Bridge St. near Stronach Park
18	N44 57.199	W65 00.096	Wilmot	Bridge on Old Mill Road
NS01	N44 56.942	W65 01.769	Wilmot	Bridge on Bayard Road
25	N44 56.213	W65 03.969	Middleton	Bridge on Hwy 10, near Riverside Park
35	N44 52.850	W65 09.476	Lawrencetown	Bridge on Lawrencetown Lane
40	N44 52.045	W65 12.384	Paradise	Bridge on Paradise Lane
49	N44 50.335	W65 17.492	Bridgetown	Bridge on Queen Street

The NS01 and Ref sites were sampled for turbidity and TSS only.

Appendix C – Quality Assurance / Quality Control Data

Introduction

Following a contamination event in 2003, CARP initiated a number of procedures to ensure the quality of data collected. In addition to instituting a new collection procedure for fecal bacteria, CARP has put in place a program of regular quality control checks on sampling equipment and methods. Further information on the quality assurance/quality control (QA/QC) program can be found in CARP's draft QA/QC Project Plan (Sharpe and Sullivan 2006). An important initial step in the QA/QC program is the training of volunteers. A refresher session was held for all volunteers on April 29th, 2008 at Middleton Regional High School. During the 2008 season, CARP staff conducted visits with each of the Annapolis River Guardian volunteers on collection days in order to both collect a series of blank and split samples, as well as to ensure the consistency in collection procedures. In total, twenty-one QA/QC samples were collected during the 2008 season. These were, in summary:

- 7 Dissolved oxygen split samples
- 7 *E. coli* travel blanks
- 7 *E. coli* duplicate samples
- 7 split turbidity/TSS samples

Background

For the purposes of CARP's water quality monitoring programs, a blank sample is a sample that is known not to contain any of the substance in question. For CARP's monitoring of *E. coli* bacteria, either distilled or un-chlorinated tap water is added to the sample bottle. There are two types of blank samples that are collected for QA/QC analysis:

- Travel blanks are obtained by filling the sample bottle with distilled/tap water before the start of a sampling day, and placing them in the same cooler among other surface water samples. Travel blanks are used to ensure there is no cross-contamination between samples while they are being transported in the same cooler. They should always produce plates with no fecal bacteria growth.
- Field blanks are obtained by performing the entire sampling protocol (i.e.: attaching the bottle to the clamp, and lowering the apparatus to the water surface) but NOT submerging the bottle. The bottle is instead lifted up empty and filled with distilled/tap water on the bridge. This type of blank sample is used to test the sampling procedure and should also always produce plates with no fecal bacteria growth. A positive result on a field blank would lead to further investigations to determine the source of contamination (for example: operator, equipment, distilled water, etc). No field blanks were collected for *E. coli* in 2008

Split samples are used to measure both precision and accuracy. Precision is expressed as the degree of agreement among repeated measurement of the same parameter and provides information on the reproducibility and consistency of the methods used. Accuracy, on the other hand, consists of how close a measurement is to the "true" value.

A split sample is a single sample volume that is divided in two samples that are analysed separately. Split samples can provide information on the precision of the lab method (i.e.: the precision of Valley

Regional Hospital's *E. coli* analysis). Split samples can also provide information on the accuracy of the method used (i.e.: the accuracy of volunteers at the Winkler titration).

The degree of variability between two split samples can be evaluated by calculating their relative percent difference (RPD). The RPD is expressed as the absolute difference of the two measurements multiplied by 100 and divided by the average of the two values:

$$RPD = \frac{|X_1 - X_2| \times 100}{(X_1 + X_2)/2}$$

When more than two samples are to be compared, the degree of variability is estimated by calculating their Relative Standard Deviation (RSD). Both the RPD and the RSD are expressions of precision, the smaller the value, the greater the precision.

$$RSD = \frac{s}{X_m} \times 100$$

s = standard deviation
X_m = mean of duplicate samples

Accuracy is estimated by taking the absolute difference between the "true" value and the "test" value. When there are multiple measurements, the true value is subtracted from the average of the test measurements. The result is compared to acceptable accuracy standards for each individual method.

Accuracy = Test/Average value – True Value

Dissolved Oxygen

Dissolved oxygen split samples were taken in 2008 using a single volume of water from a van Dorn sampler. The accuracy of volunteer DO measurements was assessed through the collection of seven split samples. The Winkler titration (described in Appendix A) is widely recognized has a standard for determining dissolved oxygen and is reported to have an accuracy of at least +/- 1 mg/L. Results from the split samples shown below in Table C1, indicate that the volunteers attained an average accuracy of +/- 0.094 mg/L (RPD = 5.4%). For comparison purposes, the average DO accuracy for 2007 was +/- 0.003 mg/L (RPD = 9.7%).

Table C1. Volunteers' level of accuracy at measuring dissolved oxygen using the Winkler titration.

Site	Date	Volunteer	Volunteer result	QA/QC result	Accuracy	Percent difference
49	24-Aug-08	Ronald Jones	9.8	9.40	-0.4	4.17
40	24-Aug-08	Matthew Guy	10.68	11.20	0.52	4.75
35	24-Aug-08	Marika Godwin, Ross Dickson	8.90	9.78	0.88	9.42
25	24-Aug-08	Claire Diggins	10.6	9.63	-0.97	9.59
18	21-Sep-08	Chelsea Fougère	9.2	9.31	0.11	1.19
35	02-Nov-08	Daren Parks	10.48	10.57	0.09	0.86
00	02-Nov-08	Tami Parks	11.4	10.51	-0.89	8.12
				Mean	-0.094	5.4427

E. coli Bacteria

Throughout the sampling season, a series of blank samples were submitted blind for analysis to the microbiology laboratory at Valley Regional Hospital. The seven travel blanks analysed all had coliform counts of 0 cfu/100ml, which indicates that no cross-contamination was occurring during transportation of the samples. Although no field blanks were collected in 2008, the two field blanks collected in 2007 showed no *E. coli* growth, indicating that the fecal bacteria sample collection procedure was not contaminating the samples. The sample collection procedure has not changed between the two years.

Throughout the 2008 sampling season, a total of seven split samples were collected during the sampling visits with the volunteers. These samples were submitted to the Valley Regional Hospital Microbiology Laboratory under fictitious sample identification numbers. The purpose of this was to assess the reproducibility of the *E. coli* MPN analysis method used. The results of this are presented in Table C2. The mean RPD for these split samples was found to be 23.3%. The mean RPD for the 2006 and 2007 seasons was 15.5% and 42.5%, respectively.

All analysis methods have inherent variability; this is particularly the case with IDEXX, as the Most Probable Number result is statistically derived. Table C2 prevents some of the confidence interval values for the IDEXX method. The variability values are taken from the IDEXX Quanti-Tray®/2000 MPN Table (per 100mL) with 95% Confidence Limits (no date). For each volunteer result, the 95% confidence range was found and compared to the confidence range of the QA result. If these ranges overlapped, then the variability between the two results can be explained by the inherent variability of the procedure. Only 1 of the 8 volunteer results had a value whose confidence range that did not overlap with that of the QA result. This was the Bridgetown reading taken by Ronald Jones, having an RPD of 96%. During the summer, Bridgetown tended to have the lowest *E. coli* values of all of the locations. Possible reasons for the atypical result include contamination during collection or transportation or that the analysis procedure was not carried out properly. Without including this value in the average, the RPD mean is 11%.

The 2008 RPD mean is much lower than the 2007 value, which seems to indicate that the test procedure is being carried out with greater consistency this year. The test performed is the Colilert

Most Probable Number analysis, and it is performed at the Microbiology Laboratory at Valley Regional Hospital.

Table C2. Relative percent difference in duplicate samples analysed for fecal coliforms.

Site	Date	Volunteer	Volunteer result	QA/QC result	Accuracy	Percent difference
49	24-Aug-08	Ronald Jones	54	19	-35	95.89
40	24-Aug-08	Matthew Guy	32	34	2	6.06
35	24-Aug-08	Marika Godwin, Ross Dickson	36	33	-3	8.70
25	24-Aug-08	Claire Diggins	101	93	-8	8.25
18	21-Sep-08	Chelsea Fougère	135	115	-20	16.00
35	02-Nov-08	Daren Parks	162	204	42	22.95
00	02-Nov-08	Tami Parks	131	124	-7	5.49
				Mean	-4.143	23.3

Table C3. Confidence interval limits for IDEXX Colilert Most Probable Number procedure.

	95% Confidence	
MPN	Lower Limit	Upper Limit
0	0	3.7
10	5	18
50	36	69
100	81	121
150	124	181
200	166	242
500	405	619
1000	740	1320
1500	1010	2350
2000	1220	3300
>2419	1440	infinite

Turbidity/TSS QA/QC

As turbidity/TSS samples were collected by volunteers in 2008, QA/QC protocol for turbidity/TSS measurements was added. A split sample was taken from van Dorn sampler and both samples were analyzed for TSS and turbidity. The results for TSS and turbidity are presented in tables C4 and C5.

Table C4. Relative percent difference in duplicate samples analysed for total suspended solids.

Site	Date	Volunteer	Volunteer result	QA/QC result	Accuracy	Percent difference
49	24-Aug-08	Ronald Jones	9.8	20.8	11.0	71.90
40	24-Aug-08	Matthew Guy	1.0	1.2	0.2	18.18
35	24-Aug-08	Marika Godwin, Ross Dickson	0.4	0.4	0	0.00
25	24-Aug-08	Claire Diggins	-0.6	0.1	0.7	-280.00
18	21-Sep-08	Chelsea Fougère	5.2	4.8	-0.4	8.00
35	02-Nov-08	Daren Parks	3.2	3.8	0.6	17.14
00	02-Nov-08	Tami Parks	2.0	3.5	1.5	54.55
				Mean	1.9	-15.75

Table C5. Relative percent difference in duplicate samples analysed for turbidity.

Site	Date	Volunteer	Volunteer result	QA/QC result	Accuracy	Percent difference
49	24-Aug-08	Ronald Jones	No sample	7.25		
40	24-Aug-08	Matthew Guy	1.35	1.55	0.2	13.79
35	24-Aug-08	Marika Godwin, Ross Dickson	1.68	1.29	-0.39	26.26
25	24-Aug-08	Claire Diggins	2.37	1.59	-0.78	39.39
18	21-Sep-08	Chelsea Fougère	3.41	3.94	0.53	14.42
35	02-Nov-08	Daren Parks	3.74	3.82	0.08	2.12
00	02-Nov-08	Tami Parks	4.91	5.52	0.61	11.70
				Mean	0.0417	17.947

The TSS results in Table C4 have a large variety of percent difference results. Most of the QA sampling was done at low-flow events, meaning there would be little suspended particulate matter in the river at that time. Many of the values recorded during these low flow events were returned at negative numbers due to random procedural error. Since the numbers are so low, any small variability would return a very large percent difference. If the same variability occurred during a high-flow event, the percent difference values would likely be much lower.

In addition to these QA/QC samples taken with the volunteers, regular blank, split, duplicate and triplicate samples were collected. Generally, for TSS and turbidity, when blanks were collected, duplicates and triplicates were collected of them as well. Split and duplicate results tended to be very close to each other; the standard deviations for TSS duplicates tended to be between 0.0001g/L and 0.006g/L while the standard deviations for turbidity samples tended to fall between 0.01 NTU and 1.0 NTU, with a few exceptions for both parameters.

The blank samples always tended to be very close to 0 for the TSS analysis, having an average reading 0.000 g/L. The turbidity blanks had an average reading of 0.23 NTU. Overall, 144 QA/QC samples were collected, 15 of these samples were blanks. This figure counts duplicate and

triplicate samples as 2 samples and 3 samples respectively, rather than 1 sample. An attempt was made to collect QA/QC samples at each of the ten turbidity-sampling locations.

Benthic Invertebrate sampling QA/QC

The CABIN protocols for benthic invertebrate collections outline the quality assurance and control procedures for sampling.

- The 2008 Marchant Box sub-samples for Wilmot, Paradise and Millville were all re-picked to assess picking efficiency. A 95% efficiency was required for the procedure. In each case, the picking efficiency was within acceptable parameters.
- All samples collected were sent to the Environment Canada Taxonomy Laboratory for verification. This has not yet occurred for the 2008 samples, but the samples from previous years have all been verified.
- Every tenth sample collected must be collected in triplicate. The Fales River sample in 2003, the Paradise sample in 2005 and the Millville sample in 2008 were all collected in triplicate. The results from these replicate samples are presented below, in table C6.

Table C5. Family Biotic Index replicate measurements for CABIN samples

Location and Year	Test	Duplicate	Triplicate
Fales Brook, 2003	4.54	4.19	3.79
Paradise, Annapolis River, 2005	4.83	5.02	4.71
Millville, South Annapolis, 2008	3.23	3.09	3.47

These numbers were used to calculate an error percentage for the Family Biotic Index calculation and collection. The difference between the largest and smallest number for each triplicate sample was calculated and divided by the average of the three replicate measurements and multiplied by 100. The resulting percentages were averaged across the three locations to give an error percentage of 12.07%.

- The residual sediment that was elutriated from each sample was picked. This is to determine the efficiency of the collection procedure.