Annapolis River Guardians
Volunteer Water Quality Monitoring Program

2004 Annual Report

Prepared By:
Denise Sullivan and Andy Sharpe
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Clean Annapolis River Project
P.O. Box 395, 21 St. Anthony Street, Annapolis Royal, NS, B0S 1A0
carp@annapolisriver.ca
www.annapolisriver.ca

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Executive Summary

In 2004, the Annapolis River Guardians completed their 13th year of continuous water quality monitoring on the Annapolis River. Fifteen volunteers monitored nine sites over the course of the season, which ran from May to November. A number of parameters were measured, including dissolved oxygen, fecal coliform bacteria, nitrate-Nitrogen, chloride, sulphate, air and water temperature, pH and conductivity, as well as local weather conditions.

There was a general increase in fecal coliform levels along the Annapolis River in 2004. Elevated levels of fecal coliforms have again been observed at the upper river sample sites (Aylesford, Kingston, Wilmot). During 2004, the lower river sites (Middleton, Lawrencetown, Paradise and Bridgetown), which seemed to show a general improvement over the past few years, exceeded the guidelines for food crop irrigation more frequently. The proportion of samples exceeding this guideline, particularly at Wilmot and Paradise, may represent only a minor reduction in water quality though. Of 100 main-river samples analyzed for fecal coliforms, 37 exceeded the contact water recreation guideline of 200 cfu/100ml. Of these 37 samples, 32% were collected from a single site, Aylesford.

Despite an increase in fecal coliforms, levels of dissolved oxygen (DO) have remained within the normal range for the Annapolis River. Over 13 years of monitoring, mean DO saturation levels have remained in the range of 80-94%. In 2004, the mean DOSAT level was just under 87%. The Aylesford site showed some improvements however, with no samples having saturation levels below 60%.

The apparent warming trend detected in mean summer water temperatures continues to be of concern in 2004. Although the mean summer water temperature of 18.6ºC was down by 1.3ºC from that in 2003, temperatures continue to reach levels stressful to aquatic life, such as cold-water fish ($>$20ºC) regularly during the summer months. Although there appears to be an improvement in temperature, this important indicator should continue to be monitored closely. The expected spatial trend of higher mean summer water temperatures in lower river sites was maintained in 2004. Between Aylesford and Bridgetown, the mean summer water temperature increased by at least 5ºC.

The more quantitative method of ion chromatography was used to analyze nitrate samples in 2004. Results from the analysis showed Aylesford to have the highest levels of all sites, with a mean nitrate-N concentration of 0.70 mg/L. The lower river sites of Middleton, Lawrencetown, Paradise and Bridgetown had lower levels of nitrate-N in the range of 0.34-0.42 mg/L. Levels of chloride and sulphate were within the range expected in fresh/estuarine water.

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 values between sites fluctuated very little, ranging from 6.88-7.04. Conductivity values were also well within the natural variability of fresh/brackish water. Values recorded ranged between 0.13-0.17 mS/cm. Only the Bridgetown sites exceeded this range, due to the presence of brackish water brought in by the tides.

Split, duplicate and blank water samples were analysed during 2004 as part of CARP's Quality Assurance Project Plan. The accuracy of River Guardian dissolved oxygen readings were estimated at +/- 0.85mg/L. Laboratory, field and travel blank samples analysed for fecal coliforms consistently produced plates with 0 cfu/100ml. Duplicate samples analysed for fecal coliforms revealed high heterogeneity in the water column (13.5% relative percent difference (RPD)), as did duplicate samples analysed for nitrate-N (25.6% RPD). Chloride and sulphate duplicate samples suggested a much more homogenous distribution for chloride and sulphate (0.73% and 1.43% RPD, respectively).

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 samplers 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 on-going 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. 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 ten years, the core program 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 10 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 2004 Monitoring Season

The 2004 monitoring season commenced on May 2 and concluded on November 17. Samples were collected fortnightly, with a total of approximately 100 sampling events during the season. Samples were analysed for a variety of parameters, including fecal coliform, dissolved oxygen, temperature, nitrate-N, chloride, sulphate, pH and conductivity. Further information on the testing procedures can be found in Appendix A.

Seven stations were sampled along the Annapolis River. Further information on these and historic sampling locations is contained in Appendix B. The 2004 Annapolis River Guardians Program was complimented by the Sub-Watershed Investigative Monitoring (SWIM) program, which was also operated by CARP. The results for the SWIM program are reported separately in Appendix D. Figure 1 shows the Annapolis Watershed and the 2004 monitoring sites. The data collected by the volunteers is stored in an in-house Microsoft Access database, as well as a publicly accessible web-based, searchable, database at www.fundybay.com

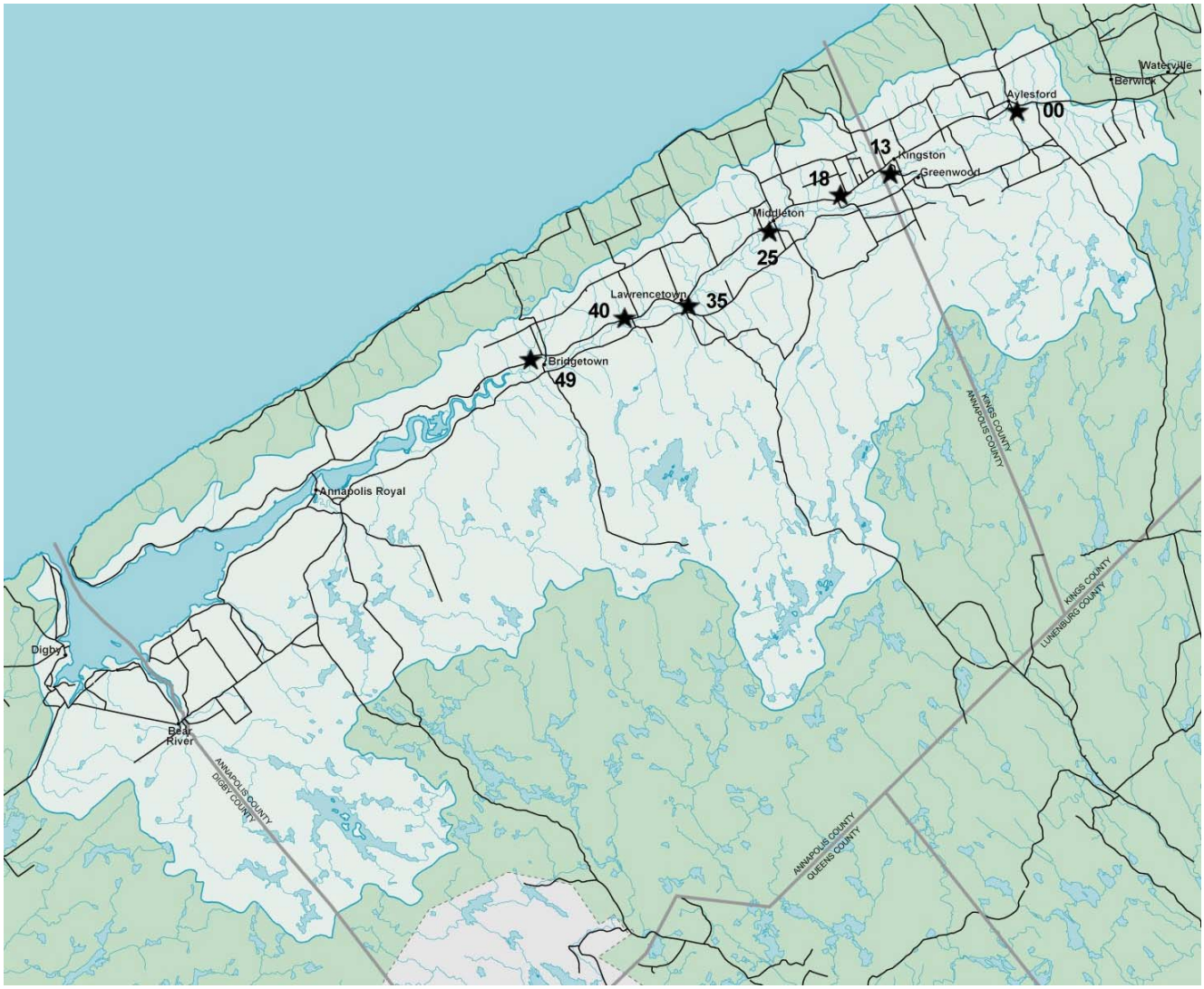

Figure 1: Annapolis Watershed with 2004 Monitoring Sites

The 2004 River Guardian sampling locations were:

00 — Aylesford	13 — Kingston	18 — Wilmot	25 — Middleton
35 — Lawrencetown	40 — Paradise	49 — Bridgetown	

The Sub-Watershed Investigative Monitoring (SWIM) program was created in 1997 to complement the monitoring of the Annapolis River Guardians (ARG). The goal of the SWIM program is to identify sources of contamination by further investigating selected sub-watersheds, which have been shown by River Guardian sampling to have poor water quality. The flexibility of the SWIM programs allows CARP to address specific questions that cannot be addressed in the long-term River Guardian monitoring program. As opposed to the ARG program, the sites and parameters tested in the SWIM program often change from year to year. In 2004, SWIM sampling aimed to provide information on the relative contribution of six selected major tributaries to the Annapolis system. Results showed that the Fales River contributed more fecal coliforms and nitrate-N than any other tributary monitored. The Nictaux River was second in terms of fecal coliform contributions; however, it supplied by far the most dissolved oxygen to the Annapolis River. The complete 2004 SWIM program information and data in contained in Appendix D.

2004 Monitoring Results

Fecal Coliform

Introduction

Fecal coliforms are rod-shaped, aerobic, lactose fermenting bacteria. They are gram-stain negative, thermotolerant and appear as dark blue colonies when cultured in the laboratory. Fecal matter of warm-blooded animals is the predominant source of fecal coliform bacteria. Because they occupy the same ecological niche as many human pathogens, fecal coliforms are used as indicators for the possible presence of other potentially dangerous pathogens. Fecal coliforms 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 agricultural livestock.

Many factors in a particular ecosystem affect the abundance of fecal coliforms in rivers. These include the type of source, the transport mechanism with which the fecal coliform is deposited, and precipitation. The result is that fecal coliform 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 the rate of predation by other microbes, 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 fecal coliform, *Escherichia coli (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)

Spatial and temporal trends in fecal coliform data over the last thirteen years are analyzed below. Over the period of 1992 to 2004, 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 2004, a number of modifications have been made. For example, in 1996, the collection of fecal coliform samples was standardised 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). Fecal coliform results are presented as colony forming units per 100 ml of sample (cfu/100 ml).

Canadian Water Quality Guidelines

Various governmental 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). CARP has summarized the guidelines for fecal coliform contamination into a concise table for public awareness purposes, shown in Table 1.

Table 1: Summary of Water Quality Guidelines for Fecal Coliforms

cfu/100ml	Water Use	Source
0	Acceptable for drinking	Health Canada, fecal coliforms/100ml.
< 50	Acceptable for livestock watering	Interpretation of CCME narrative "high-quality water given to livestock."
< 100	Acceptable for food crop irrigation	CCME Guidelines, cfu/100ml.
< 200	Acceptable for recreational use	Health Canada, Geometric Mean should not exceed 200 cfu/100 ml.

It should be noted that some guidelines are in maximum concentrations, while others are in geometric means over a period of time. Also, the numeric "50" in the table for acceptable livestock watering is based on total coliforms, rather than fecal coliforms.

Monitoring Results

The high variability of fecal coliform 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 per 100 ml to 3000 cfu per 100 ml). The use of standard data analysis methods, such as calculating and comparing mean values, inadequately describe the distribution of fecal coliform 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 2003 and 2004 fecal coliform results (See Appendix E). The distribution of data on the graph confirms that, in most cases, the differences observed between the 2003 and 2004 results are real.

Table 2 presents the proportion of fecal coliform samples exceeding 50 cfu/100 ml, the water quality guideline for livestock watering. For example, at Aylesford in 2004, 0.94 or 94% of water samples collected had fecal coliform counts in excess of 50 cfu/100ml.

Table 2: Proportion of Fecal Coliform Samples Exceeding 50 cfu/100 ml

	Aylesford	Kingston	Wilmot	Middleton	Lawrencetown	Paradise	Bridgetown
1992	1.00	0.33	1.00	1.00	1.00	1.00	
1993	0.91	0.79	0.81	0.86	0.93	0.86	
1994	0.83	0.73	0.88	0.91	0.81	0.86	0.92
1995	0.40	0.14			0.80	0.50	0.71
1996	0.50	0.80		0.75	0.93	0.75	0.80
1997	0.86	0.81	0.81	0.88	0.71	0.50	0.65
1998	0.92	0.75	0.40	0.50	0.55	0.60	0.75
1999	0.86	0.67	0.71	0.55	0.33	0.43	0.65
2000	0.60	0.53	0.45	0.46	0.50	0.57	0.36
2001	0.67	0.83	0.83	0.54	0.33	0.55	0.20
2002	1.00	0.53	0.64	0.38	0.38	0.20	0.60
2003	1.00	0.90	1.00	0.56	0.50	0.50	0.55
2004	0.94	0.93	1.00	0.85	0.79	0.86	0.86

From the data presented in Table 2, it is evident that there was a large increase in the proportion of samples exceeding 50 cfu/100 ml. Figure 2 presents the proportion of fecal coliform samples exceeding the threshold in 2003 and 2004. There was a considerable increase in the proportion of samples on the lower river sites (Middleton, Lawrencetown, Paradise and Bridgetown) exceeding the threshold. The largest increase was in Paradise, where 36% more samples surpassed the threshold.

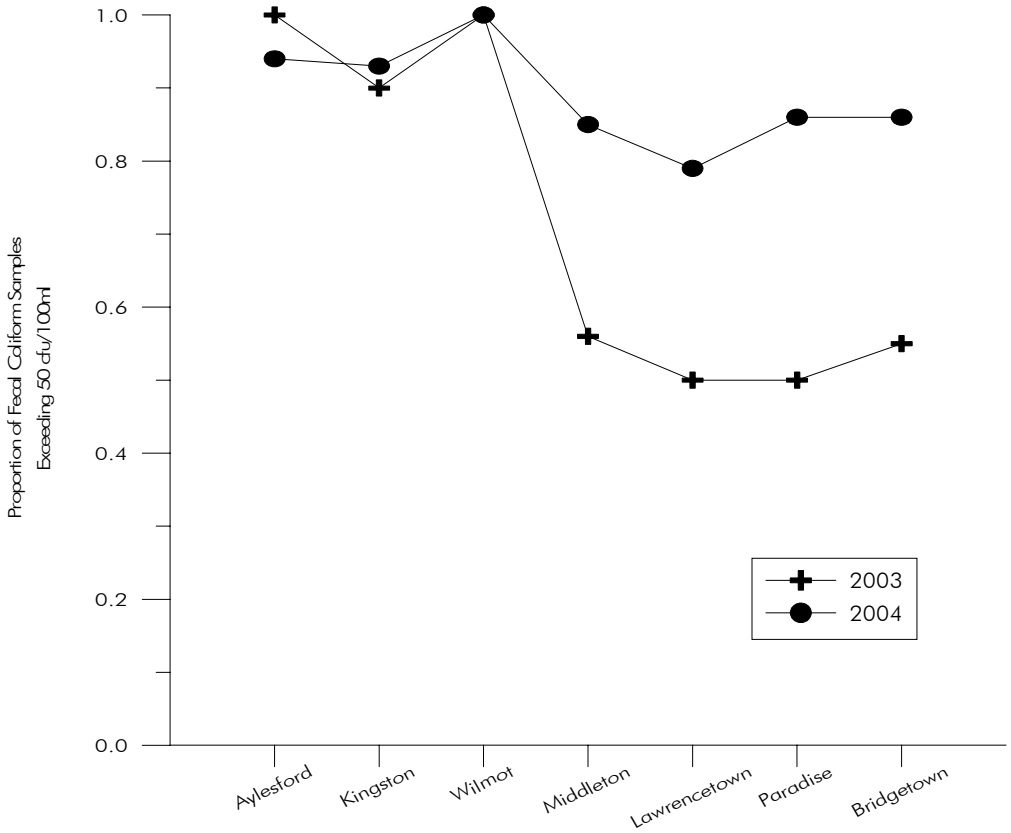

Figure 2: Proportion of Fecal Coliform Samples Exceeding 50 cfu/100 ml, 2003-2004

A slight increase in proportion of exceedences occurred during both years between the Kingston and Wilmot sites. The 2004 SWIM data revealed relatively high fecal coliform concentrations in the Fales River, which enters the Annapolis River between Kingston and Wilmot (See Appendix D). The high fecal coliform numbers from the Fales River therefore may have contributed to the high proportion of samples that exceeded the guideline in Wilmot. Further investigations in this tributary may be warranted in order to expand our understanding of its fecal coliform concentrations and possible sources.

Table 3 presents the proportion samples exceeding the water quality guideline for food crop irrigation.

Table 3: Proportion of Fecal Coliform Samples Exceeding 100 cfu/100 ml

	Aylesford	Kingston	Wilmot	Middleton	Lawrencetown	Paradise	Bridgetown
1992	1.00	0.00	0.67	0.67	0.67	1.00	
1993	0.82	0.57	0.69	0.71	0.79	0.71	
1994	0.67	0.55	0.88	0.82	0.75	0.57	0.69
1995	0.40	0.14			0.80	0.50	0.57
1996	0.50	0.50		0.63	0.79	0.56	0.60
1997	0.71	0.44	0.69	0.63	0.36	0.14	0.53
1998	0.83	0.50	0.10	0.50	0.27	0.40	0.25
1999	0.71	0.53	0.43	0.45	0.00	0.29	0.41
2000	0.60	0.40	0.27	0.23	0.33	0.43	0.07
2001	0.56	0.42	0.50	0.31	0.08	0.45	0.13
2002	1.00	0.33	0.29	0.06	0.38	0.10	0.27
2003	0.70	0.80	0.45	0.33	0.29	0.25	0.36
2004	0.94	0.79	0.79	0.62	0.50	0.64	0.79

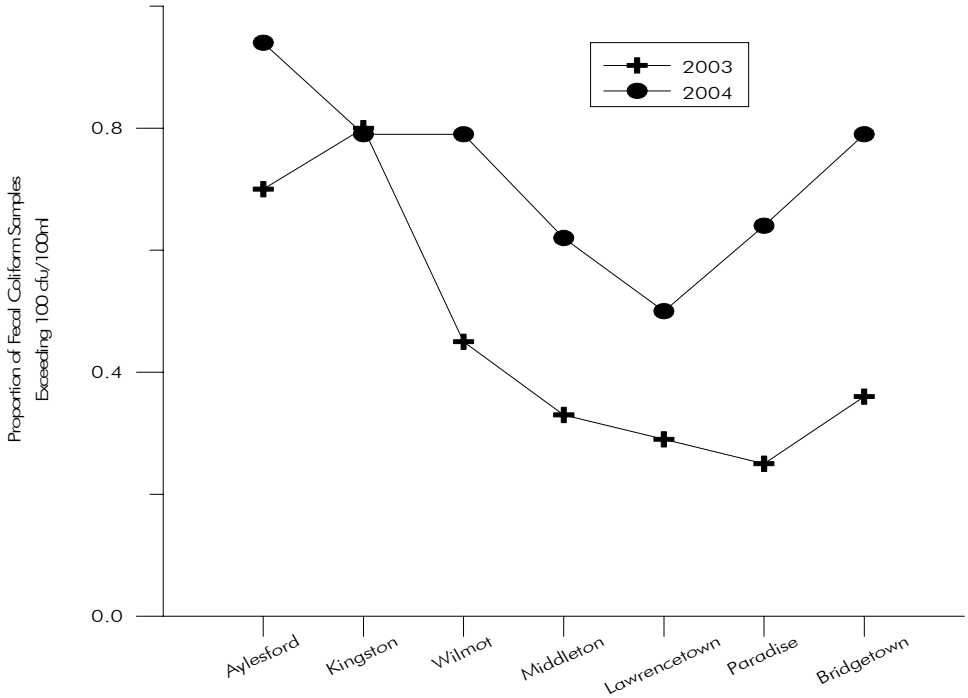

Figure 3: Proportion of Fecal Coliform Samples Exceeding 100 cfu/100ml, 2003 and 2004.

Sites had at least 20% more samples exceeding 100 cfu/100ml in 2004 than in 2003 (with the exception of Kingston). Almost 100% of samples at Aylesford exceeded this threshold, which is the CCME guideline for food crop irrigation. Similarly, nearly 80% of samples at Kingston, Wilmot and Bridgetown exceeded this threshold. These findings are significant in areas that commonly extract water for crop irrigation. Fecal coliform levels at Bridgetown reached an all-time high with 0.79, or 79% of samples exceeding 100cfu/100ml, the highest proportion recorded in 11 years of monitoring at the site.

The proportion of samples exceeding the 100 cfu/100ml guideline at the Wilmot and Paradise sites, as shown in Figure 3, may suggest a stronger decrease in water quality than what actually occurred. The bulk of the data at these two sites was just under the guideline in 2003, and just above the threshold in 2004. Although there was an increase in the proportion of samples exceeding the guideline, the difference in water quality may not have been as strong as it appears in Figure 3. See Appendix E for further information.

Figures 2 and 3 both show a noticeable decrease in proportion of samples exceeding the thresholds between Wilmot and Middleton / Lawrencetown. The cause of the decrease is not known, however several factors may be playing a role. If no new tributary is contributing high levels of fecal coliforms between the two sites, and the volume of water flowing in the river is greater as it moves downstream, a simple dilution effect may be causing the decrease. The 2004 SWIM data has shown however, that the Nictaux River, which enters the Annapolis River between Wilmot and Middleton, contributed moderately high numbers of fecal coliforms relative to other tributaries monitored. The Nictaux River contribution would therefore seem to contradict the observed decrease in this area. Another possible cause for the decrease might include fewer non-point sources along that section of the river. Similarly, fecal coliform die-off may be occurring as water flows through this section of the river.

Table 4 presents the proportion of fecal coliform samples exceeding 200 cfu/100 ml, the water quality guideline for contact water recreation.

Table 4: Proportion of Fecal Coliform Samples Exceeding 200 cfu/100 ml

	Aylesford	Kingston	Wilmot	Middleton	Lawrencetown	Paradise	Bridgetown
1992	0.50	0.00	0.67	0.67	0.33	0.33	
1993	0.55	0.21	0.50	0.29	0.57	0.36	
1994	0.50	0.55	0.56	0.55	0.31	0.57	0.46
1995	0.20	0.14			0.40	0.33	0.29
1996	0.50	0.40		0.38	0.43	0.44	0.40
1997	0.43	0.13	0.19	0.13	0.07	0.07	0.06
1998	0.58	0.13	0.00	0.25	0.09	0.20	0.08
1999	0.43	0.33	0.29	0.18	0.00	0.14	0.18
2000	0.40	0.07	0.18	0.15	0.25	0.43	0.00
2001	0.22	0.25	0.33	0.15	0.08	0.09	0.13
2002	0.50	0.13	0.14	0.00	0.00	0.00	0.13
2003	0.10	0.40	0.27	0.22	0.21	0.08	0.27
2004	0.71	0.36	0.21	0.23	0.29	0.43	0.29

The above table shows a general increase in the data with respect to this threshold, with the exception of two sites, Kingston and Wilmot. Figure 4 presents the proportion of fecal coliform samples collected at Aylesford that exceed 200

cfu/100 ml. Over 13 years of monitoring, the data from this year are the highest ever recorded. Over 70% of samples analyzed exceeded 200 cfu/100ml, and increase of 61% over the 2003 data.

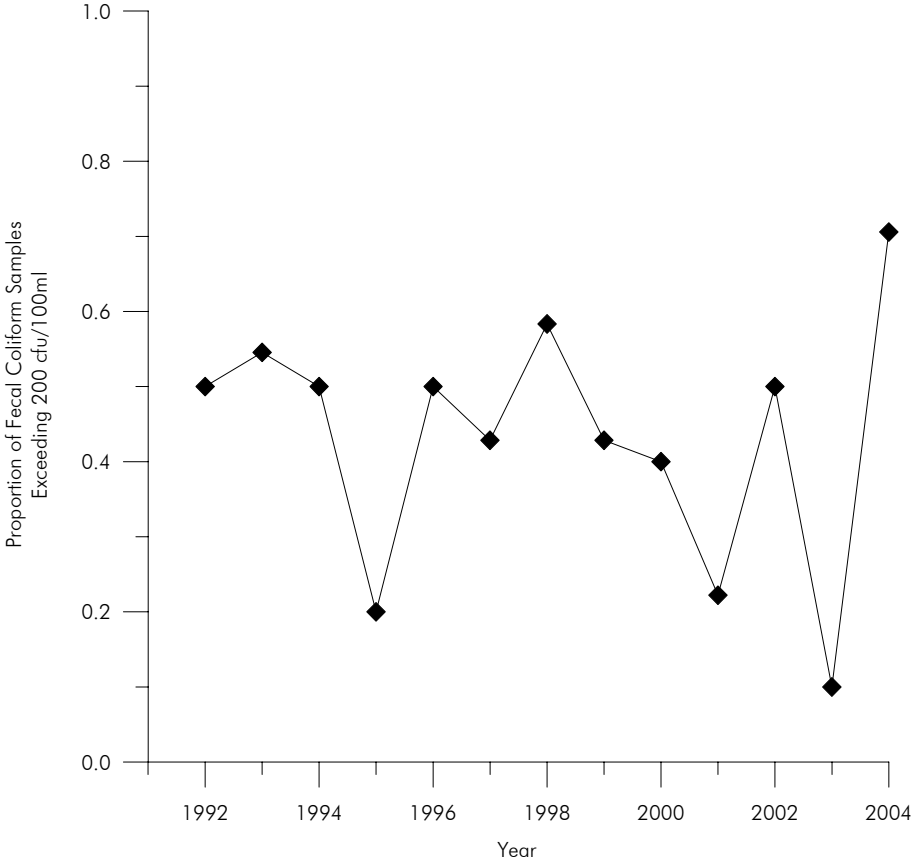

Figure 4: Proportion of Fecal Coliform Samples Collected At Aylesford Exceeding 200 cfu/100 ml.

Discussion

It is evident from the 2004 data that there have been increases in fecal coliform levels all along the main Annapolis River. Proportions of samples exceeding specific water quality guidelines reached record high levels in over 13 years of monitoring from Aylesford to Bridgetown. In Kingston, 93% of samples exceeded the guideline for livestock watering. The lower river sites, which typically had lower fecal coliform levels, also surpassed this threshold regularly in the 2004 season. There were significant increases in the proportion of samples exceeding the guideline for food crop irrigation all along the river. Finally, more samples exceeded the contact water recreation guideline in Aylesford than ever before. These findings are significant in an area such as the Annapolis Valley, which depends on the river as a source of water for all the above-mentioned activities. The natural variability of fecal coliforms makes it very difficult to predict future trends. Although it is evident that 2004 experienced increases in fecal coliform levels when compared to 2003, it is unclear whether this represents a trend.

The long-standing obstacle of source detection continued in 2004. Volunteers have collected ample quantitative evidence of high fecal coliform counts, however the exact source of contamination remains unknown. It is highly likely that several factors are contributing to the increases observed. Listed below are a number of the possible factors, with available information as to likelihood of these factors contributing to elevated fecal coliform numbers.

- Increase in precipitation – an increase in precipitation would result in more runoff in streams, which may increase contamination in some areas The mean precipitation data from 1971-2000 was compared to 2004 precipitations records (Environment Canada, 2005). This comparison revealed a drier year in 2004 than the 29-year mean. The months of May through August were on average over 30mm drier than the 29-year mean.

- Increase in human population – an increase in population would increase the pressure on both municipal sewage treatment plants and on-site septic systems. Increased pressure on existing infrastructure may increase the likelihood of malfunction.

- Changed agricultural practices / increase in livestock population – an increase in cattle access to streams and/or an increase in livestock population would increase the likelihood of contamination events. .

- Lower water temperature – there appears to be an inverse relationship between temperature and fecal coliform mortality; the lower the temperature, the longer the survival time (Jamieson et al, 2002). A seasonal analysis of water temperature data in the Annapolis River revealed that during the summer, when fecal coliform concentrations have been generally quite high, water temperatures are at their highest.

- Lower in stream flow – lower in stream flows may result in higher concentrations even though the actual fecal coliform bacteria numbers stay the same. A drier season in an area where surface runoff is not the major source of contamination may result in higher fecal coliform concentrations.

- On-site septic (domestic) septic systems / municipal sewage treatment plant – improperly maintained on-site systems are a common non-point source of fecal contamination in the Annapolis River Watershed. Continued mismanagement of these systems as well as inadequate municipal sewage treatment plants can contribute significant amounts of fecal coliforms to waterways.

Without the proper source detection tools, it is difficult to focus remediation efforts. In order to continue moving forward, it is essential for CARP to maintain support for the development of microbial source tracking (MST) technology. The importance of continued monitoring is considerable at this time, as the use of modern technologies such as MST require the collection of quantitative data, such as that being collected by River Guardian volunteers.

Future Research

Previous attempts have been made to examine the relationship between fecal coliform levels and individual rain events, but have proven to be inconclusive. In order to better understand the impact of precipitation on possible fecal coliform sources, it is recommended that this area be investigated further, but at a larger temporal scale. Fecal coliform levels over a number of years (5 to 10) will be compared against monthly precipitation data. It is hoped that by conducting this analysis for each sample site, an indication will be provided as to the principal source type (e.g. malfunctioning on-site systems, surface runoff) at that location.

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 dissolved oxygen in solution, just as terrestrial organisms need oxygen for external 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, other highly organic inputs and lower rates of photosynthesis and diffusion from the atmosphere due to ice cover can lead to decreased oxygen levels.

As the temperature of water decreases, a greater concentration of oxygen is able to dissolve in the water. 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. As water temperature decreases, more oxygen can be dissolved. 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, including fish.

Monitoring Results

a) How have dissolved oxygen levels changed over 13 years of monitoring on the main Annapolis River?

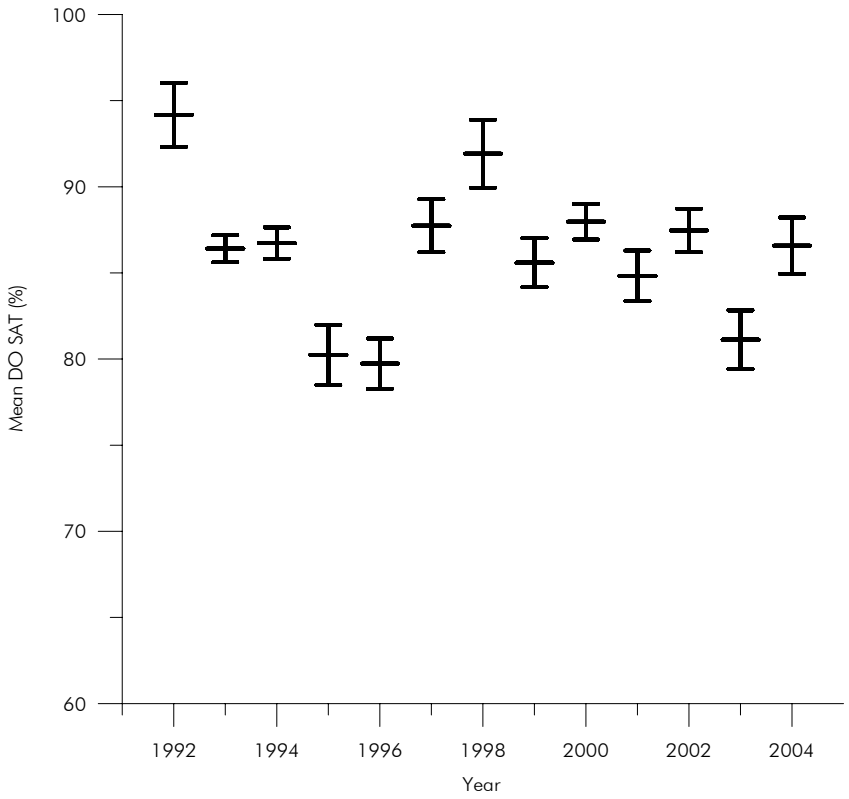

Figure 5: Mean Dissolved Oxygen Saturation (DO SAT) by year 1992 to 2004 (showing standard error of the mean)

The above figure shows that during the period of 1992 to 2004, annual mean dissolved oxygen (percent saturation) levels have varied from a high of 94.2% in 1992, to a low of 79.7% in 1996. For the values recorded during 2004, the mean dissolved oxygen saturation was 86.6%, which is within the normal range. Although it increased slightly from the 2003 data (81.1%), it does not appear to form any trend, but rather follow the natural fluctuation. The standard error of the mean is shown with error bars.

The Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life for Dissolved Oxygen is 5.5 mg/L (CCME, 2002). Only two of the seventy-five water samples analyzed by the Annapolis River Guardians had dissolved oxygen levels below this guideline (Paradise, August 8, 4.20 mg/L and Bridgetown, September 6, 4.80 mg/L).

b) How do Dissolved Oxygen levels differ between each of the main river sampling sites?

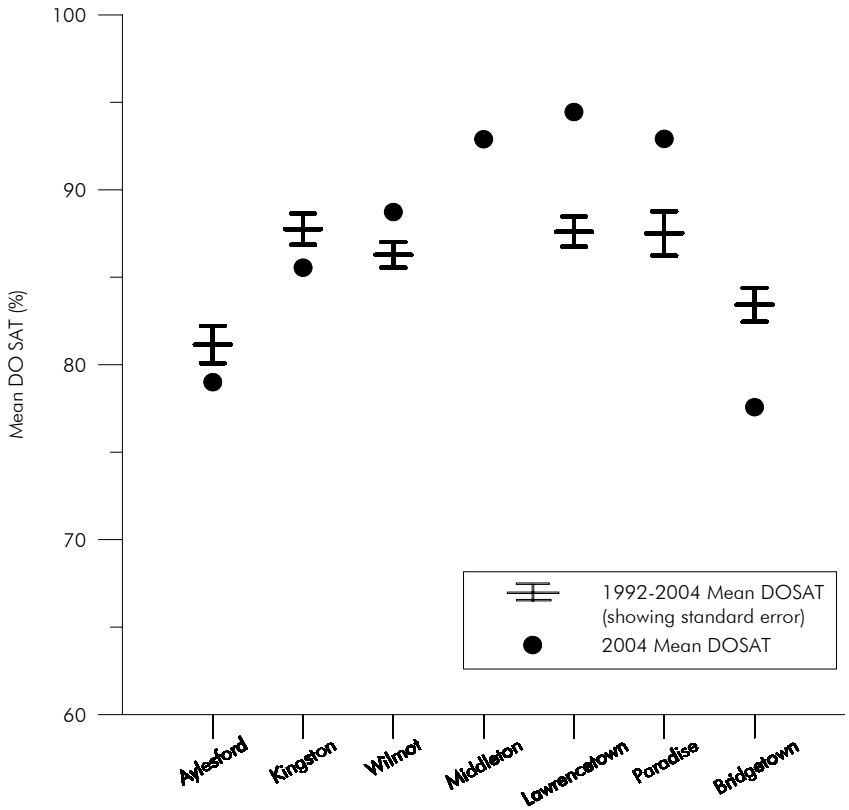

Figure 6: Mean Dissolved Oxygen Saturation (DO SAT) by sampling site, 1992 to 2004 (showing standard error of the mean)

Figure 6 presents the 13-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 2004 monitoring season. From this data, there does not appear to be a significant increasing or decreasing trend for any of the sites. A 13-year mean for Middleton is not available, as dissolved oxygen monitoring was not conducted at this site during 1995, 1996, and 1997.

c) Which River Guardian monitoring sites experienced low dissolved oxygen levels in 2004?

Table 5: Dissolved Oxygen Percent Saturation (DOSAT) Thresholds for Annapolis River.

Site	Number of Samples Collected in 2004	Percentage of samples with DOSAT below 60%	Percentage of samples with DOSAT below 75%	Percentage of samples with DOSAT above 75%
Aylesford	21	0	29	71
Kingston	19	0	5	95
Wilmot	21	0	0	100
Middleton	19	0	0	100
Lawrencetown	18	0	0	100
Paradise	20	5	5	95
Bridgetown	24	4	17	83

The data presented in Table 5 identifies the Aylesford site as having lower dissolved oxygen levels (below 75% DOSAT) more frequently. Of the 21 dissolved oxygen measurements recorded at Aylesford in 2004, 29 percent had dissolved oxygen saturation levels below 75%. Sites at both Bridgetown and Paradise recorded DOSAT levels below 60%; however this happened very rarely, on only one occasion at each site.

Although Aylesford had consistently lower DOSAT levels, there is a considerable improvement over data from the previous year. In 2003, 15% of samples taken at Aylesford were below 60% DOSAT, and 31% of samples were below 75%. Dissolved Oxygen levels at the other River Guardian sites were generally good.

Future Research

The cause of the high occurrence of low dissolved oxygen samples in Bridgetown is unknown; however, it is clear from temperature, chloride, and sulphate data collected at that site, that it is subjected to tidal influences. It is not clear though how these and other parameters change through the tidal cycle. The impact of both the tidal cycle, and depth at which the River Guardian sample is collected, is not known. Within the SWIM program, it is recommended that a study be conducted at this location, to assess the impact of the tidal cycle on dissolved oxygen, temperature, nitrate and fecal coliform levels. This would involve collection of samples for these parameters at various depths and at the various tidal stages. This study should be completed at least twice during a single month to assess the impact of the Spring versus Neap tides, and at a differing times of the year to determine the impact of river discharge during different seasons.

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 20°C, with lethality occurring with prolonged exposures to temperatures over 24°C (MacMillan *et al,* 2003).

Monitoring Results

The analysis of historical temperature data conducted for the 2003 Annual River Guardian Report revealed a possible warming trend in the mean summer water temperatures for the Annapolis River. The magnitude of the increase, particularly over the years 1996-2003 was potentially significant and a cause for concern if the trend were to continue.

The mean summer water temperature for the Annapolis River in 2004 was 18.6°C, or 1.3°C cooler than the previous year. Although the mean is lower in 2004, temperatures continue to reach levels stressful to aquatic life regularly during the summer months. Although there was a decrease in mean summer temperature, this important indicator should continue to be monitored closely. Figure 7 presents the mean seasonal water temperature by year for all the mainstem monitoring sites. For the following analysis, the data has been grouped into 3 periods as follows: Spring (April, May, June), Summer (July, August, September), and Fall (October, November, December).

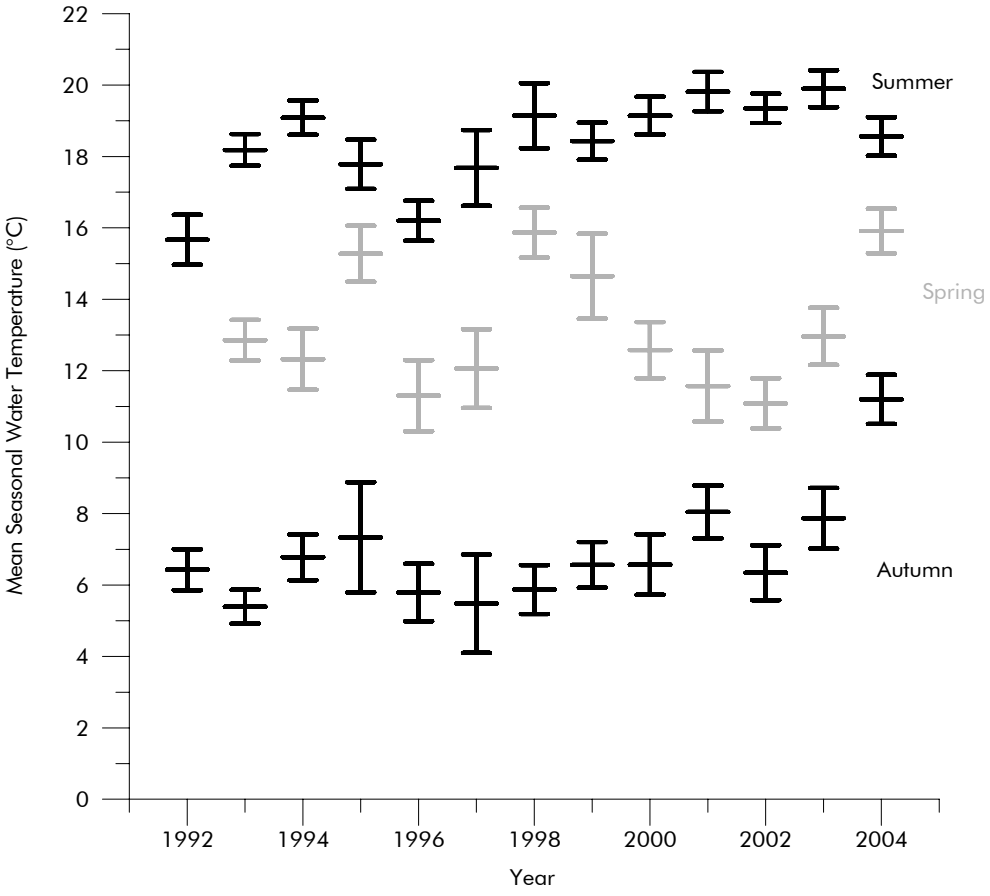

Figure 7: Mean Seasonal Water Temperature by Year, 1992-2004 (showing standard error of the mean)

Figure 7 also shows that the mean spring temperatures are highly variable from year to year. The summer and autumn temperatures generally do not vary as much from one year to the next; however, the mean autumn temperature was abnormally high in 2004, the highest by far in 13 years of monitoring.

The data from the 2003 River Guardians annual report suggested a gradual increase in temperature in the lower river sites, particularly in the summer data. Figure 8 presents the mean summer water temperature along the main Annapolis River in 2004, and shows that this spatial trend was maintained. Of the 34 temperature measurements recorded during the months of July, August and September, approximately one-third exceeded 20°C. The maximum temperature observed was 23.5°C, recorded at Middleton on August 22. Between Aylesford and Bridgetown, the mean summer water temperature increased by approximately 5°C. This warming trend is expected in most rivers and does not necessarily indicate an anthropogenic influence on water temperature.

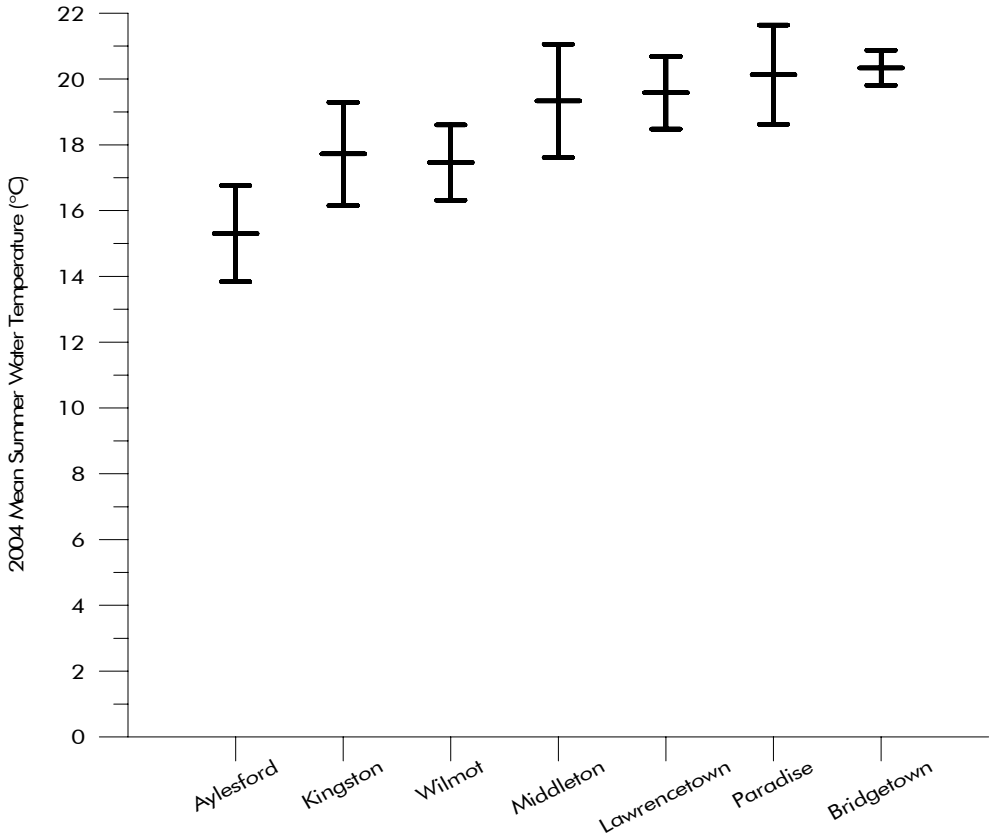

Figure 8: Mean Summer Water Temperature by Site, 2004 (showing standard error of the mean)

Future Research

It is known that surface waters undergo a daily cycle of warming and cooling. The magnitude of this cycle for the Annapolis River is not known. This, coupled with fact that River Guardian volunteers do not all collect their water samples at the same time, introduces an unknown level of variability into the River Guardian temperature results. Within the SWIM program, it is recommended that a study be conducted to assess the magnitude of the daily temperature cycle at a number of locations along the Annapolis River. Temperature measurements should be conducted at a number of times over the course of the sampling season. Through this study, the degree of variability caused by River Guardians collecting their samples at differing times could be assessed and addressed.

Nitrate-N, Chloride and Sulphate

Introduction

Elevated levels of nitrate in aquatic systems can originate from a variety of sources, including municipal wastewater, the use of chemical fertilizers and manure on agricultural land, industry, and atmospheric deposition. There are two common ways for laboratories to report nitrate concentration: nitrate-nitrogen (NO_3-N) and total nitrate (NO_3). The following guidelines as well as the data collected by River Guardians are expressed as nitrate-nitrogen (NO_3-N), and represent the amount of nitrogen in the nitrate form. The Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life for Nitrate is 13 mg/L (CCME, 2002). Table 6 shows nitrate guidelines for various freshwater uses, as either maximum or 30-day average concentrations.

Table 6: Water Quality Guidelines for Nitrate-N (mg/L)

NO_3-N (mg/L)	Water Use
<40 (average)	Protection of freshwater aquatic life
<10 (maximum)	Acceptable for recreational use
<100 (maximum)	Acceptable for livestock watering

Source: Province of British Columbia (Website: http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/approved_3.html#16)

Nitrate-N levels as low as 2.5 mg/L have been shown to cause chronic effects in a number of amphibian species (Chambers *et al,* 2001). Generally, nitrate-N levels above 1-2 mg/L indicate that the water body may be affected by anthropogenic sources.

During the 2003 season, volunteers estimated nitrate concentrations using Hach Test Strips. The protocol involved dipping the strips in water and matching the change in colour to a chart to estimate nitrate concentrations in parts per million. Although the test strips were stored in sealed containers with desiccant material at all times, a gradual discolouration of the strips was observed throughout the course of the season. Due to the qualitative nature of the protocol and resulting data, a different, more quantitative protocol was used in the 2004 season. During each collection event, a separate water sample was collected and sent for nitrate-N analysis at Environment Canada's laboratory in Moncton, New Brunswick. The samples were analysed using the more reliable technique of ion chromatography. This technique simultaneously measures levels of nitrate-N, chloride and sulphate, all of which are summarized in Table 7 below.

A common source of chloride in freshwater rivers and streams is runoff from road salt applied during winter. Other sources include effluent from industry, sewage and irrigation drainage (Nagpal *et al,* 2003). There is currently no Canadian guideline for chloride in freshwater ecosystems, however guidelines developed by the province of British Columbia suggest chronic exposure to chloride levels greater than 150 mg/L may be harmful to freshwater aquatic life, particularly vegetation and invertebrates. Acute exposure should never surpass levels of 600 mg/L.

Some anthropogenic sources of sulphate include industrial waste from mines, use of sulphate fertilizers as well as the burning of fossil fuels. It is believed that elevated levels of sulphate may negatively impact some aquatic organisms, such as some fish and aquatic mosses (Singleton, 2000). Currently, the Canadian Council for Ministers of the Environment (CCME) has no guideline on sulphate for the protection of freshwater aquatic life; however, according to British Columbia guidelines, sulphate levels in most freshwater bodies should not exceed 50 mg/L.

Monitoring Results

Table 7: River Guardian Data for Nitrate-N, Chloride and Sulphate

Site	Mean Nitrate-N (mg/L)	Mean Chloride (mg/L)	Mean Sulphate (mg/L)
Aylesford-00	0.70	17.71	9.66
Kingston-13	0.58	14.33	7.74
Wilmot-18	0.63	19.43	16.04
Middleton-25	0.38	16.30	14.17
Lawrencetown-35	0.42	18.42	14.02
Paradise-40	0.34	18.62	15.66
Bridgetown-49	0.34	1833.16	257.59

Table 7 shows that mean chloride and sulphate levels are well below the recommended guidelines. The high levels of both parameters at the Bridgetown site are due to the presence of brackish water, as this site has tidal influence. Both chloride and sulphate are abundant natural components of seawater.

Aylesford continues to have the highest levels of nitrate-N, ranging from 0.43 to 1.26 mg/L. Figure 9 shows the mean nitrate-N values for 2004, with the standard error of the mean. The upper river sites (Aylesford, Kingston, Wilmot) have the highest nitrate-N levels, followed by lower river sites (Middleton, Lawrencetown, Paradise, Bridgetown).

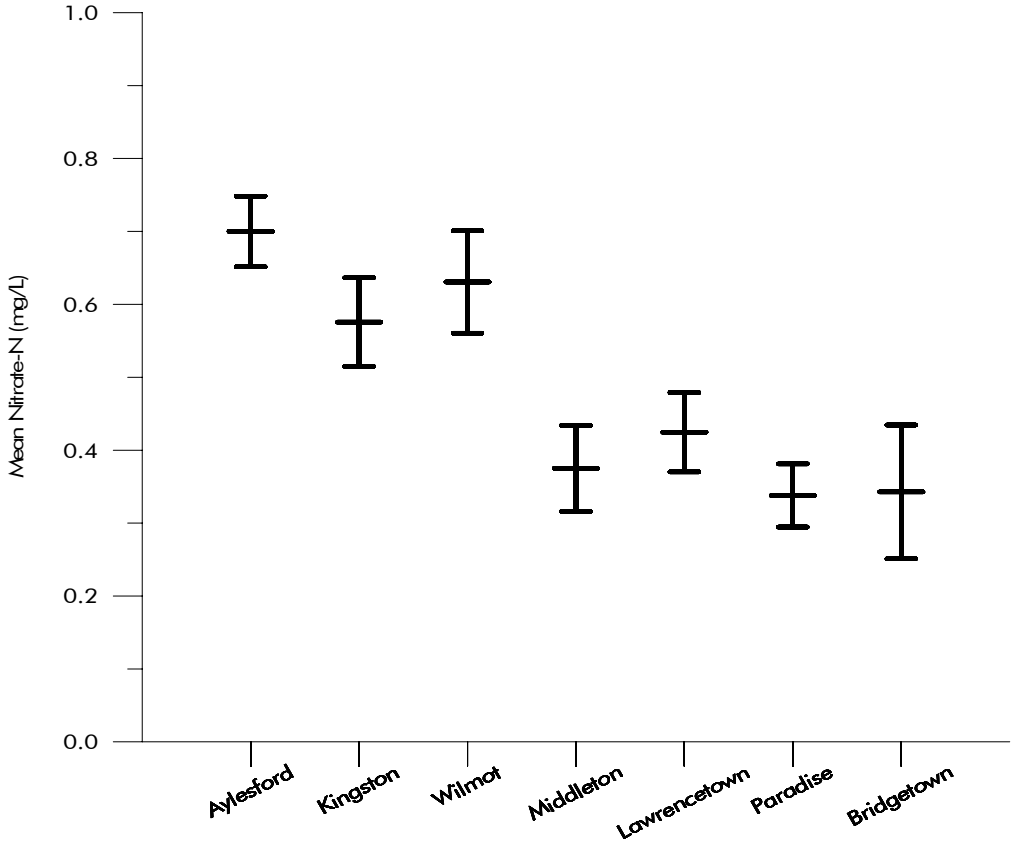

Figure 9: Mean Nitrate-N by Site, 2004 (showing standard error of the mean).

The decrease in nitrate-N concentrations between the Wilmot and Middleton sites suggests an input of low nitrate-N water from a tributary. The Nictaux River enters the mainstem between these two sites. The 2004 SWIM data showed its nitrate-N contributions to be low to moderate relative to other major tributaries monitored.

Discussion

Nitrite is another form of nitrogen that exists in surface waters. According to British Columbia guidelines, nitrite-nitrogen (NO_2-N) in excess of 0.06 mg/L can be harmful to freshwater aquatic life. Over the long term, a thirty-day mean concentration of 0.02 mg/L is recommended to ensure the protection of aquatic life.

In 1998, Dalziel *et al* reported on an investigation into the inorganic water quality of major rivers in the Maritimes. During the period of analysis (1992 to 1996) this study found that the Annapolis River had some of the highest levels of nitrate + nitrite of all rivers in mainland Nova Scotia. Concentrations were found in the range of 2 to 6 ppm (equivalent to 2 to 6 mg/L nitrate + nitrite in water).

Due to these historically high levels of nitrate/nitrite on the Annapolis River, as well as preliminary nutrient data collected in 2003 by the River Guardians, further nitrate analysis was recommended for the 2004 sampling season. Mean nitrate-N values in 2004 were well below the recommended guideline for aquatic life (40 mg/L); however, some measurements at the Aylesford site surpassed the 1-2 mg/L threshold, suggesting an anthropogenic input. No nitrite data was collected in 2004.

Future Research

Nitrogen in surface waters can occur in three possible biologically important forms: nitrate, nitrite, and ammonia. The 2004 nitrogen monitoring only conducted analysis for nitrate and thus can only present a partial picture of nitrogen levels in the Annapolis River. Phosphorus is another important nutrient in freshwaters, which can have a limiting effect on biological activity. There is little information available on phosphorus levels in the Annapolis River. It is recommended that the River Guardian nutrient monitoring be expanded to include the three forms of nitrogen, and phosphorus. By conducting this analysis over a two-year period, a much clearer picture of nutrient levels would emerge, allowing specific nutrient parameters of concern to be identified for subsequent long-term monitoring.

pH and Conductivity

Introduction

pH is a measure of the acidic/basic nature of water and is determined by measuring the concentration on the hydrogen ion (H^+). It is expressed on a logarithmic scale from 0 to 14, zero being the most acidic. Because the scale is logarithmic, every increase in the pH scale represents a tenfold increase in alkalinity. 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 negatively 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.

Conductivity is a measure of water's ability to conduct an electrical current, measured in millisiemens per centimeter (mS/cm). The greater the conductivity, the greater the amount of ions in the water. Some sources of pollution, including industrial and municipal effluent as well as road salt, increase the number of ions contained in the water. Sharp increases (or decreases) in conductivity can therefore signal anthropogenic inputs in a river system. There is currently no national guideline for conductivity in freshwater. Rivers and streams that are not influenced by anthropogenic sources typically have conductivity in the range of 0.05-1.5 mS/cm. Seawater has much higher conductivity due to the dissolved salts, and can reach values as high as 50 mS/cm.

pH and conductivity were measured on the Monday 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

Table 8 summarizes the mean pH and conductivity values at each River Guardian monitoring site.

Table 8: Mean pH and Conductivity Values at Each River Guardian Monitoring Site, 2004

Site	Mean pH	Mean Conductivity (mS/cm)
Aylesford – 00	6.90	0.15
Kingston – 13	7.02	0.13
Wilmot – 18	7.04	0.17
Middleton – 25	6.91	0.14
Lawrencetown – 35	6.88	0.15
Paradise – 40	7.03	0.14
Bridgetown – 49	6.95	5.64

Table 8 shows that pH values all along the Annapolis River are generally very good. They are consistently well within the range recommended by the CCME for the protection of freshwater aquatic life. The underlying geology in the area, the Torbrook formation, contains limestone that buffers rivers and streams in the watershed from acidification. In the past several decades, many streams in Nova Scotia have experienced decreasing pH levels as precipitation becomes more and more acidic due to increasing air pollutants. The buffering capacity of the underlying geology of the Annapolis River and many of its tributaries in effect protects the system from this decreasing pH trend.

Conductivity values for all the River Guardian sites were also well within the natural variability of fresh/brackish water. The range of conductivity for all sites (expect Bridgetown) was 0.07-0.24 mS/cm. No sharp increase or decrease in conductivity was observed at either of the River Guardian sites throughout the sampling season. In Bridgetown, the high conductivity values are due to the brackish water in that part of the estuary.

Conclusions

The 2004 monitoring season showed a general increase in fecal coliform levels along the Annapolis River. Elevated levels of fecal coliforms have again been observed at the upper river sample sites (Aylesford, Kingston, Wilmot). During 2004, the lower river sites (Middleton, Lawrencetown, Paradise and Bridgetown), which seemed to show a general improvement over the past few years, exceeded the guideline for food crop irrigation more frequently (CCME, 2002). The proportion of samples exceeding this guideline, particularly at Wilmot and Paradise, may represent only a minor reduction in water quality though. Of 100 main-river samples analyzed for fecal coliforms, 37 exceeded the contact water recreation guideline of 200 cfu/100ml. Of these 37 samples, 32% were collected from a single site, Aylesford.

Levels of dissolved oxygen have remained within the normal range for the Annapolis River. Over 12 years of monitoring, mean DOSAT levels have remained in the range of 80-94%. In 2004, the mean DOSAT level was just under 87%. The Aylesford site showed some improvements however, with no samples having saturation levels below 60%. Two of the seventy-five water samples analyzed for dissolved oxygen fell below the CCME guidelines for the protection of freshwater aquatic life of 5.5 mg/L (CCME, 2002).

Although the mean summer water temperature of 18.6ºC was down by 1.3ºC from 2003, water temperatures continue to reach levels stressful to aquatic life regularly during the summer months. Although there appears to be an improvement in temperature, this important indicator should continue to be monitored closely. A spatial trend of higher mean summer water temperatures in lower river sites was maintained in 2004. Between Aylesford and Bridgetown, the mean summer water temperature increased by approximately 5ºC. This increase is expected in most rivers.

The more quantitative method of ion chromatography was used to analyze nitrate-N samples in 2004. Results from the analysis showed Aylesford to have the highest levels of all sites, with a mean nitrate-N level of 0.70 mg/L. The lower river sites of Middleton, Lawrencetown, Paradise and Bridgetown generally had lower levels of nitrate-N in the range of 0.34-0.42 mg/L. These were well below the 1-2 mg/L threshold typically used to signal an anthropogenic influence and all were well below the CCME guideline recommended for the protection of freshwater aquatic life (13 mg/L) (CCME 2002). Levels of chloride and sulphate were within the range expected in freshwater/estuarine ecosystems.

pH levels at each of the River Guardians sites were consistently very good, never exceeding the recommended range for the protection of aquatic life. The underlying geology of the area greatly contributes to the near neutral pH values by buffering the effects of acid rain. Conductivity values were also well within the natural variability of fresh/brackish water.

The accuracy of the River Guardians' dissolved oxygen readings were generally very good, averaging at +/- 0.85 mg/L. Laboratory, field and travel blank samples analysed for fecal coliforms consistently produced plates with 0 cfu/100ml. Duplicate samples analysed for fecal coliforms revealed high heterogeneity in the water column (13.5% relative percent difference (RPD)), as did duplicate samples analysed for nitrate-N (25.6% RPD). Chloride and sulphate duplicate samples suggested a much more homogenous distribution for chloride and sulphate (0.73% and 1.43% RPD, respectively).

Recommendations

Recommendations for the River Guardians Program

- Ensure that at least 10% of samples collected are for quality assurance / quality control purposes (see Appendix D for 2004 QA/QC results). Ensure split samples are collected for all parameters to allow a more thorough evaluation of result variability (i.e.: sample collection vs. laboratory procedure).
- Given the relative stability of dissolved oxygen in the Annapolis River, reduce the frequency of testing for this parameter.
- Given the high variability and problematic nature of fecal coliforms, increase bacterial sampling efforts. Consider switching from fecal coliform to E.coli, which is becoming increasingly accepted as the standard in water quality monitoring. Consider quantifying another bacterial parameter, such as total aerobic bacteria, to determine if the variability is specific to fecal coliforms.
- Given the high rate of road salt application during the winter, consider monitoring chloride levels during snowmelt.
- Expand the River Guardian nutrient monitoring to include the three biologically important forms of nitrogen, and phosphorus. By conducting this analysis over a two-year period, a much clearer picture of nutrient levels would emerge, allowing specific nutrient parameters of concern to be identified for subsequent long-term monitoring.
- Given the high variability between fecal coliform duplicate samples, examine the current fecal coliform data dissemination methods (i.e.: roadside signs) and consider alternative methods that could be more representative of water quality.

Recommendations for the SWIM Program

- Examine the relation between observed increases in water temperature to air temperature data to determine if increases are due to climate trends, riparian changes, or other factors that may be influencing flow patterns.
- Examine in further detail the water temperature data to determine whether any statistically significant trends are occurring.
- Given the high contributions of fecal coliforms observed in 2004 from the Fales River, conduct further investigations on this tributary (i.e.: monitoring upstream/downstream of suspected point sources) to gain a better understanding of the sources of fecal coliforms.
- Given the high contributions of fecal coliforms observed in 2004 at the Aylesford site, conduct further investigations above this point to gain a better understanding of the sources of fecal coliforms.
- Examine the relationship between fecal coliform levels at each site over 5-10 years and the monthly precipitation data in order to better understand the influence from different sources (i.e.: surface vs. on-site sources).
- Examine both the tidal cycle and the depth of sample collection at the Bridgetown site to assess their impact on dissolved oxygen, temperature, nitrate, and fecal coliforms.
- Assess the magnitude of the daily temperature cycle at a number of locations along the Annapolis River to better understand the degree of variability caused by different sampling times by River Guardians.

Recommendations for CARP

- Continue supporting Microbial Source Tracking (MST) methods in order to more effectively identify and remediate the sources of fecal contamination in the Annapolis River.
- Complete the Quality Assurance Project Plan for all of CARP's Water Quality monitoring programs.
- Complete the benthic invertebrate survey of the mainstem Annapolis River to help identify some of the major sources of contamination.

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Appendices

Appendix A – Parameters Tested and Methodologies

Parameters Analyzed in 2004	Additional Parameters Analyzed in Previous Years of the Program
Fecal coliform densities	Salinity
Dissolved Oxygen	Chlorophyll a
Temperature (Water and Air)	Total Suspended Solids (TSS)
Weather conditions	Colour
Nitrate-N, Chloride, Sulphate	Transparency
pH, Conductivity, Total Dissolved Solids	

Water Collection and Fecal Coliform Enumeration

Following the contamination of some sampling equipment in 2003, a new collection procedure for fecal coliform samples was developed for the 2004 season. The sample collection unit is shown in Figure A1.

Figure A1 – Collection Unit Used for Fecal Coliform Samples in 2004.

The open sample bottle is secured in the clamp, and lowered from the mid-span of the bridge into the river. After collection, water samples are refrigerated until delivery to the lab, typically within 24 hours of collection. A measured volume of the sample is filtered through a filter pad, which is in turn transferred onto an absorbent pad containing fecal coliform selective growth media. Samples are incubated for 24 hours (+/- 2 hrs) at 44.5 ^{o}C. Visible colonies of navy blue colour are counted and expressed as the number of colony forming units (cfu) per 100 ml of sample.

For the 2004 season, the membrane filtration procedure was used to determine fecal coliform densities. The analysis was conducted at the Synova Diagnostic Inc. laboratory in Lawrencetown. The Synova lab is accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL) to perform the membrane filtration procedure.

Analytical laboratories are not currently required to report the percent error with their fecal coliform results. This is currently being phased in by CAEAL over the next 12 to 24 months. As part of its internal quality control procedures, the Synova laboratory regularly assesses the precision of their procedures. For fecal coliform samples in the range of 0 to 50 cfu/100 ml, the laboratory reports precision levels of 11%. See Appendix C for further information on the precision of the Membrane Filtration procedure at Synova.

From 1997 to 2003, fecal coliform densities were determined using the IDEXX Colilert procedure, to give a Most Probable Number of *E. coli* bacteria present. Preliminary investigations locally have indicated that the membrane filtration procedure and the IDEXX system provide comparable results (B. Reid, personal communication). A replicate study, which was conducted by Synova in the winter of 2004 to compare both methods, gave very similar results. Twenty replicate samples were taken from the Annapolis River. Ten samples were tested for fecal coliforms using the membrane filtration method, while the other ten were tested for total *E. coli* using the Colilert Most Probable Number method (Table A1). Not only did the two methods give similar results, but their coefficients of variation were also very similar. Additional testing was done in the Spring of 2004 to determine if the fecal coliforms growing on the plates were in fact *E. coli*. A study on 20 split samples collected showed that the fecal coliforms were over 90% *E.Coli* (B. Reid, personal communication, July 28, 2004). Based on the replicate and split studies, for the purpose of this report, it is assumed that the results from these two methods are comparable. See Appendix C for further information on the accuracy of the MFC method at Synova.

Table A1: Results from Synova Replicate Study, Membrane Filtration vs. Most Probable Number (December 2004)

Method	Results (n=10)	1 Standard Deviation	Coefficient of Variation (%)
	Average Count, cfu/100ml		
Fecal Coliform MFC	96	10.7	11.1
	Most Probable Number/100ml		
E. coli MPN	97	10.1	10.4

Dissolved Oxygen Content

Dissolved Oxygen samples are collected from the mid-span of bridges using a horizontal Van Dorn sampler. Dissolved Oxygen in mg/L is determined using the modified Winkler Titration using pre-packaged Hack 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.

Temperature

The Annapolis River Guardians used a combination of glass / alcohol and digital thermometers during 2004. 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 calibrated and has a reported accuracy of +/- 0.10 ^{o}C. From this comparison, a correction factor was determined for each River Guardian thermometer. These correction factors were applied to all River Guardian temperature measurements.

Nitrate-N, Chloride, Sulphate

Water samples for nitrate-N, chloride, and sulphate analysis were collected using the sampling equipment described above for fecal coliforms and shown in Figure A1. Water samples were refrigerated following collection and transported

to Environment Canada's Moncton laboratory within two to four days. The analysis was done using a Dionex Ion Chromatograph, which allows for the measurement of several nutrients simultaneously. The average recovery for each parameter is reported to be 100%, 101% and 101% for nitrate-N, chloride and sulphate, respectively.

pH, Conductivity

Water chemistry data including pH and conductivity was collected using CARP's portable HydroLab Quanta Water Quality Monitoring System. Data was collected on a fortnightly basis by CARP staff, typically the Monday following the volunteers' sampling day, at a set location on the riverbank at each River Guardian site. The meter was placed in the river a couple meters away from the bank, and allowed to stabilize, usually two to three minutes. 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 was also stored in 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. More information on calibration procedures can be found in the HydroLab Operating Manual at the CARP office.

Appendix B — Sites Monitored

The following sites have been monitored by the Annapolis River Guardians program over the period of 1992 to 2004. The sites monitored during 2004 are highlighted. These sites also have Global Positioning System coordinates given, in Universe Transverse Mercator, as recorded on a hand-held GPS (L. Durland, personal communication, 2002).

SITE	LOCATION	Easting	Northing
A1	Aylesford East, Parker Road, bridge		
A21	Aylesford, Sun Valley Drive (by the Cranberry Farm)		
A22	Aylesford, Hwy 1, bridge over Patterson Brook		
00	**Aylesford, Victoria Road, bridge at the Post Office**	**353313.34**	**4985418.70**
01	Aylesford, Maple Ave. (bridge below Sewage Treatment Plant)		
A3	Millville, Bridge over South River		
A14	Auburn, Musgrave Road, bridge		
A5	Auburn, Sawmill, bridge		
A6	Greenwood, Hwy 201, (Glebe Road), bridge		
13	**Kingston, Bridge Street, bridge**	**346748.46**	**4982480.39**
14a	Kingston, Bridge St. bridge over Zeke Brook, below CFB Greenwood		
14b	Greenwood, hall Road culvert, above CFB Greenwood		
A8	Greenwood, Hwy 201, bridge over Fales River		
15a	Kingston, south from Hwy 1, railway bridge over Walker		
17a	Wilmot, south from Hwy 1, railway crossing over Wiswall Brook		
17b	Wilmot, Hwy 1, bridge over Wiswall Brook		
17e	Melverne Square, Spa Springs Road, bridge over Wiswall Brook		
A20	Wilmot, Dodge Road, river shore		
18	**Wilmot, Old Mill Road, bridge**	**342100***	**4979500***
19a	Wilmot, Todd Branch Road, bridge over Black River		
19b	Meadowvale near Kingston, Torbrook Rd, bridge over Black River		
19c	Torbrook, Uhlman Branch Road, bridge over Black River		
19d	Torbrook, Torbrook Road, bridge over Black River		
19e	Torbrook, Messenger Rd, bridge over Black River		
19f	Torbrook, Messenger Road, Black River tributary (W. of county line)		
19g	Torbrook, Messenger Road, Black River tributary (W. of R. Chase farm)		
19h	Torbrook, Meadowvale Rd. Black River tributary (E. of county line)		
19I	Torbrook, Meadowvale Road, bridge over Black River		
21	West Wilmot, Bayard (previously Carleton) Road, bridge		
24a	Nictaux, Hwy 201, bridge over Nictaux River at old sawmill dam		
24m	Nictaux, Nictaux River's mouth		
25	**Middleton, Highway 10, bridge**	**336981.58**	**4978044.59**
31	Brickton, Mount Hanley Road, bridge		
31-x	North Williamston, Keith Lane, bridge over Delancey Brook		
35	**Lawrencetown, Lawrencetown Lane, bridge**	**329581.15**	**4971984.70**
40	**Paradise, Paradise Lane, bridge**	**325738.51**	**4970620.51**
49	**Bridgetown, Queen Street, bridge**	**318900.00**	**4967621.30**
50a	Bridgetown, Highway 1, bridge over the Solomon Chute Brook		
50b	Bridgetown, Church St. bridge over the Solomon Chute Brook		

SITE	LOCATION	Easting	Northing
51	Bridgetown, Jubilee Park, river shore		
53	Bridgetown, below mouth of Bloody Creek, on the river from a boat		
53a	Bridgetown, Highway 201, bridge over Bloody Creek		
60	Centrelea, 300m below Britex, on the river from a boat		
A19	Belleisle, Hebb's Landing (picnic park), river shore		
64	Upper Granville, river shore or from a boat		
75.1	Granville Centre, on river from boat (surface water at the depth of 1 m)		
75.6	Granville Centre, on river from boat (subsurface water at depth of 6 m)		
75a	Granville Centre, Brun Creek		
80	Mochelle, above the mouth of the Saw Mill Creek, river shore		
81.a	Mochelle, Highway 201, bridge over the Saw Mill Creek		
81b	Mochelle, bridge over the Saw Mill Creek in South Mountain		
82	Mochelle, north of Hwy 201, Mochelle Brook mouth, river shore		
82b	Mochelle, Hwy 201, bridge over Mochelle Brook		
RH05	Round Hill River		
RH20	Round Hill River, Hwy 201, upstream from bridge		
AB06	Aboiteaux Creek		
AL00	Allains River		
MS20	Moose River		

** coordinates determined from 1:50,000 map sheet*

Appendix C – Quality Assurance / Quality Control Data

Introduction

Following a contamination event in 2003, Clean Annapolis River Project has initiated a number of procedures to ensure the quality of data collected. In addition to instituting a new collection procedure for fecal coliforms, CARP is developing a program of regular quality control checks on sampling equipment and methods. During the 2004 season, the Science Coordinator conducted random visits with volunteers on collection day in order to both collect a series of blank, split and duplicate samples, as well as to ensure the consistency in collection procedures.

Background

For the purposes of CARP's Water Quality monitoring programs, a blank sample is one filled with water that is known not to contain any of the substance in question. For CARP's monitoring of fecal coliforms, either distilled or tap water is added to the sample bottle. Over the 2004 season, three different types of blanks were used: lab blanks, travel blanks, and field blanks.

- The lab blank is used to detect analytical problems with the membrane filtration technique when multiple river samples are filtered consecutively using the same filtration apparatus. A 100ml sample of distilled water is filtered both before and after actual river samples, in order to ensure that there is no carryover contamination in the filtration equipment. Plates from negative lab blanks should not contain any fecal coliform growth. During positive lab blanks, fecal coliforms from a known strain are deliberately added to distilled water before filtration. Such tests should always produce plates that are too numerous to count (TNTC). Because the positive blank plates are always TNTC, they can only detect whether or not the growth medium/incubation is working, and cannot detect percent reductions in the efficiency of method.
- 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 and should always produce plates with no fecal coliform growth.
- The field blank is the third and final type of blank sample used. Field blanks are obtained by performing the entire sampling protocol (i.e.: attaching the bottle to the clamp, and lowering the aparatus 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 coliform growth. A positive result on a field blank would lead to further investigations to determine the source of contamination (ie: operator, equipment, distilled water, etc).

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 one 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 Synova's Membrane Filtration Technique (MFT) and/or the precision of Environment Canada's Dionex Ion Chromatograph method, as well as CARP's own precision at the MFT). Split samples can also provide information on the accuracy of the method used (i.e.: the accuracy of volunteers at the Winkler titration). Dissolved oxygen split samples were taken in 2004 using a single volume of water from a Van Dorn sampler.

Duplicate samples are taken at the same time and location in two separate bottles. The degree of variability in the results from duplicate samples provides information on the heterogeneity of the water column for a specific parameter. In the 2004 sampling season, duplicate samples for fecal coliforms and nutrient analysis were collected by attaching two sample bottles to two separate clamps on the water sampler and lowering them simultaneously.

The degree of variability between two replicate or 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.

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

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

The accuracy of the volunteers performing the Winkler Titration was measured using several split samples collected during the Science Coordinator's visits with volunteers. The Winkler Titration 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, show that the volunteers attain an accuracy of +/- 0.85 mg/L. Such a high degree of accuracy gives great confidence in the validity of the dissolved oxygen data.

Table C1: Volunteers' level of accuracy at Measuring Dissolved Oxygen Using the Winkler Titration

Date	Volunteer Result (mg/L)	"True" Result (mg/L)	Accuracy +/- (mg/L)
11-Jul-04	8.40	8.15	0.25
25-Jul-04	7.8	7.57	0.23
31-Oct-04	9.8	10.17	0.37
31-Oct-04	12.9	11.03	1.87
31-Oct-04	9.9	11.43	1.53
		Mean Accuracy:	+/- 0.85

Fecal Coliform

Throughout the sampling season, a series of blank samples were submitted blind for analysis at the Synova laboratory. The two travel blanks analysed had coliform counts of 0 cfu/100ml, indicating that there is no cross contamination between samples while they are being transported. Three field blanks collected also showed no fecal coliform growth, indicating that the new collection procedure is not contaminating the samples.

As part of its internal quality assurance procedure, Synova conducted a replicate study to estimate the reproducibility of fecal coliform results. This was estimated by calculating the Relative Standard Deviation (RSD) of ten replicate samples collected and analysed using the Membrane Filtration Technique. The reported RSD for the ten samples was 11.1%. Because replicate samples were used, this value also includes variability due to the natural heterogeneity of the water column.

Throughout the 2004 sampling season, a total of five duplicate samples were sent for analysis at the Synova laboratory (Table C2). The mean RPD of 13.5% from these samples verifies the above RSD value obtained in the Synova replicate study and suggests that the results are repeatable to the same degree over time. This value does not distinguish however, the contribution in variation from the laboratory method and that due to natural variability. In order to truly test the laboratory method, the use of reference standards is required. This is problematic though with fecal coliforms.

Table C2: Relative Percent Difference in Duplicate Samples Analysed for Fecal Coliforms

Site	Date	Duplicate A (cfu/100ml)	Duplicate B (cfu/100ml)	RPD (%)
Lawrencetown - 35	11-Jul-04	34	37	8.45
Aylesford - 00	31-Oct-04	138	115	18.18
Kingston - 13	31-Oct-04	170	141	18.65
Wilmot - 18	25-Jul-04	172	189	9.42
Paradise - 40	31-Oct-04	133	117	12.80
			Mean RPD:	13.5%

The above RPD values do however validate previous concerns regarding the validity of individual fecal coliform results. The variability may be due to either the laboratory method or the natural heterogeneity; however, regardless of the cause, it is evident that the difference between individual samples can be fairly important (as high as 18.65% RPD in Kingston on October 31). This brings into question the validity of reporting on water quality using individual results, as is commonly done for fecal coliforms with the roadside signs at each monitoring site. In light of this, further consideration may be warranted in deciding the most appropriate method of data dissemination.

Nitrate-Nitrogen

The precision of the nutrient analysis procedures are assessed at Environment Canada's Environmental Science Centre using replicate samples of reference material. The relative standard deviation between the replicates is calculated and expresses the variability that occurs during the laboratory procedure. The reported precisions for nitrate-N, chloride, and sulphate analysis are 3.0%, 1.7%, and 0.8%, respectively (J. Doull, personal communication, February 17, 2005). Throughout the sampling season, several pairs of replicate samples were sent blind to the Moncton laboratory. A relative percent difference between the pairs of results was calculated to examine the sample collection variability. As these samples were not "true" split samples, the RPD values also include differences due to the heterogeneity of the

water column. As with any laboratory results, the RPD values also include the reported RSD of the lab. Table C3 shows the results of the replicate samples for each nutrient measured, as well as their relative percent difference.

Table C3: Relative Percent Difference (RPD) of Replicate Samples for Nitrate-N, Chloride, and Sulphate

Parameter	Date	Replicate A (mg/L)	Replicate B (mg/L)	RPD (%)
Nitrate-N	13-Jun-04	0.11	0.19	53.33
Nitrate-N	25-Jul-04	0.64	0.65	1.55
Nitrate-N	31-Oct-04	0.66	0.55	18.18
Nitrate-N	11-Jul-04	0.28	0.28	0.00
Nitrate-N	31-Oct-04	0.63	0.47	29.09
Nitrate-N	31-Oct-04	0.13	0.22	51.43
			Mean RPD:	25.60
Chloride	13-Jun-04	9.90	9.80	1.02
Chloride	25-Jul-04	18.30	18.70	2.16
Chloride	31-Oct-04	16.90	17.10	1.18
Chloride	11-Jul-04	12.50	12.50	0.00
Chloride	31-Oct-04	15.20	15.20	0.00
Chloride	31-Oct-04	12.20	12.20	0.00
			Mean RPD:	0.73
Sulphate	13-Jun-04	6.20	6.00	3.28
Sulphate	25-Jul-04	9.00	9.30	3.28
Sulphate	31-Oct-04	10.80	10.90	0.92
Sulphate	11-Jul-04	8.80	8.90	1.13
Sulphate	31-Oct-04	9.30	9.30	0.00
Sulphate	31-Oct-04	7.20	7.20	0.00
			Mean RPD:	0.8

For the replicate samples collected, there was greater variability in the nitrate-N results, which had a mean relative percent difference of 25.6%. This value includes the variability due to sample collection and homogeneity of the water column as well as the variability in the laboratory procedure. In order to measure the variance due to sample collection, it is recommended that "true" split samples are collected in the future. In order to verify the variance due solely to laboratory procedures, it is recommended that single samples are analysed multiple times by the same laboratory.

Appendix D – SWIM Data 2004

Introduction

The Sub-Watershed Investigative Monitoring (SWIM) program was created to complement the Annapolis River Guardians by providing additional monitoring in areas that were known to have particularly poor water quality. In 2004, focused sampling along six major tributaries to the Annapolis River was conducted. The aim was to conduct regular sampling and combine the results with discharge data for each tributary in order to gain a better understanding of the relative contribution of the various tributaries to the Annapolis system. Sampling began on July 6 and finished on November 12. The six tributaries that were monitored, with their site codes, were: Moose River (MS20), Round Hill River (RH20), Nictaux River (NX20), Black River (BR19), Fales River (FR20) and the South Annapolis River (SA30). Figure D1 shows the location of the sites within the Annapolis River Watershed and Table D1 provides further information on their locations.

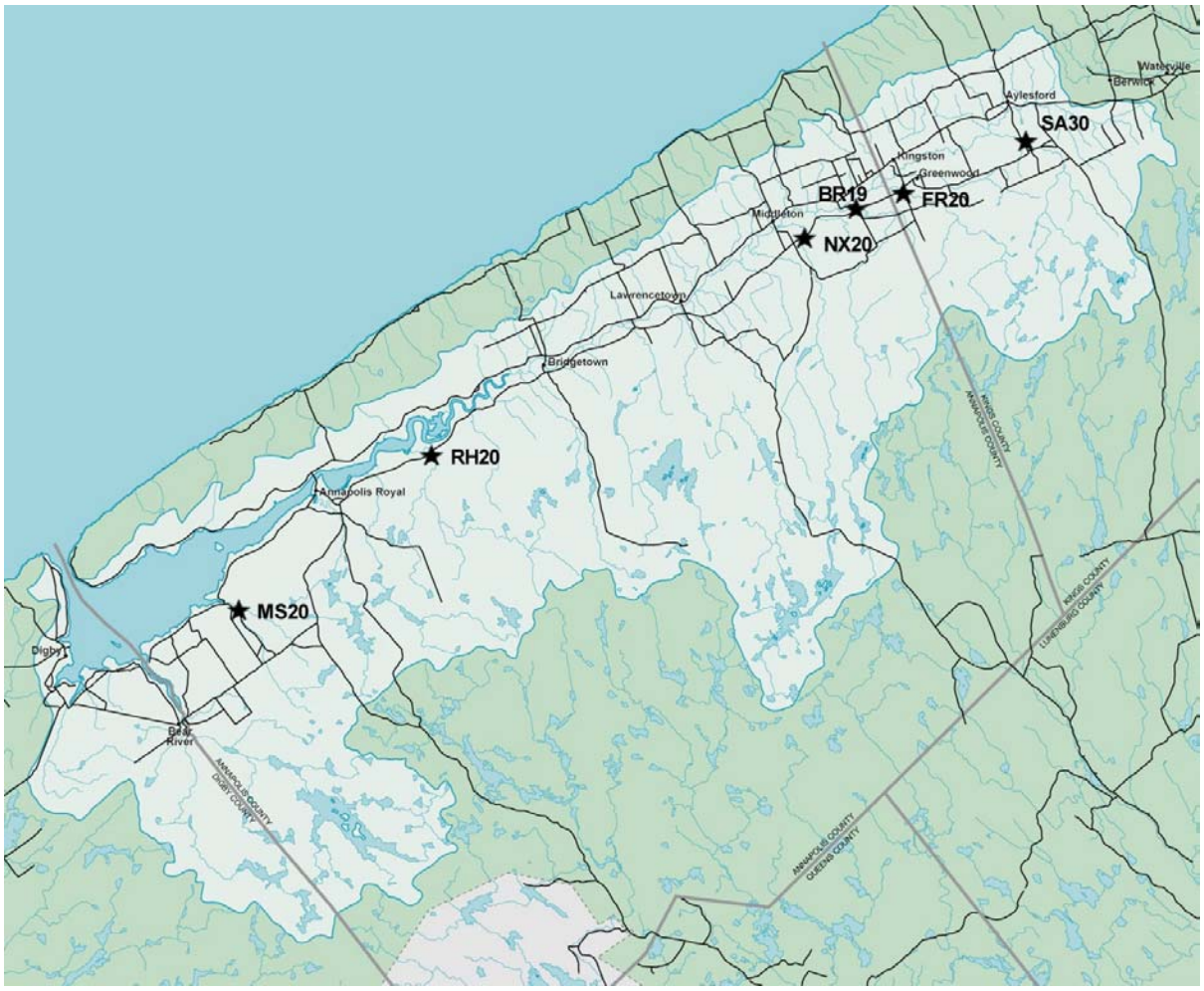

Figure D1: 2004 SWIM Site Locations Within the Annapolis River Watershed

Table D1: 2004 SWIM Site Description and Location

Site	Location	Easting	Northing
MS20	Moose River, upstream from Clementsport Dam Community Park	309735	4960546
RH20	Round Hill River, Highway 201, upstream from bridge	309750*	4960300*
NX20	Nictaux River, Highway 201, downstream from bridge	339287	4977163
BR19	Black River, Highway 201, downstream from bridge	343471	4979526
FR20	Fales River, Highway 201, downstream from bridge	346832	4981017
SA30	South Annapolis River, Victoria Road, upstream from bridge	356321	4984784

** coordinates determined from 1:50,000 map sheet*

The sampling procedures used were essentially the same as those used by the Annapolis River Guardians Program. Every two weeks, volunteers and CARP staff collected data on fecal coliforms, dissolved oxygen, nitrate-nitrogen, water temperature, pH and conductivity. Water samples were analyzed for fecal coliforms in the CARP laboratory by CARP staff, using the membrane filtration technique (see Appendix A). Water samples were sent to the Environment Canada laboratory in Moncton for nitrate-nitrogen analysis. All the other water chemistry parameters were measured using CARP's portable Hydrolab Quanta meter.

During each collection event, discharge was also measured using a General Oceanics Flowmeter (Model 2030). The average of five depth measurements was combined with the wetted width of the stream to estimate the area. The flowmeter was then placed in the thalweg at 0.6 of the total depth from the surface for a recorded amount of time (usually ~2 minutes), and the count difference recorded. For the Model 2030, meters traveled by the water are estimated by multiplying the count difference by 0.02687. The meters traveled were combined with the elapsed time to estimate velocity, which was in turn combined with the area to estimate discharge. Discharge data for the Nictaux River was obtained from Nova Scotia Power.

Monitoring Results

Table D2 details the relative contribution in fecal coliforms, dissolved oxygen, and nitrate-N for each tributary where data is available. Discharge was not measured on the Moose River; therefore only mean data is presented.

Table D2: Relative Contribution in Fecal Coliforms (FC), Dissolved Oxygen (DO) and Nitrate-N for Selected Tributaries

Site	FC Geomean (cfu/100ml)	Mean DO (mg/L)	Mean Nitrate-N (mg/L)	Mean Discharge (m^3/s)	FC Contribution (cfu/s X 10^3)	DO Contribution (mg/s)	Nitrate-N Contribution (mg/s)
MS20	3*	8.81	0.04	N/A	N/A	N/A	N/A
RH20	76	9.36	0.05	0.76	578	7114	38
NX20	141	8.74	0.04	2.41**	3,398	21063	96
BR19	246	8.10	0.15	0.47	1,156	3807	71
FR20	959	9.13	1.14	0.63	6,042	5752	718
SA30	125	9.20	0.14	0.94	1,175	8648	132

* All fecal coliform results recorded at the CARP laboratory for the Moose River site fell below the acceptable range of colonies counted per fecal coliform plate (20 to 200 colony forming units per membrane). At this site, every water sample filtered yielded counts of 4 cfu/100ml or lower. Since there were no other results available within the acceptable range, the geomean was calculated using these data. All other sites use data only within the acceptable fecal coliform range.

**Discharge data was obtained from Nova Scotia Power (NSP), which operates a power generation station that regulates flow on the river. Using the times and flows provided by NSP, the total cubic meters of water flowing per sampling day was calculated. The mean discharge was then estimated by taking the average of all sampling days (10 days total) and converting to cubic meters per second. A base flow of 0.17 m^3/s was used in the calculations when the station was "off".

It is clear from the table that the Fales River contributed the most in terms of fecal coliforms and nitrate-N in 2004. In fact, it contributed almost two times more fecal coliforms than the second highest tributary. Ten of the eleven samples collected from the Fales River exceeded 200 cfu/100ml, the highest concentration reaching 14 800 cfu/100ml. The site also had higher nitrate-N concentrations than any other tributary. Levels in the 1-2 mg/L range were recorded on the Fales River on four occasions over the 2004 season, with one sample having a concentration as high as 3.05 mg/L. Concentrations equal to or greater than 1-2 mg/L generally indicate that the river is being affected by anthropogenic sources. These concentrations can have adverse effects on salmon and trout eggs, and may be partly responsible for the decline in amphibians in Canada. The South Annapolis River had the second highest contribution of nitrate-N, however at a much lower level than the Fales River.

The Nictaux River had the second highest fecal coliform contribution, reaching over 3.3 million cfu/second. Despite this high contribution in coliforms, the Nictaux River contributed by far the most dissolved oxygen to the main stem of the Annapolis River.

Both the Moose River and the Round Hill River showed consistently good water quality, for all three parameters.

HydroLab Quanta Water Meter Data

On each sampling occasion, water chemistry was also measured using CARP's portable HydroLab Quanta water meter. Parameters including temperature, pH and conductivity were measured. Table D3 summarizes the mean values for each above mentioned parameter at each of the 2004 SWIM locations. The temperature data shown is for summer months only, July through September.

Table D3: Results for Water Temperature, pH and Conductivity, 2004 SWIM Sites

Site	Mean Water Temperature (°C)	Minimum Water Temperature (°C)	Maximum Water Temperature (°C)	Mean pH	Mean Conductivity (mS/cm)
MS20	18.77	15.00	22.10	7.19	0.10
RH20	17.36	11.10	20.30	6.22	0.06
NX20	19.61	13.64	23.39	6.11	0.05
BR19	18.91	13.59	22.28	6.95	0.13
FR20	18.23	13.16	22.08	6.68	0.13
SA30	19.11	14.09	23.12	6.64	0.05

The mean summer water temperature at each of the SWIM sites reached significantly high levels. The coolest tributary was the Round Hill River, with a mean temperature of 17.36°C. The Nictaux River, whose mean summer temperature was of 19.61°C, was the warmest tributary, followed by the South Annapolis River at 19.11°C. Temperatures in excess of 20°C are known to cause stress in fish species such as trout and salmon. Although the mean temperatures were below 20°C, each site recorded temperatures in excess of this threshold during the summer months. The Nictaux River experienced water temperatures as high as 23.39°C in the month of August.

As with most sites on the main Annapolis River, pH levels in all tributaries were generally very good. The Nictaux River had the lowest pH level, at 6.11; however this level is still within the CCME guidelines for the protection of freshwater aquatic life. Similarly, mean conductivity levels were within the expected range for freshwater streams.

SWIM Quality Assurance / Quality Control Data

As part of CARP's new internal quality assurance/quality control (QA/QC) plan, a series of blank and duplicate samples were collected throughout the 2004 sampling season. The purpose of the QA/QC samples is to test both the sampling and laboratory methods to ensure the validity of the data collected. See Appendix C for more detailed information on the Quality Assurance Project Plan (QAPP), including detailed definitions of QA/QC samples and procedures.

The QAPP defines an acceptable range of colony forming units per fecal coliform plate outside which counting is considered inaccurate. For a count to be considered valid, colonies growing on the plate must be within 20 and 200 cfu/100ml. A total of 112 SWIM samples were filtered for fecal coliform concentration as part of the QAPP. Of these 112 samples, 42 samples (37.5%) fell outside the acceptable fecal coliform range, and were therefore not included in the QA/QC analysis. Due to the high natural variability of fecal coliforms in streams, it can be difficult to estimate the correct volume of water to filter in order to get results within the acceptable range.

In order to test the membrane filtration method carried out by CARP staff at CARP's laboratory, several negative lab blanks were filtered following the same procedure used for regular river samples. 22 negative lab blanks were analysed in total at the beginning and end of each filtration session. Each blank sample had fecal coliform counts of 0 cfu/100ml. The absence of fecal coliform growth indicates that there was no carry-over contamination in the filtration equipment between samples.

A series of duplicate samples were analysed using the membrane filtration method in order to measure the variability between sample results. On several occasions during SWIM sampling, the River Guardian site in Aylesford (00), which commonly surpassed all water quality guidelines, was also sampled. Table D4 shows the results of four duplicate samples with their relative percent difference (RPD). The mean RPD attained for all duplicates using the membrane filtration method for fecal coliforms was 26.3%. This value includes natural variability of fecal coliforms in the river, and therefore cannot be interpreted as the precision of the membrane filtration procedure. The mean RPD value is more than double the RPD attained by Synova. It is unclear whether the difference is due to lab techniques or to natural variability between the Annapolis River and it's various tributaries.

Table D4: Relative Percent Difference (RPD) in Four Duplicate Samples, SWIM 2004

Site	Date	Split A (cfu/100ml)	Split B (cfu/100ml)	RPD (%)
RH20	12-Oct-04	310	158	65.0
NX20	12-Oct-04	280	258	8.2
AY00	16-Aug-04	294	330	11.5
AY00	25-Oct-04	114	140	20.5
			Mean RPD:	26.3 %

Accuracy

In order to gain an estimate of CARP's accuracy at the membrane filtration method, it is recommended that several split samples are sent to Synova Diagnostics in the future. Using the result from the certified external laboratory as a reference value, or the "true" value, the accuracy of CARP's method as preformed by CARP staff may be estimated.

Appendix E – Fecal Coliform Data Interpretation

Due to the high variability of fecal coliform bacteria, the use of standard data analysis methods, such as calculating and comparing mean values, inadequately describes their distribution. The analysis chosen for this report is therefore based on the proportion of samples analysed that exceed particular water quality thresholds. While this approach eliminates the bias of calculating means with highly variable data, it presents another type of bias. If the bulk of samples one year are just slightly below a guideline, with very few exceedences, a small increase in fecal coliform concentration the next year may cause several more samples to exceed the guideline. Although there is an increase in proportion of exceedences, there may not be a significant decrease in water quality. In order to ensure the differences observed in the analysis are real, a box-whisker plot was drawn to compare the distribution of the 2003 and 2004 fecal coliform results (See Figure E1). 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 fecal coliforms discussed in the report are shown as dotted lines at 50, 100, and 200 cfu/100ml. It is important to note that the y-axis of the graph is plotted using a logarithmic scale (Log Fecal Coliform).

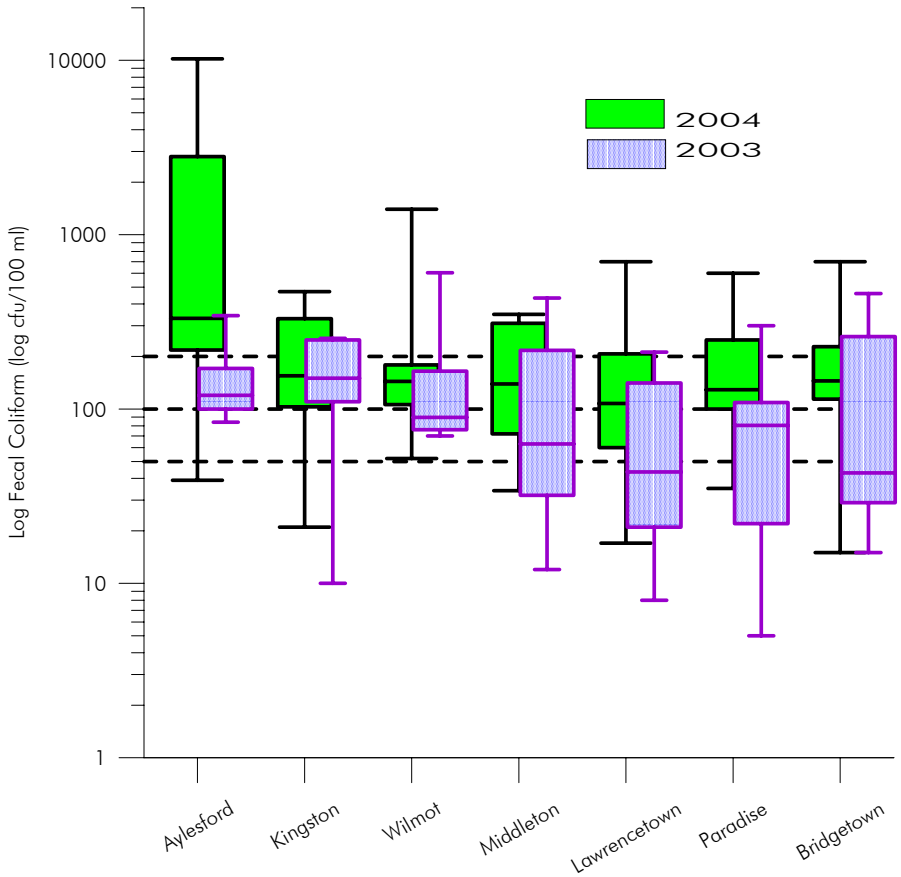

Figure E1: Box-Whisker Plot Showing Distribution of Fecal Coliform Data, 2003 and 2004 (showing water quality guidelines as dotted lines)

The distribution of the data on the graph confirms that, in most cases, the increases observed in 2004 are real. The most important increase in 2004 occurred in Aylesford, where the bulk of the samples were above 200 cfu/100ml. In 2003 however, more than 75% of samples were below that threshold. The lower river sites (Middleton, Lawrencetown,

Paradise, Bridgetown) all exceeded the 50 cfu/100ml guideline to a similar degree than that found in the proportional analysis. The 2003 data at these four these sites are not clustered directly below the 50 cfu/100ml guideline and most of the 2004 data is well above that threshold.

The proportion of samples exceeding the 100 cfu/100ml guideline at the Wilmot site (from 0.45 in 2003 to 0.79 in 2004), as shown in Figure 3, may give a stronger impression of decreasing water quality than is indicated by the box-whisker plot above. Most of the 2003 data is clustered slightly under the 100 cfu/100ml guideline, while the 2004 data is slightly above the threshold. The actual decrease in water quality at that site from one year to the next may be misrepresented by simply stating the increase in proportion of exceedances. Similarly, for the site in Paradise, the 2003 and 2004 median values are in close proximity to the 100 cfu/100ml guideline, suggesting that at least half the values for both years were very close to each other. The difference in proportion of samples surpassing the 100 cfu/100ml threshold at these two sites should therefore be interpreted with caution.