ACAP SAINT JOHN

THINKING WATER 2023-2024

Community Environmental Monitoring in Greater Saint John

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Thinking Water: Community Environmental Monitoring in Greater Saint John

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Executive Summary

This report summarizes the findings from ACAP Saint John's 2023 *Thinking Water* project. The *Thinking Water* program aims to assess the general water quality of streams within the Saint John and surrounding area, including tributaries of the Wolastoq (St. John River) and the Saint John Harbour. In a city with a long history of human and industrial influences, this program offers significant insight into the health of Saint John's waterways. ACAP Saint John has been conducting water quality monitoring in the Greater Saint John area for over 30 years, providing a long-term dataset that can be used by professionals and other organizations.

In 2023, ACAP Saint John monitored the water quality at 31 sites in freshwater streams and estuarine environments in the Saint John and surrounding area. Water Quality Index (WQI) values were calculated from field and lab measurements including water temperature, dissolved oxygen (DO), pH, salinity, turbidity, ammonia (as NH3), orthophosphate (as P), and *Escherichia coli* (*E. coli*) concentration, collected between May and October. In 2023, no sites achieved "excellent" or "poor" water quality as determined by the Canadian Council of Ministers of the Environment (CCME); improvements in water quality were observed in all but five sites (Tin Can Beach, Bayshore Beach, Kennebecasis Drive, Marsh Creek 11, Spruce Lake Stream Upstream, and Spruce Lake Stream Mouth). Five sites received a "good" WQI score, while most sites (15 of 31) achieved "fair" water quality, and eight had "marginal" water quality. in comparison to last year, where most sites had marginal water quality. As in previous years, the sites with the worst water quality index score included Marsh Creek Downstream (WQI of 45.1), Marsh Creek 11 (WQI of 48.6), and Little River (WQI of 49.4). Average phosphate concentrations exceeded the threshold limit at 22 of 31 sites (93.6%), while ammonia exceeded the limit at 7 of 31 sites (22.6%), and *E. coli* concentrations surpassed the threshold at 19 of 31 sites (61.3%). These water quality issues have been a persistent problem in these watersheds, indicating stormwater or sewage inputs and other sources of contamination continue to have considerable impact within the Saint John region, despite the modernization efforts of existing infrastructure.

Biotic communities were monitored at Courtenay Bay and Marsh Creek 2 within the Saint John Harbour in 2023. Abundances of fish and invertebrates were quantified using beach seines and fyke nets; this work aimed to continue longstanding monitoring to determine an environmental baseline for the region. In 2023, a total of 1891 individuals representing 12 species were caught, the majority of the catch consisted of sand shrimp (*Crangon septemspinosa*).

Introduction

The Wolastoq (St. John River) and its tributaries provide habitat for countless aquatic species and serves as a water source for many more terrestrial species. Three cities and numerous towns and villages in New Brunswick lie along the banks of the Wolastoq before its confluence with the Saint John Harbour on the Bay of Fundy. This expansive river is culturally, industrially, recreationally, and ecologically significant, and as it runs more than 600 kilometres inland, it impacts both humans and wildlife. Modern uses of the river generally have deleterious effects, given the influence of humans along its entire length, climate change, and other environmental phenomena also have negative impacts. The Saint John Harbour at the mouth of the river hosts frequent shipping and dredging activities and receives various industrial (e.g., pulp and paper effluent, ballast water, and oil refinery effluent) and municipal discharges; these activities all have the potential to impact overall water quality.

Starting in the mid-1800s, the City of Saint John released raw sewage into Marsh Creek and the Saint John Harbour; this was a widespread practice for port cities for centuries. This practice has left rivers and watersheds polluted, creating unsuitable habitat for aquatic species. In 2014, the Harbour Cleanup project brought an end to the routine discharge of raw sewage, resulting in the return of migrating fish species and improved water quality. Continuous monitoring projects like ACAP Saint John's water quality monitoring programs help identify specific problem areas or recent changes in water quality that need to be addressed. This report provides analysis of the current state of water quality in the Greater Saint John area and provides recommendations for further action in the city's watersheds.

The purpose of this project is to continue the water quality and fish assemblage monitoring within the Marsh Creek watershed and neighbouring waterways to document system recovery after centuries of raw sewage disposal. *Thinking Water* is a continuation of the *Rebirth of Water* monitoring program which was originally meant to track improvement after the sewage ban. The project encompasses monitoring of the tributaries of the Wolastoq and other waterways found throughout the City of Saint John.

Methods

I. Water Quality Monitoring Sites

Water quality monitoring sites are located across 10 different sub-watersheds of the Wolastoq. ACAP Saint John has been monitoring sites within the Marsh Creek watershed for over 30 years. Additional sites were selected to represent a range of brackish and freshwater streams in the Greater Saint John Area. In total, 31 sites were monitored in 2023 (Figure 1). Below is a brief overview of the selected watersheds with the primary threats to water quality identified. Further site descriptions and GPS coordinates can be found in Appendix A.

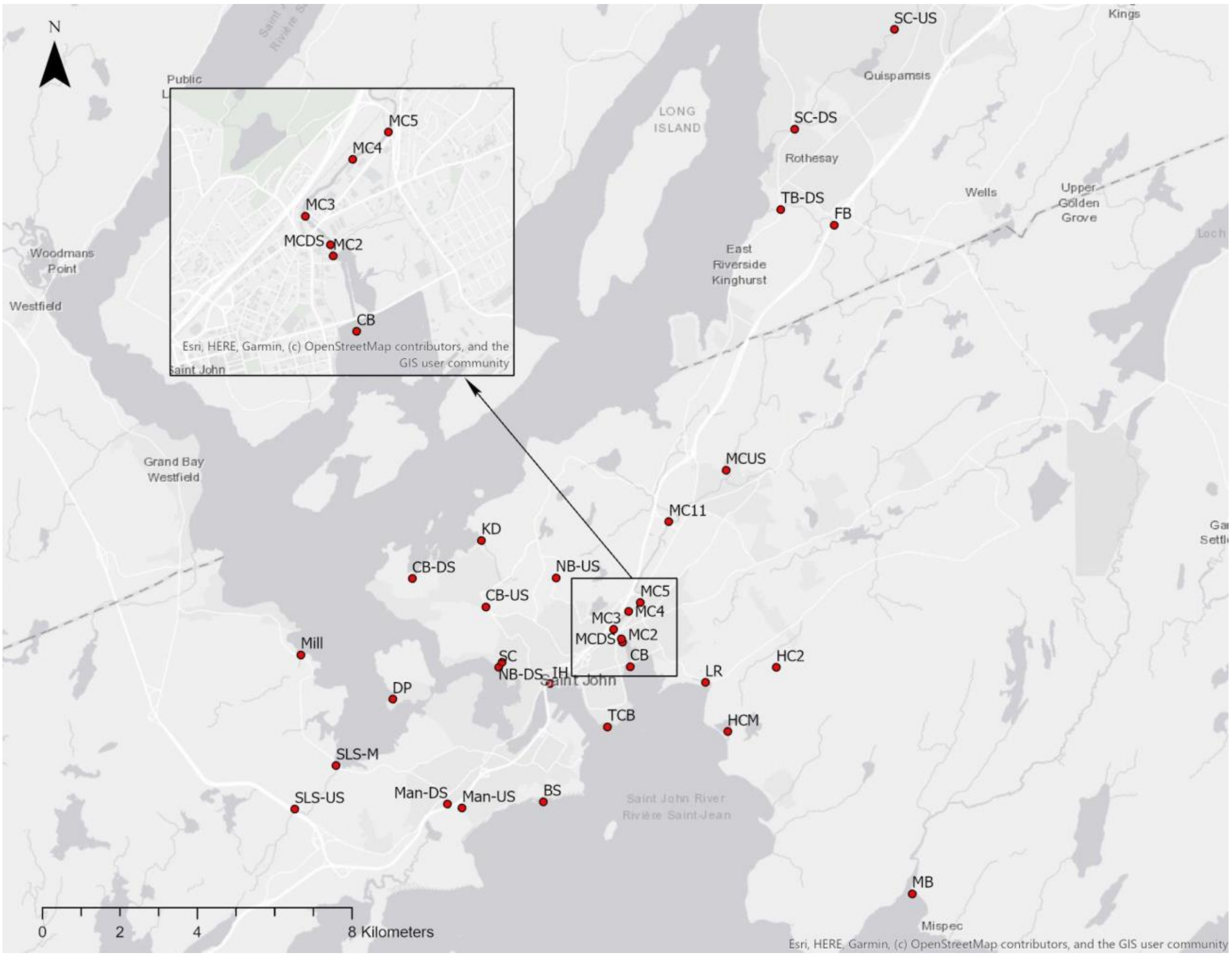

Figure 1. Locations of water quality sampling sites during the 2023 field season. Coordinates and site names are available in Appendix 1.

Marsh Creek (Courtenay Bay [CB], MC2, MC-DS, MC3, MC4, MC5, MC11, MC-US): An internationally recognized environmental concern due in large part to its receipt of untreated municipal wastewater and heavy creosote contamination in the sediments downstream.

Hazen Creek (HC-M, HC2): Flows through forested, residential, commercial, and industrial areas. As such, the watershed has suffered over the years from direct and indirect impacts of development.

Taylors Brook (TB-DS): The main threat to this watershed is potential encroachment from development as East Saint John and the Town of Rothesay expand further into the watershed.

Newman's Brook (NB-US, NB-DS, Spar Cove [SC]): The headwaters of Newman's Brook lie in an area that was once a landfill which has only been partially capped, resulting in the potential for leachate to move through the brook.

Caledonia Brook (CB-US, CB-DS): Development and encroachment have put pressure on sections of the watershed, potentially affecting the water quality.

Salmon Creek (SC-US, SC-DS): Many residences are located within this watershed and the watercourse may suffer from the effects of development, riparian area degradation, nutrient runoff, and natural flow regime changes.

Mill Creek (Mill): The watershed itself is mostly forested with some development (mostly housing) as it approaches the Wolastoq and the Saint John Marina, which is located at the outflow of the creek.

Spruce Lake Stream (SLS-US, SLS-M): A quarry within the watershed may impact the stream with sediment runoff.

Manawagonish Creek (Man-US, Man-DS): The watercourse flows through a stormwater pond and crosses Highway 1 twice before by-passing a wastewater treatment plant.

Additional sites include Bayshore Beach (BS), Mispec Beach (MB), Fairweather Brook (FB), Dominion Park (DP), Kennebecasis Drive (KD), and Inner Harbour (IH).

II. Water Quality Analysis

Water quality data was collected in the field using a handheld YSI Professional Plus multimeter (Figure 2). Dissolved oxygen and pH probes were calibrated following the manufacturer's recommendations. Turbidity was also measured in the field using a handheld turbidity meter. Ammonia and orthophosphate were quantified using a DR900 colorimeter, and total coliform and *Escherichia coli* (*E. coli*) colonies were estimated using the IDEXX Colilert-18 system. All laboratory analyses were performed at the New Brunswick Community College (NBCC) Saint John campus or at ACAP Saint John. For each day on which laboratory analysis was conducted, either a blank or a duplicate sample was assessed for each measure to ensure Quality Assurance/Quality Control (QAQC).

Figure 2. ACAP Saint John field technician deploying a YSI multimeter to collect in-situ water quality parameters.

II. i. Ammonia

Ammonia was measured using the DR900 Nitrogen, Ammonia method (Code 8155) (Figure 3). Ten mL of sample water was added to a clean test tube, and two chemical reagents were added to the sample with time between reagent additions. After allowing the sample to sit for 15 minutes, the colorimeter was calibrated using a blank sample (deionized [DI] water) and the sample was subsequently tested. The ammonia reading provided was in mg/L.

Figure 3. A chemical technology intern from NBCC Saint John conducting laboratory analysis on collected water samples.

II. ii. Orthophosphate

Orthophosphate was measured using the DR900 Phosphorus, Reactive (Orthophosphate) method (Code 8048). Results are in mg/L as concentration of both Phosphate (PO_4^{3-}) and Phosphorous (P).

II. iii. Total coliforms and *E. coli*

Total coliforms and *E. coli* were measured using an IDEXX Colilert-18 system. The Colilert-18 reagent was added to 100 mL of sample and incubated in standardized trays at 35°C for 18 hours. The trays were removed from the incubator after eighteen hours. The number of yellow and fluorescing trays corresponded to the total coliform and *E. coli* concentrations, respectively, measured as the most probable number per 100 mL (MPN/100 mL). If a site exceeded 2 ppt salinity, the sample was analyzed in a 1:10 dilution so that the salinity would not interfere with bacterial growth, and results were multiplied by ten to achieve MPN/100 mL, rendering a detection limit of 24196 MPN/100 mL for diluted sites. Undiluted freshwater sites achieving *E. coli* counts at or above the detection limit (2419.6 MPN/100 mL) were assigned the detection limit as a value. The dilution and subsequent multiplication at higher salinity sites can result in *E. coli* counts over the detection limit, but undiluted sites cannot be given values higher than the detection limit; with that, the total *E. coli* levels at various sites may be far higher than 2419.6 MPN/100 mL. Total coliform counts are unreliable outside of freshwater sites; for this reason, total coliforms are not presented in this report, though they were observed.

II. iv. Guidelines

Water quality guidelines and thresholds taken from literature were used for various parameters in this report to interpret the environmental state at each site. Values above (and below when applicable) the selected thresholds were considered suboptimal conditions and contributed to a lower water quality. Temperatures below 23°C are considered best for juvenile salmonids (Breau et al. 2007); for this report, we selected an upper thermal limit of 23.5°C to allow some flexibility with temperatures that just exceed 23°C. Other thresholds and guidelines were taken from reports made by the Canadian Council of Ministers of the Environment (CCME). The threshold for dissolved oxygen was a lower limit of 6.5 mg/L (Canadian Council of Ministers of the Environment 1999c). For pH, the guidelines used were a lower limit of 6.5 and an upper limit of 9.0 (Canadian Council of Ministers of the Environment 1999b). The threshold used for *E. coli* in 2023 was a single exceedance of 400 MPN/100 mL or an average of 200 MPN/100 mL (Canadian Council of Ministers of the Environment 1999a). For ammonia, the upper limit was 0.1 mg/L total ammonia because natural concentrations are generally below this value (Canadian Council of Ministers of the Environment 2010). Orthophosphate has no guideline from the CCME, but thresholds should be based on historic values. In this report, the threshold used for orthophosphate (PO_4-P) was 0.04 mg/L. For turbidity, threshold should also be based on deviations from background levels as there are no set guidelines from CCME; we selected 55 NTU as an upper limit.

II. v. Water Quality Index

The CCME has created a Water Quality Index (WQI) that rates water quality based on a ratio of parameters that exceed thresholds (see methods for guidelines above) for the total number of parameters measured (minimum number of four parameters measured over four timepoints). This index has five rankings: poor (0-44), marginal (45-64), fair (65-79), good (80-94), and excellent (95-100); Canadian Council of Ministers of the Environment 2001).

III. Biotic Community Monitoring

In 2023, fishing occurred monthly (July – September) at 2 sites – Courtenay Bay (45.2762102 -66.047032) and March Creek 2 (45.281834 -66.049478) which correspond to fish community monitoring sites dating back to 2015 to track changes post completion of the Harbour Cleanup project. Fishing was conducted using seine nets (one 3-minute tow per site each month) and fyke nets (one 24-hour deployment per site each month). All fish were identified, and total body lengths (mm) were measured for up to 30 individuals of each species before being returned to the water. If more than 30 individuals of a species were caught, the remaining individuals were counted but not measured before being released. This was done to reduce animal stress due to handling and time out of their environment. This fishing methodology was adopted in 2018 (prior to 2018, only fyke nets were used) to correspond with a larger, Department of Fisheries and Oceans Canada funded monitoring program to develop a baseline of fish communities within the Harbour near some of Saint John's most industrially or residentially affected sites.

Results & Discussion

I. Rainfall Occurrence

The 2022 field season saw a substantial increase in ammonia, phosphate, and *E. coli* concentrations across most sites. The nutrient loading prompted further investigation into rainfall occurrence, in particular rainfall events that coincided with water quality sampling. Rain data from 2022 and 2023 are analyzed in this report to observe the difference in rainfall influence between the years. Figure 4 below depicts monthly rainfall data over the sampling period between 2019 and 2023.

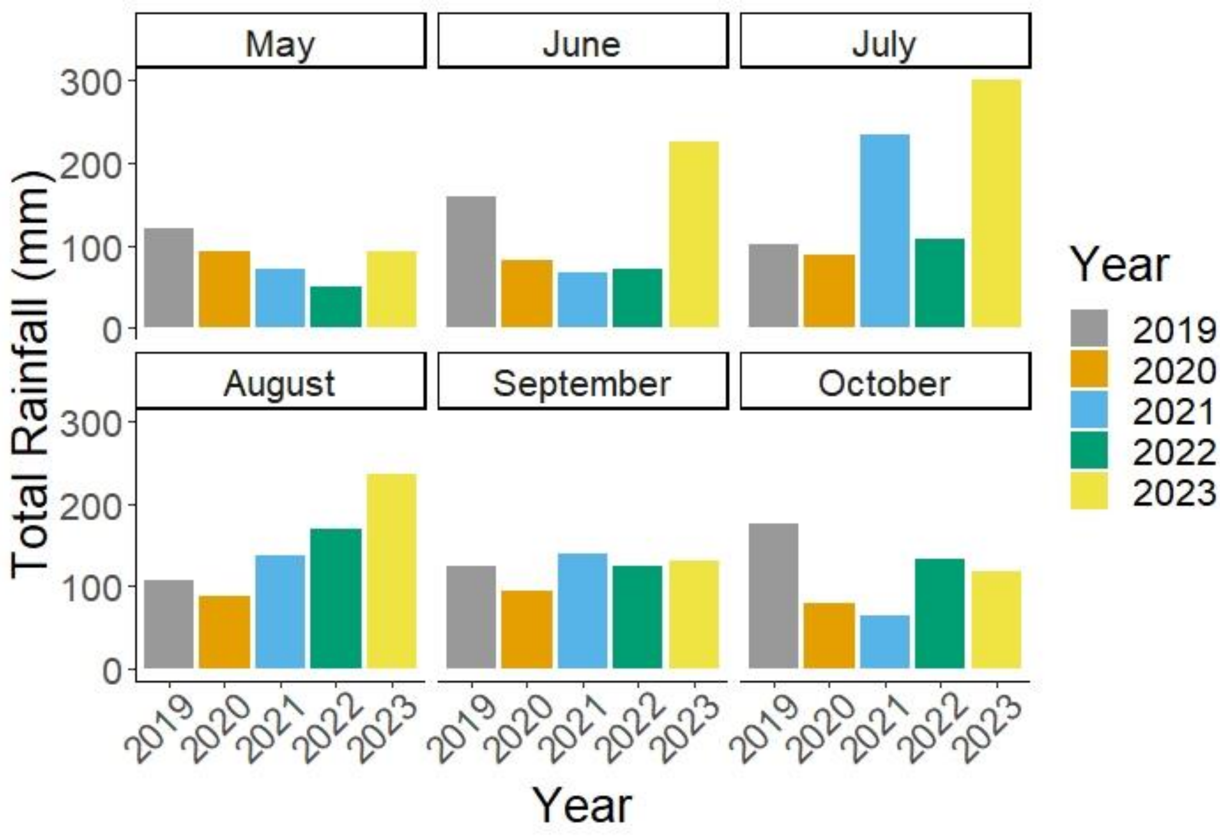

Figure 4. Rainfall per sampling month from 2019 to 2023.

Rainfall data from 2019 to 2023 reveals that the 2023 field season incurred the greatest volume of rain by 27.8% (317.3 mm). Rainfall from May to October of 2023 totaled 1104.3 mm, in comparison to the previous greatest volume of 787 mm in 2019. Similarly, it was found that 57.5 % of 2023 sampling dates were affected by rainfall events, a 10% increase of impacted days from 2022 (Table 1).

Table 1. Sampling events with rainfall influence by year. The number of rain days were determined by examining historical rain data and determining if >7 mm fell within 48 hours of sampling, and if >15 mm within five days of sample collection.

Year	Days with Rain Influence	Percent Total (%)
2019	38 of 59	64.4
2020	11 of 24	45.8
2021	25 of 45	55.6
2022	19 of 40	47.5
2023	27 of 42	57.5

Despite the increase in rainfall, nutrient, and *E. coli* levels in 2023 were generally lower than those of 2022. The overall decrease in nutrient levels and improved water quality seen in 2023, despite increased rainfall suggests that the diminished water quality from 2022 may have been the result of testing errors rather than rainfall influence.

II. Marsh Creek Water Quality

The Marsh Creek watershed is the subject of ACAP Saint John's longest running water quality monitoring program due to its historical contamination. In this report, comparisons are made between 2019 to 2023, with comments on the continued changes since 1993.

Water Quality Score

In 2023, all sites within the Marsh Creek watershed experienced improved water quality apart from Marsh Creek 11 (Figure 5). Three sites achieved a fair water quality index score while the remaining five sites had marginal water quality. The improvement in stream health can be attributed to overall lower nutrient and bacterial concentrations. The greatest contributor to diminished water quality within Marsh Creek watershed were *E. coli* and phosphate concentrations, both of which generally exceeded guideline limits on most occasions.

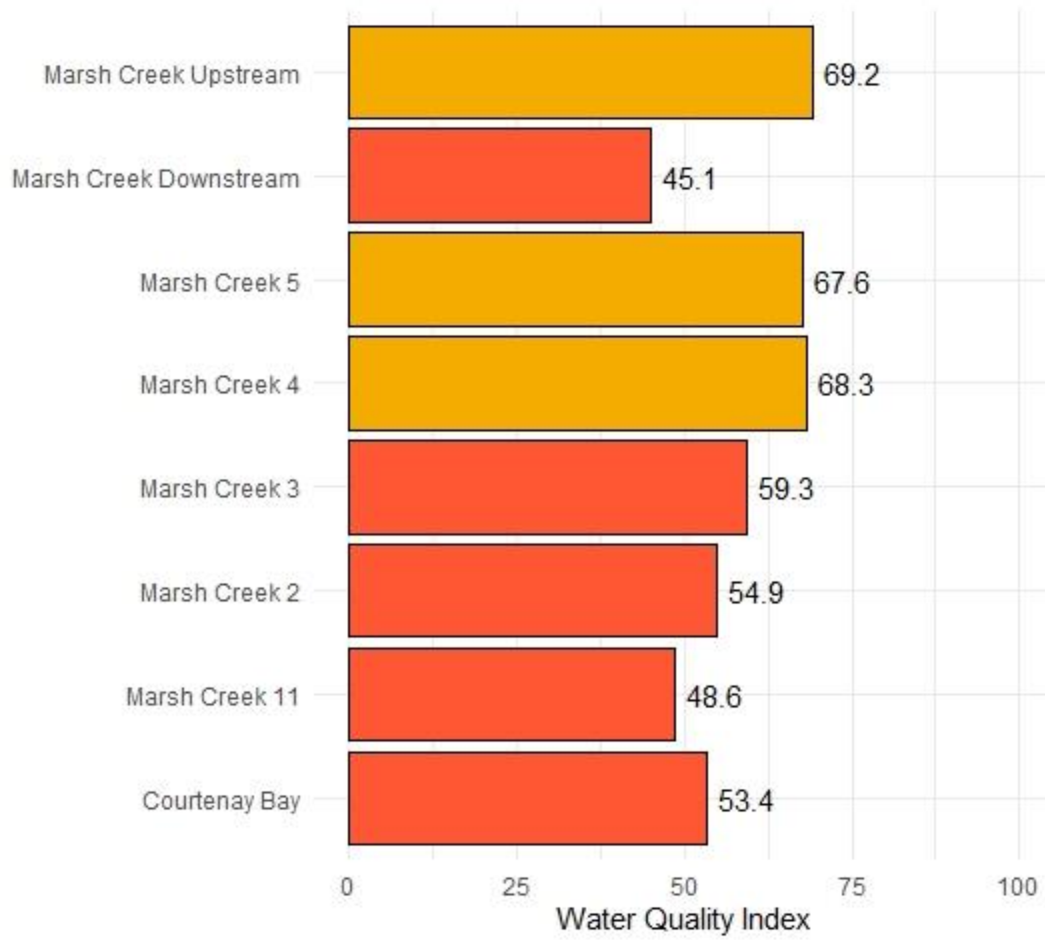

Figure 5. Water quality index (WQI) scores from Marsh Creek sampling locations. WQI scores are calculated from raw water quality data collected in 2023 according to CCME procedures.

All sites experienced significant improvements in water quality between 2022 and 2023, except for Marsh Creek 11, which decreased slightly in 2023 (Figure 6). In contrast, in 2022, five sites had poor water quality, with only two achieving marginal water quality, further demonstrating the marked improvement of 2023. As 2023 incurred more rainfall than 2022, while exhibiting improved water quality despite this, it is suspected that technical errors contributed to the degraded water quality scores seen in 2022. Improvement in water quality can likely be attributed to decreased average concentrations of ammonia, temperature, and increased dissolved oxygen.

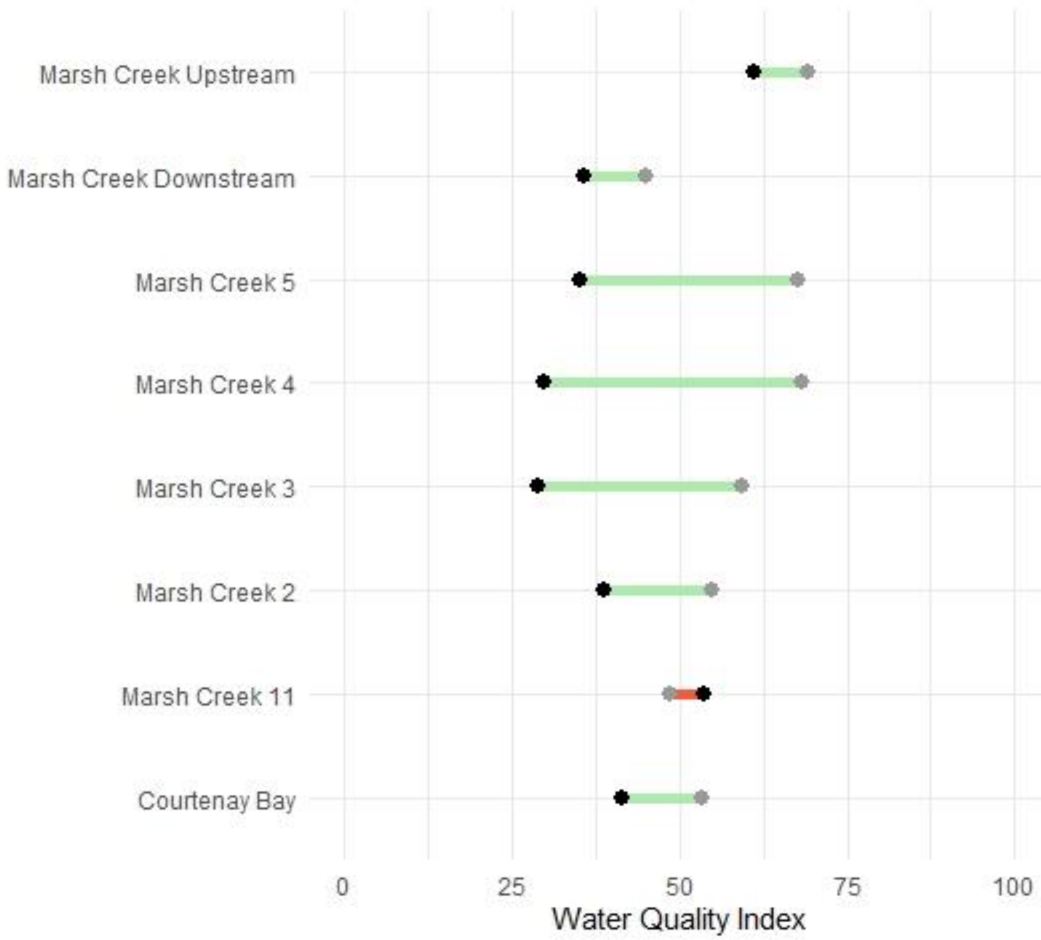

Figure 6. Change in water quality index scores between 2022 (black circles) and 2023 (grey circles) at sites within the Marsh Creek watershed, with colours indicating whether the WQI has improved (green) or declined (red).

E.coli

Each site within the Marsh Creek watershed exceeded the *E. coli* concentration threshold chosen for this report (geometric mean concentration of 200 MPN/100 mL; minimum 5 samples) and a single-sample maximum concentration (400 MPN/100 mL), at least once, if not on most occasions. Historically, Marsh Creek Upstream has had the lowest *E. coli* concentrations and in 2023, concentrations fell below this threshold on 5 of 11 occasions. A limit of a 200 MPN/100 mL average is recommended by Health Canada, where concentrations above this value may pose health risks (Health Canada, 2012). In some cases, *E. coli* concentrations were close to the detection limit (24196 MPN/100 mL); but none exceeded this value in 2023. The sites farthest downstream, Marsh Creek 2 (MC2), Marsh Creek Downstream (MCDS), and Courtenay Bay continued their historical trend of having the highest concentrations of *E. coli,* with Marsh Creek Downstream exhibiting the highest overall average (Figure 7).

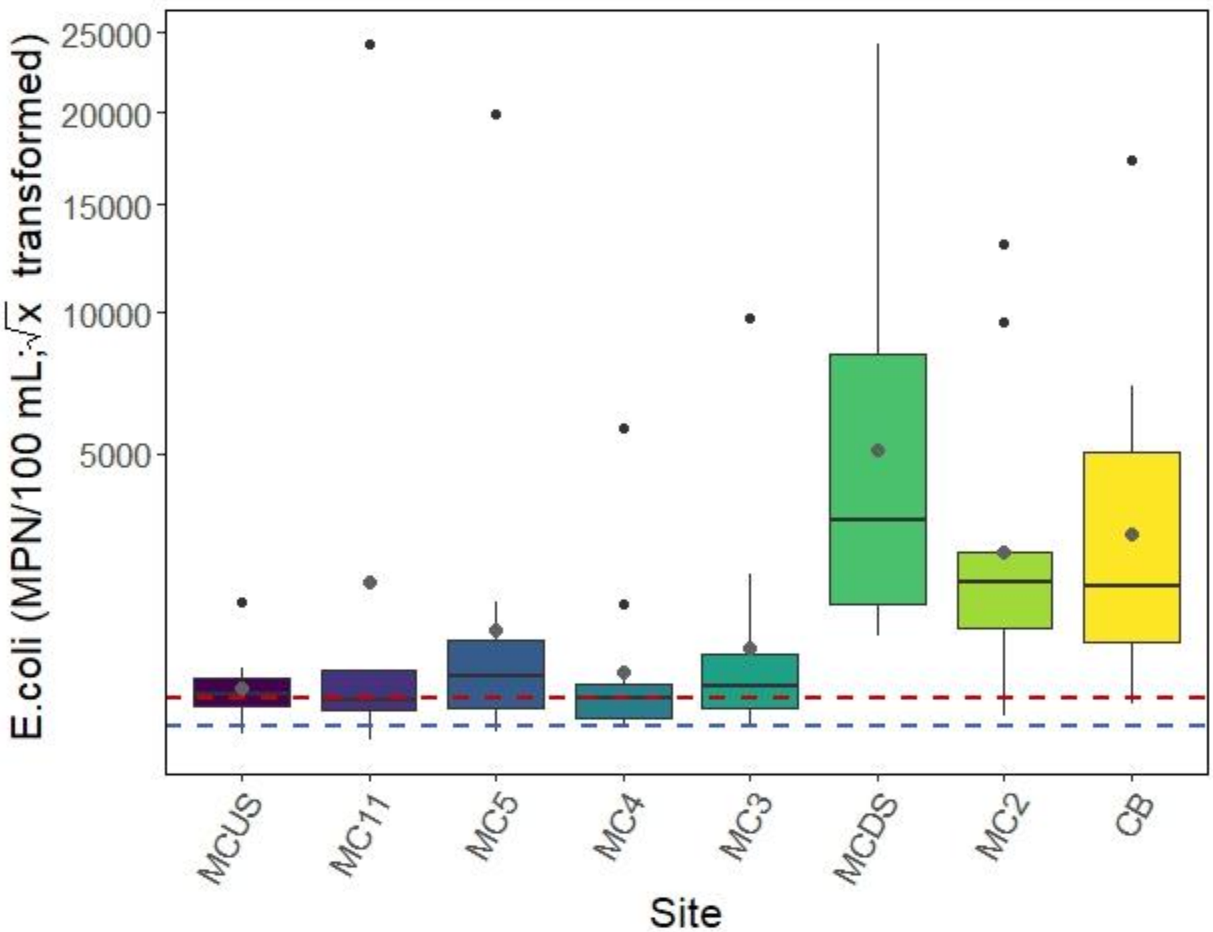

Figure 7. E. coli concentrations (MPN/100 mL) across sites within the Marsh Creek watershed in 2023. The mean values for each site are represented by grey dots, while outliers are represented by black dots. The threshold value (geometric mean concentration of 20200 MPN/100 mL; minimum 5 samples) is represented by the blue dotted line, while the single-sample maximum concentration (400 MPN/100 mL) is represented by the red dotted line.

Fecal contamination within the Marsh Creek watershed has been the result of lift station overflows and combined sewer overflows; contamination from these events persist during heavy rainfall events when the system receives too much stormwater. Many of the sampling dates in the Marsh Creek watershed in 2023 coincided with heavy rainfall events, contributing to the elevated levels of *E. coli* outlined in this report. The effects of a rainfall of just 10 mm can cause the system to overflow, with the effects of contamination persisting for up to five days after the rainfall occurrence. Within the last year, the City of Saint John has been working to modernize outdated combined sewage overflow and stormwater systems, specifically within the Lower Cove Loop, which reaches the confluence of where Marsh Creek enters Courtenay Bay. Regardless of updated infrastructure and rainfall events, the Marsh Creek watershed continues to show elevated levels of fecal contamination, indicating that this remains a consistent issue within the watercourse, although a decade has passed since the Harbour Cleanup and the cessation of raw sewage inputs.

Nutrients

In 2023, average ammonia concentrations decreased substantially across all sites, exhibiting less variability overall and lower outlier concentrations. Average concentrations exceeded the threshold of (0.1 mg/L) at three sites (MC2, MCDS, and CB) (Figure 8-Right). Similarly, average phosphorus concentrations decreased at most sites, exhibiting less variability overall and lower outlier concentrations as well. Although most sites (7 of 8, 87.5%) had average PO4 levels above the threshold value (0.04 mg/L), one site (MC4) had an average below. Despite the exceedances, three sites (MC3, MC5, MCUS) had averages close to the threshold (Figure 8- Left). In 2022, both ammonia and phosphate concentrations were elevated considerably compared to previous years; results from 2023 indicate that nutrient levels have returned to normal concentrations for the Marsh Creek watershed and suggesting that technical errors in 2022 had a substantial impact on nutrient data from Marsh Creek. In addition to heavy rainfall events occurring near to and during sampling events, the area surrounding Marsh Creek is highly industrialized, particularly near the downstream locations; the poor riparian cover allows nutrients and other contaminants to readily enter the stream with no filtration or mitigation.

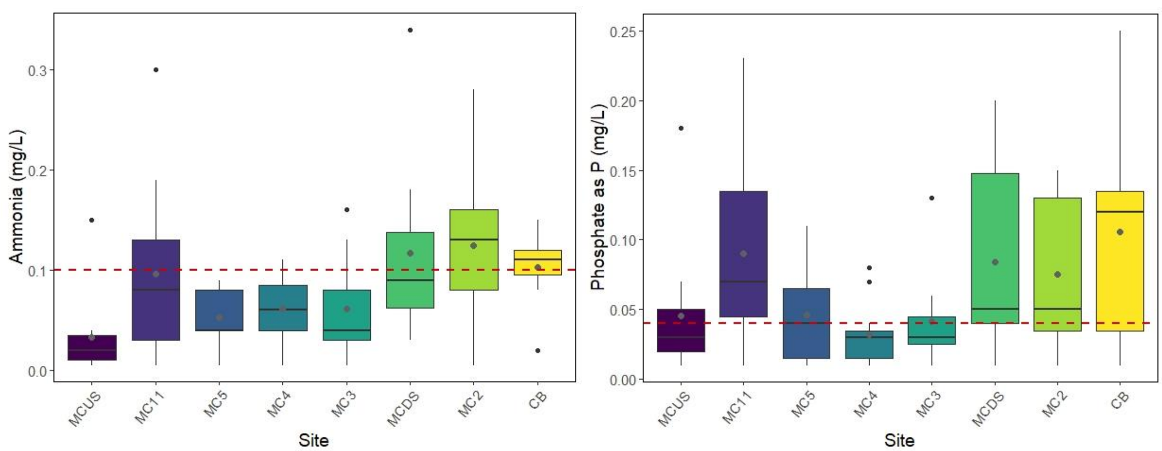

Figure 8. Left- Ammonia concentrations (mg/L) across sites in the Marsh Creek watershed in 2023. The mean values for each site are represented by grey circles, while outliers are represented by black circles, and the threshold limit (0.1 mg/L) is represented by the dotted line. Right- 2023 phosphate concentrations (mg/L) as P across sites in the Marsh Creek watershed. The mean values for each site are represented by grey circles, while the outliers are represented by black circles, and the threshold value (0.04 mg/L) is represented by the dotted line.

Field Parameters

Average dissolved oxygen (DO) concentrations measured in 2023 were above the threshold value of 6.5 mg/L at all sites within the Marsh Creek watershed (Figure 9). DO values fell below the threshold on fewer occasions in 2023 in comparison to 2022, indicating improved conditions within Marsh Creek. Greater DO levels in 2023 are likely correlated to lower the nutrient input also observed this season.

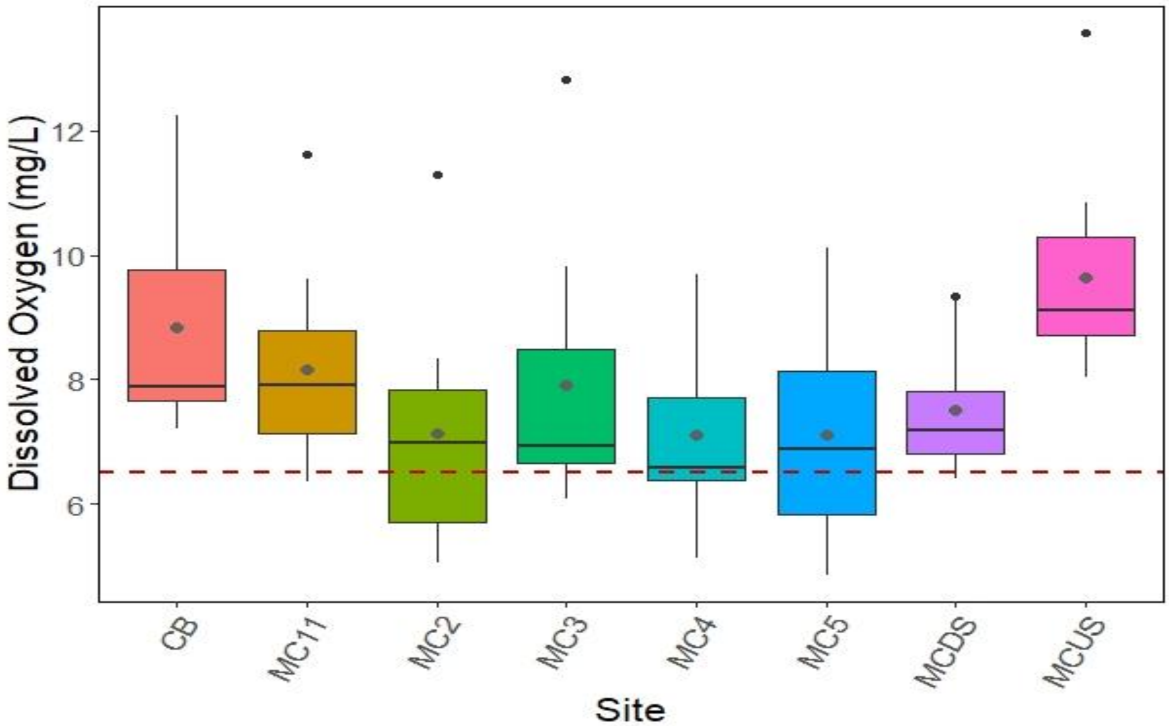

Figure 9. Dissolved oxygen concentrations (mg/L) measured across sites in the Marsh Creek watershed in 2023. The mean values for each site are represented by orange circles, while outliers are represented by blue circles, and the threshold value (6.5 mg/L) is represented by the dotted line.

All sites within the Marsh Creek watershed had average temperature values well within the threshold limit (23.5℃) in 2023, suggesting that these sites could act as thermal serve as a thermal refuge for sensitive aquatic species, if other habitat characteristics are met. Similarly, average pH and turbidity measurements were within their respective threshold ranges as well (6.5-9.0 and 55 NTU).

II.i. Marsh Creek Water Quality Comparative Analysis

The following subsection compares water quality data collected within the Marsh Creek watershed throughout 2019 to 2023. Parameters including ammonia, phosphate, and *E. coli* are presented graphically to show year-to-year trends, allowing for any changes in water quality to be identified. In 2023, the Marsh Creek watershed saw decreased levels of phosphates, ammonia, and *E. coli*; the concentrations observed in 2023 are more in-line with previous years, suggesting that results from 2022 were likely influenced by sampling errors rather than true deterioration of stream health. With Marsh Creek's history of contamination, lack of riparian cover, and heavily urbanized/industrialized reaches, this stream typically exhibits higher than average nutrient and *E. coli* concentrations.

E.coli

E. coli concentrations throughout the Marsh Creek watershed varied greatly across sites in 2023; six out of eight sites exhibited the highest averages to date, while Marsh Creek 4 had the lowest average *E. coli* concentrations over the last four years (Figure 10). Until

2020, fecal coliform concentrations (including but not limited to *E. coli*) were measured rather than *E. coli* concentrations, with that, data from 2019 was not included in Figure 12 below. Fecal coliform counts at Marsh Creek Downstream were historically much higher than those at upstream sites, with extremely high concentrations measured between 2000 and 2015. Following the cessation of raw sewage inputs in 2014, fecal coliform counts declined until more recent years, with the most downstream sites Courtenay Bay, Marsh Creek 2, and Marsh Creek Downstream all presented the highest average *E. coli* values over the last four years. These elevated levels of *E. coli* can likely be attributed to the increased occurrence and volume of rainfall that occurred in 2023. Heavy rain can result in lift station overflows, causing runoff to enter Marsh Creek. Although modernization of combined sewage overflows and lift stations occurred in 2022, the *E. coli* concentrations observed in 2023 indicate that further remediation efforts to reduce sewage outfalls and other sources of pollution within Marsh Creek remain today.

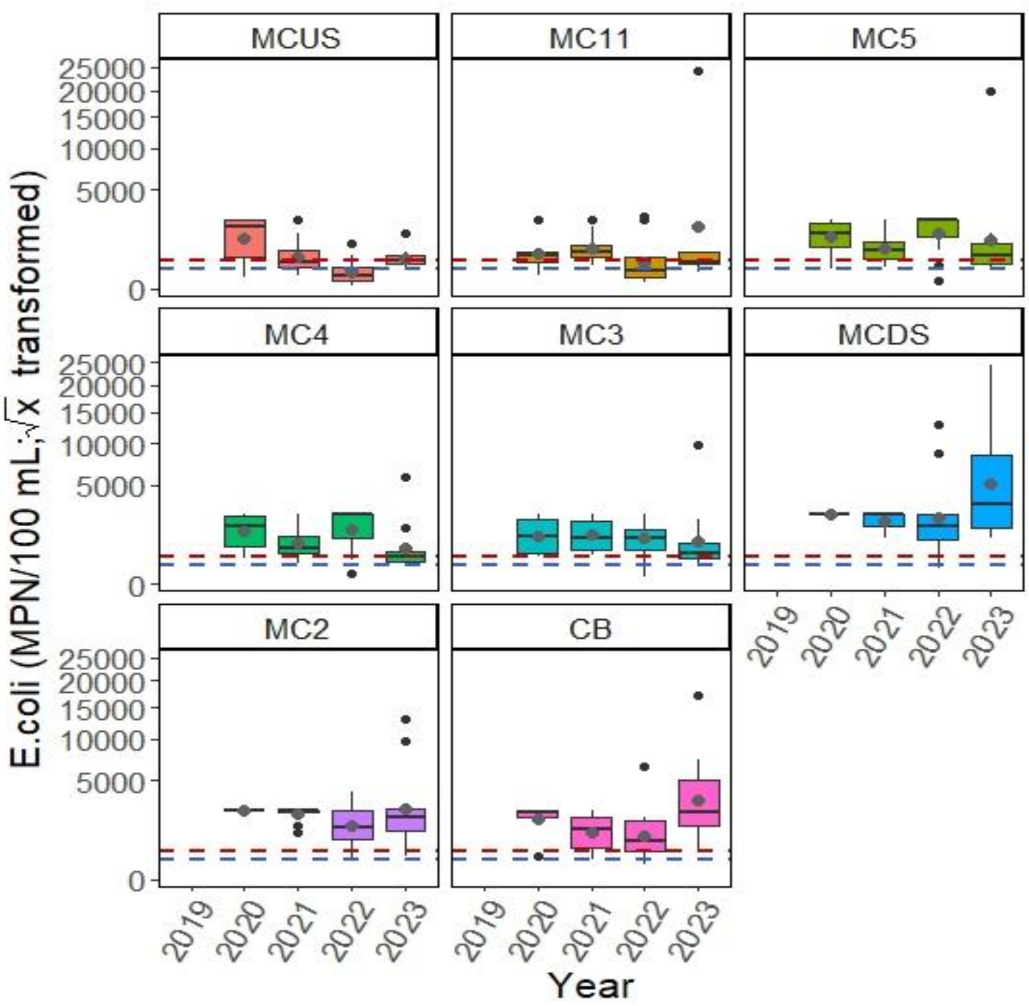

Figure 10. E. coli concentrations (MPN/100 mL) within the Marsh Creek watershed throughout 2020 to 2023 with mean values (grey circles), outliers (black circles), the threshold value (geometric mean concentration of 200 MPN/100 mL; minimum 5 samples) represented by the blue dotted line, while the single-sample maximum concentration (400 MPN/100 mL) is represented by the red dotted line.

Nutrients

Ammonia concentrations decreased at all sites between 2022 and 2023. Some sites exhibited the lowest average concentrations to date (MCUS [0.03 mg/L], MC3 [0.06 mg/L], and MC5 [0.05 mg/L]), while the remaining sites exhibited concentrations closer to those in 2020 and 2021 (Figure 11). In 2023, the average concentration of most sites remained below or close to the threshold value (0.1 mg/L), with fewer exceedances than 2021 and 2022. Ammonia levels have spiked multiple times over the past three decades, including after the cessation of raw sewage dumping in 2014. The increased ammonia concentrations observed between 2019 to 2022 may indicate continued impact from these pollution sources, presenting the need for further management.

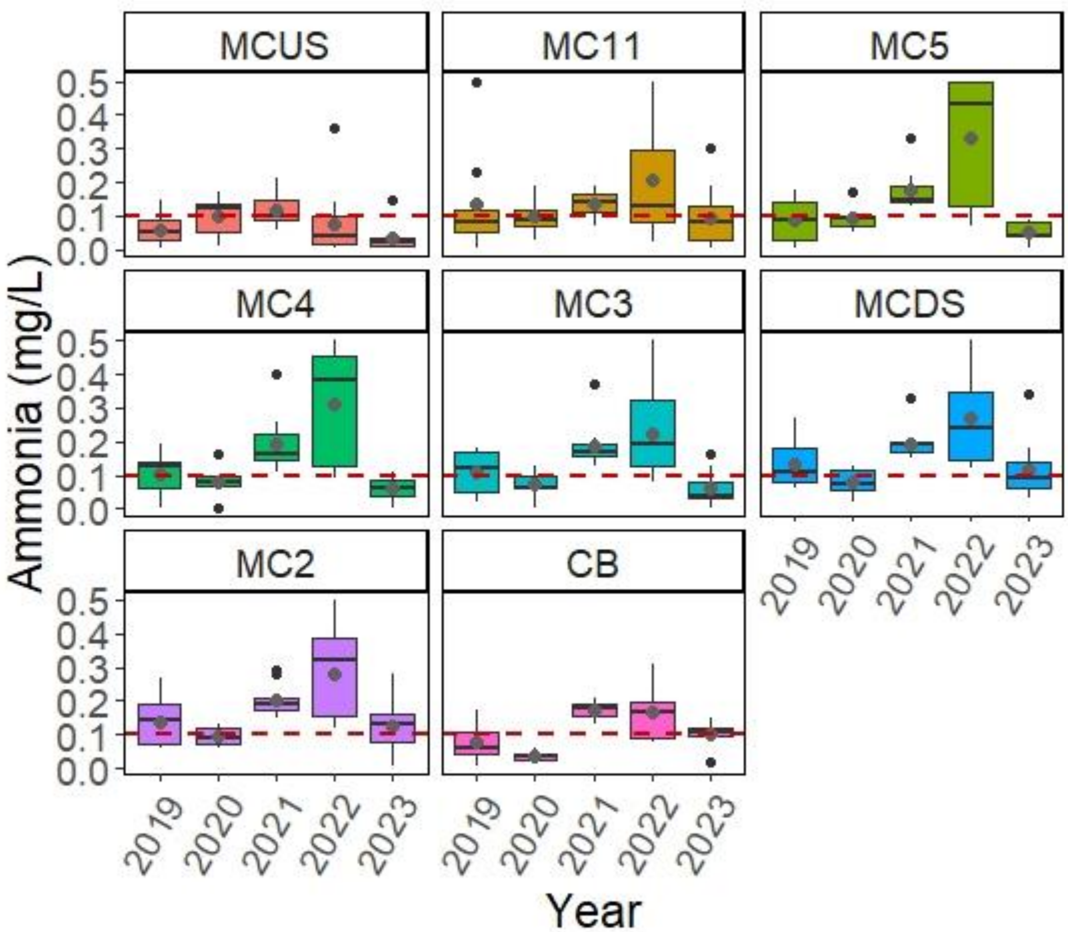

Figure 11. Ammonia concentrations (mg/L) within the Marsh Creek watershed throughout 2019 to 2023. Mean values are represented by grey circles, outliers are represented by black circles, and the threshold value (0.1 mg/L) indicated by the dotted line.

Average phosphate concentrations in 2023 exceeded the threshold value (0.04 mg/L) at all sites except for Marsh Creek 4 (0.03 mg/L), with two sites exhibiting the highest average concentrations to date (CB [0.12 mg/L] and MC11 [0.09 mg/L]) (Figure 12). As with ammonia, phosphate levels have periodically been elevated within the Marsh Creek watershed over the last decade, and the sources of phosphate entering the watercourse can vary. In addition to traditional sources of phosphorus (stormwater, fertilizers, erosion, etc.), the City of Saint John began adding phosphate to the drinking water supply to reduce corrosion of water pipes. With both lift-station overflows and fire hydrant draining, the phosphorus in the drinking water is likely contributing as a new source of phosphorus in our urban waterways.

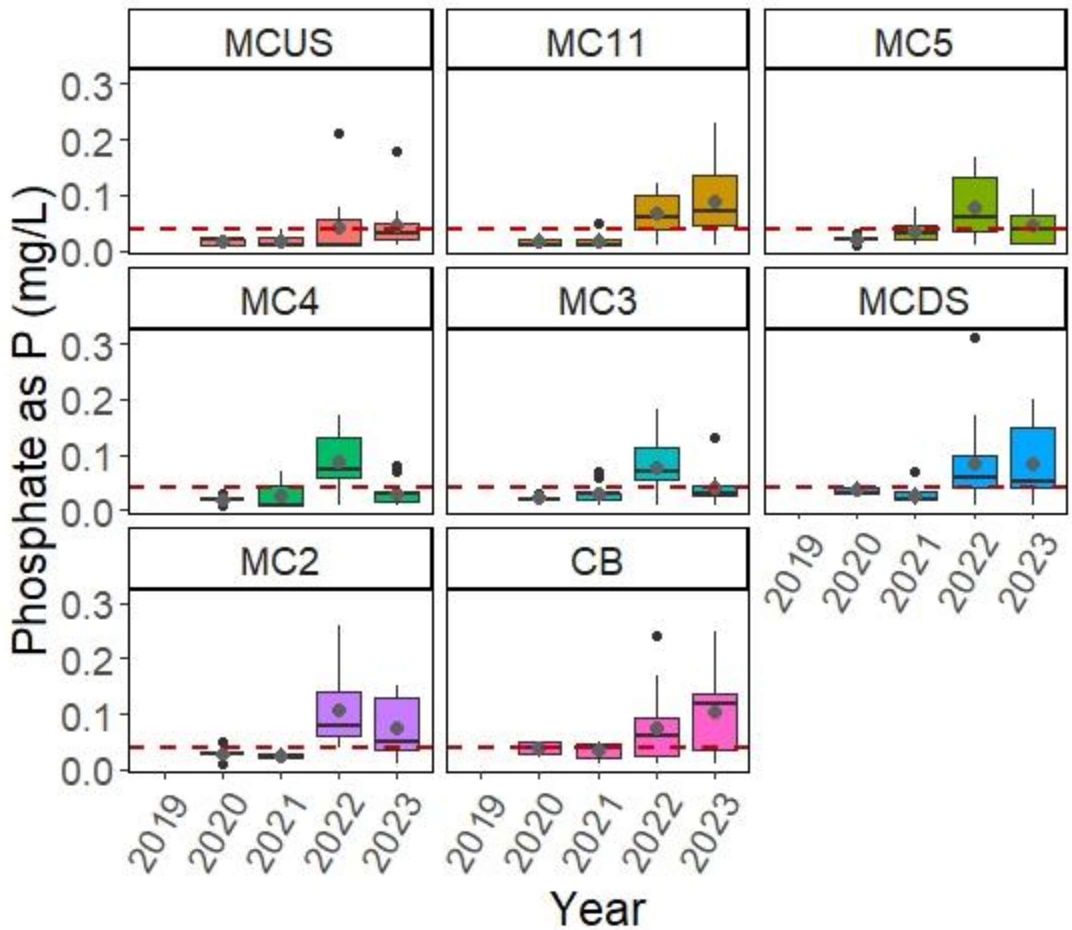

Figure 12. Orthophosphate concentrations as Phosphorus (mg/L) within the Marsh Creek watershed throughout 2019 to 2023. Mean values are represented by grey circles, outliers are represented by black circles, and the threshold value (0.04 mg/L) indicated by the dotted line.

As in previous years, the top contributors to poor water quality within the Marsh Creek watershed in 2023 remained phosphate and *E. coli* levels, with improved concentrations of ammonia. These parameters have been historically high in this watershed, and in general, continued to remain elevated across sites in 2023; this can likely be attributed to heavy rainfall occurrence before or during sampling periods within Marsh Creek. Despite its impaired water quality, Marsh Creek can support animal populations, with waterfowl and schools of fish frequently observed at various sites, yet this watershed remains polluted with higher-than-average nutrient levels and *E. coli* concentrations that often exceed recreational limits. To this day, Marsh Creek remains Saint John's most polluted watershed, further remediation efforts such as improved stormwater management and increased riparian vegetation would benefit this system.

III. Water Quality in the Greater Saint John Area

In this section, the water quality monitoring completed in the Saint John and surrounding area outside of the Marsh Creek watershed is presented. Due to the large volume of data collected within Marsh Creek since 1993, it was reported in its own section above.

Water Quality Score

Like previous years, no sites achieved an excellent water quality index score in 2023 (Figure 13). Of the sites, five exhibited good water quality, while the majority (12 sites) had fair water quality, and the remaining three had marginal water quality; no sites had poor water quality. These scores indicate that all sites had at least one parameter fall outside of the guidelines and threshold values described above. The lowest water quality was observed at Little River (WQI of 49.4) and Spar Cove (WQI of 56.8), while the best water quality was found at Mill Creek (WQI of 85.1) and Dominion Park (WQI of 84.5). The greatest contributing factor to impacted water quality was exceedances of phosphate and *E. coli* concentrations.

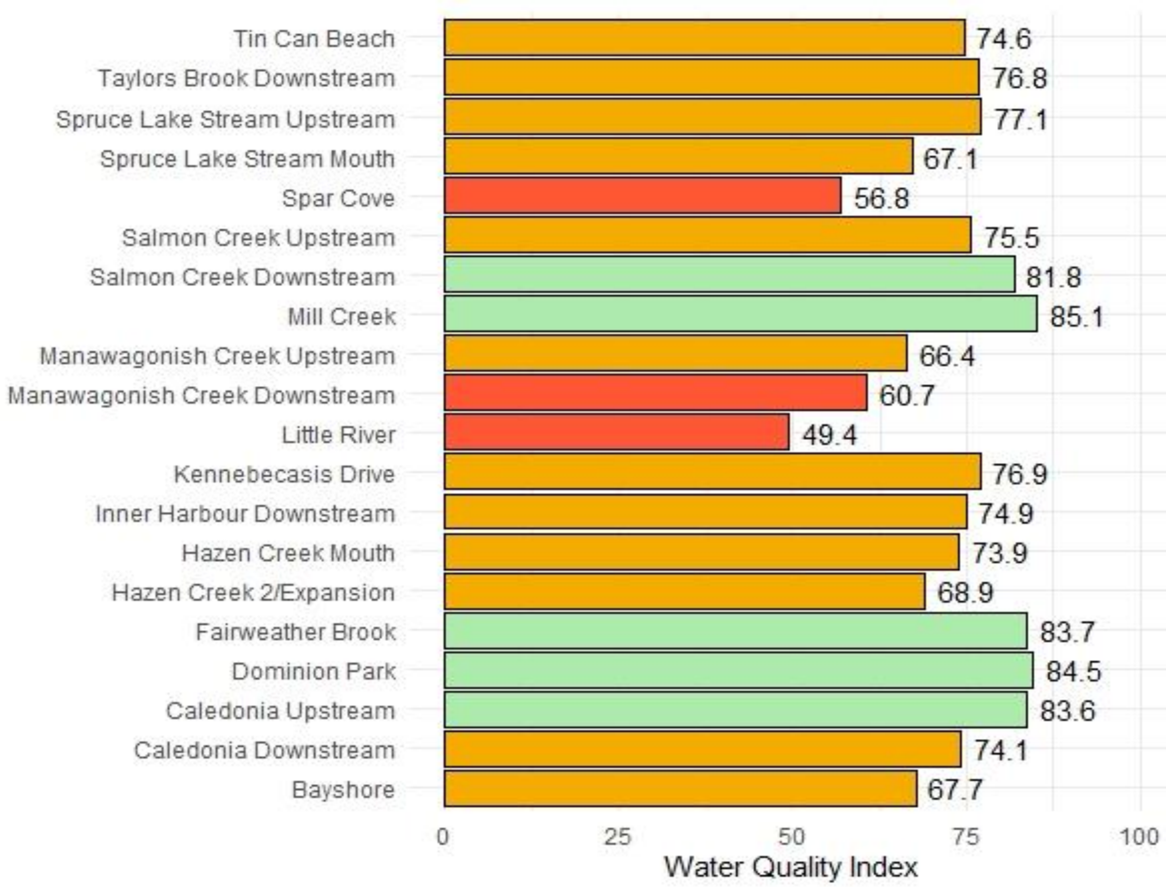

Figure 13. Water quality index values from sites within the Greater Saint John area in 2023.

Water quality in 2023 was generally much higher than that of 2022, with improvement in WQI scores observed at 15 sites (comprising 75% of sites) (Figure 14). It is expected that technical errors contributed to the diminished water quality observed in 2022, with results from 2023 aligning more with historical levels. A general decrease in ammonia and *E. coli* concentrations likely contributed to improved water quality conditions within streams of the Saint John and surrounding area.

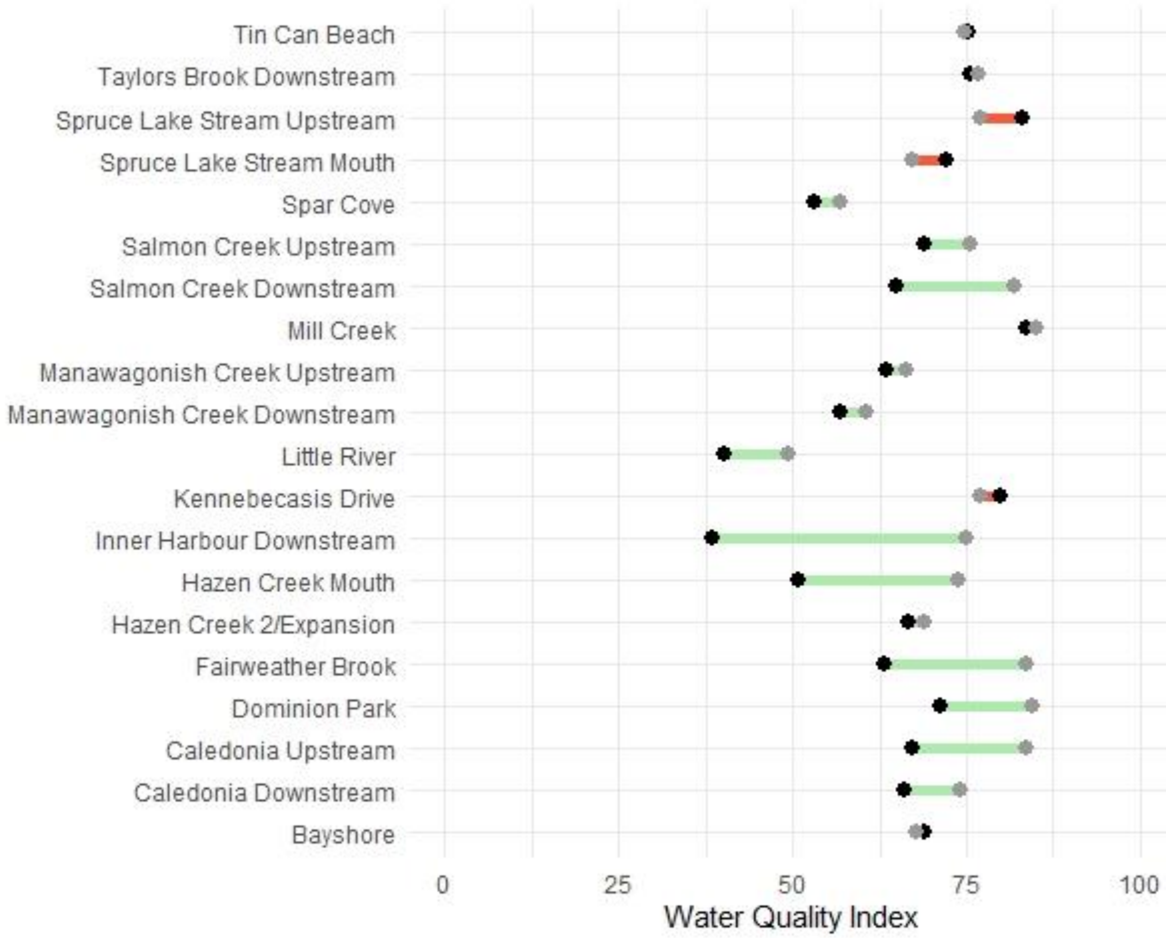

Figure 14. Changes in water quality index scores between 2022 (black circles) and 2023 (grey circles) at sites within the Greater Saint John area, with colours indicating whether the WQI score has improved (green) or declined (red) from 2022 to 2023.

E.coli

Overall, *E. coli* concentrations in 2023 exhibited less variability, while 47.8% (11 of 23) of sites had mean *E. coli* concentrations above the recommended recreational limit (200 MPN/100 mL) (Figure 15). Like previous years, the highest mean *E. coli* concentrations were measured at Spar Cove (2904 MPN/100 mL), Newman's Brook Downstream (2670 MPN/100 mL) and Caledonia Brook Downstream (1796 MPN/100 mL), continuing their historical trends of highly elevated *E. coli* values. These sites likely experienced considerable sewage inflows or runoff at some points in 2023, resulting in a highly variable range of *E. coli* concentrations and mean values. Conversely, 52.2% of sites had mean *E. coli* values below the threshold limit, with Dominion Park (25.1 MPN/100 mL) and Mill Creek (28.7 MPN/100 mL) exhibiting the lowest levels. Most sites experienced *E. coli* concentrations above the threshold limit on one or two occasions; these measurements can likely be associated with heavy rainfall events resulting in sewage inputs. Dominion Park's average value of 25.1 MPN/100 mL, with no exceedances of the threshold limit, is excellent as this site is a popular swimming location.

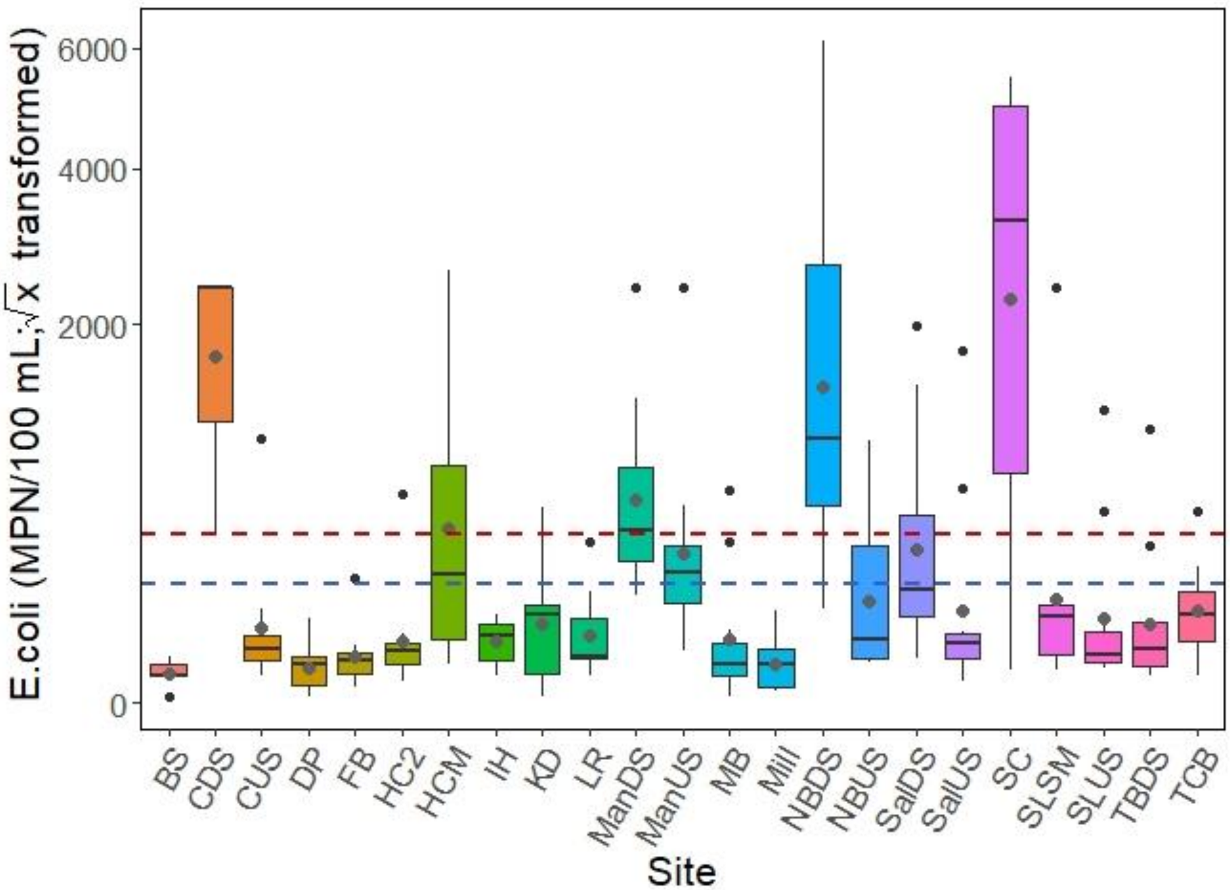

Figure 15. E. coli concentrations (MPN/100 mL) across sites in the Greater Saint John area in 2023. The mean values for each site are represented by grey circles, while the black dots represent outliers. The threshold value (geometric mean concentration of 200 MPN/100 mL; minimum 5 samples) is represented by the blue dotted line, while the single-sample maximum concentration (400 MPN/100 mL) is represented by the red dotted line.

Nutrients

In 2023, four sites had mean ammonia concentrations above the threshold limit (0.1 mg/L), Little River (0.48 mg/L), Newman's Brook Upstream (0.15 mg/L), Manawagonish Creek Downstream (0.13 mg/L), and Newman's Brook Downstream (0.1025 mg/L) (Figure 16). Little River flows through an oil refinery and is known to have extreme levels of ammonia. Similarly, Newman's Brook and Manawagonish Creek are known to receive municipal outputs and runoff from roads, creating a persistent issue with high nutrient concentrations. All other sites remained well within the threshold limit, with only two sites exceeding this limit on one or two occasions.

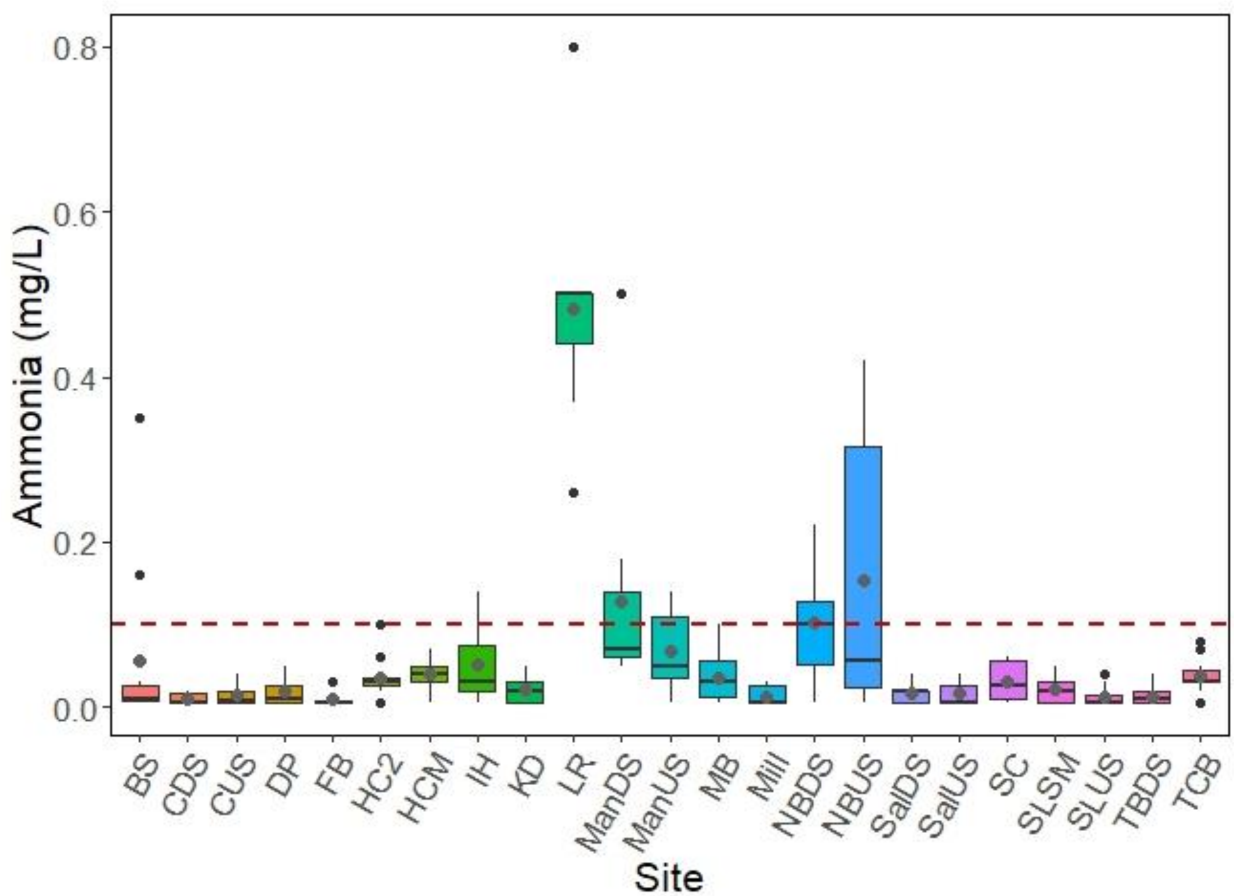

Figure 16. Ammonia concentrations (mg/L) across sites in the Greater Saint John area in 2023. The mean values for each site are represented by grey circles while the outliers are represented by black circles, and the threshold value (0.1 mg/L) is represented by the dotted line.

Conversely, Mill Creek (0.03 mg/L) was the only site with an average phosphate concentration below the threshold limit (0.04 mg/L) in 2023 (Figure 17). Three sites were close to the threshold range - Dominion Park and Manawagonish Creek Downstream (0.045 mg/L), and Caledonia Downstream (0.048 mg/L). The highest average phosphate concentrations were measured at Little River (0.288 mg/L), Mispec Beach (0.122 mg/L), and Salmon Creek Upstream (0.115 mg/L). As phosphate is more available in marine coastal waters, higher concentrations are expected at Mispec Beach, while elevated levels at Salmon Creek Upstream are likely due to incurred runoff; as mentioned, Little River is an extremely contaminated stream flowing through an oil refinery.

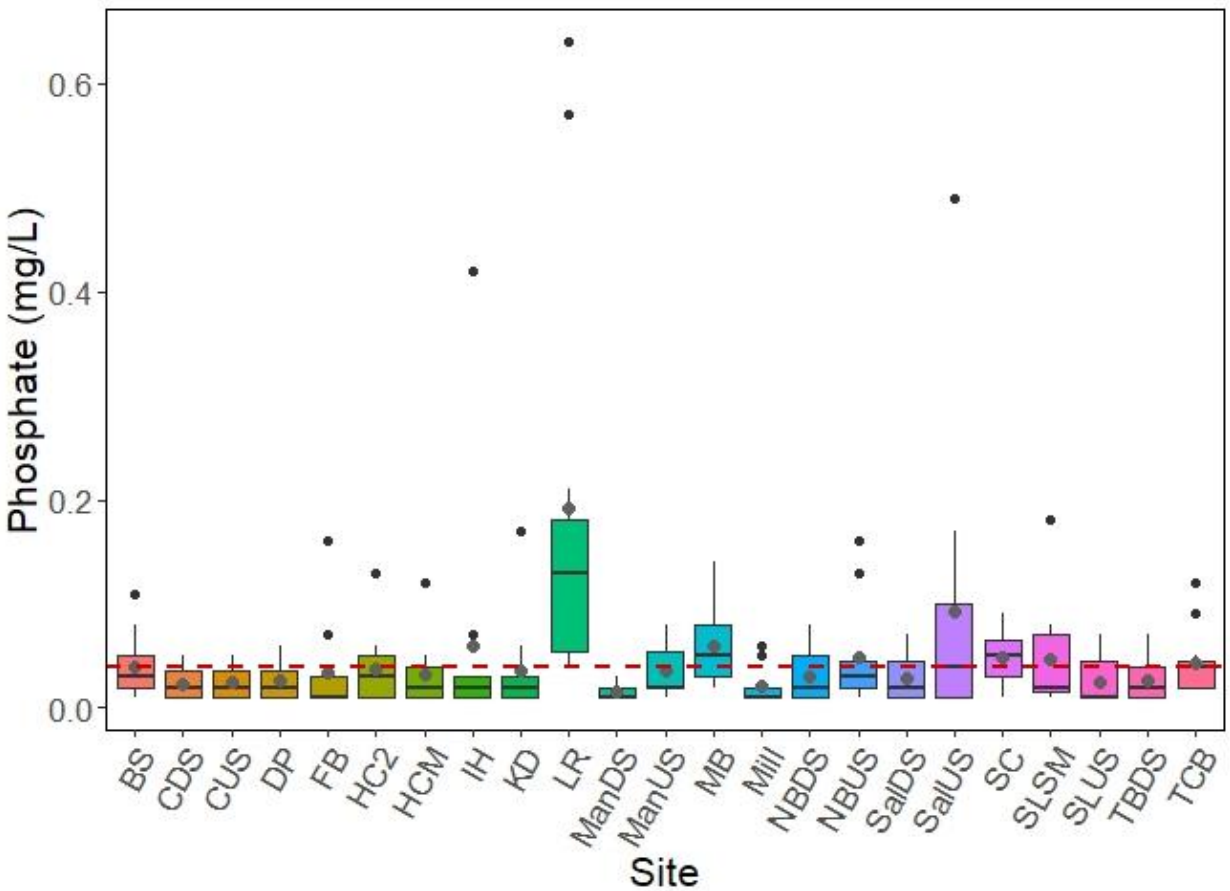

Figure 17. Orthophosphate concentrations (mg/L) as P across sites in the Greater Saint John area in 2023. The mean values for each site are represented by grey circles, while the outliers are represented by black circles, and the chosen threshold value (0.04 mg/L) is represented by the dotted line.

Field Parameters

In 2023, average dissolved oxygen concentrations were above the threshold limit (6.5 mg/L) across all sites within the Saint John and surrounding area. Like last year, DO measurements fell below the threshold on limited occasions at a few sites. Like previous years, Newman's Brook Downstream (NBDS) continued to exhibit some of the lowest concentrations (7.18 mg/L), apart from Spruce Lake Stream Mouth (SLSM), which had the lowest DO levels in 2023 (6.92 mg/L). These low DO measurements are expected at SLSM given its highly vegetated, low-flow conditions, like those of NBDS, in addition to high nutrient concentrations and fecal contamination. Overall, most sites in the Greater Saint John area have appropriate oxygen levels to support aquatic life (Figure 18).

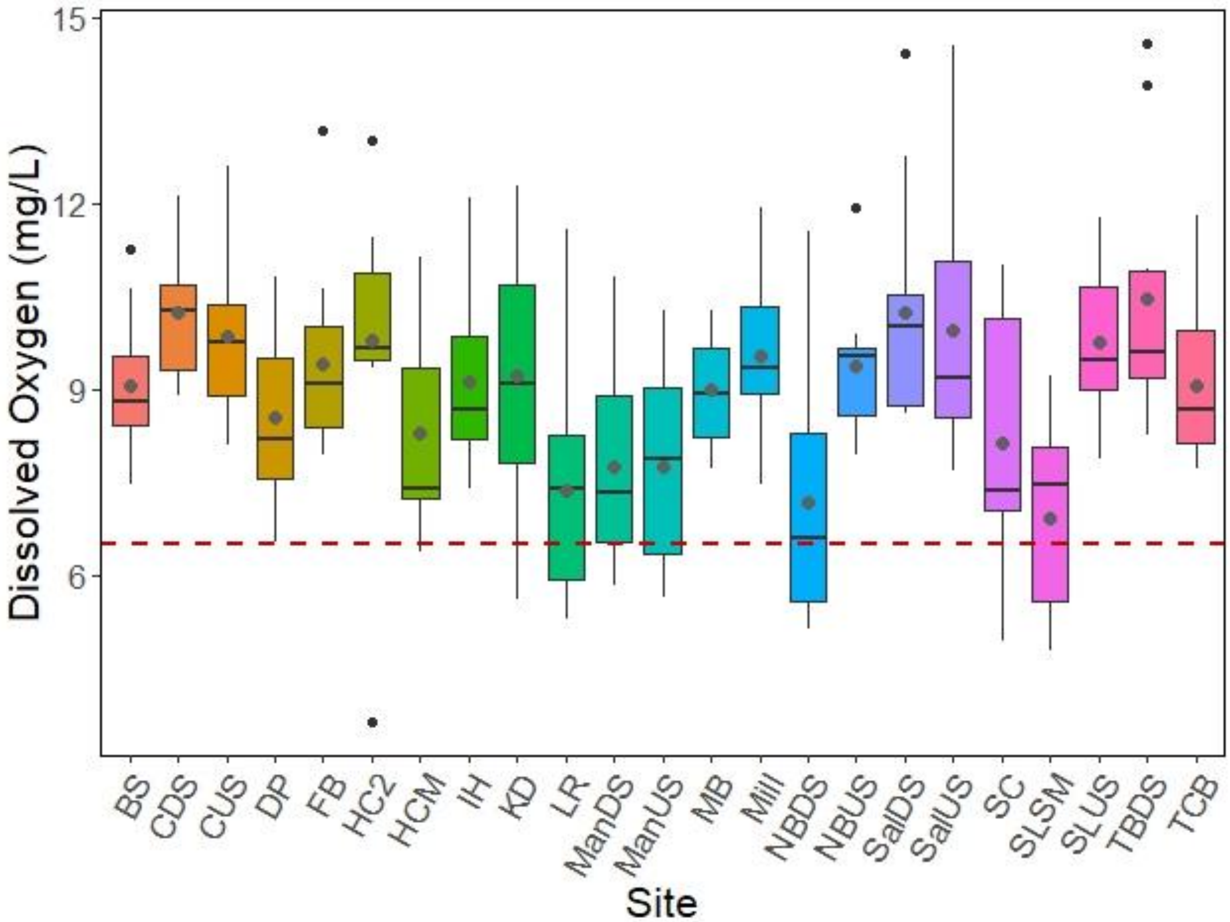

Figure 18. Dissolved oxygen concentrations (mg/L) across sites in the Greater Saint John area in 2023. The mean values for each site are represented by orange circles, while the outliers are represented by blue circles, and the threshold value (6.5 mg/L) is represented by the dotted line.

Temperature across all sites were well below the maximum threshold value (23.5 °C) chosen for this report, indicating that streams within the Saint John and surrounding area offer appropriate thermal conditions and refuge for aquatic species. Average turbidity ranged from 0.46-47.6 NTU in 2023. The highest turbidity value (122 NTU) was recorded at Mispec Beach (MB), this was the only occasion any site exceeded the threshold limit of 55 NTU. Elevated turbidity levels are expected at this site given its substrate composition of sand and fine sediments, along with strong wind and wave action that is typical for beach environments. Average pH measurements across all sites were well within the range of 6.5-9.0 throughout the 2023 field season.

III. i. Water Quality in the Greater Saint John Area Comparative Analysis

The following subsection compares water quality data collected within watersheds throughout the Greater Saint John area between 2019 to 2023. Nutrient and *E. coli* data is presented graphically to showcase year-to-year trends, allowing for changes to be observed. In 2023, most monitored watersheds across the Saint John and surrounding area saw improvement in water quality, with a general decrease in ammonia, phosphate, and *E. coli* concentrations. It is suspected that the increased nutrient levels observed in 2022 were the result of testing errors rather than a true decrease in water quality across sites.

E.coli

E. coli concentrations increased at 60.9% (14 of 23) of sites within the Saint John and surrounding area between 2022 and 2023 (Figure 19). As 2023 experienced the largest volume and frequency of rainfall within the five-year timeframe, single measurements of high *E. coli* concentrations may be the result of this. Increased runoff providing elevated nutrient concentrations, in combination with higher temperatures, allow for increased bacterial growth; these sites should be monitored closely in the following years to further investigate *E. coli* concentrations.

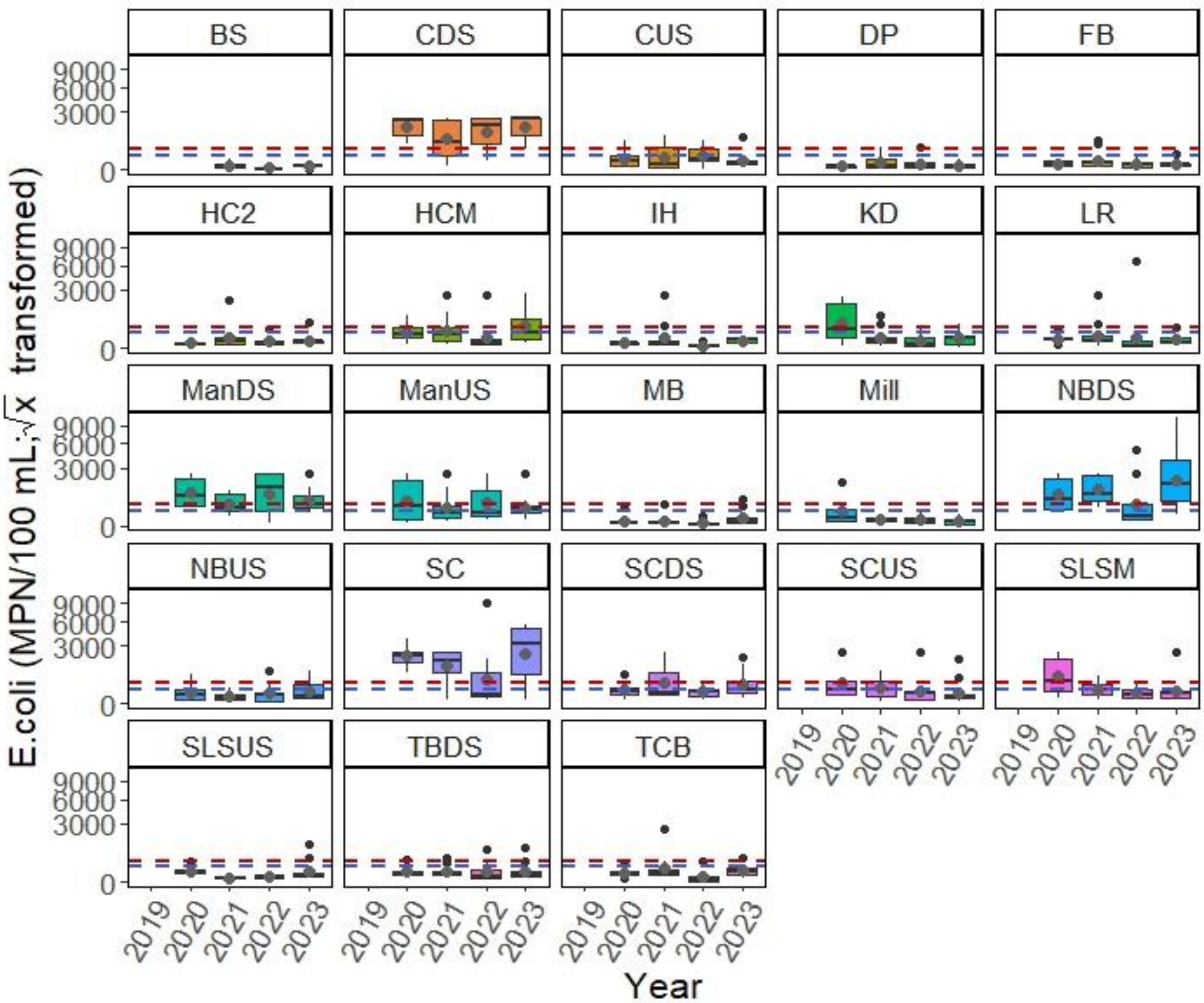

Figure 19. E. coli concentrations (MPN/100 mL) across sites in the Greater Saint John area between 2019 and 2023. The mean values for each site are represented by grey circles, outliers are represented in black circles, the threshold value (geometric mean concentration of 200 MPN/100 mL; minimum 5 samples) is represented by the blue dotted line, while the single-sample maximum concentration (400 MPN/100 mL) is represented by the red dotted line.

Nutrients

Overall ammonia concentrations were found to be lower in 2023, decreasing at 78.3% of sites (18 of 23) when compared with 2022 (Figure 20). In general, ammonia levels were less variable in 2023, although five sites did exhibit an increased mean concentration (BS, HC2, IH, KD, and NBUS), despite this, only three sites had mean concentrations above the threshold limit (0.1 mg/L). Like previous years, most sites continued to have average concentrations below the threshold. In contrast, average phosphate concentrations increased at 60.9% of sites (14 of 23) between 2022 and 2023, with all but one site (Mill Creek [0.032 mg/L]) exhibiting average concentrations above the threshold limit (0.04 mg/L) (Figure 21). Little River has consistently had the highest average values of both ammonia and phosphate over the years, with ammonia frequently exceeding the detection limit (0.5 mg/L) of lab equipment, and both phosphate and ammonia exceeding threshold limit guidelines.

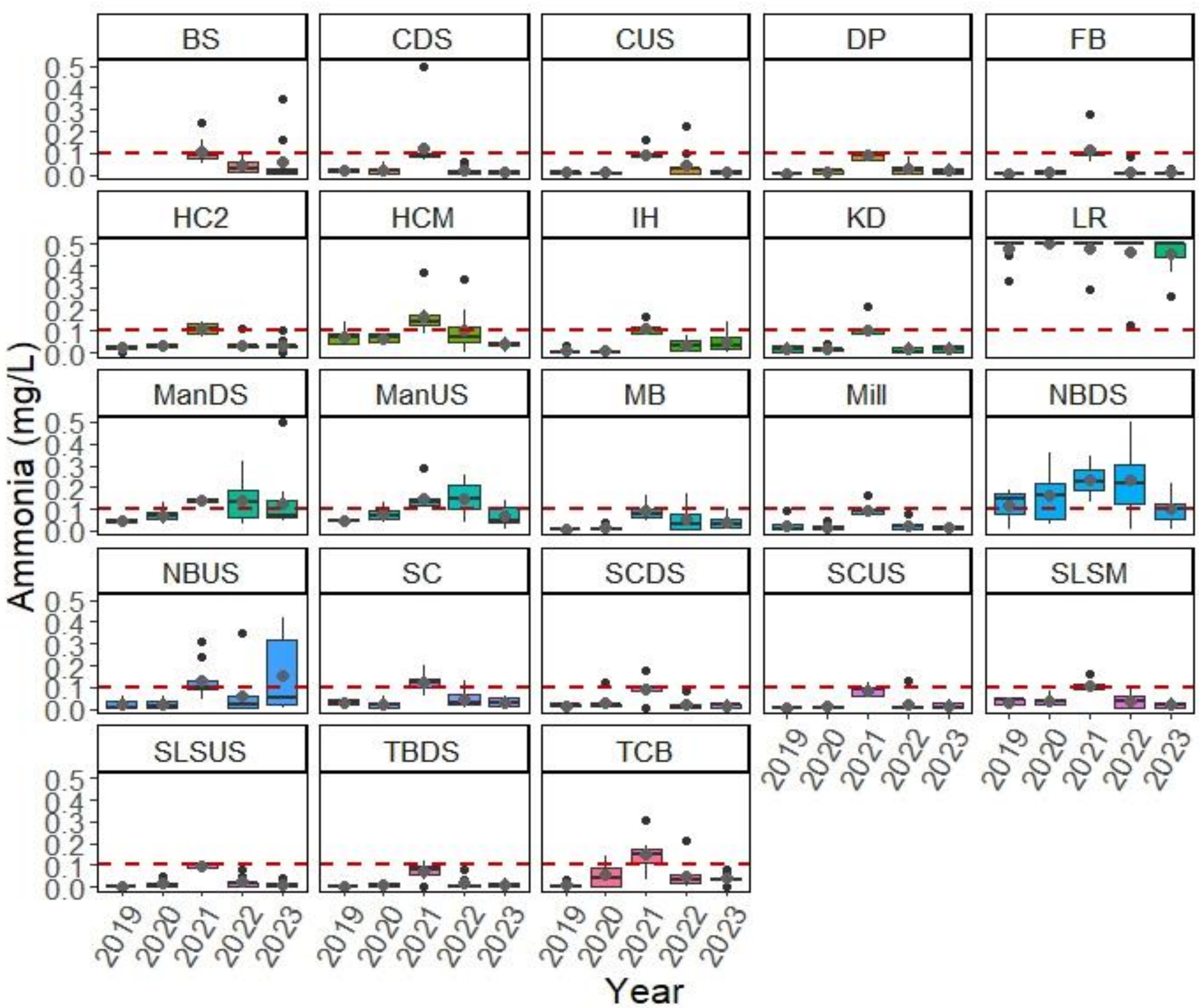

Figure 20. Ammonia concentrations (mg/L) across sites in the Greater Saint John area between 2019 and 2023. The mean values for each site are represented by grey circles, the outliers are represented by black circles, and the chosen threshold value (0.1 mg/L) is represented by the dotted line.

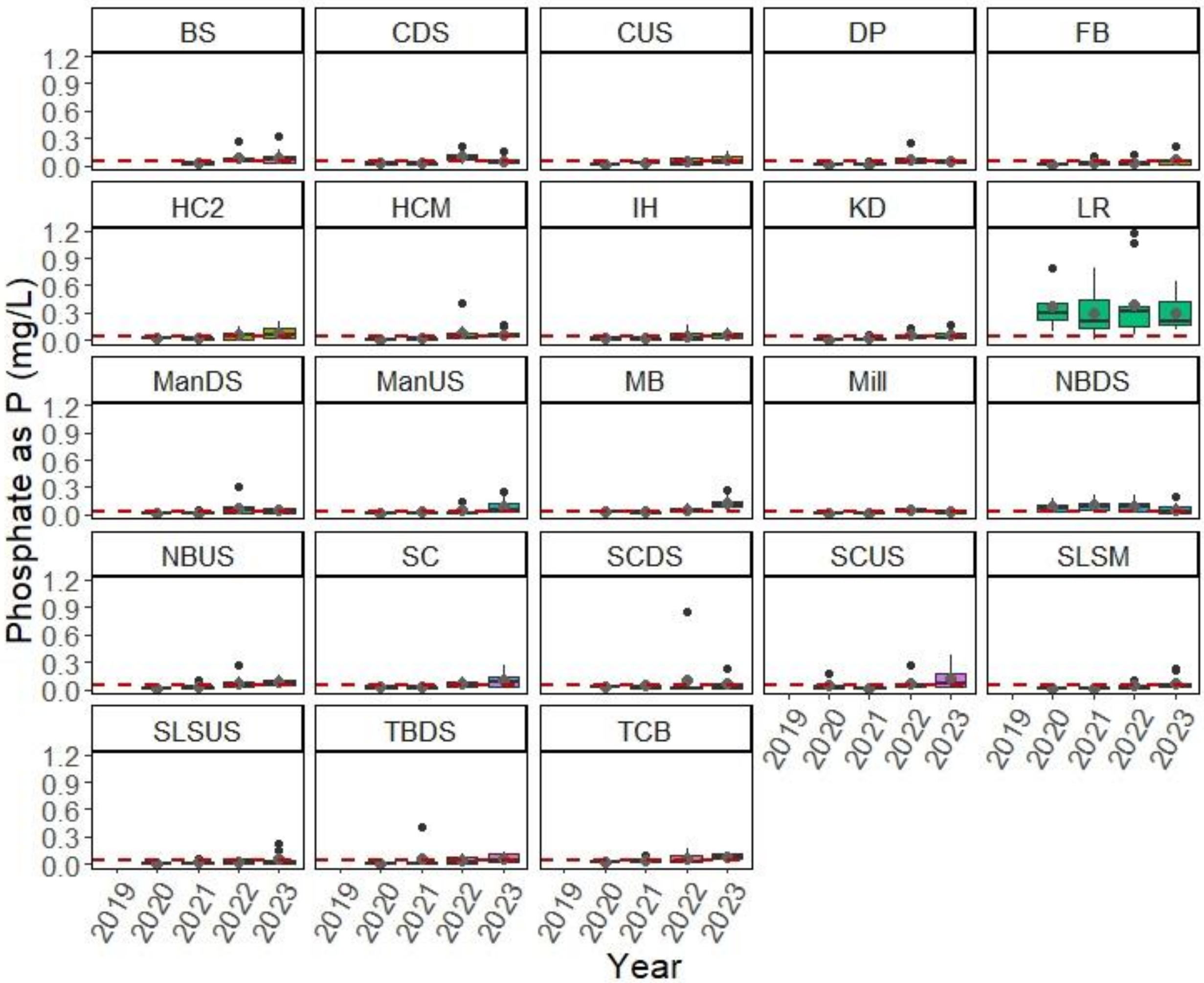

Figure 21. Phosphate concentrations as Phosphorus (mg/L) across sites in the Greater Saint John area between 2019 and 2023. The mean values for each site are represented by grey circles, the outliers are represented by black circles, and the chosen threshold value (0.04 mg/L) is represented by the dotted line.

Field Parameters

Average dissolved oxygen concentrations have generally remained stable at sites within the Saint John and surrounding area between 2019 and 2023. All twenty-three locations had average DO concentrations above the threshold limit (6.5 mg/L) in 2023 (Figure 22) with concentrations increasing at 60.9% of sites (14 of 23). In 2023, temperature decreased at 78.3% of sites (18 of 23) (Figure 23). Like DO, temperature values have remained stable over the years as well, with all sites maintaining an average temperature well below the threshold value (23.5 ℃), this suggests that streams within the greater Saint John area can provide thermal refuge for sensitive aquatic species.

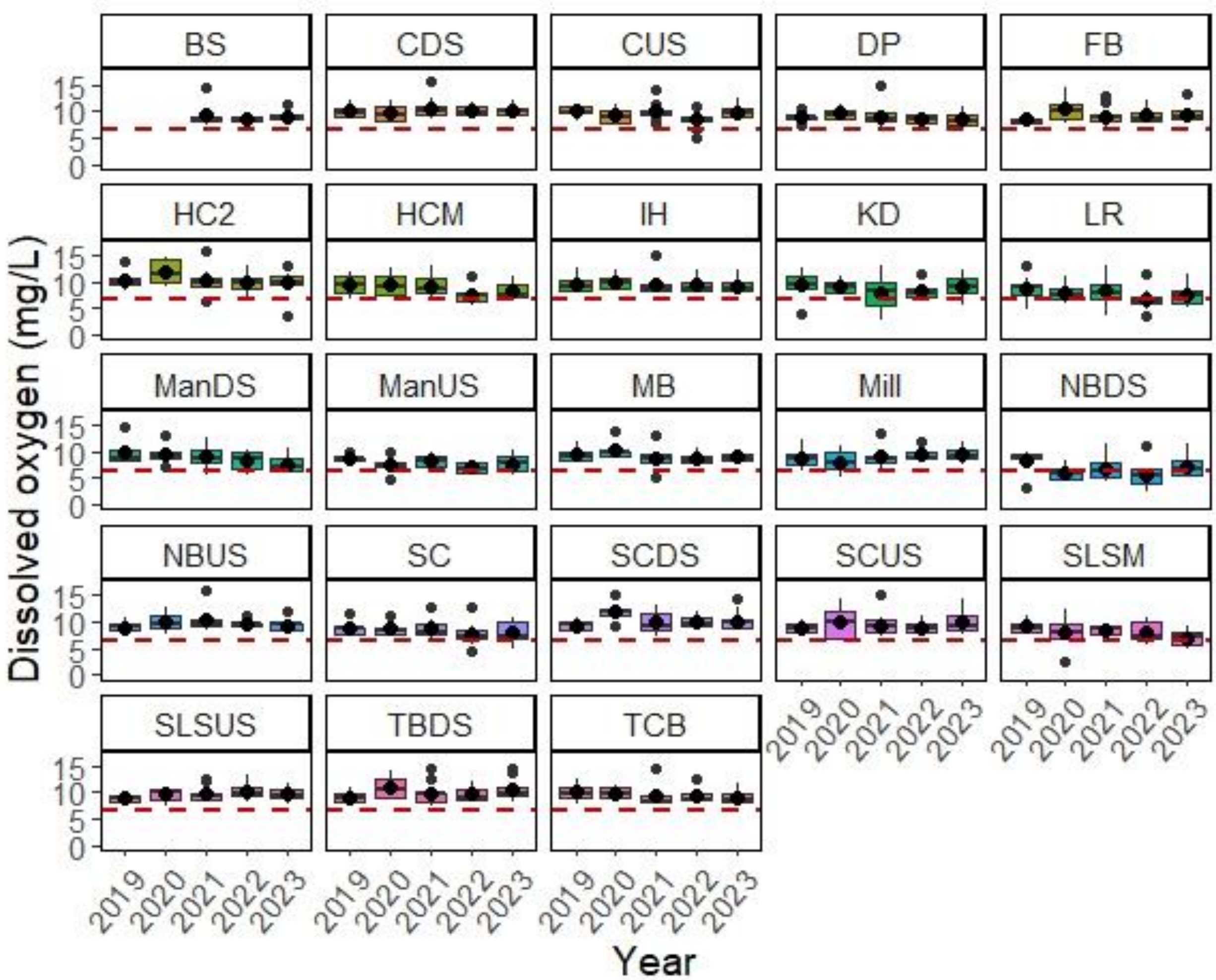

Figure 22. Dissolved oxygen (mg/L) across sites in the Greater Saint John area between 2019 and 2023, with mean concentrations represented by orange circles, outliers represented by blue circles, and the chosen threshold value (6.5 mg/L) represented by the dotted line.

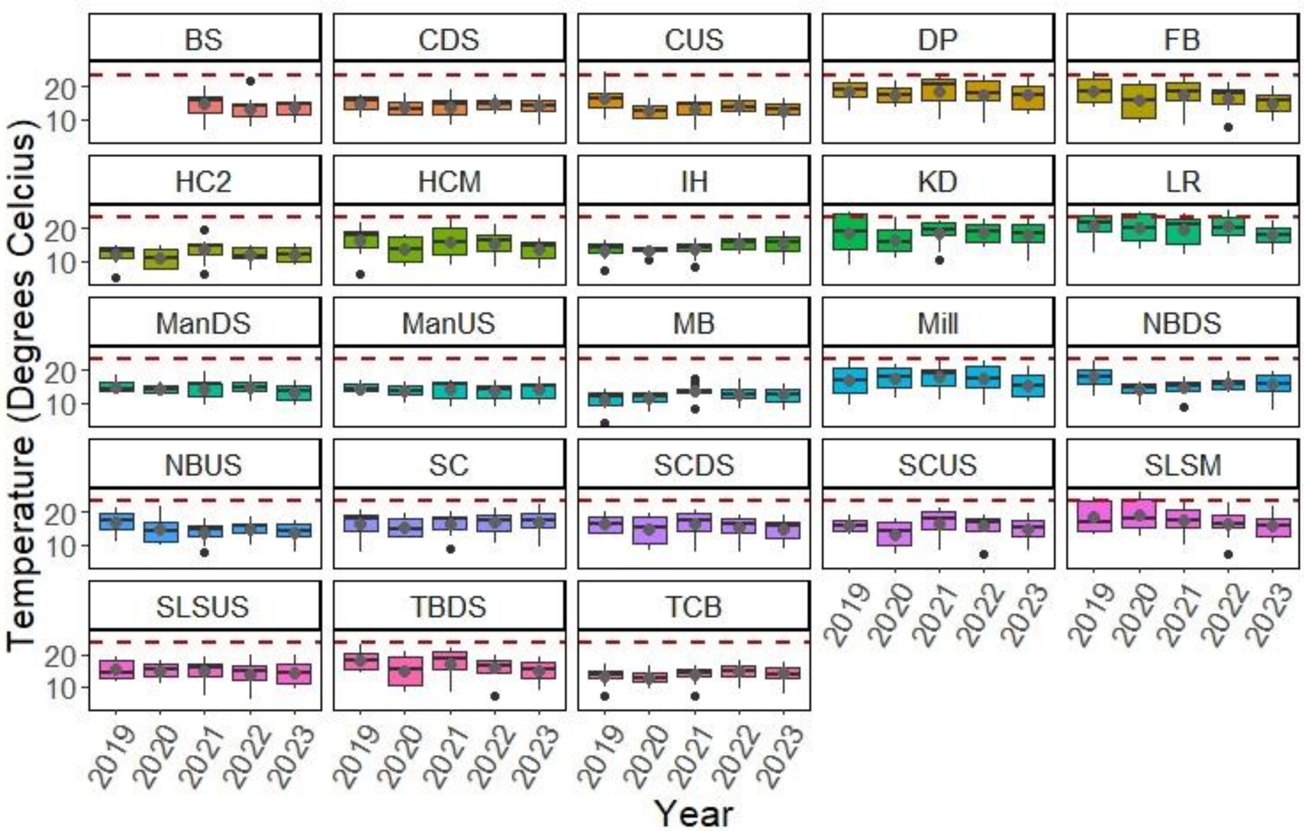

Figure 23. Water temperature (℃) across sites in the Greater Saint John area between 2019 and 2023. The mean values for each site are represented by grey circles, with outliers represented by black circles, and the threshold value (23.5 ℃) is depicted by the dotted line.

IV. Cyanobacteria

Cyanobacteria was monitored via visual assessments at all water quality monitoring sites as well as some popular swimming locations, and areas known to have had prior blooms. Monitoring for cyanobacteria was done ad hoc throughout the field season if favourable conditions for bloom formation were present. All cyanotoxin testing completed for total microcystins and anatoxin-a via rapid test kits were negative.

Over the course of the field season, visual signs of cyanobacteria were observed at Meenan's Cove, Renforth Wharf, and Kennebecasis Bay by the Royal Kennebecasis Yacht Club (RKYC). The bloom observed at Renforth Wharf was well-mixed and comprised of visible flecks; however, the bloom at Meenan's Cove was more apparent and noticeable. Originally, only flecks were observed in the Kennebecasis Bay by the RKYC, but on one occasion overnight, the flecks became a more visible bloom, and a sample of the accumulated cyanobacteria along the shoreline was collected the next morning and sent to RPC for cyanotoxin qPCR testing. The analysis confirmed the presence of cyanobacteria at this site with a total cyanobacteria concentration of 2,000,000 gc/mL. Additionally, this sample revealed that the species within this bloom were capable of producing saxitoxin (16,000 gc/mL), with lower concentrations of microcystin and anatoxin genes present (5,600 and 200 gc/mL respectfully).

V. Biotic Communities

In 2023, a total of 1891 individuals representing 12 species were caught using fyke and seine nets across two harbor monitoring sites from July to October (Figure 24). Courtenay Bay had the greatest abundance in catch, followed by Marsh Creek 2, which represented the smallest proportion of the total catch. A breakdown of total catch by seine and total catch by fyke are presented in the following sections below.

Figure 24. ACAP Saint John staff counting and measuring aquatic species captured at Marsh Creek 2.

V. i. Seine net method

In total, 1848 individuals across 10 species were captured in seine nets in 2023 between the two harbour fishing sites (Figure 25). As observed in 2022, the most abundant species caught was sand shrimp (*Crangon septemspinosa*; 74.9% of total catch), followed by Mummichog (*Fundulus heteroclitus*; 9.6% of total catch) and *Alosa sp*. (7.1% of total catch). More individuals were caught in seine nets at Courtenay Bay and Marsh Creek 2 in 2023 in comparison to 2022. Sand shrimp remained the top species in accordance with historical trends; however, the Atlantic silverside was replaced by the Mummichog as the second most-caught species in 2023. The change in abundance of Atlantic silverside is likely due to the delayed sampling period which began in July rather than May, missing the migration of Atlantic silverside, while the increased observation of Mummichog could be associated with sampling during their breeding season.

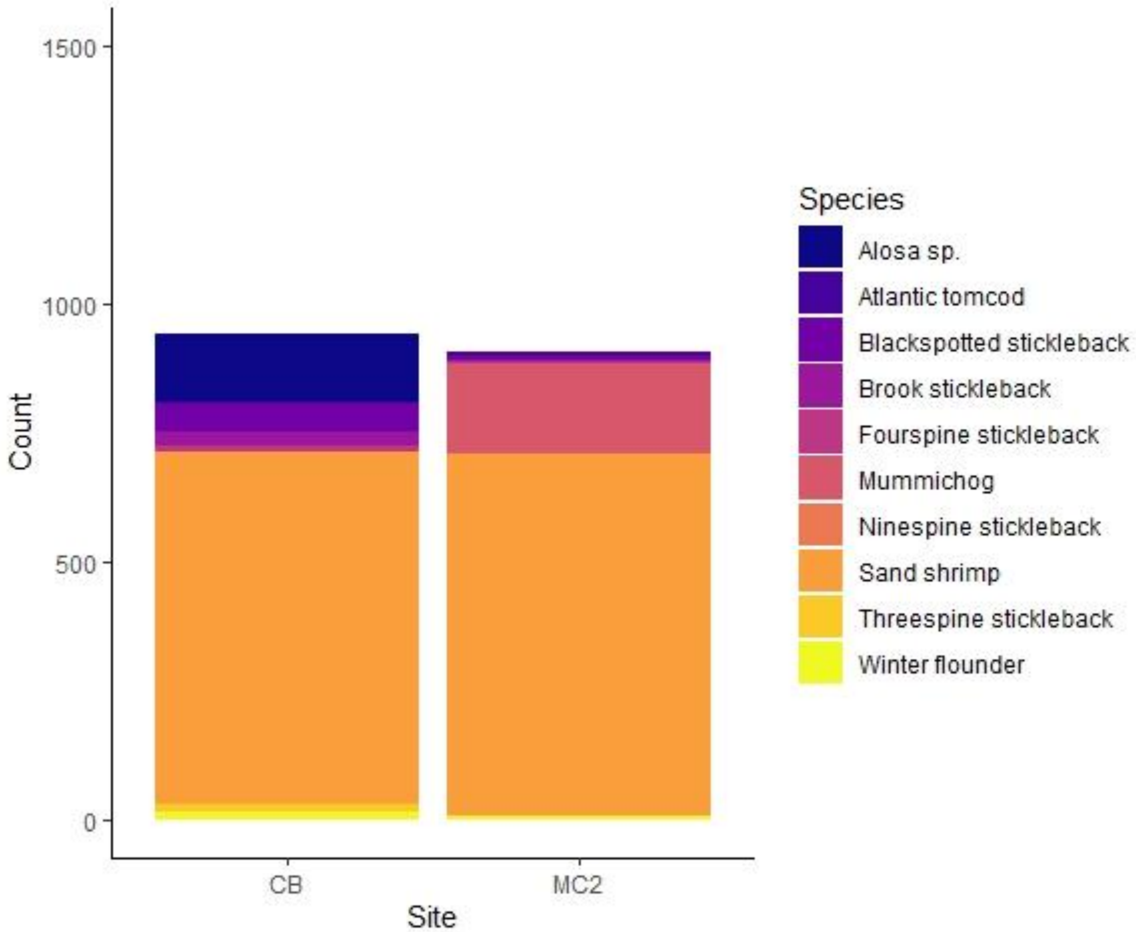

Figure 25. Total number of individuals collected using seine nets in the Harbour Monitoring program between July and October of 2023.

V. ii. Fyke net method

In 2023, a total of 43 individuals representing 7 species were captured in fyke nets (Figure 26). Like previous years, Atlantic tomcod *(Microgadus tomcod)* represented the largest proportion of the species caught (37.2% of the total catch), followed by sand shrimp (23.9% of the total catch). More individuals were caught at Courtenay Bay (65.1% of total catch) than at Marsh Creek 2 (34.8% of total catch). Most tomcods were caught at Courtenay Bay, with only one captured at Marsh Creek 2; in contrast, most sand shrimp were caught at Marsh Creek 2.

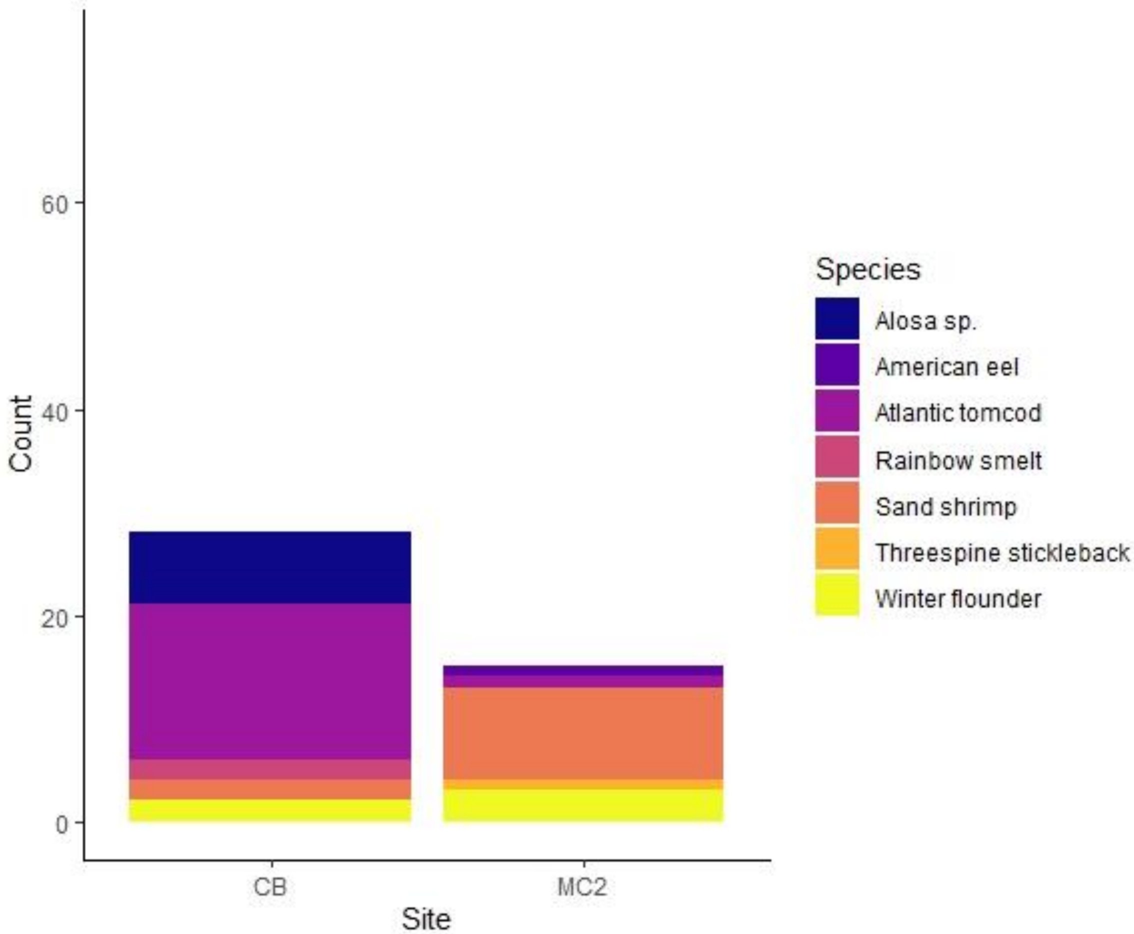

Figure 26. Total number of individuals collected using fyke nets in the Harbour Monitoring program between July and October of 2023.

V. iii. Biotic Community Analysis

In 2023, a total of 1891 individuals representing 12 species were captured using fyke and seine nets across two harbour monitoring sites. Courtenay Bay had a species richness of 11, while Marsh Creek 2 represented 10 different species; no new species were observed during this sampling period. Abundance was greatest at Courtenay Bay, with 968 individuals caught, compared to Marsh Creek 2, which had an abundance of 923 individuals. As in previous years, sand shrimp were the most abundant species observed and dominated the proportion of the catch at both sites.

Given the end of the baseline monitoring project, fish community monitoring returned to the two original sites in 2023 compared to eight in more recent years, these two sites were also sampled monthly from July until October (4 occasions), in comparison to monthly sampling between May and October (6 occasions) in previous years. Figure 27 and Figure 28 below represent the total catch by seine net and fyke net, respectively, at Courtenay Bay and Marsh Creek 2 across 2019 to 2023; note that data from May and June were excluded between years for a more representative comparison. Species abundance and richness captured in seine nets increased at both sites in 2023, with 2023 representing the second largest abundance observed since 2019 (Figure 27). Similarly, more species were caught in fyke nets at Courtenay Bay, while abundance at Marsh Creek 2 remained alike in 2023 in comparison to 2021 and 2022 (Figure 28). As mentioned, changes in abundance in species such as Atlantic silverside is likely due to the delayed sampling period, while increased observations of other species like Mummichog may be associated with the breeding season. Additionally, changes to water quality may better support species like Alosa sp., Mummichog, and Blueback Herring, which were observed in greater numbers at both sites in 2023, compared to previous years.

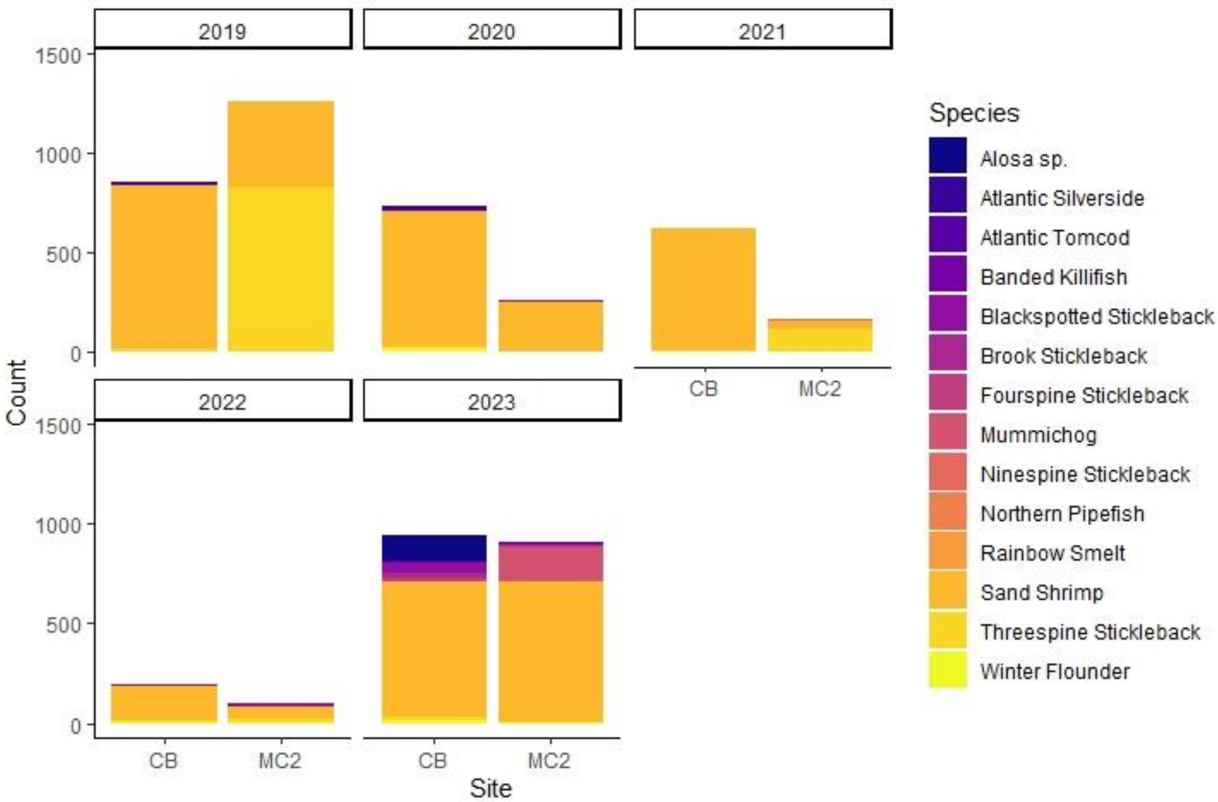

Figure 27. Total catch by seine net between July to October across years at Courtenay Bay and Marsh Creek 2.

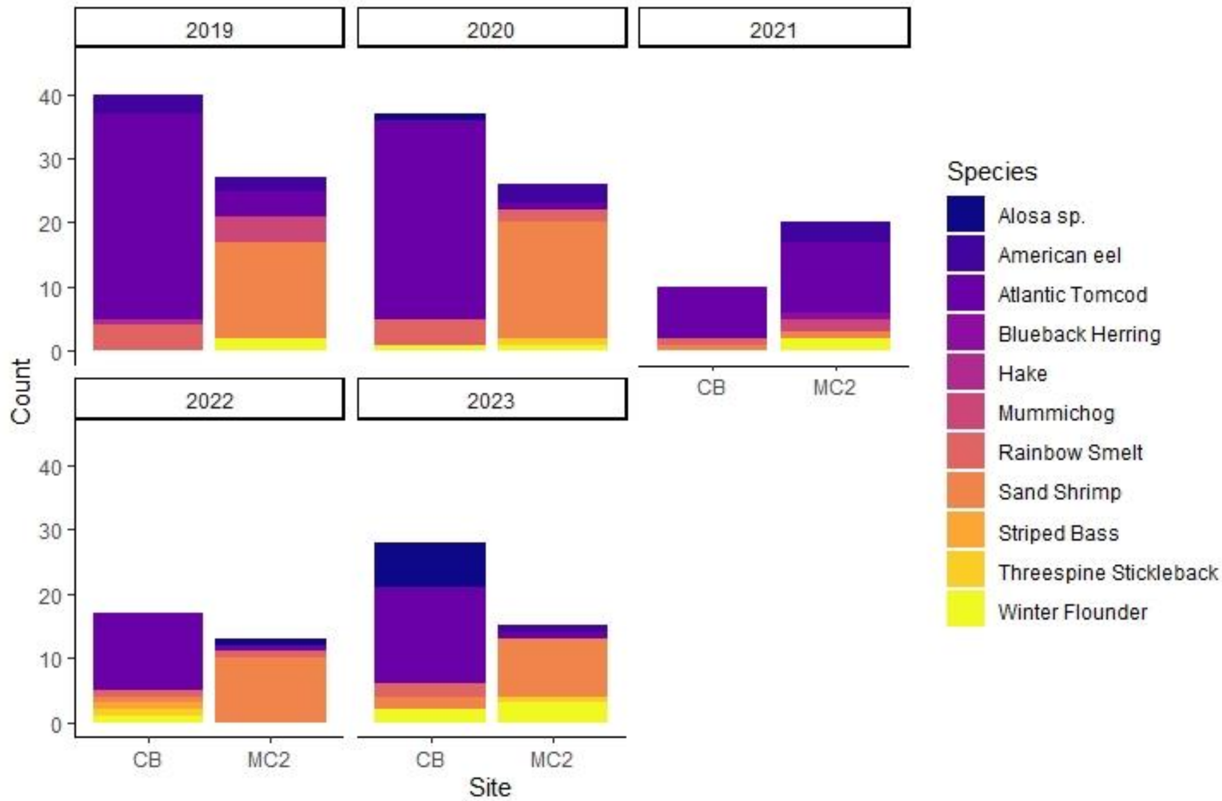

Figure 28. Total catch by fyke net between July to October across years at Courtenay Bay and Marsh Creek 2.

Construction and traffic within the Saint John continue to increase, with annual dredging, reconstruction of the seawall, and stormwater system upgrades, all of which impact aquatic life. Continued monitoring across further sites is recommended to determine migration and breeding patterns of aquatic life along with climate change and industrial impacts within the Saint John Harbour.

Conclusion

Water quality monitoring was successfully conducted at 31 sites, representing over ten watersheds within the Saint John and surrounding area in 2023. Given their locations in urban settings, many of these water courses are subject to riparian degradation, stormwater inputs, and modifications to natural flow that can impact water quality. Data from the 2023 field season suggests that the majority of monitored sites had fair water quality, indicating that most sites have water quality that is frequently threatened. Like previous years, no sites achieved an excellent WQI score, despite this, all but two sites showed improved water quality conditions. Ammonia concentrations were generally lower in 2023 compared to 2022, while phosphate and *E. coli* levels increased at some sites. Increased concentrations of these parameters are likely due to runoff and stormwater inputs from increased rainfall occurrence prior to and during sampling events. The issue of sewer and municipal inputs across the Greater Saint John area has been documented consistently in the past by ACAP Saint John; some of these issues are beginning to be addressed with the modernization of infrastructure. Despite the urban nature of many of these watercourses, the sites monitored within the Saint John and surrounding area can support healthy aquatic life given their low average temperatures, high dissolved oxygen concentrations, along with suitable pH and turbidity observed at most sites. Increased efforts to reduce nutrients and fecal contamination is recommended, including riparian/restoration enhancement, stormwater storage, and infiltration structures to help further improve water quality. ACAP Saint John will continue to work towards improving the water quality of these streams through implements above mentioned recommendations through partnership with municipalities, businesses, landowners, and the community.

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Appendix 1: Sampling Sites

Table 2. Water quality monitoring site locations and descriptions from the 2023 field season.

Site Name	Site Code	Latitude	Longitude	Site Description
Bayshore Beach	BS	45.2449	-66.075821	Located at the bottom of the hill off Sea Street.
Tin Can Beach	TCB	45.26224	-66.054578	Located at the end of Sydney St.
Spar Cove	SC	45.27615	-66.090295	Located beyond the trail near the park on Bridge St.
Little River	LR	45.27242	-66.022299	Located on the road beyond the Irving Forest Services parking lot on Bayside Drive.
Courtenay Bay	CB	45.2762	-66.047032	Located below the tide gates off the Courtenay Bay Causeway.
Marsh Creek Upstream	MC-US	45.321517	-66.015117	Located on the downstream side of the small bridge on Glen Road near MacKay Street.
Marsh Creek Downstream	MC-DS	45.282400	-66.04946	Located immediately downstream of the access road/rail crossing containing three metal culverts just beyond the Universal Truck and Trailer parking lot.
Marsh Creek 2	MC2	45.281560	-66.048694	Located approximately 500 m upstream from Site 1, just upstream of where Dutchman's Creek enters Marsh Creek.

Marsh Creek 3	MC3	45.284844	-66.052393	Located 500 m upstream from Site 2 immediately (2 m) upstream of the former raw sewage outfall adjacent to the Universal Truck and Trailer parking lot.
Marsh Creek 4	MC4	45.288143	-66.048764	Located 500 m upstream from Site 3, immediately upstream of the former raw sewage outfall.
Marsh Creek 5	MC5	45.290998	-66.043606	Located upstream of the raw sewage outfalls, approximately 2 km from the outlet of Marsh Creek at the tide gates (Site 1). This sampling station can be found beneath the train bridge adjacent to Rothesay Avenue.
Marsh Creek 11	MC11	45.30963	-66.03402	Located approximately 2.2 km upstream of Site 5, on Ashburn Lake road, directly across from Strescon.
Hazen Creek Mouth	HC-M	45.220990	-66.015505	Located upstream of the bridge crossing along Red Head Road at the outflow of Hazen Creek into the Saint John Harbour.
Hazen Creek 2/Expansion	HC2	45.275878	-65.998910	Located upstream of the culvert on Dedication Street within the industrial park.
Fairweather Brook	FB	45.378423	-65.978840	Located upstream of the McKay Highway (Highway 1) crossing next to the Dolan Road Irving gas station.
Taylors Brook Downstream	TB-DS	45.382143	-65.996388	Located under the bridge crossing on Rothesay Road by Rothesay Netherwood School.
Newman's Brook Upstream	NB-US	45.296902	-66.071298	Located along Sandy Point Road, roughly 300 m above Hazen White-St. Francis School, in the above ground section of Newman's Brook.

Newman's Brook Downstream	NB-DS	45.277345	-66.089187	Located at the furthest inland point in Spar Cove, just downstream of the stormwater/Newman's Brook outflow.
Inner Harbour	IH	45.27182	-66.07439	Located underneath the Harbour Bridge just off the Harbour Passage boardwalk.
Caledonia Brook Upstream	CB-US	45.29025	-66.09449	Located just downstream of the culvert crossing Millidge Avenue, next to the Saint John Energy substation.
Caledonia Brook Downstream	CB-DS	45.29687	-66.11867	Located just upstream of the culvert crossing at 159 Ragged Point Road.
Salmon Creek Upstream	SC-US	45.42371	-65.95859	Located upstream of the culvert crossing at 7 Rafferty Court.
Salmon Creek Downstream	SC-DS	45.40077	-65.9918	Located within Salmon Creek off Salmon Crescent where it meets Clark Road.
Spruce Lake Stream Mouth	SLS-M	45.25356	-66.14397	Located on the left-hand side of the street (Westfield Road) heading West; head down the embankment and sampling occurred near the culvert.
Spruce Lake Stream Upstream	SLS-US	45.24347	-66.15765	Located on the right-hand side of Highway 7 heading West; head down the embankment and sampling occurred near the culvert.
Manawagonish Creek Downstream	Man-DS	45.24445	-66.10737	Located off of Fairville Boulevard near the Comfort Inn parking, turn into the MelMart parking lot and park towards the end. Head down the embankment until the creek is reached.

Manawagonish Creek Upstream	Man-US	45.24355	-66.10259	Located off Honeysuckle Drive, a weir is located on the outside of the street. Water was sampled 100 m upstream of the weir.
Dominion Park	DP	45.26889	-66.1253	Located at the Dominion Beach park.
Kennebecasis Drive	DP	45.305689	-66.095746	Located on the main stem of the Wolastoq off Kennebecasis drive. Tidal area near the outflow of Alder Brook.
Mill Creek	Mill	45.27860	-66.15567	Located off the Westfield Road across the street from the Saint John Marina.

Appendix 2: Averages and Standard Errors of 2023 Water Quality Data

Table 3. Averages and standard errors of water quality parameters collected from 31 sites across the 2023 field season.

	SPC (µS/cm)		Temp (°C)		DO (mg/L)		pH		NH3 (mg/L)		PO4 (mg/L)		Turbidity (NTU)		*E. coli* (MPN/100 mL)	
Site ID	**X**	**SE**	**X**	**SE**	**X**	**SE**	**X**	**SE**	**X**	**SE**	**X**	**SE**	**X**	**SE**	**X**	**SE**
BS	22170.09	2968.07	13.37	0.87	9.04	0.35	7.37	0.23	0.06	0.03	0.09	0.03	27.12	6.25	4411.27	2949.33
CB	13876.55	2213.76	14.55	0.94	8.84	0.51	6.87	0.14	0.10	0.01	0.11	0.02	15.87	2.95	4130.87	1472.90
CDS	618.11	32.80	13.95	0.83	10.24	0.33	7.96	0.18	0.01	0.00	0.05	0.01	2.77	0.93	1796.76	246.10
CUS	1043.49	453.89	12.67	0.95	9.85	0.43	7.94	0.14	0.01	0.00	0.07	0.01	6.12	2.35	131.99	85.34
DP	3302.04	612.96	17.32	1.26	8.54	0.43	7.81	0.41	0.02	0.01	0.04	0.01	3.84	0.99	25.10	8.74
FB	224.80	90.38	14.82	1.04	9.41	0.46	7.40	0.20	0.01	0.00	0.06	0.02	0.47	0.19	40.38	17.92
HC2	237.57	57.53	12.09	0.74	9.80	0.74	7.57	0.27	0.04	0.01	0.08	0.02	1.33	0.79	85.86	55.64
HCM	7430.72	1661.75	13.44	1.02	8.27	0.49	7.12	0.16	0.04	0.01	0.06	0.02	7.57	2.64	660.21	279.09
IH	18146.45	2058.98	15.15	0.95	9.11	0.44	7.38	0.10	0.05	0.01	0.06	0.01	30.76	11.72	57.82	10.77
KD	3239.27	462.12	17.84	1.24	9.21	0.70	7.90	0.19	0.02	0.00	0.05	0.02	4.51	1.75	127.38	47.16
LR	689.57	123.48	17.86	0.97	7.35	0.56	6.99	0.36	0.48	0.04	0.29	0.05	8.00	1.52	83.25	32.11
ManDS	531.27	44.39	13.25	0.79	7.75	0.51	7.77	0.44	0.13	0.04	0.04	0.01	6.45	1.39	687.72	200.41
ManUS	1301.13	724.73	14.06	0.86	7.75	0.48	7.76	0.16	0.07	0.01	0.09	0.02	8.27	1.89	434.65	203.50
MB	29946.82	2829.67	12.37	0.83	8.98	0.27	6.99	0.22	0.04	0.01	0.12	0.02	47.63	11.84	109.50	61.05
MC11	270.59	15.22	15.16	1.00	8.17	0.46	7.17	0.26	0.10	0.03	0.09	0.02	5.23	1.17	4724.55	2903.05
MC2	9373.18	2581.17	14.98	0.93	7.13	0.54	7.18	0.13	0.12	0.02	0.08	0.02	20.59	5.14	3314.27	1230.93
MC3	474.85	119.75	15.42	0.93	7.90	0.60	7.36	0.10	0.06	0.01	0.04	0.01	12.74	4.95	1476.82	848.38
MC4	271.21	18.10	15.32	0.91	7.12	0.42	7.35	0.09	0.06	0.01	0.03	0.01	8.53	2.56	956.82	497.89
MC5	275.75	17.84	15.29	0.97	7.10	0.52	7.31	0.10	0.05	0.01	0.05	0.01	6.94	1.44	2379.82	1753.38
MCDS	791.30	309.50	16.05	0.84	7.51	0.33	7.81	0.31	0.12	0.03	0.08	0.02	7.03	1.00	6614.80	2367.53
MCUS	109.35	8.03	14.31	0.98	9.65	0.48	7.45	0.15	0.03	0.01	0.05	0.01	1.71	0.54	531.55	119.33
Mill	162.46	8.52	15.59	1.15	9.54	0.41	8.06	0.47	0.01	0.00	0.03	0.00	1.33	0.26	28.69	10.61
NBDS	8925.27	1658.80	15.75	1.06	7.18	0.67	7.44	0.28	0.10	0.02	0.06	0.02	5.21	1.40	2670.65	978.71
NBUS	204.63	14.41	13.84	0.98	9.37	0.35	7.66	0.20	0.15	0.05	0.07	0.01	3.60	1.16	213.80	87.46
SalDS	431.21	30.97	14.78	1.01	10.24	0.56	7.61	0.14	0.02	0.00	0.06	0.02	2.08	1.34	475.26	193.64
SalUS	435.88	60.91	14.71	1.08	9.96	0.59	7.59	0.11	0.02	0.00	0.11	0.03	3.66	2.20	248.93	158.41
SC	5576.73	826.83	17.15	1.14	8.14	0.62	7.72	0.25	0.03	0.01	0.10	0.02	5.27	1.49	2904.24	647.22

SLSM	1003.84	209.01	15.87	1.16	6.91	0.48	7.62	0.41	0.02	0.00	0.07	0.02	4.02	0.72	295.53	212.95
SLUS	115.15	6.40	14.24	1.08	9.75	0.37	8.09	0.33	0.01	0.00	0.05	0.02	1.59	0.83	185.63	110.92
TBDS	166.20	9.26	14.76	1.02	10.45	0.62	7.16	0.30	0.01	0.00	0.06	0.02	1.71	0.59	158.37	93.37
TCB	24827.09	2111.30	14.07	0.91	9.06	0.44	6.90	0.19	0.04	0.01	0.08	0.01	19.09	4.46	144.09	43.60