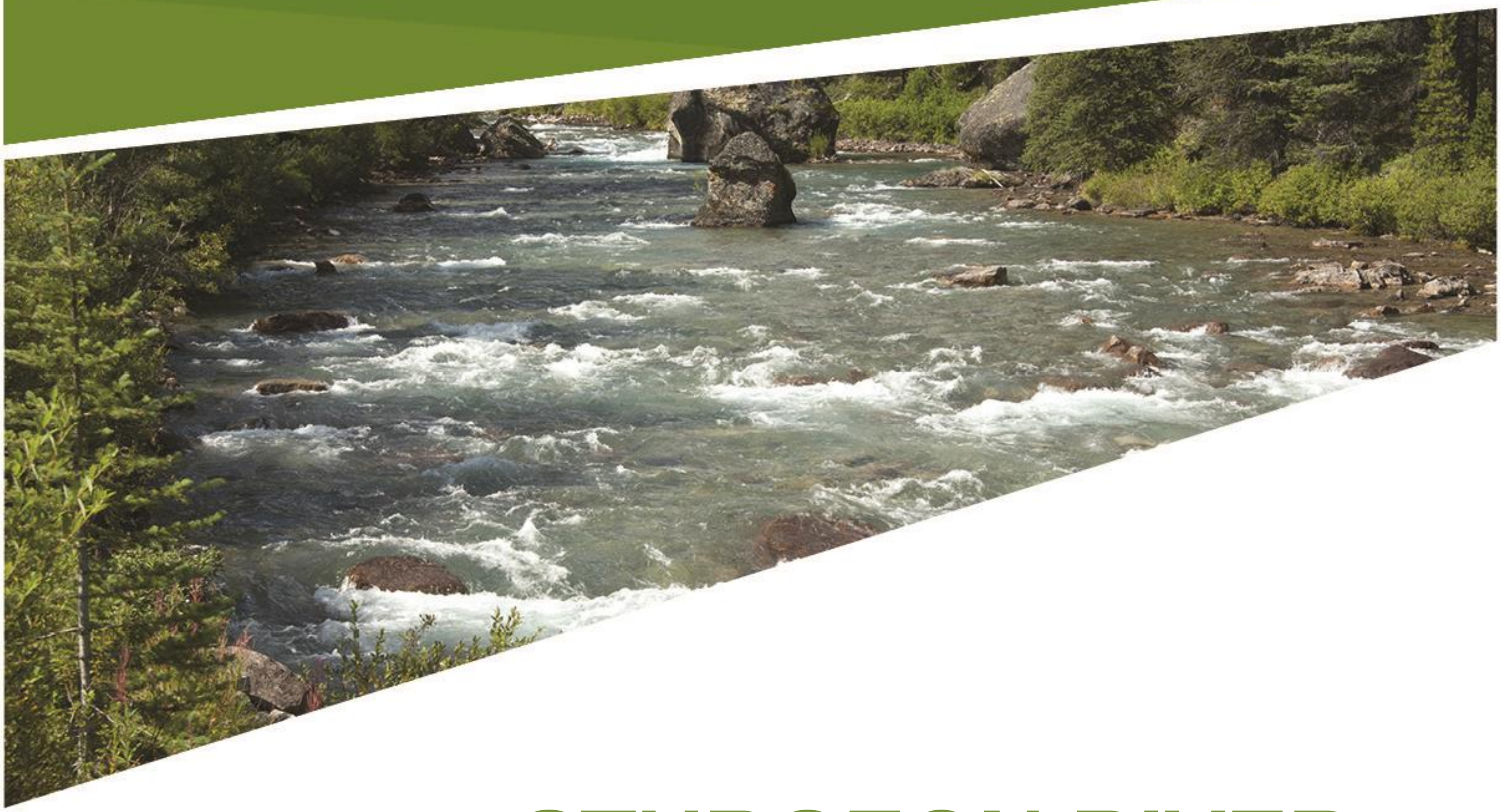

STURGEON RIVER

2017 Aquatic Ecosystem Assessment

Prepared for: North Saskatchewan Watershed Alliance

Date: January 24, 2019

NSWA
NORTH SASKATCHEWAN WATERSHED ALLIANCE

CPP ENVIRONMENTAL
Charette Pell Poscente

PROFESSIONAL SIGNOFF

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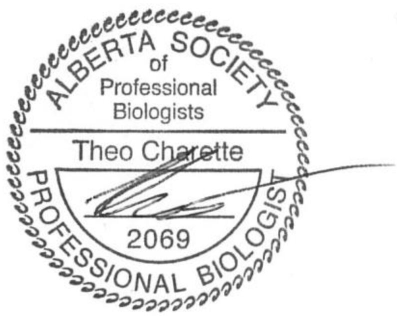


Reviewed by: ________________________________

Théo Charette, M.Sc., P.Biol.

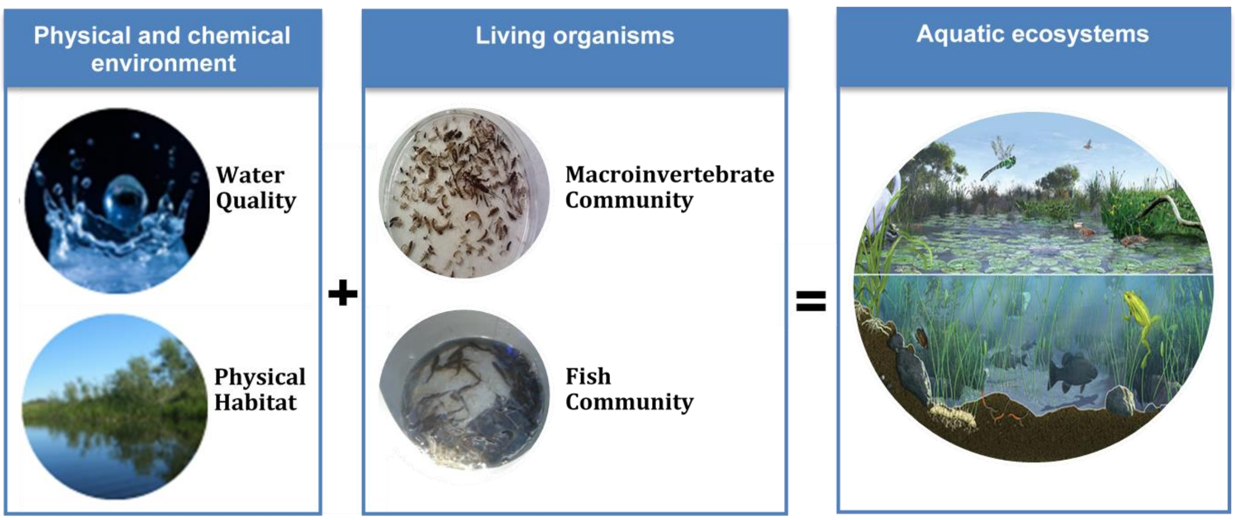
To the best of my knowledge and the best of my professional ability, recognizing the standard of care expected of a reasonable professional doing this work, it is my professional opinion that all the information contained in this Professional Report is accurate and complete, and contains all the relevant information for the purposes of this project or application.

This Professional Report, including all attachments, data and supplemental information, were prepared by me or under my direct supervision and has been reviewed and accepted by me.

All the information submitted is, to the best of my knowledge, true, accurate, and complete.

EXECUTIVE SUMMARY

The North Saskatchewan Watershed Alliance (NSWA) is responsible for making watershed management recommendations to local watershed partners and the Government of Alberta. The Sturgeon River (SR) is one of the 12 sub-watersheds within the larger North Saskatchewan River (NSR) watershed. Although the SR watershed covers a relatively large portion of the NSR watershed, comprehensive information regarding the aquatic ecosystem is not available. Thus, the North Saskatchewan Watershed Alliance (NSWA) has commissioned this survey to create a baseline and status regarding the aquatic ecosystems along the SR. The scope of this project included multiple ecosystem components, as illustrated below. The purpose of measuring all of these components is to obtain a comprehensive view of the SR aquatic ecosystems, which each are communities of living organisms and their physical and chemical environment.



The SR, located just north of Edmonton, has a gross drainage area of approximately 3,301 km^2, which includes Boreal Forest in the westernmost portion and Parkland in the east. The predominant land uses in the SR watershed are agriculture and urban, occurring predominantly in the eastern portions of the watershed. Populated centers in the SR watershed include St. Albert, Spruce Grove, the northwest corner of Edmonton, Bon Accord, Gibbons, Morinville, Onoway, Stony Plain, Calahoo, Villeneuve, Spring Lake, and the First Nations Reserves of Alexis 133 and Alexander 134. The river itself travels approximately 260 km beginning near Hoople Lake, flowing east through Lake Isle, Lac Ste. Anne, Matchayaw Lake, and Big Lake before discharging to the North Saskatchewan River. The hydrology of the river is typical of the central Canadian Prairies - it is a small river fed by precipitation, local runoff, and local and regional groundwater discharge. Peak flow occurs primarily during spring runoff, from April to mid-May. The headwaters of the river upstream of Lac Ste. Anne typically cease to flow during late summer and fall. Downstream of Lac Ste. Anne, the river flows year-round. In this middle to lower section of the river, increased groundwater inputs, as well as discharge from Toad Creek, Kilini Creek, Atim Creek, Rivière Qui Barre and Little Egg Creek greatly increases flow in the SR.

EXECUTIVE SUMMARY

The SR was surveyed at twelve sampling stations distributed throughout the length of the river, as well as the main tributaries. At each sampling station on the SR, physical habitat, water quality, vegetation, fish, and macroinvertebrate surveys took place. In the tributaries, only water quality was measured. Results of these surveys are discussed below.

Results: Aquatic Habitat

Habitat measurements taken at each sampling station included physical environmental characteristics such as stream shading, aquatic plant cover, bank undercutting, diversity of habitat types (e.g., vegetated banks, aquatic vegetation beds, snags and logs, silt/sand/gravel substrate), and bank stability. In addition to this, the chemical environment was measured through water quality sampling. These multiple measurements were compiled into a single Habitat Quality Index.

Depending on the site, the SR has low to average habitat quality (see the Figure i below), with many physical habitat metrics (shade, bank undercutting, and habitat diversity) having low scores, which is consistent with generally poor riparian health.

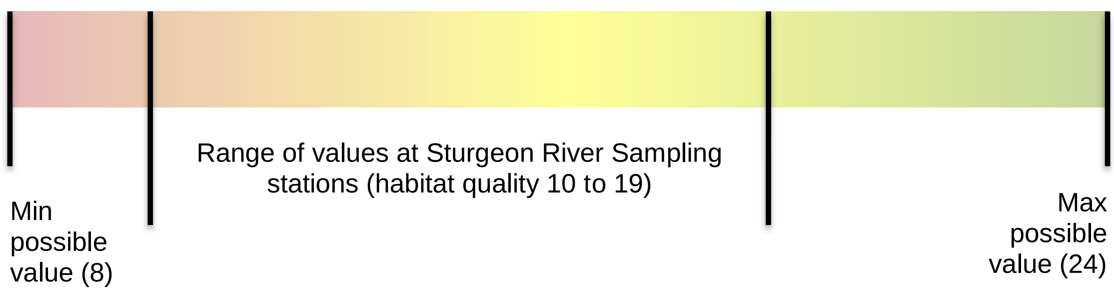


Figure i: Range in habitat quality values from sites in the SR, as compared to minimum and maximum values.

Instream aquatic habitat quality is generally poor upstream of Lac Ste. Anne, in particular between Isle Lake and Lac Ste. Anne (station M3, see Table i). This is mainly due to poor water quality. Habitat quality improves downstream of Lac Ste. Anne, primarily due to better water quality (which may be linked to higher flow) and the appearance of sand and gravel in the substrate, adding to overall habitat diversity. Station M9, which is downstream of Big Lake and upstream of the City of St. Albert, had poor water quality, had an overabundance of aquatic vegetation, and lacked habitat type diversity.

Table i: Total habitat quality scores.

Metric	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Shade	2	2	1	2	1	1	2	2	2	1	2	1
Macrophyte cover	2	2	1	3	2	2	2	3	1	3	2	2
Bank undercutting	2	2	1	1	2	2	3	1	1	1	1	1
Organic substrate	2	2	2	3	2	3	1	2	1	3	2	3
Habitat diversity	2	2	2	3	1	1	2	2	2	3	2	3
Total phosphorus	1	1	1	2	2	3	3	3	2	2	2	2
Total nitrogen	1	1	1	3	3	2	2	3	1	2	2	3
Dissolved oxygen	1	3	1	2	3	3	3	3	2	2	3	3
Total score	13	15	10	19	16	17	18	19	12	17	16	18
Score relative to maximum possible score of 24%[1]	**31**	**44**	**13**	**69**	**50**	**56**	**63**	**69**	**25**	**56**	**50**	**63**

Note. [1] Red = 1-25% (low quality); Orange = 26-50% (below average quality); Yellow = 51-75% (above average quality); Green (not present) = 76-100% (high quality).

Results: Water Quality

Water quality variables analyzed included nutrients (phosphorus and nitrogen), dissolved oxygen, suspended solids, pesticides, metals, and salts.

The SR is nutrient-rich, depending on the location (see Figures ii and iii). Open water nutrient concentrations are high in the upstream reaches that feed Lake Isle and Lac Ste. Anne. They are also very high in some of the tributaries, such as Toad Creek, Rivière Qui Barre, and Carrot Creek. The phosphorus concentrations from these tributaries are similar to those of high agricultural intensity streams elsewhere in the province (see Figure ii). Further, Rivière Qui Barre appears to cause an increase in nutrients and suspended solids in the SR. Nutrient concentrations are relatively low in between Lac Ste. Anne and the confluence of Rivière Qui Barre. Mean annual flow increases substantially in this section of river, which helps improve water quality. Also, the lakes that are part of the SR system improve water quality by capturing and retaining suspended solids and nutrients.

Salinity and chloride concentrations were very high in Carrot Creek, where they exceeded Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. In addition, chloride concentrations during ice cover were 4 to 5 times higher downstream of Big Lake as compared to all upstream sites. These sampling sites are downstream of areas that drain high road densities, thus road salt application appears to be increasing chloride values at these sites. In addition, pesticides and suspended solids were relatively high downstream of the City of St. Albert, as compared to the upstream site, indicating that stormwater runoff may be a source of these pollutants to the SR. Lastly, some pesticides and metals are high upstream of Isle Lake (upstream of Hwy 16); dissolved iron was substantially above guidelines at this site, indicating potentially toxic conditions.

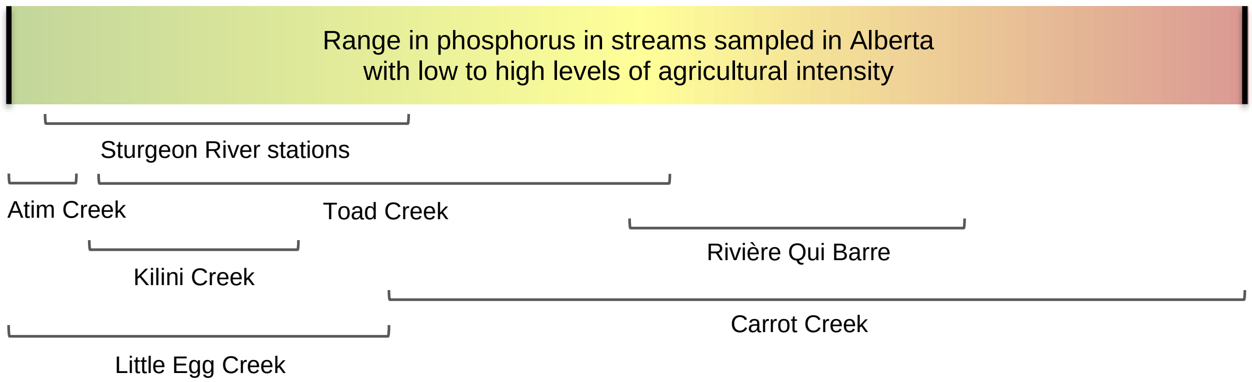


Figure ii: Open water (April to September) total phosphorus concentration for sampling stations on the Sturgeon River and its tributaries as compared to streams sampled as part of the CAESA water quality monitoring program.

Results: Living Organisms

Most of the sites that were surveyed had a macroinvertebrate community reflective of a system that is polluted with nutrients and organics and low in winter dissolved oxygen. However, the macroinvertebrate community in the middle section of the SR downstream of Matchayaw Lake indicates good to fair water quality (see Figure iii). The macroinvertebrate index goes from fair to poor downstream of the confluence with Rivière Qui Barre, indicating the effects of the poor water quality from the tributary on the SR.

The SR and the lakes that are part of the river ecosystem are capable of supporting an abundant and diverse fish community. However, poor water quality, poor physical habitat quality (in some areas) and, in particular, low dissolved oxygen concentrations are all contributing to creating stressful conditions for the fish population. Fish species that indicate poor habitat conditions (White sucker and Brook stickleback) dominate the SR system. In river sites upstream of Lac Ste. Anne, only minnows tolerant of poor environmental conditions have ever been caught from 2001 to present. Also, large-bodied fish do not appear to inhabit this segment of the river, although they could be spawning in locations near the lakes. Downstream of Lac Ste. Anne, many more fish have been caught, the fish community is more diverse, and species that are intolerant of poor habitat conditions appear in this reach, indicating better conditions. Historical and current records show that walleye appears to be a resident of the lower reaches in the SR from the Town of Gibbons to the mouth of the SR. Walleye likely migrate to and from the North Saskatchewan River.

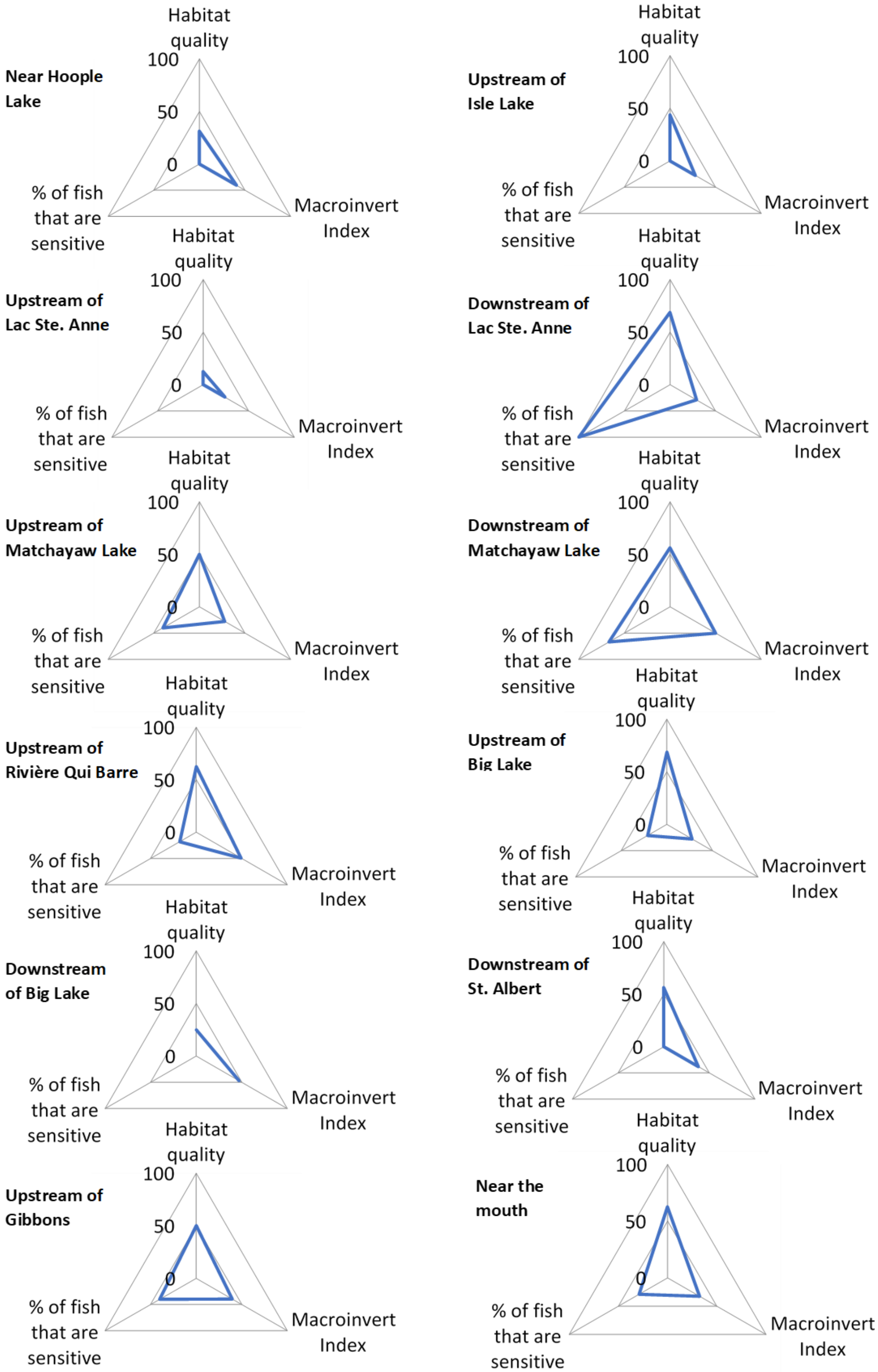


Figure iii: Integrated SR aquatic ecosystem health results: larger blue triangles represent greater health. Note: Electrofishing did not occur at the site downstream of Big Lake, which is why there is no data for % non-tolerant fish. Sensitive fish represent fish species that are intolerant and medium-tolerant of poor environmental conditions. See Section 9 for details.

Recommendations

Based on the information presented in this report, we make the following recommendations, organized under the headings of information gaps, monitoring programs, further study, and management actions.

Information Gaps

1. Based on public surveys (, sport fishing is important to users of the SR system. Fish surveys in the winter and in the spring would provide information about overwintering use of the mainstem and important spawning areas in the SR. This information would be very useful in prioritising segments of the SR to conserve and restore. As recommended by Golder (2004), spring spawning surveys should be focused in areas that were previously identified as areas with potential spawning habitat (Big Lake near inlets of Atim Cr and SR, lower SR, marsh section downstream of Matchayaw Lake, inlet of Lac Ste Anne, outlet of Isle Lake, and inlet area upstream of Isle Lake).
2. A healthy fish population in the SR system will depend on strategies to reduce the potential for winterkill, which centers on improving the input and/or storage of oxygen during winter.
3. Ice formation and breakup is very important in controlling oxygen levels in the SR. However, there appears to be no specific data available related to ice formation and breakup processes for the SR.
4. The quality of the aquatic habitat in the SR is dependent instream physical information. In spite of the information collected for this study, there is generally a shortage of data related to channel morphology and characteristics along the length of the SR. It is recommended that in the course of acquiring field data for any future macroinvertebrate or fisheries habitat assessments, the following habitat information be collected: substrate type and particle size, channel width and depth measurements, habitat diversity, bank undercutting, macrophyte cover, and shade cover. Collecting additional instream physical data will continue to improve our understanding of aquatic habitat throughout the SR.
5. There is a lack of data on the seasonal fish movements into and out of the lower SR from the North Saskatchewan River, as well as the onstream lakes. Due to beaver dams, the upstream passage of fish in the SR may be difficult. Fish telemetry studies can be used to fill this gap in information.

Monitoring Programs

6. Since pesticides were detected at relatively high concentrations in the SR, we recommend that future studies and monitoring programs measure pesticides upstream and downstream of all areas that drain highly populated areas, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. These should be measured in the months of June and/or July, which is when detections are more likely (see Anderson 2005). The City of St. Albert's monitoring program currently measures pesticides in the SR in the fall.

7. The spring runoff period occurs for about one month immediately after ice-off (typically in April). Since the majority of the export of constituents in water occurs during this time, we recommend that current and future monitoring programs capture the spring runoff period at this time. To be able to calculate constituent export and load, sampling should be paired with discharge measurements where possible. If this is not possible, discharge can be modelled, but direct measurement is best.
8. Chloride should be measured again during winter upstream and downstream of areas that drain high road densities, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. This sampling should be diagnostic in nature i.e., the sampling regime should specifically attempt to determine if high values are caused by road salt application. Adopting this type of approach will directly support a discussion on the potential adverse effects of these values and what mitigation measures, if any, are warranted. Given that road salt application addresses an important road safety issue, the monitoring program design must be exceptionally rigorous.
9. Aquatic ecosystems should be re-sampled, perhaps every 10 years, to track ecosystem health over time. Methodologies should be consistent to allow comparisons over time.

<u>Further Study</u>

10. Rivière Qui Barre and Carrot Creek have very high nutrient concentrations that are potentially contributing to the eutrophication of Big Lake. To determine the effect of this nutrient loading, a nutrient balance for Big Lake should be completed with the updated information contained in this report. If the results of this analysis determine that the tributaries contribute a significant amount of nutrient loading to the lake, sites in the effective watershed areas of these creeks could be targeted for restorative actions. For the same purpose, we also recommend creating / updating nutrient balances for the other major lakes that are part of the SR system, including Matchayaw Lake. Nutrient balances have been completed for Isle Lake and Lac Ste Anne in the *Isle Lake and Lac Ste. Anne State of the Watershed Report (2017)*. However, it would be worthwhile updating the nutrient balance using the river water quality data collected in this report.
11. Our report uses provincial water quality guidelines that are recommended to protect aquatic ecosystem health. Since these guidelines apply to all water bodes in Alberta, they are meant to provide general guidance. One limitation of these guidelines is that they are not available for all substances of concern. Some of the major substances of concern are nutrients and provincial guidelines for nutrients are in the form of a narrative statement as follows: “total nitrogen and phosphorus concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality”. Data from the water quality studies and from macroinvertebrate surveys in our study suggest an open-water total phosphorus target for the SR of 0.12 mg/L. This value may be appropriate for some segments of the SR, but perhaps not others (e.g., the lower segments naturally have more suspended solids, thus more total phosphorus). Setting site-specific nutrient objectives should be formally completed using protocols from the *Guidance for Deriving Site-Specific*

Water Quality Objectives for Alberta Rivers. Data collected as part of our study (as well as other studies) will provide the information needed for this exercise. Once site-specific nutrient objectives are created for the SR, a nutrient management plan can be developed for the SR.

12. Water quality parameters are often related to flow (CPP Environmental 2017). Further exploration of the relationship between water quality parameters and flow will aid in understanding water quality of the SR.
13. Since flow and water quality are closely tied, the relative contribution of creeks to flow should be examined more closely. The majority of flow in the SR watershed appears to be generated in the mid-section (Lac Ste. Anne to Big Lake). Maintaining flow is a critical component of maintaining the ecosystem health of the SR. Areas that generate relatively higher runoff per unit area may potentially be targeted as management priorities.
14. Dissolved iron concentrations at locations upstream of Isle Lake greatly and regularly exceeded the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. Pesticides were also notably higher immediately upstream of Isle Lake. Given that such high concentrations of dissolved iron may be toxic to aquatic life, and given that other metals and pesticides were relatively high at the same locations, further sampling and examination of metals and pesticides in water and sediment at these locations is advisable. The purpose of this sampling should be very specific i.e., to determine the extent and source of the high values to inform corrective actions.
15. Other than high nutrients, the levels of chloride in Carrot Creek have the potential to be toxic to aquatic life. Further examination is warranted considering that natural sources appear to be unlikely based on the information that is currently available.
16. Pesticides downstream of the City of St. Albert (M10) were notably higher (about 6 times), as compared to sampling stations immediately upstream of the City. At the time of sampling, concentrations were below Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. However, our study, which only sampled for pesticides once in July, provides a signal that pollution may be occurring. Further examination of the occurrence and source of these pesticides in June/July is recommended.
17. Oxygen levels were low at some locations in the SR during the summer. The quantity of dissolved oxygen within streams and rivers can change drastically during 24 hours due to differences in photosynthetic activity from day to night. For instance, our study did not measure oxygen at night, which is when it would be the lowest. There currently is a lack of information and understanding of these diurnal patterns in oxygen in the SR, which may be very important for aquatic life.
18. Oxygen levels during winter were low in most places, but high in others. It isn't currently clear why this is occurring. The role of bottom sediments and physical stream characteristics in determining late summer and winter oxygen content in the SR would better inform any discussions regarding the management of oxygen in the SR.

Management Actions

19. The Middle Reach is a stretch of river with relatively higher habitat and water quality. The Lower Reach is the only known location in the SR that is home to walleye. Kilini Creek has relatively good water quality and fish that indicate good habitat conditions. We recommend that these high-value portions of the SR be examined further for conservation measures. Shade, bank undercutting, and habitat diversity can be maintained and enhanced by protecting and planting trees on the river banks. Regulatory tools can also be implemented to protect these important areas as part of regulatory approval processes.
20. Urban runoff is contributing to sediment loading to the SR. The City of St. Albert Stormwater Master Plan is addressing sediment loading reduction through the retrofit of stormwater outfalls with grit interceptors. Another opportunity for reducing sediment loading at its source is through low impact development strategies, which have proven to be very effective in many jurisdictions across North America. The Alberta Low Impact Development Partnership is a good resource for this information.
21. Low dissolved oxygen in late summer and winter is a major driver of the SR ecosystem. Strategies to improve oxygen in the SR centers on improving the input and/or storage of oxygen, particularly during winter. The creation and maintenance of open-water areas can create winter refugia for fish. Increasing/maintaining the depth and flow of water and improving the connectivity of the river by reducing barriers would also improve the supply and storage of oxygen during winter. Finally, reducing the nutrient input and content of the water and sediments in the SR system would reduce the consumption of oxygen through bacterial and chemical processes. Many management options are possible, but these will need to be weighed against the long-term costs and benefits of their implementation.
22. Given that the SR has low flushing potential during late summer and winter, it can be thought of as a naturally sensitive ecosystem that would benefit from any nutrient reduction strategies. Many nutrient strategies options can be considered for the SR, its tributaries, and its lakes. Examples of nutrient reduction strategies include reducing the input of particulate nutrients by restoring riparian areas and improving construction beneficial management practices, limiting cattle access to the river and its tributaries through offsite water monitoring programs, improving the nutrient retention of watersheds through the restoration of wetlands, creating opportunities to allow particulate nutrients to settle out of the water column (e.g., through stormwater management Beneficial Management Practices), and chemical treatment (e.g., lime, alum, bentonite clay or phoslock) of water to remove nutrients from the water column. A nutrient management plan can be used to determine all possible strategies and evaluate feasibilities in terms of effectiveness and cost.
23. Low flows in the Upper Reach of the SR currently limit the potential for quality habitat and water quality. Any reduction in water supply have the potential to affect the aquatic ecosystems and reduce fish spawning and habitat options near Lake Isle and Lac Ste Anne. We recommend an examination of the feasibility of limiting licenced water withdrawals from this stretch of river for the purpose of meeting the flow needs required for biota. An Instream Flow Needs (IFN)

scoping study was completed by Golder Associates in 2004, but to our knowledge, an IFN was not completed.

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ACKNOWLEDGEMENTS

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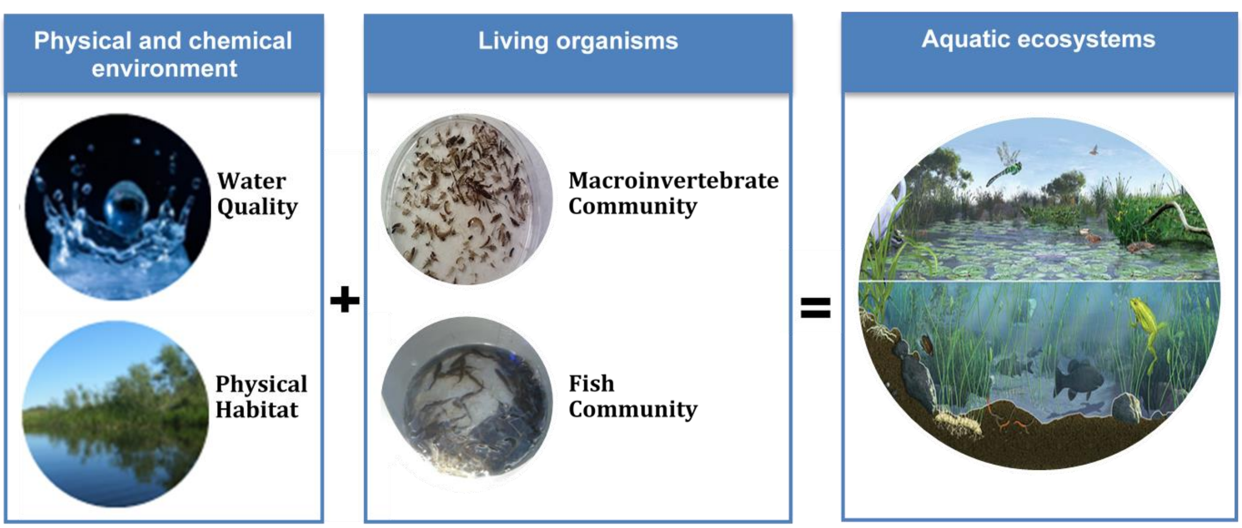
The following individuals contributed to data collection, data analysis, and report production: Adam Kraft, Sarah Davis Cornet, Angie Bouzetos, Elashia Young, Megan Watt, Théo Charette, and Marty Butts. Without them, this work would not have been possible. Particular thanks go to Michelle Desaulniers for organizing the fieldwork and leading the field crews and playing a pivotal role in data analyses and report writing.

1. Introduction

Due to its proximity to large and growing urban centers, the landscapes that drain towards the Sturgeon River (SR) (i.e., its "watershed") are actively changing. Over the past century, the SR watershed has been subject to numerous activities such as urban and agricultural development, forest clearing, aggregate mining, wetland and riparian alterations, stormwater and sewage production and discharge, channelization, and the installation of water management structures such as dams and weirs (City of St. Albert 2012). In some ways, these activities have undeniably altered the aquatic ecosystems and the lands that provide runoff to them.

By definition, aquatic ecological health is the capacity of a waterbody to maintain ecological structure and function over time and in a manner that is similar to the natural or undisturbed ecosystem of the region's past (Alberta Environment 2005). A healthy aquatic ecosystem is an aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability (Alberta Water Council 2008). However, we lack data regarding the state of aquatic ecosystems in the SR to use as a baseline and to determine the nature and magnitude of any changes that might be occurring. Thus, the North Saskatchewan Watershed Alliance (NSWA) has commissioned this project to document a multitude of aquatic ecosystems along the SR to provide a baseline and status regarding the relative health of these systems.

The scope of this project included multiple ecosystem components, as illustrated and described below. The purpose of measuring all of these components is to obtain a comprehensive view of the SR aquatic ecosystems, which each are communities of living organisms and their physical and chemical environment.



Water Quality

The concentration of certain chemicals that make up water determines the suitability of the aquatic environment to sustain life. The chemicals that were measured were compared to Alberta Surface Water Quality Guidelines (AEP 2014) for the Protection of Aquatic Life and for Agricultural Uses. We also present the data as constituent concentrations along the SR. Combined with physical habitat (see below), water quality helps in understanding the amount and distribution of aquatic biota in the SR.

Physical Habitat

The size and shape of the river (river morphometry) and types of macrophytes (aquatic vegetation) can strongly influence the presence or absence of other aquatic organisms (Wallace and Webster 1996). In other words, the diversity of many aquatic species is positively related to the diversity of its habitat. Habitat components are assessed and presented through visual cross sections of the underwater habitat with plant community descriptions of diversity and abundance. In addition, these data were synthesized in a multi-metric index of habitat quality (Barbour et al. 1999, USEPA 1997), which was used to compare habitat quality along the SR. Converting the habitat data into a single index helps in understanding the species distribution and ecology among the stations in the SR.

Macroinvertebrate Community

An abundant and diverse fish prey base (i.e., macroinvertebrates) is critical for maintaining energy transfer to growing fish. Macroinvertebrates are also ideal candidates for biomonitoring because they are sensitive to their chemical environment and they can reveal past and present water quality conditions (Anderson 1990). Macroinvertebrate surveys were completed to document this important biological component of the ecosystem (Alberta Environment 2006).

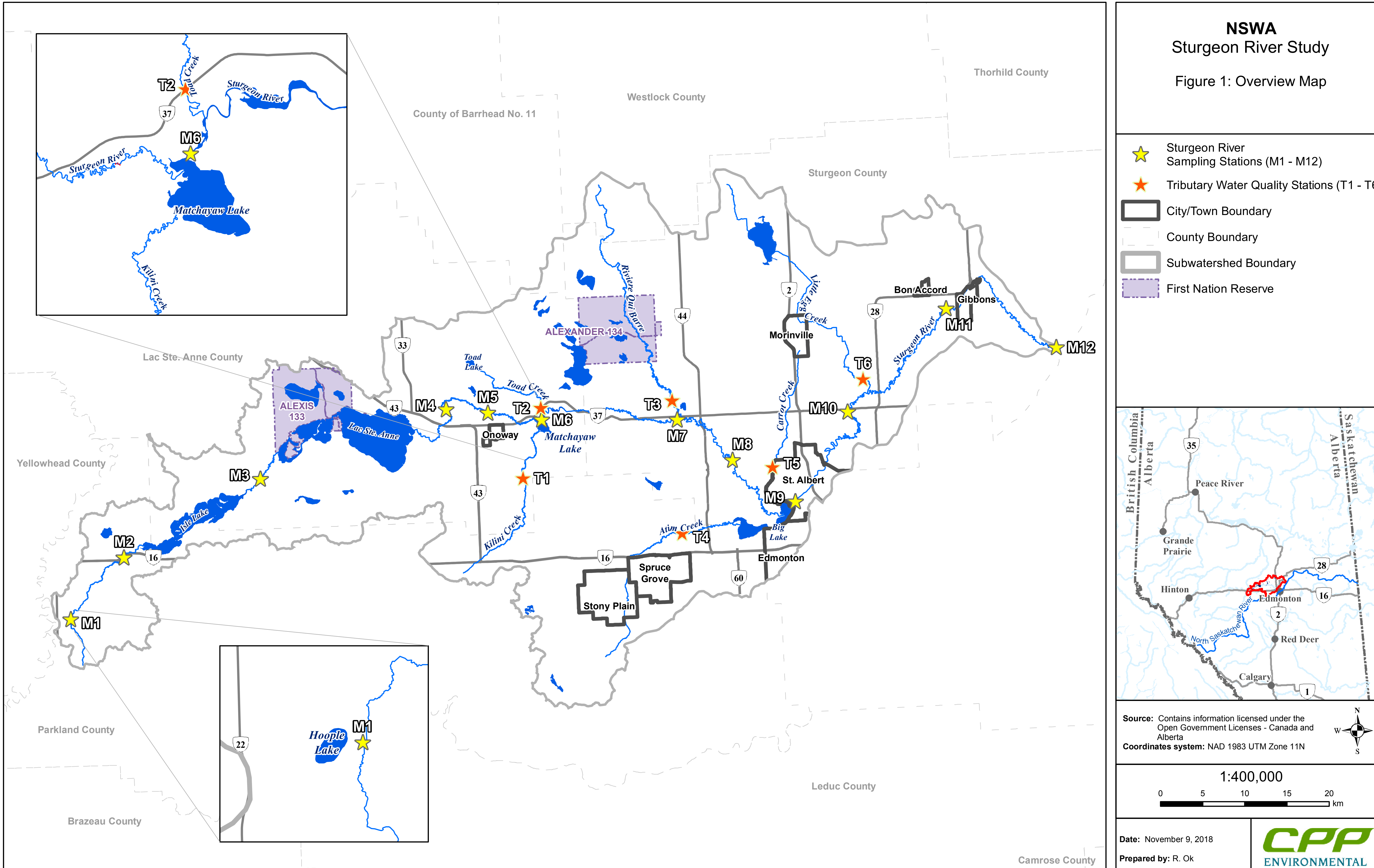
Fish Community

The fish community relies on water quality, physical habitat, and food such as macroinvertebrates. Thus, fish surveys were completed to understand the top level of the food chain. Through their ability to move through the river and its tributaries, the presence or absence of fish can act as good indicators of overall environmental health or stress (Karr and Chu 1999).

2. Background

Just north of Edmonton, the SR watershed flows through the Boreal Forest and Parkland Natural Regions of Alberta. The river itself travels approximately 260 km beginning near Hoople Lake, flowing east through Lake Isle, Lac Ste. Anne, Matchayaw Lake, and Big Lake before discharging to the North Saskatchewan river (NSR, **Figure 1**). The hydrology is typical of the central Canadian Prairies - it is a small river fed by precipitation, local runoff, and local and regional groundwater discharge. The hydrograph closely follows seasonal patterns in precipitation. Peaks in discharge occur during spring runoff (main peak) and in during the early summer rains in late June / early July (**Figure 2**). By August-September, the headwaters of the river largely cease to flow and behave similarly to a string of shallow open water wetlands or small lakes. The middle to lower reaches of the river can flow year-round due to the larger cumulative drainage area and because of the low topographical position in relation to the regional groundwater flow system (i.e., more groundwater inputs), although flow can drop down to low amounts during ice cover. Flows from smaller creeks such as Toad Creek, Kilini Creek, Atim Creek, Rivière Qui Barre and Little Egg Creek contribute to the flows of the SR. Only about ten percent of the watershed (353 km^2) is considered non-contributing under average runoff conditions (City of St. Albert 2012).

The SR has a gross drainage area of approximately 3,301 km^2, which includes Boreal Forest in the westernmost portion and Parkland in the east. The main landscape types in the watershed are the low- to high-relief hummocky topography of the Boreal Forest Natural Region and the predominantly flat topography in the Parkland Natural Region (**Figure 3 and Figure 4**). The watershed is predominantly covered by agricultural land uses (e.g., annual/perennial croplands, pasture; **Figure 5**), which are concentrated in the flatter terrain and on high productivity soils of the Parkland Region. Urban land uses are primarily associated with the populated centers of St. Albert, Spruce Grove, the northwest corner of Edmonton, Bon Accord, Gibbons, Morinville, Onoway, Stony Plain, Calahoo, Villeneuve, Spring Lake, and the First Nations Reserves of Alexis 133 and Alexander 134. Plant species characteristic of the remaining natural parkland forests include stands of aspen and balsam poplar trees, and an understory of snowberry, saskatoon, beaked hazelnut, choke cherry, bunchberry, lily-of-the-valley, red osier dogwood, pussy willow, northern gooseberry, green alder, bracted honeysuckle, and baneberry. Although native grasslands are part of the Parkland Region, they are now quite rare and are thus protected under provincial legislation. Plant species characteristic of the remaining natural boreal forest sites include pure or mixed stands of aspen, balsam poplar, white spruce, black spruce, and jack pine. The understory consists of rose, beaked hazelnut, low-bush cranberry, and red-osier dogwood.


NSWA
Sturgeon River Study
Figure 1: Overview Map
Sturgeon River Sampling Stations (M1 - M12)
Tributary Water Quality Stations (T1 - T6)
City/Town Boundary
County Boundary
Subwatershed Boundary
First Nation Reserve
Source: Contains information licensed under the Open Government Licenses - Canada and Alberta
Coordinates system: NAD 1983 UTM Zone 11N
1:400,000
0 5 10 15 20 km
Date: November 9, 2018
Prepared by: R. Ok
CPP ENVIRONMENTAL
Thorhild County
Westlock County
County of Barrhead No. 11
Sturgeon County
Lac Ste. Anne County
Yellowhead County
Parkland County
Brazeau County
Leduc County
Camrose County
ALEXANDER 134
ALEXIS 133
Lac Ste. Anne
Isle Lake
Matchayaw Lake
Toad Lake
Toad Creek
Riviere Qui Barre
Little Egg Creek
Carrot Creek
Kilini Creek
Atim Creek
Big Lake
Sturgeon River
Hoople Lake
Onoway
Morinville
Bon Accord
Gibbons
St. Albert
Edmonton
Spruce Grove
Stony Plain
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
M11
M12
T1
T2
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T4
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T6
British Columbia
Alberta
Saskatchewan
Peace River
Grande Prairie
Hinton
Red Deer
Calgary
North Saskatchewan River

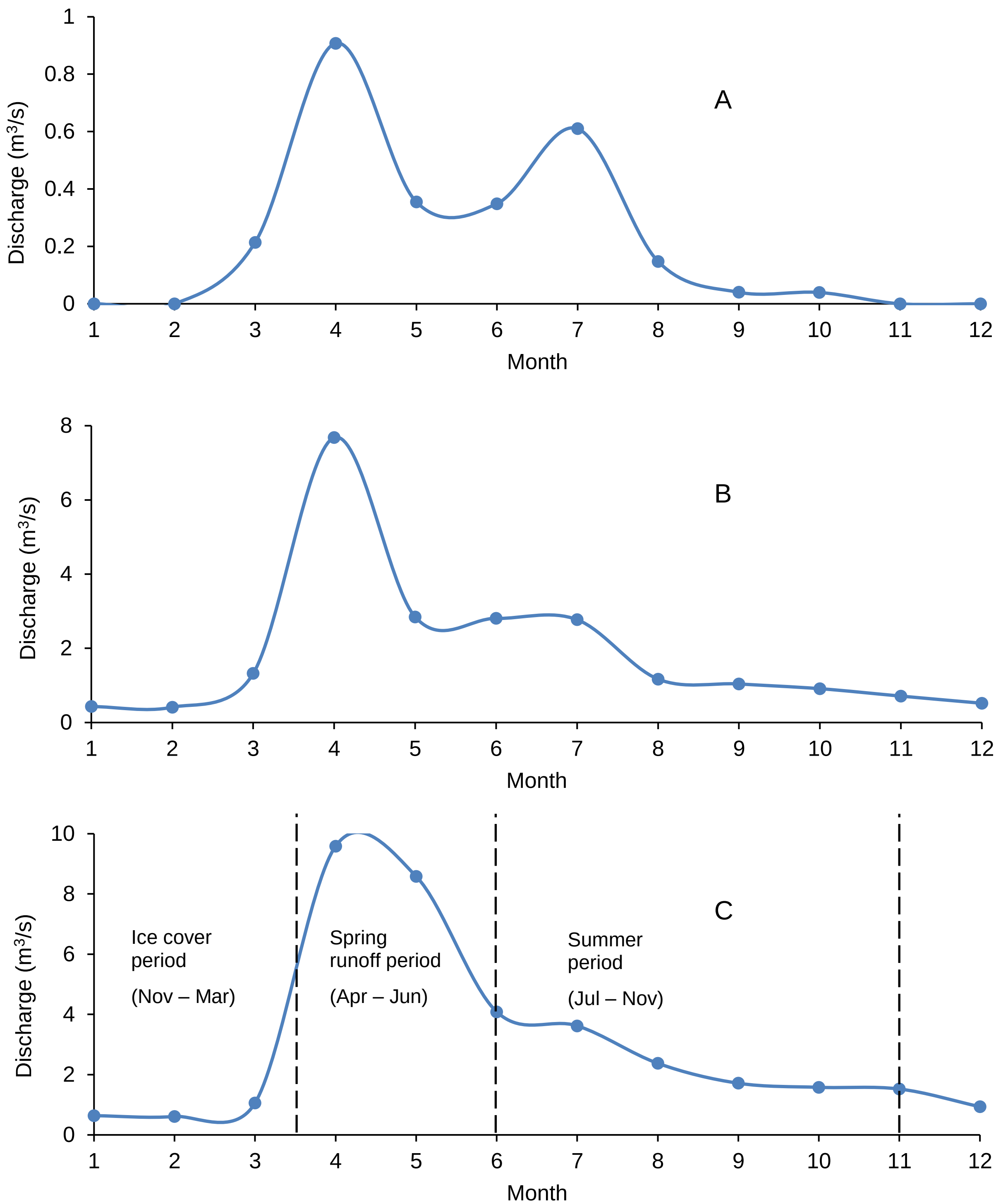


Figure 2: Average monthly discharge from 1914 to 2013 for the Sturgeon River at the following gauging stations: A – 05EA010 near Magnolia Bridge (near station M2); B – 05EA005 near Villeneuve (near station M8); C - 05EA001 near Fort Saskatchewan (between station M11 and M12).

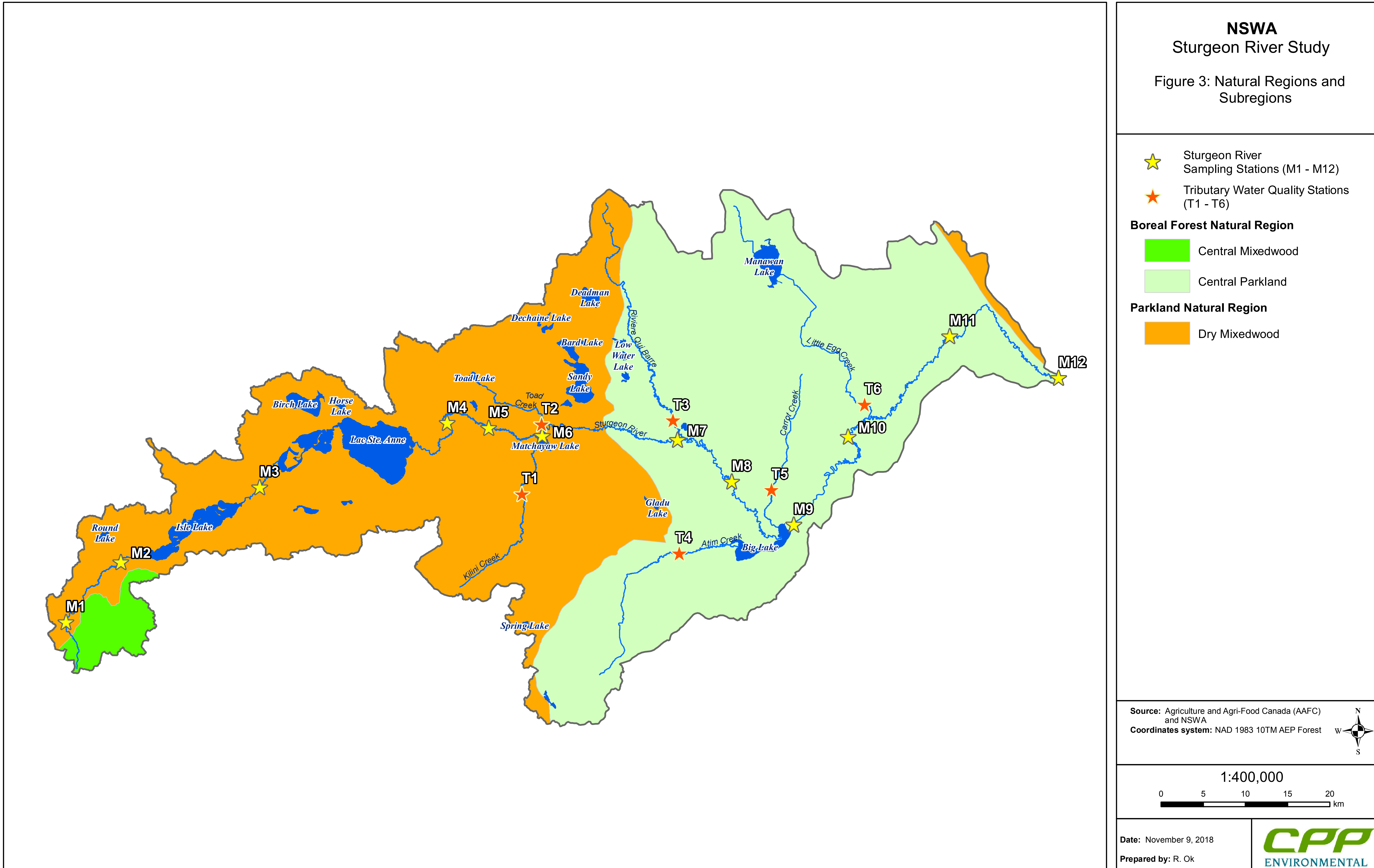
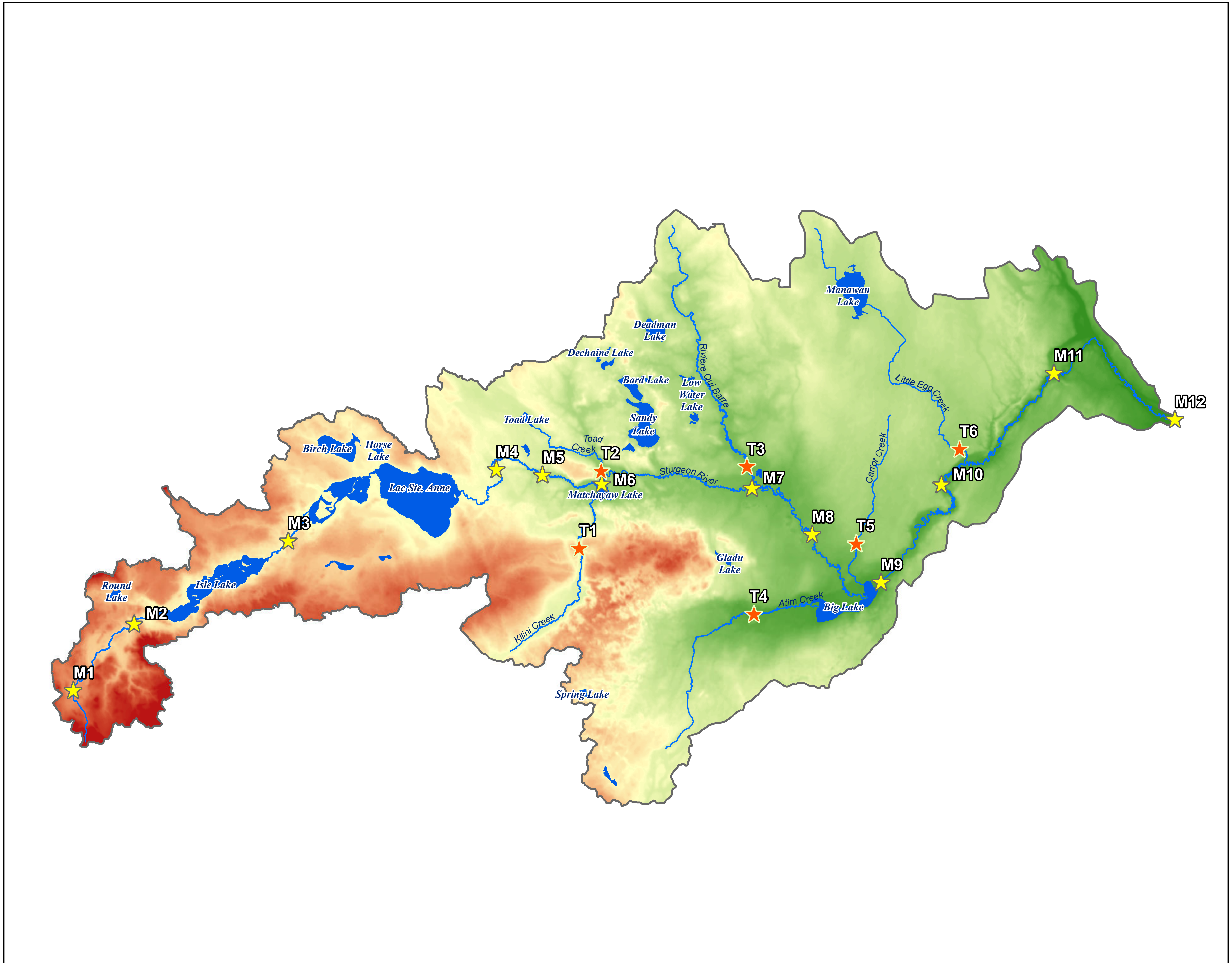


Figure 3: Natural Regions and Subregions



NSWA
Sturgeon River Study

Figure 4: Topography

Sturgeon River Sampling Stations (M1 - M12)

Tributary Water Quality Stations (T1 - T6)

Elevation

In meters Above Sea Level

High : 870

Low : 601

Source: Agriculture and Agri-Food Canada (AAFC) and NSWA

Coordinates system: NAD 1983 10TM AEP Forest

N W E S

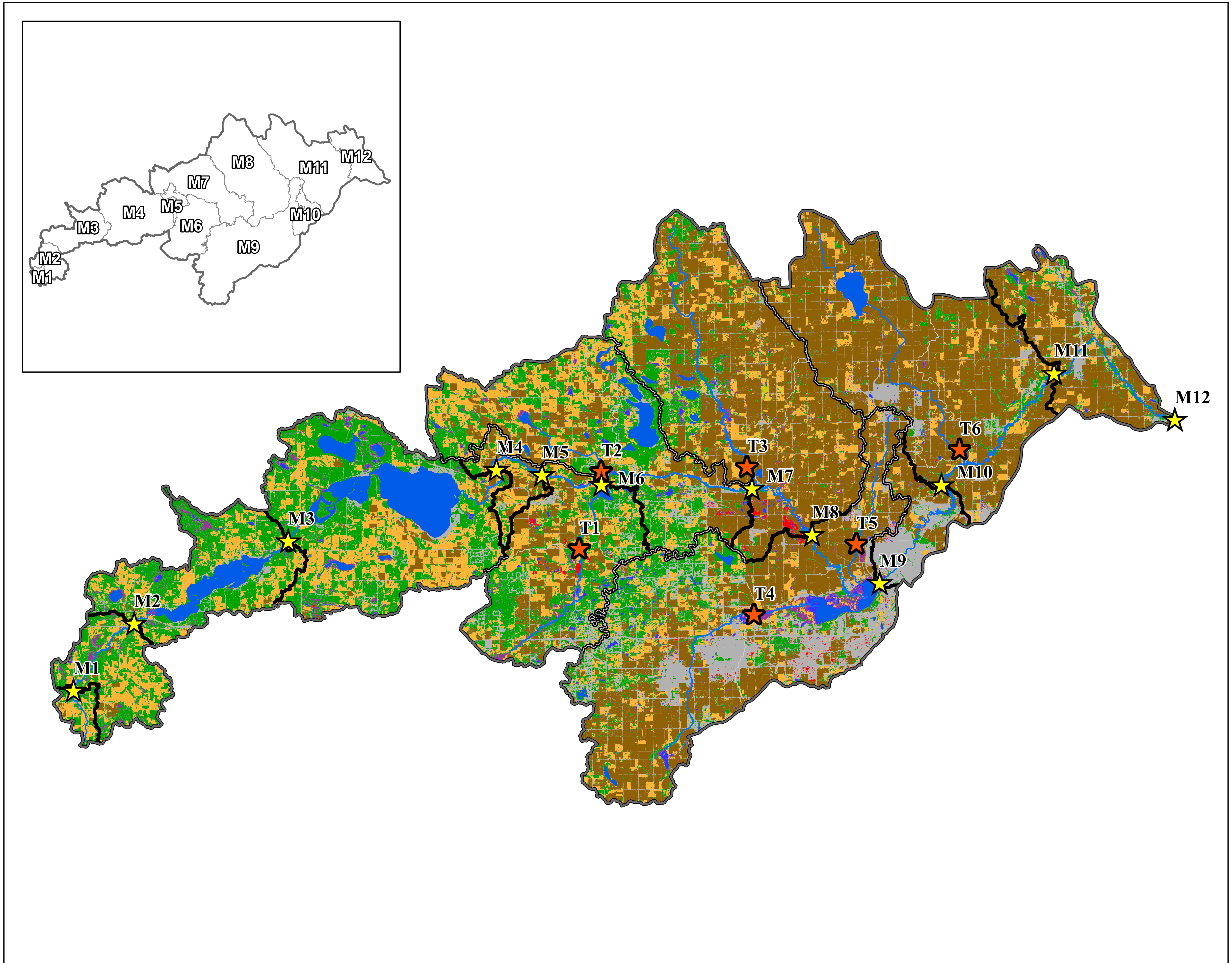
1:400,000

0 5 10 15 20 km

Date: November 9, 2018

Prepared by: R. Ok

CPP ENVIRONMENTAL



NSWA
Sturgeon River Study

Figure 5: Watershed Land Cover 2017

Sturgeon River Sampling Station (M1 - M12)
Tributary Water Quality Stations (T1 - T6)

Boundary
Monitoring Station Catchment
Tributary Station Catchment

Land Cover Class
Cropland
Exposed Land and Barren
Forest
Grassland
Pasture and Forages
Shrubland
Urban and Developed
Water
Wetland

Source: Agriculture and Agri-Food Canada (AAFC) and NSWA
Coordinates system: NAD 1983 10TM AEP Forest

N W E S

1:400,000
0 5 10 15 20 km

Date: November 9, 2018
Prepared by: R. Ok

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3. Sampling Stations

The SR was surveyed at twelve stations distributed throughout the length of the river. These locations were pre-determined based on location relative to important features such as lakes and urban areas, as well as historical hydrometric measurement locations (**Figure 1**; **Table 1**). At each station, 3 transects were established 50 m apart to allow the characterization of habitat and vegetation along a 150 m reach. Water quality, vegetation, fish, and macroinvertebrate surveys took place within each river reach. Fish sampling locations varied somewhat due to access limitations with respect to the electrofishing boat. With the exception of M10, all stations were accessed at bridge crossings and transects were placed 100 m upstream of crossings and any other barriers such as fords or beaver dams. Station M10 was placed downstream of the road because conditions upstream were not suitable. **Appendix A** includes photos of individual stations and transects surveyed in 2017. The pictures associates with the figures were taken by CPP Environmental during the survey events.

Table 1: Location of sampling stations, from upstream (M1) to downstream (M12) stations.

Sampling station	Description
M1	SR headwaters near Hoople Lake.
M2	SR upstream of Isle Lake near active WSC station #05EA010.
M3	SR downstream of Isle Lake and upstream of Lac Ste Anne. Near inactive WSC station #05EA003.
M4	SR downstream of Lac Ste Anne. Near inactive WSC station #05EA004.
M5	SR upstream of Onoway and Matchayaw Lake.
T1	Kilini Creek near its confluence with Matchayaw Lake. Near active WSC station #05EA013.
M6	SR downstream of Matchayaw Lake and upstream of Toad Creek.
T2	Toad Creek near its confluence with the SR.
M7	SR upstream of Rivière Qui Barre.
T3	Rivière Qui Barre near its confluence with the SR.
M8	SR downstream of Rivière Qui Barre and upstream of Big Lake. Near active WSC station #05EA005.
T4	Atim Creek upstream of Big Lake at RR 272. Near active WSC station #05EA012.
T5	Carrot Creek near its confluence with Big Lake near active WSC station #05EA011.
M9	SR downstream of Big Lake and upstream of the City of St. Albert. Near active WSC station #05EA002.
M10	SR upstream of Little Egg Creek.
T6	Little Egg Creek near its confluence with the SR.
M11	SR downstream of Little Egg Creek and upstream of Gibbons
M12	SR near the mouth

Table 2: Characteristics of the watersheds of each sampling station, from upstream (M1) to downstream (M12) stations. Human footprint data is from Agriculture and Agri-Food Canada 2017 Land Use dataset, which includes cropland, pasture, urban, and other development. Riparian health data is from Fiera Biological Consulting (2018).

Sampling station	Gross watershed area (km^2)	% of gross watershed as human footprint	Health of riparian areas 300 m upstream of station[1]		
			Good	Fair	Poor
M1	19.7	51	0	0	100
M2	119	43	36	46	18
M3	311	36	0	62	38
M4	713	35	40	0	60
M5	755	38	19	74	7
T1	157	52	87	13	0
M6	1009	42	9	41	50
T2	189	61	24	36	40
M7	1365	46	18	0	82
T3	366	75	34	18	48
M8	1893	55	19	9	72
T4	432	76	47	53	0
T5	55	89	34	50	16
M9	2556	60	46	46	8
M10	2633	60	79	0	21
T6	272	91	50	7	43
M11	3127	65	80	0	20
M12	3295	66	53	19	28

Note. [1]Represents 2x reach length.

4. Aquatic Habitat

CPPENV surveyed habitat characteristics and collected water quality data to determine the overall habitat quality of each station. These metrics are useful since they provide a link between the physical environment and its inhabitants (USEPA 1997).

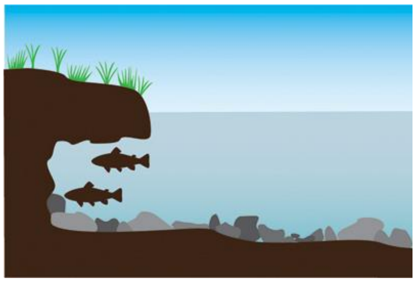
4.1 Methods

Habitat assessments occurred during low flows from August 29th to September 20th, 2017. Metrics and procedures followed the Alberta Biodiversity Monitoring Institute's Alberta-based stream field protocols (ABMI 2007) and the United States Environmental Protection Agency's procedures for low gradient streams (Barbour et al. 1999).

4.1.1 Habitat Survey

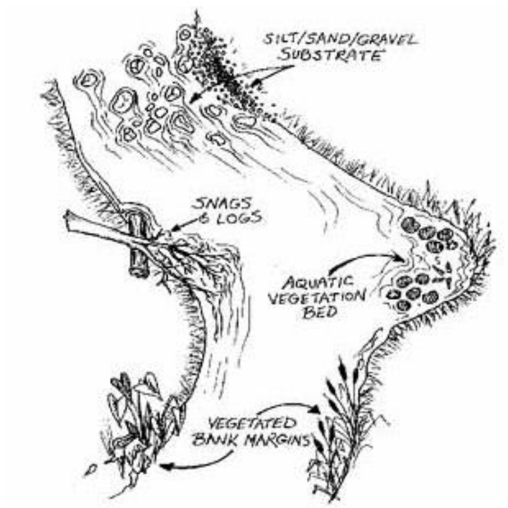
Habitat metrics were measured at 3 transects that crossed the river near each station (M1 to M12). These transects were separated by 50 m, thus they represent a 150 m stretch, or "reach", of the river at that location. Metrics included percent of bank undercutting, macrophyte coverage, substrate composition, shading and habitat diversity. These physical features support habitat diversity and provide shelter for aquatic life.

- **River bank undercutting:** an estimation of undercut banks (see image below) recorded as a percentage (%); left and right banks done separately.



Example of an undercut bank (left), which provides shelter for aquatic life (Google Images).

- **Aquatic vegetation cover:** the percent cover of aquatic vegetation along the transect, including rooted or floating aquatic plants. Aquatic vegetation provides shelter for aquatic life and some organisms are specialized for these types of environments.
- **River channel substrate composition:** percent cover of substrate materials along each transect (boulder, cobble, gravel, sand and organic matter). During the field surveys, all substrate materials were categorized; however, for the purposes of the habitat assessment scores, organic matter is the only metric analyzed since organic matter dominated substrates at the majority of stations.
- **River channel shading:** percent coverage of the water surface along each transect that is shaded by shoreline grasses, shrubs, and trees. Shade is an important factor when considering aquatic habitat because it can help regulate stream temperatures, which affect living conditions for aquatic life (cooler temperatures are suitable to most aquatic life).
- **Diversity of habitat types:** presence/absence of riffles, snags/logs, vegetated banks, and aquatic vegetation in each 150 m reach. Each of these habitat types provide feeding, resting or spawning areas for aquatic life and the more



Aquatic habitat types (above) recorded in the SR as part of the Habitat Diversity metric.

diversity the better for aquatic life functions. Each area was scored based on the quantity of habitat types:

- Excellent = 4 habitat types
- Good = 3 habitat types
- Fair = 2 habitat types
- Poor = 1 habitat type

4.1.2 Water Quality Sampling

Water quality samples were taken at each station on a monthly basis from February 2017 to September 2017. Water sampling consisted of two methods; 1) a water probe (YSI Multi-Probe) measurement and; 2) a water sample sent to a lab. Results from the August sampling event were used to describe habitat quality due to the importance of the following variables to aquatic life:

- **Oxygen:** Aquatic biota require a minimum amount of dissolved oxygen (DO) for survival. DO is controlled by physical and biological processes that affect its solubility (i.e., temperature, wind mixing, bacterial activity, photosynthesis). The saturation concentration of DO is quickly achieved at the air-water interface and in shallow rivers like the SR it is relatively consistent throughout the water column as long as there is no ice. Alberta guidelines suggest a minimum of 5.0 mg/L for short-term (instantaneous) exposure and 6.5 mg/L for long-term (7 days) exposure (AESRD 2014). Diurnal fluctuations in dissolved oxygen were not measured as part of this survey.
- **Nutrients:** The amount of phosphorus and nitrogen in water reflects the fertility of the ecosystem. High nutrients indicate eutrophication (increased plant/algae growth), which can have a negative impact on biodiversity and desirable fish species (CCME 2004).

All other water quality results are summarized in **Section 5: Water Quality**.

4.1.3 Data Analysis

Total habitat quality scores for physical and chemical metrics were computed by ranking each metric into numerical categories (USEPA 1997). All physical habitat metrics were scored based on USEPA protocols.

Physical habitat metrics were scored as follows:

Step 1: At each transect, we assigned a score number from 1 (Poor) to 4 (Excellent) for each metric (**Table 3**). For example, station M1 had 6-25% shade cover at transect 1 and therefore would score a 2.

Table 3: The habitat assessment categories for scoring metrics at each station (USEPA 1997).

Physical Metric	Excellent (Score=4)	Good (Score=3)	Fair (Score=2)	Poor (Score=1)
Shading (%)	51+	26-50	6-25	0-5
Aquatic Vegetation (%)[1]	25-50	51-75	0-25	76-100
Undercut Banks (%)	76-100	51-75	25-50	0-25
Organic Substrate (%)	0-25	25-50	51-75	76-100
Habitat Diversity[2]	Excellent	Good	Fair	Poor

Note. [1]Excess aquatic vegetation lowers habitat quality; [2] Excellent = 4 habitat types; Good = 3 habitat types; Fair = 2 habitat types; Poor = 1 habitat type

Step 2: The values of all individual transects were totaled to obtain a "total score" for each metric. Values for each metric ranged from 3 (3 transects with a score of 1) to 12 (3 transects with a score of 4) with the exception of bank undercutting. Bank undercutting ranged from 6 to 24 since measurements were completed on each river bank. Total scoring for all physical metrics and the original habitat assessment data is available in **Appendix B**.

Chemical habitat metrics were scored differently than physical habitat metrics. Total phosphorus was scored based on 25th percentiles. Dissolved oxygen was scored based on chronic and acute water quality guidelines.

Step 3: Total phosphorus and total nitrogen water quality data was separated into 3 categories using 25th percentiles from the August water quality dataset, as follows. These categories are represented in **Table 4**.

"1" represents phosphorus and nitrogen values greater than the 75th percentile and dissolved oxygen values below the Alberta Surface Water Quality Guideline for the Protection of Aquatic Life short-term exposure value (see **Table 4** for values);
"2" represents phosphorus and nitrogen values from the 25th to the 75th percentile and dissolved oxygen values in between the Alberta Surface Water Quality Guideline for the Protection of Aquatic Life short-term and long-term exposure values;
"3" represents phosphorus and nitrogen values between 0 and the 25th percentile and dissolved oxygen values above the Alberta Surface Water Quality Guideline for the Protection of Aquatic Life long-term exposure value;

A total habitat quality score was created as follows:

Step 4: Each physical habitat and chemical metric was assigned a value from 1 to 3, using **Table 3**.

Table 4: Habitat metric categories used to calculate final habitat scores.

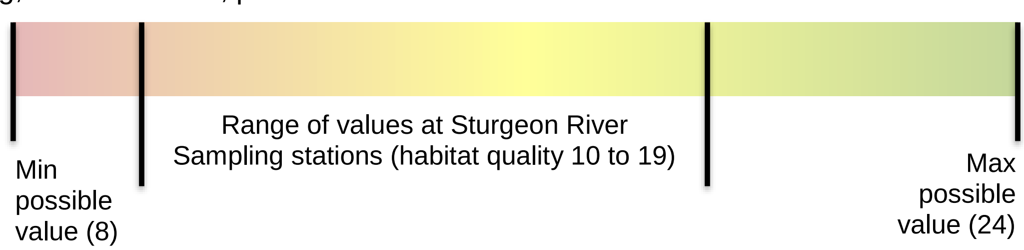
Habitat Metric	Habitat Quality		
	High=3	Medium=2	Low=1
Physical			
Shade Cover	9-12	5-8	1-4
Macrophyte Cover	9-12	5-8	1-4
Bank Undercutting	17-24	9-16	1-8
Organic Substrate	9-12	5-8	1-4
Habitat Diversity	9-12	5-8	1-4
Chemical			
Total Phosphorus (µg/L)	<0.12	0.12-0.26	>0.26
Total Nitrogen (µg/L)	<1.4	1.4-2.1	>2.1
Dissolved Oxygen (mg/L)	>6.5	5-6.5	<5

Step 6: Values were totaled by sampling station to obtain a total habitat quality score (see results below).

4.2 Results

4.2.1 Habitat Quality

Total habitat quality scores for each SR sampling station are presented in **Table 5**. The minimum possible score is 8 and the maximum possible score is 24. Scores for the SR stations range from 10 to 19 (see illustration below). These values represent approximately 13 to 69 % of the maximum possible value, after correcting for out of bound values (i.e., 0 to 7). This means that the SR generally has low to average habitat quality. Many physical habitat metrics had relatively low values, such as shade, bank undercutting, and habitat diversity. None of the stations had high habitat quality. This isn't particularly surprising, given that the SR is a slow-moving, mud-bottomed, prairie river.



Low habitat quality stations: Stations M3 and M9 had very low total habitat scores. Station M3, which is downstream of Lake Isle and upstream of Lac Ste Anne, had the lowest score of all stations due to poor water quality, little to no aquatic vegetation cover, and minimal shade coverage. Station M9, which is downstream of Big Lake and upstream of the City of St. Albert, had poor water quality, had an overabundance of aquatic vegetation, and lacked habitat type diversity. Golder Associates (2004) refers to this stretch or river as having been modified (straightened), which would explain low habitat scores, however there is no reference in their report to confirm this statement. Also, since this site on the SR is immediately downstream of Big Lake, it is possible that the low habitat diversity has been caused by the lake's influence.

Below average habitat quality stations: Stations M1 and M2, which are located upstream of Lake Isle, had below average habitat quality primarily due to very poor water quality and a medium quality of physical habitat. Stations M5 (upstream of Matchayaw Lake) and M11 (downstream of Little Egg Creek and upstream of Gibbons) had medium total habitat quality, which is reflective of the values of most of the metrics.

Above average habitat quality stations: Stations M4, M6, M7, M8, M10, and M12 had the highest overall station scores, largely a result of higher habitat diversity, substrate composition, and water quality. Water quality is notably better downstream of Lac Ste Anne (between stations M4 and M8), which improves habitat quality substantially.

Table 5: Total habitat quality score results.

Metric	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Shade	2	2	1	2	1	1	2	2	2	1	2	1
Macrophyte cover	2	2	1	3	2	2	2	3	1	3	2	2
Bank undercutting	2	2	1	1	2	2	3	1	1	1	1	1
Organic substrate	2	2	2	3	2	3	1	2	1	3	2	3
Habitat diversity	2	2	2	3	1	1	2	2	2	3	2	3
Total phosphorus	1	1	1	2	2	3	3	3	2	2	2	2
Total nitrogen	1	1	1	3	3	2	2	3	1	2	2	3
Dissolved oxygen	1	3	1	2	3	3	3	3	2	2	3	3
Total score	13	15	10	19	16	17	18	19	12	17	16	18
Score relative to maximum possible score of 24%[1]	**31**	**44**	**13**	**69**	**50**	**56**	**63**	**69**	**25**	**56**	**50**	**63**

Note. [1] Red = 1-25% (low quality); Orange = 26-50% (below average quality); Yellow = 51-75% (above average quality); Green (not present) = 76-100% (high quality).

4.2.2 Other Physical Metrics

The habitat survey also involved the characterization of other physical features that were not included in the metric scoring but are essential components of aquatic health (**Appendix B**). Physical metrics include the following:

- Bank stability: assessment of eroded banks through the amount of exposed soil that shows recent scouring, disturbance or failure. Recorded as stable (>90% vegetated banks), moderate (50-90%), low (25-50%), or unstable (<25%).
- Shoreline vegetation: the percent cover of grasses, shrubs and trees. Shoreline vegetation mostly comprised of grass or shrubs at all SR stations.
- Bottom type: determination of the type of bottom as: hard (sand or gravel), soft (easy to walk), very soft (hard to walk), not wadeable (deep).
- Substrate embeddedness: assessment of a 10 m section of stream centered on each transect, estimation of the embeddedness as one of 4 categories, based on the extent to which the predominant substrate material is embedded in fines or sands. Due to the dominance of organic material at the majority of stations, this measurement was only applicable at station M12 and on some transects at the upstream stations (M1-M3).
- Periphyton coverage on substrate: The degrees to which rocks are covered in algae was only applicable at stations with rocks.

4.3 Summary and Discussion: Aquatic Habitat

Based on ecological and geographical information (i.e., ecoregions), hydro-morphological information (i.e., location of basins such as lakes), and results from our study regarding the quality of aquatic habitat, we have divided the SR watershed into reaches as follows for ease of discussion:

- Upper Reach: Headwaters to upstream of Lac Ste Anne, represented by stations M1 to M3. Includes stations higher in landscape position located in Boreal Central Mixedwood and Dry Mixedwood Natural Subregions with very low flow.
- Middle Reach: Lac Ste Anne to upstream of Big Lake, represented by stations M4 to M8. Includes stations primarily in Boreal Dry Mixedwood Natural Subregion, with some Central Parkland Natural Subregion. Flows in this reach increase substantially (about 10 times higher than in the Upper Reach). Sand and gravel also appear in the substrate.
- Lower Reach: Big Lake to the confluence with the North Saskatchewan River, represented by stations M9 to M12. Includes stations primarily in the Parkland Natural Subregion that are very low in landscape position and thus receive relatively more groundwater contributions and have higher and more consistent flows. Cobbles and boulders also appear in the substrate.

Upper Reach (stations M1 to M3)

- Instream aquatic habitat quality is generally poor upstream of Lac Ste. Anne (stations M1 to M3), and in particular between Lac Ste. Anne and Isle Lake (station M3). This is mainly due to poor water quality. This poor water feeds the lakes in question, which likely plays a part in their eutrophication. Total phosphorus (0.46 mg/L) and nitrogen (4.2

mg/L) concentrations were very high at station M3 in August, suggesting the Isle Lake is a source of high nutrients to Lac Ste. Anne (see **Section 5** below).

- Due to their connectivity to the lakes, the river segments represented by stations M2 and M3 may provide important spawning and rearing habitat, as well as travel corridors for migrating fish. These sites could be targeted for management to maintain or improve fish habitat, which will increase the resilience of lake fish populations.

Middle Reach (stations M4 to M8)

- Habitat quality improves substantially downstream of Lac Ste. Anne, primarily due to improvements in water quality (In August 2017, total P concentration goes from 0.46 mg/L at M3 to 0.17 mg/L at M4; it is about 3 times lower downstream of Lac Ste. Anne), which may also be related to higher flows. This suggests that Lac Ste. Anne plays an important role in nutrient retention and in the downstream quality of habitat. Lac Ste. Anne is a key component of the SR system.
- Given that the Middle Reach is a stretch of river with relatively higher habitat quality, it could be targeted for habitat conservation initiatives that would protect the river and its riparian areas. Not only will this maintain and potentially further improve habitat quality in the SR, but it could allow suitable habitat for travel and transfer of biological organisms from Lac Ste. Anne to Matchayaw Lake to Big Lake and vice-versa.

Lower Reach (stations M9 to M12)

- Habitat quality degrades substantially at station M9, largely due to excessive growth of rooted aquatic vegetation and high nutrient concentrations. Nutrient limitation experiments can be conducted to determine what is causing this growth. However, it is likely that the very high nitrogen (3.7 mg/L), relative to phosphorus (0.12 mg/L) concentration, is a contributing factor. Also, the consistent flow and nutrients being released from Big Lake also may be causal factors. As described in Section 5, tributaries that feed Big Lake, such as Rivière Qui Barre Carrot Creek, have high phosphorus concentrations. Also, shallow lakes such as Big Lake tend to export relatively high amounts of nutrients due to the constant loads from bottom sediments. These combined factors likely play a role in relatively high nutrient export from Big Lake. Otherwise, channel modifications occurred upstream of M9 (upstream of Ray Gibbon Dr.) to create a fish habitat compensation area (Pisces Environmental Consulting Services 2008). Although this did not create a direct impact to station M9, it is possible that indirect impacts occurred in the form of sediment transport and deposition either during or after excavations. Golder Associates (2001) also mentioned that the section of river that passes through St. Albert was historically altered, which would explain the low habitat quality values; however, we have found no documentation to confirm this claim.
- Habitat quality improves downstream of station M9. A significant observation in the lower reach is the presence of walleye (see **Section 8**). Walleye likely migrate from the North Saskatchewan river and it appears that the lower reaches of the SR provide suitable

habitat for this important fish species. It would be interesting to conduct fish telemetry studies to determine the SR walleye migratory routes, which would inform habitat management planning. In the meantime, we recommend habitat conservation measures in the lower portion of the SR.

- Improvement of habitat quality can occur by reducing nutrient enrichment generated by Big Lake (see **Section 5** for recommendations), which will in turn improve on the overabundance of aquatic plants and organic substrate.
- Shade, bank undercutting, and habitat diversity can be maintained and enhanced by protecting and planting riparian vegetation such as willows and poplar on the river banks.

5. Water Quality

5.1 Methods

5.1.1 Sample Collection and Lab Analyses

Water quality samples were taken at each station on approximately a monthly basis from December 2016 to September 2017 in mainstem sites, and from April to September 2017 in tributary sites. Water sampling consisted of two methods: 1) a water probe (YSI Multi-Probe) measurement and, 2) a water sample sent to a lab. The following table describes the water sampling variables and schedule.

Parameter	Dec 2016 to Feb 2017[1]	April	May	June	July	Aug	Sept
Routine variables (salts, pH, etc.)	x	x		x		x	
Metals, total		x		x		x	
Total suspended solids		x	x	x	x	x	x
Oxygen, dissolved	x	x	x	x	x	x	x
Nutrients							
Nitrogen, Total Kjeldahl	x	x	x	x	x	x	x
Nitrogen, ammonia	x	x	x	x	x	x	x
Nitrogen, nitrate+nitrite		x	x	x	x	x	X
Phosphorus, total	x	x	x	x	x	x	x
Phosphorus, dissolved		x	x	x	x	x	x
Biological (*E. coli*, total coliforms)		x	x	x	x	x	x
Pesticides					x		

Note. [1] Mainstem sites only

5.1.2 Data Analyses

Water quality data was analyzed in three ways, as follows:

- General statistics (min, max, 5th, 50th, and 95th percentiles) were calculated for each station to document and summarize the data. This data is presented in **Appendix D**.
- Water quality variables were compared to Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life and for Agricultural Uses. These guidelines are meant to provide general guidance in evaluating surface water quality. These guidelines are used in combination with water quality monitoring data to identify areas with potential water quality concerns. If monitoring data do not exceed the guidelines, problems are unlikely. If the guidelines are exceeded, a detailed assessment might be required in order to

determine the extent, cause, and potential adverse effects arising from the exceedance. It is important to note that guidelines are sometimes exceeded due to natural causes, such as heavy runoff during snowmelt or heavy rain events.

- Each water quality variable was graphed in relation to features of interest (sampling stations, lakes, towns). The data was calculated as the median concentration for each of 3 separate seasons representing under-ice conditions (winter: December 2016 to February 2017), spring runoff (April to June 2017), and summer (July to September 2017). The following metrics were used to assess the water quality of the SR.

Metric	Description
Nutrients (N, P) during the open water period	Excessive nutrients cause organic pollution, which can in turn cause critically low oxygen levels. The spring season is critical since most of the nutrients in river ecosystems are being exported and deposited at this time. Human-related sources of nutrients include application of chemical fertilizers, manure production and management, excessive sedimentation, and urban runoff
Oxygen during the ice cover period	Dissolved oxygen is the most fundamental parameter in water. Reduced oxygen levels have been shown to cause lethal and sublethal (physiological and behavioural) effects in various organisms, especially fish. Mortality and/or loss of equilibrium typically occurs between 1 and 3 mg/L of dissolved oxygen in the water. Low oxygen levels in the winter is a known stressor in the SR - it is responsible for fish kills every 2-3 years. Productive waterbodies with low flow/low water levels, such as the SR during winter, have a high oxygen demand and low oxygen supply, and thus can be more susceptible to winter fish kills.
Pesticides in July	Pesticides are very good indicators of pollution stemming from human activities (vegetation and pest control associated with crop management, urban areas, golf courses, ditch areas, powerlines, forestry, etc.) since they are exclusively manmade. Since pesticides tend to bind to soils, detection of pesticides in surface waters is a conservative indicator that urban and/or agricultural pollution is occurring. Thus, a pesticide detection is an indicator that other problems may exist.
Metals during the open water period	Metal concentrations can be naturally elevated during high flow since they are associated with erodible soil particles. Levels of certain metals during low flow conditions (late summer) can indicate pollution from human-related causes, although groundwater contributions can also play a role.
Chloride during the ice cover period	A major source of chloride to the environment is the application of road salts for snow and ice control in the winter. It is estimated that most (97%) of the road salt used in Canada is in the form of NaCl (sodium chloride; CCME 2011). High salt concentrations can limit

	ecosystem productivity. Chloride is also one of the most damaging ions for crops because it can accumulate in plant tissue.
Suspended solids during the Spring runoff period	Suspended solids in the SR are related to flow (Golder 2004). A spike in suspended solids during high flows (spring snowmelt) can indicate areas of excessive erosion or inputs of particles from stormwater discharge.

5.2 Results

5.2.1 Exceedances to Water Quality Guidelines

Out of the 36 water quality parameters that have guideline values, 7 did not meet guidelines including dissolved oxygen, pH, chloride, aluminum, iron, total arsenic and total cobalt (**Appendix E)**. Dissolved oxygen did not meet guidelines since it was very low during the winter and summer seasons at many sites. This is occurring due to the biochemical demand placed on water due to high organic content. Field measured pH was slightly below guidelines during winter at sites downstream of Big Lake (M9, M11, and M12). This is most likely caused by natural under-ice biological and chemical reduction processes. Dissolved aluminum concentrations exceeded guidelines during spring runoff in Rivière Qui Barre and at downstream sampling locations (M8, M9, M10). Iron exceedances are common throughout the Sturgeon River and its tributaries. Given that iron is common in our geology and in our groundwater, this is not unusual. However, both total and dissolved iron are substantially above guidelines and very high at sites M2 and T3 (Rivière Qui Barre), whereas they are not particularly high in other places (**Figure 9**). Chloride concentrations exceeded guidelines in Carrot Creek. Also, at this site total arsenic exceeded the PAL guidelines on one occasion in August. Arsenic exceedances in Alberta surface waters have been documented in lakes in the Beaver River watershed. These exceedances are thought to be caused by groundwater discharge as it is known that groundwater can have relatively high amounts of arsenic in some places in Alberta (Alberta Health and Wellness 2000). However, non-natural arsenic exceedances could also occur. The extent, cause, and potential adverse effects of these exceedances should be examined further.

5.2.2 Water Quality along the River

All water quality figures are included in **Appendix F**. Notable patterns are described below.

Nutrients

Generally, the highest nutrient concentrations in the SR mainstem occur in the headwaters feeding Lake Isle and Lac Ste. Anne (i.e., stations M1 to M3; **Figure 6**). These sites generally have poor upstream riparian health and the majority of their watersheds disturbed. The concentration of total phosphorus at these stations (open water season) are within the range of other streams in the province that have watersheds with high agricultural intensity (**Figure 7**). As described in **Section 4**, nutrient concentrations decrease substantially downstream of Lac

Ste. Anne (station M4), meaning that the lake appears to retain a significant amount of nutrients. Stations M4 to M7 have the lowest nutrient concentrations of all stations during the open water period, with M7 being the lowest. Total phosphorus concentrations at these stations, as well as M8-M9 and M11-M12, are within the range of other streams in the province that have watersheds with low agricultural intensity (**Figure 7**). These stations may serve as good reference sites from a water quality perspective.

Total phosphorus concentrations during the open water period in Toad Creek, Rivière Qui Barre, and Carrot Creek are about 3 to 5 times greater than in nearby SR stations, ranging from 0.091 to 1.2 mg/L (Toad Creek: 0.091-0.49 mg/L; Rivière Qui Barre: 0.46-0.7 mg/L; Carrot Creek: 0.3-1.2 mg/L) (**Figure 6**). Very high total phosphorus concentrations were also noted by Hunt and Webb (2012) in 2011, with most of this phosphorus in dissolved (bioavailable) form. These values are consistent with other creeks sampled in the province in 1995 and 1996 that drain watersheds with high agricultural intensity (median: 0.348 mg/L; range 0.071-0.898 mg/L; Anderson et al. 1998). Thus, these tributaries are contributing high concentrations of nutrients to the SR and this appears to be causing an increase in SR concentrations (i.e., station M8 and M9 have higher concentrations than those upstream of tributaries (M4 to M6). To determine the full effect of these high nutrient concentrations, loads (i.e., concentration times water discharge) should be calculated which means that discharge would need to be modelled for each sampling location where data doesn’t exist. The median concentration of total phosphorus in the other creeks (Kilini Creek, Atim Creek and Little Egg Creek) appears to be similar to those of nearby stations on the SR.

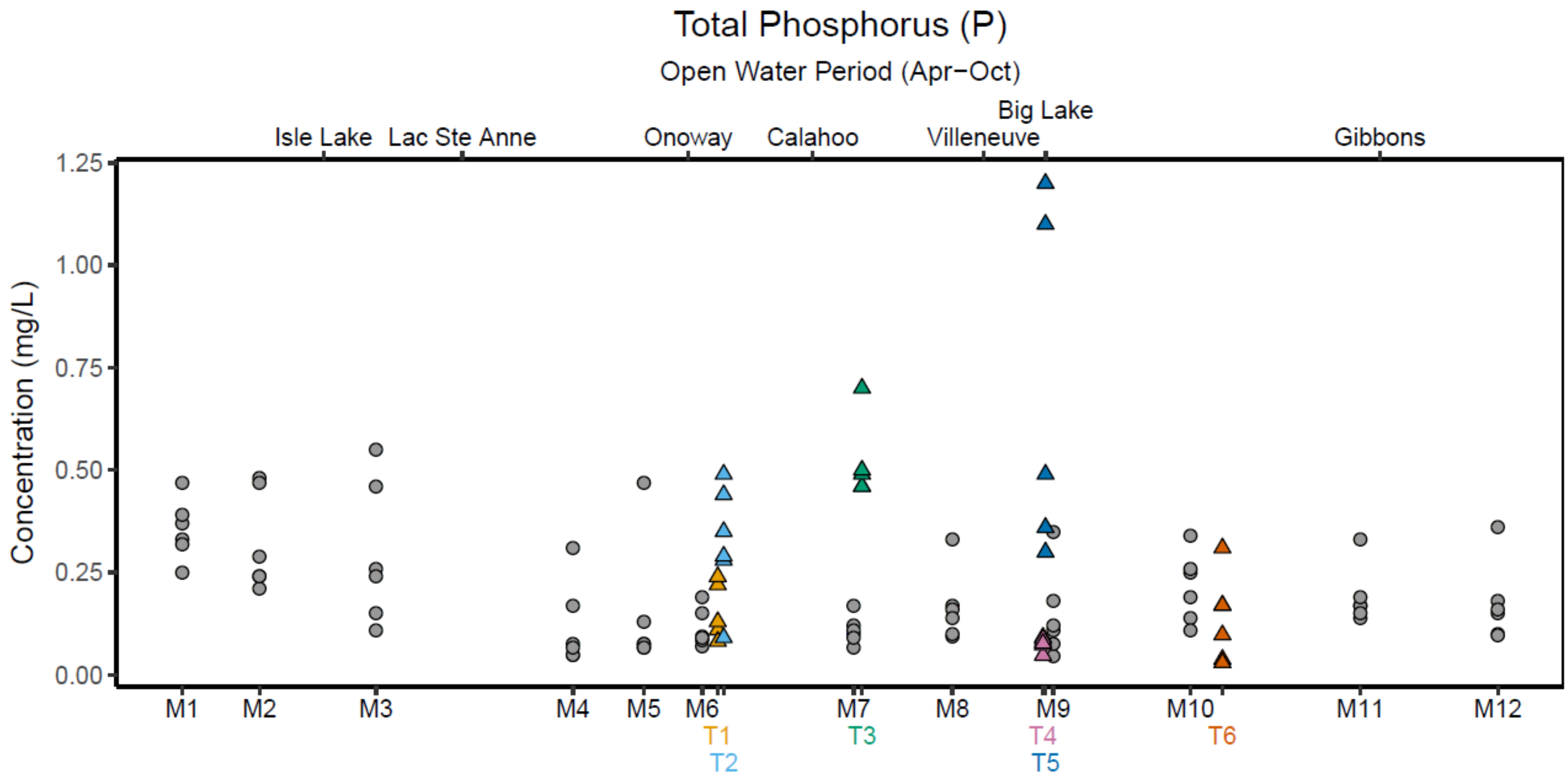


Figure 6a: Concentrations of total phosphorus along the Sturgeon River during the open water period (April to October). Note. Each point represents a sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

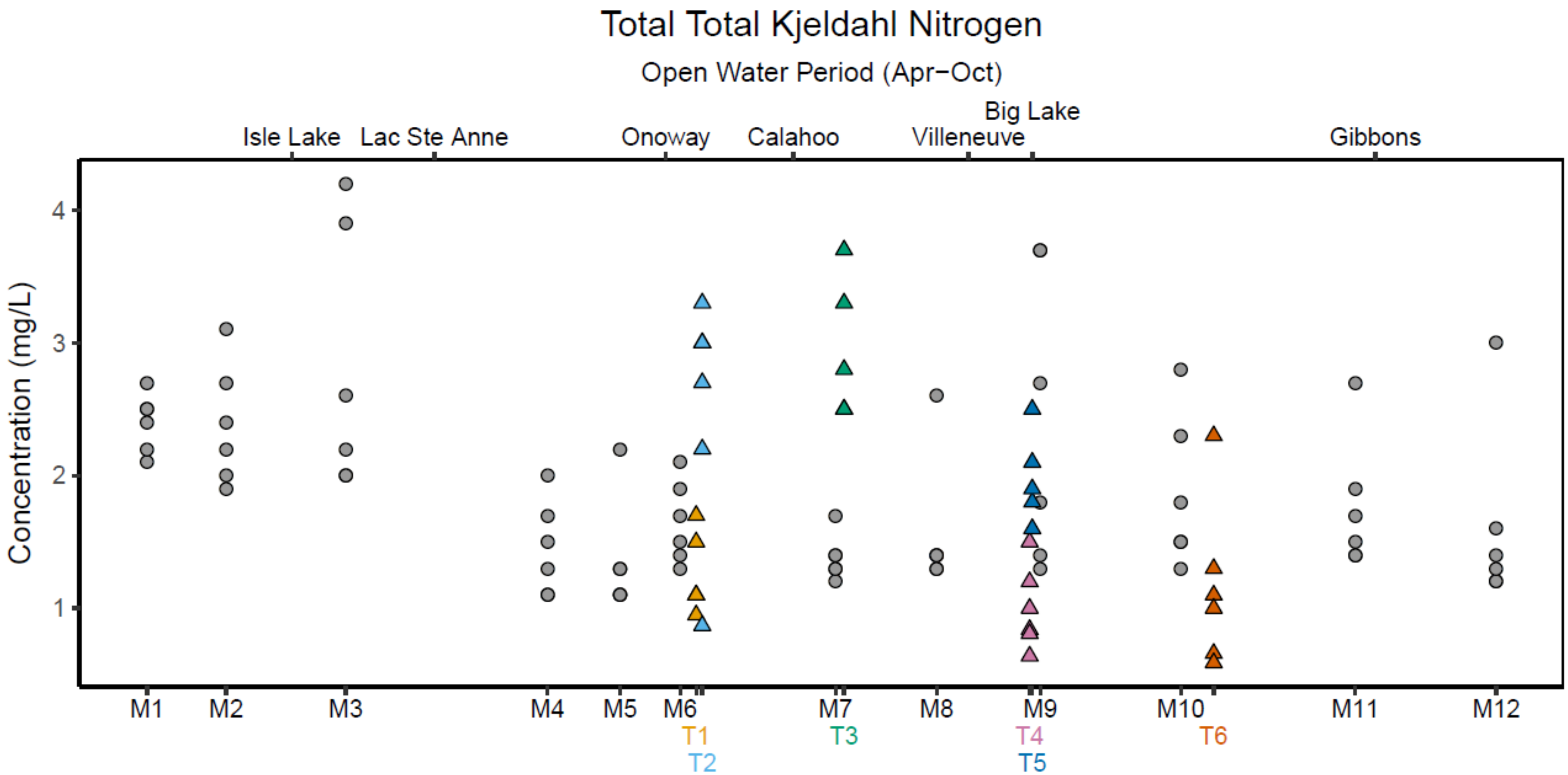


Figure 7b: Concentrations of total Kjeldahl nitrogen along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

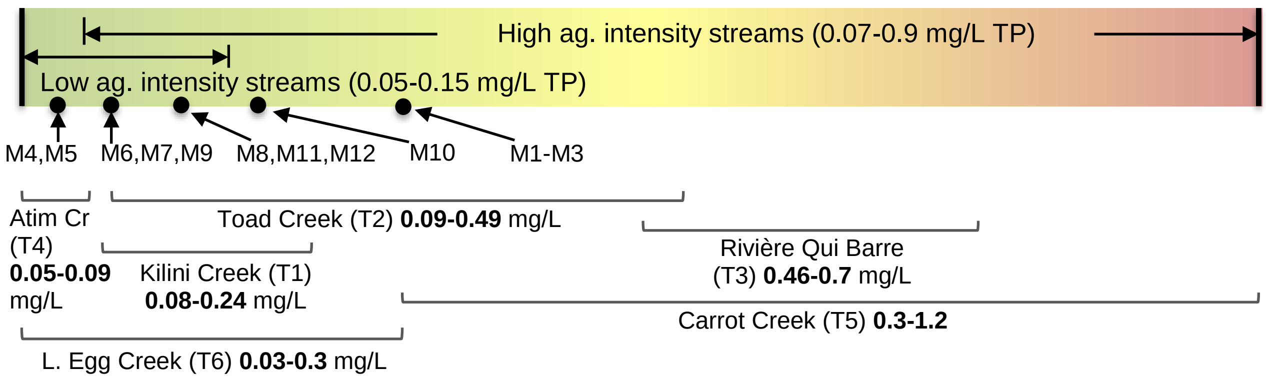


Figure 8: Open water (April to October) total phosphorus concentrations for sampling stations on the SR and its tributaries as compared to streams sampled as part of the CAESA program that had watersheds with "High Agricultural Intensity" and "Low Agricultural Intensity" (Anderson et al. 1998). Stations on the SR (M1 to M12) represent open water (April to October) median values. For tributaries, the range in total phosphorus concentration during the open water period is shown.

Routine Water Parameters (Salts)

Salinity (as represented by specific conductivity) during the open water period is relatively similar across stations on the SR (**Figure 8a**). During winter, when the influence of groundwater is relatively greater, salinity increases gradually downstream in the SR, going from about 400 to 1400 µS/cm (**Figure 8c**). This is somewhat expected since, as it moves east, the SR decreases in elevation and thus intercepts a greater proportion of groundwater, which tends to be more saline than precipitation and surface runoff. Indeed, salt concentrations in buried valleys in the area are high (TDS = 2,730 mg/L in the Onoway Channel at Big Lake outlet; MacDonald 2018). Note that salinity is relatively high at M2 (upstream of Isle Lake), due to bicarbonate and sodium. It is currently unclear what may be causing these values in salts at this site.

During the open water period, two tributaries (Carrot and Little Egg) contained slightly saline to saline waters that are elevated in sodium, sulphate, and chloride (see **Appendix F** for sodium and chloride). Chloride was particularly elevated in Carrot Creek during the summer - in July and August, concentrations of chloride in Carrot Creek exceeded Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (for long-term exposure) (**Figure 8b**). These high values in Carrot Creek are consistent with those of the 2017 City of St. Albert water quality monitoring program (Tetra Tech 2018). Sodium and sulphate concentrations in the tributaries are consistent with that of buried valleys underlying the area. However, chloride concentrations in shallow and bedrock aquifers within the SR watershed boundary is fairly low (from just above 0 to 85 mg/L; MacDonald 2018), meaning that a saline groundwater source is not likely. Chloride can be of concern since it is highly soluble and it is not susceptible to degradation. The levels of chloride in Carrot Creek during the summer have the potential to be toxic to aquatic life, thus further examination is warranted.

During winter, chloride concentrations were 4 to 5 times higher downstream of Big Lake (M9 to M12), as compared to upstream locations (M1 to M8). In some cases (station M10 in particular), these values were near the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (120 mg/L). Similarly, the 2017 City of St. Albert water quality monitoring program reports 2 to 3 times higher concentrations of chloride in the SR (spring and fall) downstream of Big Lake, as compared to an upstream location (Tetra Tech 2018). Concentrations measured in the SR are consistent with values from the local surface and bedrock aquifers (see above), however, we would expect a dilution effect in the river. It is possible that the SR receives a combination of chloride inputs from groundwater, Carrot Creek, and anthropogenic sources.

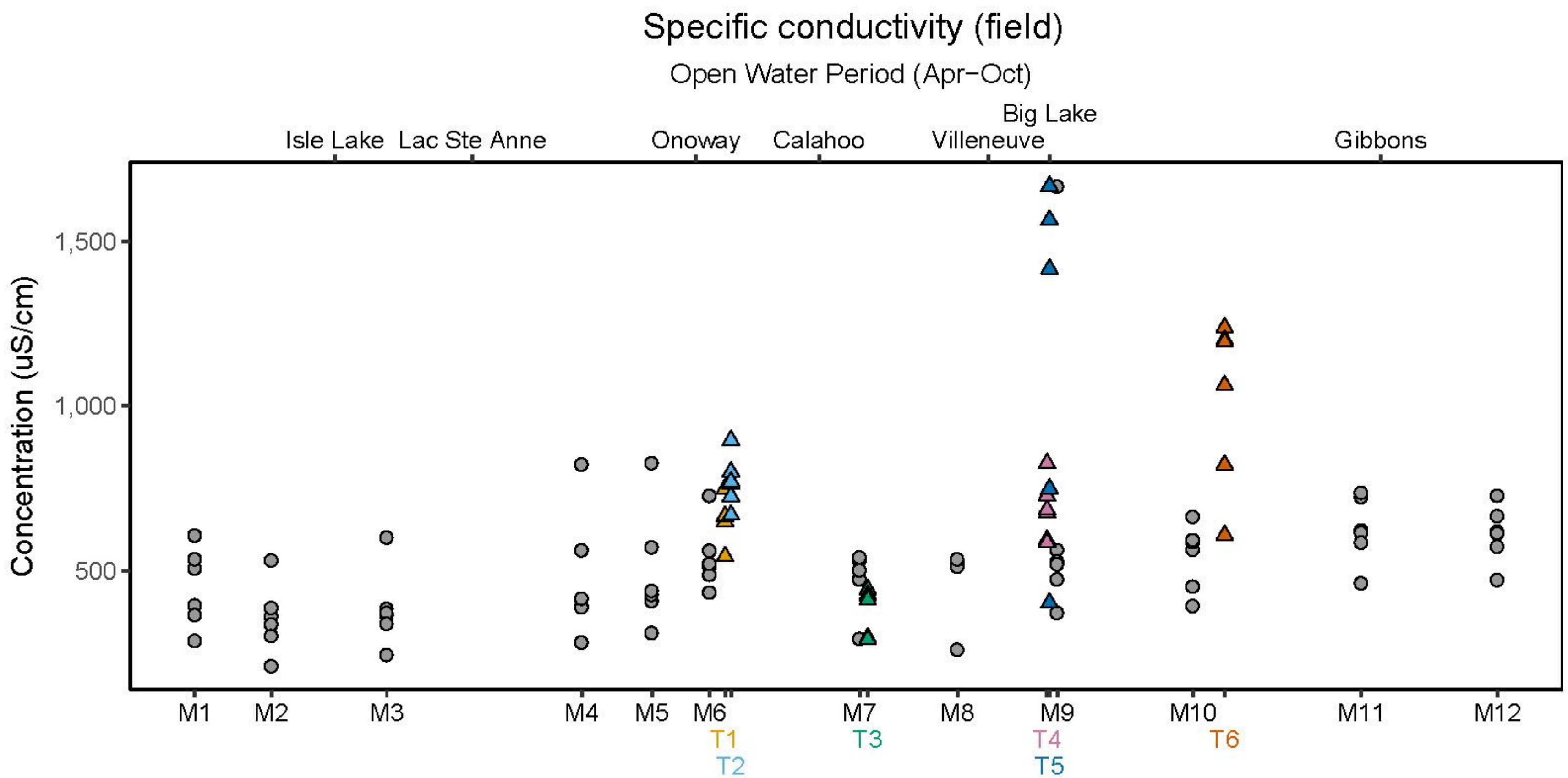


Figure 9a: Specific conductivity along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

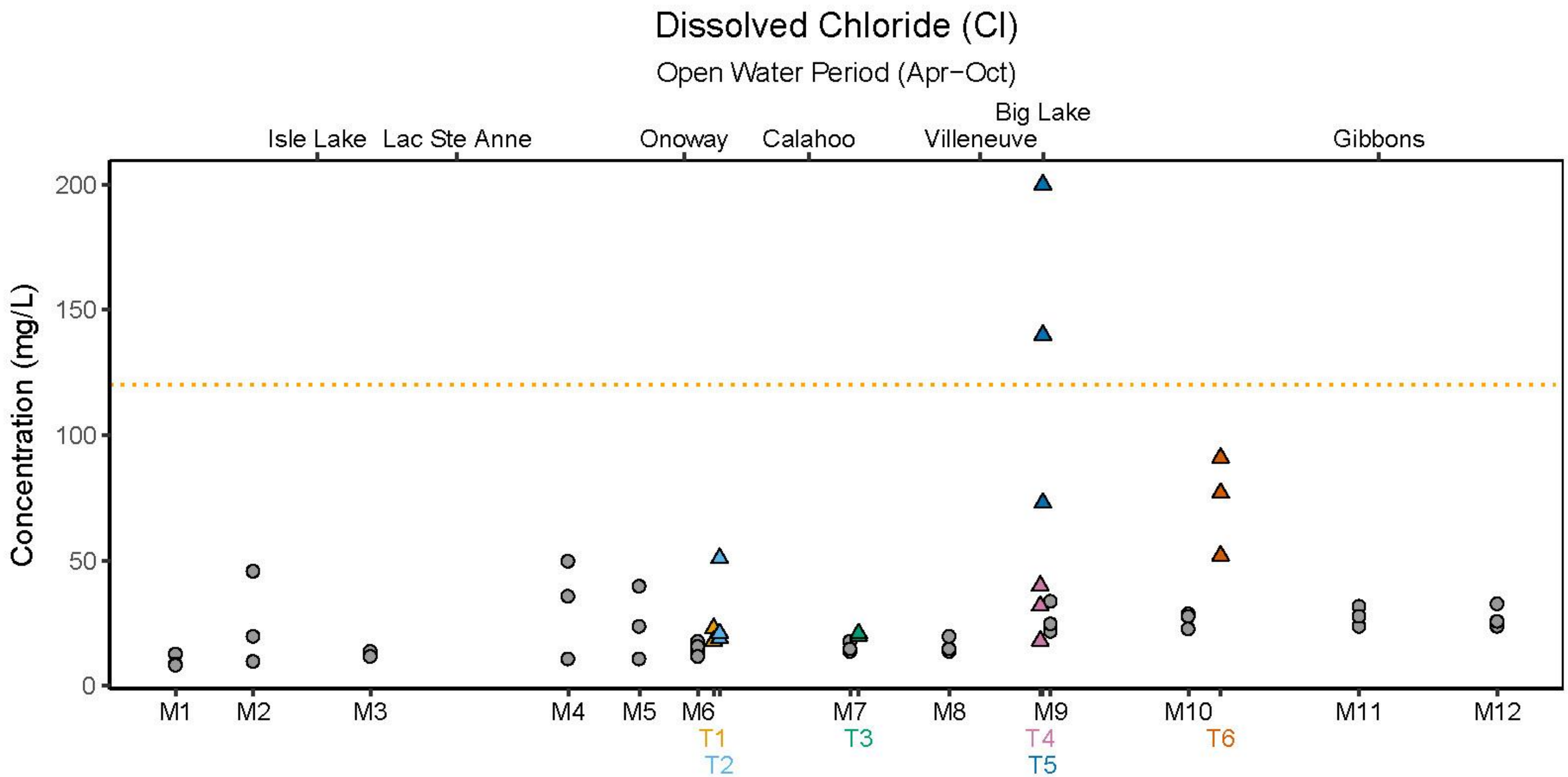


Figure 10b: Concentration of dissolved chloride along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

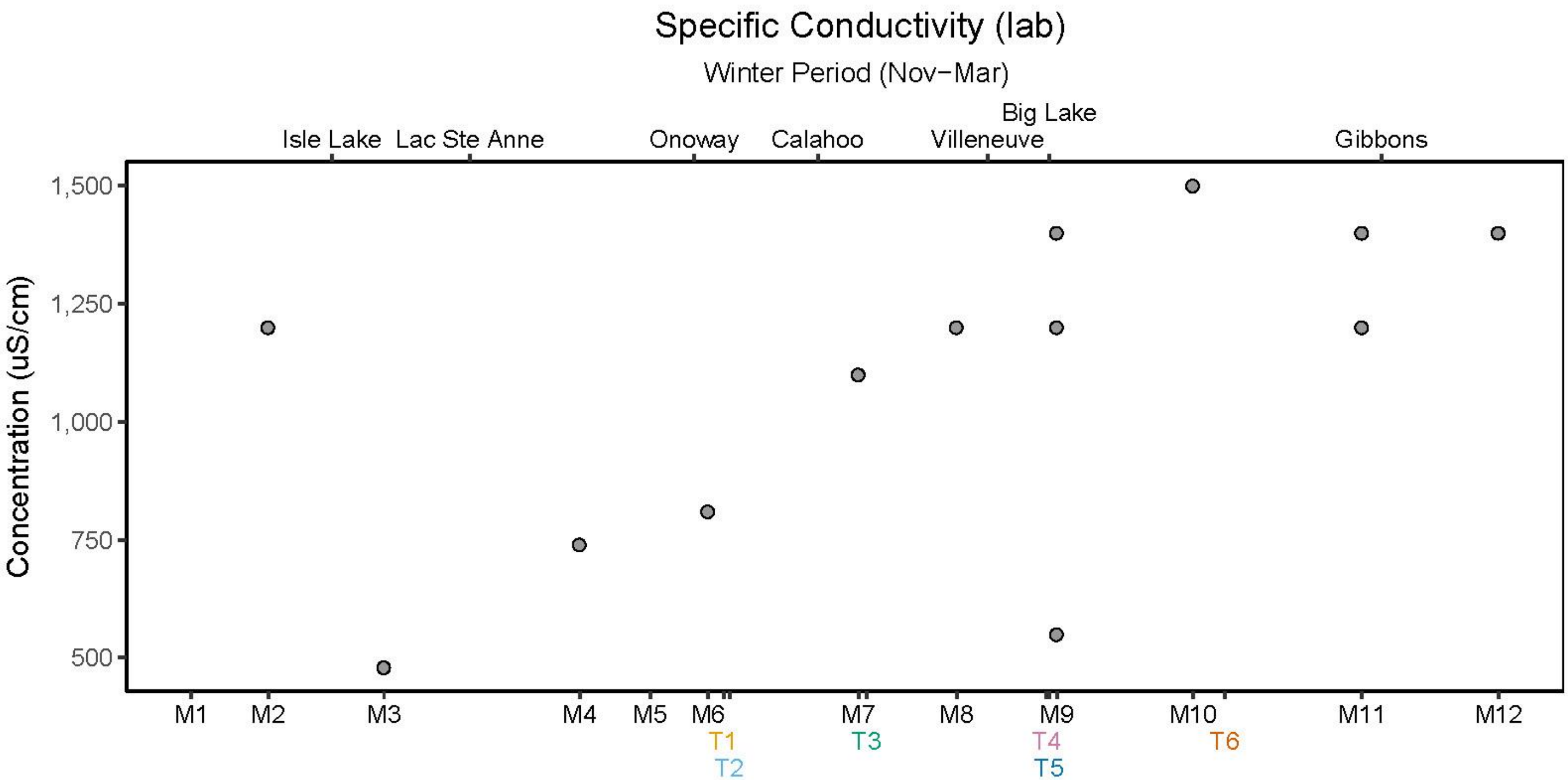


Figure 11c: Specific conductivity along the Sturgeon River during the ice cover period (November to March). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

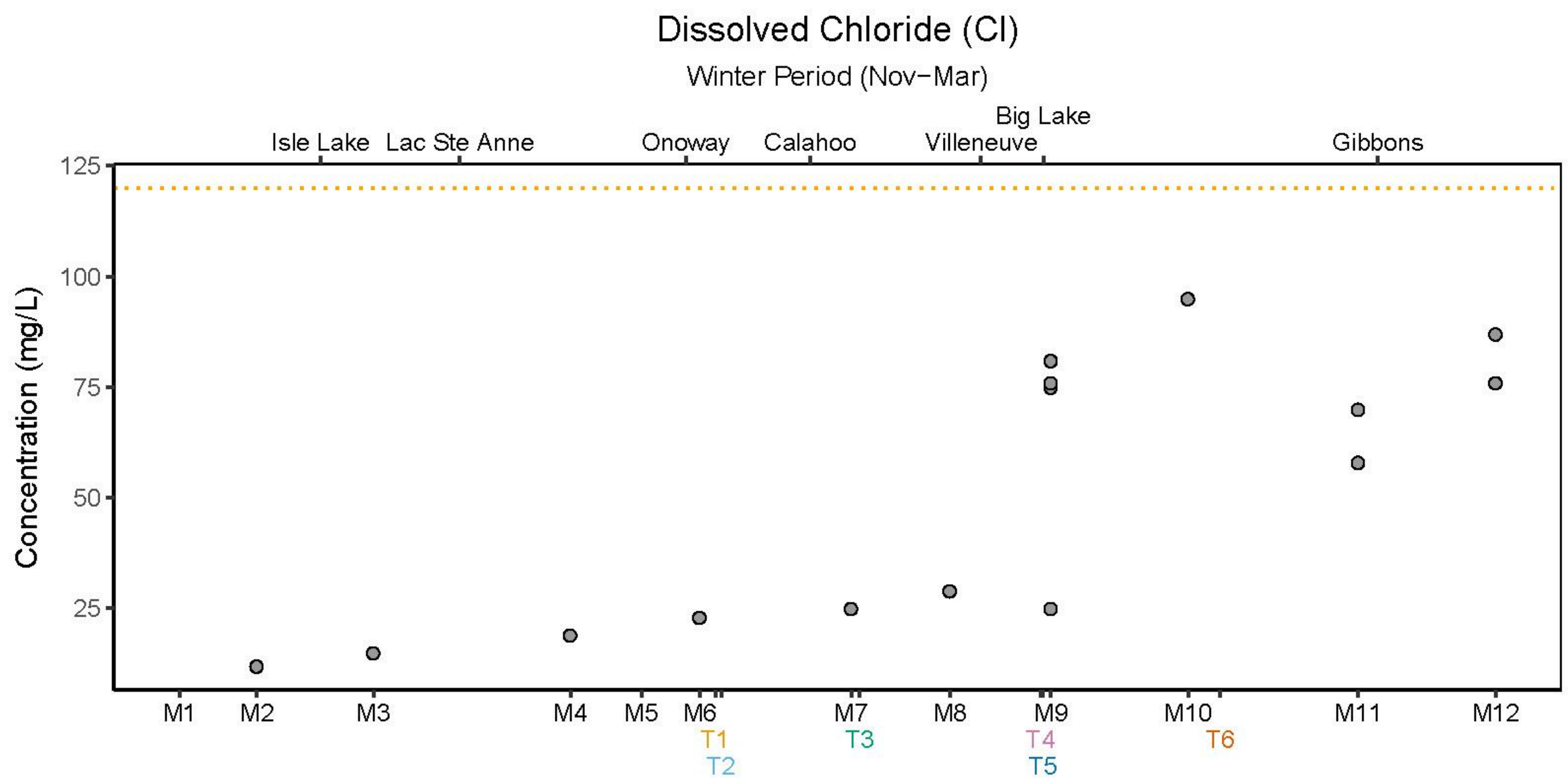


Figure 12d: Concentration of dissolved chloride along the Sturgeon River during the ice cover period (November to March). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

Metals

In general, the concentration of several metals (nickel, lead, iron, copper, cobalt, arsenic) during summer low flow conditions is noticeably higher immediately upstream of Lake Isle (M1 and M2, **Figure 9**). These relatively higher metal concentrations co-occur with high dissolved organic carbon (see **Appendix F**), indicating the likely presence of metal - dissolved organic matter complexes. Dissolved iron concentrations (which are bioavailable) at these locations (M1 and M2), as well as in Rivière Qui Barre, greatly and regularly exceeded the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. The guideline value of 0.3 mg/L has been recommended by several toxicological studies to protect a wide variety of biological organisms such as invertebrates, plants, and fish (BCMOE 2008). Given that there is a risk that such high concentrations of dissolved iron may cause some toxicity to aquatic life, and given that other metals were relatively high at the same locations, further sampling and examination of metals in water and sediment at these locations is advisable.

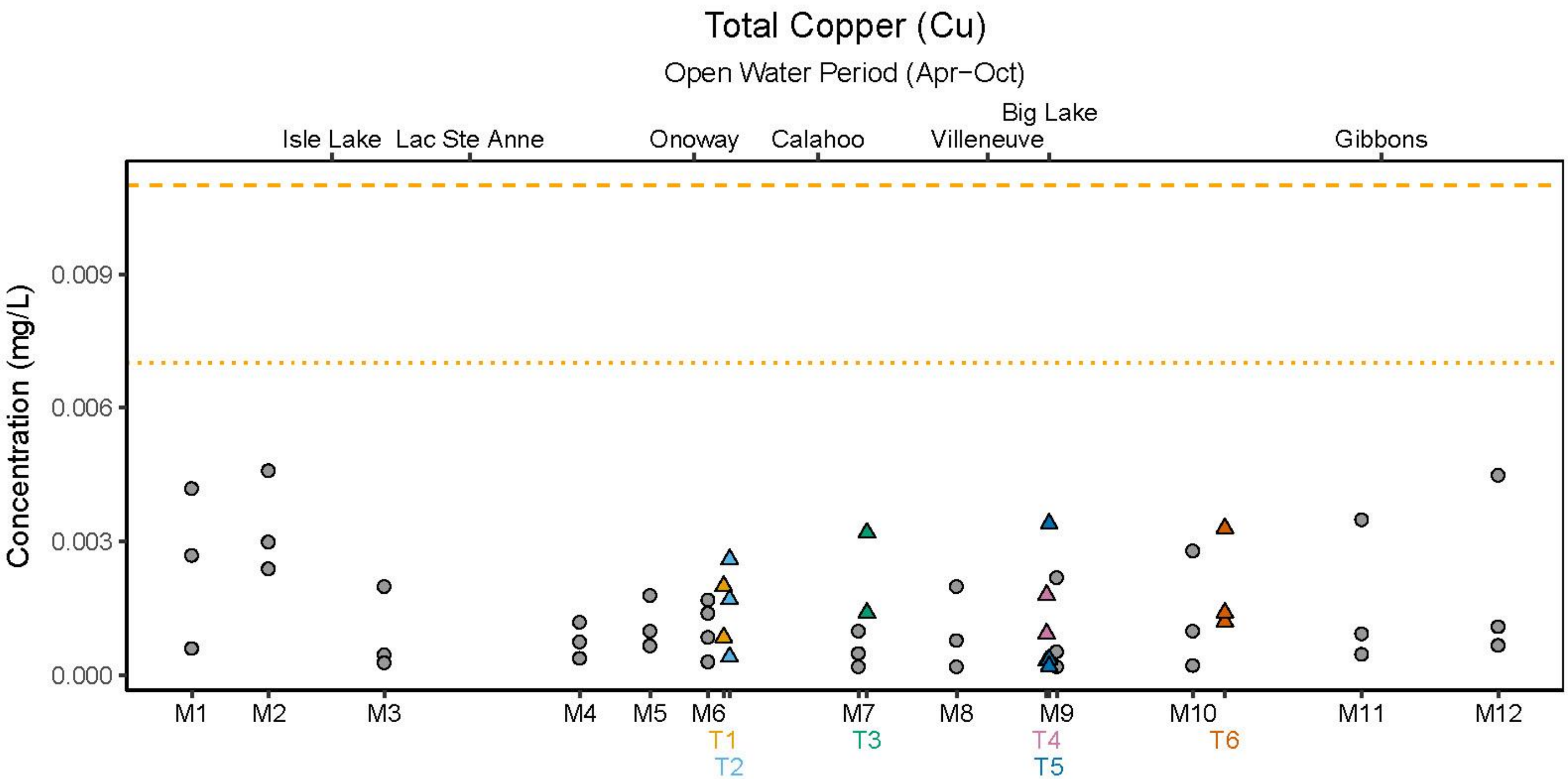


Figure 13a: Concentration of total copper along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

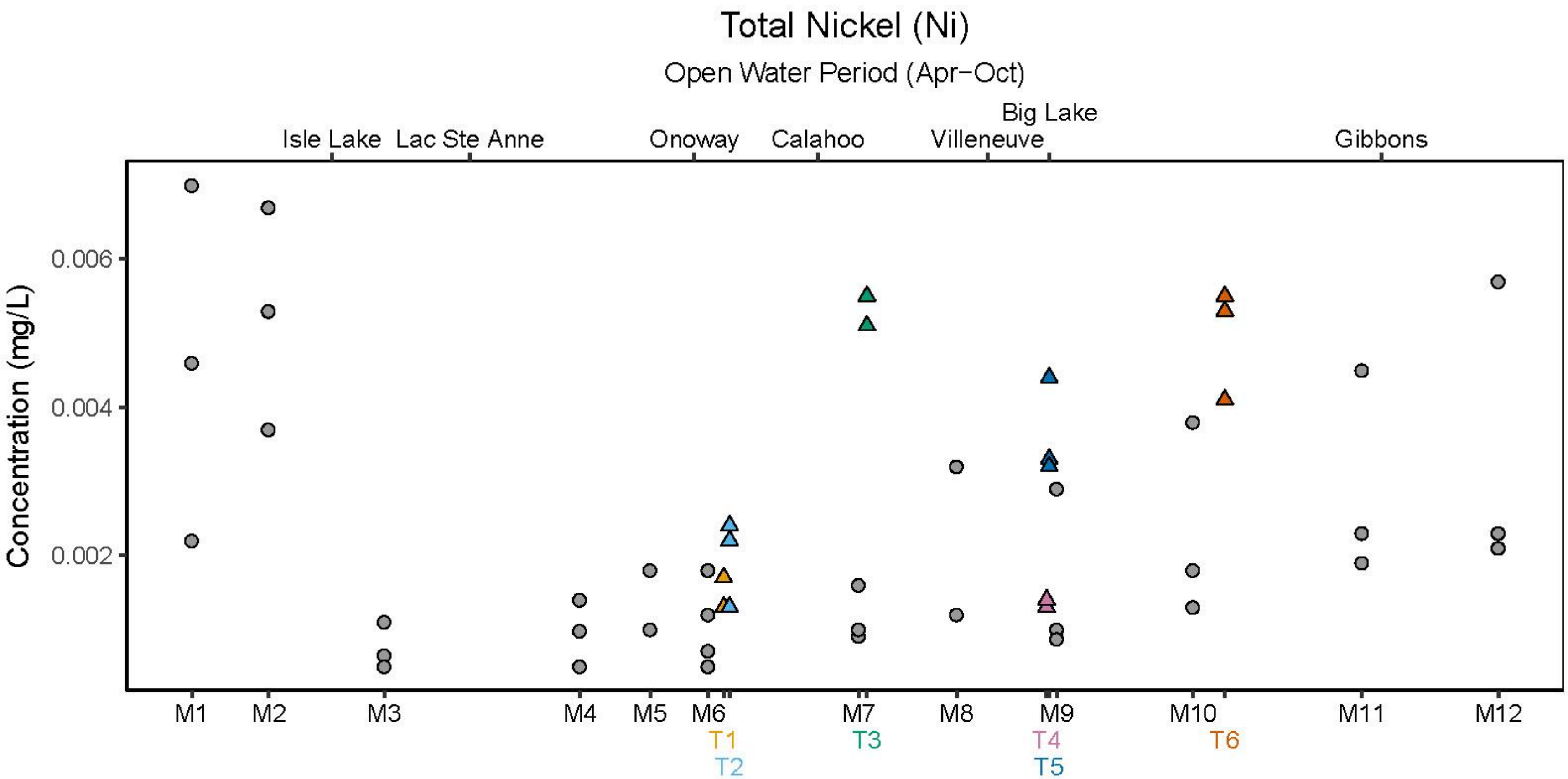


Figure 14b: Concentration of total nickel along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

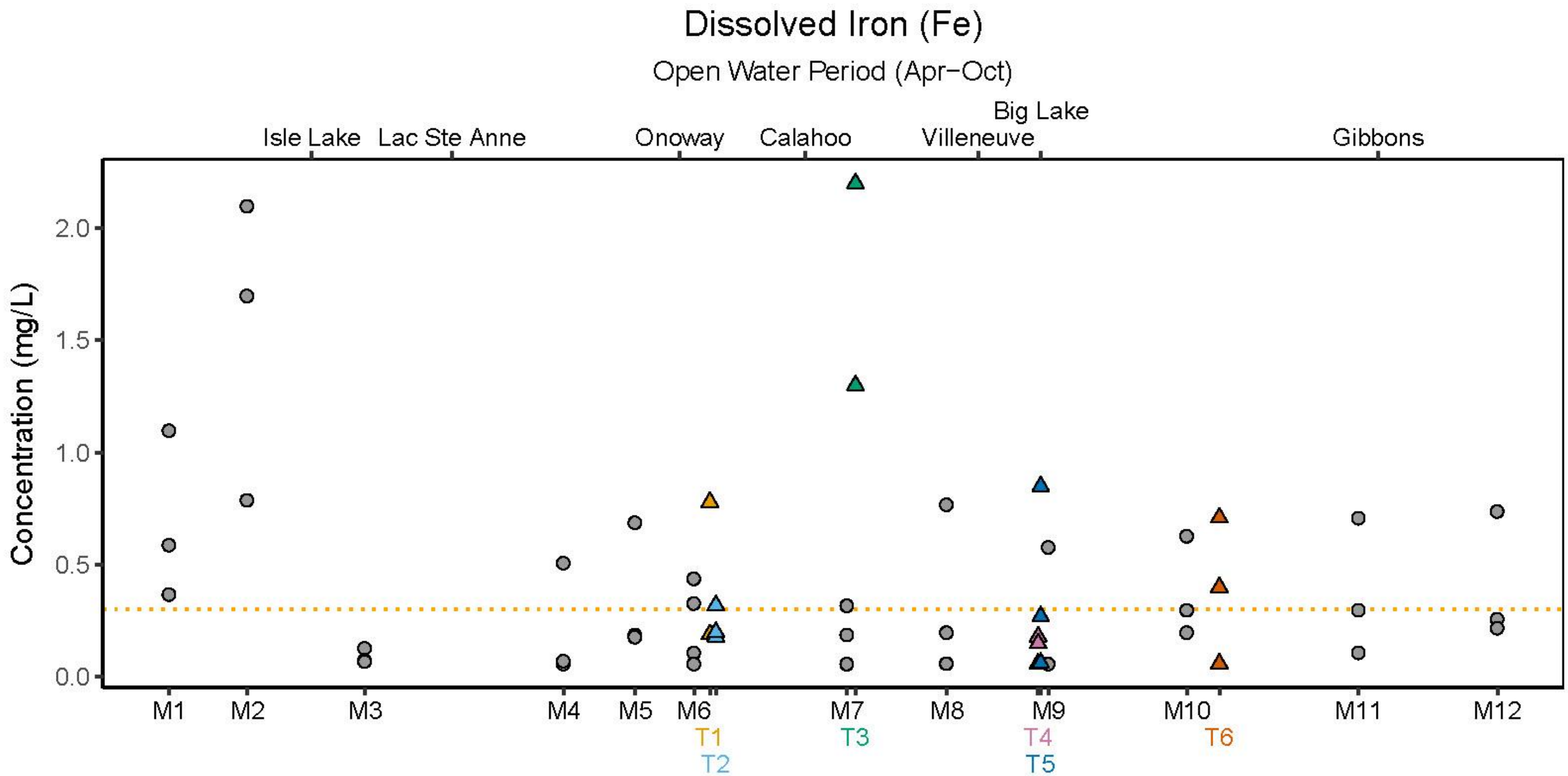


Figure 15c: Concentration of dissolved iron along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

Pesticides

Pesticides are synthetic substances introduced into the environment to control broad-leaved weeds that interfere with crop production, forestry, rights-of-way, and the cosmetic appearance of landscaped areas. There are no natural sources of pesticides. Other than from spills, contamination of surface water from pesticides may occur directly due to nontarget drift from spraying operations, or indirectly through leaching into groundwater and subsequently recharging to surface waters. The risk of contamination to water bodies increases when pesticides applied in the fall or early spring are moved into water bodies either by snowmelt or when extreme rainfall events occur within days of application, and when application occurs during windy days.

Five pesticides, which are herbicides often used in combination, were detectable at most sampling stations in the SR: Bentazon, Dicamba, MCPP, MCPA, 2,4-D (**Figure 10**). These pesticides are the most commonly detected in Alberta rivers and streams (Anderson 2005, Phelan 2012). All of these, except for MCPP (or Mecoprop) and Bentazon, have Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. These guidelines were not exceeded at the time of sampling, meaning that problems are unlikely, unless the herbicides are present at higher concentrations than we detected at the time of sampling.

Depending on the pesticide, pesticides were notably higher (6+ times higher than background) upstream of Lake Isle (M2), downstream of the City of St. Albert (M10), in Carrot Creek, and in Little Egg Creek, as compared to sampling stations immediately upstream of these sites. MCPA was found at M10 and Little Egg Creek, but it was noticeably higher in Carrot Creek. Bentazon was high only at one station (M8), which is not consistent with the low values at upstream M7 and Rivière Qui Barre. This high value may indicate a very localized source in between Rivière Qui Barre and M8, or it could be a false-positive since only one sample was analyzed. This warrants further examination.

The 2017 City of St. Albert water quality monitoring program did not detect pesticides in the SR and Carrot Creek (Tetra Tech 2018), which might be because samples were collected in the fall, whereas pesticides are typically detected in the months of June and July (Anderson 2005, Lorenz et al. 2008). Increased concentrations of pesticides downstream of major urban centers have been documented in Alberta by Anderson (2005). There are no major urban centers for sampling station M2. Potential sources of pesticides for this site include the Trestle Creek Golf Resort, which is a large development adjacent to the SR, or spraying associated with roadways and/or other right-of-ways.

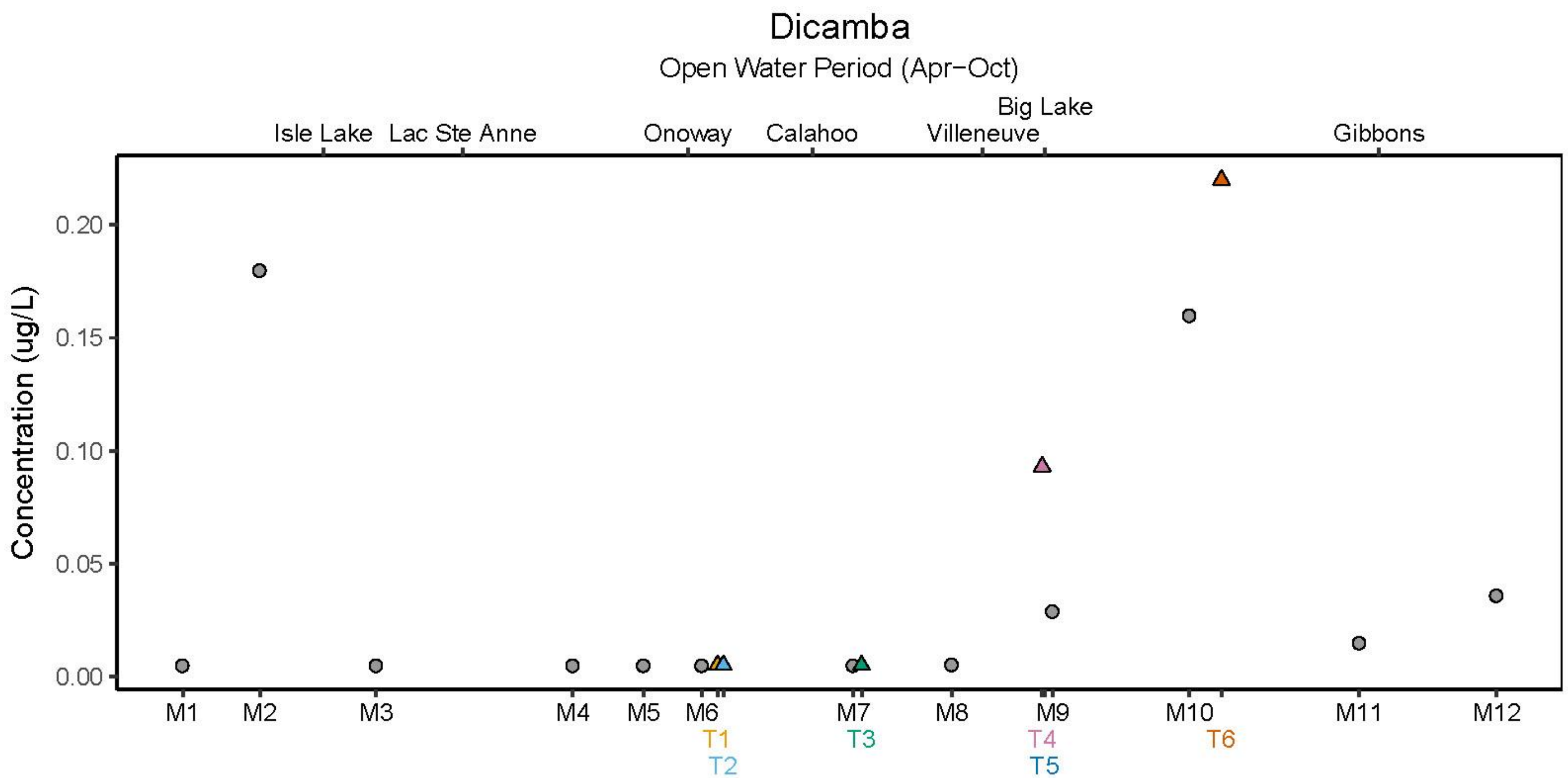


Figure 16a: Concentration of Dicamba along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

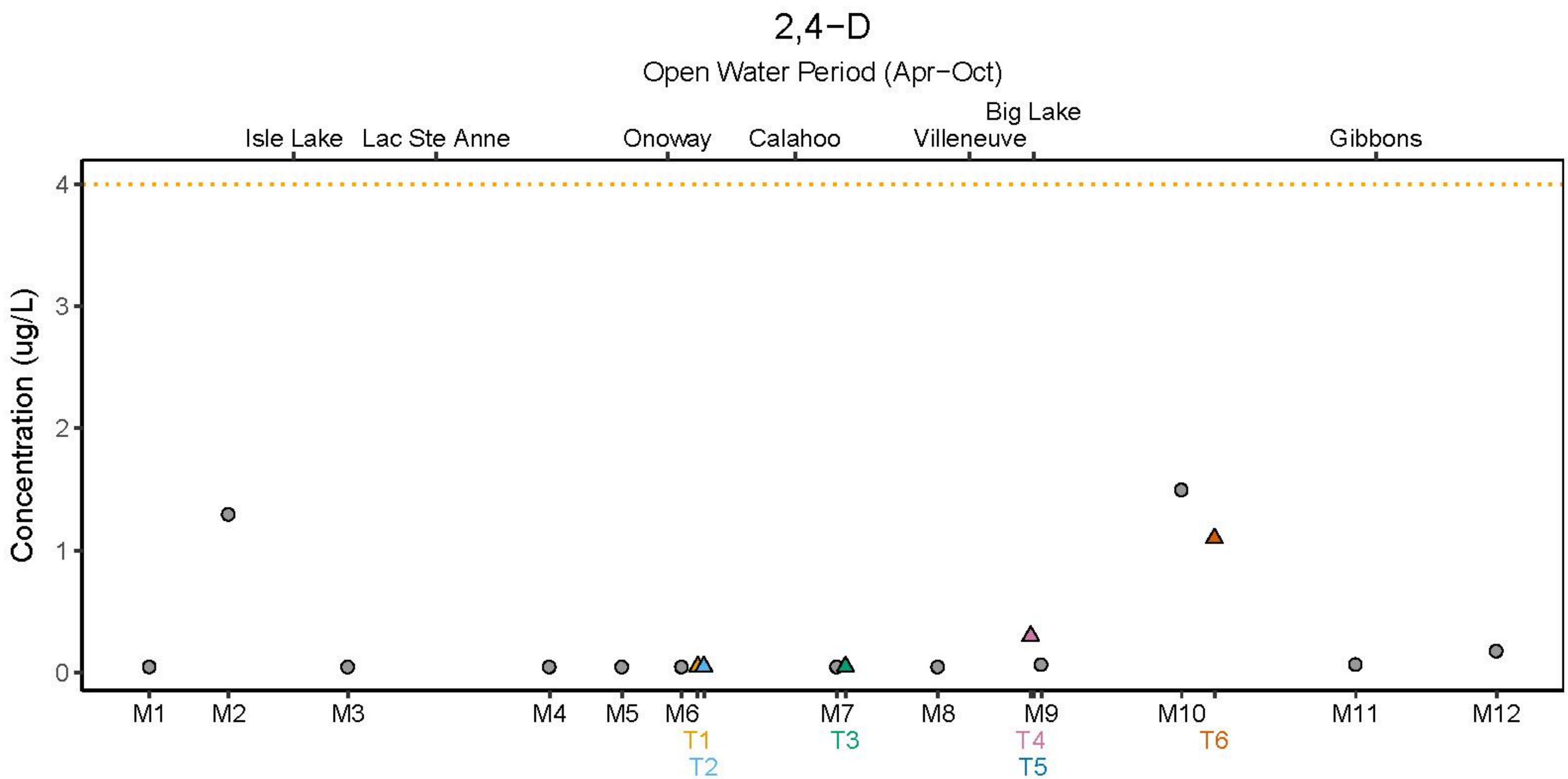


Figure 17b: Concentration of 2,4-D along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

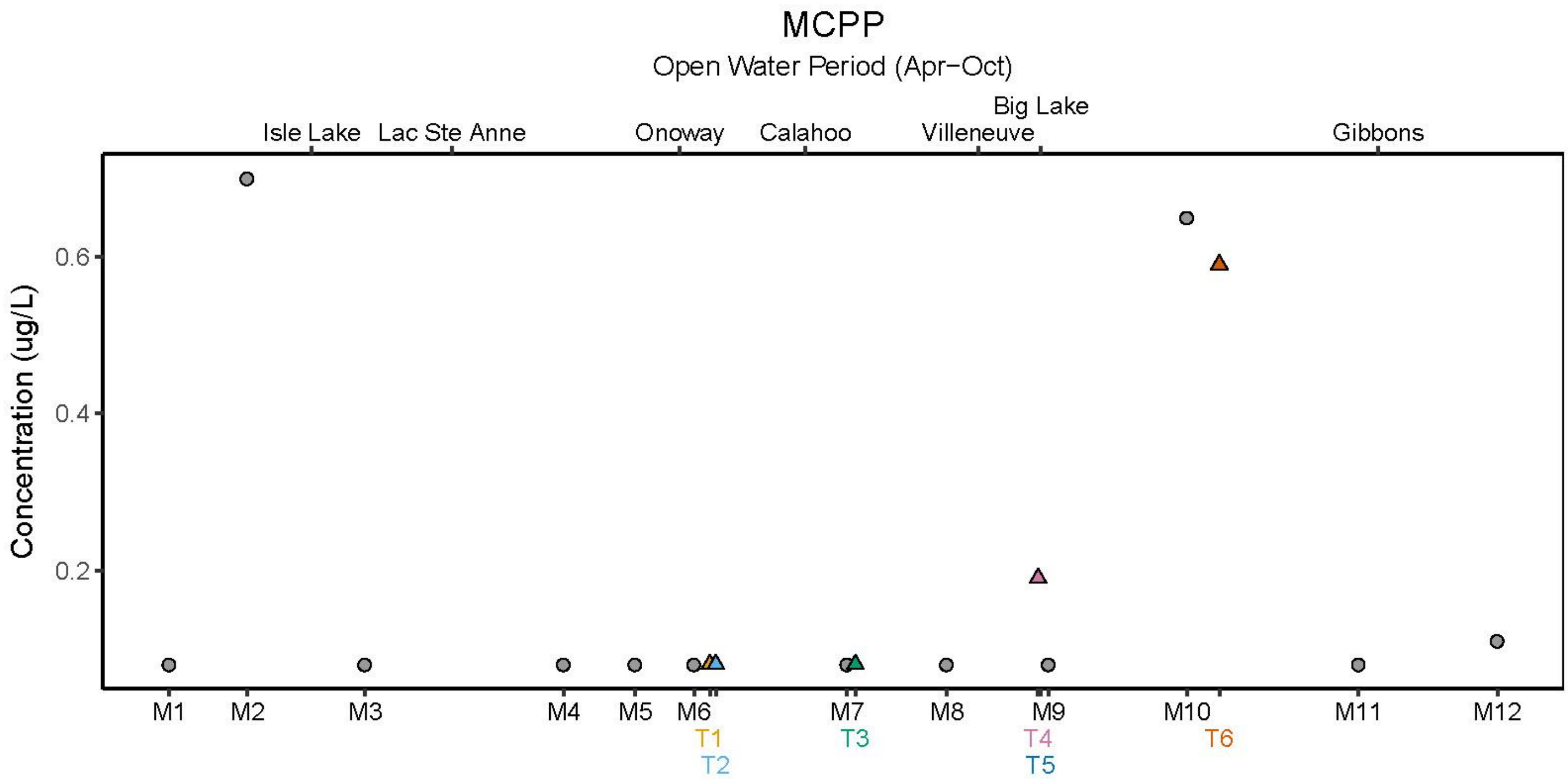


Figure 18c: Concentration of MCPP along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

Oxygen (winter)

Winterkill is a natural phenomenon in Alberta, which can be worsened by human activities. Open water oxygen concentrations are generally above Guidelines (**Figure 11a**). However, they were below acute guidelines (5 mg/L) in the upper reaches near Hoople Lake (M1) and in between Isle Lake and Lac Ste. Anne. Dissolved oxygen concentrations were also critically low in Toad Creek, Rivière Qui Barre, and Carrot Creek in late summer. These sites all had high nutrient concentrations (see “Nutrients” above).

Winter oxygen concentrations are critically low (less than 5 mg/L) at some point during winter at most sites sampled along the SR (**Figure 11b**). Sites with high nutrient and organic concentrations typically have low winter oxygen (**Figure 12**). These concentrations are prohibitive and/or lethal to aquatic life, which is consistent with the numerous reported historical winter fish kills observed in the SR (City of St. Albert 2012). Some sampling stations (M3, M6, M8, M11) had relatively higher oxygen concentrations during winter. Golder (2004) also reported higher winter oxygen concentrations in segments of the river corresponding to M3, M6, and M11, indicating that these locations are potentially oxygenated during the winter over the years. M3 and M6 are likely receiving oxygen from upstream lakes, whereas M11 is likely more oxygenated due to generally higher flows in the lower landscape position.

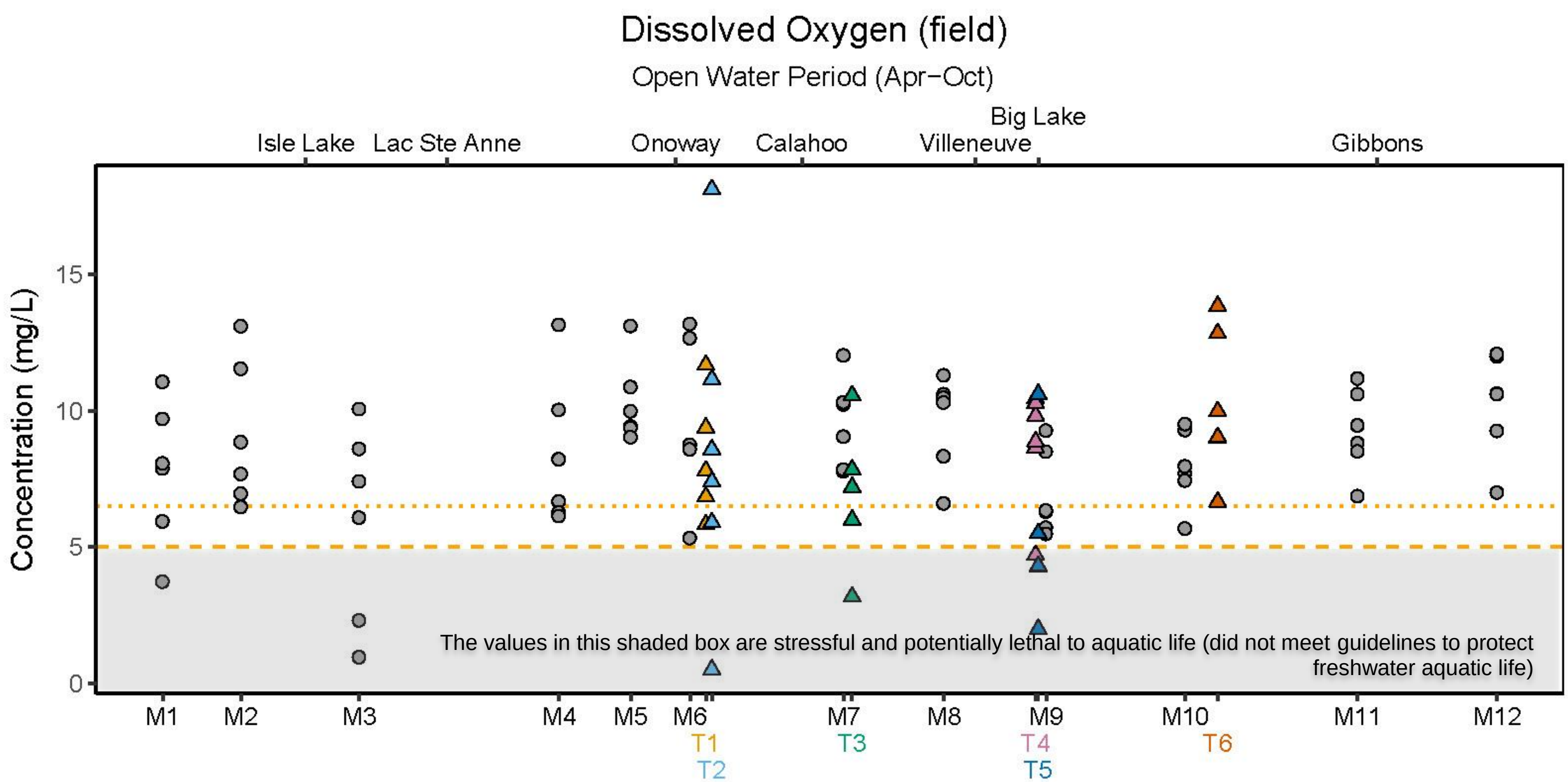


Figure 19a: Concentration of dissolved oxygen along the Sturgeon River during the open water period (April to October). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

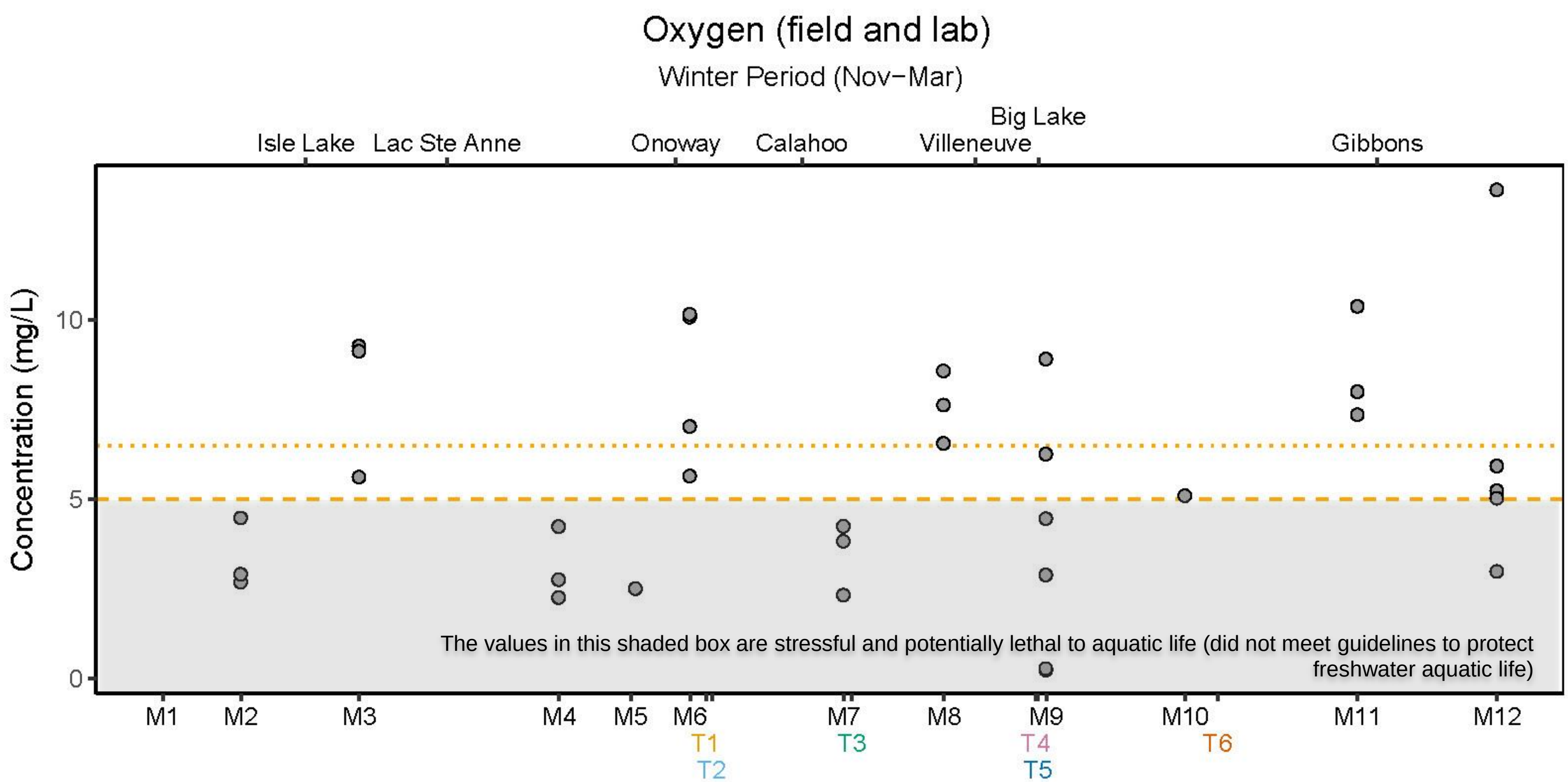


Figure 20b: Concentration of dissolved oxygen along the Sturgeon River during the ice cover period (November to March). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

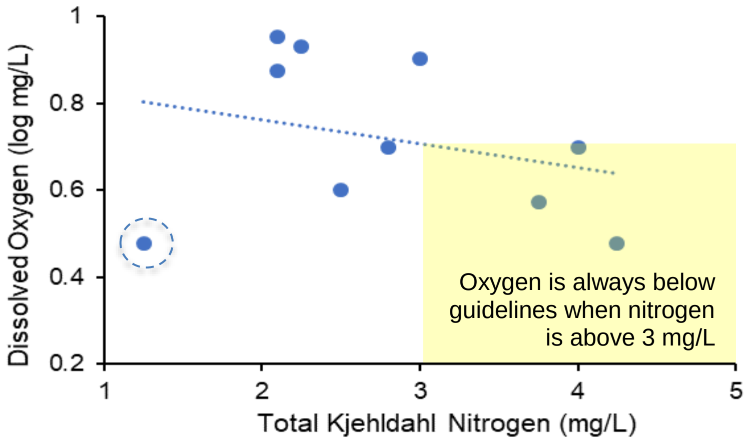


Figure 21: The median concentration of dissolved oxygen in relation to total Kjehldahl nitrogen in stations on the Sturgeon River during the winter season. Note that station M2 (dashed circle) appears to be an outlier in the relationship – it has low oxygen even though nitrogen is low.

Suspended solids (sediment in water)

The concentration of total suspended solids (TSS) during spring was lowest at sites M6 and M9, which are downstream of Matchayaw Lake and Big Lake, respectively (**Figure 13**). Sites M4 (downstream of Lac Ste. Anne), M7 (upstream of Rivière Qui Barre) and M8 (downstream of Rivière Qui Barre) also have relatively low TSS. These results suggest an important role of the lakes in the SR river system in capturing and storing suspended solids, as well as the associated suspended nutrients (see Nutrients sub-section above). Other observations include:

- SR tributaries do not appear to be an important source of TSS, which is consistent with Tetra Tech's results from spring sampling in Carrot Creek (Tetra Tech 2018). TSS goes up slightly between stations M7 and M8, which appears to be a result of TSS loading from Rivière Qui Barre, although the generally poor riparian areas 300 m upstream of M8 could also be the cause.
- TSS increases approximately 2-3 times from station M9 (upstream of St. Albert) to M10 (downstream of St. Albert), indicating that stormwater runoff may be a source of sediment in between these stations. These results are consistent with those of the 2017 City of St. Albert water quality monitoring program when the most downstream site (Station 4, Tetra Tech 2018) is compared to the site near M9 from our report (Station 2, Tetra Tech 2018), even though the sampling occurred after spring runoff concluded (end of May). TSS continues to increase downstream (stations M11 and M12), which is likely the result of additional river scouring where flows have high energy. In this portion of the river, Little Egg Creek does not appear to be a significant source of TSS.
- Stations upstream of Isle Lake (M1 and M2) have relatively higher TSS, which may be caused by degraded riparian conditions and associated bank erosion (see **Table 2**).
- Station M5 had relatively high TSS, which appear to be the result of localized conditions perhaps an erosional issue from a bridge crossing or ditch, etc.). Riparian conditions 300 m upstream of M5 appear to be relatively good, which does not explain the high values. Since this site is upstream of Matchayaw Lake, significant TSS loading to the lake may be occurring and thus further monitoring and an inspection of this stretch of river is recommended.

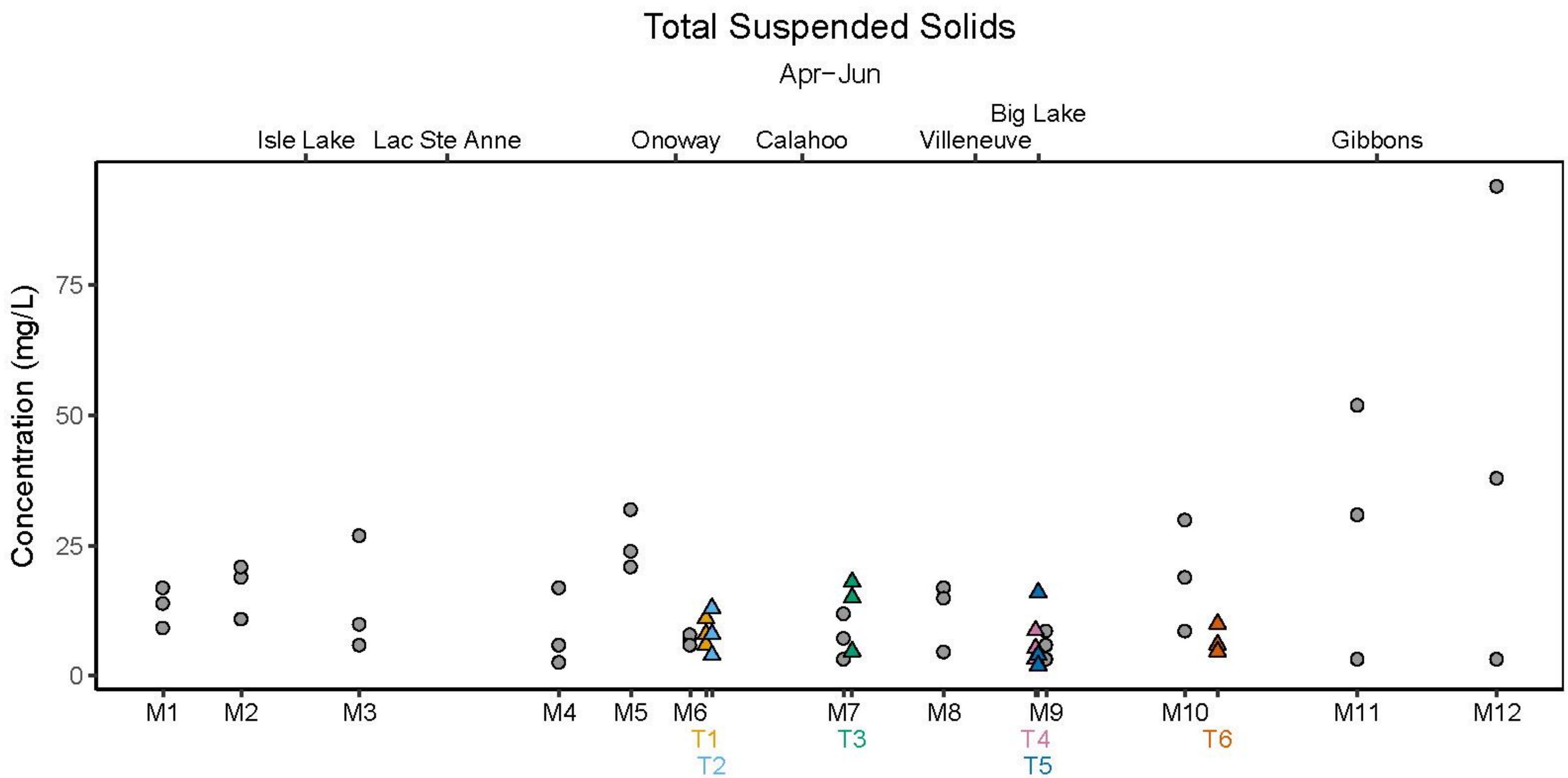


Figure 22: Concentration of total suspended solids along the Sturgeon River during the Spring runoff period (April to June). Note. Each point represents one sampling event. The X-axes represent distance along the SR river, from upstream to downstream, and shows major features such as waterbodies, major centers, and tributary inflows.

5.3 Summary and Discussion: Water Quality

Nutrients

The SR is nutrient-rich, depending on the location. Open water nutrient concentrations are high in the upstream reaches that feed Lake Isle and Lac Ste. Anne. They are also very high in some of the tributaries, such as Toad Creek, Rivière Qui Barre, and Carrot Creek. The phosphorus concentrations from these tributaries are similar to those of high agricultural intensity streams that were sampled as part of the CAESA program, and they appear to cause an increase in SR nutrient concentrations in some cases (Rivière Qui Barre, and Carrot Creek in particular). Toad Creek, Rivière Qui Barre, and Carrot Creek are highly nutrient-enriched, which is not surprising since over 75% of their watersheds are disturbed (see **Table 2**). Total phosphorus concentrations in between Lac Ste. Anne and the confluence of Rivière Qui Barre are relatively low and similar to those of other streams in Alberta with watersheds that have low agricultural intensity. Because of this, this stretch or river may offer good reference points for setting water quality objectives for the SR.

A nutrient balance should be calculated for the SR using existing data (from this study, the City of St. Albert monitoring program, AEP, NAIT, and Water Survey of Canada hydrometric monitoring program, etc.) to allow an evaluation of the relative contribution of tributaries and reaches of the SR to the mainstem SR water quality. This will identify areas that export the greatest amount of nutrients, which can be targeted for conservation and restoration initiatives. Although current flow data is limited, flows can be modelled within a reasonably good degree of accuracy.

Routine Water Parameters (salts)

Salt concentrations during low-flow periods (winter) generally increase as we travel downstream along the SR. This is consistent with an increase in the relative contribution of groundwater as the river lowers in elevation and intercepts groundwater flow paths, however, this does not mean that these high values are all of natural origin. Total salinity is very high in Carrot Creek during the summer to the point that chloride exceeded Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (for long-term exposure). Sources of chloride could include road salts from high-density road areas (e.g., Morinville) or Highway 2, which runs parallel to a manmade drainage channel which is part of the Carrot Creek system.

During winter, chloride concentrations were 4 to 5 times higher downstream of Big Lake as compared to all upstream sites. Concentrations measured in the SR are consistent with values from the local surface and bedrock aquifers, meaning that the source of chloride could be from these sources. However, given that: 1) these higher values are located downstream of where road densities are high, 2) road salt application is a known major source of chloride to the environment, and 3) values are near provincial guidelines; further examination and mapping of chloride during the winter is recommended. We recommend that chloride concentrations be measured again during winter upstream and downstream of areas that drain high road densities, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. This sampling should be diagnostic in nature i.e., the sampling regime should specifically attempt to determine if high values are caused by road salt application. Adopting this type of approach will directly support a discussion on the potential adverse effects of these values and what mitigation measures, if any, are warranted. Given that road salt application addresses an important health and safety issue, the monitoring program design must be exceptionally rigorous.

Metals

In general, the concentration of several metals (nickel, lead, manganese, iron, copper, cobalt) during summer low flow conditions are noticeably higher immediately upstream of Lake Isle. These relatively higher metal concentrations co-occur with high dissolved organic carbon, indicating the likely presence of metal - dissolved organic matter complexes. Dissolved iron concentrations (which are bioavailable) at these locations (M1 and M2), as well as in Rivière Qui Barre, greatly and regularly exceeded the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. Given that such high concentrations of dissolved iron may be toxic to aquatic life, and given that other metals were relatively high at the same locations, further sampling and examination of metals in water and sediment at these locations is advisable. The purpose of this sampling should be very specific i.e., to determine the extent and source of the high values to inform corrective actions.

Pesticides

Five pesticides that are commonly detected in Alberta waters were detectable at most sampling stations in the SR: Bentazon, Dicamba, MCPP, MCPA, 2,4-D. At the time of sampling, Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life were not exceeded, meaning that problems are unlikely at the time of sampling. However, pesticides were notably higher (6+ times higher than background) upstream of Lake Isle (M2), downstream of the City of St. Albert (M10), in Carrot Creek, and in Little Egg Creek, as compared to sampling stations immediately upstream of these sites. MCPA was found at M10 and Little Egg Creek, but it was noticeably higher in Carrot Creek. Bentazon was high only at one station (M8), which is not consistent with the low values at upstream M7 and Rivière Qui Barre. This high value may indicate a very localized source in between Rivière Qui Barre and M8, or it could be a false-positive since only one sample was analyzed. This warrants further examination.

On the surface, it would appear that pesticides may be introduced into the SR from use in the City of St. Albert. However, extensive sampling in the fall through the City of St. Albert surface water monitoring program has rarely detected pesticides. This may be due to the timing of sampling, since pesticide detections in rivers typically occur in the June-July time period. We recommend that pesticides be measured during June-July upstream and downstream of areas that drain highly populated areas, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. The City of St. Albert Environmental Master Plan aims to improve water quality of the Sturgeon River by working towards reduction targets for pesticides use within City limits. Potential source of pesticides for sampling station M2 (upstream of Lake Isle) are currently unknown. Given that there are no obvious sources at this location, and given that concentrations are higher than what would be considered as background values, we recommend a focused inspection of pesticides upstream of this site. Similarly to metals, the purpose of this sampling should be very specific i.e., to determine the extent and source of the high values to inform corrective actions.

Winter oxygen

Oxygen depletion is a natural phenomenon in Alberta, which can be worsened by human activities, such as nutrient enrichment. The extent of winter oxygen depletion and the susceptibility of the aquatic ecosystem to winterkill will vary depending on a suite of environmental factors. The input and storage of oxygenated water in the waterbody during the winter period is the key factor influencing how much oxygen is present in the system. For example, a site with shallow water depths has low storage capacity for oxygen. Also, a site with high organics and nutrients will have high oxygen demand due to bacterial activity, which consumes oxygen. See **Section 8.3** for a thorough description of factors that affect oxygen in aquatic ecosystems.

The SR has shallow water depths and therefore low storage capacity for oxygen. The high nutrient concentrations in some stretches of the SR cause a high degree of organic production, which in turn causes oxygen consumption by bacteria and then chronically and critically low dissolved oxygen concentrations in many locations during winter. Oxygen in these locations is at a level that is prohibitive and/or lethal to aquatic life during winter, which is why fish kill events occur in the SR. Given that the SR has low flushing potential during late summer and winter, it can be thought of as a naturally sensitive ecosystem that would benefit from any nutrient reduction strategies. Many nutrient strategies options can be considered for the SR, its tributaries, and its lakes. Examples of nutrient reduction strategies include reducing the input of particulate nutrients by restoring riparian areas and improving construction beneficial management practices, limiting cattle access to the river and its tributaries through offsite water monitoring programs, improving the nutrient retention of watersheds through the restoration of wetlands, creating opportunities to allow particulate nutrients to settle out of the water column (e.g., through stormwater management Beneficial Management Practices), and chemical treatment (e.g., lime, alum, or bentonite clay such as Phoslock) of water to remove nutrients from the water column. A nutrient management plan can be used to determine all possible strategies and evaluate feasibilities in terms of effectiveness and cost.

Suspended solids

About half of the suspended solids (as well as the constituents associated with suspended solids) that runoff into the SR are captured and retained by lakes that are part of the SR system, highlighting the importance of the lakes to SR ecosystems in general. Downstream of Big Lake, the concentration of suspended solids in water increases approximately 2-3 times after it passes through the City of St. Albert, indicating that stormwater may be a source of TSS. Surprisingly, tributaries had relatively low amounts of TSS in the spring, except perhaps for Rivière Qui Barre, which may be causing an increase of TSS in the SR. Otherwise, stations upstream of Isle Lake and upstream of Matchayaw Lake also had high TSS concentrations. Further examination of sediment loading in the above locations is recommended since suspended sediment, other than being harmful in itself, also contains high amounts of contaminants such as nutrients and metals. With respect to reducing sediment loading from urban runoff, the City of St. Albert Stormwater Master Plan addresses sediment loading reduction through the retrofit of stormwater outfalls with grit interceptors. In spite of this, suspended solids remain high downstream of St. Albert. Low impact development strategies have proven to be very effective in reducing suspended solids from urban areas in many jurisdictions across North America. For more information regarding Low Impact Development, refer to the Alberta Low Impact Development Partnership.

6. River Morphometry & Aquatic Vegetation

River morphometry and aquatic vegetation provide the physical structure that aquatic fauna depend on for life processes (Barbour et al. 1999). In this section we describe the physical environment and aquatic plant community at each station on the Sturgeon River.

6.1 Methods

6.1.1 Fieldwork

River morphometry and aquatic vegetation surveys were completed from August 29th, 2017 to September 20, 2017. Transects were surveyed by using a rope stretched across the width of the river. The rope contained markings to delineate 1m x 1m quadrats and every quadrat was assessed for plant identification, percent coverage of each plant species, water depth, and dominant and secondary substrate types. A rake was used to collect submerged vegetation not visible at the surface and based on the volume collected an estimation of percent cover was applied. The data collected during the vegetation survey is available in **Appendix G**.

CPPENV staff gathering aquatic vegetation for a vegetation sample.

Determining the width of river and 1 meter transects for each station.

The following parameters were measured during the river morphometry surveys:

- Bankfull width is the horizontal width of the channel from right bank to left bank; the bank ends at the point where over-bank flow begins during a flooding event.
- Wetted width is the horizontal width of the channel containing water at the time of the survey.
- Bankfull wetted depth is a vertical measurement from the surface of the water to the top of the stream bank; it represents the potential wetted depth if the stream channel was filled to its greatest depth.
- Water depth was recorded during the vegetation surveys at each 1mx1m vegetation quadrant; for the purpose of this table, only the maximum depths are represented.

Visual cross sections of station transects were created using MS Excel spreadsheets. The cross sections are designed to represent total percent coverage of the various vegetation types identified in the river and are a true representation of the wetted width and depth.

6.1.2 Data Analysis

River morphometry was analyzed by averaging all 3 transects at each station to summarize the overall physical structures of the entire river reach. Species diversity for aquatic vegetation was calculated by measuring species richness and applying a modified Shannon-Wiener Index. This modified approach to the Shannon-Wiener Index is meant to represent patterns in diversity and abundance. The plant community was analyzed as follows:

- The Shannon-Wiener Index is an equation that shows the community composition and abundance of aquatic species present within a stream reach. The Shannon-Wiener Index is commonly used in ecological studies and is calculated using the following formula:

$$\text{Shannon-Wiener index (H)} = -\sum Pi \log_n Pi$$

Where *Pi* is the proportion of individuals found of species *i.* The estimated proportion of *Pi = ni/N*, where *ni* is the number of individuals in species *i*, and *N* is the total number of individuals in the community. Since by definition the *Pi* will all be between zero and one, the natural log makes all of the terms of the summation negative, which is why the inverse of the sum is used.

The Shannon-Wiener index increases as both the richness and the evenness of the community increase. The Shannon-Wiener index is typically calculated using individual plant species counts; however, this information was not collected during the vegetation survey. Instead the total percent cover was estimated for each individual species within a quadrant. As means of estimating diversity, for the purpose of comparing the stations, total percent coverage was ranked in one of the four classes, as follows:

Total Percent Cover	Cover Class Rank
1-25	1
25-50	2
50-75	3
75-100	4

Species evenness is calculated by dividing the result of the Shannon-Wiener index by the species richness to show the distribution of species abundance. Ultimately, it quantifies how equal the community is numerically (e.g., if there are 40 coontail and 1000 common duckweed plants, then the community is not even). The results will always be between 0 to 1, with 0 signifying no evenness and 1 as complete evenness. Species richness is the number of plant species at each station. Species abundance was calculated by dividing the total sum of all cover class ranks per station by the total sum of all cover class ranks in the Sturgeon River.

6.2 Results

River morphometry was very variable from one sampling station to the next. Stream channel width (bankfull width) was largest at station M9 (106 m) and smallest at station M1 (4.6 m) (**Table 6**). The maximum depth of the river was also quite variable, ranging from 0.8 m at station M6 to 2.2 m at station M10. See **Appendix C** for visual cross-sections of the different stations.

Table 6: River morphometry at Sturgeon River stations. Bankfull width, wetted width, and bankfull wetted depth are averages from all three transects.

Station Name	Bankfull Width (m)	Wetted Width (m)	Max Depth (cm)
M1	4.6	3.8	95
M2	8.7	8	120
M3	14	13	110
M4	9.9	8.3	130
M5	10.5	9.3	110
M6	8.9	7.1	80
M7	14.8	13.5	210
M8	27.3	26.7	160
M9	106	98	130
M10	14.5	13	220
M11	16.9	15.2	140
M12	16.9	14.6	90

Substrates in the SR were predominantly fines with some inclusions of sand at some sites. Similar to results from Golder (2004), sand and gravel appear more dominantly in the middle reaches of the SR (M6-M8) upstream of Big Lake and re-appear again downstream of the City of St. Albert (M10-M12). The substrate in the lowermost reaches of the SR increases dramatically in diversity through the incorporation of gravels, cobbles, and boulders.

Overall, the physical conditions of many of the SR sites are ideal for aquatic vegetation growth due to shallow water depths, slow-moving water, and finer substrate material. Shallow water depths allow for sufficient light penetration, and the finer, nutrient-rich substrate allows roots to take anchorage, thereby supporting plant growth (Lahring 2003). That said, vegetation cover was quite variable from one station to the next, ranging from an average of 2% (station M1) to 30% (M9) of plots covered with aquatic vegetation (**Table 7**). M9 stands out with an over-abundance of aquatic vegetation. In spite of the high density, the plant community diversity at this site is not low (i.e., it is not a monoculture).

The sampling stations with the highest aquatic plant species diversity were M2, M4, M8, and M10 to M12. Plant community diversity is lowest (by far) at M1, likely due to the morphometry of this river segment, which has steep sides and relatively deep water. The aquatic vegetation surveys documented a total of 42 native species, 11 species identified to genus and 23 different families. Dominant species include northern water milfoil (*Myriophyllum exalbescens*), common duckweed (*Lemna minor*), coontail (*Ceratophyllum demersum*), sago pondweed (*Stuckenia pectinata*), vernal water starwort (*Callitriche verna*), reed canary grass (*Phalaris arundinaceae*), ivy-leaved duckweed (*Lemna trisulca*), large-leaved white water crowfoot (*Ranunculus aquatilis*), narrow-leaved bur-reed (*Sparganium angustifolium*), nodding beggartick (*Bidens cernua*), small-leaf pondweed (*Potamongeton pusillus*) and Richardson’s pondweed (*Pontamogeton richardsonii)* (**Table 7**).

Upstream view of station M1. M1 has the narrowest stream channel and the lowest plant species diversity.

Downstream view of station M2, which is the sampling stations with the highest aquatic plant species diversity.

Table 7: Species richness, evenness, abundance, diversity, and top three dominant plant species at each station on the SR. The colour scheme i.e., green-yellow-red is used to indicate highest (green) to lowest (red) plant community diversity.

Station	Species Richness (# of plant species)	Species Evenness (scale of 0 to 1)	Vegetation Cover (%)	Shannon-Wiener Index (plant community diversity)	3 Most Dominant Species
M1	6	0.12	2	**0.71**	Common duckweed, Nodding beggartick, Small-leaf pondweed
M2	16	0.15	4	**2.37**	Vernal water starwort, Large-leaved whitewater crowfoot, Sago pondweed
M3	15	0.12	10	**1.79**	Pondweed spp., Common duckweed, Coontail
M4	16	0.13	7	**2.13**	Reed canary grass, Sago pondweed, Richardson's pondweed
M5	15	0.11	6	**1.66**	Sago pondweed, Coontail, Vernal water starwort
M6	9	0.18	4	**1.62**	Sago pondweed, Northern milfoil, Richardson's pondweed,
M7	10	0.19	4	**1.87**	Northern milfoil, Ivy-leaved duckweed, Common duckweed
M8	21	0.11	14	**2.33**	Northern milfoil, Common duckweed, Coontail
M9	15	0.13	30	**1.90**	Coontail, Sago pondweed, Ivy-leaved duckweed
M10	15	0.15	8	**2.18**	Richardson's pondweed, Ivy-leaved duckweed, Northern milfoil
M11	17	0.14	5	**2.34**	Northern Milfoil, Coontail, Narrow-leaved bur-red
M12	22	0.11	7	**2.31**	Sago pondweed, Northern milfoil, Narrow-leaved bur-reed

6.3 Summary and Discussion: River Morphometry and Aquatic Vegetation

The SR is a productive aquatic ecosystem that has abundant aquatic vegetation at some locations. As described in **Section 4**, M9 stands out with an over-abundance of aquatic vegetation, due to high nutrient concentrations, slow-moving water, and relatively shallow depths. This abundance of aquatic vegetation can make river navigation, general recreation, and fishing challenging at times. In spite of this high density of plants, plant community diversity is not low (it is not a monoculture). Plant community diversity was lowest at M1, likely due to the morphometry of this river segment. Plant community diversity was highest at M2, M4, M8, and M10 to M12. These stations typically have healthier riparian areas (M2, M4, M10-M12; see **Table 2**), or diverse substrate diversity (M8, M10-M12). Other sites (M3, M5-M7, M9) had moderate plant diversity.

Substrates in the SR were predominantly fines, although sand and gravel appear in between Matchayaw Lake and Big Lake (M6-M8) and re-appear again downstream of the City of St. Albert (M10-M12). The substrate near the mouth of the SR becomes very diverse through the incorporation of gravels, cobbles, and boulders.

7. Macroinvertebrates

Macroinvertebrates are important biomonitoring subjects since they reflect the interaction of various factors within their environment including water quality (Clifford 1991). They also represent the middle trophic level, between plants and fish. The main objective of the field collection was to capture and document species' presence and abundance for the purpose of measuring the biological component of the ecosystem (Plafkin et al. 1989).

7.1 Methods

7.1.1 Fieldwork

Macroinvertebrate sampling was completed at all twelve river reaches on the SR from October 16th to 20th, 2017. Sampling protocols followed the United States Environmental Protection Agency (USEPA) protocols for a multi-habitat approach (Barbour et al 1999). The multi-habitat approach was ideal for the SR since every station had a fines-dominated substrate and varied in vegetation cover. The habitat types sampled included snags, vegetated banks, and submerged macrophytes. Macroinvertebrates were collected systematically from all available habitats by jabbing the area with a D-frame dip net. A total of 20 jabs were conducted within each 150 m study reach in proportion to the abundance of habitat type present. For example, if submerged macrophytes comprised 50% of the reach, and snags comprised the other 50%, then 10 jabs would be conducted in each habitat type. Sampling efforts began at the downstream end of the reach and proceeded upstream until all 20 jabs were completed.

After each jab, the samples were transferred from the net into a 500 µm sieve. The sieve was used to rinse the macroinvertebrates of sediments and remove vegetation. The samples were then transferred to labelled jars and preserved using 95% ethanol. Samples were then sent to be identified following CABIN Laboratory Methods: processing, taxonomy, and quality control of benthic macroinvertebrate samples (Environment Canada, 2014). In the laboratory, samples were washed using sieves to remove residual sediment and larger pieces of vegetation or debris. Samples were then randomly subsampled using a Marchant box (Marchant 1989) to a minimum of 300 organisms. Subsamples were then placed in 70% ethanol for preservation and later sorting. An Olympus SZ61 microscope was used for picking, sorting and identification. Family level identifications were made using *Aquatic Invertebrates of Alberta: An Illustrated Guide* (Clifford 1991). Where characteristics necessary for family-level identification were absent, individuals were identified to order.

7.1.2 Data Analysis

Two different biomonitoring techniques were implemented to analyze the results: functional feeding groups and the Family Biotic Index.

7.1.2.1 Functional Feeding Groups

A functional feeding group (FFG) is a classification approach that is based on behavioral mechanisms of food acquisition (Merritt and Cummins 1996). The FFG classification system reveals how the macro-invertebrates are functioning as a community, which also reveals the character of a stream. Individuals are categorized into one of five feeding groups:

- scrapers (grazers): consume algae
- shredders: consume leaf litter or other coarse particulate organic matter (CPOM), including wood
- collectors: gather fine particulate organic matter (FPOM) from the stream bottom
- filterers: gather FPOM from the water column using a variety of filters
- predators: feed on other aquatic invertebrates and in some cases small-bodied fish

It should be noted that many organisms shift from one feeding class to another as they advance through their respective life stages and some may be considered in two or more categories. For the purpose of this study, organisms with multiple feeding groups are represented by their dominant feeding group.

7.1.2.2 Family Biotic Index (FBI)

The Family Biotic Index (FBI) (Hilsenhoff, 1988) is a useful tool for understanding species distribution in relation to organic pollution. The FBI is an equation that estimates the overall tolerance of the invertebrate community, weighed by the relative abundance of each taxonomic group. The first step in calculating the FBI involved assigning tolerance values from 0 (very intolerant) to 10 (highly tolerant) for each family (Mandaville 2002). The FBI was calculated using the following equation:

$$FBI= \sum \frac{(ni)(ai)}{Nt}$$

Where ni is the number of individuals in family i, ai is the pollution tolerance value of family i, and Nt is the total number of individuals in the sample (Hilsenhoff 1988). FBI values quantified the extent of organic pollution, as per **Table 8**.

Table 8: Family Biotic Index (FBI) scores and associated water quality scores (Hilsenhoff 1988).

Biotic Index	Water Quality	Degree of Organic Pollution
0 - 3.75	Excellent	Organic pollution unlikely
3.76 - 4.25	Very Good	Possible slight organic pollution
4.26 - 5.00	Good	Some organic pollution probable
5.01 - 5.75	Fair	Fairly substantial pollution likely
5.76 - 6.50	Fairly Poor	Substantial pollution likely
6.51 - 7.25	Poor	Very substantial pollution likely
7.26 - 10.00	Very Poor	Severe organic pollution likely

7.2 Results

Sampling resulted in 8,624 captures, identified to 13 orders that represent the SR communities (**Figure 14**).

7.2.1 Functional Feeding Groups

7.2.1.1 Collectors

Collectors accounted for the vast majority (84%) of the entire macroinvertebrate capture in the SR and dominated at the majority of stations (**Figures 15-18**). Collectors are usually the most abundant river macro-invertebrate group and primarily feed on fine particles (<1mm diameter) (Wallace and Webster 1996). The group is represented by the Amphipoda (Crustacea) and Diptera (Fly) orders, which have high tolerances to pollution. The Crustacea order is mostly composed of the Hyalellidae and Gammaridae families and the Fly order is represented by the Chironomidae (non-biting midges) family. Both orders are diverse and important food sources for predators such as sticklebacks, waterfowl and beetles (Clifford 1991). Station M3 had the highest percent of collectors, which represented almost the entire (99.5%) population. M11 had the lowest relative proportion of collectors (73%).

Microscopic view of a species in the Amphipoda (crustacean) order, commonly referred to as a scud (CPP ENV 2018).

Microscopic view of a species in the Diptera (Fly) order and Chironomidae family (CPP ENV 2018).

7.2.1.2 Predators

Predators accounted for 7% of the entire SR captures and were present at all stations except M3, which had low diversity in macroinvertebrates. Predators had the highest captures at stations M10 (18%) and M2 (16%). At all other stations, they occupied <15% of species feeding groups. Stations M4, M1, and M6 had predator captures less than 2%. As in other ecosystems, predators in rivers have top-down effects on their prey through direct consumption and reduction of prey populations (Wallace and Webster 1996). The tolerance of predators varies amongst individuals including the Odonata (damselflies), Coleoptera (beetle), Diptera (flies), Hemiptera (true bugs) and Hydrachnidia (water mites) orders. These predators are important members of the aquatic community because in addition to controlling populations, their impacts include nonlethal effects on prey feeding activities, growth rate, fecundity and behavior (Wallace et al. 1996).

Microscopic view of a damselfly (CPP ENV 2018).

Microscopic view of a water-mite (*Hydrachnidia*).

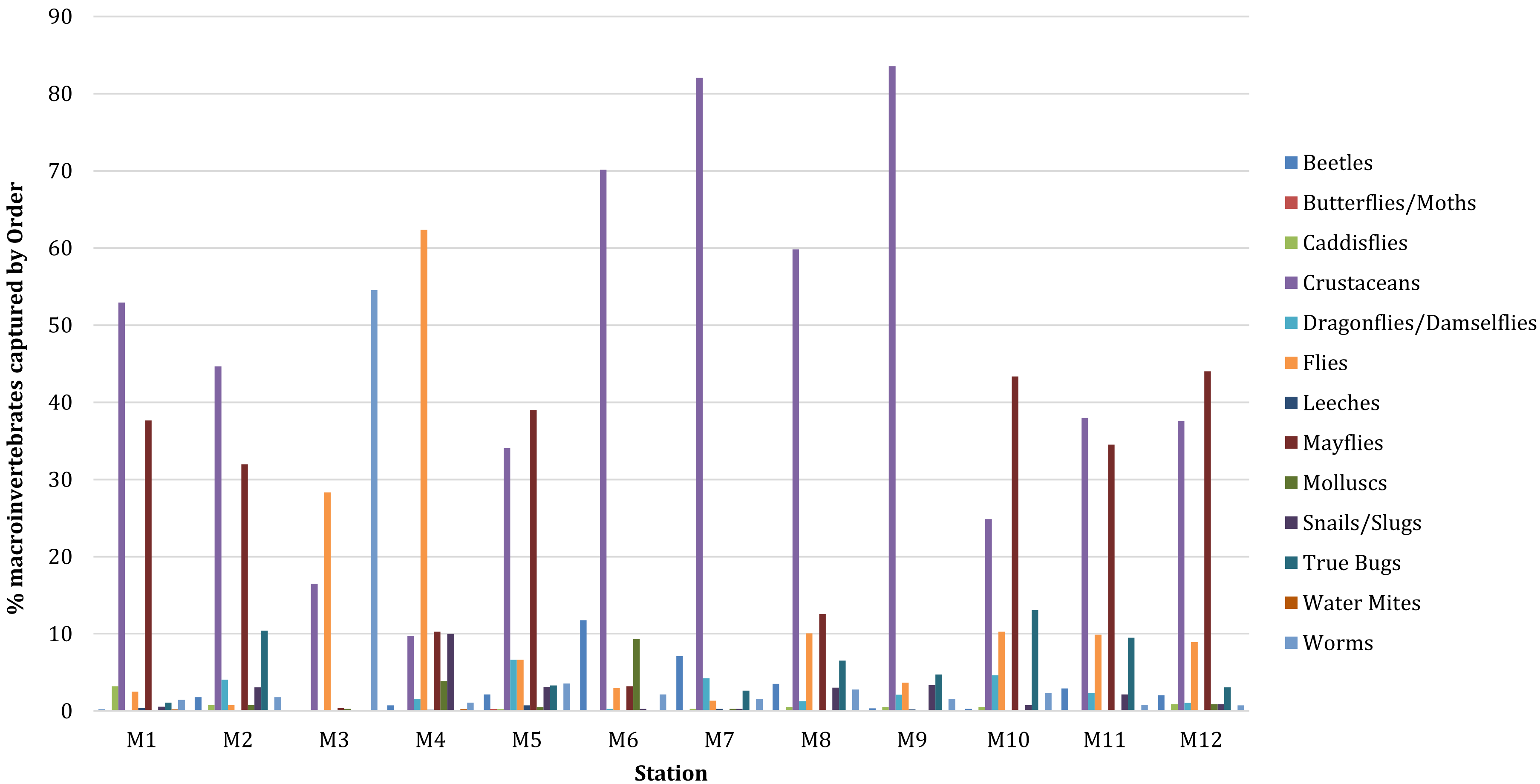


Figure 23: Total percent of macro-invertebrate captured at each station by Order.

7.2.1.3 Scrapers

Scrapers accounted for 6% of the entire SR captures at all stations. At individual stations, scrapers commonly represented <10% of the captures except at stations M4 (10%), M6 (12%), and M11 (13%). The majority of scrapers in the SR are represented by the snail (Basommatophora) order, Ephemeroptera (mayfly) order and some beetle larvae and fly pupae. Scrapers are adapted to graze or scrape materials (periphyton or algae) from mineral and organic substrates. Algal primary production is typically lower when scrapers are present (Webster et al. 1996).

Microscopic view of a snail in the Physidae family.

7.2.1.4 Filterers

Filterers accounted for 2% of the SR invertebrate captures. Filter feeders are specialized for water column feeding and remove particles from suspension. The highest captures rates occurred at M6 (9%) and M4 (4%). All other stations had a total station capture rate of <1% for the filtering feeding guild. The filtering species include the Bivalvia order and all specimens were within the Sphaeriidae family. Filter-feeding invertebrates constitute important pathways for energy flow and are important in the productivity of aquatic environments (Wallace et al. 1996). Due to their sensitivity, filtering invertebrates usually are the first group to decrease when exposed to pollution (high TSS, nutrients and organics) (Plafkin et al. 1989).

Microscopic view of a mollusc (Sphaeriidae) family (CPPENV 2018).

Regular view of a molluscs (Sphaeriidae) family (Google Images 2018).

7.2.1.5 Shredders

Shredders were rarely captured in the SR, accounting for 1% of the entire SR captures at all stations. Shredders fluctuated throughout the stations but had the highest percentage at station M1 (3%). Shredders feed on coarse particulate organic matter (CPOM) from terrestrial vegetation inputs, which they transform into fine particulate organic matter (FPOM) - an important function in the food web of making materials more available for other types of consumers (Wallace and Webster 1996). Shredder species rely on riparian shrubs and trees for terrestrial litter input and therefore are sensitive to riparian disturbance (Plafkin et. al 1989).

Shredders also promote wood decomposition by gouging wood and these activities expose further microbial colonization and decomposition. The shredder orders are Coleoptera (beetles), Diptera (flies) and Trichoptera (caddisflies). Given that riparian areas are generally in a poor state along the SR, it is not surprising that shredders are not present in high numbers.

Microscopic view of a caddisfly larva in the Phryganeidae family (CPPENV 2018).

The Coleoptera order, showing the Haliplidae family in larvae and adults forms (Google Images 2018).

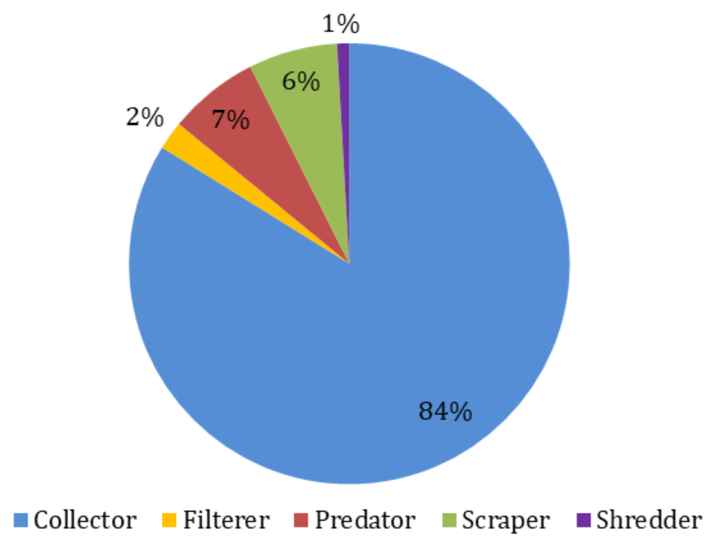


Figure 24: SR Macroinvertebrate captures and the functional feeding group that the captures represent.

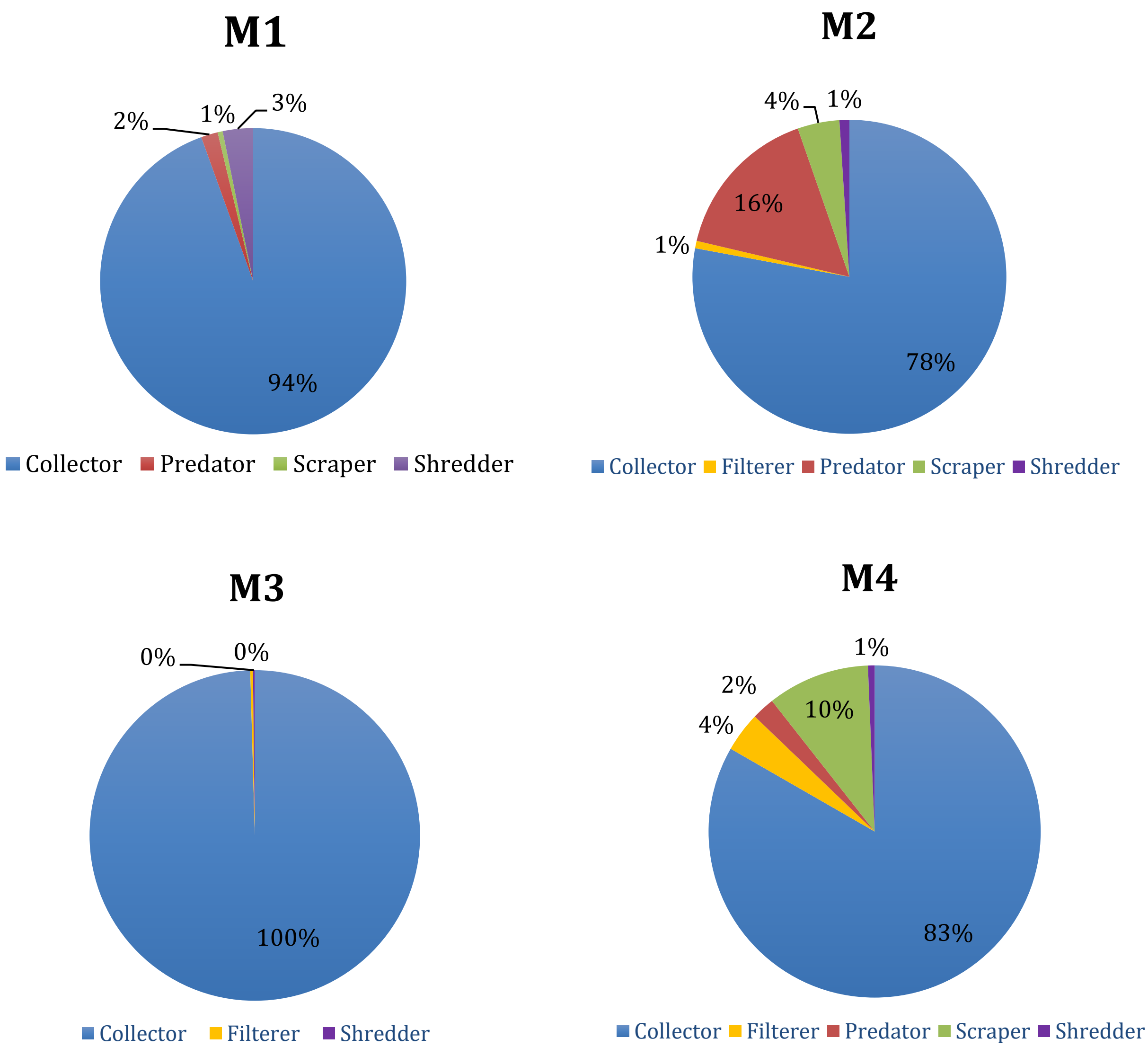


Figure 25: Stations M1 to M4 showing distribution of functional feeding guilds for macro-invertebrates.

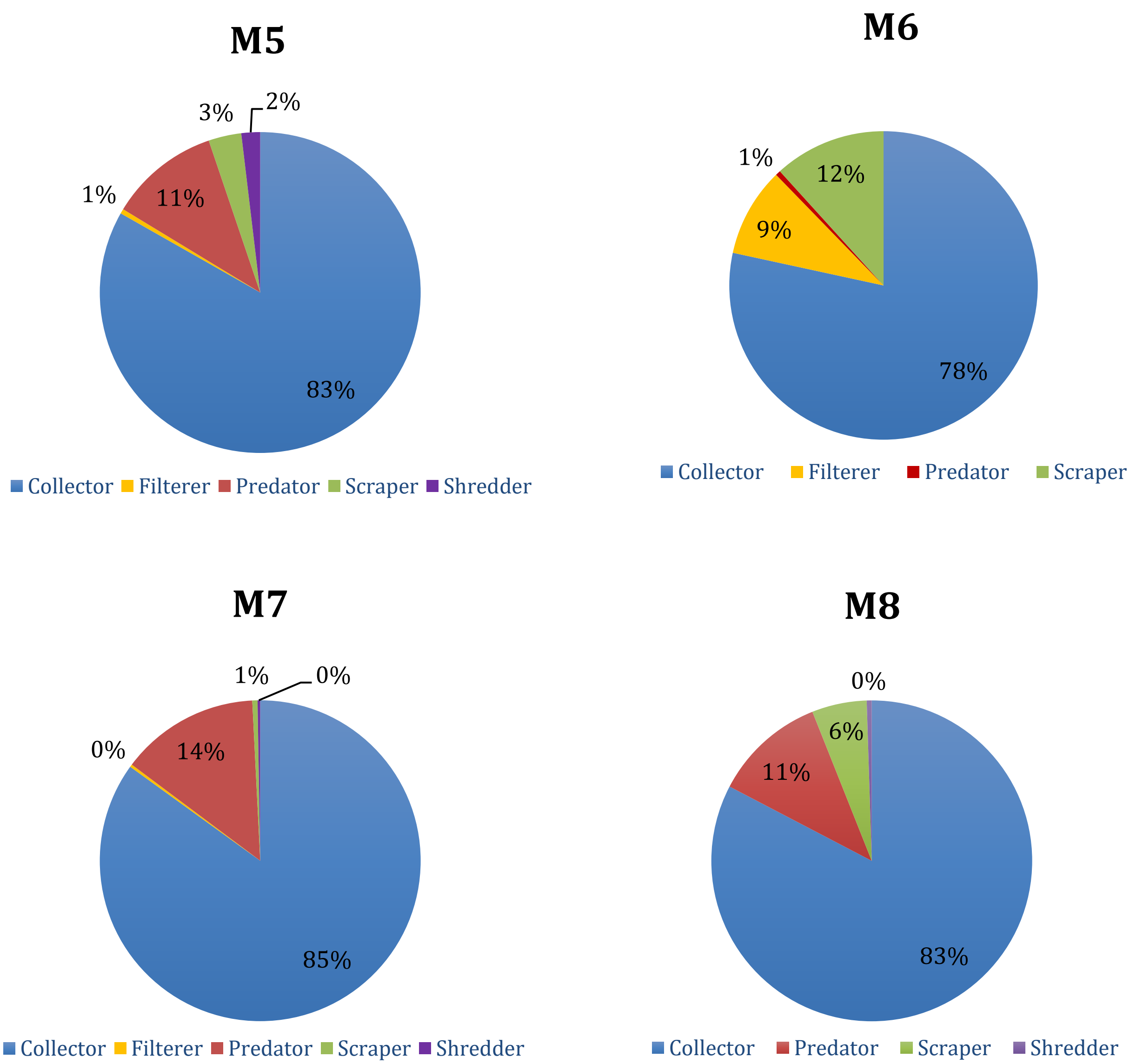


Figure 26: Stations M5 to M8 showing distribution of functional feeding guilds for macro-invertebrates.

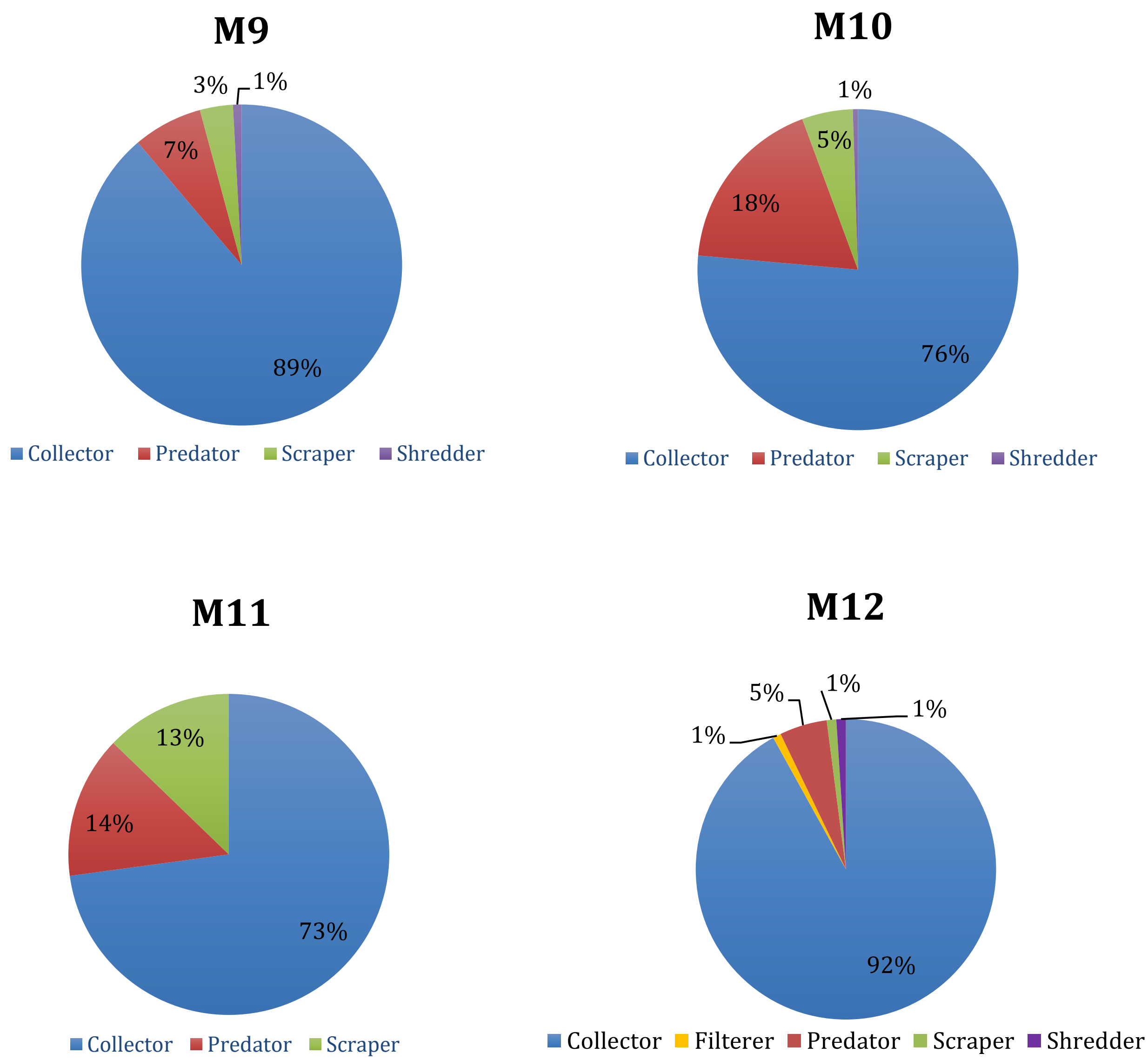


Figure 27: Stations M9 to M12 showing distribution of functional feeding guilds for macro-invertebrates.

6.2.2 Family Biotic Index (FBI)

Based on the Family Biotic Index (FBI), the macroinvertebrate community composition is indicative of variable water quality depending on the location – from good to very poor (**Table 9**). Macroinvertebrate community results are generally consistent with those of water quality (**Figures 19 & 20**). Sampling station M3 (upstream of Lac Ste. Anne), which had the highest FBI score, has a macroinvertebrate community that is representative of severe pollution. This is consistent with very high total phosphorus and ammonia concentrations during the open water period. Station M5 (upstream of Matchayaw Lake) had similar results. Macroinvertebrate data from stations downstream of Matchayaw Lake (M6 and M7) indicated good to fair conditions, which is consistent with the relatively good water quality at these sites. Stations M4 and M5 (downstream of Lac Ste. Anne / upstream of Matchayaw Lake) had an FBI indicative of very substantial pollution. This is somewhat surprising since water quality at these sites were better than at other sites. However, winter oxygen levels were critically low at these sites, which may have limited the macroinvertebrate population. Station M8 (downstream of the confluence with Rivière Qui Barre / upstream of Big Lake) indicated fairly substantial organic pollution. This site is under the direct influence of water from Rivière Qui Barre, which drains a large area of high agricultural intensity and contains some of the highest nutrients and suspended solids measured in the watershed. As presented in **Section 5**, Rivière Qui Barre appears to cause an increase in suspended solids in the SR, which may be impairing the macroinvertebrate community. Immediately downstream of Big Lake, macroinvertebrates at station M9 indicated fair water quality, which is an improvement from the upstream station. The FBI scores worsen at sites downstream of the City of St. Albert (M10 to M12), which reflects higher nutrient and suspended solid levels.

Table 9: FBI results at each station and the associated water quality score (Hilsenhoff 1988).

Station	Biotic Index	Water Quality	Extent of Organic Pollution
M1	5.93	Fairly poor	Substantial pollution likely
M2	7.21	Poor	Very substantial pollution
M3	7.62	Very poor	Severe pollution likely
M4	7.09	Poor	Very substantial pollution
M5	7.23	Poor	Very substantial pollution
M6	5.00	Good	Some pollution probable
M7	5.08	Fair	Fairly substantial pollution likely
M8	7.23	Poor	Very substantial pollution
M9	5.32	Fair	Fairly substantial pollution likely
M10	6.21	Fairly poor	Substantial pollution likely
M11	6.06	Fairly poor	Substantial pollution likely
M12	6.75	Poor	Very substantial pollution

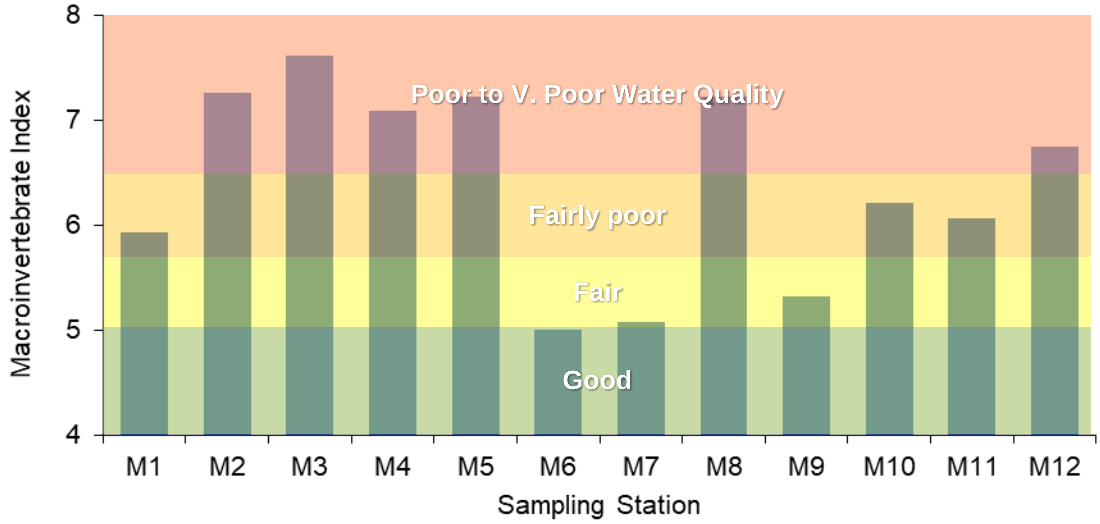


Figure 28: Family Biotic Index (FBI) scores indicating degree of organic pollution at each station. Water quality scores are as per **Table 8**.

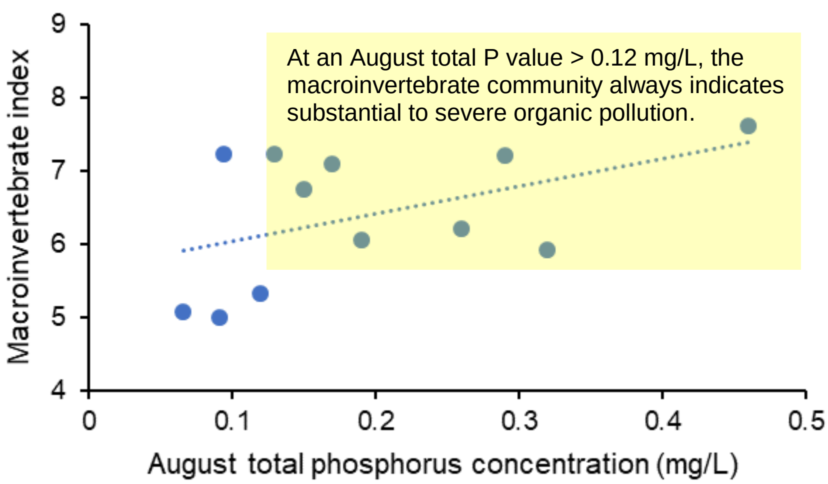


Figure 29: Family Biotic Index (FBI) scores vs August 2017 total phosphorus concentration. This relationship had an R^2 value of 0.27 (on a log-log scale; not shown). The yellow box represents the total phosphorus concentration at which FBI values are always representative of “Substantial” to “Severe” organic pollution.

7.3 Summary and Discussion: Macroinvertebrates

The macroinvertebrate community in the SR was highly dominated by collectors, which are highly tolerant of poor conditions. Site M3 stands out in that the macroinvertebrate community is dominated (99%) by individuals from the collector group, indicating substantial pollution at this site. The macroinvertebrate community indicates other (albeit less) poor sites from M2 (upstream of Isle Lake), all the way to M5 (upstream of Matchayaw Lake).

The macroinvertebrate community in the middle to lower reaches of the SR (M6, M7, and M9) indicate good to fair water quality. From a macroinvertebrate perspective, sites M6 and M7 could perhaps be used as a baseline (best possible current condition for the SR). These sites also had relatively good water quality (see **Section 5**). In August, when the total phosphorus value exceeded 0.12 mg/L, the macroinvertebrate community always indicated substantial to severe organic pollution, suggesting that an overall total phosphorus water quality target of 0.12 or less would be representative of good to fair water quality consistent with Alberta streams with low agricultural intensity (see **Section 5.2.2**).

As observed in **Section 5 – Water Quality**, water quality generally worsens at M10, which is also reflected in the macroinvertebrate community. A bit of an anomaly is M8, where the macroinvertebrate index goes from Fair (M7) to Very Poor (M8). Rivière Qui Barre flows into the SR in between these two stations. This tributary is one of the largest tributaries in the watershed where very poor water quality conditions have been documented (see **Section 5**). As per recommendations in **Section 5**, the relative contribution of pollutants from this river should be examined further. Given that the macroinvertebrate community responds to water quality, all of the recommendations from **Section 5** apply.

8. Fish Assessment

Fish are good indicators of ecological status since they occupy a range of ecological niches (Karr and Chu 1999). The main objectives of the fish survey were to document current and historical species presence and abundance throughout the SR watershed, and use ecological metrics derived from the species data to describe the biological condition of the SR.

8.1 Methods

8.1.1 Field Assessment

Historical data on fish species presence in the SR watershed were documented prior to the field assessment to understand current conditions and implement appropriate fish capture methods (Fish and Wildlife Internet Mapping System (FWMIS), accessed on July 19th, 2017). All sampling stations, except M9 (upstream of St. Albert) were assessed during August and September of 2017 to determine fish species, health and fork length (cm). Station M9 was not sampled due to the popularity of the area for public recreation, such as dog walking, canoeing, fishing, etc., which created potentially unsafe conditions.

Stations were surveyed using electroshocking methods for a minimum total shocking time of at least 2000 seconds, which was equal to a river reach with a distance of approximately 400 to 600 m. Due to limited access for the electrofishing boat and trailer, sites were selected in the field based on access but were within close proximity to desktop-determined locations. All stations were sampled with the boat, except for stations M2 and M12, which were sampled with a Halltech HT-2000 Backpack electro-fisher. Both methods of electrofishing occurred in all habitat types and involved single sweep passes moving upstream in a zig zag pattern. These capture methods selectively favour the sampling of late juvenile to adult life stages of large-bodied species. Minnow traps were deployed to capture smaller fish but unfortunately this was unsuccessful since the traps were filled with northern crayfish. Historical fish capture data from FWMIS was used to supplement our data to represent a more complete depiction of the species that occupy the SR.

Fish surveys were conducted under a valid Fish Research License (FRL # 15-6034) and operations followed best management practices for sampling small bodied fish in streams in Alberta (Alberta Fisheries Management Branch 2013). All captured fish, were identified to species, recorded fork length and examined for DELTS: deformity, disease eroded fins, lesions and tumours.

Smith-Root GPP Model 5.0 Portable Electrofisher

Haltech-2000 backpack electrofisher.

8.1.1 Data Analysis

Metrics for determining the ecological state of rivers was first proposed by Karr (1981) in the *Assessment of Biotic Integrity Using Fish Communities*. Since then, multiple studies have implemented multi-metric variables for assessing the health of aquatic ecosystems (Stevens and Council 2008). Fish counts have been summarized into the following metrics to reflect the aquatic ecosystem:

- Trophic guilds:
  - Omnivores – consumer of both aquatic plants and other animals. Percent of omnivores are expected to increase as river quality declines.

  - Carnivores – consumer of meats (fish, insects, macro-invertebrates). Percent of carnivores are expected to be present in balanced, trophically diverse ecosystems.
  - Invertivores – consumer of invertivores (macroinvertebrates and zooplankton). Percent of invertivores are expected to decline with increase in human influence
- Individual tolerance to environmental conditions (habitat requirements, water quality):
  - Intolerant – requires specific habitat characteristics such as specific water quality parameters or particular habitat types such as riffles. Percent of intolerant individuals are expected to be the first species to decline with increasing anthropogenic influence.
  - Tolerant – doesn't require specific habitat characteristics and is considered a generalist that can tolerant wide ranges of water quality and habitat types
  - Large-bodied fish – Large-bodied fish are at the top of the food chain, thus ecosystems with large-bodied fish indicate good energy transfer up the food chain.
- Health indicators
  - DELTS – fish with observed deformities, erosion, lesions or tumours indicating environmental stressors. Percent of individuals with DELTS can reflect stress.

Tolerance designations are a part and result of Index of Biotic Integrity (IBI) aggregation of biological parameters that are based on a fish species tolerance to an array of stressors and trophic composition (Barbour et al. 1999, Plafkin et al. 1989). Using the biologist's best professional judgement (BPJ) from various related articles, we have utilized tolerance classifications: tolerant, moderate/intermediate and intolerant, of relevant fish species for this report (Barbour et al 1999, Cantin & Johns 2012, and Grabarkiewicz & Davis 2008). When it comes to a tolerance characteristic system, it is important to modify or substitute in regional information to determine an appropriate regional tolerance characterization system (Plafkin et al 1989).

Historical (2001 to 2015) fish captures from FWMIS were summarized into the following categories to represent fish species distribution throughout the Sturgeon River:

- Distribution and abundance of tolerant minnow species: brook stickleback, lake chub, and fathead minnow
- Distribution and abundance of intolerant minnow species: spottail shiner, and longnose dace

8.2 Results

8.2.1 Historical Fish Data

Provincial government database records (FWMIS) include fish data from October 17, 2001 to August 18, 2015. The sampling events from FWMIS were largely completed by environmental consultants on stormwater outfall and road crossing replacement projects and by NAIT or the Royal Alberta Museum for research purposes.

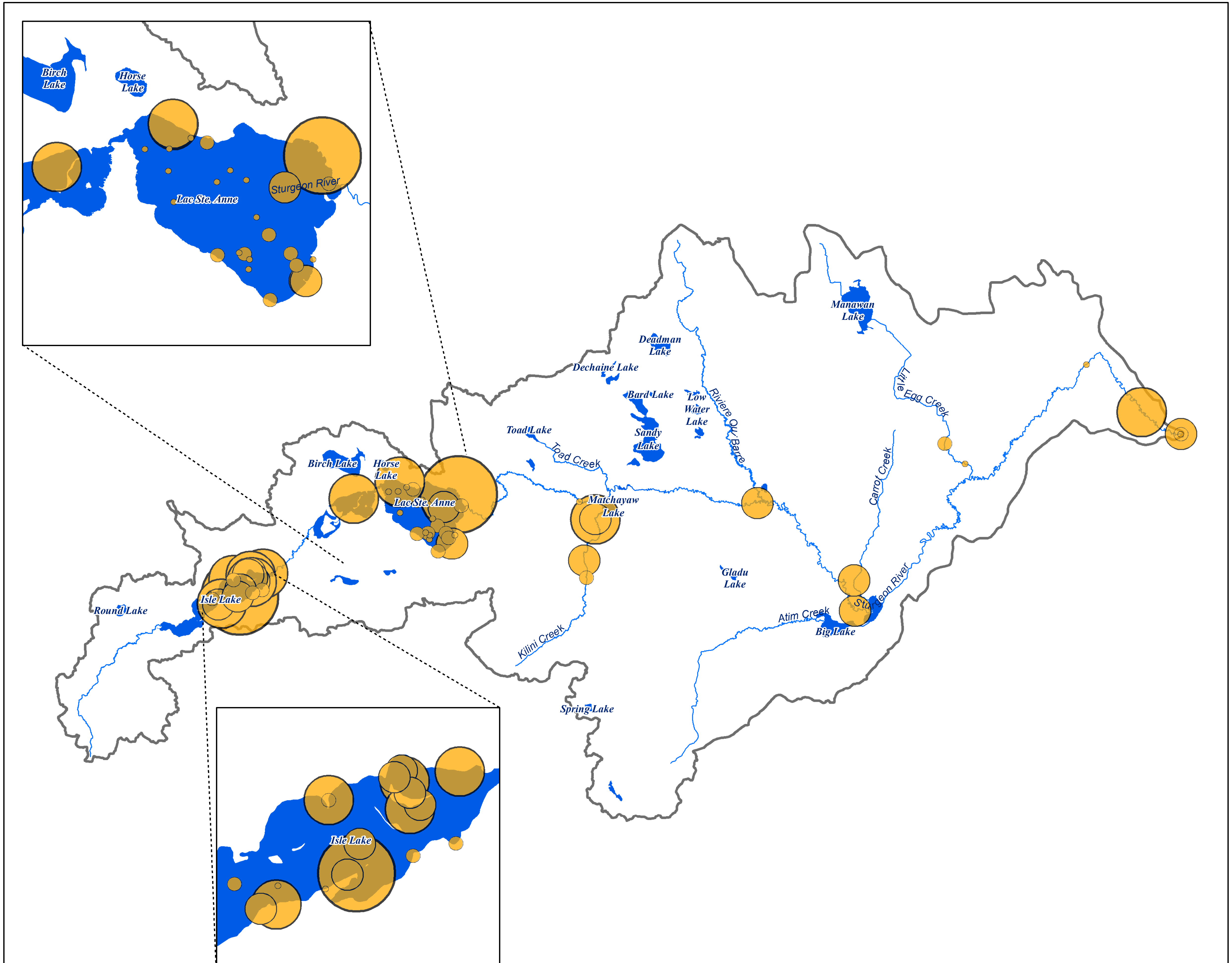
In total, 14 species of fish have been documented in the SR, its lakes, and tributaries in FWMIS between 2001 and 2015 (**Table 10**). These species are listed as secure under the Species at Risk Act (SARA) and the Alberta *Wildlife Act* and none are considered a Species of Management Concern. About half of the 3549 fish caught up to 2015 were brook stickleback. About a quarter (22.1%) of the historical fish catch was white sucker, and fifteen percent was northern pike. These three fish species are tolerant to highly tolerant of poor water quality and habitat types. The rest of the species caught in the SR accounted for less than 5% of the total catch. Goldeye, Mooneye, Lake sturgeon, Sauger, Silver redhorse have also been documented as rarely found in the SR mainstem previously (Golder 2004).

Table 10: Historical fish captures in the SR, its lakes, and tributaries (FWMIS; 2001 to 2015).

Common Name	Scientific Name	Trophic Guild	Tolerance to poor environmental conditions	% total individuals caught in the SR from 2001 to 2015*
Brook stickleback	*Culaea inconstans*	Omnivore	Tolerant	49.4
White sucker	*Catostomus commersoni*	Omnivore	Tolerant	22.1
Northern pike	*Esox lucius*	Carnivore	Mod/Int Tolerant	15.8
Lake chub	*Couesius plumbeus*	Omnivore	Tolerant	5.0
Fathead minnow	*Pimephales promelas*	Omnivore	Tolerant	2.6
Longnose dace	*Rhinichthys cataractae*	Invertivore	Intolerant	2.5
Longnose sucker	*Catostomus catostomus*	Invertivore	Mod/Int Tolerant	0.9
Spottail shiner	*Notropis hudsonius*	Invertivore	Mod/Int Tolerant	0.4
Burbot	*Lota lota*	Carnivore	Mod/Int Tolerant	0.3
Shorthead redhorse	*Moxostoma macrolepidotum*	Invertivore	Mod/Int Tolerant	0.3
Walleye	*Sander vitreus*	Carnivore	Mod/Int Tolerant	0.2
Yellow perch	*Perca flavescens*	Carnivore	Mod/Int Tolerant	0.2
Trout-perch	*Percopsis omiscomaycus*	Invertivore	Mod/Int Tolerant	0.1
Iowa darter	*Etheostoma exile*	Invertivore	Intolerant	0.03

** % of grand total represents historical capture results from all previous sampling (295 sampling events for a total of 3539 individuals).*

Other than in the lakes, few sensitive minnows that are intolerant of poor habitat conditions were found in the SR, which is consistent with results from the macroinvertebrate survey where the majority of macroinvertebrates that were caught were indicative of poor conditions. In the SR mainstem, the majority of the sensitive individuals were captured near the mouth and in Kilini Creek (**Figure 21**), which are sites that have relatively good water quality (see **Section 5**). Some of these individuals were also captured in the lower reaches of Little Egg Creek and Carrot Creek, although the majority of fish caught in these tributaries were species tolerant of poor environmental conditions (**Figure 22**). No sensitive fish were caught upstream of Isle Lake (corresponds to stations M1 and M2), in between Isle Lake and Lac Ste Anne, in between Big Lake and Gibbons (corresponds to stations M9 to M11), and in between Lac Ste Anne and Matchayaw Lake (with one exception). These results are also consistent with those of the macroinvertebrate survey, which generally indicated poor conditions at these sites. No sensitive fish were also caught in Atim Creek and Rivière Qui Barre, which have highly developed watersheds.



NSWA
Sturgeon River Study

Figure 21: Distribution and Abundance of Minnows Intolerant of Poor Habitat Conditions (2001-2017)

Number of Fish Captured

- 1
- 2
- 3 - 13
- 14 - 200
- 201 - 1056

Source: AEP Fish and Wildlife Internet Mapping Tool
Coordinates system: NAD 1983 10TM AEP Forest

N E S W

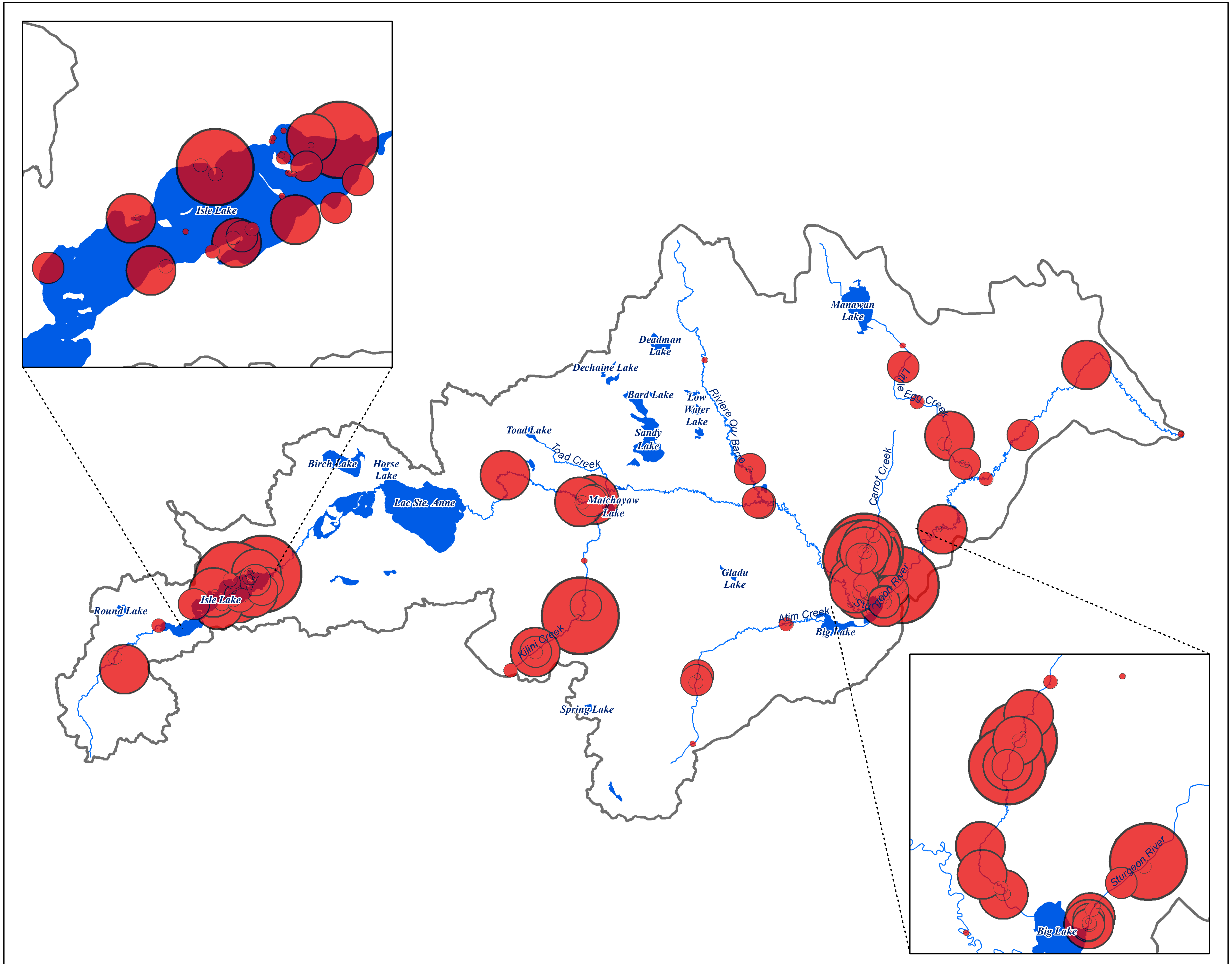
1:400,000

0 5 10 15 20 km

Date: July 18, 2018

Prepared by: R. Ok

CPP ENVIRONMENTAL



NSWA
Sturgeon River Study

Figure 22: Distribution and Abundance of Minnows Tolerant of Poor Habitat Conditions (2001-2017)

Number of Fish Captured

1 - 3
4 - 11
12 - 37
38 - 285
286 - 565

Source: AEP Fish and Wildlife Internet Mapping Tool
Coordinates system: NAD 1983 10TM AEP Forest

N W E S

1:400,000

0 5 10 15 20 km

Date: July 18, 2018

Prepared by: R. Ok

CPP ENVIRONMENTAL

8.2.2 Fish Captured in 2017

The 2017 Sturgeon River fish assessment was successful in capturing and documenting the various species occupying the river and the habitat characteristics shaping the aquatic ecosystem. The total catch per unit of effort appears to be lower than that provided in historical records. However, similar species to previous records. In total, 457 minutes of electrofishing at all 11 stations resulted in the capture of 122 fish (refer to **Appendix H**). Fish captures included a total of 5 families and 8 species (**Table 11, Figure 23**) and all captured fish have been historically documented in the SR. Northern Crayfish (*Orconectes virilis)* was a by-catch at stations M2, M7, M8, M11 and M12. Few fish were caught in the SR mainstem upstream of Lac Ste Anne (no fish at station M1 and 1 fish at M2 and M3), which is consistent with a lack of large-bodied fish caught historically at these locations.

Overall, recent captures are similar to historical documentation with northern pike and white sucker yielding the highest capture rates. Historically, minnow captures were statistically higher, which is most likely due to fishing methods. Beach seining and other forms of netting and trapping were common in historical surveying events, which created higher capture rates of minnow species. CPPENV fishing methods did not include seine netting but did involve boat electrofishing, which targets larger fish in deeper areas. Hence, yellow perch and walleye capture rates were higher due to the electro-fishing methods.

Table 11: Fish species caught in 2017 in the Sturgeon River.

Family	Common Name	Scientific Name	Abbreviation	Percent of Total Individuals Caught
Gasterosteidae	Brook Stickleback	*Culaea inconstans*	BRST	2.5
Esocidae	Northern Pike	*Esox lucius*	NRPK	22
Cyprinidae	Longnose Dace	*Rhinichthys cataractae*	LNDC	1.6
	Spottail Shiner	*Notropis hudonius*	SPSH	2.5
Percidae	Walleye	*Sander vitreus*	WALL	1.6
	Yellow Perch	*Perca flavescens*	YLPR	8.2
Catostomidae	White Sucker	*Catostomus commersoni*	WHSC	61
	Shorthead Redhorse	*Moxostoma macrolepidotum*	SHRH	0.8

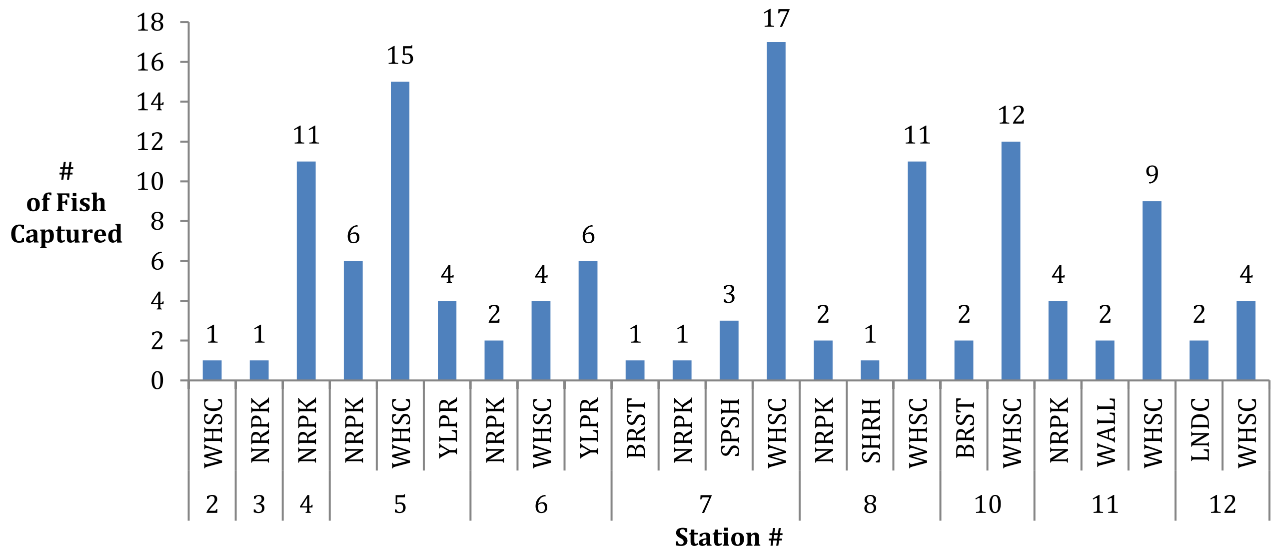


Figure 32: Number of fishes captured by species at each station. Refer to **Table 11** for species code names.

8.2.2.1 Functional Feeding Groups

Trophic Feeding Guilds

All fish captured in the Sturgeon River have been assigned a trophic guild to represent feeding preferences of each fish species (**Table 10**). Feeding preferences and specific aquatic habitat requirements for individual fish species are detailed in **Appendix H**.

Omnivores

Omnivores represent fish species that will eat plant material, insect larvae, zooplankton and invertebrates (Stevens & Council 2008, RAM 2015). The percentage of omnivores can be expected to increase as habitat, water quality and watershed conditions degrade (Stevens & Council 2008). They were the most abundant feeding group found at all stations, accounting for 63% of the total SR catch, represented by Brook stickleback and White sucker. White suckers were captured at most stations and were the most abundant species of omnivore, representing 96% of the omnivore catch. Brook stickleback were less common in the 2017 survey (4% of the omnivore catch), but historical documentation shows they are the most abundant fish in the SR. The high relative proportion of omnivores in the SR indicate generally poor habitat conditions.

White sucker (*Catostomus commersoni*) at M5

Brook stickleback (*Culaea inconstans*) at M7

Carnivores

Carnivores accounted for 26% of the SR catch in 2017. They represent fish species that prey on other fish, insects, animals and birds. Northern pike represented 69% of the carnivorous catch and was documented at the majority of stations. Northern pike have been documented to feed on birds, yellow perch and smaller fishes, rodents, and amphibians (Joynt & Sullivan 2003). Yellow perch were found at sites M5 and M6 and consisted of 26% of all carnivores caught in the SR. Walleye was only caught as site M11 and represented 5% of all carnivores caught in the SR. Yellow perch and walleye will also feed on invertebrates and the trophic guild may also be classified as carnivore-invertivore.

Northern pike (*Esox Lucius*) found at M6

Yellow perch (*Perca flavescens*) found at M5

Walleye (*Sander vitreus*) found at M11

Invertivores

Invertivores accounted for 5% of the entire SR catch and represent fish that feed strictly on invertebrates (Simon 1999). Invertivores included the Spottail shiner, Longnose dace and Shorthead redhorse (Stevens and Council 2008, RAM 2006, and Bramblett et al 2005). Spottail shiner was only recorded at site M7. It accounted for 50% of the invertivores caught in the SR. Longnose dace was only recorded at site M12 and it represented 33% of the invertivores caught in the SR. Shorthead Redhorse was only recorded at site M8 where it represented 17% of the invertivore catch. Invertivores can be a used in aquatic ecosystem health assessments since there can be a shift from the presence of invertivores species to omnivorous species as invertebrate food decreases in abundance.

Spottail shiner (*Notropis hudonis*) at M7

Longnose dace (*Rhinichthys cataractae*) at M12

Shorthead redhorse (*Moxostoma macrolepidotum*) at M8

8.2.2.2 Fish Species Tolerance

Tolerant Species

Tolerant species are defined by their ability to withstand low oxygen levels, high pH values, and low flows (Nelson & Paetz 1992; RAM 2006; Stewart et al. 2007; Stevens & Council 2008). Thus, the relative number of tolerant individuals is expected to increase as habitat and water quality degrade (Stevens & Council 2008). Of total fish captured, most (63%) were tolerant species, which included White sucker and Brook stickleback. White suckers were relatively abundant at all stations on the SR downstream of Lac Ste Anne in 2017, whereas Brook stickleback were only found at M7 and M10. However, based on the historical documentation, it is reasonable to assume that Brook stickleback are common throughout the SR system.

Tolerant species were the only type of fish caught upstream of Isle Lake and in between Big Lake and the Town of Gibbons, which is consistent with historical results (see **Section 8.2.1**). Overall, tolerant species dominated the SR.

Intolerant Species

Intolerant species accounted for 1.6% of Sturgeon River captures and represented fish that prefer specific habitat features and are negatively affected by pollution (Nelson & Paetz 1992; Stevens and Council 2008; Spafford 1999; Bramlett et al. 2005; Jeffries et al. 2008). Longnose dace is the only intolerant species observed and it was documented at site M12 exclusively. Longnose dace can tolerate abrupt environmental changes for short periods of time but are sensitive to excessive silt, low dissolved oxygen, and disturbances that results in reduction of available gravel habitat for spawning (Becker 1983, Stevens & Council 2008). The habitat type preference of Longnose dace is riffles in higher velocity waters, which are present at M12 near the confluence of the North Saskatchewan River (Edwards 1983). This habitat type was not observed anywhere else.

Moderate/Intermediate Tolerant Species

Mod/int tolerant species can be sensitive to non-specific stressors (anthropogenic effects) that vary from species to species. For example, a fish species “A” might be tolerant to pollution and disruptions but sensitive to specific habitat degradation for spawning purposes, however fish species “B” species might be tolerant to habitat changes but sensitive to pollution, resulting in species “A and B” both being classified as moderate/intermediate tolerance. Northern pike are susceptible to channel and backwater modification (Grabarkiewicz & Davis 2008). Walleye populations are sensitive to damming of rivers, excessive siltation, and turbidity due to the species being highly migratory (Grabarkiewicz & Davis 2008). Shorthead redhorse is very sensitive to siltation and sedimentation; however, it can endure warmer waters than most fish (Joynt & Sullivan 2003). Spottail shiner are highly sensitive to sedimentation/turbidity (Kilgour & Associates LTD 2010). Yellow perch are adapted to a wide range of habitat types, however are susceptible to over-fishing and habitat degradation that results in aquatic vegetation loss which is used for protection (Grabarkiewicz & Davis 2008 and Joynt & Sullivan 2003).

Moderate/intermediate tolerance individuals accounted for 35% of the Sturgeon River catch and represented a relatively diverse population of 5 different species: Northern pike (62.7% of mod/int tolerant group), Yellow perch (23.3%), Spottail shiner (7%), Walleye (4.7%), and Shorthead redhorse (2.3%). Moderate/intermediate tolerance fish species were caught at most sites, except upstream of Isle Lake (M1 and 2) and from downstream of Big Lake to the Town of Gibbons (M10).

8.2.2.3 Health Indicators

DELTS (deformities, erosion, lesions or tumous)

Blackspot parasite (*Neascus spp.)* was the only DELT observed and they were visible on 27% of the total fish catch. According to Alberta Fish and Wildlife (2014), blackspot disease is relatively common and a natural condition in many Alberta fishes. It mostly affects Spottail shiners, Northern pike, minnows and dace. 12% of the northern pike and 83% of the white suckers caught had blackspot parasite.

8.3 Summary and Discussion: Fish Community

Overall, species tolerant of poor habitat conditions (White sucker and Brook stickleback) dominate the SR system. Northern pike are generally present and are the most widely distributed sportfish species in the SR system, which is supported by a strong prey (minnow) population. Based on conversations with landowners (in particular those living in the City of St. Albert), the Northern pike population is actively sought after for sport, which greatly adds to the recreational value of the SR. Walleye, which are also a very popular sport fish, are not widespread in the river as they were only present downstream of the Town of Gibbons (M11 and M12) in 2017 and historically (2001 to 2017). Walleye were present in three of the onstream lakes (Isle Lake, Lac Ste Anne, Matchayaw Lake), but they apparently do not disperse from the lakes into the mainstem river. Since this species can travel great distances, we suspect that the lower reach of the SR provides suitable habitat for walleye at least during summer. The higher gradient of the river in this segment of the river (Golder 2004) likely limits beaver dam development, allowing walleye to migrate into this segment of the SR from the North Saskatchewan River. Yellow perch, also a valued sportfish species, is not widely distributed in the SR mainstem, but may be locally abundant in the vicinity of Matchayaw Lake and Isle Lake (Golder 2004).

As described above, the SR and the lakes that are part of the river ecosystem are capable of supporting an abundant and diverse fish community. However, poor water quality, poor physical habitat quality (in some areas) and, in particular, low dissolved oxygen concentrations are all contributing in a concerted way to creating stressful conditions for the fish population. In Alberta, winter oxygen depletion is a key factor that can affect fish assemblage composition. Indeed, low winter oxygen has been attributed to large fish kills in the SR system every 2 to 3 years.

Winterkill is a natural phenomenon in Alberta, which can be worsened by human activities. **Figure 24** conceptually describes the susceptibility of a natural aquatic ecosystem to winterkill. The extent of winter oxygen depletion and the susceptibility of the aquatic ecosystem to winterkill will vary depending on a suite of environmental factors that can be arranged hierarchically from regional to local scales, as follows:

- At the regional level, the input and storage of oxygenated water for the winter period will influence the probability of winterkill. Below average precipitation can affect the survival of fish by eliminating a supply of relatively oxygen-rich water from streamflow during winter. Also, an extended duration of ice cover reduces the atmospheric supply of oxygen. Thus, if the ice-covered period is 2 weeks to 1 month longer than normal, fish population declines in the following year or two can occur. However, even if the ice-covered period is short, a heavy accumulation of snow can limit under-ice photosynthesis and its contribution of oxygen to the water column and thus cause winterkill conditions.

- At the sub-regional (landscape) scale, a site that is low in the landscape receives a relatively greater amount of water from stream and groundwater sources, meaning that it is less susceptible to climate-related fluctuations in water level and water residency time (i.e., the amount of time that it takes to replace the volume of water in a basin). Also, a site that is lower in the landscape tends to be better connected to streams and lakes, which assists in recolonization following local fish kill events. Thus, these sites that are lower in the landscape have greater potential to support multiple fish species. The lakes and lower reaches that are part of the SR are good examples of sites that are lower in the landscape.
- Locally, a site with shallow water depths reduces the storage capacity of oxygen, thus an event such as a drop in water levels due to the collapse of a beaver dam may lead to a winterkill event. Finally, nutrient-rich systems with high production of organic matter have relatively higher oxygen demand due to bacterial decomposition of readily available carbon, which is a process that consumes oxygen. This consumption reduces the amount of oxygen stored under ice.

There is a general absence of winter fish data, thus direct information on overwintering use of the mainstem is not available. However, a healthy fish population in the SR system will depend on strategies to reduce the potential for fish winterkill, which centers on improving the input and/or storage of oxygen during winter. The creation and maintenance of open-water areas can create winter refugia for fish. Improving the connectivity of the river by reducing barriers would also improve the supply and storage of oxygen during winter, although beaver dams provide some ecological value. Finally, reducing the nutrient input and content of the water and sediments in the SR system would reduce the consumption of oxygen through bacterial and chemical processes. This would not only improve water quality and aquatic habitat, but it would also reduce the negative effects associated with nutrient enrichment from a recreational and aesthetic perspective. Otherwise, many fisheries management options are possible, but these will need to be weighed against the long-term costs and benefits of their implementation. The presence and health of large-bodied fish will also depend on quality physical habitat. As described above, in the SR large-bodied fish were not present where habitat was poor. Strategies to improve aquatic habitat are listed in **Section 4.3**. Strategies to reduce nutrient concentrations are listed in **Section 5.3**.

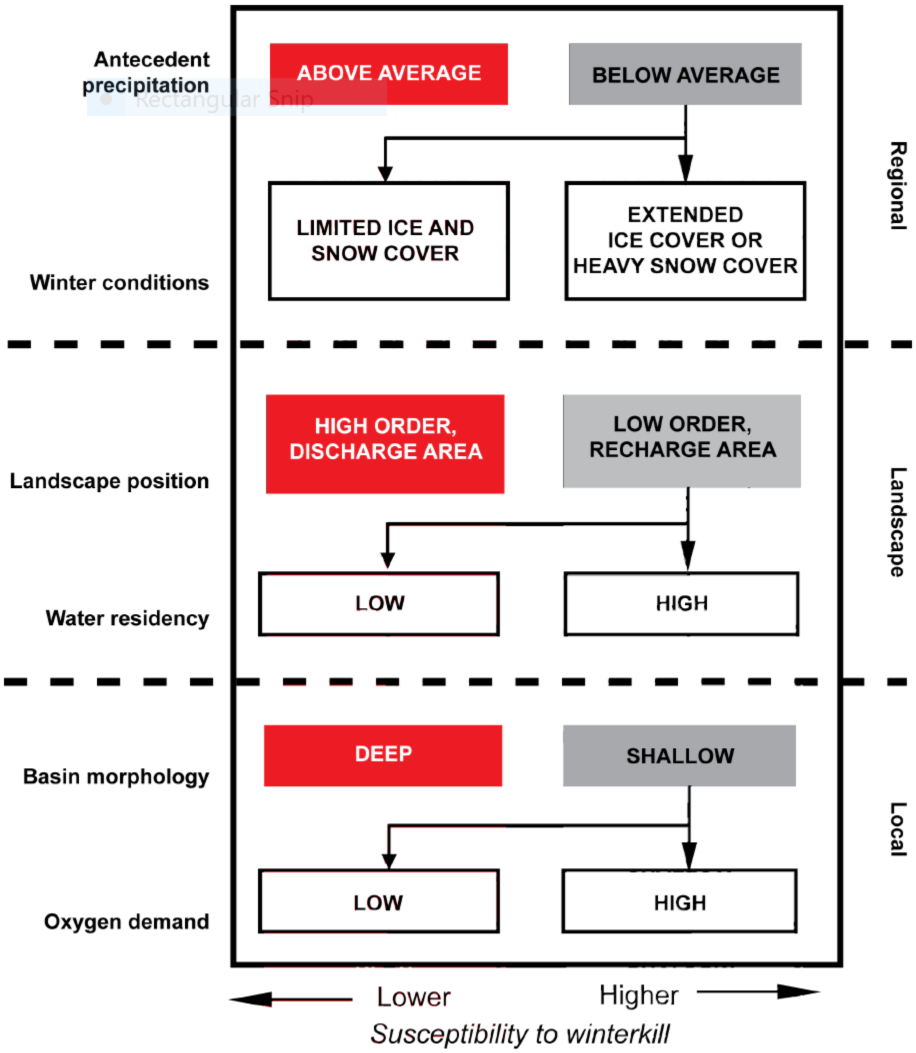


Figure 33: Conceptual model for the relative influence of local, landscape, and regional factors on the susceptibility to experience winterkill of fish (modified from Danylchuk and Tonn 2003).

9. Summary and Discussion

The SR is a small, slow-moving, mud-bottomed prairie river. Depending on the site, the SR has low to average habitat quality, with many physical habitat metrics (shade, bank undercutting, and habitat diversity) having low scores, which is consistent with poor riparian health at some sites. Important sinks for nutrients and suspended solids include the lakes that function in the same way as settling ponds, and are integral components of the SR system. Most of the sites that were surveyed had a macroinvertebrate community reflective of a system that is polluted with nutrients and organics and low in winter dissolved oxygen. When summer total phosphorus concentrations are above 0.12 mg/L, which occurs at most sites, the macroinvertebrate community reflects poor conditions. The SR and the lakes that are part of the river ecosystem are capable of supporting an abundant and diverse fish community. However, poor water quality, poor physical habitat quality and, in particular, low dissolved oxygen concentrations are all contributing in a concerted way to creating stressful conditions for the fish population. Fish species that indicate poor habitat conditions (White sucker and Brook stickleback) dominate the SR system.

Based on ecological and geographical information (i.e., ecoregions), hydrological information (i.e., flow and location of basins such as lakes), and results from our study regarding the quality of aquatic habitat, we have divided the SR watershed into reaches as follows for ease of discussion:

- Upper Reach: Headwaters to upstream of Lac Ste Anne, represented by stations M1 to M3. Includes stations higher in landscape position located in Boreal Central Mixedwood and Dry Mixedwood Natural Subregions with very low flow.
- Middle Reach: Lac Ste Anne to upstream of Big Lake, represented by stations M4 to M8. Includes stations primarily in Boreal Dry Mixedwood Natural Subregion, with some Central Parkland Natural Subregion. Flows in this reach increase substantially (about 10 times higher than in the Upper Reach). Sand and gravel also appear in the substrate.
- Lower Reach: Big Lake to the confluence with the North Saskatchewan River, represented by stations M9 to M12. Includes stations primarily in the Parkland Natural Subregion that are very low in landscape position and thus receive relatively more groundwater contributions. Cobbles and boulders also appear in the substrate.

Key habitat and biological results are described and summarized by reach in the following section.

Upper Reach (stations M1 to M3 upstream of Lac Ste. Anne; see Figure 25)

- **Habitat quality:** Instream aquatic habitat quality is generally poor, in particular between Lac Ste. Anne and Isle Lake (station M3). This is mainly due to poor water quality. Phosphorus values in this reach are similar to other streams in Alberta situated in areas of high agricultural intensity. This poor water feeds Isle Lake and Lac Ste. Anne, which partly contributes to their eutrophication.
- **Water quality:** Mean annual flow is low in this reach. Some pesticides and metals are high upstream of Isle Lake upstream of Hwy 16 (M2); dissolved iron was substantially above guidelines at this site. Nutrient concentrations are also high at these sites. Overall, the water quality is poor to very poor in this reach.
- **Macroinvertebrates:** The macroinvertebrate community is consistent with water quality results, in that it is dominated by individuals that can live in poor to very poor conditions.
- **Fish:** Only 2 fish were captured in the SR upstream of Lac Ste Anne in 2017. Historically (2001 to 2015), only minnows tolerant of poor environmental conditions have ever been caught upstream of Lac Ste Anne. Large-bodied fish do not appear to inhabit the SR river upstream of Isle Lake, although they could be spawning in locations near the lakes.

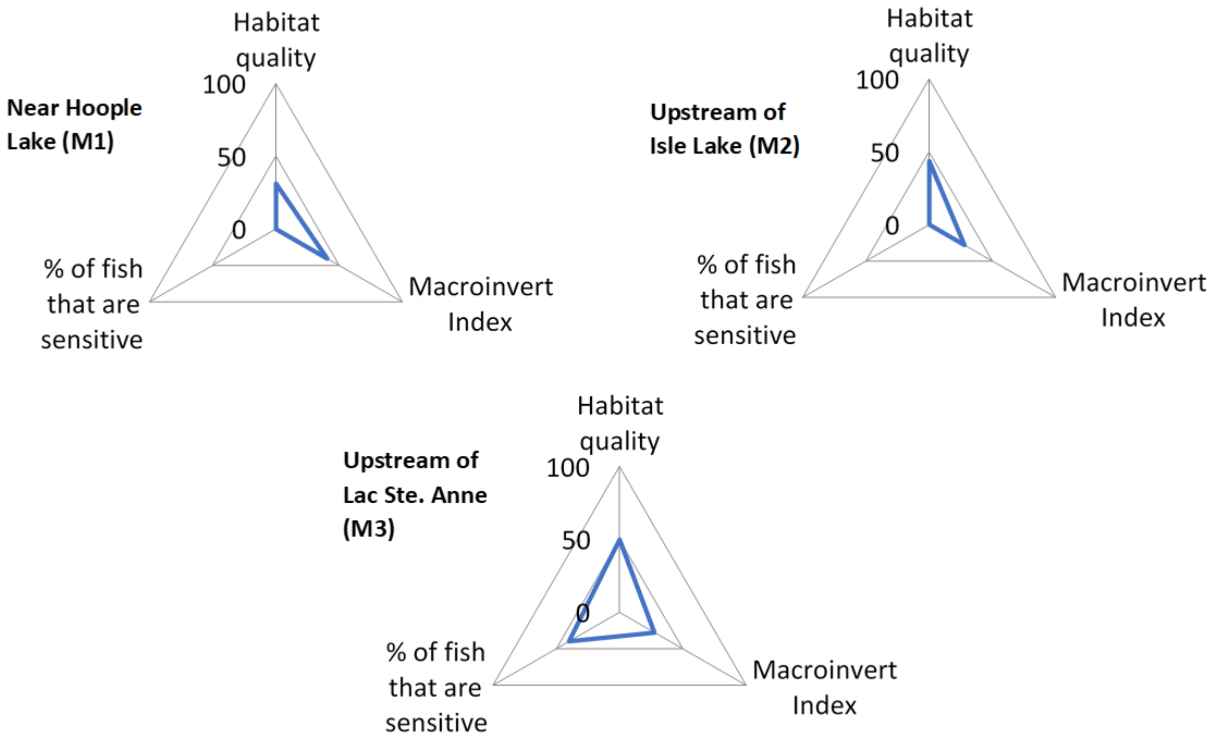


Figure 34: Integrated aquatic ecosystem health assessment at SR sampling stations M1 to M3. The middle of the triangle represents 0% and the tips are 100%. The larger the area of the blue triangle, the greater is the overall health of the site. Note: Habitat quality refers to scores from Table 5. The macroinvertebrate index (FBI) scores (see Section 7) were inversed and expressed as a percentage so that high values represent better conditions. Due to safety concerns, electrofishing did not occur at site M9, which is why there is no data for sensitive fish. Sensitive fish represent intolerant and medium-tolerant fish species (see Section 8).

Middle Reach (downstream of Lac Ste. Anne to Big Lake, stations M4 to M8; see Figure 26)

- **Habitat quality:** Habitat quality improves substantially downstream of Lac Ste. Anne, primarily due to improvements in water quality. Lac Ste Anne plays an important role in nutrient retention and thus in downstream habitat quality. Sand and gravel appears in the substrate in this reach, adding to overall habitat diversity.
- **Water quality:** Water quality is relatively good here, particularly between Matchayaw Lake and Rivière Qui Barre confluence (stations M6 and M7). Mean annual flow increases substantially in this reach, which likely helps improve water quality. Phosphorus at these locations are amongst the lowest recorded in other creeks and small rivers in Alberta. Rivière Qui Barre appears to cause an increase in suspended solids in the SR during the spring. Suspended solids are also relatively high at station M5 upstream of Matchayaw Lake, which should be looked into.
- **Macroinvertebrates:** The macroinvertebrate community indicates poor to very poor conditions, except between Matchayaw Lake and Rivière Qui Barre confluence which indicates good to fair conditions. This latter stretch of river appears to also have the best water quality, which is consistent with the macroinvertebrate results. An abrupt decrease in conditions from fair to very poor downstream of the Rivière Qui Barre confluence indicates that the tributary may be negatively impacting the SR. Rivière Qui Barre has high nutrients and suspended solids (see below under "Tributaries").
- **Fish:** The fish community is more diverse and more fish were caught in this reach as compared to the Upper Reach. Sensitive fish species that are intolerant of poor habitat conditions appear in this reach, indicating better conditions.

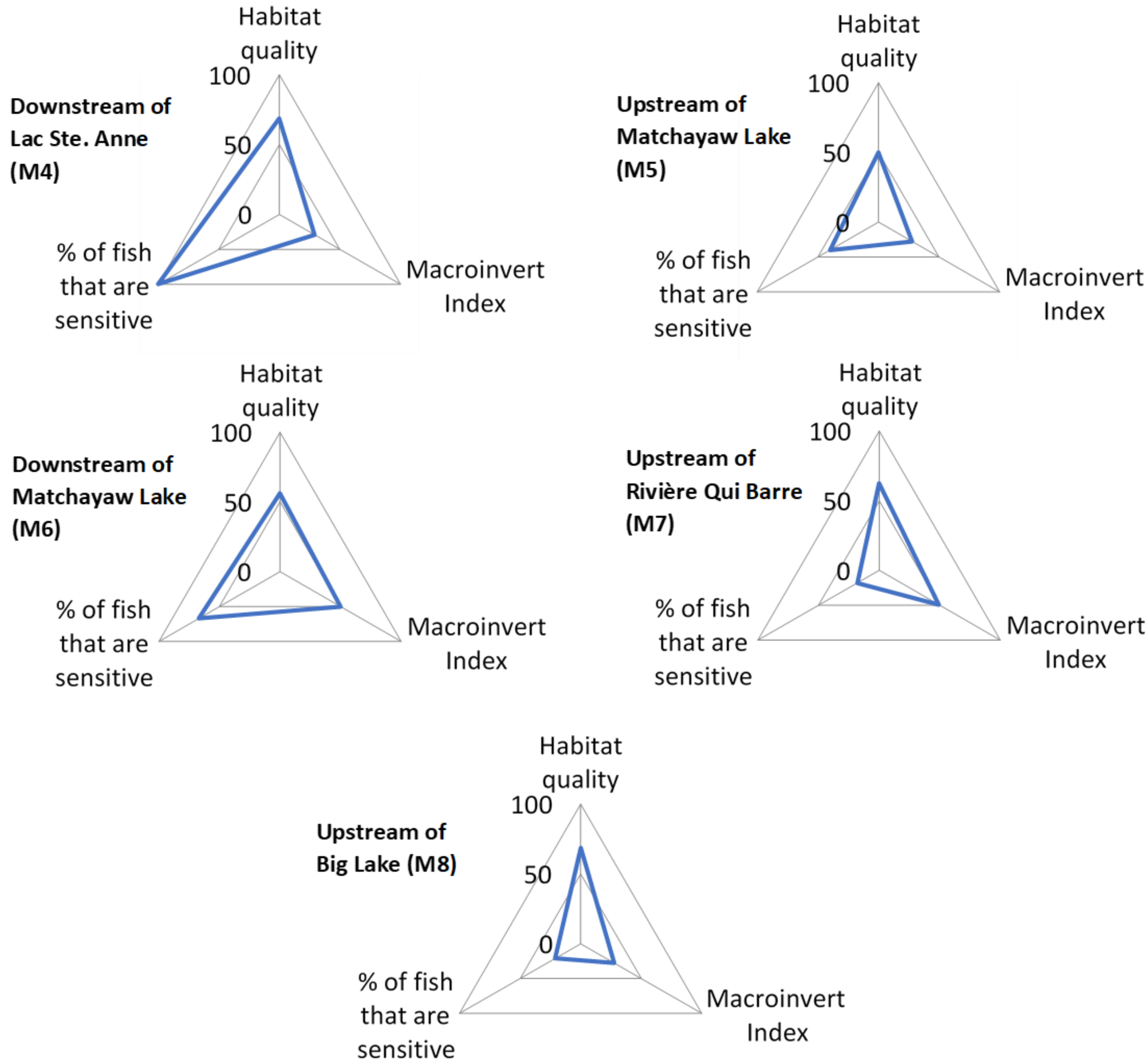


Figure 35: Integrated aquatic ecosystem health assessment at SR sampling stations M4 to M8. The middle of the triangle represents 0% and the tips are 100%. The larger the area of the blue triangle, the greater is the overall health of the site. Note: Habitat quality refers to scores from Table 5. The macroinvertebrate index (FBI) scores (see Section 7) were inversed and expressed as a percentage so that high values represent better conditions. Due to safety concerns, electrofishing did not occur at site M9, which is why there is no data for sensitive fish. Sensitive fish represent intolerant and medium-tolerant fish species (see Section 8).

Lower Reach (downstream of Big Lake, stations M9 to M12; see Figure 27)

- **Habitat quality:** Habitat quality is poor immediately downstream of Big Lake, largely due to excessive growth of rooted aquatic vegetation and high nutrient concentrations. Habitat quality improves downstream of this station. Cobbles and boulders appear in the substrate in this reach, further adding to habitat diversity.
- **Water quality:** Mean annual flow continues to increase slightly in this reach, as compared to the Middle Reach. Downstream of Big Lake, dissolved chloride during winter was 4 to 5 times higher than upstream sites, which may be caused by inputs from a variety of sources, namely groundwater discharge, loading from Carrot Creek, and road salt application. In addition, pesticides were relatively high downstream of St. Albert in July. Suspended solids also increased about 4 times downstream of the City of St. Albert, as compared to the upstream site, indicating that stormwater runoff may be a source of sediment here. Dissolved oxygen concentrations are relatively better in this reach, likely due to higher flows in the lower topographical position of this reach.
- **Macroinvertebrates:** The macroinvertebrate community indicates fair to fairly poor conditions in this reach. Conditions worsen to fairly poor downstream of the City of St. Albert, which is consistent with increased sedimentation, nutrients, and pesticides at station M10.
- **Fish:** Historical and current records show that walleye appears to be a resident of the lower reaches in the SR from the Town of Gibbons to where it meets the North Saskatchewan River. Walleye likely migrate to and from the North Saskatchewan River. The most downstream sections of this reach (station M12) is inhabited by minnows that are intolerant of poor habitat conditions, which is consistent with relatively good habitat, riparian, and water quality at this site.

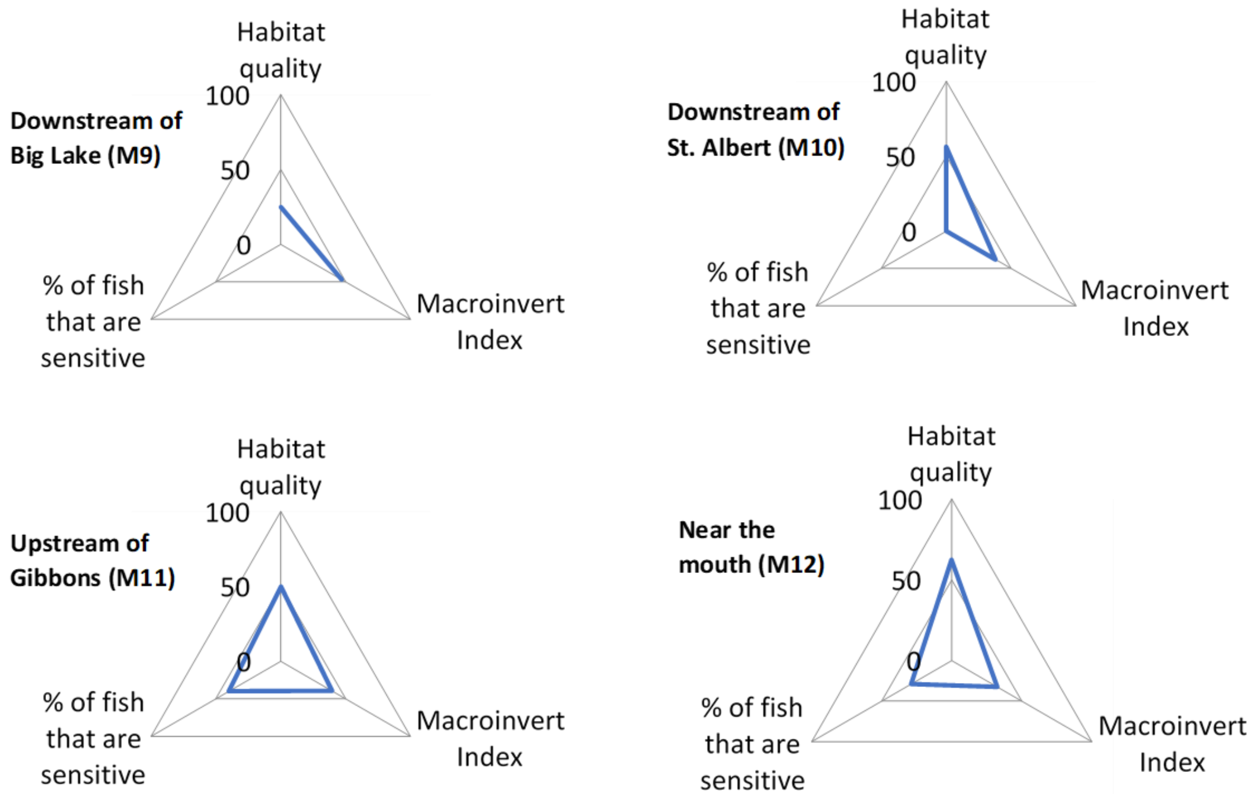


Figure 36: Integrated aquatic ecosystem health assessment at SR sampling stations M9 to M12. The middle of the triangle represents 0% and the tips are 100%. The larger the area of the blue triangle, the greater is the overall health of the site. Note: Habitat quality refers to scores from Table 5. The macroinvertebrate index (FBI) scores (see Section 7) were inversed and expressed as a percentage so that high values represent better conditions. Due to safety concerns, electrofishing did not occur at site M9, which is why there is no data for sensitive fish. Sensitive fish represent intolerant and medium-tolerant fish species (see Section 8).

Tributaries (stations T1 to T6)

Water quality was sampled in Toad Creek, Kilini Creek, Rivière Qui Barre, Atim Creek, Carrot Creek, and Little Egg Creek during the summer of 2017. Notable results from this sampling is as follows.

- Median total phosphorus concentrations during the spring runoff period in Toad Creek, Rivière Qui Barre, and Carrot Creek are about 4 to 5 times greater than in nearby SR stations. These values are consistent with other creeks sampled in the province in 1995 and 1996 that drain watersheds with high agricultural intensity. These tributaries are contributing high concentrations of nutrients to the SR and this appears to be causing an increase in SR concentrations. The median concentration of total phosphorus in the other creeks (Kilini Creek, Atim Creek and Little Egg Creek) appears to be similar to those of nearby stations on the SR.
- Chloride concentrations in Carrot Creek exceeded Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (for long-term exposure).
- As mentioned above, Rivière Qui Barre appears to be a source of suspended solids to the SR during the spring runoff period.
- Kilini Creek has good water quality and contains fish that are intolerant of poor habitat conditions, indicating that this creek is in relatively good health.

10. Recommendations

Based on the information presented in this report, we make the following recommendations, organized under the headings of information gaps, monitoring programs, further study, and management actions.

Information Gaps

1. Based on public surveys (Hunt and Webb 2013), sport fishing is important to users of the SR system. Fish surveys in the winter and in the spring would provide information about overwintering use of the mainstem and important spawning areas in the SR. This information would be very useful in prioritising segments of the SR to conserve and restore for their fish habitat. As recommended by Golder (2004), spring spawning surveys should be focused in areas that were previously identified as areas with potential spawning habitat (Big Lake near inlets of Atim Cr and SR, lower SR, marsh section downstream of Matchayaw Lake, inlet of Lac Ste Anne, outlet of Isle Lake, and inlet area upstream of Isle Lake).
2. A healthy fish population in the SR system will depend on strategies to reduce the potential for winterkill, which centers on improving the input and/or storage of oxygen during winter.

3. Ice formation and breakup is very important in controlling oxygen levels in the SR. However, there appears to be no specific data available related to ice formation and breakup processes for the SR.
4. The quality of the aquatic habitat in the SR is dependent instream physical information. In spite of the information collected for this study, there is generally a shortage of data related to channel morphology and characteristics along the length of the SR. It is recommended that in the course of acquiring field data for any future macroinvertebrate or fisheries habitat assessments, the following habitat information be collected: substrate type and particle size, channel width and depth measurements, habitat diversity, bank undercutting, macrophyte cover, and shade cover. Collecting additional instream physical data will continue to improve our understanding of aquatic habitat throughout the SR.
5. There is a lack of data on the seasonal fish movements into and out of the lower SR from the North Saskatchewan River, as well as the onstream lakes. Due to beaver dams, the upstream passage of fish in the SR may be difficult. Fish telemetry studies can be used to fill this gap in information.

Monitoring Programs

6. Since pesticides were detected at relatively high concentrations in the SR, we recommend that future studies and monitoring programs measure pesticides upstream and downstream of all areas that drain highly populated areas, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. These should be measured in the months of June and/or July, which is when detections are more likely (see Anderson 2005). The City of St. Albert’s monitoring program currently measures pesticides in the SR in the fall.
7. The spring runoff period occurs for about one month immediately after ice-off (typically in April). Since the majority of the export of constituents in water occurs during this time, we recommend that current and future monitoring programs capture the spring runoff period at this time. To be able to calculate constituent export and load, sampling should be paired with discharge measurements where possible. If this is not possible, discharge can be modelled, but direct measurement is best.
8. Chloride should be measured again during winter upstream and downstream of areas that drain high road densities, such as Atim Creek, Carrot Creek, Little Egg Creek, and the lower SR. This sampling should be diagnostic in nature i.e., the sampling regime should specifically attempt to determine if high values are caused by road salt application. Adopting this type of approach will directly support a discussion on the potential adverse effects of these values and what mitigation measures, if any, are warranted. Given that road salt is used to improve transportation safety, the monitoring program design must be exceptionally rigorous.
9. Aquatic ecosystems should be re-sampled, perhaps every 10 years, to track ecosystem health over time. Methodologies should be consistent to allow comparisons over time.

Further Study

10. Rivière Qui Barre and Carrot Creek have very high nutrient concentrations that are potentially contributing to the eutrophication of Big Lake. To determine the effect of this nutrient loading, a nutrient balance for Big Lake should be completed with the updated information contained in this report. If the results of this analysis determine that the tributaries contribute a significant amount of nutrient loading to the lake, sites in the effective watershed areas of these creeks could be targeted for restorative actions. For the same purpose, we also recommend creating / updating nutrient balances for the other major lakes that are part of the SR system, including Matchayaw Lake. Nutrient balances have been completed for Isle Lake and Lac Ste Anne in the *Isle Lake and Lac Ste. Anne State of the Watershed Report (2017)*. However, it would be worthwhile updating the nutrient balance using the river water quality data collected in this report.
11. Our report uses provincial water quality guidelines that are recommended to protect aquatic ecosystem health. Since these guidelines apply to all water bodes in Alberta, they are meant to provide general guidance. One limitation of these guidelines is that they are not available for all substances of concern. Some of the major substances of concern are nutrients and provincial guidelines for nutrients are in the form of a narrative statement as follows: "total nitrogen and phosphorus concentrations should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality". Data from the water quality studies and from macroinvertebrate surveys in our study suggest an open-water total phosphorus target for the SR of 0.12 mg/L. This value may be appropriate for some segments of the SR, but perhaps not others (e.g., the lower segments naturally have more suspended solids, thus more total phosphorus). Setting site-specific nutrient objectives should be formally completed using protocols from the *Guidance for Deriving Site-Specific Water Quality Objectives for Alberta Rivers*. Data collected as part of our study (as well as other studies) will provide the information needed for this exercise. Once site-specific nutrient objectives are created for the SR, a nutrient management plan can be developed for the SR.
12. Water quality parameters are often related to flow (CPP Environmental 2017). Further exploration of the relationship between water quality parameters and flow will aid in understanding water quality of the SR.
13. Since flow and water quality are closely tied, the relative contribution of creeks to flow should be examined more closely. The majority of flow in the SR watershed appears to be generated in the mid-section (Lac Ste. Anne to Big Lake). Maintaining flow is a critical component of maintaining the ecosystem health of the SR. Areas that generate relatively higher runoff per unit area may potentially be targeted as management priorities.
14. Dissolved iron concentrations at locations upstream of Isle Lake greatly and regularly exceeded the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. Pesticides were also notably higher immediately upstream of Isle Lake. Given that such high concentrations of dissolved iron may be toxic to aquatic life, and given that

other metals and pesticides were relatively high at the same locations, further sampling and examination of metals and pesticides in water and sediment at these locations is advisable. The purpose of this sampling should be very specific i.e., to determine the extent and source of the high values to inform corrective actions.

15. Other than high nutrients, the levels of chloride in Carrot Creek have the potential to be toxic to aquatic life. Further examination is warranted considering that natural sources appear to be unlikely based on the information that is currently available.
16. Pesticides downstream of the City of St. Albert (M10) were notably higher (about 6 times), as compared to sampling stations immediately upstream of the City. At the time of sampling, concentrations were below Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. However, our study, which only sampled for pesticides once in July, provides a signal that pollution may be occurring. Further examination of the occurrence and source of these pesticides in June/July is recommended.
17. Oxygen levels were low at some locations in the SR during the summer. The quantity of dissolved oxygen within streams and rivers can change drastically during 24 hours due to differences in photosynthetic activity from day to night. For instance, our study did not measure oxygen at night, which is when it would be the lowest. There currently is a lack of information and understanding of these diurnal patterns in oxygen in the SR, which may be very important for aquatic life.
18. Oxygen levels during winter were variable, depending on the location. It isn't currently clear why this is occurring. The role of bottom sediments and physical stream characteristics in determining late summer and winter oxygen content in the SR would better inform any discussions regarding the management of oxygen in the SR.

Management Actions

19. The Middle Reach of the SR is a stretch of river with relatively higher habitat and water quality. The Lower Reach is the only known location in the SR that is home to walleye. Kilini Creek has relatively good water quality and fish that indicate good habitat conditions. We recommend that these high-value portions of the SR be examined further for conservation measures. Shade, bank undercutting, and habitat diversity can be maintained and enhanced by protecting and planting trees on the river banks. Regulatory tools can also be implemented to protect these important areas as part of regulatory approval processes.
20. Urban runoff is contributing to sediment loading to the SR. The City of St. Albert Stormwater Master Plan is addressing sediment loading reduction through the retrofit of stormwater outfalls with grit interceptors. Sediment loading reduction strategies such as this should be explored further by municipalities. Another opportunity for reducing sediment loading at its source is through low impact development strategies, which have proven to be very effective in many jurisdictions across North America. The Alberta Low Impact Development Partnership is a good resource for this information.

21. Low dissolved oxygen in late summer and winter is a major driver of the SR ecosystem. Strategies to improve oxygen in the SR centers on improving the input and/or storage of oxygen, particularly during winter. The creation and maintenance of open-water areas can create winter refugia for fish, although the feasibility of such an approach may be prohibitive. Maintaining the depth and flow of water and improving the connectivity of the river by reducing barriers would also improve the supply and storage of oxygen during winter. Finally, reducing the nutrient input and content of the water and sediments in the SR system would reduce the consumption of oxygen through bacterial and chemical processes. Many management options are possible, but these will need to be weighed against the long-term costs and benefits of their implementation.
22. Given that the SR has low flushing potential during late summer and winter, it can be thought of as a naturally sensitive ecosystem that would benefit from any nutrient reduction strategies. Many nutrient strategies options can be considered for the SR, its tributaries, and its lakes. Examples of nutrient reduction strategies include reducing the input of particulate nutrients by restoring riparian areas and improving construction beneficial management practices, limiting cattle access to the river and its tributaries through offsite water monitoring programs, improving the nutrient retention of watersheds through the restoration of wetlands, creating opportunities to allow particulate nutrients to settle out of the water column (e.g., through stormwater management Beneficial Management Practices), and chemical treatment (e.g., lime, alum, bentonite clay or phoslock) of water to remove nutrients from the water column. A nutrient management plan can be used to determine all possible strategies and evaluate feasibilities in terms of effectiveness and cost.
23. Low flows in the Upper Reach of the SR currently limit the potential for quality habitat and water quality. Any reduction in water supply have the potential to affect the aquatic ecosystems and reduce fish spawning and habitat options near Lake Isle and Lac Ste Anne. We recommend an examination of the feasibility of limiting licenced water withdrawals from this stretch of river for the purpose of meeting the flow needs required for biota. An Instream Flow Needs (IFN) scoping study was completed by Golder Associates in 2004, but to our knowledge, an IFN was not completed.

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12. Appendices

Contents