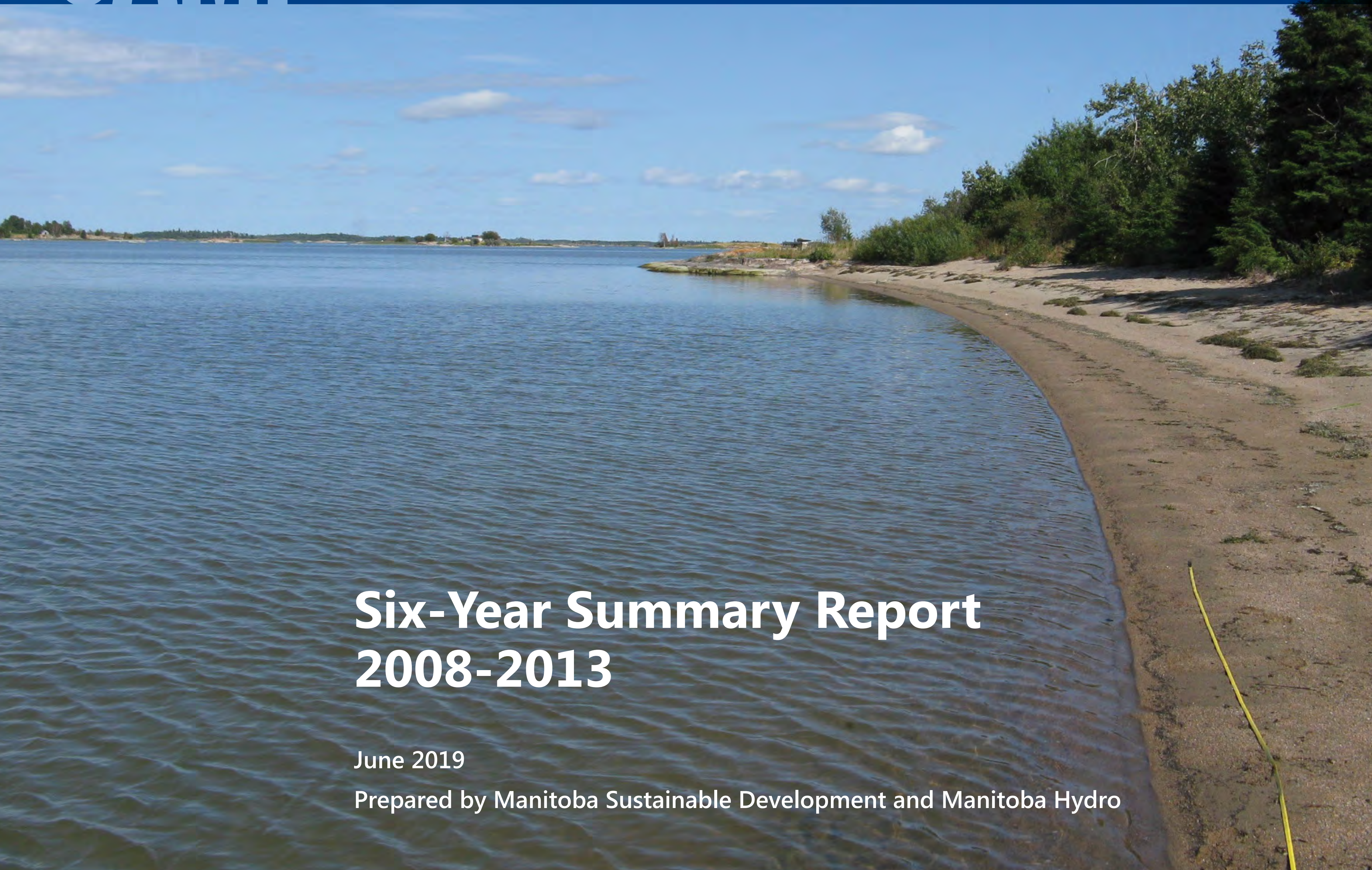
CAMP

Coordinated Aquatic Monitoring Program



Six-Year Summary Report 2008-2013

June 2019

Prepared by Manitoba Sustainable Development and Manitoba Hydro

Front cover: Playgreen Lake
Inside cover: Setting Lake

The Coordinated Aquatic Monitoring Program (CAMP) was established in 2006 with a Memorandum of Understanding between Manitoba Sustainable Development (formerly Manitoba Conservation and Water Stewardship) and Manitoba Hydro. The program was formed to bring together existing monitoring activities from both organizations, and create a coordinated approach to understand the aquatic environment affected by hydroelectric operations. Monitoring is conducted in eight regions across the province from the Winnipeg River Region to the Churchill River Region. Sampling began in 2008 and the first three years of the program were considered "pilot" to establish and review methodologies.

As per the CAMP reporting framework, synthesis reports are prepared every three years. Each synthesis document reports on analyses of all the data since the program began, and identifies trends and observations for each region and monitoring parameter. This document serves as the Plain Language Summary report of the six-year synthesis (i.e., the Six-Year Technical Documents, which are available online at www.campmb.com). The six-year analysis spans the period from April 2008 to March 2014.

Overall observations made from the first six years of data include the following:

- The CAMP monitors on a rotational basis; this means that some waterbodies and parameters are sampled annually, while others are sampled every three or six years. Therefore, although the CAMP covers a large geographic area and many monitoring parameters, many sites in this reporting cycle only have six observations (i.e., data points) per parameter, while the rotational sites have less sampling points. Scientifically, a sample size of six is quite low and does not provide enough data to make definitive conclusions regarding the state of the environment or any changes that might be occurring. Since it is a long-term program, data trends and changes will emerge over time and will become more obvious. As such, the observations that are presented in this report may change over time as new data are collected and new insights can be gleaned.
- As expected, regional variations exist between sampling parameters results and other environmental conditions. There is a great variety in geography, physical environment, water flows and latitude across Manitoba that all contribute to the differences observed in the sampling parameters across the regions.
- Benthos data indicates there is a wide variation in abundance and diversity results not only across regions but also within the same sites between years. This variation may indicate the need for reviewing the sampling protocols or the interpretation of the data.

PREAMBLE

The Coordinated Aquatic Monitoring Program synthesis reports are prepared every three years and analyze all the previous data collected under the Program. The intention of this reporting structure is to review the information to date to identify trends or observable environmental changes, especially those related to Manitoba Hydro System operations.

This document serves as the plain language summary of the detailed technical analysis contained in the Six-Year Summary Report Technical Documents (i.e., 2008 – 2013), which are available at www.campmb.com under Publications. The intention is to provide the highlights and results of the technical documents in an accessible format for a wide audience.

The information and observations described in this document are based on the data available at the time of monitoring and analysis. Conclusions are expected to evolve over time as the Program obtains more data. As well, others' perspectives and ideas about the CAMP and the conclusions are welcomed and viewed as valuable inputs to improve the Program.

How to Use this Document

This summary document is arranged with an Introduction about the Program, followed by short descriptions to explain complex topics that are important to the CAMP (such as Manitoba Hydro system operations, trophic levels, monitoring indicators and benthic macroinvertebrates). After the Introduction, the monitoring results are arranged under each one of the CAMP's eight regions. Each region's section in the report is easily identified by the unique coloured band and region name at the top of each page.

The review of information from the first six years is consistent across the regions and follows a "Pathways of Effects" approach. This approach follows that the hydrology and physical environment of a region will influence the other components of the environment, and effects may be observed at different levels in the trophic pyramid. As such, hydrology and physical environment (e.g., geography, geology, water quality) are described first, followed by the remaining monitoring parameters from the lowest trophic levels (i.e., lowest levels on the food web, such as algae and insects) up to the top predators (e.g., Walleye [pickerel] and Northern Pike [jackfish]). Each regional section ends with conclusions and future considerations. Lastly, general conclusions and future considerations are provided at the end of the document to provide some insight into the first six years of the Coordinated Aquatic Monitoring Program.

Since countless biological, chemical and physical components make up the aquatic environment, and potentially could be monitored, the CAMP has chosen to report on "indicators" for efficiency. Indicators include hydrometrics, water quality, benthic macroinvertebrates and fish community. A more detailed description of the role of indicators under the program is provided in the Aquatic Ecosystem Health Indicators section.

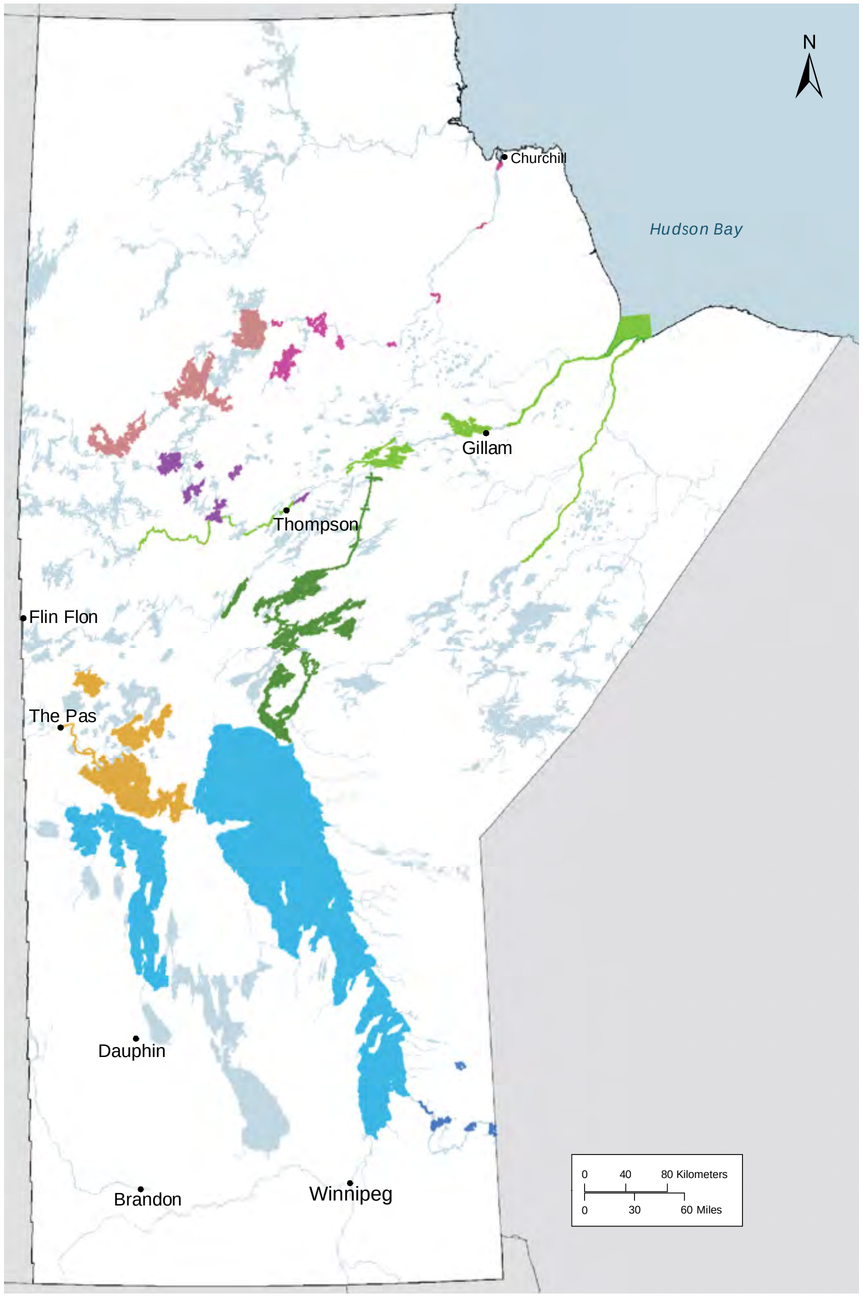
Coordinated Aquatic Monitoring Program

The Coordinated Aquatic Monitoring Program (CAMP) is an ecosystem health-monitoring program with the objective to understand the operating effects of Manitoba Hydro's hydrologic system. The Program was established in 2006 with a Memorandum of Understanding between Manitoba Sustainable Development (formerly Manitoba Conservation and Water Stewardship) and Manitoba Hydro. Both organizations had been conducting aquatic monitoring activities in isolation prior to the CAMP and there was a growing need to bring them together. The Program created a partnership so monitoring could be coordinated and efficiencies could be found between organizations.

Building on the existing monitoring activities, the CAMP was developed with direction from regulatory agencies and input from academics and federal researchers based on modern science. The sampling methods for data collection were chosen from existing programs with the intention of maximizing the value and use of historical data from other programs like Manitoba's fisheries index netting and Manitoba Hydro's water quality sampling programs.

The conceptual model for the CAMP is that Manitoba Hydro's water management has effects on the physical configurations of, and chemical inputs to, aquatic ecosystems. This affects energy flows through the food web, which are reflected in changes to ecosystem community characteristics. This change ultimately affects ecological goods and services, such as wildlife and fish for hunting, fishing and related industries. The CAMP was designed to sample various trophic levels (i.e., levels of the food web) within the aquatic ecosystem so the effects of water management could be better understood.

- Winnipeg River Region
- Saskatchewan River Region
- Lake Winnipeg Region
- Churchill Diver Diversion Region
- Upper Churchill River Region
- Lower Churchill River Region
- Upper Nelson River Region
- Lower Nelson River Region



Coordinated Aquatic Monitoring Program Study Regions

CAMP

The CAMP divides Manitoba Hydro's operating system into eight study regions across Manitoba as follows:

- Winnipeg River Region
- Saskatchewan River Region
- Lake Winnipeg Region
- Churchill River Diversion Region
- Upper Churchill River Region
- Lower Churchill River Region
- Upper Nelson River Region
- Lower Nelson River Region

Types of Waterbodies

On-system *waterbodies are those located on, and are influenced by, Manitoba Hydro's hydraulic operating system such as reservoirs and areas downstream of hydroelectric generating stations and control structures.*

Off-system *waterbodies include lakes and river reaches where water levels and flows are either entirely or largely unaffected by Manitoba Hydro's hydraulic operating system.*

Program Scope

Manitoba Hydro's generating system was developed in the early 1900s for the southern generating stations, while the northern stations were mostly developed in the 1960s and beyond. The CAMP cannot compare the current environmental conditions with those before the developments because similar historical data is not available. Moreover, since Manitoba waterbodies differ by geography, drainage type, latitude, species assemblages and societal use, lakes cannot be compared easily to each other, and information collected about one region does not necessarily indicate any broader trend. However, lakes can be compared to themselves over time. As such, the CAMP is designed to assess the relative health (and associated changes) of each individual CAMP waterbody over time, beginning in 2008 when monitoring was initiated.

The CAMP also samples off-system waterbodies in the region. These reference waterbodies help determine if environmental parameters, other than water management, have contributed to observed changes in the broader study areas. The off-system waterbodies are intended to provide regional context and are not to be used as 1:1 comparisons.

The program monitoring information consists of four primary components, as follows:

1. **Hydrometrics** refer to water levels and flows within the CAMP study regions. Legislation and licence conditions for Manitoba Hydro generally define water level limits. These conditions are intended to optimize hydroelectric power generation and minimize ecological impacts. However, hydrologic flows and water level conditions are also heavily influenced by upstream water management in other provinces and the United States as well as precipitation that affects inflows and water levels, often beyond Manitoba Hydro's control.
2. **Water Quality** refers to the chemicals in the water, which determines the ability of the water to support aquatic life. Water quality is affected by water levels and flows, climate and erosion. The quality of water can affect or determine the abundance and diversity of lower trophic levels in the food chain, which can also affect the quantity, sizes and diversity of fish species.
3. **Benthic Macroinvertebrates** are relatively slow-moving invertebrates that live at least part of their lives in the mud and bottom sediments of lakes and rivers. Their presence and abundance is often determined by the physical (e.g., water velocity, water depth) and chemical (e.g., minerals and nutrients) characteristics of the water. The abundance and kind

of benthic macroinvertebrates present is therefore considered an indicator of the health of an ecosystem and its water quality. The sampling design was modified in 2010 to better reflect ecosystem conditions and reduce variability so benthic macroinvertebrate data are restricted to a four-year period (2010-2013).

4. **Fish** are important to measure because they are important to people. As they are at the top of regional aquatic food webs, they are the product of the ecosystem's functioning and therefore reflect all of the conditions of the waterbody. Much like a healthy land produces top-level predators like wolves; a healthy aquatic food web has enough food to support an abundance of predatory fish like Walleye and Northern Pike.

Key indicators for the four core components were selected in 2015 by a process facilitated by the International Institute for Sustainable Development along with the CAMP experts. Measuring ecological conditions under large-scale, comprehensive monitoring programs provides a high-level overview of the system's integrity and can highlight key areas where mitigation actions or further investigation of detailed background data is warranted as per International Institute of Sustainable Development's 2015 Indicator Report.

Although six years is not enough time to draw conclusions about trends, this Report summarizes the aquatic ecosystem data available during the 2008-2013 period. These data are reported in the sections that follow for each study region.

The CAMP sampling also includes the collection of fish muscle samples to measure the amount of mercury in the fish. This information is presented in Appendix 2.

For more detailed descriptions of the water bodies, ecosystem indicator selection and the six-year data analyses, please refer to the CAMP website www.campmb.com/reports/

- Coordinated Aquatic Monitoring Pilot Program: Three Year Summary Report (2008-2010)
- Indicator Framework Report by the International Institute for Sustainable Development
- Six-Year Summary Report (Technical Documents) 2008-2013

Stephens Lake North

IMPORTANT CAMP CONCEPTS

Several concepts are central to the CAMP analysis and reporting; some of them are complex and further explanation is needed. The following concepts are described in the subsequent sections as basic reference material for the broader analysis:

- Hydrology 101
- Manitoba Hydro System Operation
- Trophic Levels and Food Webs
- Aquatic Ecosystem Health Indicators
- Water Quality
- Benthic Macroinvertebrates
- Fish as an Indicator

MV Namao at 2-Mile Channel

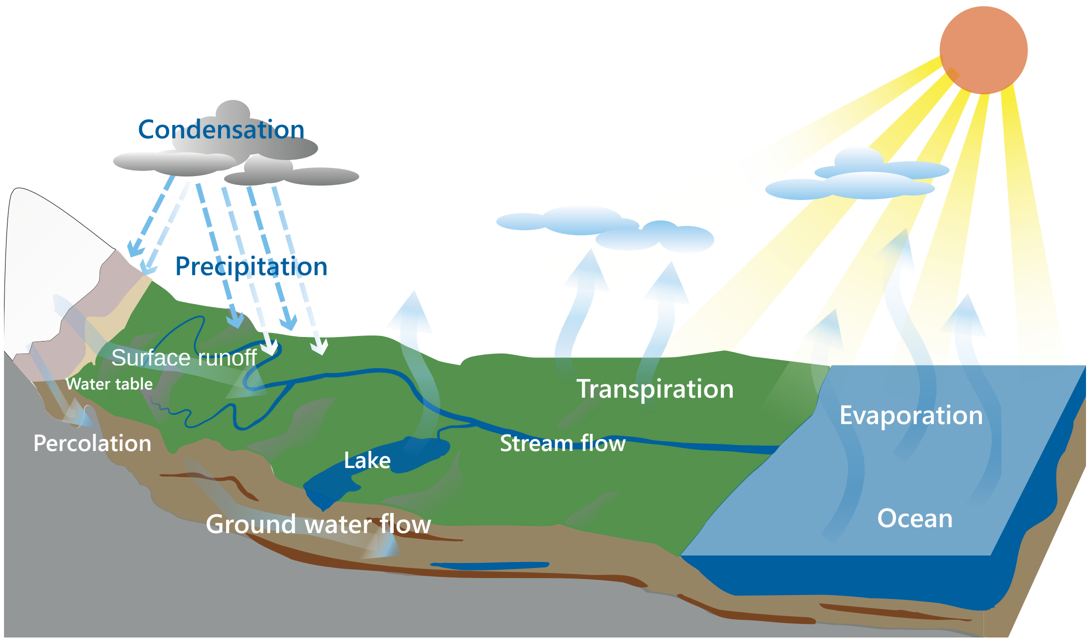
Hydrology 101

What is Hydrology?

Hydrology is the study of water, including when, where and how water interacts with our environment throughout the water cycle. Water is used for household and commercial use, industry, recreation, irrigation and for the production of hydroelectricity. The water cycle is a continuous process by which water is purified by evaporation and transported from the earth's surface (including the oceans) to the atmosphere and back to the land and oceans.

Deciding how much water to release from a reservoir and how much to store depends on the time of year, flow predictions for the next several months, energy demands and the needs of other water uses. Information is collected across the system through a network of monitoring stations measuring water depths and flows, precipitation and snowpack to understand the current hydrologic conditions and help decide how to operate Manitoba Hydro's system. This information is also used by scientists to understand how water interacts with the aquatic ecosystem.

The mean annual flow within each CAMP region for each flow year (January 1 to December 31) was compared with the range of mean annual flows for the region from January 1, 1980 – December 31, 2013 in order to categorize the flow years as being either very dry, dry, average, wet or very wet. Charts are in Appendix 1.



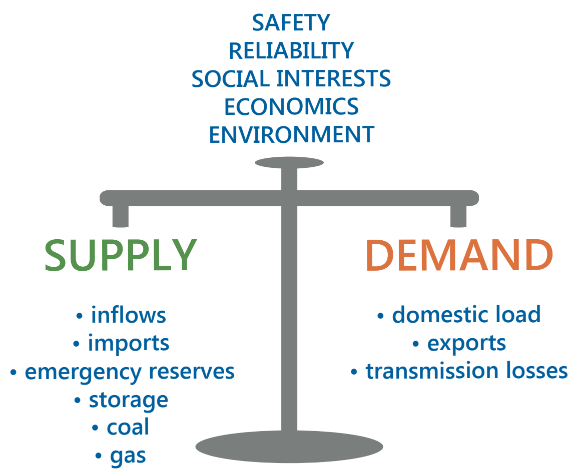
Water cycle

Water level gauge station in winter

Manitoba Hydro System Operation

System Operations

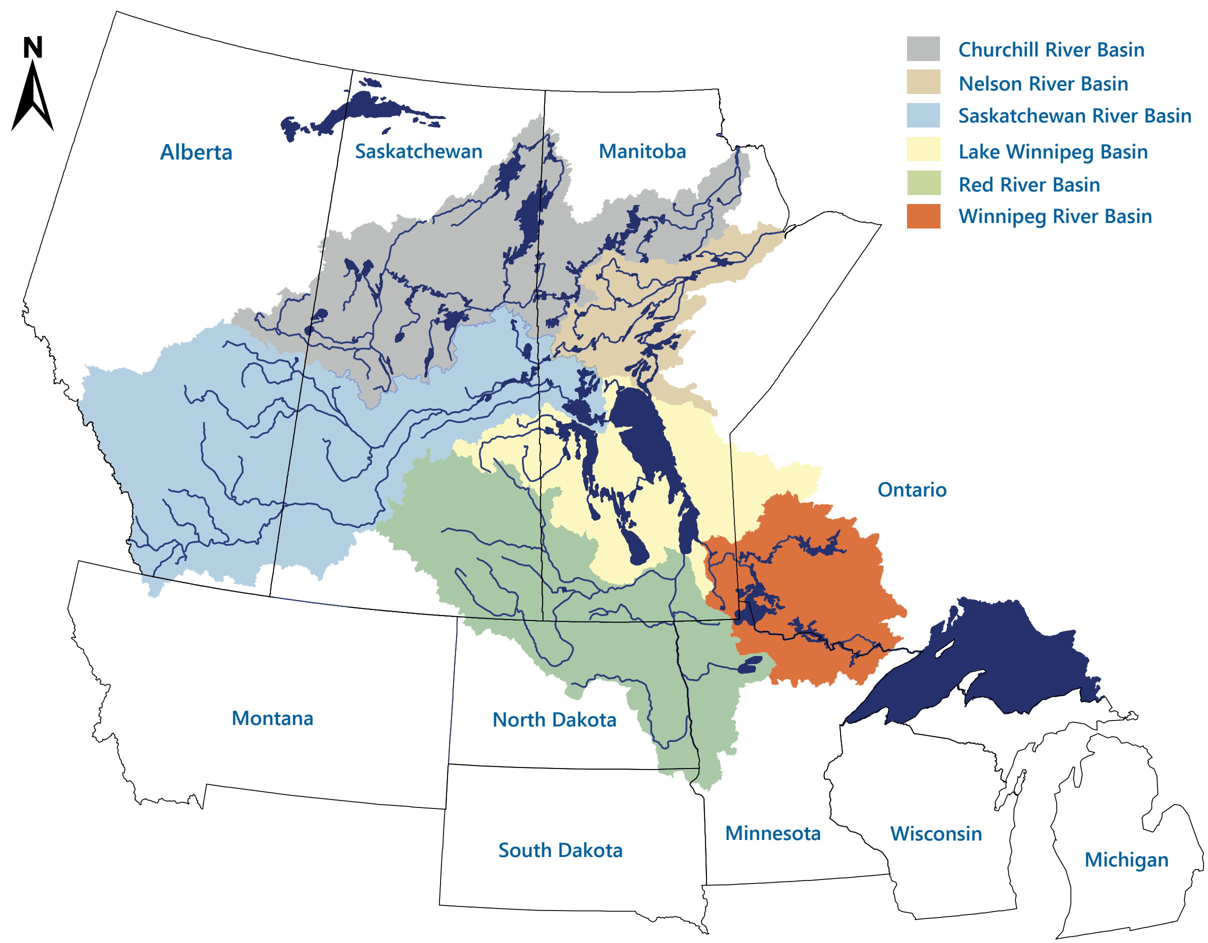
Operating a power system involves developing a plan, or series of planned operating decisions, to ensure that supply (electrical generation) and demand (electrical power load) will be in balance over the entire operating timeframe from the next hour to months in the future. Developing an optimal plan would be relatively simple if economics were the only priority. The actual challenge is more complex because additional, often competing, priorities must be considered.



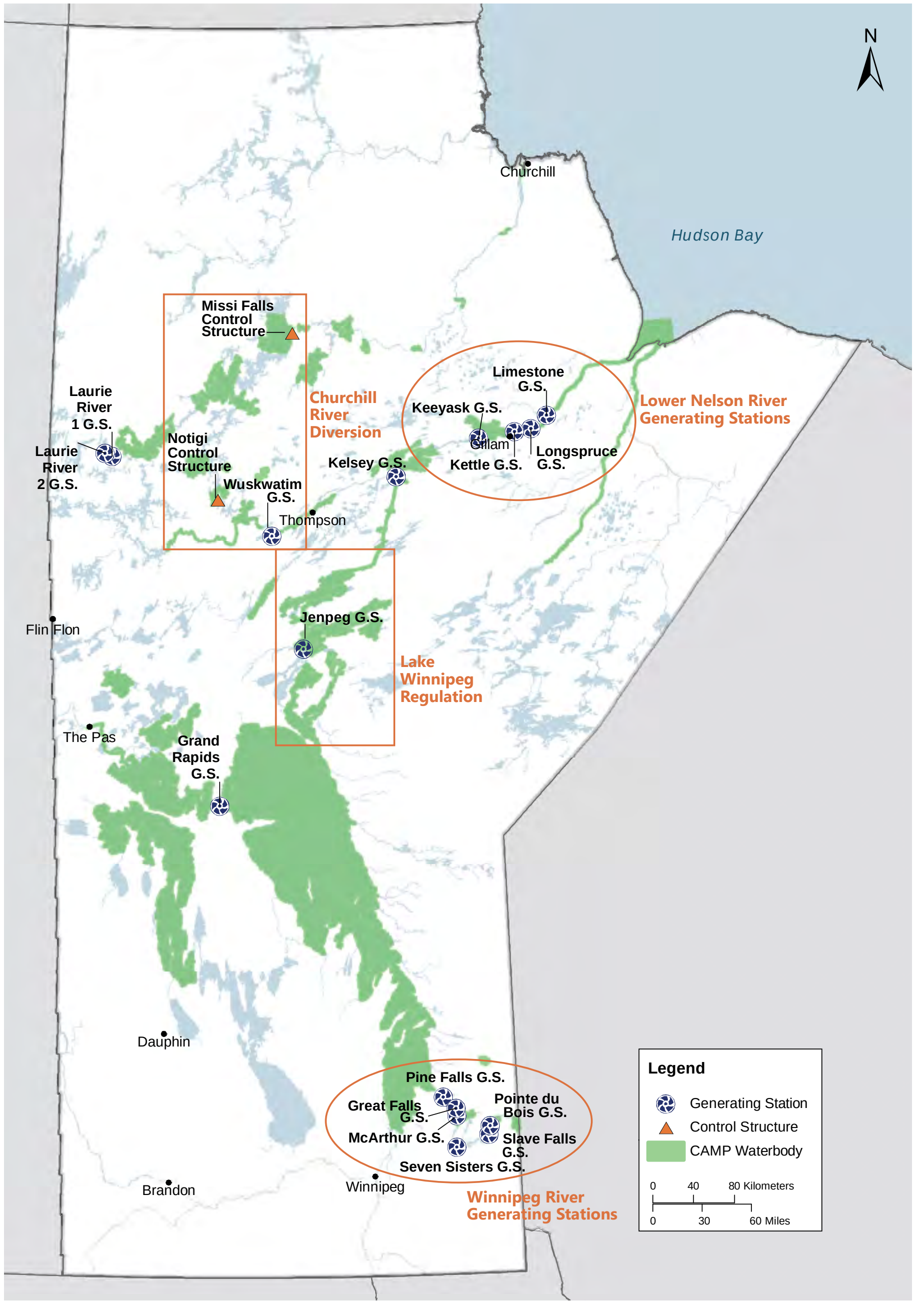
Energy supply and demand

Inflows

Inflows are a major driver of Manitoba Hydro's operations. Inflows are driven by rainfall and snowfall in the more than 1,300,000 km^2 area of land, or watershed that supplies water to Manitoba. Inflows vary considerably from year to year due to variability in rainfall and snowfall. Manitoba Hydro constantly monitors rainfall, river flows and lake levels to adjust operations to changing conditions.



Churchill and Nelson rivers watershed



Manitoba Hydro System

Types of Generating Stations

Load following: *A generating station where water discharges are increased during peak use times in the day to generate more electricity. This causes cycling of water levels.*

Run-of-the-river: *A generating station where the flow discharged downstream from the reservoir equals the inflow to the reservoir so that water is not stored for use later. Water flows through the system with very little cycling of water levels.*

Winnipeg River Operation

Manitoba Hydro's six generating stations along the Winnipeg River are operated primarily as run-of-the-river plants. That means that water flowing to them from upstream is used immediately over the course of the day and is not stored in the reservoirs for later use. Almost all of the flow of the Winnipeg River in Manitoba originates in Ontario and the Lake of the Woods

Winnipeg River at Pine Falls

Grand Rapids Operation

Grand Rapids is Manitoba Hydro's only generating station along the Saskatchewan River. As well as producing electricity, it is also the controlling station for the entire power system – meaning the units respond to short-term changes in the demand for electricity to keep supply and demand in balance. Grand Rapids operates with Cedar Lake as a reservoir allowing water to be stored during lower demand periods of the year for use during winter.

Grand Rapids reservoir

Lake Winnipeg Regulation and Churchill River Diversion

The Manitoba Hydro System is generally operated to maximize flows to the lower Nelson River during the winter to supply electrical generation when Manitoba's electricity demand is the highest. This means that Lake Winnipeg Regulation outflow from Lake Winnipeg at the Jenpeg GS and Churchill River Diversion outflow from Southern Indian Lake at the Notigi Control Structure are typically maximized for most of the winter season each year.

Operations during the spring, summer and fall are more variable and driven by changing inflows and other competing priorities as described above. During drought conditions, Lake Winnipeg Regulation and Churchill River Diversion outflows at Jenpeg and Notigi are reduced to conserve water in Lake Winnipeg and Southern Indian Lake to meet energy demands in the following winter. During flood conditions, outflows at the Jenpeg GS are increased to reduce flooding on Lake Winnipeg and excess water in Southern Indian Lake is released at the Missi Falls Control Structure.

Lower Nelson River Generating Stations

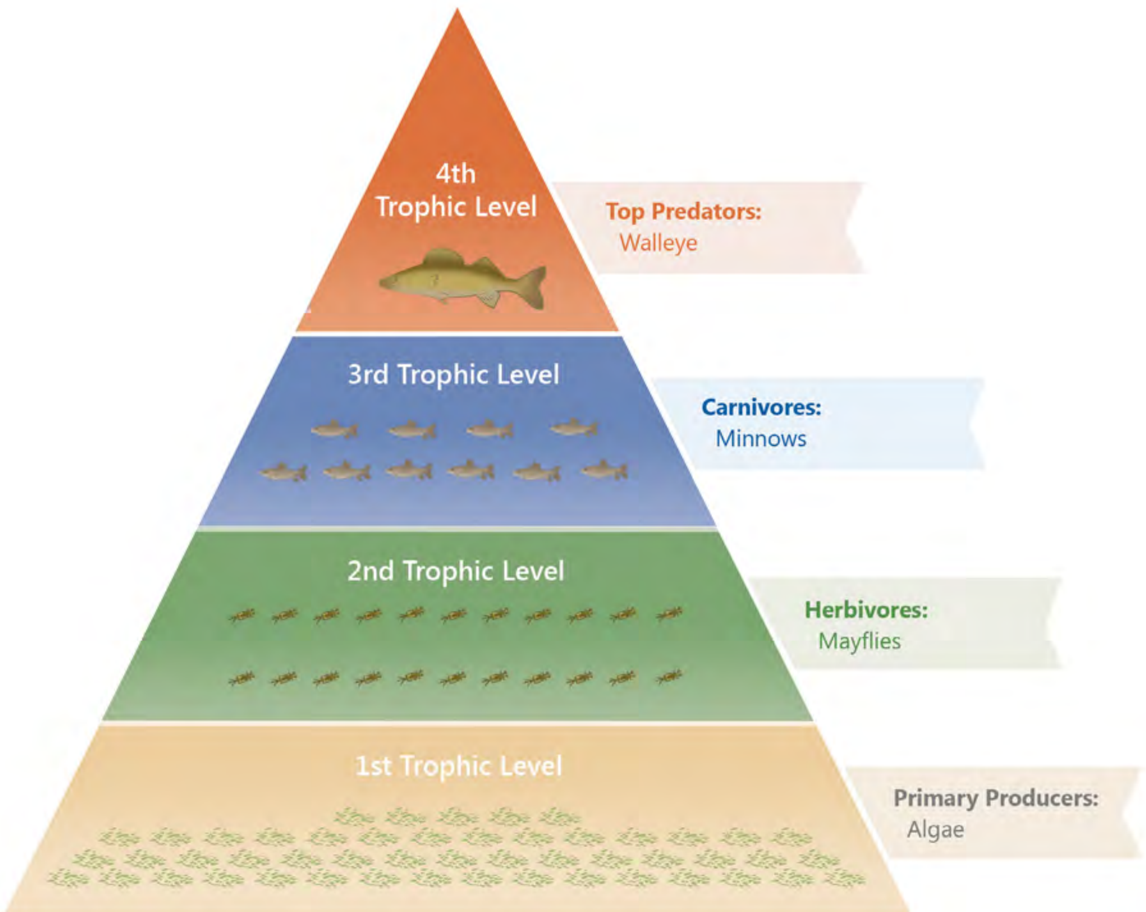
Manitoba Hydro operates the Kettle, Long Spruce, and Limestone generating stations with a daily cycling pattern to match daily and weekly energy production to consumption patterns. Flows are increased each morning and maintained until late afternoon or evening when they are decreased to reach lowest levels overnight.

Limestone Generating Station

Trophic Levels and Food Webs

What are Trophic Levels?

Trophic levels explain how energy is transferred through the ecosystem. The relationships between trophic levels are often shown as a pyramid, with layers from bottom to top. The trophic pyramid shows one example of how food energy enters an aquatic ecosystem and moves up to the top predators: invertebrates, in this case, mayflies, eat algae. Minnows then eat the invertebrates, and Walleye eat the minnows.



Aquatic ecosystem trophic pyramid

The bottom layer of the pyramid (the first trophic level) represents the primary producers, plants and algae that grow using the sun's energy. Primary producers are then eaten by herbivores, which make up the next layer (second trophic level) in the pyramid. In lakes and rivers, herbivores may be invertebrates, including microscopic zooplankton that eat algae in the water, or the larger benthic macroinvertebrates such as mayflies that consume algae floating in the water or graze attached algae on rocks. Since it takes many algae to feed one invertebrate, this second layer is smaller than the bottom layer.

Many kinds of larger invertebrates and small fish, such minnows and forage fish, form the third trophic level, the next layer of the pyramid. These carnivores eat the herbivores. If these invertebrates or fish are eaten by larger fish, these larger fish represent a fourth trophic level. Walleye is an example of a top predator that occurs in Manitoba's lakes and rivers.

One important trophic level in aquatic ecosystems that does not fit neatly into a layer on the pyramid is the detritivores. The detritivores include both bacteria that break down dead plants and animals, and also the animals that eat these bacteria.

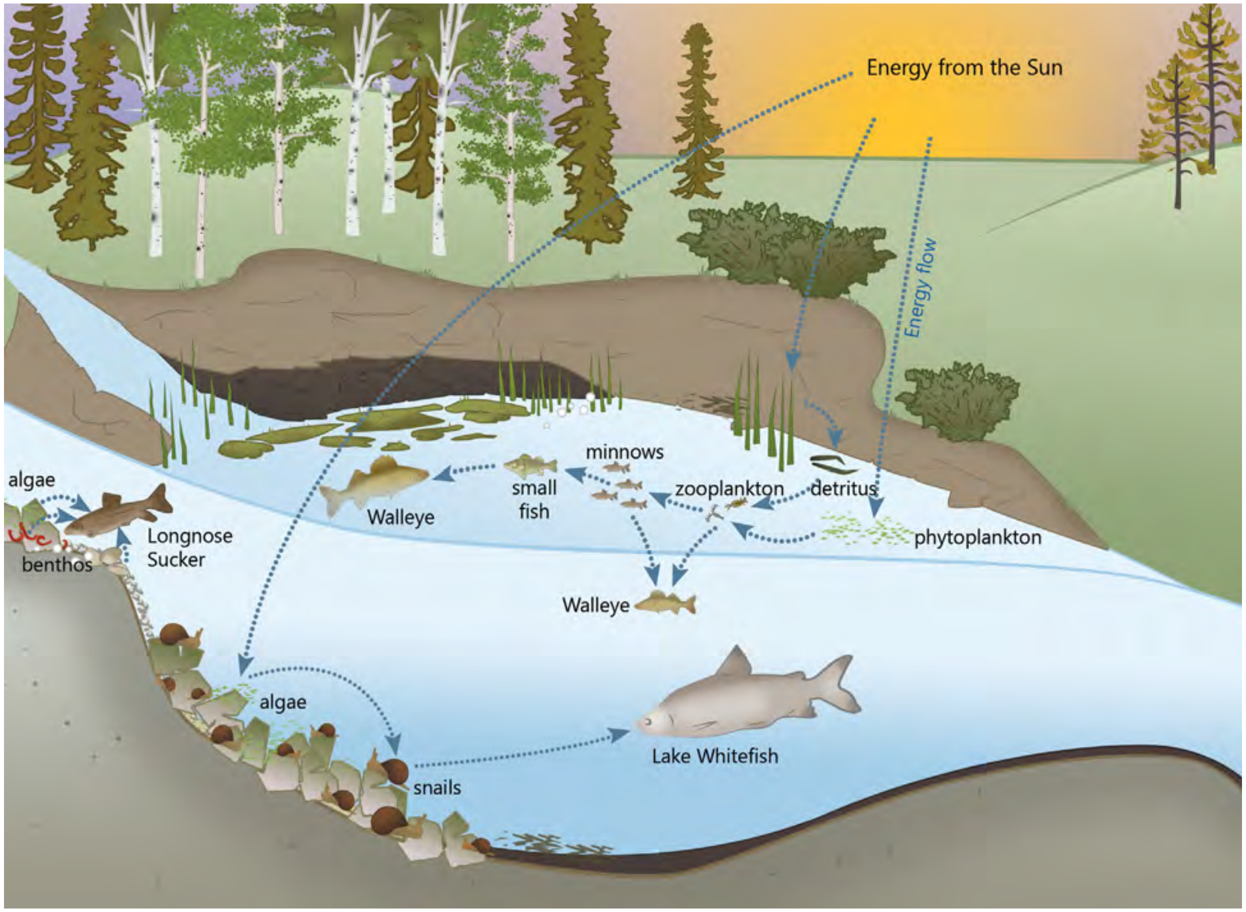
The aquatic ecosystem food web shown here is a simplified display of what happens in aquatic ecosystems because organisms in lakes and rivers often eat food at more than one trophic level. For example, adult Lake Whitefish eat invertebrates such as snails (herbivores), while Longnose Sucker eats both algae (primary producers) and benthos (herbivores) as parts of their diet. Some carnivores also change what level they feed at as they grow, a newly hatched Walleye drifts in the water and eats zooplankton, then switches from eating larger invertebrates (e.g., mayflies) to minnows and eventually other predatory fish.

Why is it important to understand trophic levels in an ecosystem?

Just like a pyramid with many layers, if one of the trophic layers in an ecosystem starts to shrink or otherwise change, it will affect the layers above and below it. If plants or invertebrates in an ecosystem start to die, there will not be enough food for animals in the third and fourth trophic levels. If a middle trophic level declines, then an over-abundance of the trophic level below it may occur.

Why are trophic levels important to the CAMP?

Monitoring conducted by the CAMP looks at organisms at many trophic levels – including algae in the water (measured in the water quality program), invertebrates (measured in the benthic macroinvertebrate program) and small forage fish and large predatory fish (measured in the fish community program). By looking at several different trophic levels, we will be better able to understand changes that may occur over time.



Aquatic ecosystem food web

Aquatic Ecosystem Health Indicators

The information gathered by the CAMP is extensive (for example, over 75 water quality parameters are analyzed). The first formal report produced was the Three Year Summary Report, which covered the Coordinated Aquatic Monitoring pilot program: 2008–2010. This report was intended to be comprehensive and examine all parameters measured as part of the CAMP to assist with selecting key parameters that appear to be most suitable for long-term detailed analysis. This report was approximately 4,000 pages long and it became apparent that future summary reports should focus on a smaller list of parameters for reporting. This is why a selection of key indicators was chosen.

The use of indicators for reporting on ecological conditions measured under large-scale, comprehensive monitoring programs is common practice and provides the advantage of a high-level overview of the system's integrity, highlighting key areas where mitigation or further investigation is required.

The CAMP is composed of seven components: hydrometrics, water quality, benthos (benthic macroinvertebrates), fish community, mercury concentrations in fish, phytoplankton and sediment quality. Four components form the core of the program: hydrometrics, water quality, benthos and fish community/ fish mercury.

In late 2014, the International Institute of Sustainable Development led a process to develop a short list of key indicators to focus reporting for the CAMP Six-Year Summary Report (2008-2013). The following table lists the key indicators that were selected for three (water quality, benthos, and fish) of the four core components of the CAMP.

Indicators of Aquatic Ecosystem Health

Water Quality	Benthic Macroinvertebrates	Fish
Total Phosphorus	Total abundance	Abundance – catch per unit effort (CPUE)
Total Nitrogen	Total number of families	Diversity
Phytoplankton (algae) & chlorophyll *a*	Proportion / composition of major groups	Growth – length; weight
Water Clarity – Total Suspended Solids	Number of Ephemeroptera (mayflies), Plecoptra (stoneflies) and Trichoptera (caddisflies) taxa	Condition – fatness, K-factor
Dissolved Oxygen (DO)	Diversity	Mercury – parts per million wet weight (ppm ww)

Water Quality

What is Water Quality?

Water quality refers to the chemical (e.g., nutrients such as phosphorus), physical (e.g., water temperature or the clarity of water), and biological (e.g., microbiological organisms) characteristics of water. Water quality reflects the local climate and natural characteristics of the surrounding drainage basin. Water quality is also affected by human activities in the drainage basin (e.g., agriculture, municipal and industrial developments) and through activities that directly affect a waterbody (e.g., changes to flows due to water withdrawal or hydroelectric development).

Seven Sisters Generating Station

Why is it Monitored?

Water quality is fundamentally important to all aquatic life, and is commonly monitored to gauge the health of aquatic ecosystems. Poor water quality may be harmful to aquatic life and may affect the condition, growth, survival and reproduction of freshwater organisms.

Sediment plume off eroding shoreline in Rat Lake

How Do We Monitor Water Quality?

Water quality is monitored by measuring conditions directly in the lakes and rivers using meters and probes (e.g., thermometers) and by collecting samples of water that are analysed with specialized instruments in a laboratory.

Water quality is measured four times per year to capture a range of conditions that vary seasonally, such as temperature or river flow. It also provides information on conditions during critical periods of the year, such as during the winter when dissolved oxygen concentrations may decline due to the ice cover. The program is not designed to detect results caused by specific precipitation events. As such, pulses of nutrients potentially associated with high precipitation events were not apparent due to the infrequent sampling schedule (i.e., 3 times per year in open water and once in the winter).

Sampling water off a float plane

Sampling water with a Kemmerer sampler

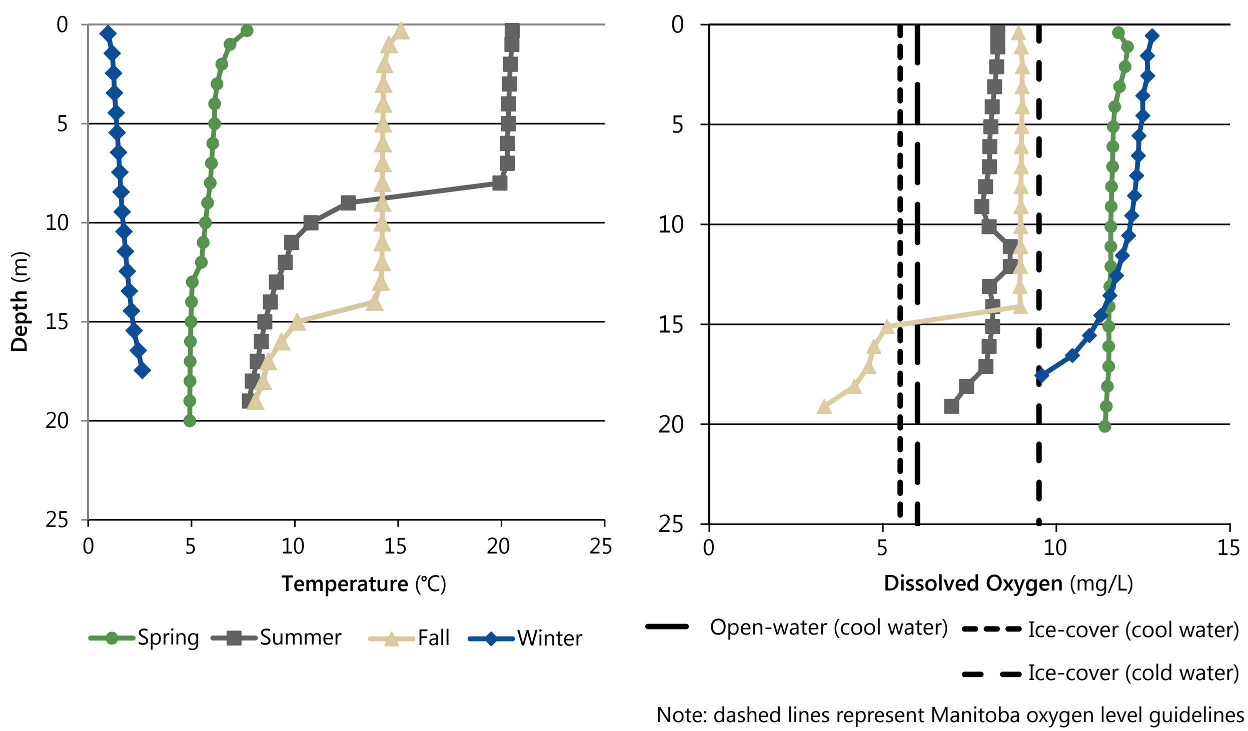
Winter water quality sampling at the lower Churchill River at the Little Churchill River

Why We Assess Water Quality

Some water quality parameters are essential to aquatic life, such as nutrients or dissolved oxygen, while others are non-essential (e.g., some metals such as cadmium). Water quality conditions that are suitable for aquatic life depend on a number of factors. These factors include the species present (some species are more sensitive than others), the life stages (e.g., fish eggs, embryos, mature fish), and other conditions (e.g., water hardness or temperature).

Some substances in surface waters may be harmful to aquatic life when outside of the desirable range. Water quality objectives or guidelines are often used as standards to gauge whether conditions pose a risk to aquatic life in lakes and rivers. The Province of Manitoba has developed water quality objectives and guidelines (provincial guidelines) for many water quality parameters; these can be used to assess the suitability of a waterbody to support aquatic life.

Some lakes stratify in the open water seasons; this is due to the different physical properties of the water layers. The top layer of the lake is warmer and less dense than the bottom layer and the two do not mix. Decomposition of organic material (e.g., from algal blooms) uses dissolved oxygen and decreases levels at the bottom of all lakes; however in stratified lakes the bottom layer is isolated from receiving a fresh supply of oxygen from wind mixing. In these lakes, levels of dissolved oxygen in the lower layer can drop below the provincial guidelines in some summers, autumns and winters. The off-system Manigotagan Lake is an example of a lake that stratifies.



Temperature and dissolved oxygen depth profiles in Manigotagan Lake 2011/2012

CAMP

Benthic Macroinvertebrates

What are Benthic Macroinvertebrates?

Benthic macroinvertebrates (commonly known as benthos) are small invertebrates that live in the sediments and on the rocks at the bottoms of lakes and rivers, and are large enough that they can be seen without a microscope (i.e., macroscopic, not microscopic). This group includes animals that spend their whole lives in the water (e.g., worms, snails, and clams) and also insects that spend the first part of their lives in the water and then transform into flying insects as adults (e.g., mayflies and dragonflies).

What Does Benthos Tell Us About the Conditions of Lakes and Rivers?

Generally, lakes and rivers that contain many different kinds of benthos are considered healthier. Some types of benthos can withstand adverse conditions, such as chemical pollutants and sediment from eroding banks, but other types of benthos are too sensitive to survive these changes to their environment.

Benthos is also an important part of the food web in lakes and rivers. They are an important intermediate trophic level, eating primary producers such as algae and microscopic groups such as zooplankton and in turn being eaten by many kinds of fish.

Dragonfly larva (Arthropoda) *Credit: Karl Kroeker*

Adult dragonfly *Credit: Karl Kroeker*

How Do We Measure Changes in the Number or Types of Benthos in a Lake or River?

Because benthos live underwater, they are not easily counted. Instead, a specialized grab sampler is used to capture them in scoops of mud taken from the bottom of lakes and rivers. In shallow water, a specialized net (kicknet sampler) is used to capture benthos when the bottom is stirred up.

The total number of individuals caught is referred to as benthos abundance. Benthos is then sorted into groups to figure out how many different kinds were caught (richness), and the numbers of benthos in each group are also compared (composition). Diversity looks at the number of groups present, as well as the relative abundance of each group.

Using a Kicknet for sampling benthos in nearshore areas

Using a Petite Ponar, a type of grab sampler, to collect mud with benthos in offshore areas

Clam, an example of the group, Bivalva

Credit: Karl Kroeker

Mayfly (fish fly larva), Ephemeroptera

Freshwater shrimp, Amphipoda

Groups used to classify Benthic Macroinvertebrates

Aquatic organism groups	Classifying groups
freshwater shrimp	Amphipoda
clams	Bivalva
midges	Chironomidae
diving beetles and water boatmen	Corixids
mayflies	Ephemeroptera
snails and slugs	Gastopoda
worms	Oligochaeta
stoneflies	Plecoptera
caddisflies	Trichoptera
crayfish	Arthropoda

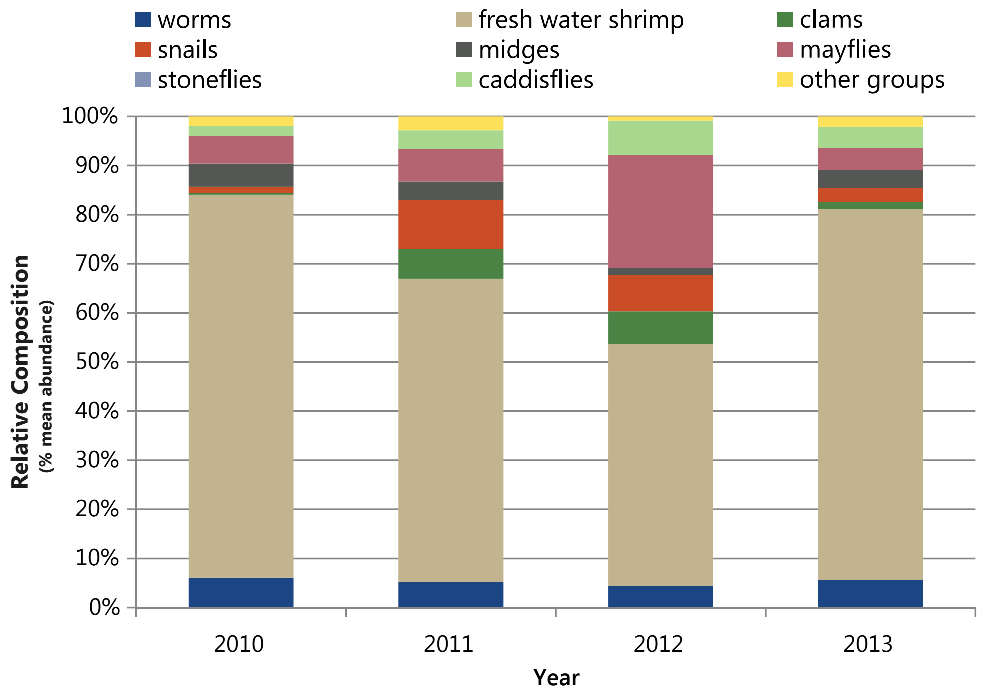
Why is Benthos a CAMP indicator?

In general, there is higher benthos diversity when the area is wetted longer or the habitat is more diverse in the nearshore. There is also a geographical gradient with benthos diversity decreasing going north. Over time, if the total number of benthic macroinvertebrates in a lake changes, if the number of different benthos groups decreases or the relative composition of the benthos groups changes, this can be a sign that the environment has changed.

Mayflies, stoneflies, and caddisflies are generally considered to be more sensitive while midges less sensitive to changes such as nutrient enrichment or low dissolved oxygen. If these changes are harmful to the benthos, they may also be harmful to other aquatic organisms such as fish.

Crayfish, an example of the group, Arthropoda

Diving beetle, Corixid



Relative composition of the benthos groups in the nearshore habitat of Lac Du Bonnet

Nearshore/Offshore

Nearshore: *Aquatic habitat occurring at the interface between a lake or stream and adjacent terrestrial habitat; usually includes areas up to 3 m in depth.*

Offshore: *Aquatic habitat located some distance from shore; usually greater than 3 m in depth.*

Fish as an Indicator

The fish community within a given waterbody may be one or two species in some Arctic environments and 30–40 species in temperate regions. These species, and the interactions between them, represent the fish community of a specific waterbody.

Why are Fish Monitored?

Fish occupy several trophic (feeding) levels in aquatic ecosystems and are common components of aquatic ecosystem monitoring. The fish community reflects the condition of the aquatic ecosystem as a whole, since various fish species require different habitat types, are dependent on production from lower trophic levels like invertebrates and algae, and are affected by changes. Many species of fish are directly important to people (i.e., harvested in Indigenous, commercial, and/or recreational fisheries).

What is Monitored?

Monitoring the fish community is a key component of the program. There were 48 different fish species sampled during the program. Monitoring targets both small-bodied fish species (i.e., forage fish such as minnows) and large-bodied fish species (e.g., Walleye and Northern Pike).

The program monitors fish community diversity as the number of species present in the community and the relative abundance of these species by how many fish are captured (total catch and catch of target species), fish size (lengths and weights), fish ages, and the condition (fatness) of the fish. Some of these indicators are measured for the whole fish community (i.e., fish species diversity, species composition, and abundance) while others (i.e., abundance, growth and condition) are directed at target species for analysis based on their importance to fisheries.

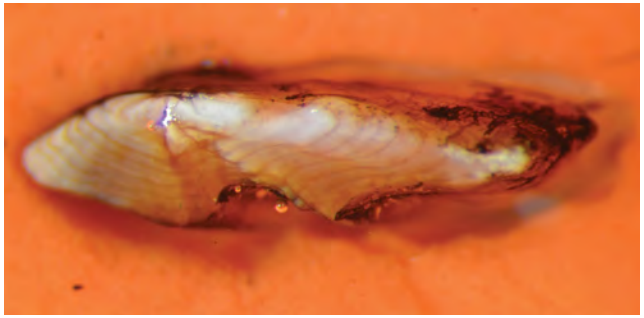
CAMP Top Predators and Target Fish

Species	Top predators	Target fish
Northern Pike	Yes	Yes
Walleye	Yes	Yes
Sauger	Yes	Yes
Channel Catfish	Yes	
Burbot	Yes	
Smallmouth Bass	Yes	
Yellow Perch	In some cases	
Brook Trout	In some cases	
Lake Whitefish		Yes

Spottail Shiner – one of the many species of minnows found in the sampled waterbodies

Northern Pike a type of large bodied predatory fish

Walleye showing a higher (top) and lower (bottom) condition (fatness)



Walleye otolith (inner ear bone) showing annuli or rings used to identify the age of the fish

How are Fish Monitored?

Monitoring is conducted every year at annual waterbodies and every three years at rotational waterbodies as part of the program. The fish community is monitored through use of standardized nets to allow for comparison between years. In fisheries and conservation biology, the catch per unit effort (CPUE) is an indirect measure of the abundance of a target species. Changes in the catch per unit effort reflect the changes in the species true abundance.

Gill net being pulled at Leftrook Lake

The CAMP monitoring regions are diverse in geography, land use, latitude and water management. This wide variety of features within and across regions, results in data that are also variable. As such, CAMP regions are not compared against one another; instead, CAMP was designed so that each waterbody would be compared to itself over time as monitoring data is acquired.

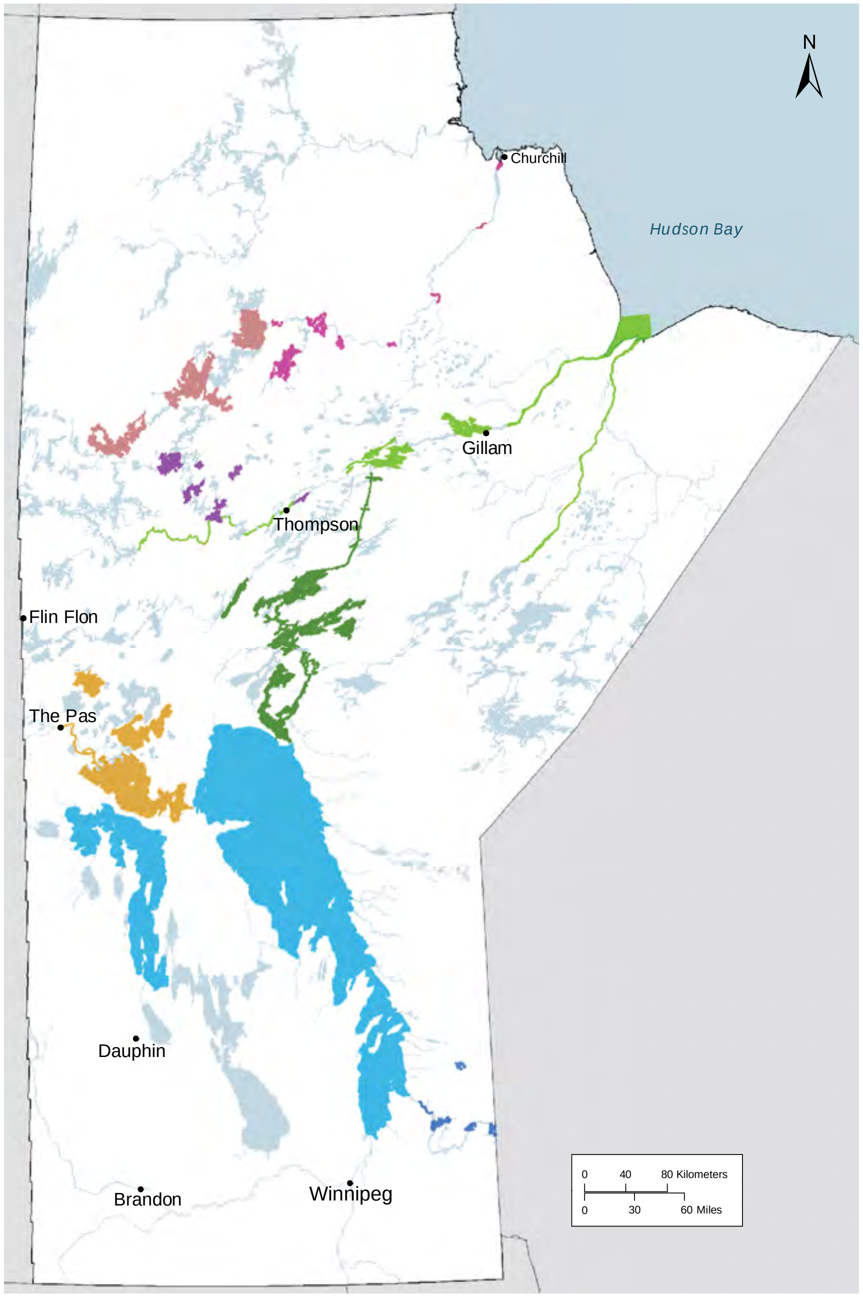
Although there are many regional differences in the data, some conditions are generally applicable to all regions. For example, total phosphorus frequently exceeds provincial guidelines in many managed and unmanaged Manitoba waters. As well, aluminum results are often high. These results would indicate that other factors (such as geology) and not just hydroelectric effects are present.

While the CAMP monitoring period covers 2008-2013, additional earlier water years were included in the hydrologic review to account for aquatic ecosystem processes that may be influenced by a lag period. To assess these components for the 2005-2013 discharges, the start and end dates of the annual freshet/high flows were documented to evaluate its timing and duration, and the date of the one day annual maximum discharge was identified to determine its timing and magnitude.

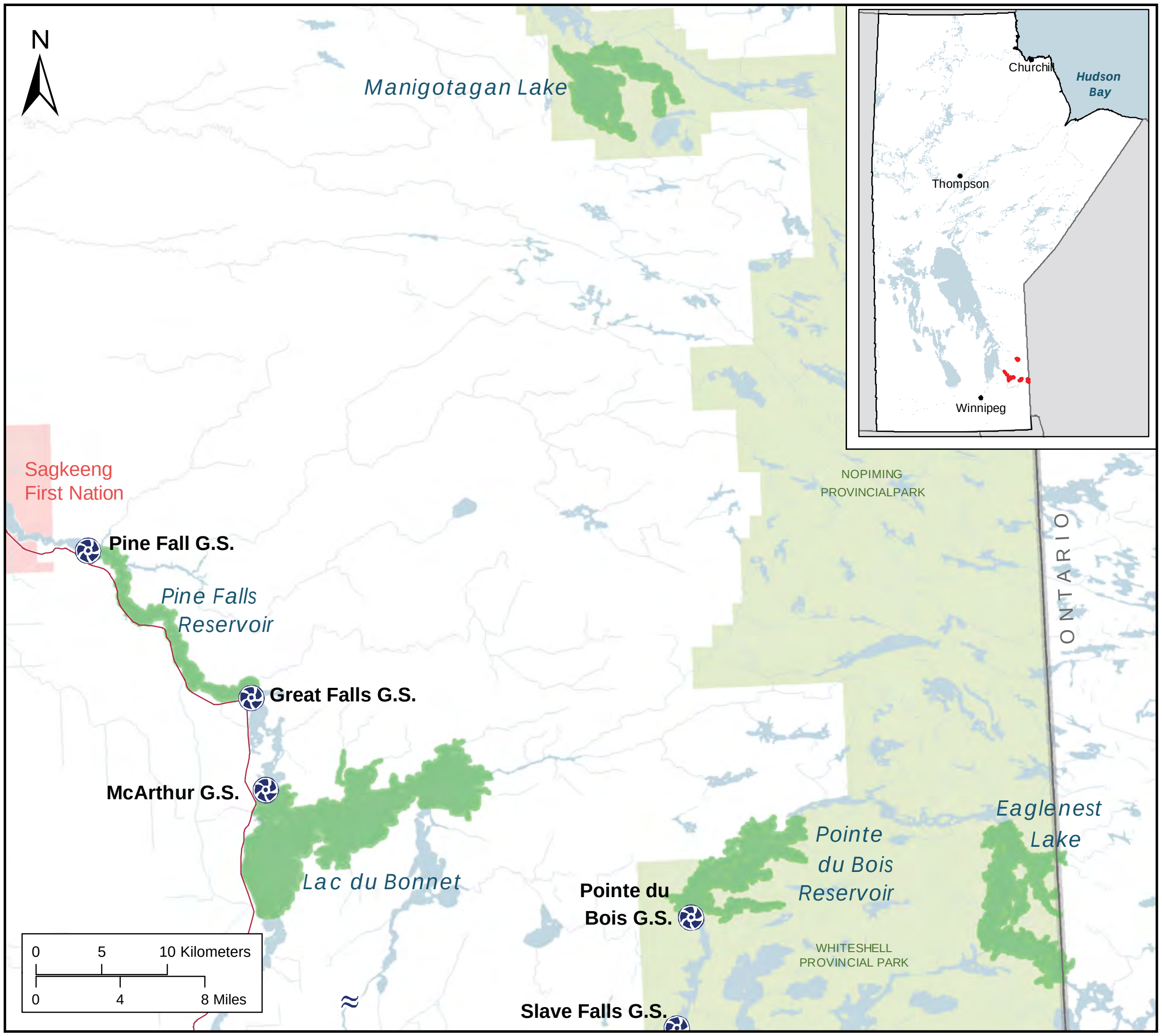
The benthic macroinvertebrate sampling design was modified in 2010 to better reflect ecosystem conditions and reduce variability. As such, benthic macroinvertebrate data are restricted to a four-year period (2010-2013), rather than the full six years.

- Winnipeg River Region
- Saskatchewan River Region
- Lake Winnipeg Region
- Churchill Diver Diversion Region
- Upper Churchill River Region
- Lower Churchill River Region
- Upper Nelson River Region
- Lower Nelson River Region

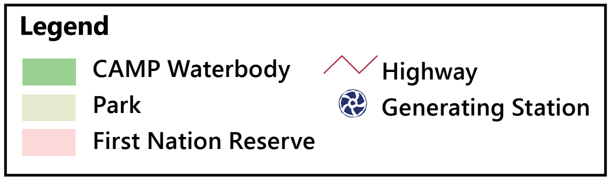
Note: The colours in the map correspond with the top coloured bands for the pages of each region.



Coordinated Aquatic Monitoring Program Study Regions



Winnipeg River Region



Sampling Sites

On-system monitoring

- **Annual** – Pointe du Bois Reservoir, Lac du Bonnet
- **Rotational** – Pine Falls Reservoir

Off-system monitoring

- **Annual** - Manigotagan Lake
- **Rotational** – Eaglenest Lake

Regional Highlights

- **Geography** – The Winnipeg River flows over the Canadian Shield, which is dominated by granitic bedrock and shallow soils. This causes rain to remain on the surface soil and quickly drain into the waterways.
- **Manitoba Hydro setting** – Generating Stations on the Winnipeg River are 60 to 100 years old with limited water storage in their upstream reservoirs. The large amount of property development along the shoreline means that water levels are held relatively steady and the generating stations are managed as run-of-the-river.

- **Hydrology** – River flows in this region are controlled by Lake of the Woods Control Board. There was a tendency for flows to be higher than average through the six-year reporting period. Peak flow and duration was variable through the open water season.
- **Observed Results**
    - Water is clear and generally within provincial guidelines.
    - Variability in benthos indicators did not appear to be related to changes in river flows. The composition of offshore benthos varied considerably among years and sites.
      It is unclear whether observed sampling differences are part of normal year to year variability or are related to the types of lake bottom that were sampled.
    - Fish community results were relatively stable through the six-year sampling period. An abundance of predatory fish in standard gill nets in both on- and off-system waterbodies suggests that the ecosystem has sufficient food to support top-level predators.

Eaglenest Lake, an off-system lake

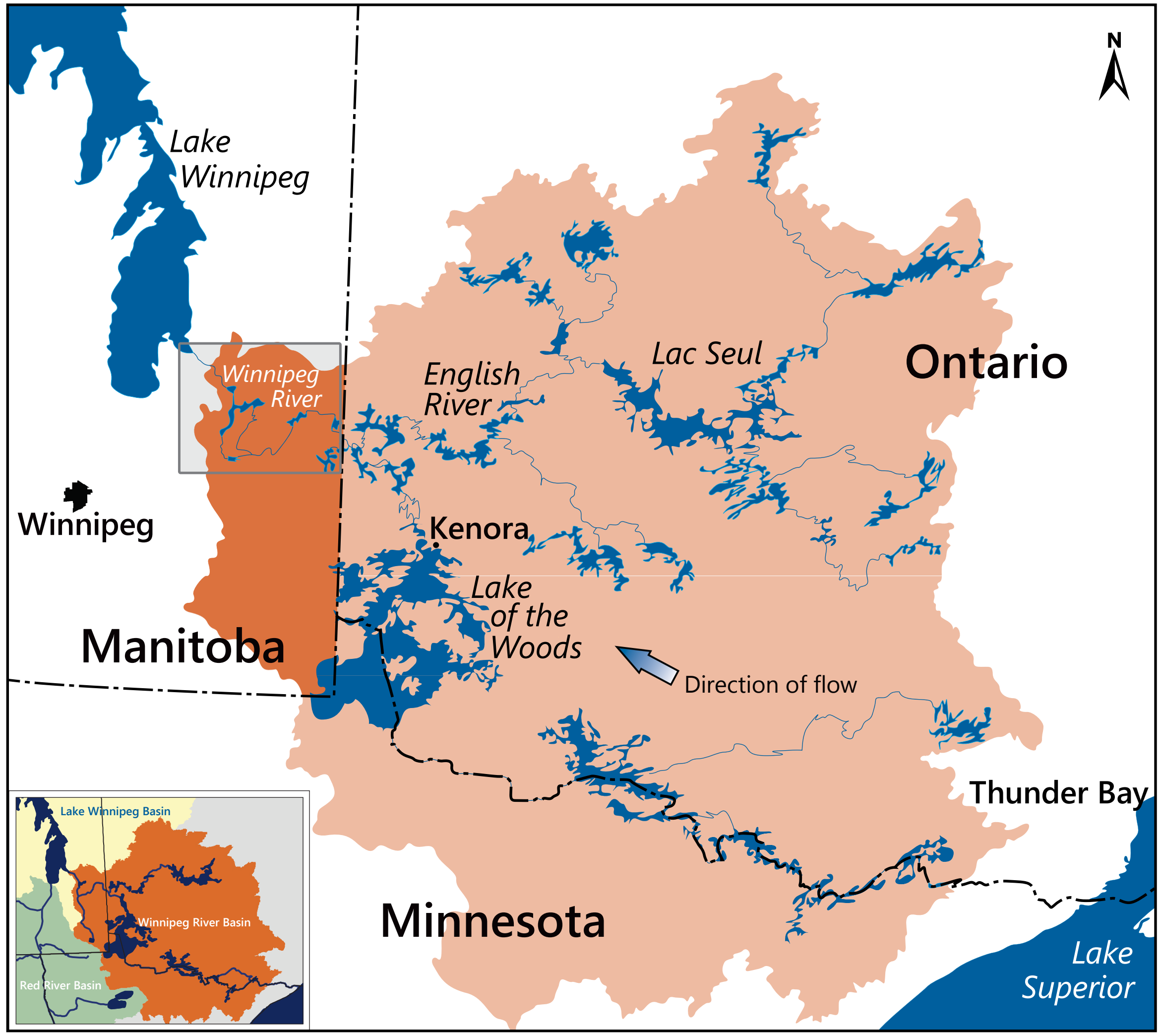
Winnipeg River Region Description

In Manitoba, the Winnipeg River region runs through the Boreal Shield Ecozone, which is mostly underlain by bedrock. The precipitation that falls in the drainage area quickly runs over the bedrock toward the Winnipeg River. The dominant land cover of the region is classified as mixed forest; however, peatlands with black spruce-sphagnum (moss) bogs are common.

Only 9% of the 137,000 km^2 of land drained by the Winnipeg River is in Manitoba. Seventy percent of the water in the Winnipeg River comes from northwestern Ontario with another 21% from Minnesota.

In the whole Winnipeg River drainage basin, international and interprovincial regulatory boards oversee water level and flow regulation. In Manitoba, there are six generating stations on the Winnipeg River, which have a relatively small capacity (56 to 165 MW).

The Winnipeg River Region is also well developed with towns and properties including abundant cottages on the shoreline throughout the length of the river in Manitoba. The upstream portion of the region runs through the Whiteshell Provincial Park while the downstream portion flows through agricultural land and through the Sagkeeng First Nation. Due to the abundant development along the shoreline, the water is managed to maintain relatively stable water levels.

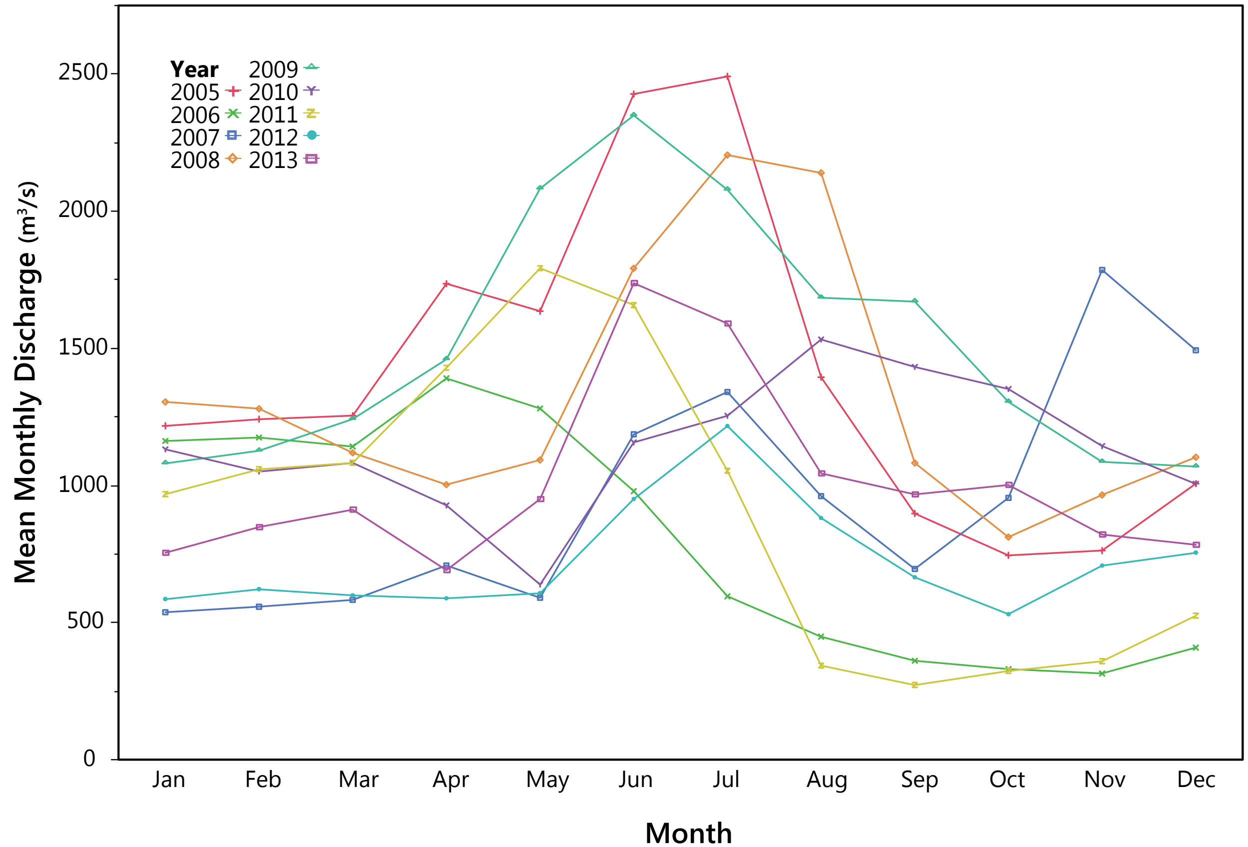


Winnipeg River Drainage Basin

Winnipeg River Hydrology

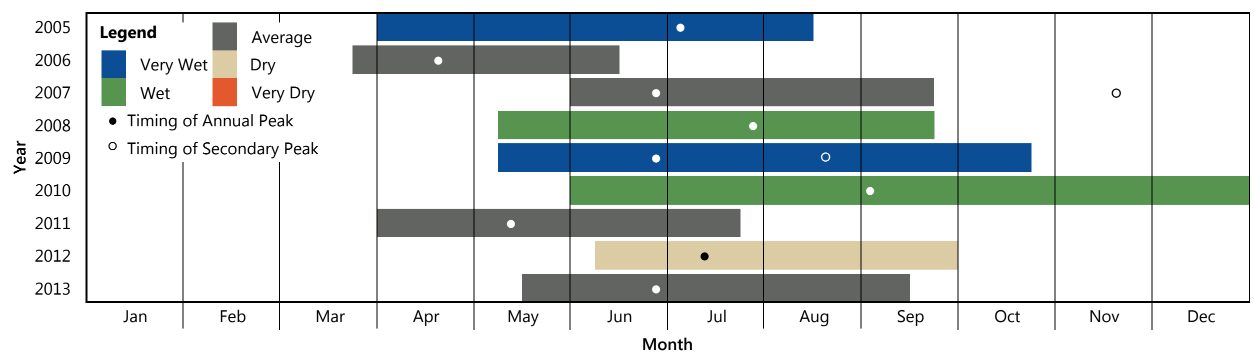
Winnipeg River stations are generally managed as run-of-the-river. The Pine Falls Generating Station mean monthly discharges were between 500-1,250 m^3/s from January to March. Discharges began increasing in April, peaking in summer and declining in September towards decreasing winter flows.

Mean annual flows from 1980-2013 were used to categorize years by wetness. During the six-year reporting period, there was a tendency to be wetter than the historical average conditions (see Appendix 1 for more information on hydrologic conditions).



Mean monthly Pine Falls Generating Station discharges 2005-2013

Manigotagan Lake, an off-system lake



Winnipeg River at Pine Falls Generating Station annual high discharge duration, timing and peaks

CAMP

Sediment Summary

Portions of the Winnipeg River that are outside of the reservoirs often include rocky cliffs with bays and mineral soil shorelines. Water levels vary more widely in these areas than in the reservoirs. Higher flows increase water levels in localized areas and erosion can cause shorelines to recede and release sediments into the water.

In general, the Canadian Shield bedrock does not contribute much sediment. The Winnipeg River hydroelectric generating stations were built in the early 1900s so the shorelines have had time to stabilize, decreasing erosion resulting in clearer water.

Ecosystem Hypotheses

The Winnipeg River flows through the Canadian Shield bedrock and on-system CAMP sampling sites are all in reservoirs that have stable water levels, erosion is expected to occur at low rates resulting in clear water. Similarly, nutrient levels are anticipated to be lower than a river that is enriched by sediment inputs.

The stable water levels should also mean that benthic macroinvertebrate habitat is consistently wetted and stable. Sampling should therefore yield more consistent results than sites where water levels are more variable.

The stable water levels and steady productivity of the lower trophic levels at the Winnipeg River sampling sites are expected to yield a stable and consistent fish community.

Results

Water Quality

There were no trends in the water quality parameters and water quality conditions did not appear to follow the flow patterns. Most water quality parameters measured in the Winnipeg River Region were within the provincial guidelines except for total phosphorous, aluminum, and iron. Occurrences of relatively high levels of these parameters is common in many on and off-system waters in Manitoba due to land-use practices (e.g., cultivation and drainage) and the soils and substrates that Manitoba rivers flow through.

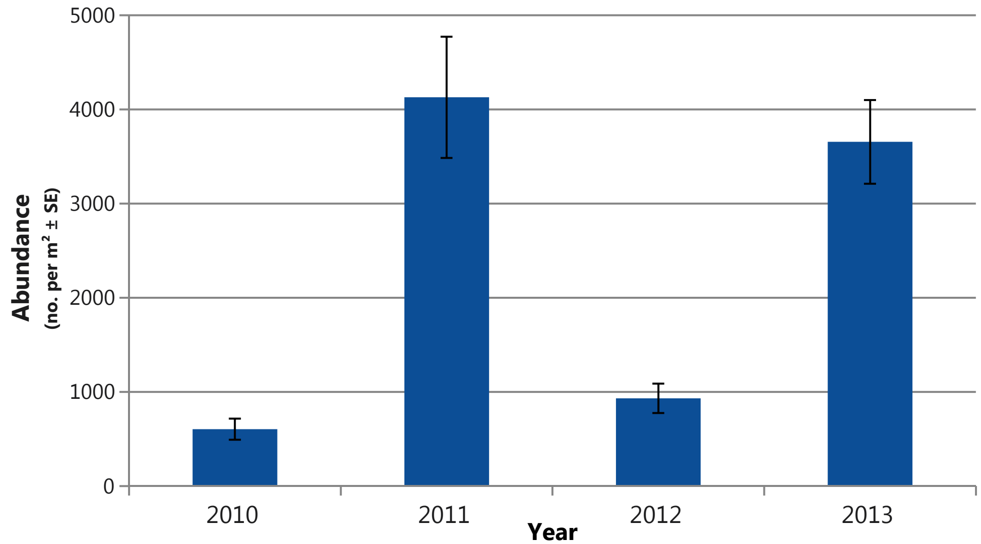
In general, the Winnipeg River sites were well-oxygenated with the only low oxygen occurrences noted in the off-system Manigotagan Lake, which stratified in the open-water-seasons – meaning the water column was not mixed. Levels of dissolved oxygen were below the provincial guidelines in the lower part of the water column in some summers, autumns, and winters.

Overall, water clarity decreased slightly (total suspended solids and turbidity increased) with increasing distance downstream but that did not seem to affect primary productivity and overall, the Winnipeg River was generally moderately to highly productive based on nitrogen, phosphorus, and chlorophyll *a* – an indicator of algal abundance.

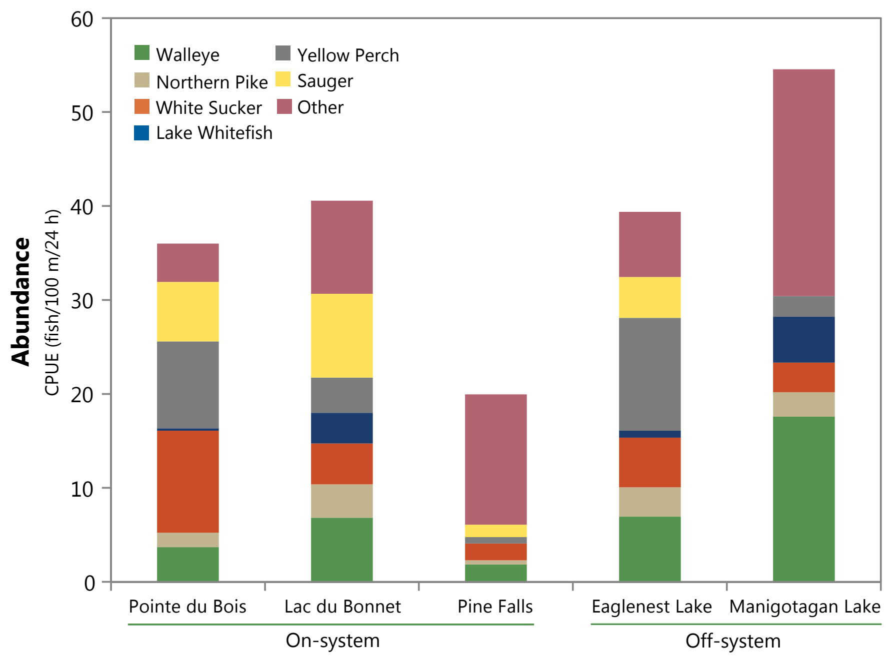
Benthic Macroinvertebrates

Variability in benthos indicators did not appear to be related to changes in discharge. Nearshore samples were generally dominated by freshwater shrimp with lesser numbers of other groups such as worms and larval stages of insects such as midges and mayflies.

The composition of offshore benthos varied considerably among years and sites. For example, benthic invertebrate density varied between years in the offshore of habitat of Pointe du Bois reservoir. The burrowing mayfly is commonly found in soft benthic substrates. Differences between years were due to high numbers of the burrowing mayfly, which has a one to two-year life cycle in this part of Manitoba. Benthos abundance in Manigotagan Lake was lower than the Winnipeg River sites.



Annual differences in benthos abundance in the offshore habitat of the Pointe du Bois Reservoir



Abundance of fish species in the Winnipeg River Region by waterbody

Fish

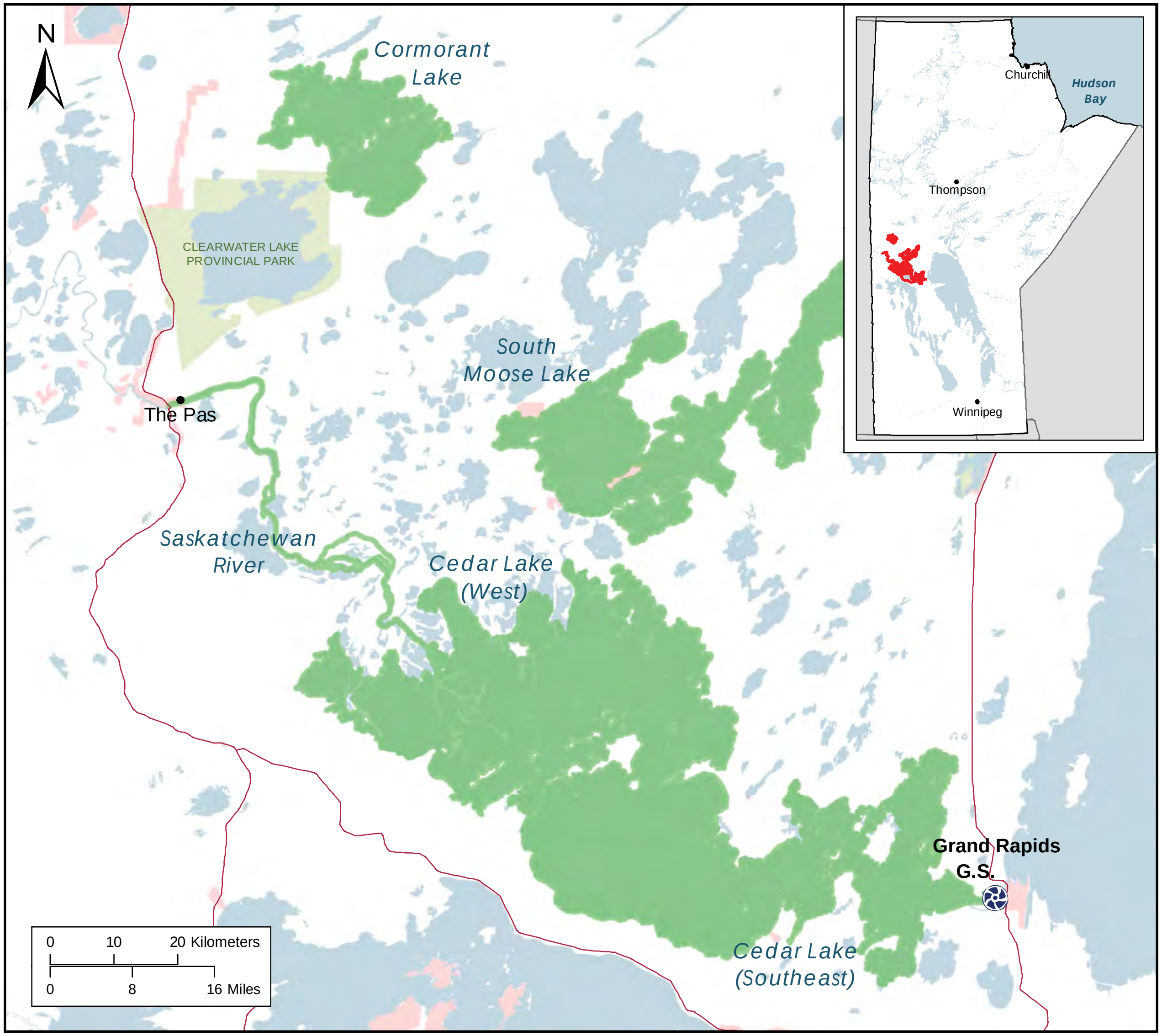
The most common large-bodied species in Lac du Bonnet and the Pointe du Bois Reservoir were Sauger, Walleye, White Sucker and Yellow Perch. Walleye, Sauger and Northern Pike were more abundant in Lac du Bonnet, while White Sucker were more abundant in the Pointe du Bois Reservoir. Gill netting results showed an increase in Yellow Perch and Spottail Shiner in Lac du Bonnet and the Pointe du Bois Reservoir between the 2008 to 2010 period and the 2011 to 2013 period. The growth rate of young Northern Pike, Sauger and Walleye was higher in Lac du Bonnet than in the Pointe du Bois reservoir. No trends were found between fish indicators and water flows and levels during 2008-2013.

Conclusions

- Results show that water quality in the Winnipeg River is mostly within provincial guidelines and is relatively clear.
- Fish community data suggest that a functioning ecosystem exists in that it supports all levels of the food web including predatory species like Sauger, Walleye and Northern Pike.

Future Considerations

- Expanding the use of habitat mapping will assist in understanding differences and similarities between waterbodies and sites.



Saskatchewan River Region

Legend

- CAMP Waterbody
- Park
- First Nation Reserve
- Highway
- Generating Station

Sampling Sites

On-system monitoring

- **Annual** – Cedar Lake, southeast basin
- **Rotational** – Saskatchewan River; South Moose Lake; Cedar Lake, west basin

Off-system monitoring

- **Annual** – Cormorant Lake

Regional Highlights

- **Geography** – The Saskatchewan River flows through the Boreal Plains and the prairies of western Canada. As a prairie river, the water has a significant sediment load and therefore it is naturally quite turbid.
- **Manitoba Hydro setting** – The Saskatchewan River flows east from Saskatchewan and into Cedar Lake, which is the reservoir of the Grand Rapids Generating Station. The Generating Station controls Cedar Lake water levels and outflows as the Saskatchewan River flows into Lake Winnipeg. It is a load following facility in that it is used to adjust flows and address smaller, short-term changes in power demand.

- **Hydrology** – Incoming flows are heavily influenced by upstream water management in Saskatchewan. There was a tendency for flows to be higher through the six-year reporting period. Peak flow and duration of the spring runoff could start as early as February but it peaked consistently in April.
- **Observed Results**
    - Water quality ranged from being more turbid upstream on the Saskatchewan River to being quite clear in Cedar Lake where suspended material settles out. Water quality was generally within the provincial guidelines.
    - The benthos community of the on-system lakes appeared to be influenced by the type of substrate. Overall, the invertebrate community showed remarkably little effect from overwinter water drawdowns on Cedar Lake and high flows on the Saskatchewan River.
    - The fish community had an abundance of predatory fish.

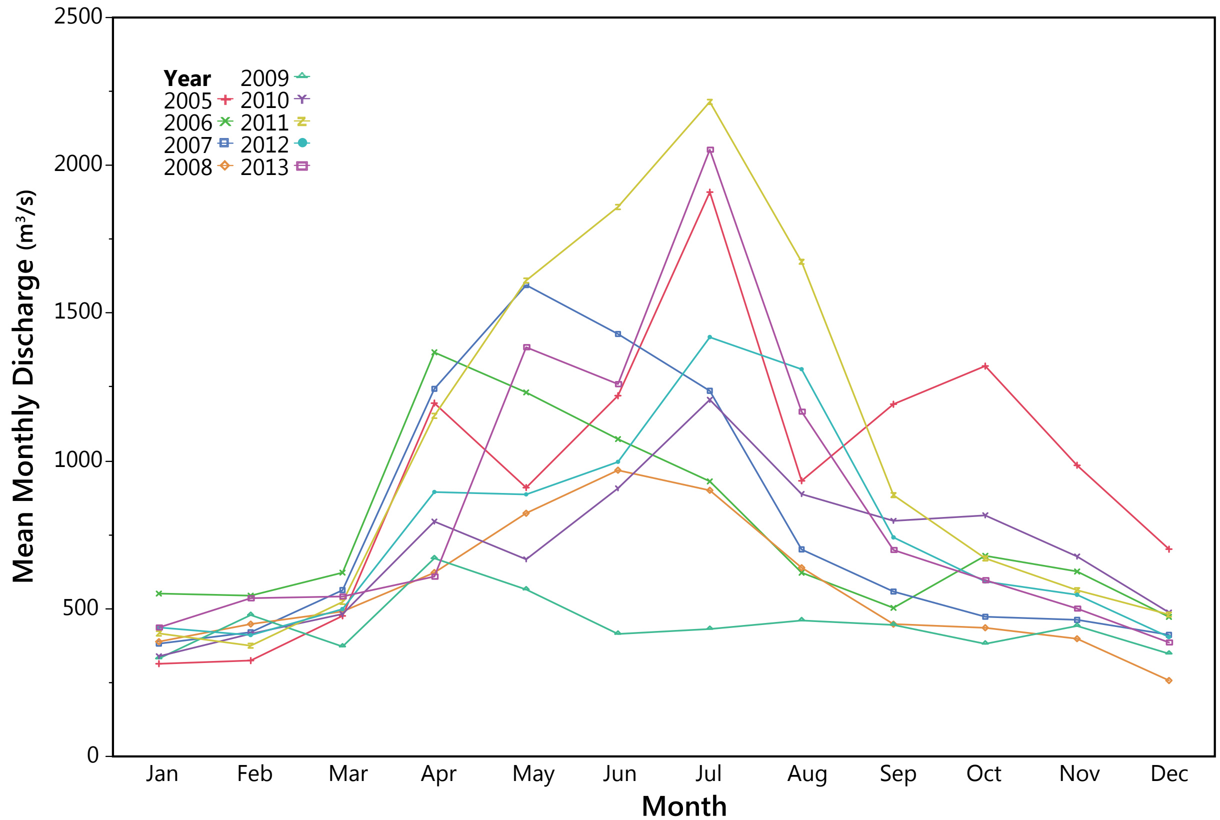
Cedar Lake, an on-system lake

Saskatchewan River Region Description

The Saskatchewan River drainage basin is 416,000 km^2 and covers much of the Boreal Plains and the western portion of the prairies of western Canada. Saskatchewan River flows entering Manitoba are influenced by precipitation in the Saskatchewan River basin and flows, which can originate as far away as the east-facing slopes of the Rocky Mountains.

Because the Saskatchewan River runs through the prairie region, it carries a lot of prairie soil as its sediment load. Within Manitoba, downstream of The Pas, the river slows depositing much of that sediment into the Saskatchewan River delta (which is a large complex of shallow lakes, river channels, fens, marshes and forested embankments) before flowing into Cedar Lake.

The dominant land cover of much of the upstream watershed is cultivated crops. To support land uses and hydroelectric power generation there are several reservoirs along the river that affect sedimentation processes, evaporation and flow dynamics. For example, Lake Diefenbaker in Saskatchewan is used for irrigation and local water supplies and Tobin Lake was formed by the construction of SaskPower's E.B. Campbell Hydroelectric Station. Water slows in these reservoirs and sediment settles to the bottom. Downstream in Manitoba, the flow dynamics on the Saskatchewan River and Cedar Lake are impacted by those upstream activities as well as local hydroelectric development. In Manitoba, the Saskatchewan River and Cedar Lake are regulated by the Grand Rapids Generating Station, which is located at the mouth of the Saskatchewan River where it flows into Lake Winnipeg. Grand Rapids Generating Station is a load following facility in that it is adjusted to address smaller, short-term changes in power demand.



Mean monthly flows in the Saskatchewan River at The Pas 2005-2013

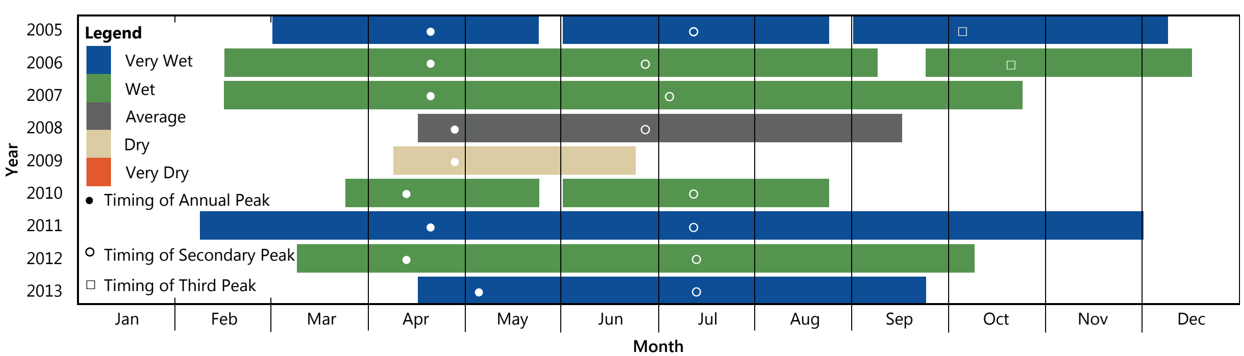
Saskatchewan River Hydrology

Mean monthly flow records from the Saskatchewan River gauging station at The Pas were used; flows were between 250 - 600m^3/s from December through March each year. Spring flows, which are important for many ecological processes generally, increased beginning in April, peaking between 1,000 and 2,250m^3/s during the spring and summer.

While the annual increase in spring high flow events can start as early as February, the one-day annual peak flows occurred during April in all years except for the very wet year of 2013, which peaked in May. Additional subsequent peaks were also observed most years.

Mean annual flows at The Pas from January 1980 – December 31, 2013, were used to categorize years from "very wet" to "very dry". Seven of the nine years were "wet" or "very wet". In contrast, there were only three "wet" years and no "very wet" years during the preceding 25 years (Appendix 1).

While Cedar Lake water levels were generally within the normal range from 2008 – 2013, there were some notable higher and lower water level exceptions. South Moose Lake water levels remained generally within normal limits.



Saskatchewan River at The Pas annual high discharge duration, timing and peaks

Sediment Summary

Sediment transport in the Saskatchewan River at The Pas is approximately half of what it was prior to construction of the dams upstream in Saskatchewan.

Upstream changes in the flow regime have also affected the timing of peak sediment loads. Review of the sedimentation processes of Cedar Lake and Moose Lake show that the vast majority of sediment is deposited before it reaches Lake Winnipeg.

Sediment sample from the Saskatchewan River

Ecosystem Hypotheses

The Saskatchewan River drainage basin in Manitoba is a large complex of shallow lakes, river channels, bogs, fens, marshes and forested embankments. The diversity of this geography makes it difficult to understand completely the ecosystem dynamics in this region. It is difficult to separate out the effects on ecosystem health and function of Grand Rapids operations from upstream water management.

Most of the CAMP sampling in this region has occurred on the southeast basin of Cedar Lake. Much of the sediment load in the Saskatchewan River including nutrients, settle in Cedar Lake resulting in quite clear water in the lake.

Given that Cedar Lake was enlarged by the flooding of Saskatchewan River delta habitats, it was thought that the deeper water would have soft and poorly oxygenated substrates from the decomposition of organic materials. That would then yield an abundant but not very diverse benthos community. Cedar Lake water levels are also drawn down during winter, which might affect nearshore benthos abundance and diversity (i.e., more exposure, drying and freezing than the offshore sites).

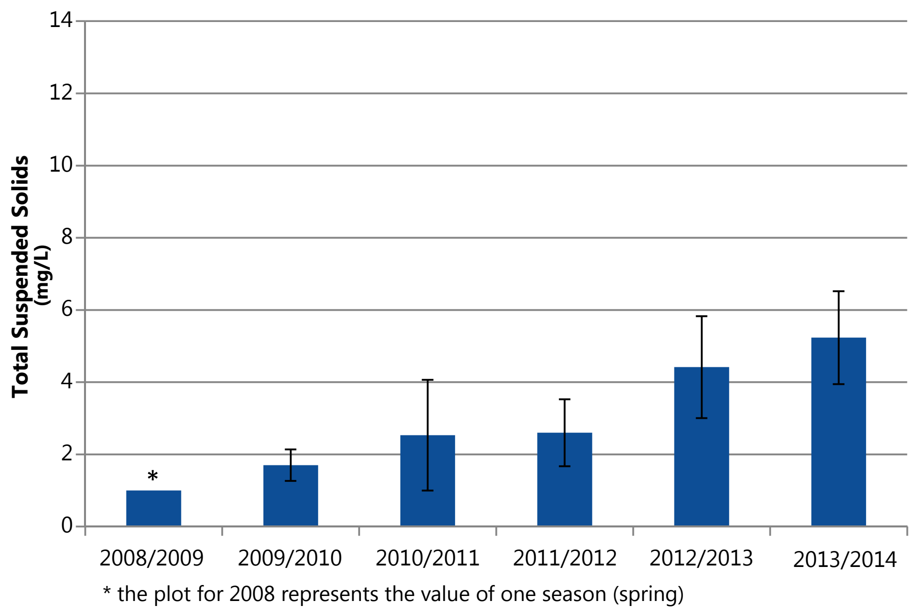
The longstanding commercial fishery targets top predators like Walleye and Northern Pike. The winter water drawdown could dewater shallow areas that might affect the survival of Lake Whitefish eggs that overwinter in those types of areas. If that were the case, then those years with notable winter drawdowns (e.g., winter of 2008/09) would be associated with poor survival of Lake Whitefish eggs and a reduction in the 2009 year-class.

Results

Water Quality

While the available data suggest some water quality parameters may be related to seasonal cycles and/or water levels in Cedar Lake, additional data are required to confirm these preliminary observations. Overall, on-system lakes and the Saskatchewan River were well-oxygenated and generally did not stratify during the open-water seasons. Most water quality parameters in the Saskatchewan River were within the provincial guidelines. However, aluminum and iron exceeded these guidelines, which are common in other Manitoba lakes and rivers, including off-system sites monitored under the CAMP.

Low dissolved oxygen concentrations (i.e., below provincial guidelines) were observed during the winter months near the bottom of the water column in South Moose Lake and in some winters in the southeast basin of Cedar



Total suspended solids in Cedar Lake southeast basin

Lake. In comparison, the off-system Cormorant Lake was more frequently stratified and prone to oxygen depletion during both open-water and ice-cover seasons.

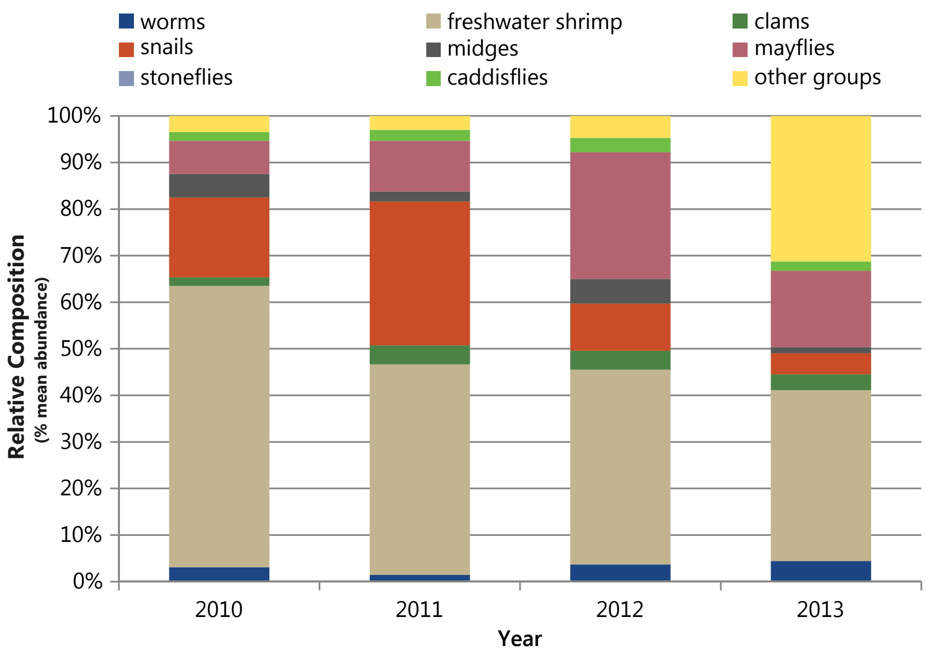
On-system sites in the region had moderate to high nutrient and chlorophyll *a* concentrations, with Cedar Lake – west showing higher levels than South Moose Lake. The Saskatchewan River was even more nutrient-rich and contained similar levels of algae to Cedar Lake. No samples collected in South Moose Lake or the off-system Cormorant Lake had total phosphorus concentrations outside of the provincial guidelines. The other sites showed some levels of phosphorus above the provincial guidelines.

There was a slight trend to increased sediment (and therefore decreased water clarity) over the six-year sampling period. Geographically, sediment and nutrient levels decreased from the Saskatchewan River to the southeast area of Cedar Lake as suspended materials settled within Cedar Lake.

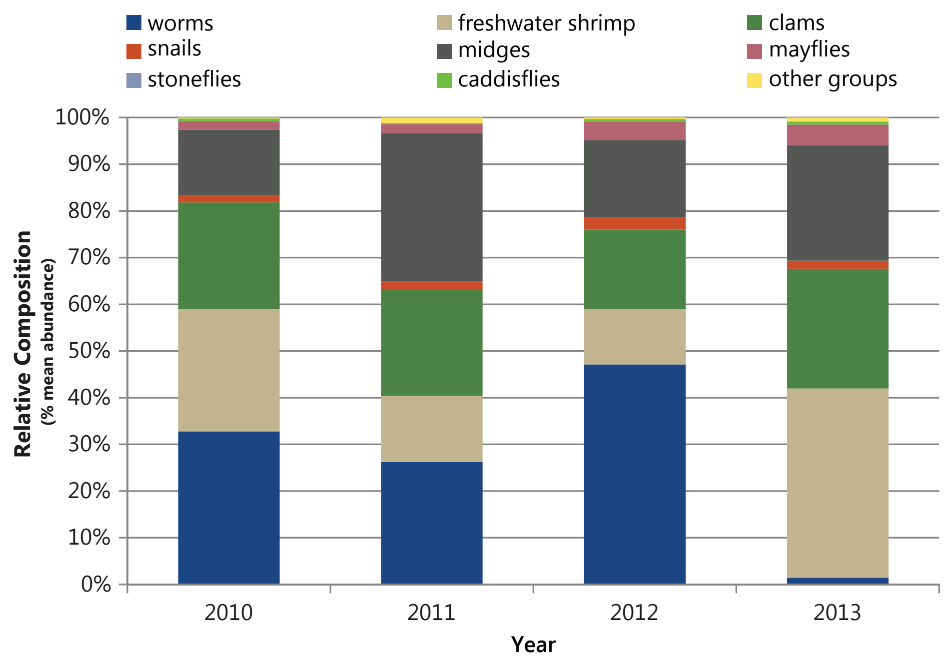
Benthic Macroinvertebrates

In general, the benthos community of the on-system lakes was dominated by freshwater shrimp, with varying amounts of other groups such as mayflies, snails and, in some sites, worms, in the cobble nearshore habitat, and primarily worms, midges, freshwater shrimp and clams in the fine-textured sediments of the offshore habitat. Non-insects were often more abundant than insects.

In the Saskatchewan River upstream of Cedar Lake, the benthos community was less diverse

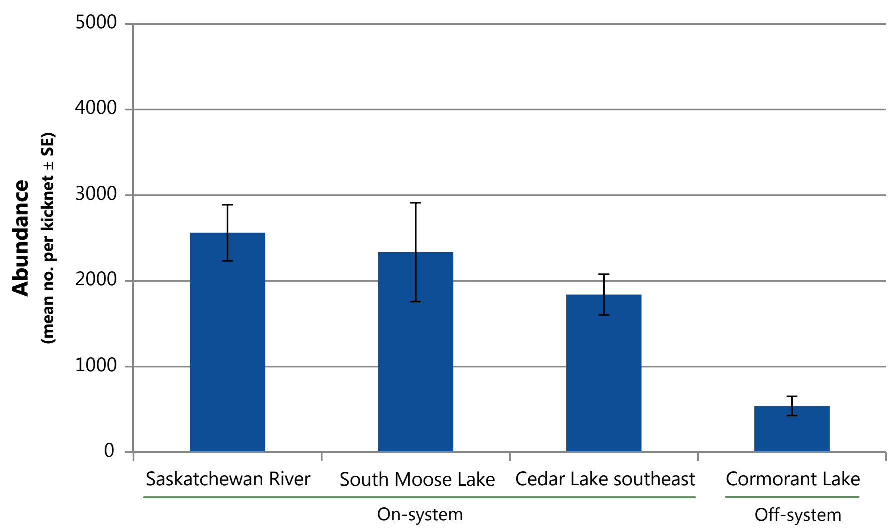


Relative composition of benthos groups in the nearshore habitat of Cedar Lake southeast basin



Relative composition of benthos groups in the offshore habitat of Cedar Lake southeast basin and was dominated by worms and one genus of mayflies in the nearshore environment. The low diversity was attributed to habitat as the river site had a silty clay substrate.

Contrary to our hypotheses, drawdown during the winter on Cedar Lake and high flood flows on the Saskatchewan River showed remarkably little effect on the nearshore benthos community, in terms of total abundance, richness and diversity. Moreover, benthos abundance, richness and diversity in the highly regulated Cedar Lake were comparable to, or greater than lakes that experienced less or no flow regulation effects, such as the upstream, on-system South Moose Lake; and the off-system Cormorant Lake.



Note: the Saskatchewan River site was sampled with a benthic grab sampler, units are mean no. per m^2

Abundance of benthos at each nearshore site in the Saskatchewan River Region 2010 to 2013

Fish

The common species in the on-system waterbodies were typically White Sucker, Walleye and Northern Pike, with Cisco, Yellow Perch and Sauger common in some waterbodies. The abundance of predatory species like Walleye, Northern Pike and Sauger at the top of the food chain suggests a functioning ecosystem with sufficient food.

The abundance of fish captured in standard gill nets was lowest in the Saskatchewan River, which probably reflects the lower biomass of fish typically found in a river, and the limitations of netting in faster flowing water.

In general, there was some variation between years in the fish community of both the on-system (Cedar Lake, southeast basin) and off-system (Cormorant Lake) waterbodies that were sampled annually. While a few trends were identified, six years of sampling is not sufficient to distinguish between natural variability and long-term trends. Continued sampling should help clarify if observed trends are ecologically relevant.

Few Lake Whitefish were caught in the Cedar Lake southeast basin. While more Lake Whitefish were sampled in South Moose Lake. It must be noted that fall sampling in South Moose Lake may have biased catches towards more Lake Whitefish, which are a fall spawning species and may have been more active during fall. It is unclear whether the low abundance of Lake Whitefish in Cedar Lake is a product of available habitat, winter drawdown effects, historical and ongoing harvest activity, food web changes, or some combination of each.

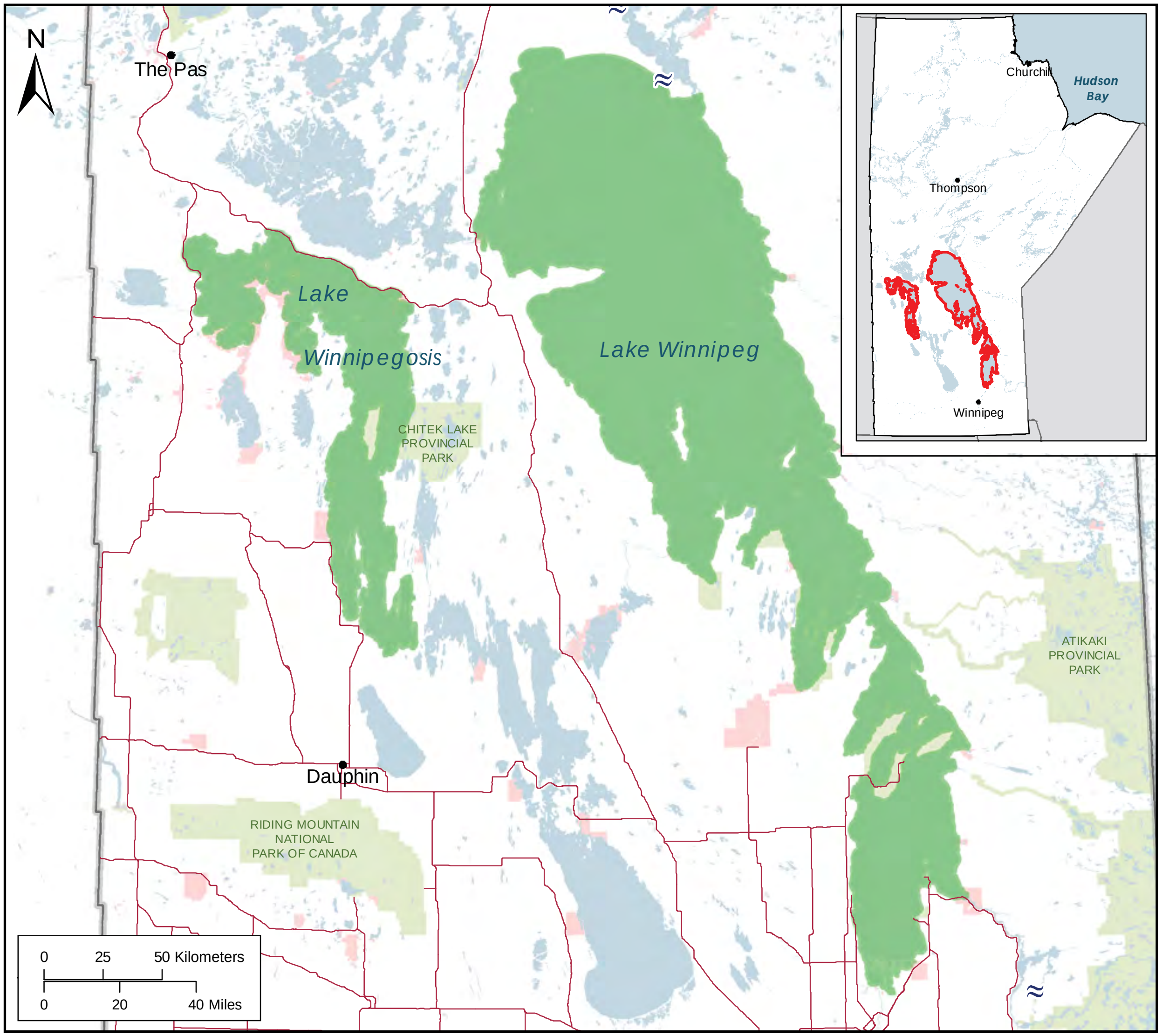
Conclusions

- The CAMP sampling seems to indicate that the Saskatchewan River's aquatic ecosystems are resilient to operational changes and are functioning with water quality that is generally within provincial guidelines, abundant benthos communities and fish communities with relatively abundant predatory fish at the top of the food web.
- Continued program monitoring relative to hydrology and flow should help increase the understanding of effects that upstream flow management, precipitation and inflow rates, and hydro operations have on Saskatchewan River ecosystem health.

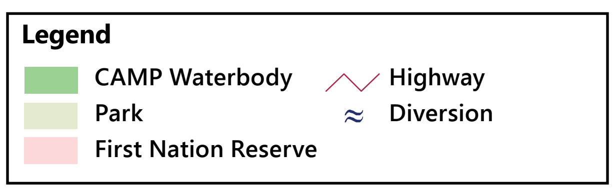
Future Considerations

- Benthos communities are dependent on substrate type. Habitat depth and substrate mapping will be conducted to increase the understanding of the lower trophic level communities with respect to the water flow and level effects on near and offshore benthos.

Cormorant Lake, an off-system lake



Lake Winnipeg Region



Sampling Sites

On-system monitoring

- **Annual** – Grand Rapids; Sturgeon Bay; Mossy Bay

Off-system monitoring

- **Annual** - Lake Winnipegosis, north and south basin

Regional Highlights

- **Geography** – Lake Winnipeg is the largest lake in Manitoba and the tenth largest freshwater lake in the world. The water is rich in sediments because Lake Winnipeg is a shallow lake. Sediments are mixed frequently due to wind generated waves and the currents within the lake.
- **Manitoba Hydro setting** – While the primary reason for undertaking Lake Winnipeg Regulation was to reduce overland flooding in the southern part of Manitoba, Lake Winnipeg is Manitoba Hydro's largest source of water for power generation. Outflows are managed through constructed drainage channels and flow releases at Jenpeg Generating Station. Lake Winnipeg waters are typically managed to ensure that flows released during the winter can meet Manitoba's local power demands.

- **Hydrology** – Incoming flows are heavily influenced by upstream water management in multiple jurisdictions (provincial, national and international). Inflows were high during the six-year reporting period, and lake water levels were likewise higher than average.
- **Observed Results**
  - Water in the north basin of Lake Winnipeg is quite clear and water quality is generally within provincial guidelines. Nutrient levels are high, largely due to inflow from the Red River. Occasional low oxygen levels were observed.
  - The benthos community appeared to be heavily influenced by the substrate with differences between Grand Rapids and Mossy Bay sites. Overall, total abundance, richness and diversity, was not related to water levels.
  - The fish community sampling revealed a relatively stable fish community with an abundance of predators. The condition of Walleye fish may have been affected by the reduction of one of their food sources, Rainbow Smelt.

The MV Namao is used for collection of water quality samples in Lake Winnipeg

Lake Winnipeg Region Description

With a total surface area of 23,750 km^2, Lake Winnipeg is the largest lake in Manitoba and the tenth largest freshwater lake in the world. Water flowing to Lake Winnipeg comes from the second-largest drainage basin in Canada, covering almost 1,000,000 km^2.

The majority of the Lake Winnipeg watershed flows through sedimentary landscapes with semi-arid and temperate prairies throughout. These landscapes include croplands with some grasslands extending back to Alberta, Saskatchewan, Ontario, Montana, North Dakota, South Dakota and Minnesota. See the Churchill and Nelson rivers watershed map (p. 7), which includes the Lake Winnipeg basin. Lake Winnipeg lies within the Boreal Plain Ecozone, with portions of it in several ecoregions.

Lake Winnipeg supports large commercial, domestic food and recreational fisheries, as well as other recreational activities and residential lakeshore communities. The lake also has a long history of inflow water management going back to the late 1800s. Drainage and water control projects in Ontario, Manitoba, Saskatchewan, Alberta, Minnesota and North Dakota have all affected natural inflows to the lake.

In Manitoba, generating stations were first constructed 100 years ago along the Winnipeg River. Lake Manitoba flows into the Dauphin River were first regulated by the Fairford Dam (a control structure operated by the provincial government) in the early 1960s. The Grand Rapids GS was completed in 1968 affecting Saskatchewan River inflows.

Since the late 1970s, outflows have been controlled by drainage enhancement works and the Jenpeg GS. This is known as the Lake Winnipeg Regulation project and it has provided flood control for Lake Winnipeg communities as well as being a critical component of Manitoba Hydro's system operation.

Land use practices have also affected the water. Nutrients carried into the lake from the Red River are largely responsible for the heavy algal blooms on Lake Winnipeg. This issue is extensively monitored by other programs and Manitoba Hydro's regulation of the outflow of Lake Winnipeg is considered small in comparison to the changes resulting from increased nutrient inflow in the Red River.

On-system CAMP sampling in the Lake Winnipeg Region is restricted to the north basin of Lake Winnipeg at three sites. This is because a very large and longstanding Federal – Provincial Lake Winnipeg Basin initiative was already focused on Lake Winnipeg when sampling began. Creating an overlapping program was not viewed as beneficial and therefore sampling is restricted to a small sampling program using the CAMP protocol to provide some information to compare with the other CAMP sampling sites and the longstanding Lake Winnipeg data collection programs.

Isostatic rebound: *The rising of a land surface following the removal of the enormous weight of glacial ice.*

Wind effects: *Sustained high winds from one direction push water levels up at one end of the lake with a corresponding drop in the water level at the opposite end.*

Lake Winnipeg Hydrology

The Winnipeg and Saskatchewan rivers account for 75% of Lake Winnipeg's inflow with the Red, Assiniboine, Dauphin, Pigeon and Berens rivers, etc. adding the remaining 25%. While Manitoba Hydro manages some of the flow of the Winnipeg and Saskatchewan rivers, the rain that falls in the drainage basin flows into Lake Winnipeg.

Lake Winnipeg continues to be shaped by the after effects of the glacier that formed it. Uplift due to isostatic rebound is occurring at a greater rate in the north where the glacier disappeared last. This is slowly raising the outlet into Playgreen Lake. As the lake "tips" very slowly it is promoting shoreline erosion at the south-end of the lake.

Lake Winnipeg water levels are influenced by short changes resulting from evaporation and wind effects. Over a longer time scale, the effects of climate change will also change inflows and inflow timing into Lake Winnipeg.

Outflows from Lake Winnipeg are managed by Lake Winnipeg Regulation depending on Lake Winnipeg's water level. When the water is higher than an elevation of 715 ft, Jenpeg GS is operated to maximize discharge out of Lake Winnipeg. This results in higher outflows from Lake Winnipeg. When Lake Winnipeg is below 715 ft but above 711 ft, upper Nelson River flows are generally managed for power production, which typically means higher outflows during the winter and lower outflows during the open water period. Should the level of Lake Winnipeg drop below 711 ft, outflows would be managed during a drought by the Minister of Sustainable Development.

From 2008 to 2013, water levels on Lake Winnipeg were generally above average due to above average precipitation in the Lake Winnipeg drainage basin. Water levels did not drop below the normal range during this period.

Lake Winnipegosis, an off-system during fall sampling

Sediment Summary

Lake Winnipeg receives sediment-laden water from many prairie rivers and streams and as well as sediment from the many kilometers of erodible shorelines around the lake. Lake Winnipeg is a shallow lake and sediments that settle in the lake are re-suspended many times due to wind generated waves and the currents within the lake.

At low flows, the amount of sediment coming in from the Winnipeg and Red rivers are low. At higher flows, the Red River carries an order of magnitude more sediment due to its more erodible shorelines. While the Saskatchewan River carries a similar sediment load to the Red River, much of its sediment is deposited in the Moose and Cedar lakes, and does not reach Lake Winnipeg.

The northern and western ends of the north basin of Lake Winnipeg were often very turbid from the shoreline sediment sources in contrast to the relatively clear water in the center of the basin.

It is believed the lake level rise, largely driven by uplift, is the principal driver of shoreline erosion at the south end of the lake (Thorleifson, 2015).

Ecosystem Hypotheses

Average water levels on Lake Winnipeg are similar before and after Lake Winnipeg regulation. However, current high water events are lower than the historical ones as more water can be released through 2-Mile Channel and other channel enhancements. It is not expected that Lake Winnipeg Regulation has affected the ecosystem productivity, as water levels ranges are generally similar. The benthos and fish communities are expected to be consistent from year to year due the maintained water levels.

Lake Winnipeg is influenced by many environmental variables, like climate variation, commercial fishing, nutrient loading, aquatic invasive species, etc., which can affect benthos and fish communities, as opposed to managed water levels.

As was noted previously, three CAMP sampling sites in the north basin of Lake Winnipeg represent a small sample size of a lake as large as Lake Winnipeg. The CAMP sampling will provide some data for comparison with nearby CAMP regions as well as other external research and programs on the lake.

Results

Water Quality

Data from Lake Winnipeg north basin near Grand Rapids showed moderate to high levels of total phosphorus, total nitrogen and chlorophyll *a*. On average, total phosphorus concentrations were in excess of the provincial guidelines each year in Lake Winnipeg and Lake Winnipegosis.

Lake Winnipeg is a shallow lake and surface winds and turbulence keep the water column generally well mixed and oxygenated. Despite that tendency, dissolved oxygen concentrations occasionally fell below provincial guidelines during some sampling events. Low dissolved oxygen conditions occurred more regularly in the off-system Lake Winnipegosis, which was typically stratified in winter and in some spring and summers.

Water clarity was relatively high at the Lake Winnipeg sites and was similar to those observations upstream of the Grand Rapids GS in Cedar Lake, as well as the off-system Lake Winnipegosis.

Overall, water quality was within provincial guidelines. The off-system Lake Winnipegosis has a relatively high concentration of chloride, which was above the provincial guideline. These concentrations are the result of discharge of saline waters from the groundwater system caused by the local geology.

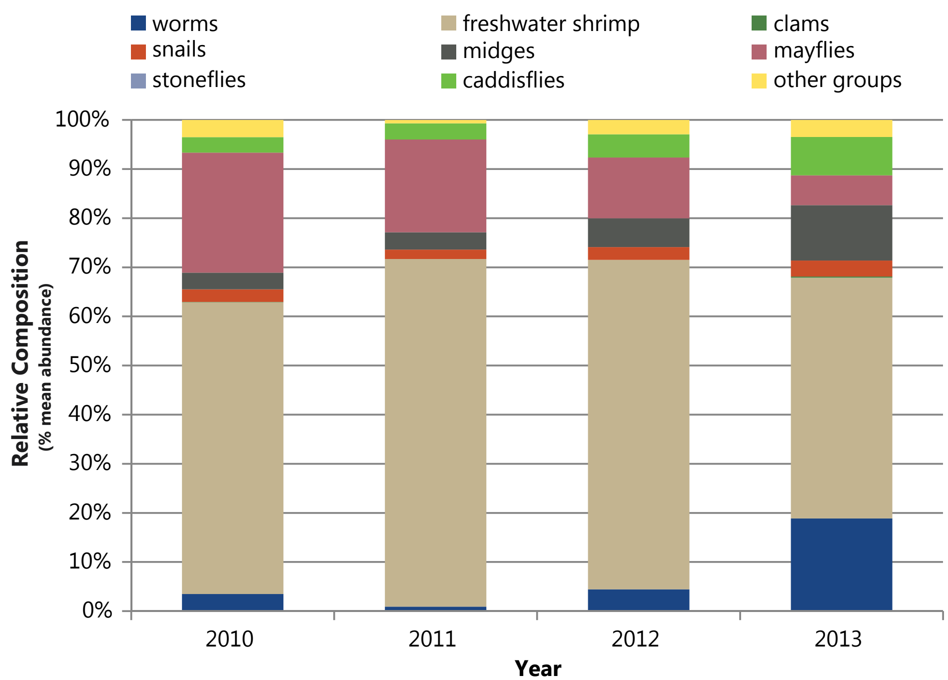
During the assessment period there was no indication of trends over time in water quality, however, long-term changes will be assessed as additional data are acquired.

Sampling benthos in Lake Winnipeg

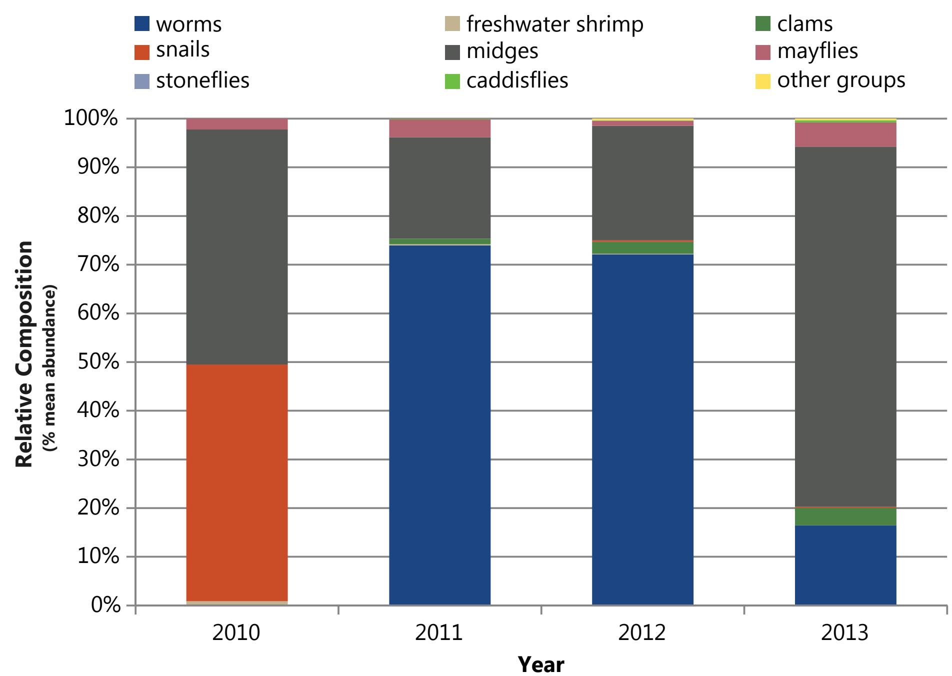
Benthic Macroinvertebrates

Due to the three-year rotational sampling schedule and a change in sampling methodology in 2010, benthos was only sampled in 2013 at the Grand Rapids and Mossy Bay sites. Therefore, data collected prior to 2010 cannot be used for analysis.

Annual sampling occurred in Lake Winnipegosis since 2010. Freshwater shrimp were typically the most abundant overall taxon, with mayflies generally being the predominant insect. Worms and midges were present in substantial numbers in at least one of the sample years. Offshore in Lake Winnipegosis worms and midges were the predominant organisms, except for 2010 when snails were more abundant than worms.



Relative composition of the benthos groups in the nearshore habitat of Lake Winnipegosis



Relative composition of the benthos groups in the offshore habitat of Lake Winnipegosis

CAMP

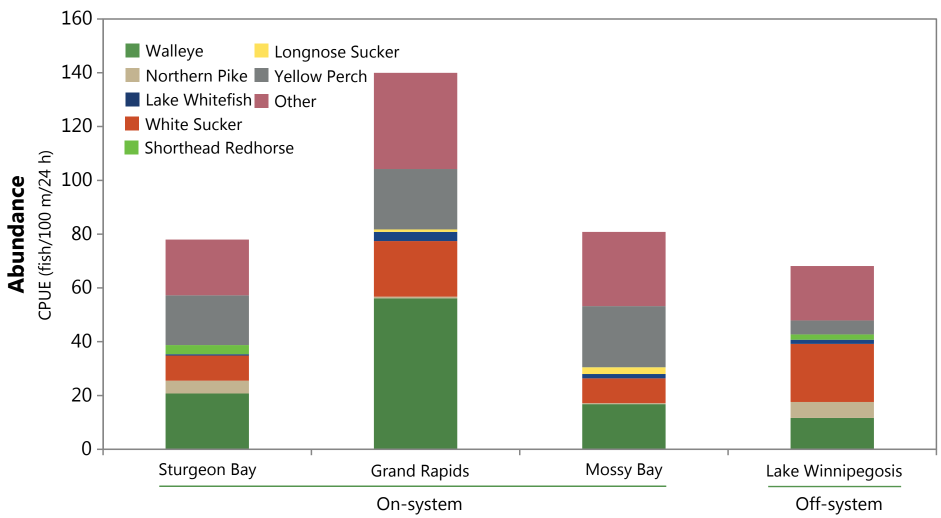
Fish

Due to a small sample size, there were no clear, ecologically relevant relationships observed between the fish community and water levels on either Lake Winnipeg or Lake Winnipegosis.

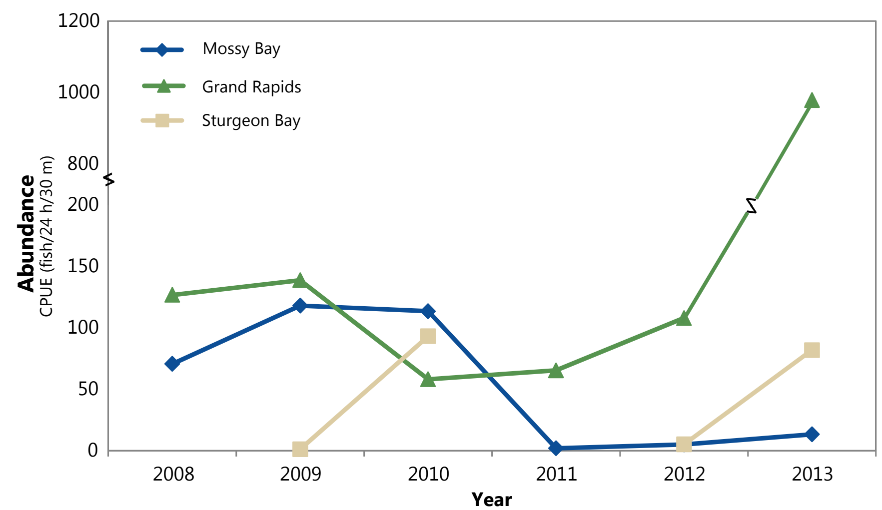
CAMP fish sampling occurs annually in both the north and south basins of Lake Winnipegosis. Lake Winnipegosis also supports a longstanding commercial fishery and domestic / subsistence fishing for the communities in the area.

On Lake Winnipeg, the abundance of fish caught in standard gill nets was highest in the Grand Rapids area compared to the Mossy Bay and Sturgeon Bay areas. The most commonly caught species at each location in the north basin of Lake Winnipeg were Walleye, Yellow Perch and White Sucker. However, there were differences in the species composition among areas. Sauger were most abundant in the Grand Rapids area of the lake, Longnose Sucker were most abundant in Mossy Bay, while Northern Pike and Shorthead Redhorse were more common in Sturgeon Bay.

The abundance of Sauger increased at all three locations (particularly in the Grand Rapids and Mossy Bay areas) in Lake Winnipeg, notably in 2012 and 2013. The condition of Walleye has shown a decreasing trend after 2010 with the most pronounced decline in Mossy Bay. The decrease in Walleye condition in Mossy Bay is likely attributable, at least in part, to concurrent declines in Rainbow Smelt, the primary prey species of Walleye. However, Rainbow Smelt catches were particularly high in the Grand Rapids area in 2013.



Abundance of fish species in the Lake Winnipeg Region by waterbody



Average annual abundance of Rainbow Smelt in Lake Winnipeg by location

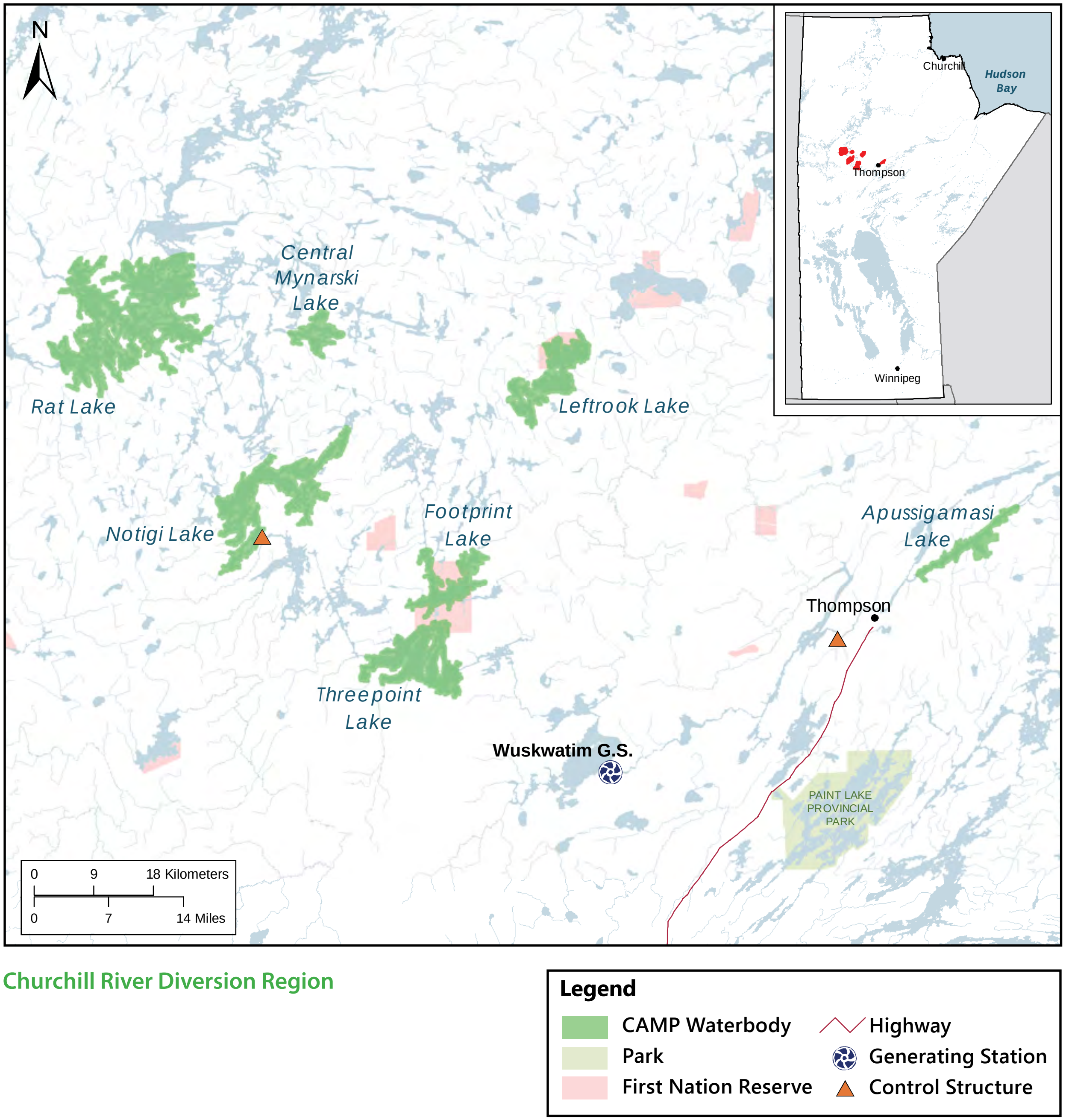
Conclusions

The number of sampling sites in Lake Winnipeg is small relative to its size and to other CAMP waterbodies. The utility of the data is therefore restricted to general comparisons to other data collected with other sampling protocols on Lake Winnipeg, and to other more intensely sampled CAMP sampling sites.

Future Considerations

- Lake Winnipeg CAMP sites should continue to be sampled with a view to ongoing and future data integration and linkages.
- Consideration of external sampling programs on Lake Winnipeg should be reviewed and CAMP sampling protocols and locations could be aligned, as appropriate.

Lake Winnipeg beach



Churchill River Diversion Region

Sampling Sites

On-system monitoring

- **Annual** – Threepoint Lake
- **Rotational** – Rat Lake; Central Mynarski Lake; Notigi Reservoir; Footprint Lake; Apussigamasi Lake

Off-system monitoring

- **Annual** – Leftrook Lake

Regional Highlights

- **Geography** – The majority of the Churchill River Diversion Region is in the Churchill River Uplands Ecoregion of the Boreal Shield Ecozone. The upstream portion of this region consists of a series of flooded waterbodies resulting from the diversion of Churchill River water out of Southern Indian Lake at South Bay. Outflows from this area are regulated by the Notigi Control Structure. Flooding and increased flows from the Churchill River Diversion have significantly increased water levels in what was previously a smaller river system.
- **Manitoba Hydro setting** – The diversion of Churchill River water is designed to increase water flow for hydropower generation on the lower Nelson River.

Churchill River waters are released at the Notigi Control Structure and flows are generally timed to increase during winter months. In the open water season, Notigi Control Structure outflows are then typically reduced to store water on Southern Indian Lake for the following winter.

- **Hydrology** – While overall flow at the Notigi Control Structure has been higher than average during the reporting period, Churchill River Diversion flows are a highly managed component of the system and overall discharge is not as widely variable as other regions. Typically, the lowest flows from Notigi occur from April to September in contrast to natural rivers which peak during this time. However, often a May to June pulse of water is also released as part of the operation of the Notigi Control Structure.
- **Observed Results**
  - Overall water quality was within provincial guidelines however, the on-system water bodies upstream of Notigi experienced more pronounced oxygen depletion than other parts of the Manitoba Hydro system.
  - Upstream of the Notigi Control Structure, the abundance of nearshore benthos communities in the fine textured sediment with lower oxygen levels was lower. Downstream of Notigi, shorelines were less vegetated due to the reversed seasonal flow and the greater variability of water levels during the open water. This changed the nearshore benthos habitat.
  - In general, aquatic ecosystems produced fish communities with abundant top predators. Immediately upstream of the Notigi Control Structure predatory fish had a somewhat lower condition (fatness) than elsewhere.

Apussigamasi Lake - an on-system lake

CAMP

Churchill River Diversion Region Description

The Churchill River Diversion region extends from the constructed outlet of Southern Indian Lake at South Bay, through the Rat/ Burntwood river system to First Rapids, approximately 20 km upstream of Split Lake.

The majority of the Churchill River Diversion Region is in the Churchill River Upland Ecoregion of the Boreal Shield Ecozone where waters are not typically as turbid. However, some streams and lakes in the area are underlain by glacial clay deposits and are naturally turbid.

The Churchill River Diversion project was constructed between 1973 and 1976 to divert water from the Churchill River to hydroelectric generating stations on the Nelson River. This was accomplished with three main components:

- Missi Falls Control Structure which regulates the amount of water passed down the Churchill River and Impounds Southern Indian
- South Bay Diversion Channel which allows Churchill River water to flow into the Rat/ Burntwood River system, and
- Notigi Control Structure which regulates the amount of water released through the diversion route and impounds Rate lake.

Churchill River Diversion Hydrology

The Churchill River Diversion was constructed to improve downstream hydropower generation. Along with Lake Winnipeg winter outflows, the Notigi Control Structure flows are generally timed to increase during winter months. In the open water season, the Notigi Control Structure outflows are then reduced to allow water levels to restore on Southern Indian Lake for the following winter. This increase also occurs in waterbodies upstream of the Notigi Control Structure.

Water levels downstream of the Notigi Control Structure in the Burntwood River and Threepoint, Footprint and Apussigamasi lakes mirror the Notigi Control Structure flow releases. The seasonal flow reversal yields higher downstream flows in winter than in the spring / summer and is the opposite of what happens in a natural ecosystem. Unregulated tributaries below Notigi add more seasonal flows and to some extent temper the flow reversal on the Burntwood River.

Notigi Control Structure discharges can also be reduced for flood protection reasons when Nelson River flows are very high. In extreme high water events, water discharge is increased at the Missi Falls Control Structure and is released into the lower Churchill River to Hudson Bay. This avoids adding more water to the Nelson River via Notigi Control Structure during high water conditions.

The only years without a flow pulse during May and June, were 2009 and 2011. This flow pulse was found to be important for spring spawning fish in natural stream and river ecosystems. High flows resumed during August-October each year and continued through the next winter except in 2006 and 2012 where high flows resumed in May.

Sediment Summary

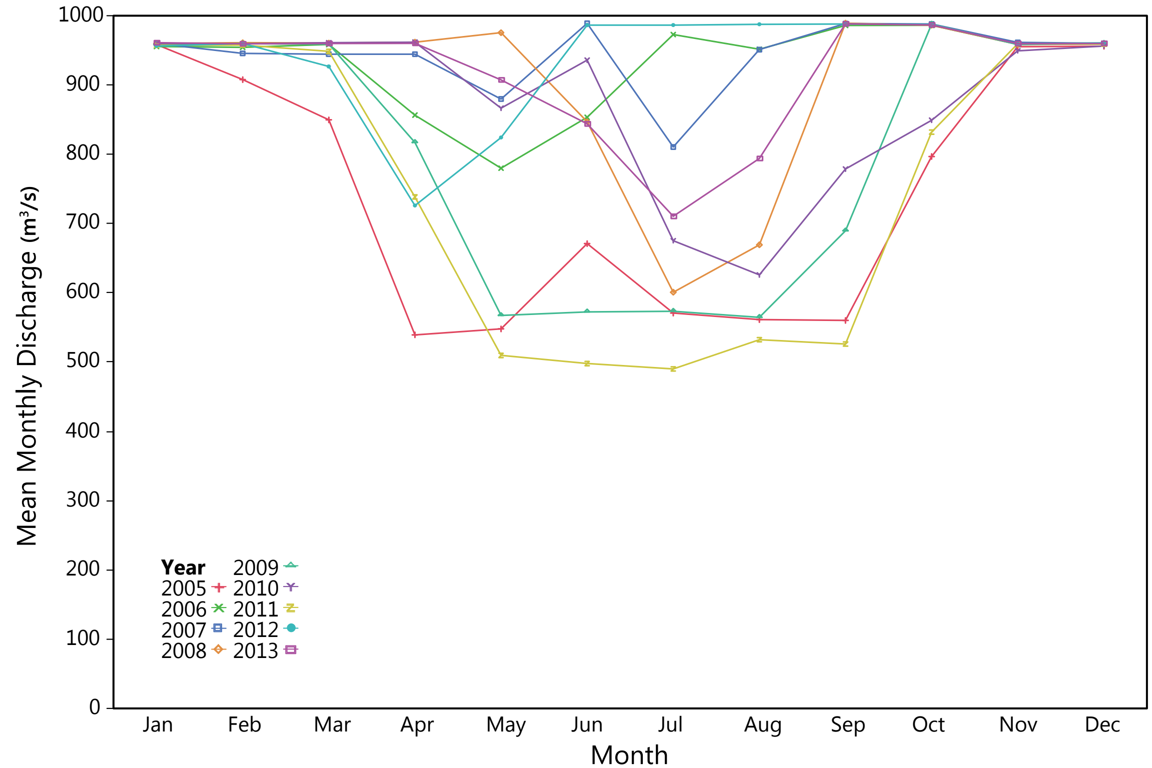
Upstream of the Notigi Control Structure, the impounded water raised water levels in what was previously a smaller river channel (Rat River). The increased water levels eroded the silts and clays in the flooded shorelines and deposited sediment near the shore area where it continues to re-suspend depending on water levels and wind conditions. As water slows in downstream lakes, sediment settled to the bottom. Wind events cause spikes of suspended sediment from these sediment reserves independent of the day-to-day operation of the Notigi Control Structure.

From the Notigi Control Structure to Wuskwatim Lake, the Rat/Burntwood River system consists of larger lakes including Threepoint Lake. The Burntwood River flows from the west into and out of Threepoint Lake. From that point, the Burntwood River flows through glacial Lake Agassiz deposits and most shorelines and backshore areas exhibit silts and clays overlying bedrock. In general, irregular and narrow channel sections exhibit bedrock-controlled shorelines while channel widenings and bays are characterized by silt and clay shorelines.

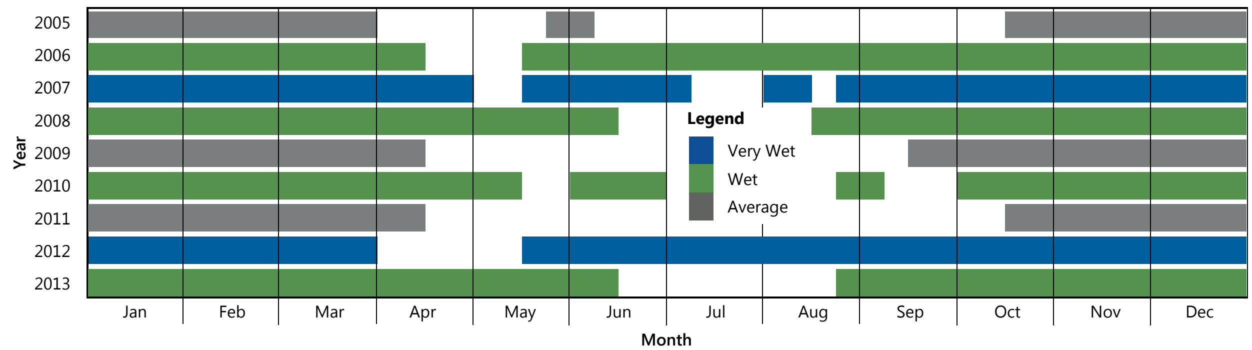
While sediment concentrations remained the same after the Churchill River Diversion, the water volume increased dramatically and the total sediment carried increased with the increase flow. This affects deposition in delta forming areas and the total amount of sediment load carried by the water increased from 7 to 26 times after the Churchill River Diversion.

Recent Wuskwatim Generating Station monitoring studies have shown that after the Churchill River Diversion, while suspended sediment tends to increase along riverine reaches of the system, lakes trap the sediment during calm periods. These lakes then become sources of sediment during wind events.

Wind appears to be the major driver of increases in sediment during the open water period. Sustained high wind increases sediment concentrations primarily due to waves stirring up eroded material that has deposited in the near shore areas and from shoreline erosion. Increases in wind generated sediment results in a high degree of variability in sediment concentrations measured at sites along the system.



Mean monthly discharges from the Notigi Control Structure 2005-2013



Notigi Control Structure annual high flow duration, timing and peaks

Ecosystem Hypotheses

Notigi Control Structure

Upstream of the Notigi Control Structure water levels were increased creating reservoir habitat with more lake-like water levels that flooded highly erodible shorelines. This has resulted in ongoing erosion of the shorelines. It is therefore expected that reservoir bottom substrates are soft from continual sediment deposition in these lakes. This would affect the benthos community increasing soft bottom, low oxygen tolerant midges and worms' abundance.

The resuspension and shoreline erosion associated with wind events would be expected to increase turbidity and reduce photosynthesis, yielding low primary production and lower overall ecosystem production. The reduced water clarity and the lower range of vision for feeding fish might also reduce their condition.

The change in water level and velocity would also be expected to result in a shift of the fish community from riverine to more lake-like fish species. However, the ongoing shoreline erosion and the re-suspension of deposited sediment in nearshore habitats would likely mean that the productive nearshore habitat for forage and large bodied fish species is lacking and a reduced fish community would therefore be expected in these areas. For example, Lake Whitefish spawning success may be lowered as overwintering eggs would be more likely to be covered in settling sediments.

Reduced flows through the Notigi Control Structure in the spring cause downstream tributary mouths to have lower water levels. This could result in reduced spawning success for Walleye and others, which depend on access to these tributaries.

Sediment from Footprint Lake

Results

Water Quality

While relatively shallow lakes, such as Threepoint and Apussigamasi located along the main flow of the Rat/Burntwood River system did not have temperature layers (i.e. were well mixed and did not stratify) and were well-oxygenated during all sampling periods. However, the deeper lakes (i.e., Central Mynarski, Rat, Footprint, and Notigi lakes) did stratify and were depleted of oxygen in the lower layer. Reduced oxygen concentrations can also be influenced by deposition and decomposition of the eroding organic materials. Oxygen levels were below provincial guidelines in the latter lakes during at least one sampling period.

Off-system waterbodies, such as Leftrook Lake also showed lower oxygen levels, which can be a consequence of the specific shape and flow characteristics of the lake.

Using a secchi disk to measure water clarity in Notigi Lake

Water clarity in the region ranged from low to high across sites located along the Churchill River Diversion route. Central Mynarski Lake, located off the main flow path of the Rat/ Burntwood River was notably clearer, and the most downstream lakes (Threepoint and Apussigamasi lakes) were more turbid than the other on-system sites.

Generally, the lakes located along the Churchill River Diversion were considered low to moderately productive based on nutrient levels. On average, total phosphorus concentrations were below the provincial guideline in Rat, Central Mynarski, Notigi - West, and Notigi - East lakes. However, mean annual total phosphorus concentrations at the downstream waterbodies (Threepoint, Footprint, and Apussigamasi lakes), occasionally exceeded this guideline.

Total phosphorus levels also occasionally exceeded the guideline in the off-system Leftrook Lake (25% of samples). Trophic status of the off-system Leftrook Lake was similar to that of the on-system sites, though nutrient concentrations were somewhat higher and Leftrook Lake supported higher levels of algae (measured as chlorophyll *a*). Conditions in this lake were most similar to the on-system Central Mynarski Lake. Overall, water quality was within provincial guidelines.

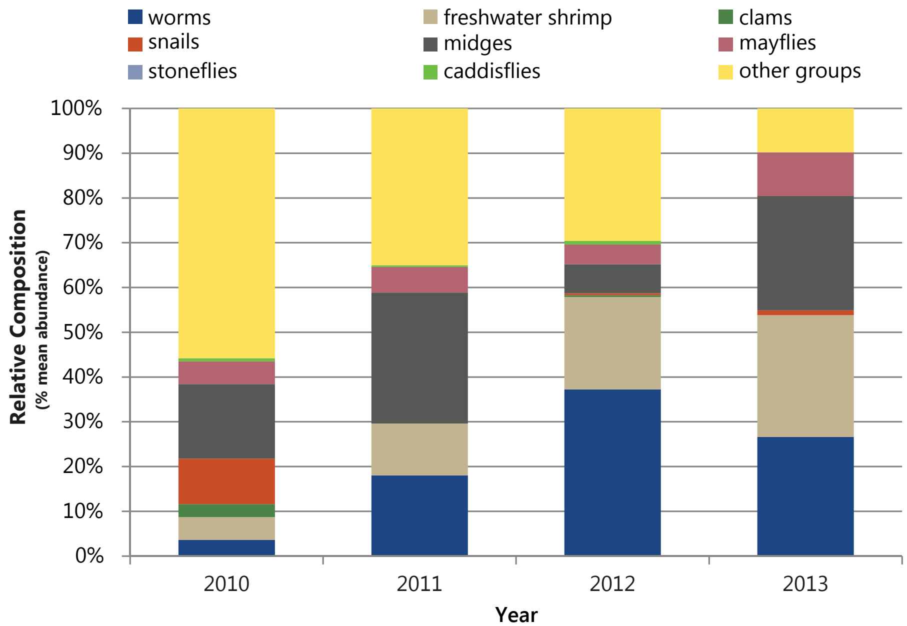
Benthic Macroinvertebrates

Benthos communities have colonized waterbodies of the Churchill River Diversion Region even with the hydrological effects of flow regulation. The benthos communities of the Churchill River Diversion Region were generally less abundant than in the off-system Leftrook Lake.

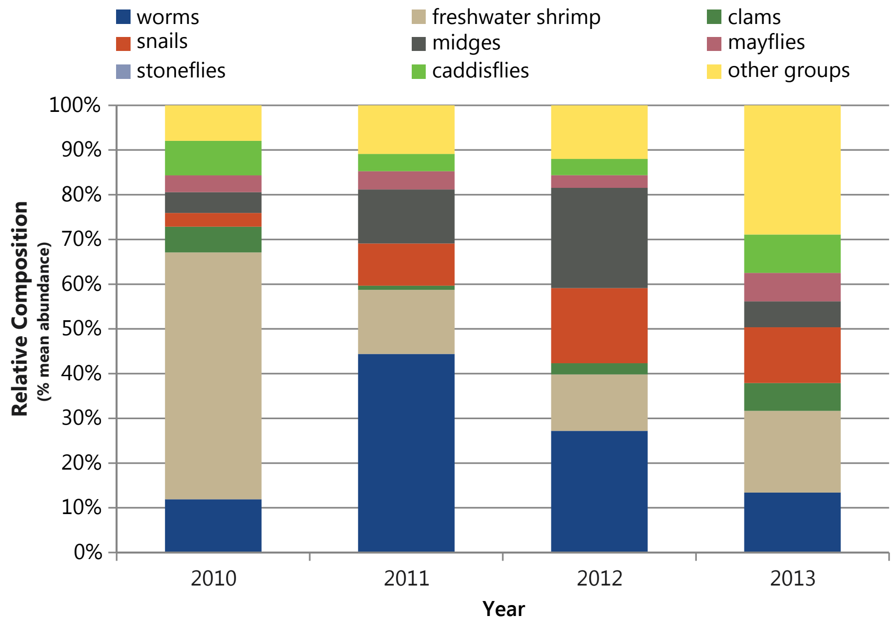
The nearshore benthos communities were more diverse than the offshore communities at both the on-system (Threepoint Lake) and off-system sites (Leftrook Lake). Nearshore communities were dominated by midges, water boatmen, worms and freshwater shrimp; with worms, freshwater shrimp, clams, midges and mayflies in the offshore habitat.

Substrate type, vegetation and water regime affect the nearshore habitat, dictating the abundance, richness and diversity of the benthos community. Riparian vegetation at sampling sites in lakes upstream of the Notigi Control Structure tends to be better developed than downstream of the control structure, where the shoreline is largely devoid of vegetation, creating habitat that is less diverse.

Overall, analysis of the four years of CAMP benthos monitoring data collected in the Churchill River Diversion Region did not show a consistent increasing or decreasing trend over this period. However, abundance in the nearshore and offshore of Leftrook Lake and the offshore of Threepoint Lake was significantly higher in 2013 than other years. This difference was not apparently linked to hydrology or other parameters considered during this study, indicating the complexity of factors influencing the benthos community.



Relative composition of the benthos groups in the nearshore habitat of Threepoint Lake (on-system_)



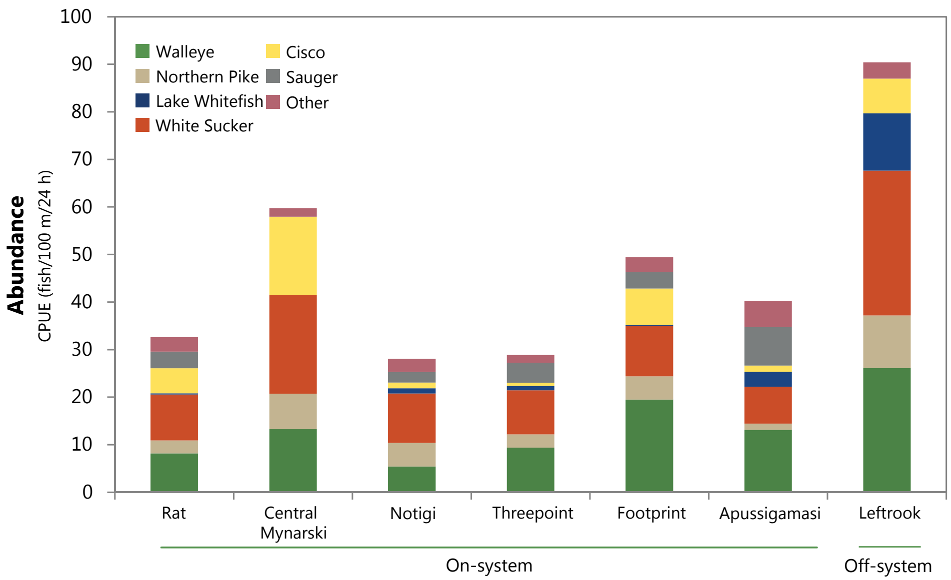
Relative composition of the benthos groups in the nearshore habitat of Leftrook Lake(off-system)

Fish

The abundance of fish caught in standard gill nets was typically higher off-system (Leftrook Lake) versus on-system lakes. The most commonly captured species in each lake were typically Walleye and White Sucker. However, Sauger were typically more abundant in the lakes downstream of the Notigi Control Structure, while Cisco were particularly abundant in Central Mynarski Lake and Footprint Lake.

The condition (or fatness) of Northern Pike and, to a lesser extent, Walleye was generally lower immediately upstream of the Notigi Control Structure on Notigi Lake compared to the lakes downstream of the Notigi Control Structure.

In general, there was considerable variability in the fish community in both the on-system (Threepoint Lake) and off-system (Leftrook Lake) waterbodies that were monitored annually. No consistent trends were observed over the five-year sampling period. It should also be noted that shoreline sampling in areas of higher shoreline debris was restricted, meaning that fish community information is lacking.



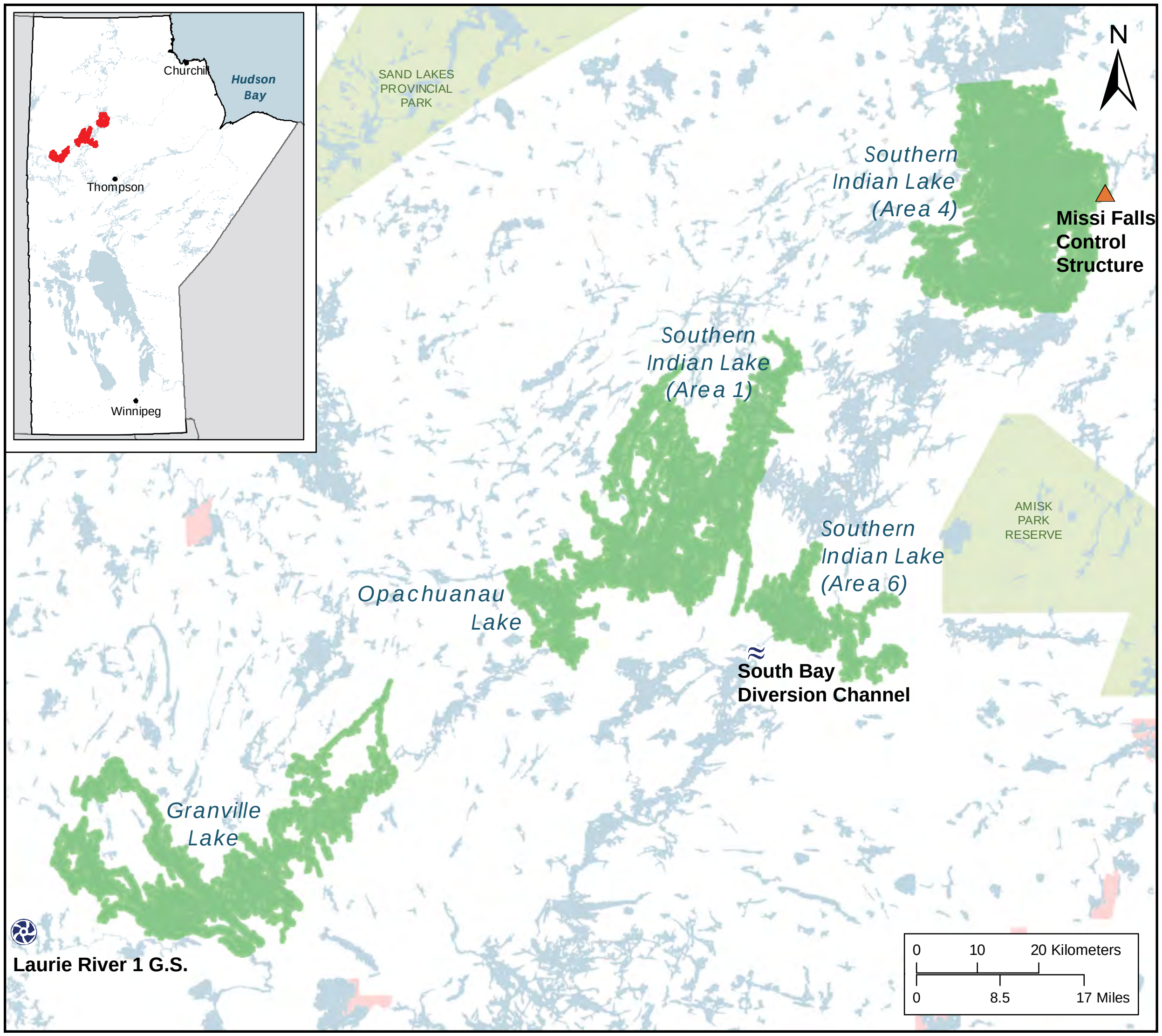
Abundance of fish species in the Churchill River Diversion region by waterbody

Conclusions

- While the on-system water bodies upstream of the Notigi Control Structure may experience increased oxygen depletion in the bottom of the water column due to increased water levels and water residence times from reservoir inundation, this phenomenon also occurs, and is more pronounced in the off-system waterbody sampled.
- The aquatic ecosystems in this region are producing fish communities with abundant top predators suggesting that the lower levels of the food web are adequate.
- Some waterbodies showed periodic stratification resulting in low-oxygen events.

Future Considerations

- A better understanding of the water depth and substrates in these water bodies would yield a better understanding of benthos habitat suitability and the interpretation of existing and future CAMP data.



Upper Churchill River Region

Legend

- CAMP Waterbody
- Park
- First Nation Reserve
- Generating Station
- Control Structure
- Diversion

Sampling Sites

On-system monitoring

- **Annual** – Southern Indian Lake Area 4
- **Rotational** – Opachuanau Lake; Southern Indian Lake Area 1; Southern Indian Lake Area 6

Off-system monitoring

- **Annual** – Granville Lake, Gauer Lake (used as reference from the Lower Churchill River Region)

Regional Highlights

- **Geography** – The Upper Churchill River Region drains approximately 260,000 km^2 and extends in Manitoba from the Saskatchewan-Manitoba border downstream to the natural outlet of Southern Indian Lake at Missi Falls and the constructed outlet at South Bay. The majority of the Upper Churchill River Region lies within the Churchill River Upland Ecoregion of the Boreal Shield Ecozone, and the dominant land cover within the upper Churchill River drainage basin is coniferous forest.
- **Manitoba Hydro setting** – In 1976, the Churchill River was impounded at the outlet of Southern Indian Lake by

the Missi Falls Control Structure. Water levels were raised in Southern Indian Lake for diversion to the Nelson River to supplement Lake Winnipeg Regulation flows.

- **Hydrology** – Incoming flows from Saskatchewan are influenced by upstream water usage, including hydropower and agriculture activities. During 2008 to 2013, water flows in the upper Churchill River typically increased slowly from April with peak flows ranging from spring to early fall.

- **Observed Results**
  - Water is generally clear and within provincial guidelines. Increased water levels and the associated shoreline erosion and sedimentation processes may be contributing to increased turbidity in Southern Indian Lake Area 4.
  - The nearshore benthos community appeared to be affected by variable water levels. Offshore habitats exhibited notable inter-annual differences. Overall, analysis of the four years of benthos data from this region showed no obvious trends.
  - The condition and growth rates of Lake Whitefish in Southern Indian Lake Area 4 were lower than in other on-system areas.

Granville Lake, an off-system lake

Upper Churchill River Region Description

The Upper Churchill River Region is composed of the Churchill River watershed extending from the Saskatchewan/Manitoba border downstream to the natural outlet of Southern Indian Lake at Missi Falls and the constructed outlet at South Bay. The upper Churchill River watershed drains approximately 260,000 km^2 of northern Alberta, Saskatchewan and Manitoba, eventually emptying into Southern Indian Lake, Manitoba.

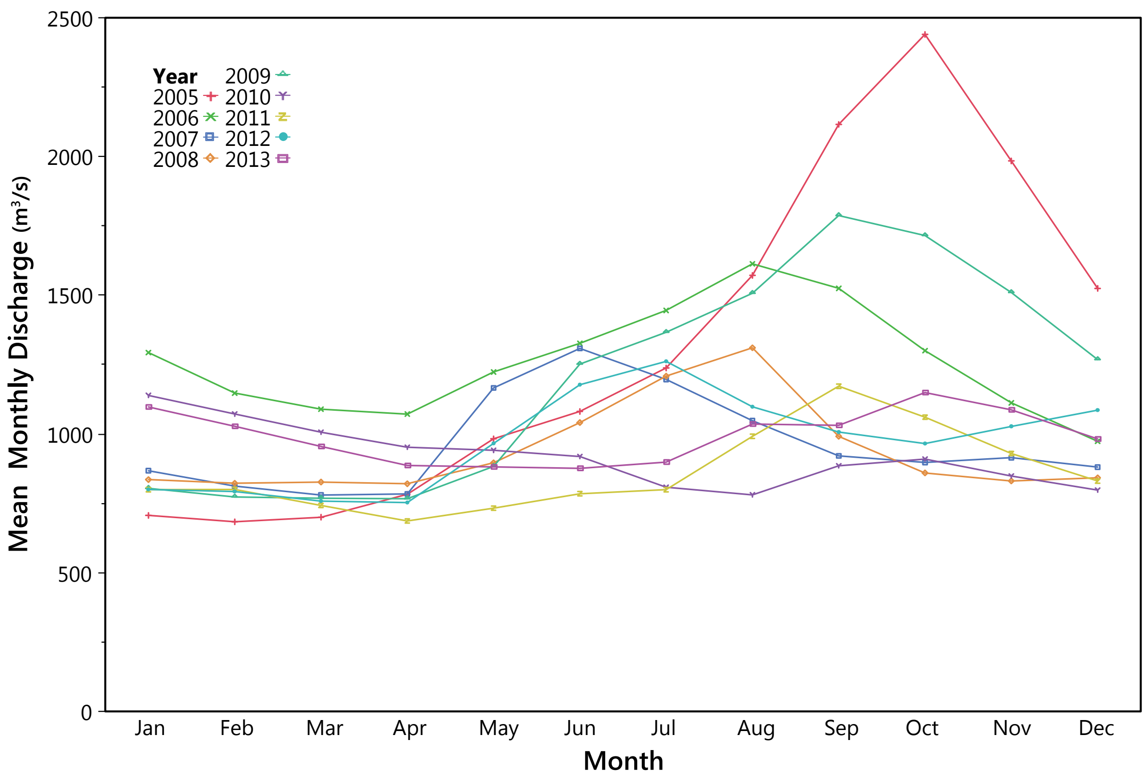
In 1976, the Churchill River was impounded at the outlet of Southern Indian Lake by the Missi Falls Control Structure. Water levels were raised in Southern Indian Lake and most of its flow was diverted out by way of the South Bay diversion channel into the Rat/Burntwood river system to increase hydroelectric potential on the Nelson River.

The majority of the Upper Churchill River Region lies within the Churchill River Upland Ecoregion of the Boreal Shield Ecozone, although the northern portion of Southern Indian Lake falls within the Selwyn Lake Upland Ecoregion of the Taiga Shield Ecozone. The dominant land cover within the upper Churchill River drainage basin is coniferous forest.

Upper Churchill River Hydrology

Upper Churchill River flows entering Manitoba are influenced by runoff from snowmelt, precipitation and water use across the Churchill River drainage basin and by SaskPower flow regulation at the Island Falls generating station. This includes augmenting Churchill River flows with Reindeer Lake releases. In Manitoba, Southern Indian Lake and Opachuanau Lake are managed together as a hydroelectric reservoir. Licensed limits describe both minimum flow release requirements from the Missi Falls Control Structure and water level limits on Southern Indian Lake.

Granville Lake is considered an off-system waterbody under the CAMP because water levels are not affected by the Churchill River Diversion most of the time. The water levels of Granville Lake are also affected by flow regulation upstream in the Saskatchewan portion of the watershed.



Mean monthly discharges from the Churchill River above Leaf Rapids 2005-2013

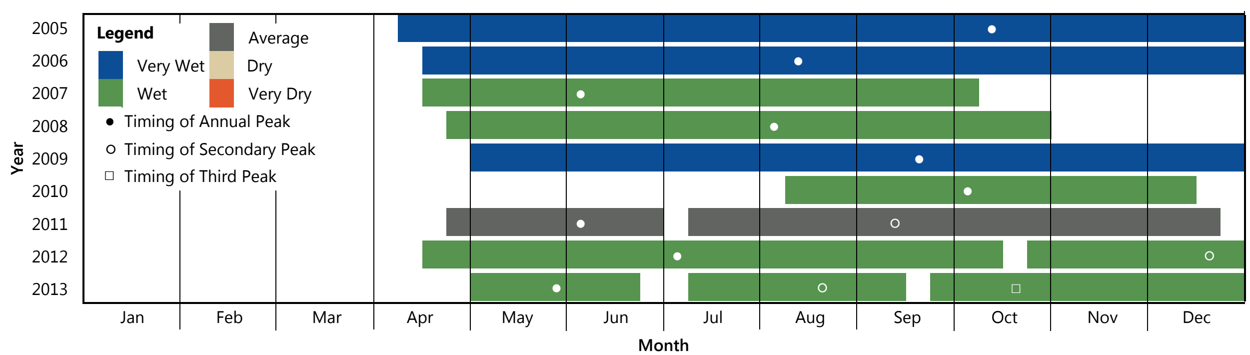
Typically in spring, Southern Indian Lake water levels rise due to increased snowmelt inflows and reduced outflows at the Notigi Control Structure (as energy demands drop). This refills Southern Indian Lake and summer outflows are managed so that water levels peak in late summer/fall for use in the winter. Southern Indian Lake water levels then decline through the winter as inflows decrease and Notigi Control Structure outflows are increased to meet the high winter energy requirements. Releases to the lower Churchill River at Missi Falls happen when Southern Indian Lake storage is near capacity and / or Notigi Control Structure releases are not required.

During 2008-2013, water flows in the upper Churchill River typically increased slowly from April with peak flows ranging from late May to early October and at levels between 1,000 and 1,500 m^3/s. Flows then decreased in November – December to 750 and 1,250 m^3/s in January.

The timeframe of spring flow increases is quite long with peak flows occurring anywhere from May to October during the 2008 to 2013 period.

Mean average flows indicated that eight of the last nine years were wet or very wet due to above average precipitation in the basin. In contrast, there were only three wet years and no very wet years in the preceding 25 years (Appendix 1). Granville Lake water levels followed a similar trend to the upper Churchill River flows from 2008 to 2013.

During this time, annual water elevation fluctuations on Southern Indian Lake were kept to within the licensed range by balancing upper Churchill River inflows with releases from the Notigi and Missi Falls control structures. During summer, high inflows were released through Missi Falls down the lower Churchill River as needed to maintain the Southern Indian Lake level just below the upper licensed limit into fall when the seasonal cycle restarts.



Runoff duration, timing and peak flows in the upper Churchill River above Leaf Rapids

Sediment Summary

The geology of the northern portion of Southern Indian Lake is characterized by extensive glacial lake silt and clay deposits and local granular deposits overlaying bedrock. The southern reaches are dominated by bedrock shorelines, with the exception of South Bay, where silt and clay shorelines are common.

The impoundment of water at the Missi Falls Control Structure and the diversion of the Churchill River water south through the South Bay diversion channel, changed Southern Indian Lake's hydrology and sedimentation processes.

Additionally, the Southern Indian Lake shorelines are still adjusting from the raised water levels. When the lake levels were raised, new shorelines were exposed to wind action. This increased shoreline erosion and added sediment into the water that is now being mobilized and moved towards the center of the lake. Substrate mapping in Area 4 indicates that much of the lake bottom consists of a mix of silt and clay sediments.

Shoreline erosion can be extensive at times due to wind action and appears to be independent of water levels.

The program's offshore water quality sites show low total suspended solids on average with many samples being lower than the detection limit of 2 mg/l. Water flowing out of the South Bay diversion channel has higher sediment concentrations than the Churchill River inflow to Southern Indian Lake. Within Area 4, suspended sediment levels near the bottom have been observed to be higher than mid and surface levels. This may be due to resuspension linked to bottom currents or overturning, although the nature and extent of this phenomenon is not well understood.

Post-Churchill River Diversion studies estimated that the sediment contribution from eroding shorelines is greater than the sediment loadings brought in by the Churchill River and this sediment is mostly retained within the lake.

Ecosystem Hypotheses

Due to the commercial fishery, the sampling of the upper Churchill River was focused in Southern Indian Lake, specifically in Area 4. Due to the altered hydrology of the area, water and nutrients flow through Area 4 only when flows are high into Southern Indian Lake and must be released down the lower Churchill River through Missi Falls. In the past, these releases were infrequent and caused Lake Whitefish to move to other areas in Southern Indian Lake. This decreased the commercial harvest of export-grade Lake Whitefish. When flows were reduced, fish would then move back into more familiar locations and commercial fish harvests returned to normal levels.

More recently, the wet and very wet years have resulted in large releases of water from the Missi Falls Control Structure. While Lake Whitefish are still abundant, they are clearly skinnier, smaller (i.e. lower condition) and not as valuable. This appears to be a food related issue and may be associated with recent observations that turbidity and suspended sediment concentrations near the bottom are higher than at mid and surface levels. This would cause reduced light levels decreasing benthic algal growth, along with the reduction of benthos density and diversity. This may result in reduced growth for Lake Whitefish given their tendency to feed at the bottom of a lake. These concerns would not be expected for Opachuanau Lake and Southern Indian Lake Areas 1 and 6 as they have remained more on-current.

Results

Water Quality

Lakes in the upper Churchill River region were well-oxygenated year-round with dissolved oxygen concentrations consistently above provincial guidelines, despite thermal stratification events occurring in each monitoring area of Southern Indian Lake during some spring or summer sampling events. Water clarity was moderate to high in this region, though clarity was higher in Southern Indian Lake - Area 4 than the upstream areas and South Bay. As an off-current area, this is likely in part due to settling.

The off-system Granville Lake and Opachuanau Lake and Areas 1, 4, and 6 of Southern Indian Lake were all considered low to moderately productive based on total phosphorus, total nitrogen and chlorophyll *a* concentrations. With one exception, mean open water total phosphorus concentrations were within the provincial guidelines.

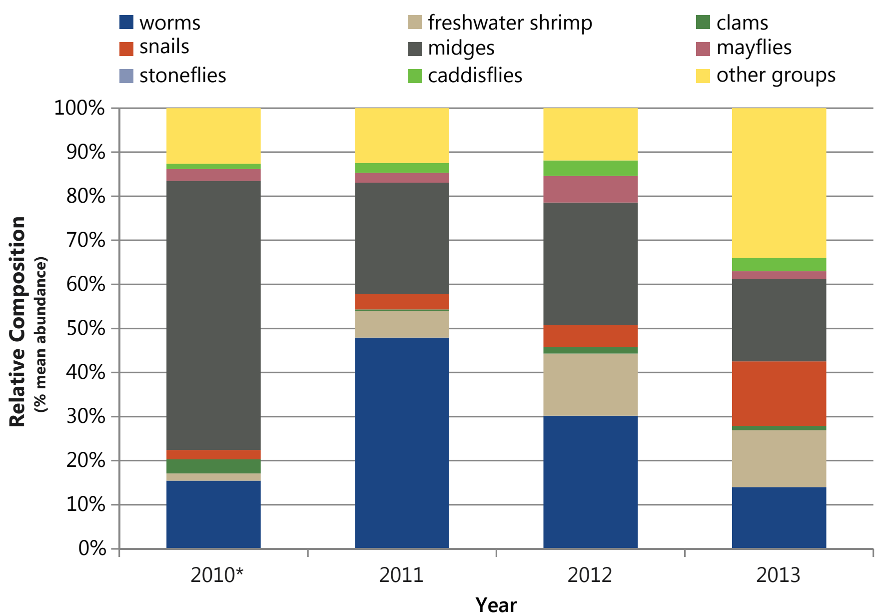
Benthic Macroinvertebrates

The nearshore benthos community was generally comprised equally of insects and

Shoreline of Southern Indian Lake

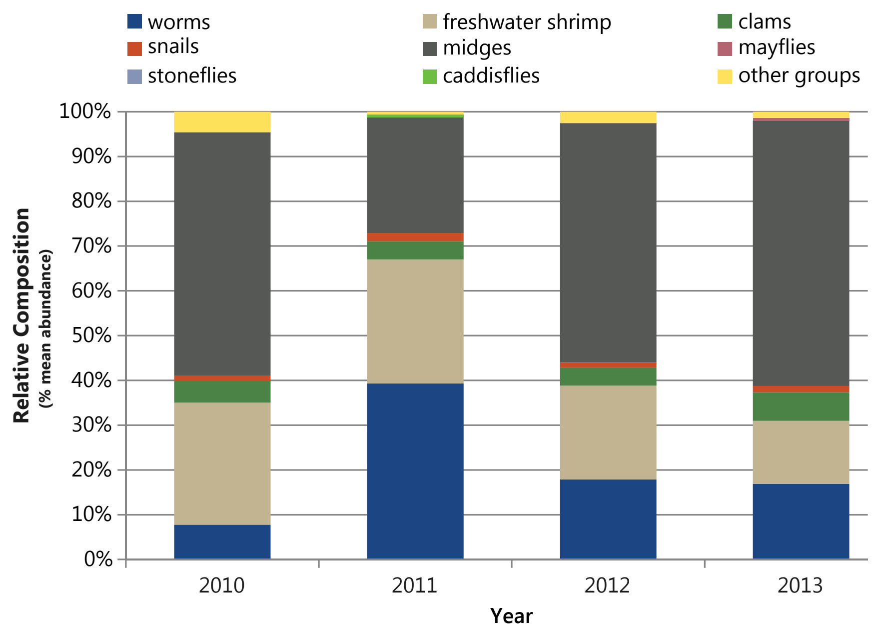
non-insects, with water boatmen, worms, snails and freshwater shrimp being the most abundant. Offshore substrate in Southern Indian Lake Area 4 was sandy while other areas were more silt and clay. Despite this difference of substrate, the dominant groups were the same for all sites (midges, freshwater shrimp and worms). Mayflies were uncommon in the nearshore and completely absent from Southern Indian Lake Area 4 offshore samples in most years.

As in many other sites and regions, the nearshore benthos community samples were affected by variable water levels and benthos abundance in the nearshore was lower at sites with a shorter duration of wetting. Offshore habitats also exhibited notable inter-annual differences, but the cause could not be readily determined. Overall, analysis of the four years of benthos data collected in the upper Churchill River region showed no obvious trends.



2010* grab sampler units are no. per m^2

Relative composition of the benthos groups in the nearshore habitat of Southern Indian Lake Area 4



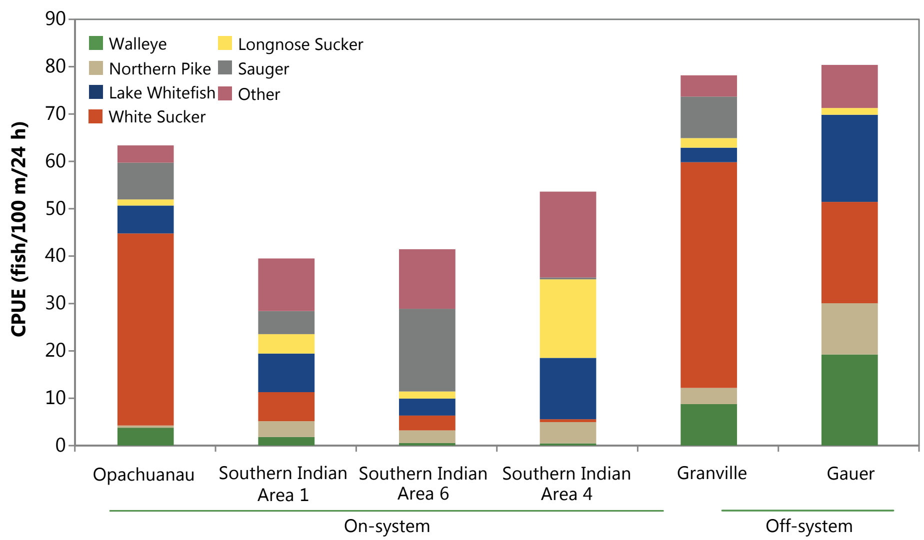
Relative composition of the benthos groups in the offshore habitat of Southern Indian Lake Area 4

Fish

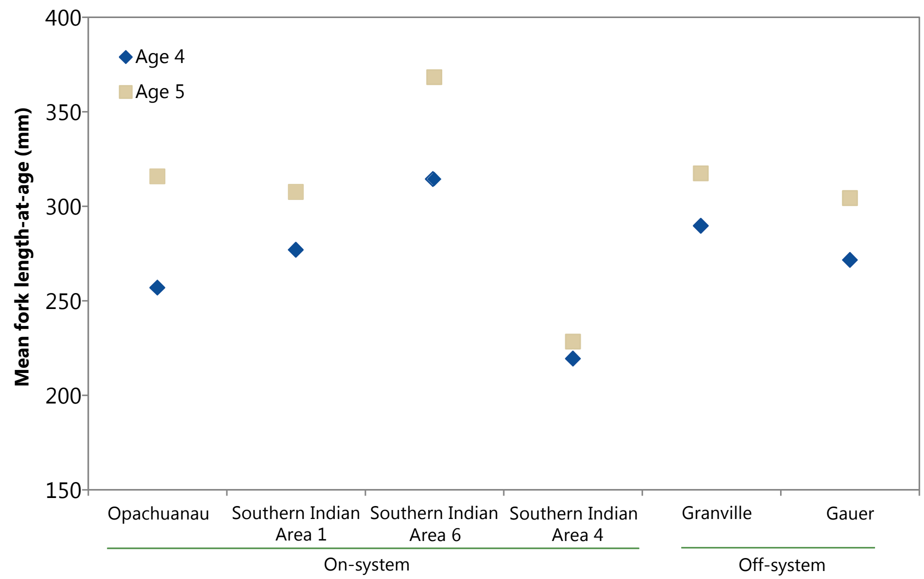
Species diversity was higher at the Southern Indian Lake Area 1 site than any of the other on-system sites. Catches from the other sites had a lower average number of species detected per year.

Among on-system sites, fish abundance was higher in Opachuanau Lake and Southern Indian Lake Area 4 compared to Southern Indian Lake – Areas 1 and 6. Lake Whitefish were most abundant in Southern Indian Lake Areas 4 and 1 while Sauger were abundant in Southern Indian Lake Area 6. Longnose Suckers, which are often considered a more riverine species, were the most abundant in Southern Indian Lake Area 4 and rare elsewhere.

The condition or fatness of Lake Whitefish in Southern Indian Lake Area 4 was considerably lower than the other on-system areas. The condition of White Sucker (also a bottom feeding fish species) was also lowest in Southern Indian Lake Area 4. The length of the 4- and 5-year-old Lake Whitefish was lower in Southern Indian Lake Area 4 compared to the other on-system areas.



Abundance of fish species in the Upper Churchill River Region by waterbody



Average length of the 4 and 5-year old Lake Whitefish by waterbody

Benthic sampling using a kicknet on Opachuanau Lake, an on-system lake

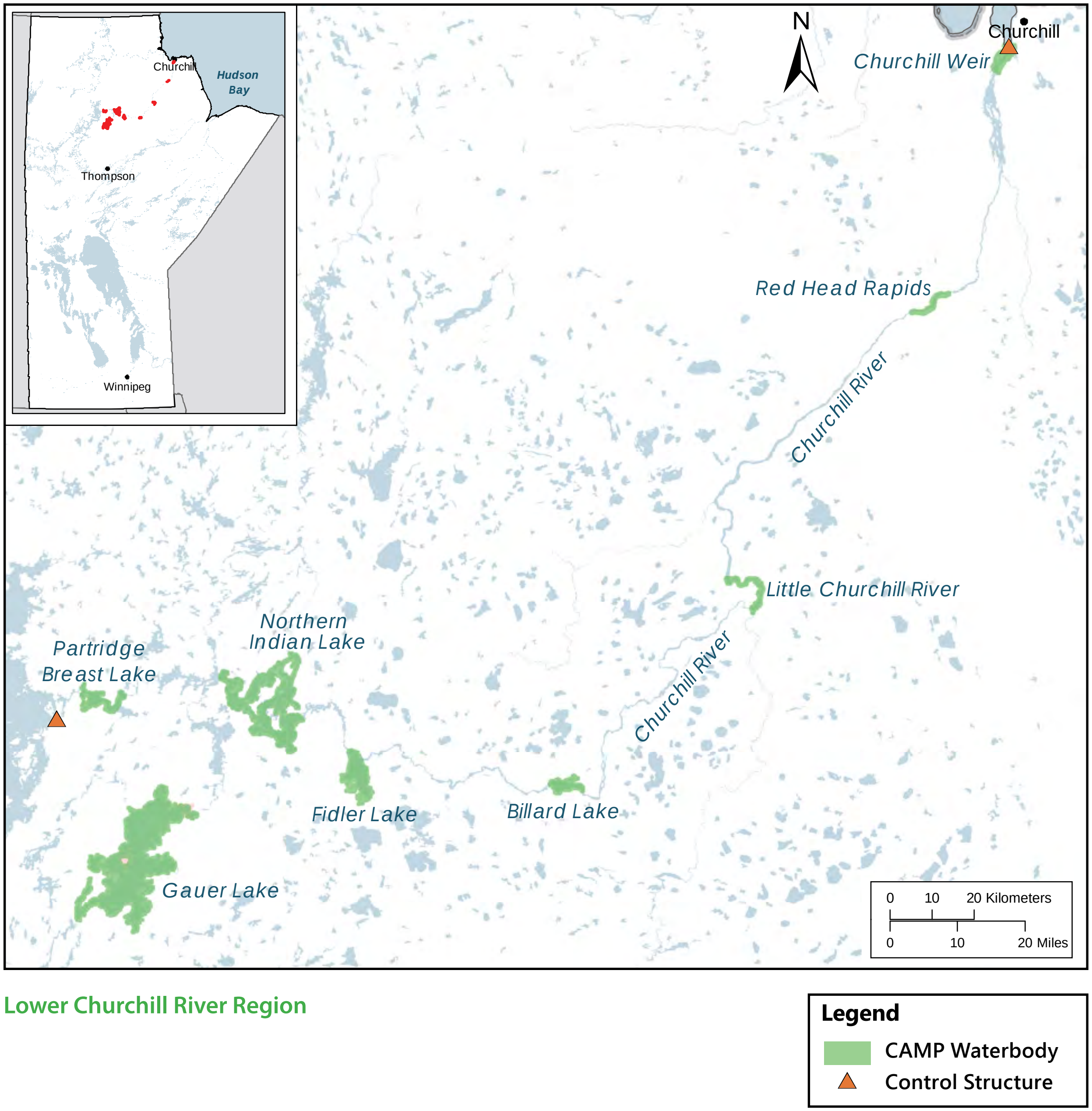
Conclusions

- Water quality parameters were generally within the provincial guidelines.
- The benthos sampling showed a tendency towards burrowing and more low-oxygen tolerant organisms like midges and worms but no trends were identified associated with water levels or between years during the first six years of sampling.
- The lower condition and growth rates of Lake Whitefish in Southern Indian Lake Area 4 compared to other on-system waterbodies within the region will continue to be monitored and assessed.

Future Considerations

- Benthos communities are dependent on sediment and substrate type. Completing habitat depth and substrate mapping for the area will assist with further understanding of the lower trophic level communities with respect to the water flow and level effects on near and offshore benthos.
- More monitoring would be required to determine what associations there are between ecosystem parameters and water flows and levels.

Shoreline of Granville Lake, an off system lake



Lower Churchill River Region

Sampling Sites

On-system monitoring

- **Annual** – Northern Indian Lake; Churchill River at the confluence of the Little Churchill River
- **Rotational** – Partridge Breast Lake; Fidler Lake; Billard Lake; Churchill River at the Churchill Weir

Off-system monitoring

- **Annual** – Gauer Lake

Regional Highlights

- **Geography** – The Lower Churchill River Region extends from the outlet of Southern Indian Lake downstream of Manitoba Hydro's Missi Falls Control Structure to Hudson Bay. It spans three ecozones (Boreal Shield, Taiga Shield and Hudson Plain). The upper portion is characterized by numerous lakes and slow draining wetlands while the lower portion has more flat muskeg plains, extensive permafrost, shallow lakes, and raised gravel beaches. After the Churchill River Diversion in 1976, 80% of the Churchill River Basin's flow was diverted to the lower Nelson River for power production. Consequently, post-Churchill River Diversion discharge along the lower Churchill River is considerably lower than historically.

Winter water quality sampling on the lower Churchill River

- **Manitoba Hydro setting** – The Churchill River Diversion allows Manitoba Hydro to utilize Churchill River flows for hydroelectric power generation without having to build additional generating stations on the Churchill River. The lower Churchill River currently serves as a release outlet for excess water from the northern portion of Manitoba Hydro's system, specifically when upper Churchill River flows are high and Southern Indian Lake is full, or when Nelson River flows are high, water is released to flow down the lower Churchill River to Hudson Bay.
- **Hydrology** – Precipitation and inflows in the rest of Manitoba Hydro's system have been high, therefore periodic releases at the Missi Falls Control Structure have been required and flows on the lower Churchill River have ranged from the more historically low flow to very high flows based on precipitation and system operation needs.
- **Observed Results**
    - Water is typically clear and within provincial guidelines and as larger releases occur, water chemistry changes but is still generally within the provincial guidelines. Waterbodies are considered low to moderately productive.
    - The benthos community varied with the degree of water level fluctuation and the substrates available.
    - While there were differences in fish communities among the lakes, the most commonly caught species included Northern Pike and Walleye. In riverine sites, it was found that fish abundance changed with flows, suggesting that increased flows may have reduced gill net sampling efficiency.

Lower Churchill River Region Description

The Lower Churchill River Region is composed of the portion of the Churchill River extending from the Missi Falls Control Structure at the natural outlet of Southern Indian Lake to the mouth of the Churchill River at the Town of Churchill on Hudson Bay. Prior to the Churchill River Diversion project, the Churchill River at Southern Indian Lake drained approximately 260,000 km^2 of northern Alberta, Saskatchewan and Manitoba. Since Churchill River Diversion in 1976, 80% of the Churchill River flow was diverted to the lower Nelson River.

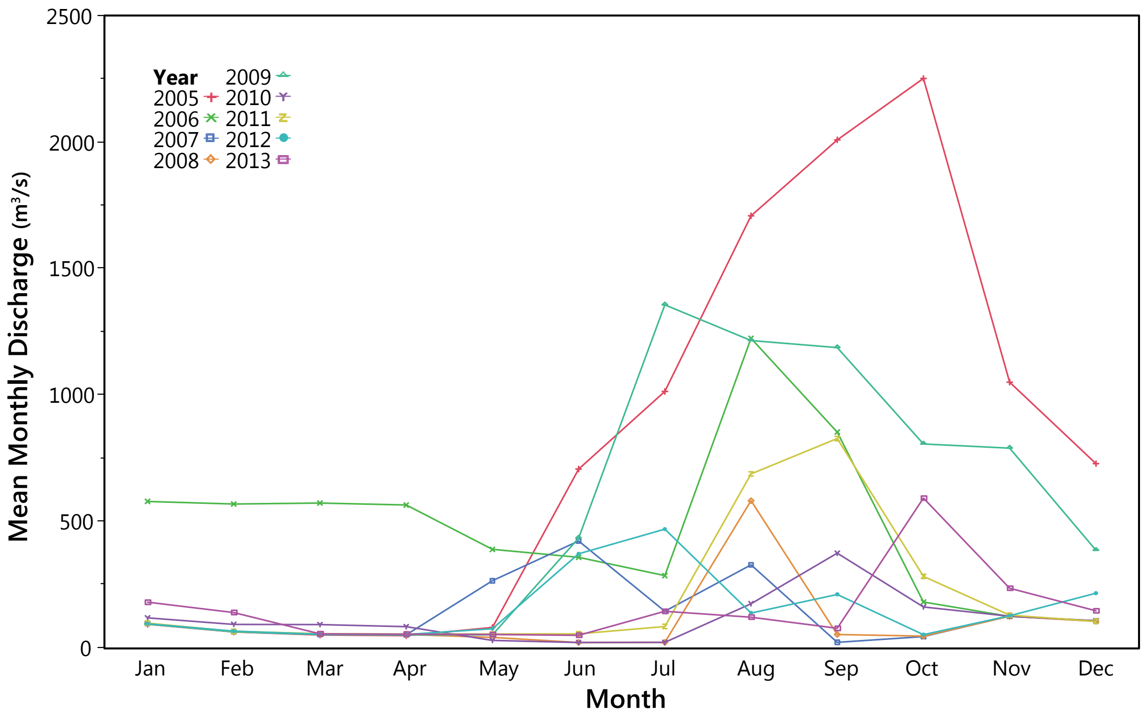
The Lower Churchill River Region spans three ecozones (Boreal Shield, Taiga Shield and Hudson Plain) and four ecoregions (Churchill River Upland, Selwyn Lake Upland, Hudson Bay Lowland and Coastal Hudson Bay Lowland). The shield ecozones are characterized by numerous lakes and wetlands and have a poorly organized drainage system. The lower portion of the lower Churchill River flows through the Hudson Plain Ecozone, an area characterized by flat muskeg plains, extensive permafrost, shallow lakes, and raised gravel beaches. The dominant land cover of the Lower Churchill River Region is classified as sparse coniferous forest.

The only water management structure on the lower Churchill River is a weir at the town of Churchill that is used to help provide fresh water for the town of Churchill and to facilitate local river access.

Lower Churchill River Hydrology

Lower Churchill River flows have been drastically modified by the diversion of 80% of the upper Churchill River flow through the Rat-Burntwood River system to the Nelson River for power production. The Missi Falls Control Structure releases water from Southern Indian Lake into the lower Churchill River largely as system overflow. All releases are increased by local inflows from numerous downstream tributaries to the Churchill River.

Manitoba Hydro's operating process to optimize hydropower generation means that Missi Falls Control Structure outflows are typically held just above the licensed minimum outflow to allow flows to be primarily managed at the Notigi Control Structure. The licensed minimum release at the Missi Falls Control Structure is 14 m^3/s during the open water period and varies from 42 to 113 m^3/s during the winter months. Missi Falls Control Structure outflows are



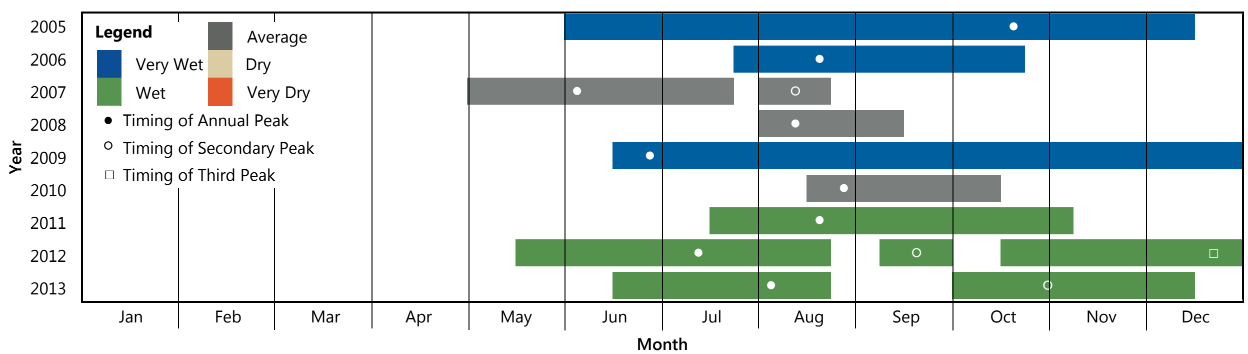
Mean monthly discharges from the Missi Falls Control Structure 2005-2013 increased during times of high inflow to Southern Indian Lake, and when the lake is near its upper licensed limit. Higher Missi Falls Control Structure outflows can also be influenced by flood conditions on the Nelson River when Notigi Control Structure outflows are reduced to avoid aggravating flooding along the lower Nelson River.

Missi Falls Control Structure mean monthly flows indicate that a general but variable increase in flows starts in May – June (between 250 and 1500 m³/s) depending on weather and upstream storage conditions. Mean monthly winter flows were generally between 14-250 m³/s from December through April during the period of interest and peak discharge during the open water was variable peaking anywhere between early June and October during this period.

Categorization of wet and dry years indicated that for the period of interest, one third of the nine years were average, one third were "wet", and one third were "very wet". By contrast, only four of the preceding 25 years were "wet" water years and there were no" very wet" years during this period (Appendix 1).

Lower Churchill River flows are influenced by Missi Falls Control Structure outflows but tributaries downstream of Missi Falls also add water to the lower Churchill River as it flows to Hudson Bay. The combined effect of upstream releases and tributary inflows results in the reservoir behind the Churchill weir fluctuating generally in the range of 1.5-2.0 m between 2008 and 2013.

Gauer Lake receives inflows from the upper portion of the Gauer River and a few smaller tributaries. Between 2008 and 2014, Gauer River flows were generally close to average during the winter months and increased each year in late-April to May with snowmelt runoff.



The Missi Falls Control Structure annual runoff timing, duration and peaks

Sediment Summary

While the Churchill River flows through several lakes in the upstream area, the lower Churchill River system is more riverine than the other CAMP regions. This means that the Lower Churchill River Region is less likely influenced by reservoir settling of sediments and wind erosion processes.

The Churchill River flows through the Canadian Shield before flowing through an area of Paleozoic limestone and Precambrian sandstone. The CAMP data indicate that the upstream lakes have lower sediment concentrations than sites in the river as sediment is deposited in the slow-moving lakes. The lakes along the lower Churchill are also not exposed to increased water levels and wind driven erosion that releases sediments to the water. As the river approaches Hudson Bay, it has eroded into a channel characterized by vertical rock shorelines, active slumping in soil deposits and ice-scoured shorelines.

In this region while large floods still occur, the flows are typically reduced by 80% and side channels can remain dry. Associated with this, tributary outlets now flow into the smaller lower Churchill River through enlarged braided deltas. This is due to lower flows on the Churchill River that cannot carry away sediments brought in by the tributaries. In general, physical changes to the channel shape are considered relatively minor and progressing at very slow rates.

Total suspended solids on the system were generally low; with results below the analytical detection limit of 2 mg/L in approximately 25-37% of samples collected.

Ecosystem Hypotheses

Since the flows on the lower Churchill River have been decreased by 80%, the river has adapted to these new conditions. Occasional large floods will alter the river pattern, substrates and nutrient levels, resulting in a change in the ecosystem.

During the normal lower flow conditions, local tributaries contribute a larger portion of the water in the lower Churchill River and exert more influence on the water chemistry. Water from these tributaries is thought to have lower nutrients and sediment than the Churchill River proper and this would result in a smaller, less productive river.

Periodic high flows from Southern Indian Lake inundate the flood plain and bring terrestrial debris and nutrients into the river channel, and move benthos and fish into downstream habitats. This flood effect would persist for some period after the flood has subsided. Consequently, the largest changes in water quality, benthos and fish, would be expected from these infrequent, large floods.

The high flows and the associated nutrient inputs may result in overall greater ecosystem productivity without increasing the production of large bodied fish species as they are still constrained by reduced habitat during the overall dominant, low flow state.

The effects of winter and ice freezing to the bottom in places of the Lower Churchill River Region are expected to reduce ecosystem productivity. In some years, water sampling at sites was not possible as the river was frozen to the bottom.

Results

Water Quality

Lakes and river reaches along the lower Churchill River were typically well mixed and oxygenated year-round. Water clarity was relatively high in this region and total suspended solids levels were below the analytical detection limit of 2 mg/L in about one third of the samples. In general, water quality was within provincial guidelines.
No trends were apparent in water quality over the six-year period.

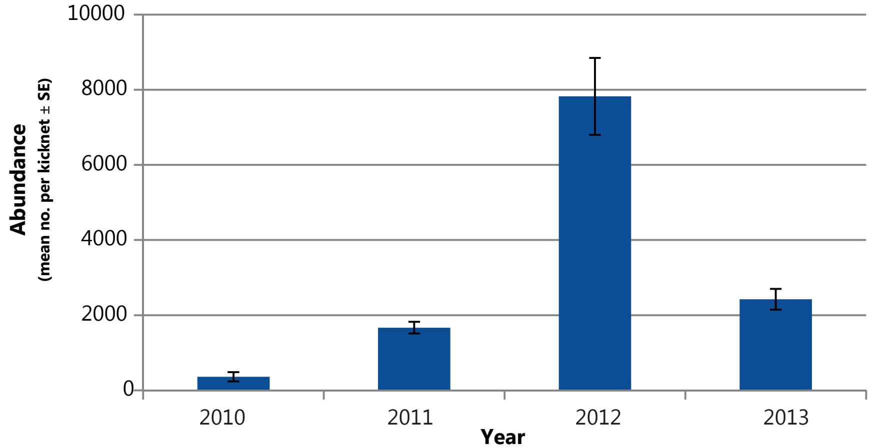
Lakes and rivers located along the lower Churchill River were generally considered low to moderately productive based on phosphorous, nitrogen and chlorophyll *a*. Occasional exceedances of the provincial nutrient guideline for total phosphorous were observed at Northern Indian Lake (8% of samples) and Partridge Breast Lake (13% of samples).

Based on only six years of data, some water quality parameters (e.g., total phosphorus, total suspended solids and turbidity) increased with discharge and water levels, while others (e.g., specific conductance and alkalinity) decreased.

Shoreline of the Churchill River

Benthic Macroinvertebrates

Water level variation influences the length of inundation of the nearshore habitat, which typically affects the benthos community. For example, lower water levels prior to sampling in 2010 and 2011 at Northern Indian Lake likely resulted in lower benthos abundances and diversity in the nearshore habitat because the area where sampling took place had been wetted a shorter period of time compared to other years when it was wetted for most of the open water season.



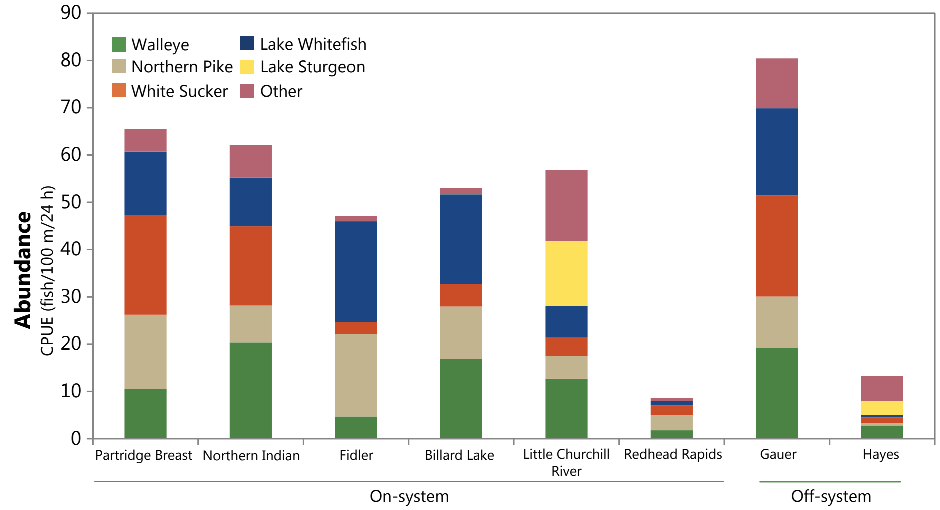
Annual differences in the benthos abundance in the nearshore habitat of Northern Indian Lake

Fish

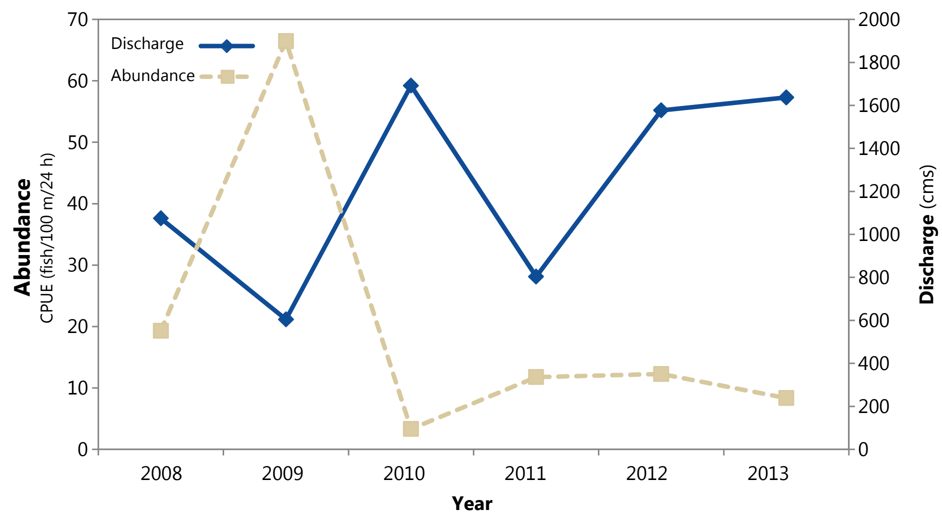
The abundance of fish captured in standard gill nets generally decreased in a downstream direction, and was higher at Partridge Breast and Northern Indian lakes compared to Fidler and Billard lakes. Fish abundance was considerably lower in the lower Churchill River at Red Head Rapids compared to the lower Churchill River at the Little Churchill River.

The most commonly caught species in most waterbodies included top predators (Northern Pike and Walleye) along with Lake Whitefish and White Sucker.

There was a notable inverse relationship between fish abundance (i.e., CPUE) and discharge in the lower Churchill River at the Little Churchill River where catches in gill nets decreased with higher flows during the sampling period. This difference was largely a result of decreased catches of Lake Sturgeon in high flow years. A similar pattern was also observed on the Hayes River where the total catch, as well as that of Northern Pike, decreased as flows increased during the sampling period. This relationship in riverine sites is most likely the product of fish dispersing to the margins of the river and a reduction in gill net sampling efficiency. Essentially, as flows increase sampling efficiency decreases rather than an actual reduction in fish abundance occurring.



Abundance of fish species in the Lower Churchill River Region by waterbody



Relationship between abundance and discharge in the lower Churchill River at the Little Churchill River

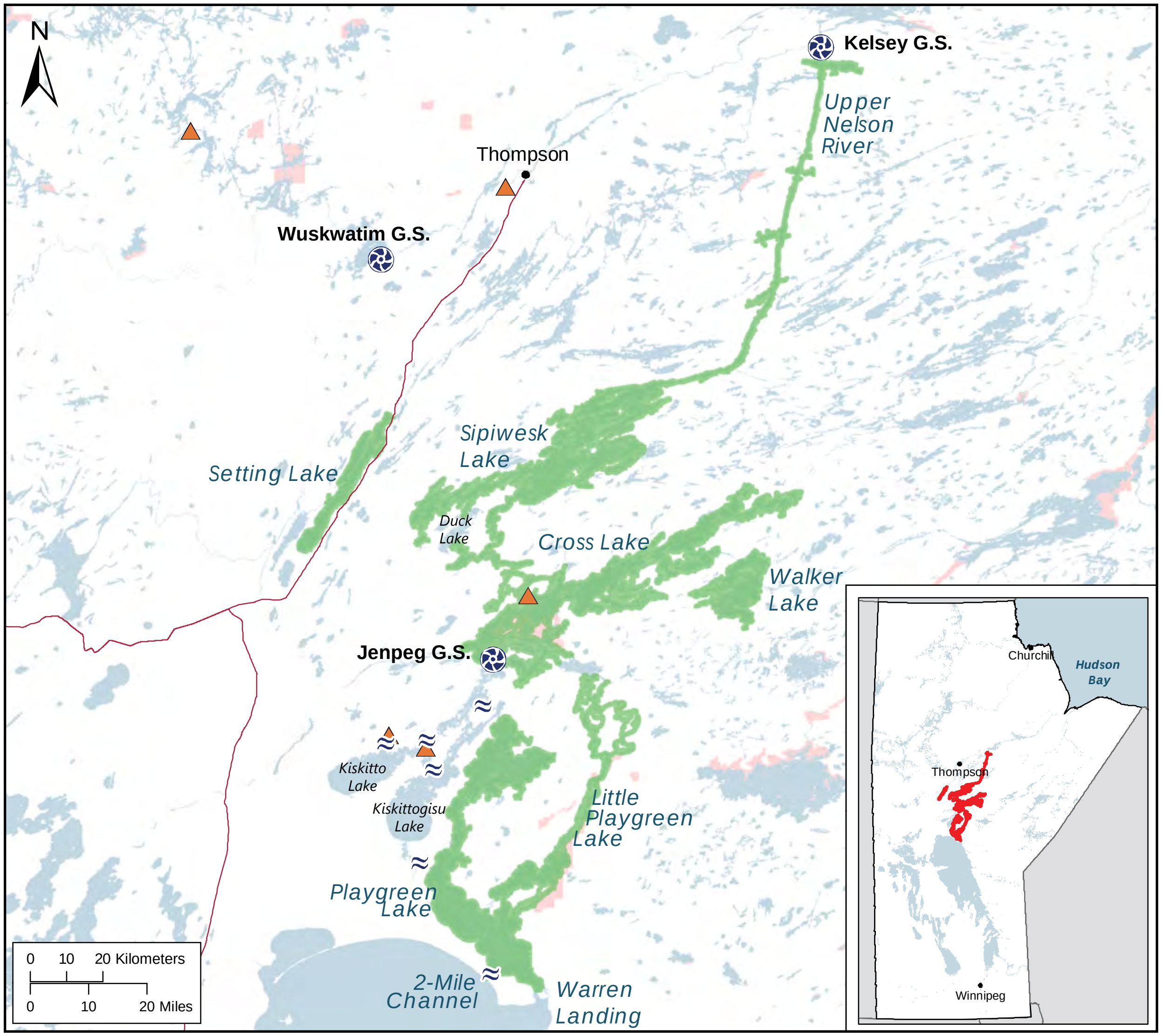
Conclusions

- Lower Churchill River water is less productive in general due to reduced upper Churchill River flows out of Southern Indian Lake.
- Increasing water levels were associated with increased abundance of some of the benthos. When water levels decreased, some habitat was lost (i.e., dried) resulting in lower benthos abundance.
- In riverine waterbodies, low flows concentrate fish, making them easier to sample and CPUE is typically higher (falsely suggesting higher abundance). Under high flows, fish may move into adjacent inundated floodplains that cannot be sampled (falsely suggesting lower abundance).

Future Considerations

- Continued CAMP sampling is recommended to help clarify relationships between low and high flows.

Aerial view of the Churchill River



Upper Nelson River Region

Legend

- CAMP Waterbody
- First Nation Reserve
- Highway
- Generating Station
- Control Structure
- Diversion

Sampling Sites

On-system monitoring

- **Annual** – Cross Lake, west basin
- **Rotational** – Playgreen Lake; Little Playgreen Lake; Sipiwesk Lake; Nelson River upstream of the Kelsey Generating Station
- **Annual water quality** – 2-Mile Channel; Warren Landing

Off-system monitoring

- **Annual** – Setting Lake
- **Rotational** – Walker Lake

Regional Highlights

- **Geography** – The upper Nelson River drains Lake Winnipeg and a watershed of approximately 1,050,000 km^2. The Nelson River flows through thick deposits of silt and clay, locally covered by thick organic deposits. The Upper Nelson River Region lies exclusively within the Boreal Shield Ecozone and primarily within the Hayes River Upland Ecoregion.
- **Manitoba Hydro setting** – The Jenpeg and Kelsey Generating Stations bound the upper and lower limits of the upper Nelson River. Upstream, the Jenpeg GS controls 85% of the flows out of Lake Winnipeg into Cross Lake while the remaining 15% of

the Nelson River flows pass unregulated through the East Channel into Cross Lake. At the downstream end of the upper Nelson River, the flow passes through the Kelsey Generating station and into Split Lake.

- **Hydrology** – Upper Nelson River flows are the product of Lake Winnipeg inflows and the high water levels experienced through the six-year reporting period. Consequently, upper Nelson River flows were also high.
- **Observed Results**
    - Most water quality results were within the provincial guidelines. Nutrient levels and other water quality parameters are a product of the upper Nelson River's water source, Lake Winnipeg.
    - Benthos were consistent in the upper Nelson River as high and steady water levels are maintaining stable habitat due to Lake Winnipeg Regulation.
    - The abundance of predatory fish (Walleye and Northern Pike) in Cross Lake is comparable to that of the upstream outlet lakes (Playgreen and Little Playgreen lakes).

Setting Lake, an off-system lake

Upper Nelson River Region Description

The Upper Nelson River Region extends from the outlet of Lake Winnipeg at Manitoba Hydro's 2-Mile Channel and Warren Landing downstream to the Kelsey GS near Split Lake. The Nelson River is the only outflow from Lake Winnipeg and the watershed drains a total area of approximately 1,050,000 km^2, including the Saskatchewan, Winnipeg, and Red river basins. Cultivated crops are the dominant land cover within the entire Nelson River drainage basin.

The upper Nelson River divides into two channels at Playgreen Lake: the east channel conveys 15% of the flow into Cross Lake. The west channel directs the remaining 85% of the water through a series of smaller lakes, including Playgreen Lake, to the Jenpeg GS.

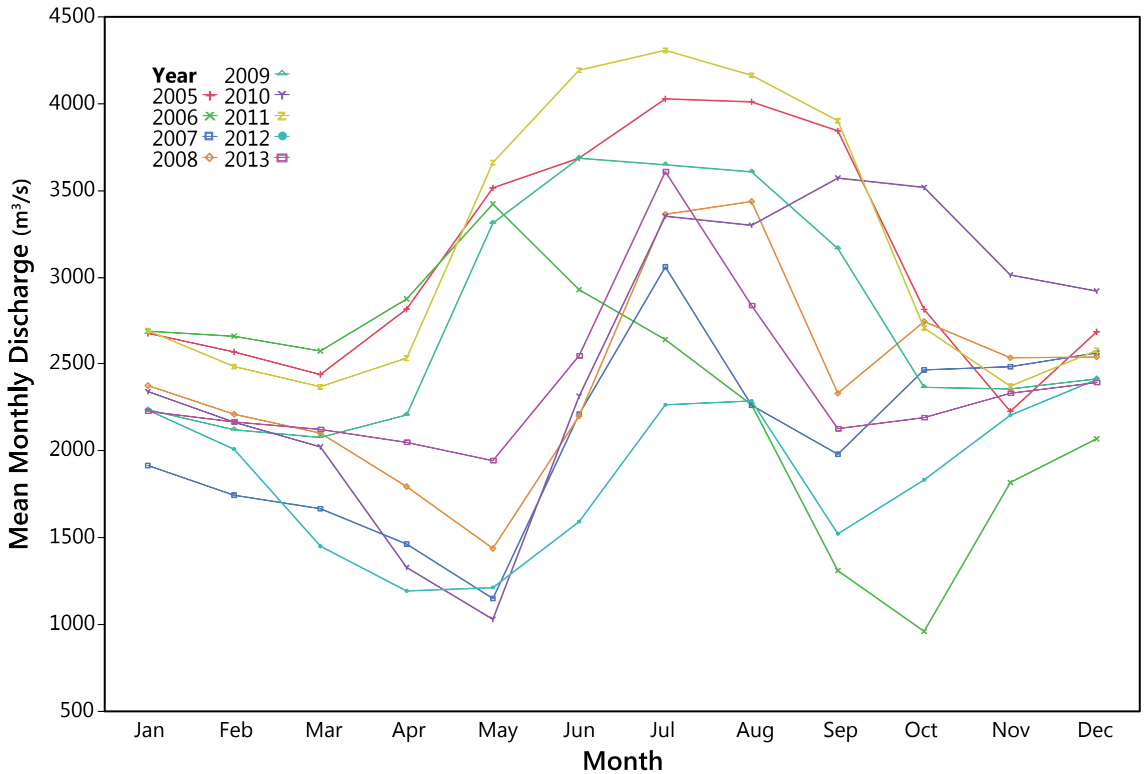
From the north end of Lake Winnipeg, the Nelson River flows through thick deposits of silt and clay, locally covered by thick organic deposits. Highly erodible silt and clay shorelines are dominant along the southwest shore of Playgreen Lake. Bedrock shorelines become increasingly common toward the northeast within the Playgreen, Kiskittogisu and Kiskitto lakes.

Cross Lake contains large islands that separate the lake into numerous basins and interconnecting channels. The lakeshore is dominated by low bedrock shorelines, some of which contain backshore soil deposits occasionally a few metres thick.

At the outlet of Cross Lake, the Nelson River forms one channel as it continues northward. A mixture of bedrock, soil and organic shorelines are also present within the downstream Sipiwesk Lake and Kelsey reservoir. The Kelsey GS releases water into Split Lake at the downstream boundary of the Upper Nelson River Region.

Upper Nelson River Hydrology

Jenpeg GS is operated so that its outflows are maximized when Lake Winnipeg is above 715 ft (217.9 m). When Lake Winnipeg is below 715 ft but above 711 ft (216.7 m), flows are managed primarily for power production, which typically means higher flow release during the winter than occurred prior to Lake Winnipeg Regulation. When power demand is reduced, lower flow releases generally occur



Mean monthly flows in the Upper Nelson River at Jenpeg Generating Station 2005-2013 during the open water period. Should Lake Winnipeg ever drop below 711 ft, outflows would be managed by the Minister of Sustainable Development.

The effects of variable flows out of Lake Winnipeg into Cross Lake are mitigated by the weir at the outlet of Cross Lake that was constructed in the early 1990s to increase the average water level. A wider outlet from Cross Lake also increases the ability of the outlet to pass water at higher flows.

Downstream from Cross Lake, water levels are affected by both upstream Jenpeg GS releases and the backwater effects and operation of Kelsey GS. This can result in widely varying water levels in Sipiwesk Lake.

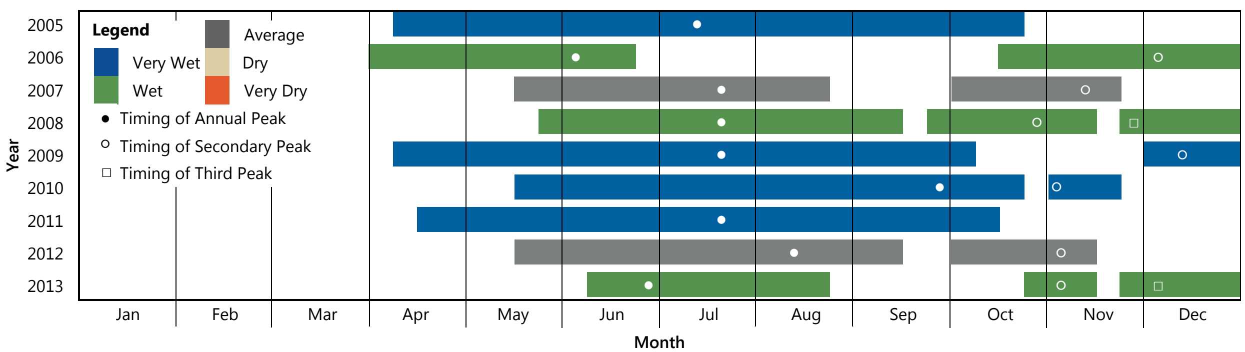
Mean monthly flows at Jenpeg GS indicate that flows followed a natural seasonal pattern in that discharges increased in May and continued at high levels through the summer then decreased with low levels in the fall and winter. Peak flows were typically in July to early fall.

Backwater effect: *In hydrologic terms, the effect that a dam or other obstruction has in raising the surface of the water upstream from it.*

This pattern is associated with generally wet conditions and as noted for the other CAMP regions, this six-year period was predominantly classified as "wet" to "very wet". By contrast, only three of the previous 25 years were classified as "wet" years and there were no "very wet" years.

From 2008 to 2013, the Kelsey GS reservoir was controlled within a typical range and water levels were decreased for a short period when there was a high power demand and then the reservoir refilled as power demand was reduced.

The off-system Walker Lake also experienced above average water levels from 2008 to 2013. Although considered off-system, Walker Lake water levels are periodically affected by high water levels at Cross Lake. This backwatering effect occurred in 2010 and 2013 when Walker Lake was sampled. The other off-system lake in the Upper Nelson River Region is Setting Lake. Based on the limited data available, it appears that 2010 and 2013 were lower water level years during the summer season, with water levels increasing in the late fall due to precipitation.



Jenpeg Generating Station annual high flow duration, timing and peaks

Sediment Summary

Sedimentation processes are complex in the Upper Nelson River Region as the system is dominated by the numerous lakes connected by riverine reaches. High flows and water levels in 2011 caused the formation of a new channel at the exit of Duck Lake.

During open water periods, sediment transport is highly influenced by winds that cause shoreline erosion and re-suspension of bottom sediments. This was notable at 2-Mile Channel where south winds eroded and re-suspended sediment on the north shoreline of Lake Winnipeg that is then carried through 2-Mile Channel into Playgreen Lake. Conversely, north winds caused the same occurrence on the south shoreline of Playgreen Lake. In both cases, a distinct sediment plume was apparent along the southwest part of Playgreen Lake while the northeast portion was much clearer. At times the sediment plume was then directed through 8-Mile Channel and into Kiskittogisu Lake.

Due to the limited data and complicated water flows through the east and west channels in the upper Nelson River area, the overall sediment transport conditions through the area are not well understood.

Ecosystem Hypotheses

Playgreen and Kiskittogisu lakes – High Lake Winnipeg water levels resulted in high flows, nutrients and an increase in primary productivity in these three lakes.

Within Playgreen Lake, the sediment plume along the southwest shoreline is distinctly different from the bedrock controlled and clearer northeast shore. This turbid southwest shore water from Playgreen Lake exits out of 8-Mile Channel into Kiskittogisu Lake while clearer northeast shore water continues to flow north through the remainder of Playgreen Lake. It is expected that the different substrate and water quality conditions on the two sides of Playgreen Lake will affect ecosystem functions and productivity.

2-Mile Channel sediment plume

Benthos variability is expected due to the differences in substrates on the east and west shores of Playgreen Lake. Soft substrates occur on the west shore, while harder bottom substrates and increased algae attached to rocks are present in the clearer water of the east shore. This benthos variability could affect fish community structure.

In Kiskittogisu Lake, the addition of Playgreen Lake southwest shore sediment would tend to settle or continue in suspension downstream to the Jenpeg reservoir. Some sediment would settle in the reservoir and the remainder would continue downstream through the station.

Cross and Walker lakes – While extreme low spring and summer water levels were observed in Cross Lake in the late 1970s, immediately after the construction of Lake Winnipeg Regulation, these water level effects have been mitigated by the Cross Lake Weir. Reduced spring flows caused settling of sediment in Cross Lake. Due to many islands and channels in Cross Lake, increased sediment deposition is less likely to be noticed.

Sipiwesk Lake – Sipiwesk Lake water levels have been high during the first six years of the CAMP. Consistently wetted habitat should yield relatively stable benthos abundances and consistent fish abundance. Downstream of Sipiwesk Lake, relatively steady high water levels in the Kelsey Reservoir and slower reservoir water velocities likely means that the Kelsey reservoir is a sediment deposition zone with softer offshore sediments and a benthic community composed of organisms adapted to that type of bottom habitat.

Due to the steep sides of the Nelson River channel in this area, the higher water levels upstream of the Kelsey GS are contained within the banks of the Nelson River with relatively little littoral zone. However, flooding into stream valleys in this reach does provide slower, littoral habitat where a more complex fish community would be expected to exist. Larger predatory, reservoir-adapted fish would be expected in the main Nelson River channel.

Results

Water Quality

In general, water quality was within provincial guidelines. Both lakes and rivers were well mixed and oxygenated. Low oxygen was only observed in one winter in Cross Lake. As in other regions, the off-system lakes (Walker and Setting lakes) were more prone to thermal stratification (layering of the water column) and lower oxygen levels that were outside of the provincial guidelines.

Water clarity was somewhat variable in this region, with higher spikes in total suspended solids occasionally at some sites. The upper Nelson River was moderately to highly productive, based on nitrogen, phosphorus and chlorophyll *a* parameters. On average, total phosphorus concentrations exceeded provincial guidelines in each year at all on-system sites. While high phosphorus is commonly observed in other lakes and streams in Manitoba, phosphorus concentrations were higher along the Nelson River than most other river systems monitored under the CAMP, which reflects the nutrient loading conditions upstream in Lake Winnipeg.

Data indicate a recent increasing trend for total alkalinity, hardness, specific conductance, and major cations and anions, which may reflect changes upstream (i.e., Lake Winnipeg drainage basin). While these particular water quality parameters are not CAMP indicators, relationships with hydrology and evaluation of trends will be further explored as additional data are acquired.

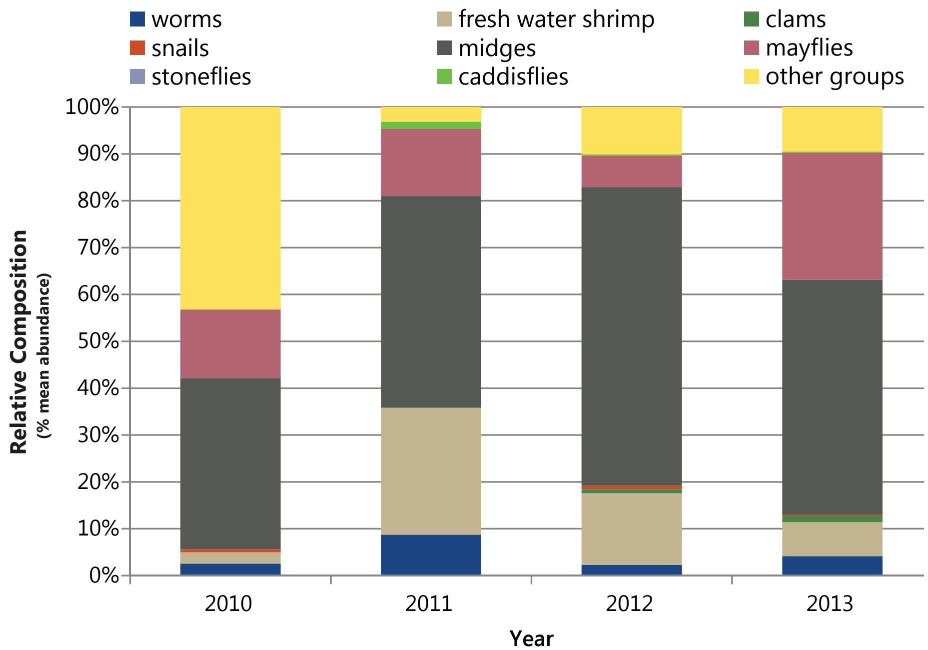
Warren Landing, an annual water quality sampling site

Benthic Macroinvertebrates

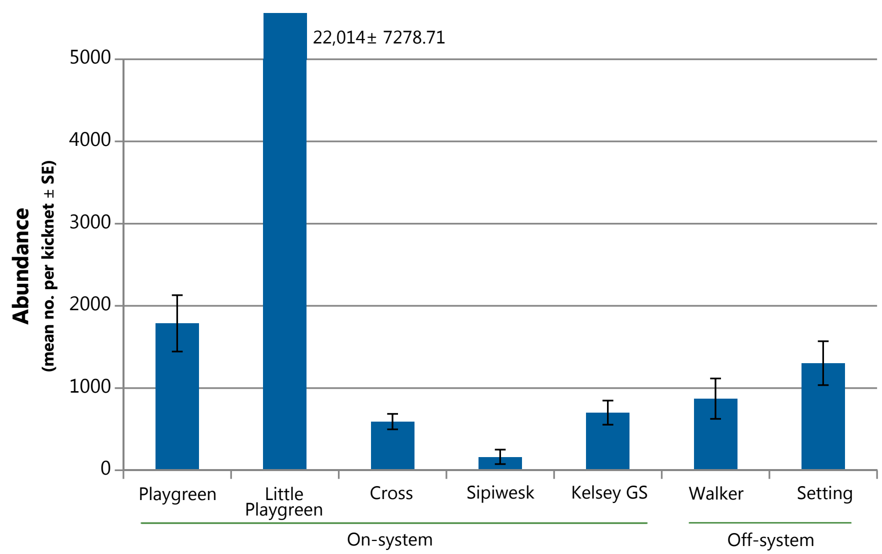
The nearshore benthos community of Cross Lake was comprised mostly of insects with midges generally outnumbering mayflies. Freshwater shrimp was consistently the most abundant group of non-insects. Nearshore benthos abundance of other on-system sites in the upper Nelson River was generally within the range observed in Cross Lake. Little Playgreen Lake was an exception where benthos abundance was more than ten times greater than the other lakes.

In Cross Lake, water levels were generally low during the first part of the growing season and increased to higher levels in late summer through early fall. Under these conditions, most nearshore sampling occurred in areas that were exposed for at least part of the growing season. The benthos community of the nearshore zone of Cross Lake showed little response to the large differences in the duration of wetting. As such, there were no differences between years in abundance, richness or diversity, despite the differences in water regime.

In offshore habitat, benthos abundance varied between waterbodies and years, with the highest values occurring in Little Playgreen Lake in 2010. Non-insects generally dominated the offshore fauna, and midges and mayflies were the dominant insects.



Relative composition of the benthos groups in the nearshore habitat of Cross Lake



Abundance of benthos at each nearshore site in the Upper Nelson River Region 2010 to 2013

Fish

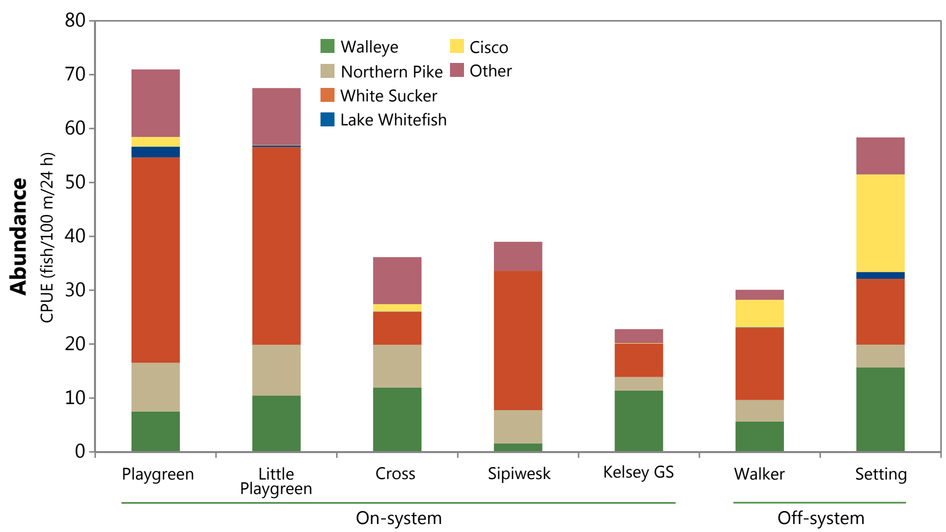
The diversity of the fish community of the lakes along the Upper Nelson River Region was generally similar except for Little Playgreen Lake, which was lower.

The total abundance of fish caught in standard gill nets was considerably higher in lakes upstream of Jenpeg GS (Playgreen and Little Playgreen lakes) as compared to those downstream of the generating station (Cross and Sipiwesk lakes). Some of this difference is explained by the greater abundance of White Sucker in the upstream lakes.

High water events on Sipiwesk Lake affected fish sampling. Lower abundance of Walleye in index nets was explained by local observation that the Walleye were plentiful but dispersed in the nearshore flooded shoreline where sampling could not be conducted for logistical reasons.

The condition (or fatness) of Northern Pike and Walleye was considerably lower in Cross Lake compared to the other on-system waterbodies within the region but was similar to those of Northern Pike and Walleye from Setting Lake. The condition of Northern Pike and Walleye declined from 2010 to 2013 in Cross Lake. The same pattern of declining condition from 2010 to 2013 was observed for Northern Pike from Setting Lake, but not for Setting Lake Walleye. Further study will determine whether this pattern has persisted.

The fish community varied considerably among sampling years at both the annual on-system (Cross Lake) and off-system (Setting Lake) waterbodies. With the exception of the decline in the condition factor of Northern Pike and Walleye in Cross Lake and Northern Pike in Setting Lake mentioned above, there were no notable trends.



Abundance of fish species in the Upper Nelson River Region by waterbody

Cross Lake shoreline

Conclusions

Playgreen and Kiskittogisu lake water flows and levels were less affected by Manitoba Hydro operations at the Jenpeg Generating Station than by Lake Winnipeg water levels which are determined by inflows to Lake Winnipeg.

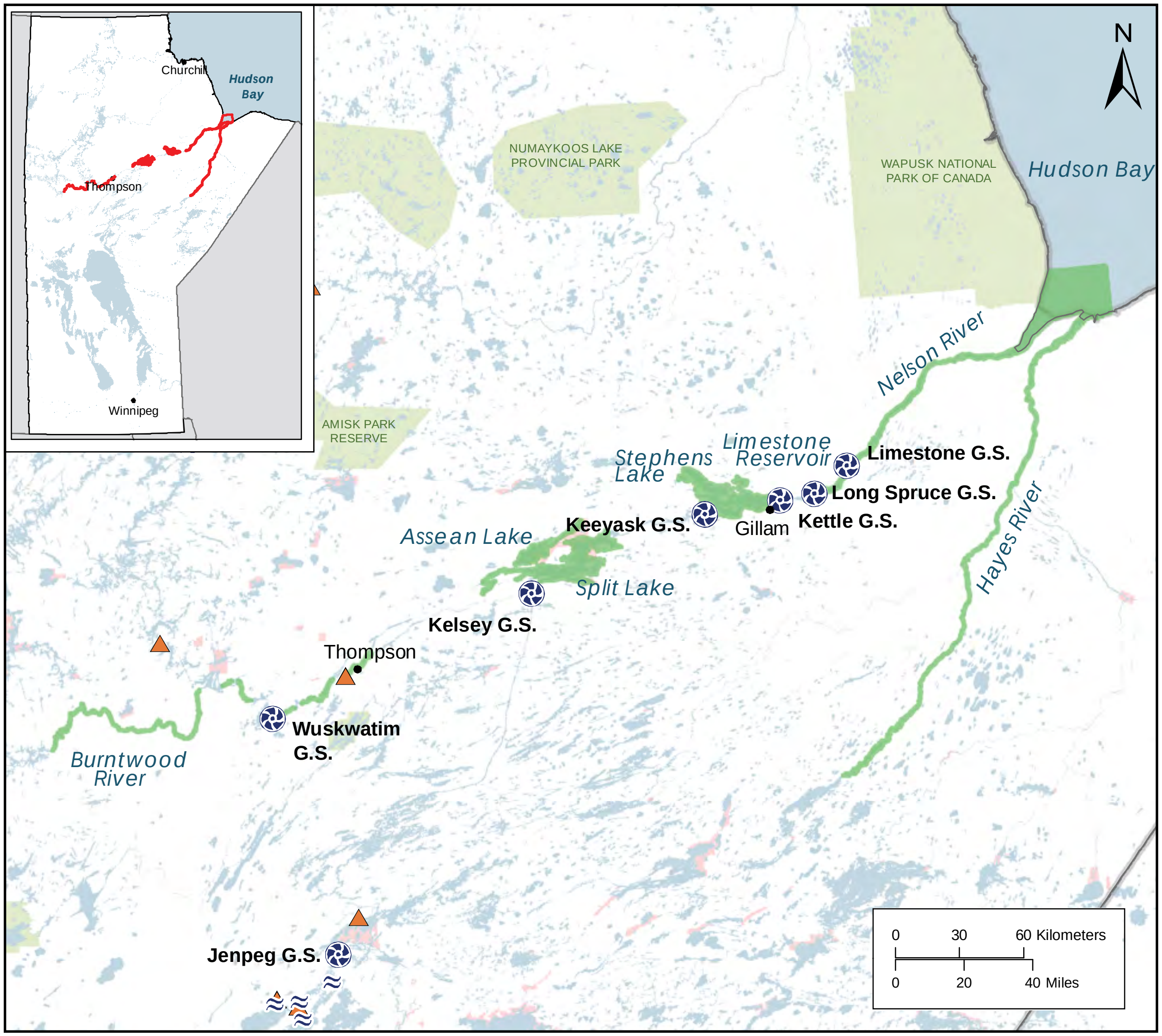
Water quality was mostly within provincial guidelines. Nutrients and chlorophyll *a* were relatively similar across sites in the Upper Nelson River Region. The Lake Winnipeg outflow conditions largely determine water quality along the upper Nelson River, rather than local influences

Benthos abundance is stable and adequate to support the fish community in the upper Nelson River as high and steady water levels are maintaining relatively consistent habitat. The abundance of Northern Pike and Walleye in Cross Lake is similar to the upstream Playgreen and Little Playgreen lakes. Upstream of the Kelsey GS, the Nelson River has a less diverse fish community and lower total fish abundance; however, as with Cross Lake, the relatively high catch of Walleye suggests that forage fish and lower trophic levels are sufficient to support a relatively healthy Walleye population.

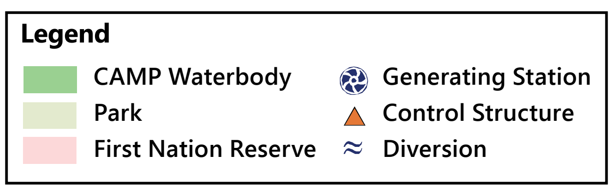
Future Considerations

- Continual mapping of substrate type and sediment deposition will provide a better understanding of the benthos distribution.
- Analyses of Playgreen Lake's southwest and northeast shoreline sampling sites should be performed to characterize any differences in benthos and fish communities.

Setting up for substrate mapping of Playgreen Lake



Lower Nelson River Region



Sampling Sites

On-system monitoring

- **Annual** – Split Lake, lower Nelson River downstream of the Limestone Generating Station
- **Rotational** – Stephens Lake south, Stephens Lake north and Limestone reservoir
- Burntwood River (annual – water quality, rotational – benthos and fish)

Off-system monitoring

- **Annual** – Hayes River
- **Rotational** – Assean Lake

Regional Highlights

- **Geography** – While the Lower Nelson River Region itself cuts through the Boreal Shield and Hudson Plain ecozones and is situated on the Canadian Shield, the Nelson River watershed encompasses almost all other ecozones in Manitoba, including the
Taiga Shield, the Boreal Plain and the Prairie. Lacustrine clay materials underlie much of the very large drainage basin of 1,400,000 km^2, the lower Nelson River

carries more dissolved solids and a higher sediment load than most other Canadian Shield rivers.

- **Manitoba Hydro setting** – Three large generating stations on the lower Nelson River generate 70% of the hydropower generated in Manitoba. Flow releases at those generating stations are synchronized to increase during periods of high power demand and then decrease when power demand is lower in the evening or on weekends.
- **Hydrology** – The flows on the lower Nelson River encompass most of flows from the rest of the system. During the six-year reporting period, precipitation and flows were higher than average across the system, resulting in higher flows in the lower Nelson River as well as the off-system Hayes River.

Hayes River - an off-system river

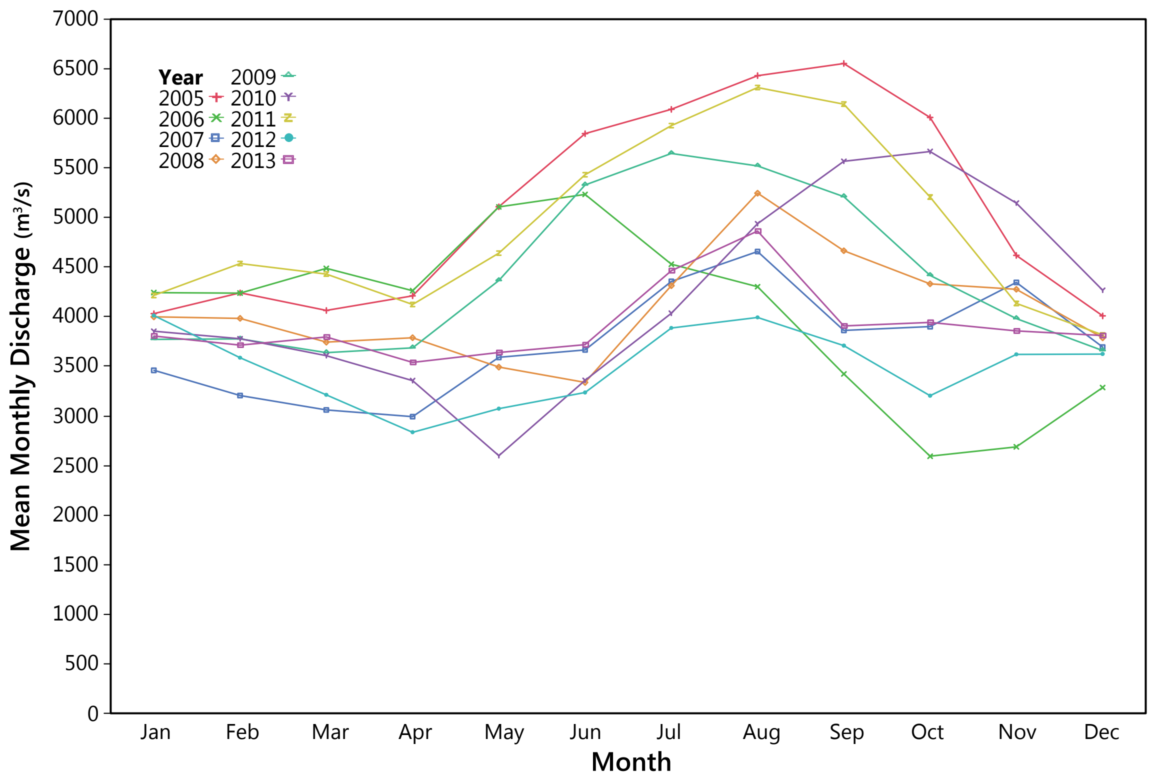
- **Observed Results**
  - Water clarity was moderate and most parameters were within provincial guidelines. Conditions largely reflected the combined effects of the two major inflows, the Burntwood and upper Nelson rivers.
  - Benthos community abundance and diversity were higher in those habitats that were consistently wetted leading up to the sampling period. Benthos varied considerably but was also related to the substrate.
  - Fish community was relatively consistent. Healthy abundances of predators in index netting in most waterbodies suggest that the ecosystem has sufficient food for top-level predators.

Lower Nelson River Region Description

The Lower Nelson River Region extends from the Kelsey GS downstream to Hudson Bay and includes the Burntwood River from First Rapids to Split Lake. The lower Nelson River flows in a relatively straight single channel from Split Lake to its mouth on Hudson Bay, flowing through a series of lakes and reservoirs. Portions of this reach of the river have steep banks that gradually decrease in slope as they approach Hudson Bay. Waterbodies along the lower Nelson River include Split, Clark, Gull, and Stephens lakes, and the Long Spruce and Limestone GS reservoirs.

At its mouth, the Nelson River drains an area of approximately 1,400,000 km^2. The lower Nelson River cuts through the Boreal Shield and Hudson Plain ecozones, but the watershed encompasses almost all other ecozones in Manitoba, including the Taiga Shield, the Boreal Plain and the Prairie. Lacustrine clay materials underlie much of the drainage basin upstream of Lake Winnipeg. The dominant land cover within the upper watershed is cultivated crops; however, the vegetation community of the region is characterized by stunted black spruce, aspen and willows.

The lower Nelson River is regulated for hydroelectricity generation, with three existing (Kettle, Long Spruce and Limestone generating stations) and one under construction (Keeyask GS). The large generating stations on the lower Nelson River provide 70% of the electricity produced in Manitoba.



Mean monthly discharge from the Kettle Generating Station in the lower Nelson River from 2005-2013

Lower Nelson River Hydrology

Lower Nelson River flows are influenced by Lake Winnipeg outflows, and inputs of the Churchill River Diversion, which diverts the majority of the Churchill River flow into the Nelson River through the Rat-Burntwood River system.

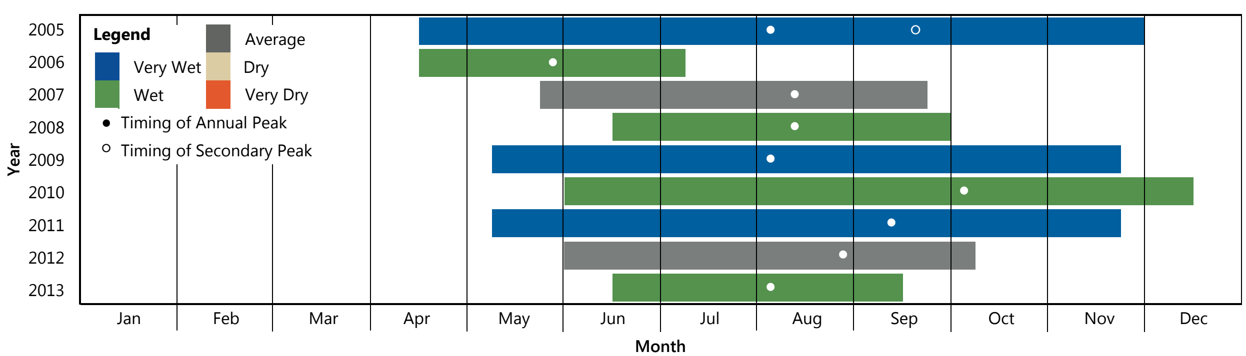
Data show that mean monthly discharges were generally between 3,000-4,500 m^3/s from December through April each year, and increased beginning in May through summer or early fall, peaking between 4,000 and 6,500 m^3/s and then began declining towards December. Peak flows during open water were generally reached in August of each year during 2008-2013.

As with the rest of Manitoba Hydro's system, high inflows and precipitation mean that lower Nelson River water flows were generally above average with almost no periods falling below the lower quartile. By contrast, only three of the previous 25 years were classified as "wet" years and there were no "very wet" years (Appendix 1).

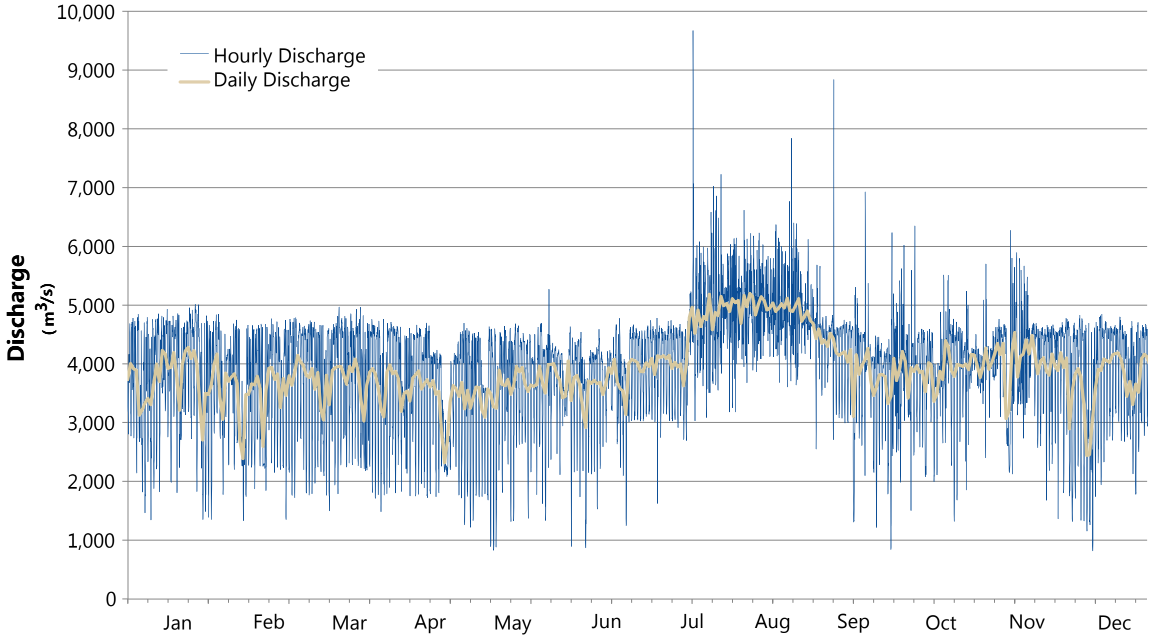
The daily flow cycling is started at Kettle GS and then repeated downstream at the Long Spruce and Limestone generating stations. Flows are increased to generate electricity during work hours and then are reduced to store water upstream in the reservoirs, when demand is low during the evening. Because there is relatively little storage capacity in the Long Spruce and Limestone GS reservoirs, releases follow the Kelsey GS outflow pattern.

Depending on river flows and generating station operations, the Limestone GS discharge can range daily between 880 m^3/s and 4600 m^3/s. When this happens, reservoir and tailrace water elevations fluctuate resulting in a band of intermittently watered habitat on the edge of the river on a daily basis.

The off-system reference waterbody is the Hayes River, which follows a typical flow pattern for an unregulated river. Flows peaked in April-May and then declined throughout the winter. Assean Lake was more comparable to the upstream lakes and reservoirs on-system as water levels followed a similar pattern with a peak in mid-April to early-May and a slow decline throughout the winter. Water levels were most variable in the summer months depending on local precipitation in the basin.



Kettle Generating Station annual high flow duration, timing and peaks



Note: discharges include spill when it occurs

Limestone Generating Station hourly and daily total discharges in 2013

Sediment Summary

Split Lake sedimentation is influenced by the contributions of the upper Nelson River and the Burntwood River. Full mixing of those sediment plumes occurs at or near the exit of the lake. The composition of the two plumes also varies with lighter suspended sediment entering from the Churchill River and darker sediment entering from the Nelson River. As noted in the Churchill River Diversion Region chapter, the Burntwood River carries higher sediment loads into Split Lake since the Churchill River Diversion.

Further downstream, the shorelines between Clark Lake and Gull Rapids consist predominantly of peat but coarse-textured and fine-textured mineral soils are also common. Keeyask environmental assessment studies showed that the suspended sediment concentrations typically varied from 5–30 mg/L, averaging about 13-16 mg/L, from Clark Lake to Gull Rapids.

Average monthly suspended sediment concentrations at six Stephens Lake sites ranged from approximately 3 to 19 mg/L in the open water months with an overall average of approximately 9 mg/L. Concentrations in Stephens Lake decreased in the downstream direction suggesting that some of the suspended material transported by the Nelson River is settling in Stephens Lake.

Within the Long Spruce and Limestone reservoirs, the old riverbed is generally still composed of coarse material with deposition of finer material contained to the nearshore areas. From the Limestone GS to Hudson Bay the river shorelines transition from bedrock to ice-scoured terraces to slumping shorelines with some ice-scoured till banks. It has been determined that along the lower Nelson River below Limestone GS the overall morphology of the Nelson River has remained relatively unchanged since the 1950s.

The sediment load changes along the course of the lower Nelson River with turbidity and total suspended solids generally increasing from upstream to downstream along the Nelson River upstream of Gull Lake with Stephens Lake acting as a sediment trap, trapping approximately 30% of the sediment that enters it.

As observed in other lake-influenced areas, periods of high wind speeds contribute to increases in total suspended solids concentrations in the lower Nelson River and total suspended solids concentrations generally show no correlation to instantaneous discharge. Studies have also indicated that bedload is a negligible portion of the total sediment load on riverine reaches of the lower Nelson River downstream of Split Lake and downstream of the Limestone GS.

Ecosystem Hypotheses

In Split Lake, there are two inflows with different water quality and suspended sediment characteristics, which stay separate in plumes through the length of the lake. Since both water sources remain unmixed through Split Lake, this may result in ecosystem differences. Sampling can be expanded to test for differences based on the distinct separation of water quality and any sedimentation in these two plumes. Upon leaving Split Lake, the water is fully mixed.

Stephens Lake is a depositional site for Nelson River sediment load, suggesting that the benthos community in those areas is composed of organisms that are adapted to softer depositional sediments and potentially low oxygen conditions. The off-current northern arm of Stephens Lake is the exception, where water is clearer, wind is less intense, and aquatic plants may grow more easily in the shallow shoreline areas. This may result in a more diverse benthic and forage fish community.

Downstream of Kettle GS in the Long Spruce and Limestone GS reservoirs, habitats have changed from riverine to more lake-like. While these reservoirs are affected by large Kettle GS daily flow fluctuations, shorelines remain wet due to the backwater effect of downstream dams. The fish community in these reservoirs is therefore expected to reflect the change. The old river channel would likely have a different benthic community than the flooded nearshore areas where the soft bottom, would facilitate burrowing invertebrates in a relatively low diversity community.

The largest effect is anticipated to be downstream of Limestone GS where large daily flow changes creates a band of intermittently wetted habitat along the shoreline. This will likely reduce primary and secondary productivity, and result in decreased ecosystem productivity and fish community. Insectivorous fish would be reduced in the more riverine fish community.

If there is intermittent wetting during spring spawning, fish may deposit eggs further up the shore during the daytime. These areas might then be dewatered in the evening as flows and water elevations drop. This would expose eggs and dry them out, reducing spawning success.

Results

Water Quality

Water quality was generally within provincial guidelines, and usually well-mixed and oxygenated year-round. The lower Nelson River was moderately to highly nutrient-rich. On average, total phosphorus concentrations were in excess of the provincial guidelines. This also occurred in other CAMP regions. Water quality conditions along the lower Nelson River were relatively similar and largely defined by those of the major inflow (i.e., upper Nelson River), rather than local influences. The upper Nelson River contributes approximately 75% of the flow to the lower Nelson River on average and is therefore the dominating influence on water quality in this region.

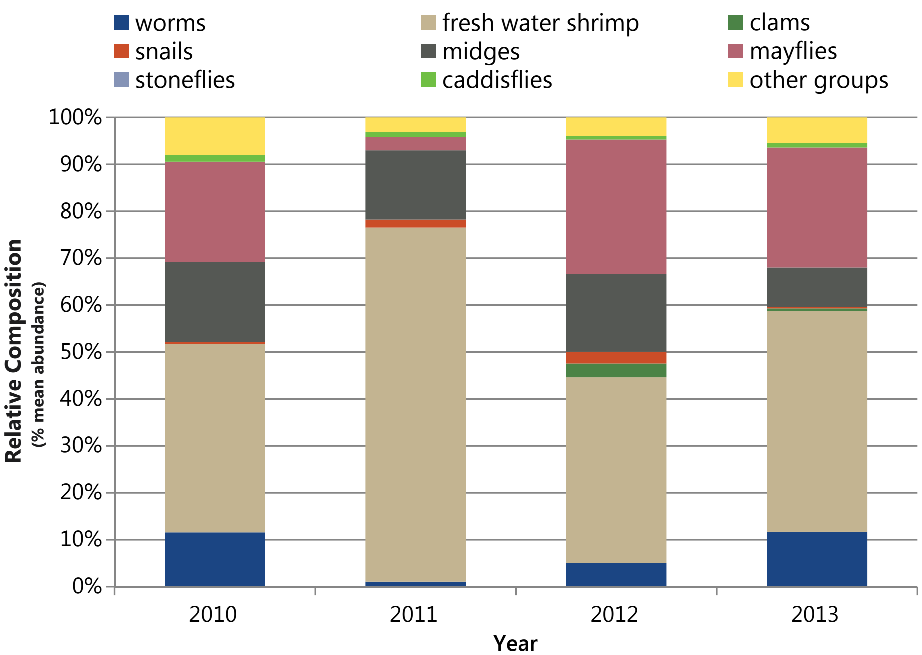
The CAMP data indicate a potential recent increasing trend for several non-key indicators of water quality (total alkalinity, hardness, specific conductance, and major cations and anions). Available information suggests that these recent increases, notably those observed in 2013, may reflect changes upstream in the Lake Winnipeg drainage basin.

Benthic Macroinvertebrates

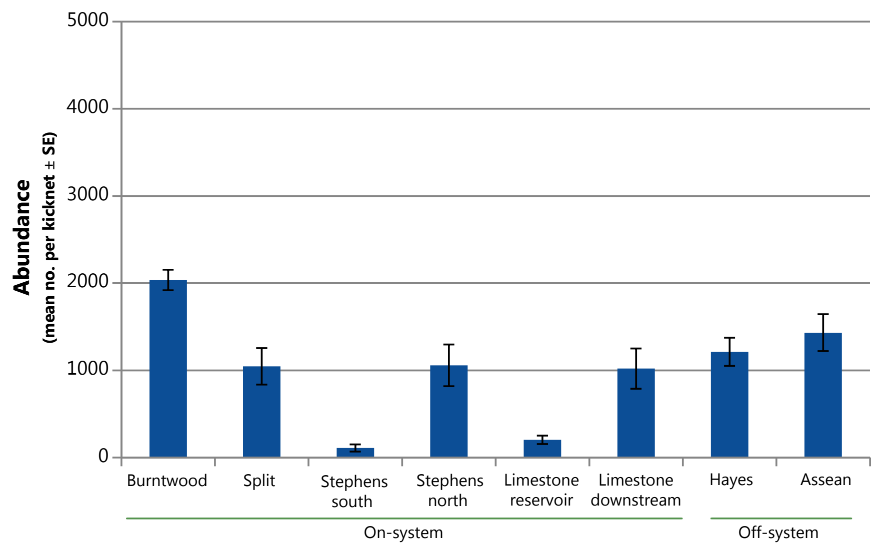
In the nearshore of Split Lake, freshwater shrimp were consistently abundant, along with worms, midges, mayflies and water boatmen, although the relative abundance of these groups varied among years. Habitats that were consistently wetted in Split Lake were more suitable for benthos. For example, in 2012, sampling was conducted at a low elevation that was permanently wetted and abundance was markedly higher than in other years.

As with Split Lake, the duration of shoreline exposure and water levels affected abundance in the nearshore of Stephens Lake, the Limestone Reservoir and the lower Nelson River benthos samples. The benthos in the nearshore of the off-system waterbodies was more diverse, possibly due to the presence of cobble, rather than sand/silt substrates. As with the on-system waterbodies, abundance was also affected by the duration of wetting in the nearshore habitat.

Overall, analysis of the four years of benthos monitoring data collected in the Lower Nelson River Region indicated that there were no consistent trends.



Relative composition of the benthos groups in the nearshore habitat of Split Lake



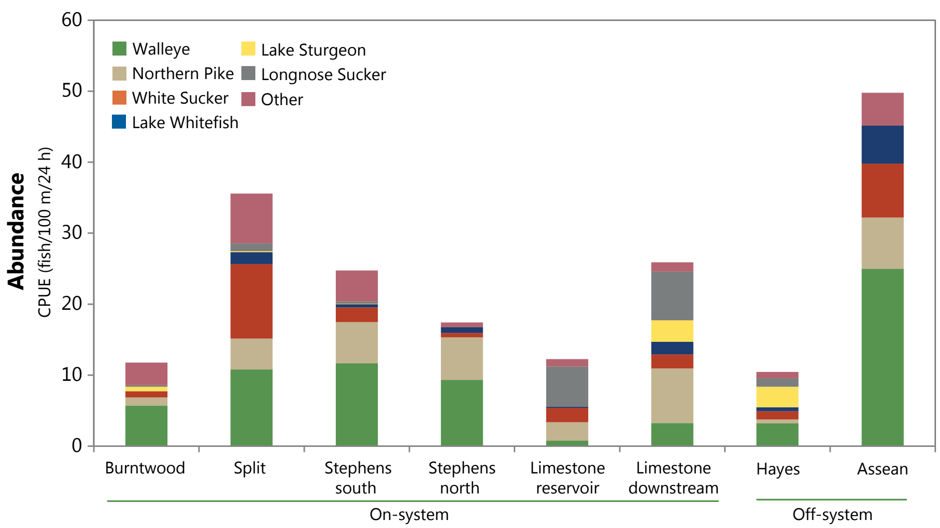
Abundance of benthos at each nearshore site in the Lower Nelson River Region 2010 to 2013

Fish

Fish community diversity in the lakes within this region generally decreased downstream. While at the riverine locations, the diversity trend was reversed with the Burntwood River having a higher diversity than the lower Nelson River, downstream of the Limestone GS.

The most commonly captured species in the on-system waterbodies were typically Walleye and Northern Pike, although there were differences in the species composition among waterbodies. Walleye was the most abundant species in the waterbodies upstream of the Kettle GS, but accounted for a smaller proportion of catches downstream of the GS where Longnose Sucker and Northern Pike were particularly abundant. White Sucker were most abundant in Split Lake.

The condition of Walleye and Northern Pike from Split Lake and Northern Pike in the lower Nelson River downstream of the Limestone GS decreased in the last two years of the six-year sampling period. As in Lake Winnipeg, the decline in condition coincided with a decrease in the abundance of Rainbow Smelt, an invasive forage species and principal diet item of Walleye and Northern Pike when abundant.



Abundance of fish species in the Lower Nelson River Region by waterbody

Conclusions

- Water quality is generally within the provincial guidelines. High nutrient levels in Lake Winnipeg are reflected in relatively high productivity downstream of Lake Winnipeg on the lower Nelson River.
- Benthos is likely affected by the degree of nearshore dewatering that occurs and the substrates that are present.
- Aquatic ecosystems are functioning to produce an abundance of predatory fish at the top of the food web; however, there appears to be a lower diversity of fish present in general in reservoirs than in the Burntwood River, downstream of First Rapids and in Split Lake.
- The diversity and abundance of fish in the lower Nelson River, downstream of the Limestone GS, suggests that while fish populations may be affected by daily flow fluctuations, the ecosystem is still functioning to produce a fish community with predatory fish.

Future Considerations

- A better understanding of benthos distribution and effects of water management will be increased as CAMP coverage of sampling site water depth and substrate mapping increases.
- Determining the full effects of cycled flow will require much more data.

Observations and Next Steps

The first six years of the CAMP were informative on several levels. While we have a growing understanding of hydro-related effects on Manitoba's aquatic environment, the first six years of data collection has not been long enough to be able to make definitive conclusions. As more information is collected over time, it will continue to be used to help inform a variety of processes from regulatory decision making to scientific research.

Statistical analysis can and has been used to help interpret the data as outlined in the regional descriptions. Throughout the reports, observations have been made where data appears to be showing some patterns, and relationships between variables may be emerging. As more information is gathered over the coming years, these initial observations may be challenged and new conclusions may be drawn. The CAMP views this as an opportunity for ongoing dialogue and is an indication of the transparency of the process we want to maintain. This dialogue will help us to continuously learn, improve, acknowledge and report on new understandings.

Even though six years of data is a relatively small data set, some observations about the program and the data from 2008 to 2013 have been made:

- All regions experienced generally wetter (i.e. higher flows) than average conditions.
- As expected, regional differences exist for some variables due to geography, latitude, climate, etc. (e.g. northern fish are known to grow slower than southern fish). These differences will continue to be studied and noted as the program progresses.
- There is a desire to better understand the physical environment, in particular sedimentation. As such, sedimentation studies and monitoring are planned for future years.
- The methodology for sampling benthos was changed in 2010 to provide more consistency from year to year and be more reflective of lake conditions.
- It was apparent that as flows increased, fish sampling efficiency decreased. This situation showed up in the data as a reduction in fish; however, local fishers indicated that the fish were in different locations, as higher water increased habitat rather than an actual reduction in fish abundance. We will continue to monitor this sampling bias and adjust methods, if possible, to better reflect actual conditions.

Based on the first six years of data, the following opportunities have been identified for consideration as next steps:

- Implement greater use of remote sensing/satellite imagery and continuous monitoring for water quality to supplement, and enhance fieldwork. Since the program covers such a vast geographic area, using tools that require little to no fieldwork would be economical and efficient, where feasible (i.e., not all variables can be measured using remote sensing).
- Initially, benthos sample sites were chosen based on "representative shorelines" with the assumption that typical shoreline conditions reflected typical substrates under the water. With better information from substrate and depth mapping, the CAMP should review benthos sampling to see if site selections should be modified to ensure that sites are representative of the sediment types for the waterbodies.
- A review of Lake Winnipeg water quality sites could be undertaken to determine if the sites are adequate to capture the water quality exiting the lake and entering Playgreen Lake.

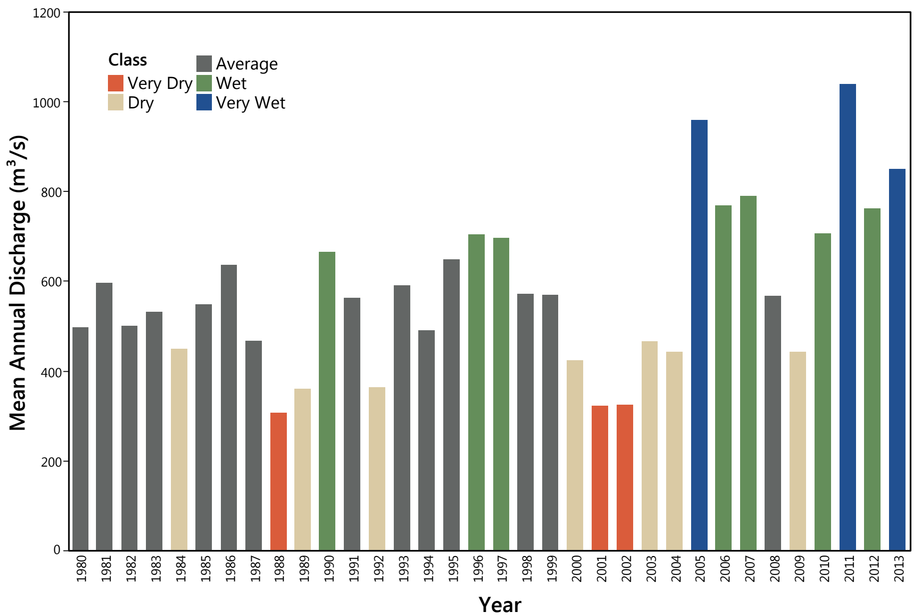
- When the CAMP was initially developed, there was a plan to eventually include a physical shoreline-monitoring component. While the initial phase of the CAMP focused on the aquatic ecosystem parameters and sampling protocols it is now appropriate to integrate a shoreline component to the CAMP monitoring.
- The next report will continue to build on the existing knowledge and review the entire program and data to date. We anticipate that as more data are gathered, more observations and confidence can be provided regarding the effects of Manitoba Hydro's operations.

The Coordinated Aquatic Monitoring Program strives to be credible and scientific through adherence to well-developed protocols and quality control measures, and will continue to provide objective information about hydrometric and environmental effects of hydroelectric development. The program will also continue to work to make that information available through the development and presentation of clear and understandable reports and materials for communities and the public, on the state, and aquatic effects of Manitoba Hydro's operations.

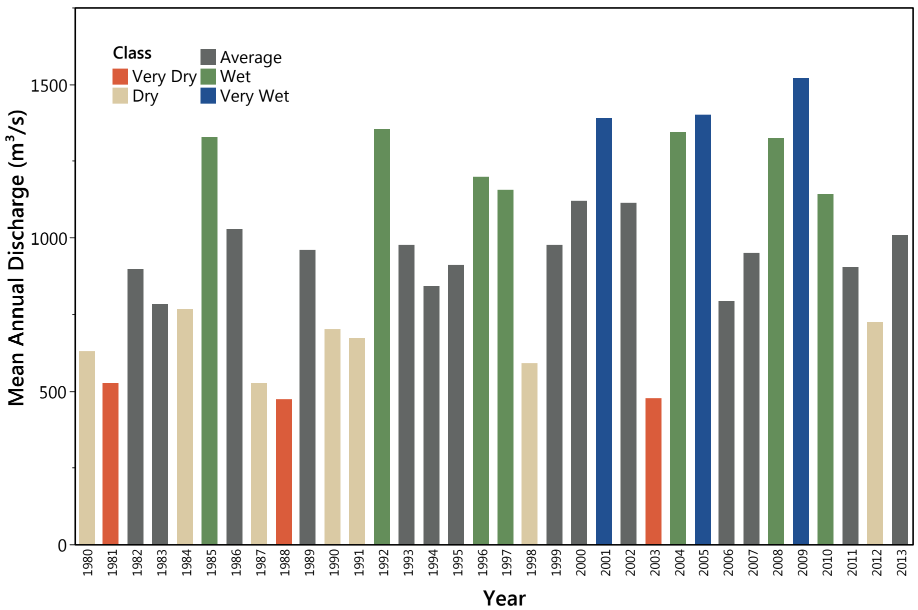
Charting bathymetry of Playgreen Lake

APPENDIX 1: CLASSIFICATION OF WATER YEARS

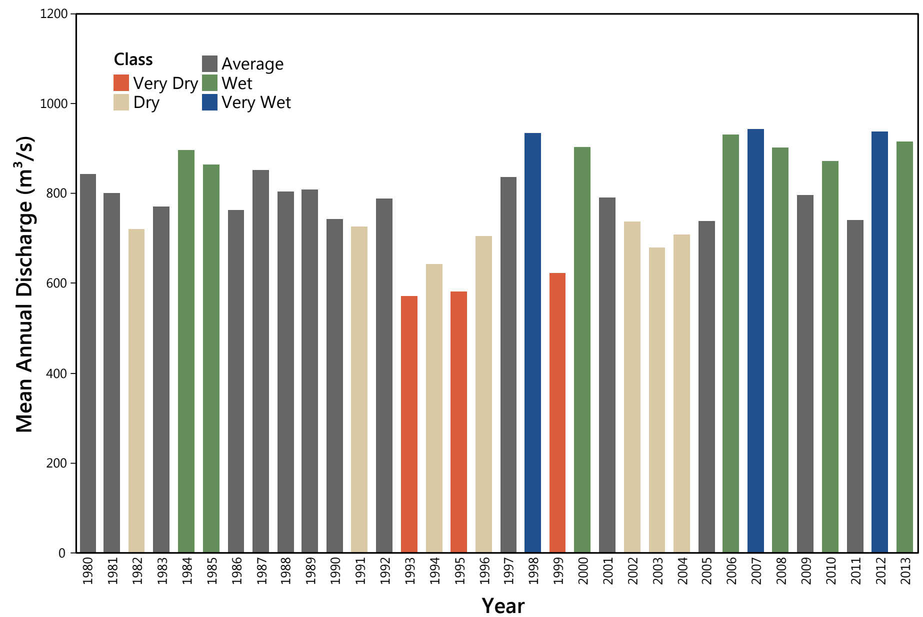
The mean annual flow within each CAMP region for each water year (January 1 to December 31) was compared with the range of mean annual flows for the region from January 1, 1980 – December 31, 2013 in order to categorize the water years as being either very dry, dry, average, wet or very wet. The category and percentile ranges were Very Dry 0 – 10%; Dry 10-30%; Average 30-70%; Wet 70-90%; Very Wet 90-100%.



Classification of water years in the Saskatchewan River Region on the Saskatchewan River at The Pas

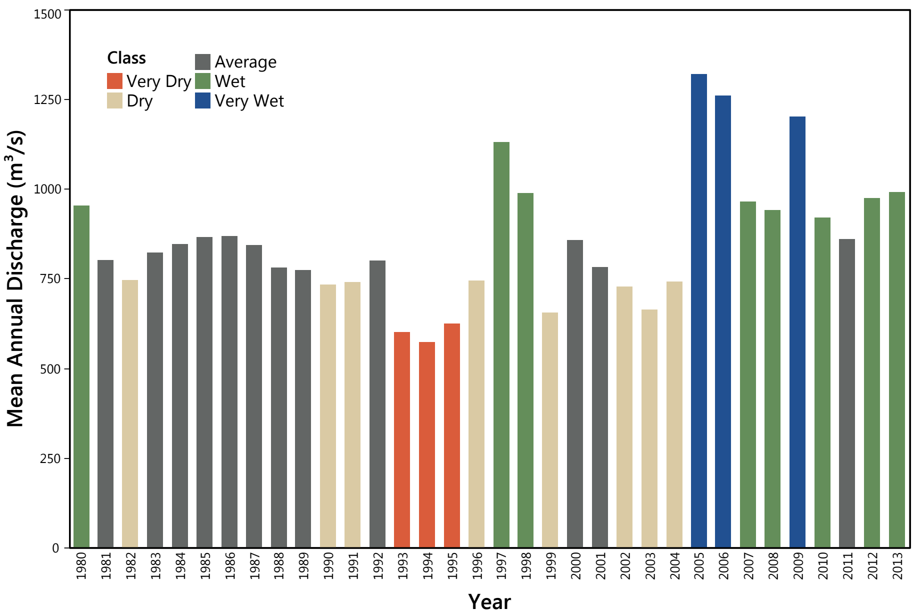


Classification of water years in the Winnipeg River Region on the Winnipeg River at the Pine Falls Generating Station

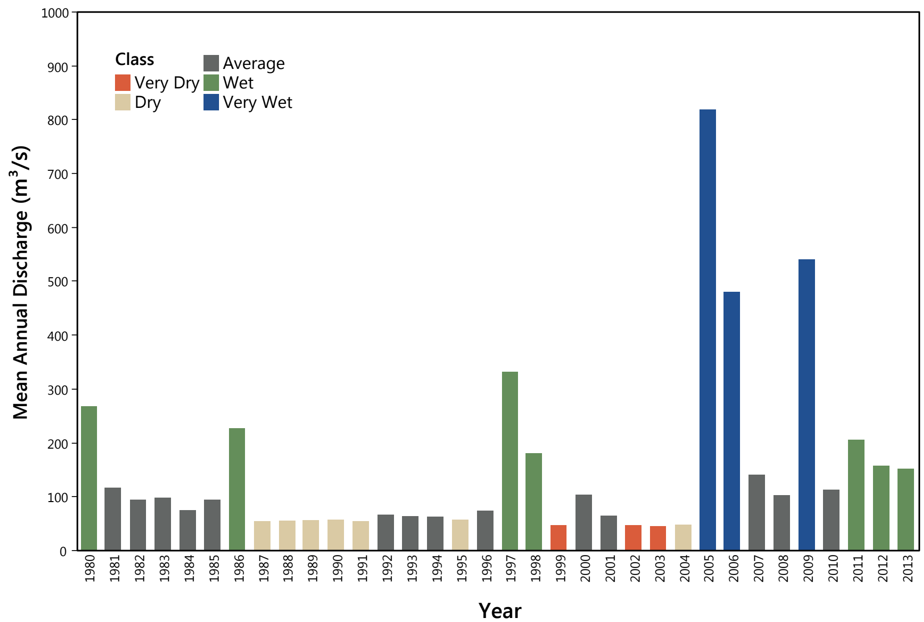


Classification of water years in the Churchill River Diversion Region at the Notigi Control Structure

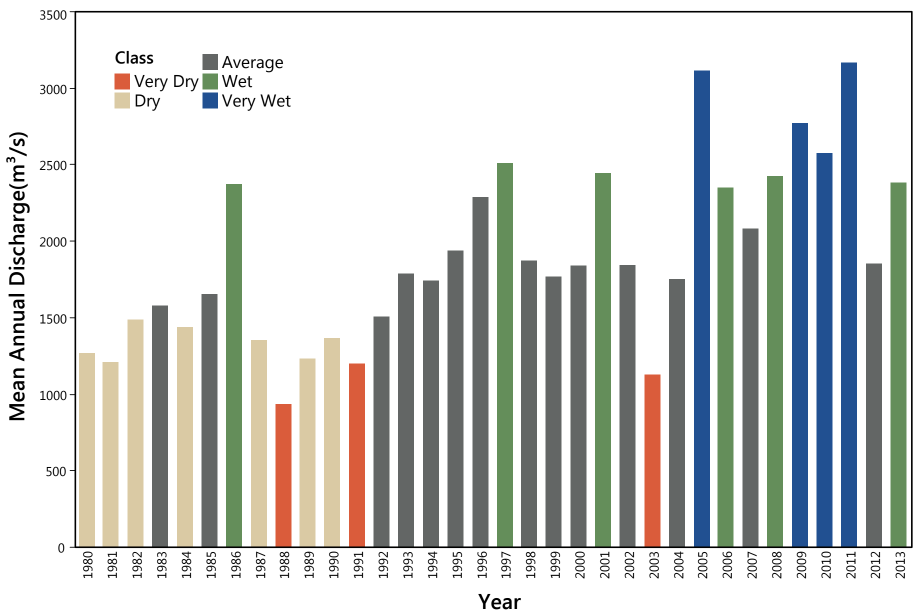
APPENDIX 1: CLASSIFICATION OF WATER YEARS



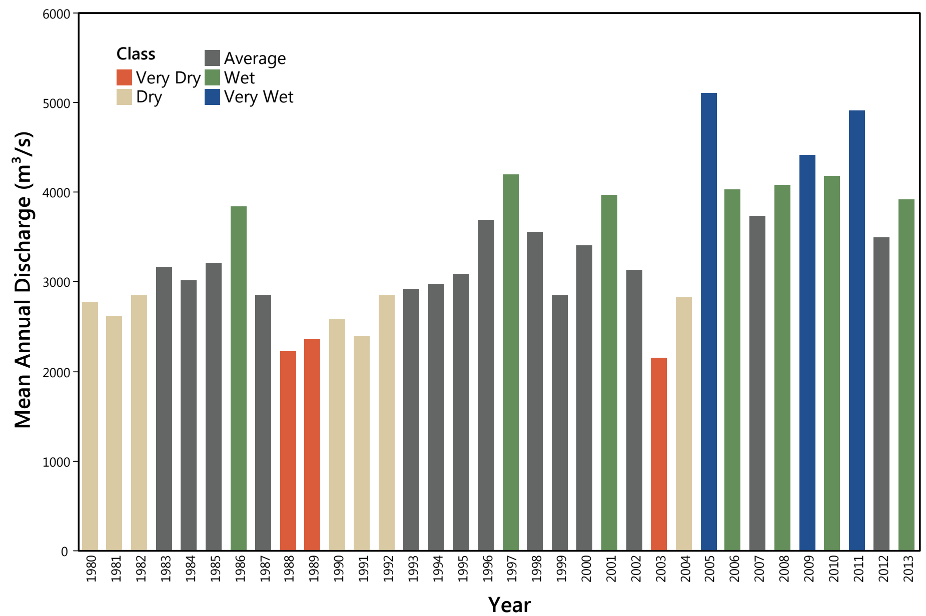
Classification of water years in the Upper Churchill River Region on the Churchill River above Leaf Rapids



Classification of water years in the Lower Churchill River Region at the Missi Falls Control Structure



Classification of water years in the Upper Nelson River Region at the Jenpeg Generating Station



Classification of water years in the Lower Nelson River Region on the Kettle Generating Station

CAMP

Mercury in Fish

Manitoba Hydro's developments in the late 1960s and the 1970s unexpectedly led to increased levels of mercury in fish along waterways affected by flooding. It was not fully understood at the time that when soil with high organic content is flooded, inorganic mercury is transformed by bacteria into "methylmercury" and subsequently released into the water. Methylmercury (referred to as mercury in this document) is taken up by primary producers (such as algae) in the water and transported throughout the food web where it reaches highest concentrations in predatory fish. Mercury in fish has been and continues to be a significant issue/concern for Indigenous communities in northern Manitoba.

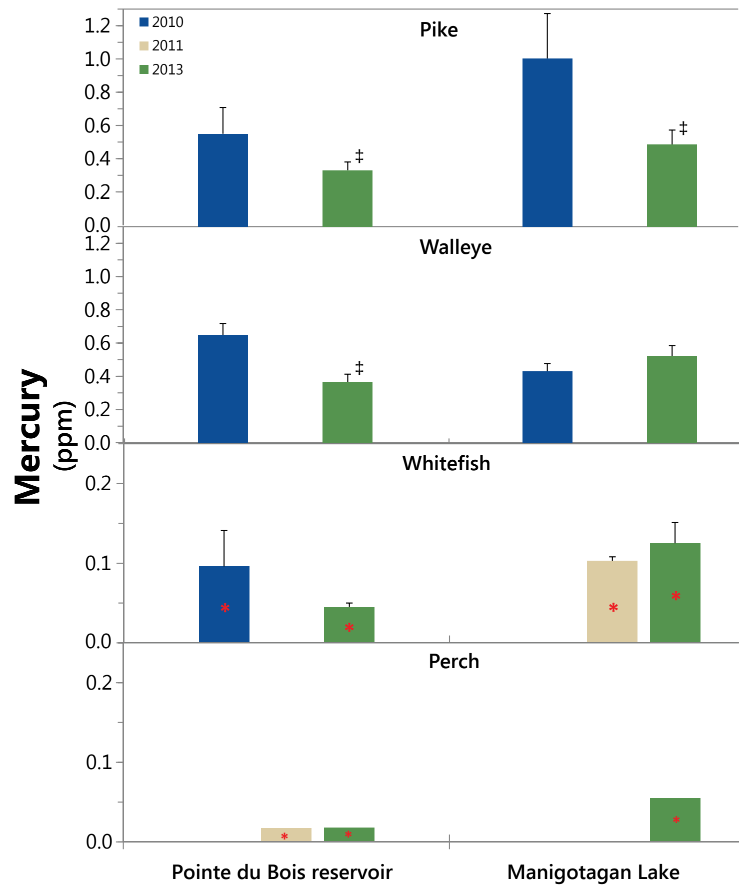
Currently, monitoring mercury in fish is ongoing under the Manitoba/ Manitoba Hydro Coordinated Aquatic Monitoring Program (as well as project specific monitoring under Wuskwatim and Keeyask).

Current monitoring results have shown that fish mercury concentrations in most lakes have fluctuated but generally declined reaching a minimum in 2005, which represented the lowest observed concentrations since flooding associated with Churchill River Diversion and generating stations on the Nelson River (Kelsey and Kettle Generating Stations). Since 2005 levels have fluctuated and have increased in fish in both regulated and unregulated waterbodies particularly in predatory fish; overall, however, levels are much lower than the maximum recorded soon after impoundment.

Due to the low levels of mercury in non-predatory fish (i.e., Whitefish and Perch) as compared to the predatory fish (Walleye and Pike), the scales on the following graphs have different ranges for clearer visualization of the data between lakes.

Winnipeg River Region

Fish mercury data were collected from one on-system waterbody (the Pointe du Bois Reservoir) and one off-system lake (Manigotagan Lake).

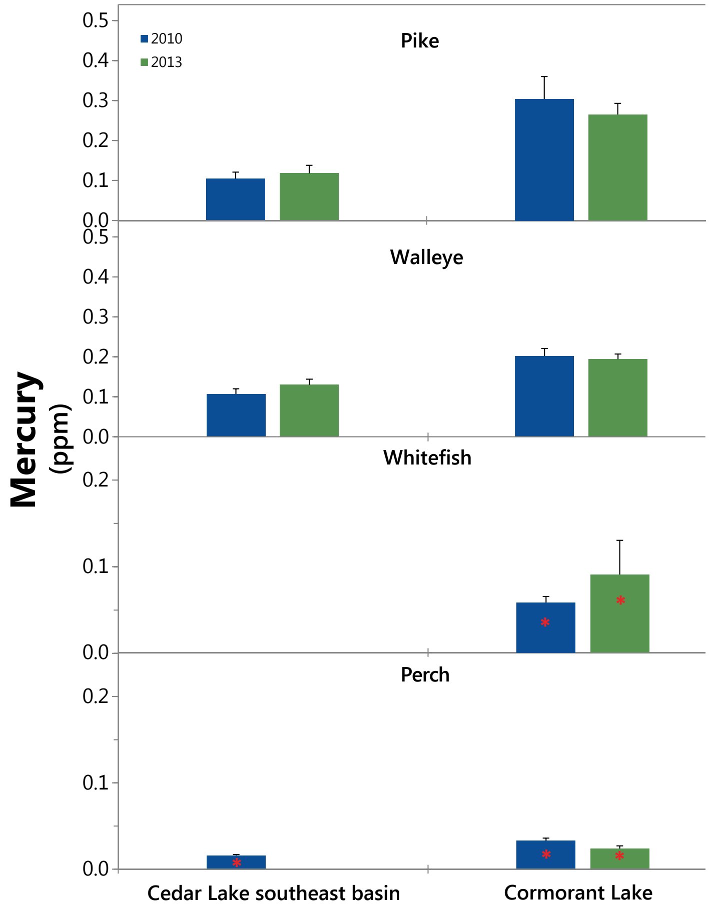


Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Winnipeg River Region waterbodies

Saskatchewan River Region

Fish mercury data were collected from one on-system site (Cedar Lake, southeast basin) and one off-system lake (Cormorant Lake) in 2010 and 2013.

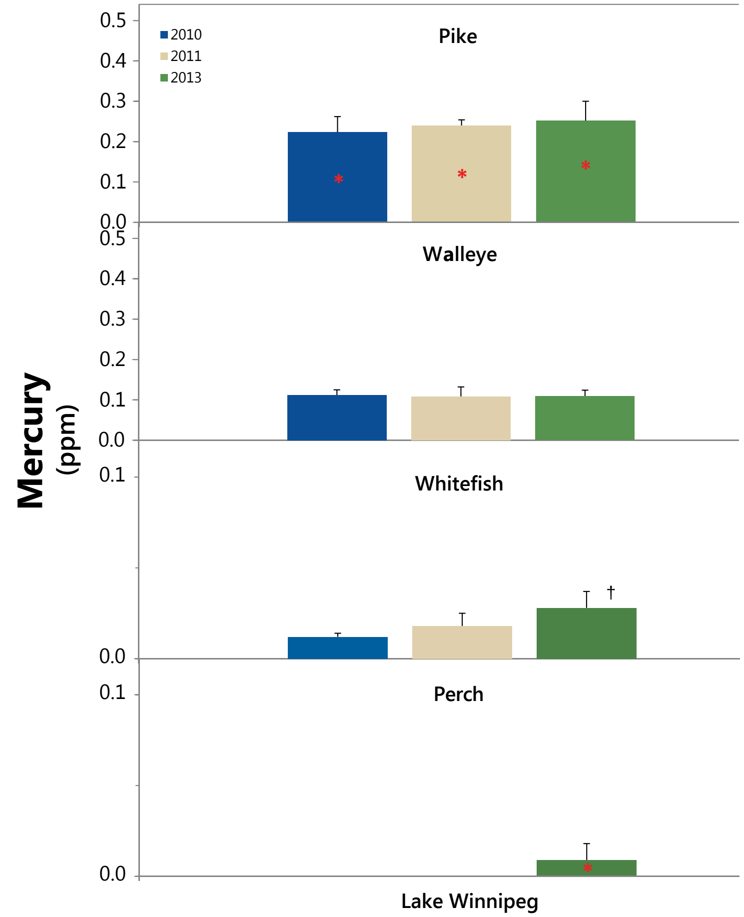


Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Saskatchewan River Region waterbodies

Lake Winnipeg Region

Fish mercury data were collected from Mossy Bay in Lake Winnipeg in 2010 to 2013.



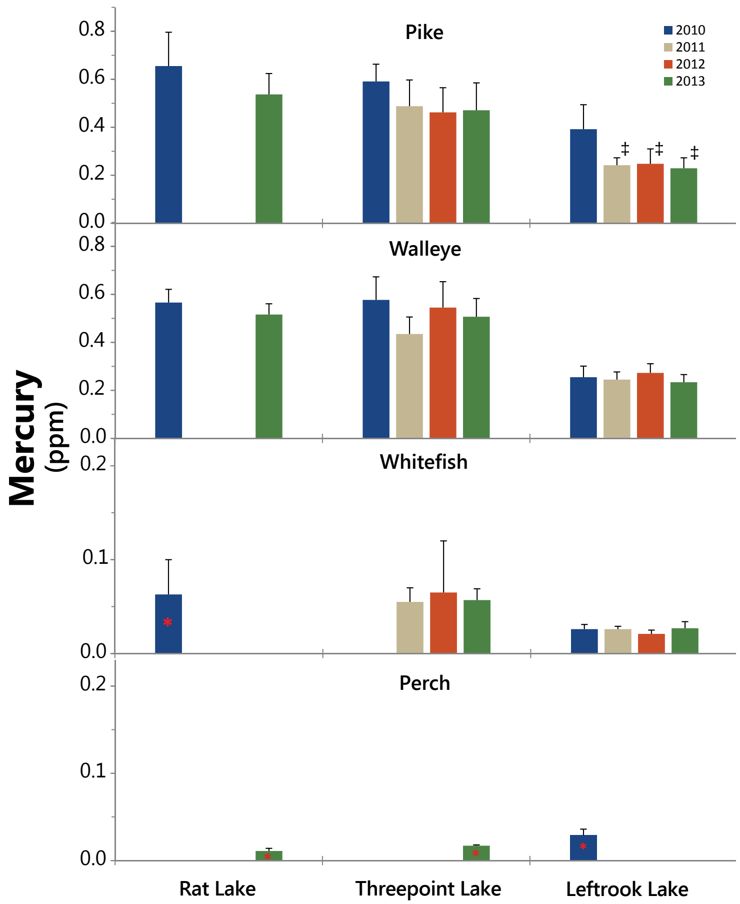
Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from Lake Winnipeg at the Mossy Bay site

Churchill River Diversion Region

Fish mercury data were collected in three lakes in the Churchill River Diversion Region. Two of the lakes (the on-system Threepoint Lake and the off-system Leftrook Lake) were monitored annually beginning in 2010. One additional on-system lake (Rat Lake) was monitored on a three-year rotation (2010 and 2013).

Annual monitoring of Threepoint and Leftrook lakes was intended to identify any short-term changes in mercury levels that may be indicative of potential regional effects. Leftrook Lake had a substantial historic record and Threepoint Lake has had the longest recovery time from the diversion impacts.

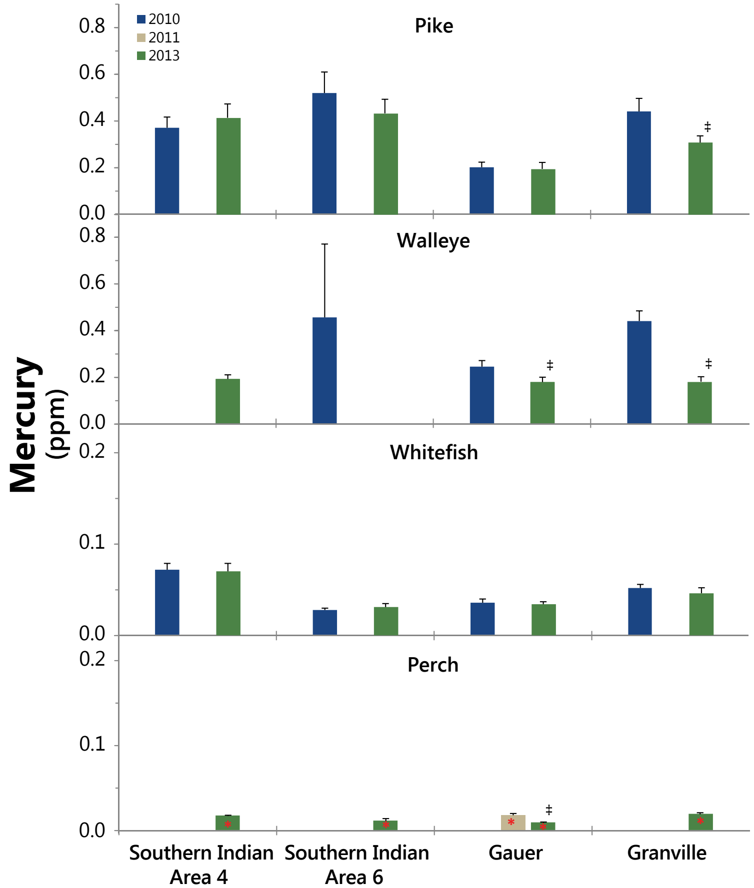


Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Churchill River Diversion Region waterbodies

Upper Churchill River Region

Fish mercury data were collected from two areas of the on-system Southern Indian Lake (Areas 4 and 6) and the off-system Granville Lake located upstream. Data collected from nearby Gauer Lake – the off-system waterbody for the Lower Churchill River Region – were also considered collectively with the results obtained for the upper Churchill River.

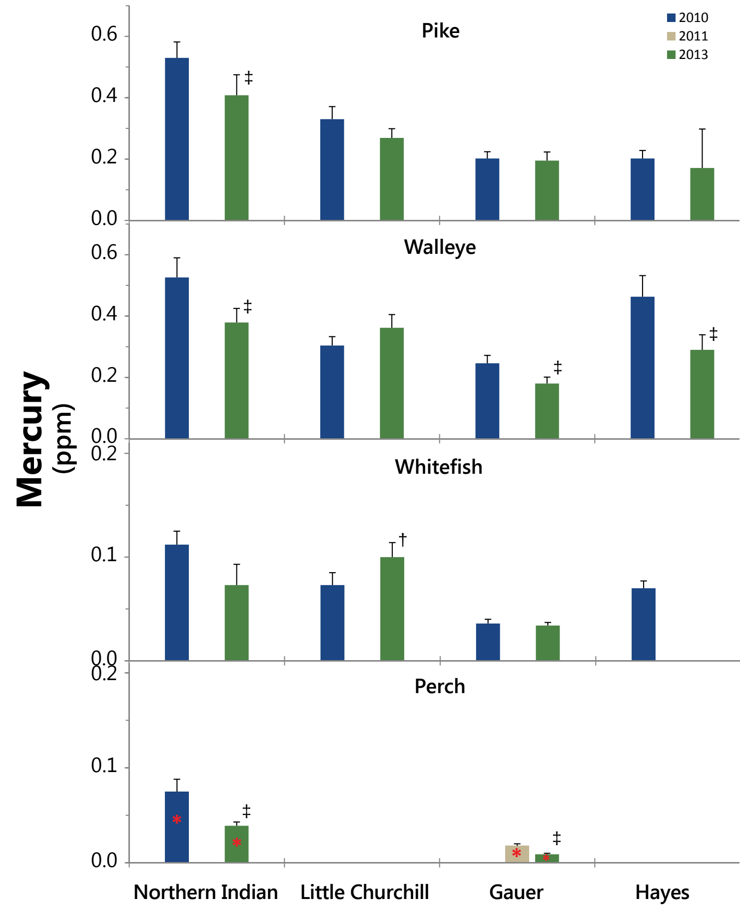


Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Upper Churchill River Region waterbodies

Lower Churchill River Region

Fish mercury data were collected from one on-system lake and one river site (lower Churchill River at the Little Churchill River) and from one off-system lake (Gauer Lake). Results for the Lower Churchill River Region were also compared to the off-system Hayes River.



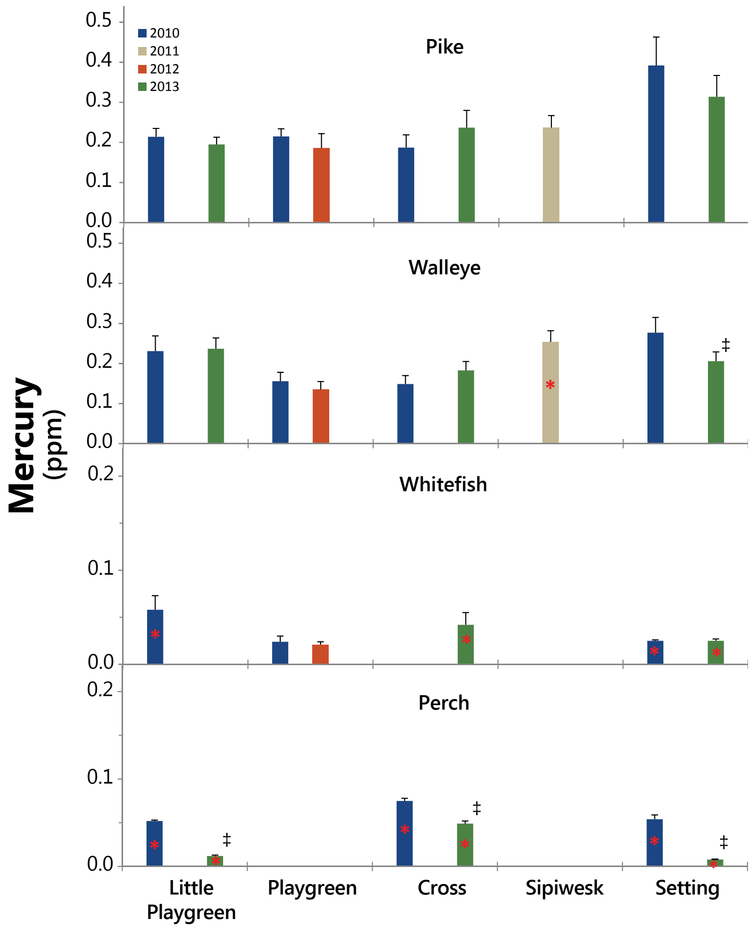
Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Lower Churchill River Region waterbodies

CAMP

Upper Nelson River Region

Fish mercury data were collected from four on-system waterbodies (Playgreen, Little Playgreen, Cross, and Sipiwesk lakes) and the off-system Setting Lake. For most lakes sampling occurred in 2010 and 2013. Playgreen Lake was sampled in 2010 and 2012 and samples from Sipiwesk Lake were collected in 2011.

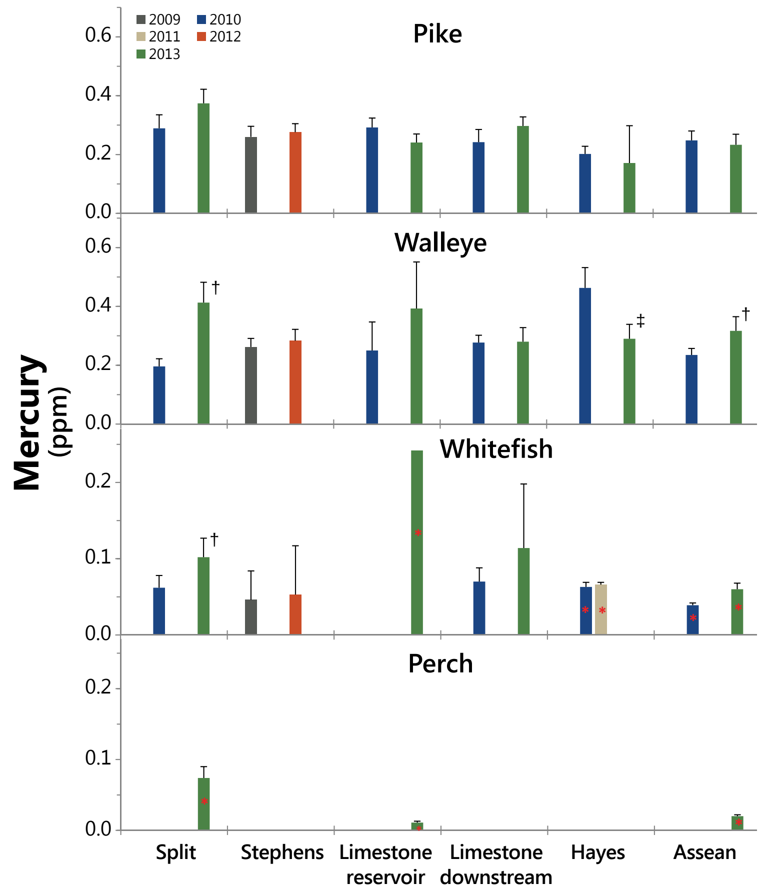


Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Upper Nelson River Region waterbodies

Lower Nelson River Region

Fish mercury sampling was conducted on a three-year rotation in Split Lake, Stephens Lake, the Limestone GS Reservoir, the lower Nelson River downstream of the Limestone GS, and the off-system Assean Lake and Hayes River.



Note: Length-standardized or arithmetic mean (denoted with an asterisk)

Mean concentrations of mercury in fish from the Lower Nelson River Region waterbodies

Back cover: Southern Indian Lake
Inside back cover: Setting Lake

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