Lake Winnipeg Research Consortium Inc.

2018 / 2019 Annual Report

Science and Education Programs

April 2019

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Programs Coordinator

LAKE WINNIPEG
RESEARCH CONSORTIUM

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INTRODUCTION

The Lake Winnipeg Research Consortium (LWRC) Inc. is a registered charity that was founded in 1998 to address the need for scientific studies on Lake Winnipeg following the 1997 Red River flood of the century. Its main objective, realized through the Science Program, is to facilitate science on Lake Winnipeg by providing dedicated research platforms, the Motor Vessels (MV) *Namao* and *Fylgja*, to its science members, and by convening those members and others who are actively involved in Lake Winnipeg science, at an annual Science Workshop. A secondary objective of the LWRC, met through its Education Program, is to provide educational opportunities related to Lake Winnipeg to schools and other institutions of learning.

The 2018 – 2019 season was marked by numerous challenges, most arduous being the the MV *Namao*'s drydocking. In order to meet Transport Canada's safety requirements, the ship must pass an out-of-water inspection every five years. With the closure of the drydock facility in Selkirk, hauling a vessel of this size out of the water has proven challenging and consequently disruptive to both the Science and Education Programs. Nevertheless, those and other unanticipated challenges, were all overcome, and another open water season was accomplished.

In addition, we were honoured to host Minister McKenna for a half day on board the MV *Namao* in the south basin. We are also pleased to announce our new website (www.lakewinnipegresearch.org) and Instagram site (@lakewpgresearch), both of which aim to share with the general public, what we do in our Programs and why we do it. This report summarizes the main activities associated with LWRC's Science and Education Programs.

EDUCATION PROGRAM

The primary goal of the LWRC's Education Program is to contribute to greater environmental literacy through the study of Lake Winnipeg. To this end, the Education Program has two main components, the Lake Ecology Field Program (LEFP) and the development of web-based, mixed-media resources. Classroom visits and supporting Special Projects are an implicit component of the LWRC's education programming. The LWRC also offers support to public school students through the *Water Award* offered at the Manitoba Schools Science Symposium.

Lake Ecology Field Program

Due to disruptions associated with drydock of the MV *Namao*, the Lake Ecology Field Program was not offered during the 2018 open water season. It will, however, resume in the spring of 2019.

"LWRC Water Award" - Manitoba Schools Science Symposium

The LWRC offers a *Water Award* at the Manitoba Schools Science Symposium (MSSS) in support of junior, intermediate or senior student projects that focus on water quality, quantity or remediation. Winners receive a certificate, a cash prize of $100, and an opportunity to join the LWRC science team for a half day on board the MV *Namao* during the summer research survey.

This year's Water Award winner was Myriam Alarie for her project entitled "*La rivière Rouge, serait-elle la source de pollution du lac Winnipeg*?" Myriam's project involved collecting samples along the Red River all the way from Grand Forks to Lake Winnipeg. She is shown here on board MV *Namao* helping to sort fish from the pelagic trawling program carried out by Fisheries and Oceans Canada. Congratulations to Myriam for an excellent project.

LWRC's Honours and Graduate Student Scholarship

The LWRC offers a scholarship in support of honours and graduate student research. The establishment of this fund in 2011—2012 was made possible by a generous initial contribution of $20,000 over five years by the Manitoba Government and General Employees' Union (MGEU), and subsequent smaller contributions are being made on an ongoing basis to help maintain the fund.

Two students, Nicole Turner and Rachel Mandryk, received the LWRC's Honours and Graduate Student Scholarship in 2018—2019.

Nicole is a Master's student from Lakehead University, studying under Dr. Michael Rennie. She received $2,500 in support of her research to evaluate movement patterns of walleye (pickerel) in Lake Winnipeg. This work will help discern how ecologically distinct north and south basin walleye are from one another, as well as differences in movement rates between 'dwarf' and 'normal' walleye. Nicole is shown here tagging a walleye with an acoustic transmitter.

Rachel is an undergraduate student at the University of Manitoba who is working with Drs. Tim Papakyriakou and David Capelle. She received $1,500 to help defray costs associated with conference travel. Rachel's work characterizing methane in Lake Winnipeg will contribute to a better understanding of the carbon budget.

SCIENCE PROGRAM

Station Network

Since 2002, the LWRC has offered three, whole-lake surveys annually aboard the MV *Namao*—spring, summer and fall—that cover an established network of sampling stations (Appendix A). For the first 10 years of the LWRC's existence, roughly 65 stations comprised the "offshore" station network on Lake Winnipeg. However, as research questions and monitoring needs change, the LWRC's Science Program has responded in part by modifying this station network. In 2012, two "nearshore" stations were introduced in the north basin in an effort to begin to characterize the nearshore area prior to the imminent arrival of zebra mussels. In 2014, 10 additional nearshore sites were introduced for a total of 12 stations encompassing the entire lake, while the offshore network was reduced to 50 stations. There are also three stations at the lake's outlets—the inflow and outflow of Two-Mile Channel and Warren's Landing. Due to their shallow nature, all nearshore and outflow stations are accessed by workboat, deployed from the MV *Namao*. An additional station was introduced in 2017 at Big Mossy Point (near Two-Mile Channel) to serve the needs of the Coordinated Aquatic Monitoring Program (Manitoba Hydro/Manitoba Sustainable Development).

In addition to the sampling station network, there is a network of moorings for instrumentation run by Environment and Climate Change Canada. In 2019, a new mooring site was introduced near the outflow of the lake (Appendix B).

Field Program - Open Water Season 2018

Appendix C provides a summary of the research and monitoring carried out during the 2018 field season on board MV *Namao*. Appendix D describes the procedure required to successfully haul the MV *Namao* to drydock, prepared by Ryan Johnson, Superintendent of Marine Operations.

With the MV *Namao* out of commission until July 10th, the spring survey (June 12th to July 19th) was carried out primarily using the workboat in the south basin and channel and on occasion MV *Fylgja*. Consequently, a reduced suite of parameters was sampled. Once the MV *Namao* was relaunched, the north basin W stations were sampled, and moorings deployed. The summer survey ran between July 31st and August 6th with no disruptions. The fall survey was carried out between September 24th and October 22nd,

with interruptions caused by a grounding at the mouth of George Island Harbour, a medical emergency near Grand Rapids, and foul weather.

Science Workshop

The annual Science Workshop was held on March 19th and 20th at the Qualico Family Centre, Assiniboine Park in Winnipeg (Appendix E) with nearly 60 scientists, managers and students in attendance (Appendix F). This year's Workshop was held prior to and in conjunction with ECCC's Lake Winnipeg Basin Program Symposium and the Gordon Foundation's launch of Datastream, with all events taking place during Canada Water Week.

The LWRC's Science Workshop aimed to provide an opportunity to update the larger on-lake science community on previous and ongoing studies, as well as future planning of new projects. Abstracts of the workshop presentations are below. If no abstract was submitted, a brief summary of the presentations was prepared for this report.

Science Workshop Abstracts

Lake Winnipeg Basin Program – Update

Ute Holweger and Sharon Reedyk

Environment and Climate Change Canada, Winnipeg

No abstract was submitted. This presentation provided a brief overview of ECCC's activities in the Lake Winnipeg Basin and associated with the Lake Winnipeg Basin Program (Phase 3), which was renewed with a budget of $25.7M over 5 years (2017—2022). The three program pillars include nutrients (science and nutrient reduction), strengthening collaborative watershed governance, and strengthening Indigenous engagement. The 2018—2019 activity updates included the Phase 2 report, progress made by the Canada-Manitoba MOU Steering Committee, the indicator factsheet series, State of the Lake report, and Science Plan placemat and factsheets.

Lake and Watershed Modeling – Update
Red and Assiniboine River Basins and Lake Winnipeg 3D Modeling

Luis Leon[1], R. Valipour[1], D. Depew[1], J. Zhao[1], P. Fong[1], A. Richards[1], R. Yerubandi, [1] Y. Dibike[2], R. Shrestha[2], L. de Rham[2], J. Rowley[2], A. Muhammad[2], G. Evenson[2], C. Spence[2] B. Bonsai[2]

Environment and Climate Change Canada, [1]Burlington and [2]Saskatoon

No abstract was submitted. Updates were provided on both lake and watershed (Red and Assiniboine river basins) models. A Can/SWAT Red River Basin watershed model is

in year 2 of its development. This model will help improve understanding and prediction of nutrient dynamics at different scales. Integrated with the lake model, it will be used to assess agricultural best management practices (BMPs), climate change adaptation scenarios and both BMPs and climate change scenarios combined. In addition, it will provide lake input loading estimates to assist in modeling the lake's response to changes in the watershed. Similar to the Red River model, the Assiniboine River Basin SWAT model, will be applied under different BMP and climate scenarios. It will, however, include dynamic contributing areas to represent the "fill-and-spill" process of prairie potholes.

Substrate Mapping of Lake Winnipeg

Tyana Rudolfsen, D. Watkinson, C. Charles, C. Kovachik, E. Enders

Freshwater Institute, Fisheries and Oceans Canada

Substrate mapping in aquatic ecosystems allows for identifying habitat types. By linking fish movement data with these habitat types, we can describe fish habitat use and potentially predict fish habitat quantity and quality. The aim of this study is to describe the bathymetry and substrate types of Lake Winnipeg, Manitoba, Canada, to be able to develop an association between habitat types and fish movement. Using a Biosonics MX echosounder along a pre-determined 7 km grid and two nearshore contours (3 m and 6 m depth contours), we obtained raw echosounder data that can be used to determine bathymetry and substrate type. In a first step, the echosounder raw data was corrected to standard water elevation and data was then interpolated into bathymetry maps. Then, substrate maps were developed. To ground truth the substrate type classification in these substrate maps, we used PONAR grabs that were taken on the same 7 km grid and particle size of these substrate samples was analysed. Cluster analysis produced three different substrate types (i.e., clay muck, silt muck, and sand/gravel). The particle size analysis was used to associate substrate types with the echosounder data. With this, the interpolated map was found to be an accurate predictor of the substrate type throughout the south basin. Moreover, ongoing fish tracking studies are showing a potential correlation between movement patterns and the bathymetry/substrate type maps. This knowledge may increase our understanding of habitat preference and movement patterns of fish, thus, strengthening current and future management and conservation efforts.

Lake Winnipeg Nearshore Monitoring Overview

Elise Watchorn

Environment and Climate Change Canada, Winnipeg

No abstract was submitted. This presentation described ECCC's nearshore monitoring program on Lake Winnipeg. A pilot program was introduced in 2009 to monitor nearshore water quality and biota. It included five stations in the south basin, and a number of sites in Netley-Libau Marsh, sampled once per season. After two years, the program was paused until 2017 when it resumed. Nine stations are now sampled as well as Netley-Libau Marsh, and the frequency of sampling has increased to three times a year, coinciding with the offshore sampling program conducted off the MV *Namao*. Parameters sampled include: water quality (integrated depth samples analyzed for nutrients, metals, ions and chlorophyll); phytoplankton; zooplankton; benthic invertebrates; and forage fishes (in collaboration with Fisheries and Oceans Canada).

An Overview of Water Quality in Lake Winnipeg: Recent Results of the Provincial Long-Term Water Quality Monitoring Program

Andrew Burton

Manitoba Sustainable Development

Since 1999, Manitoba Sustainable Development, in partnership with the Lake Winnipeg Research Consortium Inc., has operated an extensive water quality monitoring program on Lake Winnipeg. The water quality program consists of a network of 65 stations (i.e. nearshore, offshore, river mouths and outflows) monitored for a variety of physical, chemical and biological parameters throughout the open water season (spring, summer and fall). A reduced suite of sites have been sampled during the winter. While much work is underway to characterize and better understand stressors influencing water quality in Lake Winnipeg, continuous monitoring is required. The objective of this talk is to highlight current and emerging water quality concerns in Lake Winnipeg and to summarize recent water quality data (e.g. general chemistry, nutrients and trace elements) collected as part of the Lake Winnipeg water quality monitoring program.

Quality of groundwater and surface water in the Assiniboine Delta Aquifer area

Serban Danielescu[1], V. Morand[2] , F. Barbecot[2]

[1]Environment and Climate Change Canada and Agriculture and Agri-Food Canada, Fredericton; [2]Université du Québec

Despite several studies, there are significant gaps regarding the amount, fate and transport of nitrogen and phosphorus in groundwater. The contribution of groundwater nutrient fluxes to surface water in the Lake Winnipeg Basin (LWB) is not known. 2017 marked the first year of this five-year pilot project focusing on the Assiniboine Delta Aquifer (3800 km^2) – an area where groundwater discharge to

surface water is suspected to play a significant role – and investigating the significance of groundwater inputs to the LWB nutrient balance.

Historical Variability and Future Changes in Temperature, Precipitation and Snow in the Assiniboine-Red Basin

Rajesh Shrestha[1], B. Bonsal[2], A. Kayastha[1], Y. Dibike[1], C. Spence[2]

[1]Watershed Hydrology and Ecology Research Division, Environment and Climate Change Canada, Water and Climate Impacts Research Centre, University of Victoria, Victoria, BC; [2]Watershed Hydrology and Ecology Research Division, Environment and Climate Change Canada, Saskatoon

The snow-dominated hydrologic regime in the Assiniboine-Red basin is sensitive to climate variability and change, affecting water and nutrient fluxes to Lake Winnipeg. Our study evaluates the historical variability and future changes in hydro-climatic drivers (temperature and precipitation) using statistically downscaled Global Climate Model (GCM) outputs. Further, we developed a process-based snow model for projecting future changes in snow regime in the basin, and evaluating it's controls on hydrologic and nutrient transport processes. Analysis of the 1951-2013 historical climate data indicate warming trend in the basin, especially for minimum temperature. Future projections from downscaled GCMs indicate continued warming in the basin, with higher increases in winter months. The annual and majority of monthly precipitation are projected to increase, while summer precipitation is projected to decline. The implications of these changes could be seen in simulated snow storage. Snow model simulations indicate future declines in monthly mean, annual and maximum snowpacks, and an earlier snow melt.

Temporal changes (1929-2015) in emergent vegetation cover in Netley-Libau Marsh

Gordon Goldsborough[1]; Elise Watchorn[2]; Paige Kowal[1]; Christiane Hudon[1]2

University of Manitoba[1]; Environment & Climate Change Canada[2]

Shoreline erosion and loss of emergent vegetation areal extent since 1929 has resulted in large expanses of open water in Netley-Libau Marsh on the south shore of Lake Winnipeg. Archival air (1929-2015) and satellite (1990-2013) photos of the marsh were digitized to examine temporal changes in plant cover and their correlations with Lake Winnipeg level and Red River flow. In the post-1990 period, three distinct periods were distinguished. The first period (1990-2002) coincided with the rise in open water areas coincident with rising lake levels and river flows. The second period (2003) marked major wetland regeneration and a decline of open water area under extremely low levels and flows. Between 2005 and 2013, open water area remained roughly constant under variable levels and flows. Two hydrological factors contributing to long-term

marsh vegetation loss may be increased Red River discharge via the man-made Netley Cut and the reduced frequency and duration of low-water periods. The greatest gains in emergent vegetation area occurred in years when average Lake Winnipeg level was at or below 217 m asl. Periods of extremely low water as short as one year induced rapid expansion in plant cover which persisted over the next ten years. Rather than being gradual, changes in the spatial extent of marsh plants appear to proceed by fits and starts, wherein periods of relative stasis are disrupted by major shifts in vegetation.

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Provincial AIS Program Update

Laureen Janusz

Manitoba Sustainable Development

The provincial AIS program is broken down into five main pillars: 1) Legislation; 2) Prevention (including Watercraft Inspection, Public Engagement, Certified Service Provider and Partnerships programs); 3) Monitoring; 4) Early Detection and Rapid Response; and 5) Management and Control. An overview will be provided on the 2018 results/initiatives within these pillars as well as proposed enhancements for 2019.

Temporal and spatial variation in densities of Bythotrephes (spiny water flea) in Lake Winnipeg, 2012-2017

Brenda Hann[1], W. Jansen[2], and Laureen Janusz[3]

[1]Department of Biological Sciences, University of Manitoba; [2]North South Consultants; [3]Manitoba Sustainable Development

Bythotrephes longimanus invaded Lake Winnipeg in 2011, likely via the Winnipeg River from Lake of the Woods (Jansen et al. 2017). By 2012, *Bythotrephes* was distributed in low densities throughout the lake in South basin, the Narrows, and North basin. Samples collected during summer and fall surveys of the lake over the subsequent five years displayed considerable spatial and temporal variability. By 2014-2017, populations were almost entirely concentrated in the North basin despite evidence for a continued influx of individuals into Traverse Bay via the Winnipeg River. Factors influencing the distribution of *Bythotrephes* in the lake include: planktivorous fish densities, summer water temperatures, cyanobacterial blooms.

Lake Winnipeg Zebra mussel distribution update

David Depew, K. Rattan, L. Leon

Environment and Climate Change Canada, Burlington

The establishment of dreissenid mussels in Lake Winnipeg may have profound consequences for energy and nutrient cycling within the lake. To enable capacity for monitoring and reporting as well as ecological modelling, in 2017 we initiated a systematic survey approach adopted from the Great Lakes to assess the distribution and spread of dreissenid mussels in Lake Winnipeg at this early invasion stage. This presentation will provide an update on the distribution of dreissenid mussel biomass and size – frequency distributions for samples collected in 2017 and 2018 and contrast to other patterns observed in the Laurentian Great Lakes.

How do changes in climate and wetlandscape hydrology contribute to algal blooms in Lake Winnipeg?

Forough Fendereski[1], I. Creed[1], C. Trick[2]

[1]School of Environment and Sustainability, University of Saskatchewan; [2]Department of Biology, Western University

Over the past few decades, algal blooms in Lake Winnipeg have been increasing in severity, extent, and frequency. These blooms have expensive ecological, social, and economic consequences and improved management measures are required to reduce these consequences. Implementing efficient management strategies for algal blooms requires in-depth understanding of past, current, and future bloom occurrence(s), and the drivers behind spatial and inter-annual changes in algal blooms. Previous studies have found links between climate change, increased nutrient inputs (N and P, including bioavailable forms), and the recent increase in algal blooms in freshwater lakes. Given the nutrient retention and transformation role that wetlands play in watersheds, we hypothesize that wetland loss is also contributing to increased algal blooms in freshwater lakes. This hypothesis is especially important for the Lake Winnipeg basin which has experienced high wetland number and area loss. Our research focuses on the influence of climate change and changes in wetlandscapes on algal blooms in Lake Winnipeg. Remote sensing technologies will be used to study multi-decadal changes in wetlandscapes (e.g., number, size, distribution, and connectivity of individual wetlands) in the Lake Winnipeg basin and algal biomass in Lake Winnipeg. The results of this study will allow the development of policies and associated management strategies to protect or restore wetlands to optimize agricultural productivity while minimizing loss of aquatic ecosystem services and algal blooms in Lake Winnipeg and its basin.

Toxin Analysis of Cyanobacterial Blooms in Lake Winnipeg

Susan Murch, S. Bishop

Chemistry, University of British Columbia, Okanagan

No abstract was submitted. Aquatic ecosystems involving cyanobacteria have been found to contain *N*-β-methylamino-L-alanine (BMAA), and 2,4-diaminobutyric acid (DAB), non-protein amino acids that are associated with neurodegenerative disease, as well as two of the naturally occurring isomers, *N*-2(amino)ethylglycine (AEG) and β-amino-*N*-methylalanine (BAMA). Samples of cyanobacteria were collected from sampling stations and blooms in July and September of 2016 and were analyzed for BMAA, DAB, AEG and BAMA using validated analytical methods. Previously presented findings indicate that the production of non-protein amino acids varies with the depth and nutrient contents of the bloom. It is important to note that we did not measure food or water samples directly and further study of the Lake Winnipeg food web is required to determine whether BMAA bioaccumulation represents an increased risk factor for neurodegenerative disease in the region. Future research will examine the conditions under which cyanobacteria and diatoms produce BMAA (temperature, nutrient availability, species present) and the development of a biosensor for the real-time analysis and routine monitoring of target analyte.

Investigating the impacts of invasive dreissenid mussels on the phytoplankton community composition in Lake Winnipeg, Manitoba

Paul G. Matson[1], Timothy W. Davis[1], Arthur Zastepa[2]

[1] Bowling Green State University, Ohio; [2] Environment Climate Change Canada, Canada Centre for Inland Waters, Ontario, CAN

In the 1960s and 70s, harmful algal blooms in Lake Erie were primarily dominated by the cyanobacteria *Aphanizomenon* and *Anabaena.* Starting in the late 1980's, two major shifts occurred in Lake Erie: non-point source pollution increased; and dreissenid mussels were introduced and became established. Concurrently, the annual phytoplankton blooms are dominated by *Microcystis*. It is possible that dreissenid mussels have contributed to the dominance of *Microcystis* over *Aphanizomenon* and *Anabaena*. However, due to lack of monitoring during the establishment of the dreissenids, this hypothesis has not been tested. Recently, dreissenid mussels have established in Lake Winnipeg and the potential disruption to the food web, including impacts on a multi-million dollar commercial fishery, is not yet known. Our research is investigating potential changes in phytoplankton community composition in Lake Winnipeg by conducting feeding experiments with Lake Winnipeg zebra mussels across multiple seasons. These experiments will provide insight into the potential for these invasive mussels to disrupt the food web and possibly shift Lake Winnipeg to a system that may be more conducive to toxic blooms of *Microcystis*, which pose greater ecological and societal risks. In addition to providing an opportunity to explore mechanisms also relevant to the observed shifts in the Lake Erie phytoplankton community, this project serves to strengthen our bi-national partnership with ECCC.

Lake Winnipeg Remote Sensing Algal Bloom Indices; a status update and comparison with historical monitoring data

Caren Binding

Environment and Climate Change Canada, Burlington

Earth observation satellites offer frequent, synoptic views of Lake Winnipeg (LW) which enable quantitative assessments of algal biomass and can provide both near-real-time and historical information on algal bloom conditions on the lake. We present progress made on ECCC's satellite remote sensing of LW blooms using the OLCI sensor on board the European Space Agency's (ESA) Sentinel-3 satellite. Quantitative algal bloom indices are derived for algal bloom intensity, spatial extent, duration, and timing, to give a robust measure of overall bloom conditions on the lake. A detailed assessment of indices for the 2017/2018 bloom seasons will be presented in relation to historical imagery from ESA's MERIS sensor (2002-2011). Advances in image processing work flows will be presented along with an update on plans for an operational web mapping tool for visualization of near-real-time imagery. Satellite derived chlorophyll, the basis of derived algal bloom indices, will be compared with historical monitoring data collected during seasonal *Namao* cruises.

Steps towards a methane budget for Lake Winnipeg

Rachel Mandryk, T. Papakyriakou, D. Capelle

Centre for Earth Observation Science, University of Manitoba

Methane, a greenhouse gas with particularly high warming potential, has been found in concentrations in Lake Winnipeg that characterize the lake as a source. The measurements of methane flux from the lake were done by using air and water temperatures, wind speed, and discrete methane samples collected while onboard the *MV Namao*. The presence and decay of the lake's macrophyte and algal populations may be related to the amount of methane produced, particularly near river inflows and in the north basin. Further research will show if Lake Winnipeg's nearly constant mixing throughout the ice-free season indicates steady effluxes of methane into the atmosphere.

Preliminary results of Lake Winnipeg bottom and suspended sediments

Masoud Goharrokhi[1], D. Lobb[1], G. McCullough[2], P. Owens[3], S. Clark[1]

[1]Department of Soil Sciences, University of Manitoba, Winnipeg; [2]Centre for Earth Observation Science (CEOS), University of Manitoba, Winnipeg; [3]University of Northern British Columbia, Prince George

Analytical results of 2 years (2016–2017) sampling of bottom and suspended sediments across Lake Winnipeg were used to provide a better understanding of the sediment dynamics in this waterbody. Organic matter, Spectral reflectance (colour) coefficients, particle size distribution, and fallout radionuclide concentrations (Caesium-137 (^{137}Cs), Radioum-226 (^{226}R), and unsupported Lead-210 (^{210}Pb)) for both type of sediments were determined to: (i) demonstrate the temporal and spatial variability of such properties within the lake, (ii) gain insight into sedimentation pattern in different parts of the lake, and (iii) discriminate north shore versus tributary sources of sediment both in the north basin bottom sediment as well as in the outflow of the lake. The ultimate goal for this study is to investigate the utility of the sediment source fingerprinting approach to quantify the contribution of potential suspended sediment sources being exported out of the lake as well as the fate of north shore eroded materials.

Foodwebs, Nutrients and Stable Isotopes

Geoff Koehler

Environment and Climate Change Canada, Saskatoon

No abstract was submitted. Stable isotopes provide a means to answer important questions related to the food web and changes therein, such as those caused by stressors such as eutrophication, exotic species and climate change. This project aims to evaluate changes in foodweb structure and function in response to impacts associated with changes in nutrient loading, climate and invasive species, notably zebra mussels. Nutrient sources and foodweb structure and function is also being examined.

Common Carp movement and habitat us in the Lake Winnipeg Basin

Doug Watkinson, Colin Charles, and Eva Enders

Freshwater Institute, Fisheries and Oceans Canada

Fisheries and Oceans Canada is conducting an acoustic tagging fish movement project in the Lake Winnipeg Basin using a total of 247 receivers. In partnership with the Lake Winnipeg Foundation, common carp was one of the species tagged to better understand its spatial and temporal use of habitat in the Lake Winnipeg basin, specifically the Netley-Libau marshes. Preliminary results, after two year of study, are summarized. Specifically, mortality and/or tag loss in common carp, seasonal use of riverine, lacustrine, and wetland habitat, seasonal rates of movement, spawning site fidelity and timing, and substrate associated with fish movement will be presented.

Walleye movement patterns in Lake Winnipeg

Nicole Turner[1], M. Rennie[1], E. Enders[2], D. Watkinson[2], C. Charles[2], G. Klein[3]

[1] Lakehead University; [2]Fisheries and Oceans Canada; [13]Manitoba Sustainable Development

Over the past century Lake Winnipeg has been subjected to general declines in water quality with increased nutrient inputs, establishment of invasive species, and increased commercial and recreational fishing pressure. To date, walleye movement has been studied at the genetic level only, with contrasting conclusions as to whether separate populations exist within the lake. General walleye movement patterns will be discussed focusing on tagging location (basin) and sex. Preliminary analysis will also highlight migratory and resident movement rates and look at the distribution of individuals throughout the array at various times of the year. Ultimately this research will aid in an overall greater understanding of walleye movement patterns and behaviour throughout Lake Winnipeg. This information may be used to inform fishery managers in the development of scientific-based sustainable policy and regulation for both the commercial and recreational fisheries.

Genomics and Movement in the Lake Winnipeg Walleye (Sander vitreus)

Matt Thorstensen[1], Jennifer Jeffrey[1], PhD, and Kenneth Jeffries[1], PhD

[1] Department of Biological Sciences, University of Manitoba, Winnipeg, MB

Genomics and movement ecology of the Lake Winnipeg walleye are largely unknown, which is an unfortunate gap in scientific knowledge given walleye's great importance to Manitoba's economy. As part of a larger movement study by Fisheries and Oceans Canada, wild-caught walleye were individually tagged in 2017 and 2018 from several spawning regions for tracking with an acoustic receiver array spread throughout the Lake Winnipeg basin. Gill tissue was collected from a subset of these fish (n = 48) for RNA sequencing, where we examined gene expression patterns (i.e., mRNA levels) of fish from three collection sites over a latitudinal gradient (n = 8 per year per site). These data revealed gene expression profiles and single nucleotide polymorphisms (SNPs) that indicate differences between years and sites, along with showing signals of population differentiation in the walleye. In the future, we will combine the gene expression data with movement data using machine learning approaches such as support vector machines or Bayesian additive regression trees to determine if molecular signals underlie walleye movement patterns. Ultimately, these data may reveal population-specific movement dynamics and stressors influencing walleye movement, which will be useful for walleye management.

Partnering for Indigenous Prosperity – Indigenous Inland Commercial Fisheries Initiative

Bill Galbraith

Indigenous Services Canada

No abstract was submitted. The Indigenous Inland Commercial Fisheries Initiative (IICFI) is a multi-year coordinated effort by federal and provincial governments, in collaboration with Indigenous organizations, that aims to contribute to the sustainability and growth of the Indigenous commercial fishery in Manitoba. This will be accomplished by assisting Indigenous fishers, associations and communities acquire technical, business and resource management skills and access capital for business development. IICFI is a Strategic Partnership Initiative.

Updates from the Pelagic and Littoral Fish Survey Monitoring Programs

Eva Enders, A. Caskenette, C. Lumb, D. Watkinson

Fisheries and Oceans Canada, Freshwater Institute, Winnipeg

In 2018, Fisheries and Oceans Canada continued the Pelagic Fish Survey Monitoring Program in Lake Winnipeg and developed a Littoral Monitoring Program to study the impact of the recently introduced zebra mussel (*Dreissena polymorpha*) on the nearshore environment. The Littoral Monitoring Program is an expansion to ECCC's nearshore program sampling six stations in the south basin for a number of water quality parameters, zooplankton, benthic macroinvertebrates, and small bodied fish at six repetitions over the open water season. The pelagic fish trawls were conducted during summer and fall surveys from the MV *Namao* (Lake Winnipeg Research Consortium) to study the temporal and spatial variation of the fish assemblage in the offshore waters of Lake Winnipeg. We will provide an update on the status of the prey fish community that supports important fisheries species and highlight the importance of both monitoring program to aid the evaluation of the relative importance of aquatic invasive species. Understanding the top-down and bottom-up regulations in the Lake Winnipeg food web has important implications for fisheries and water quality management.

The collapse and extirpation of sauger in commercial fisheries: is Lake Winnipeg next?

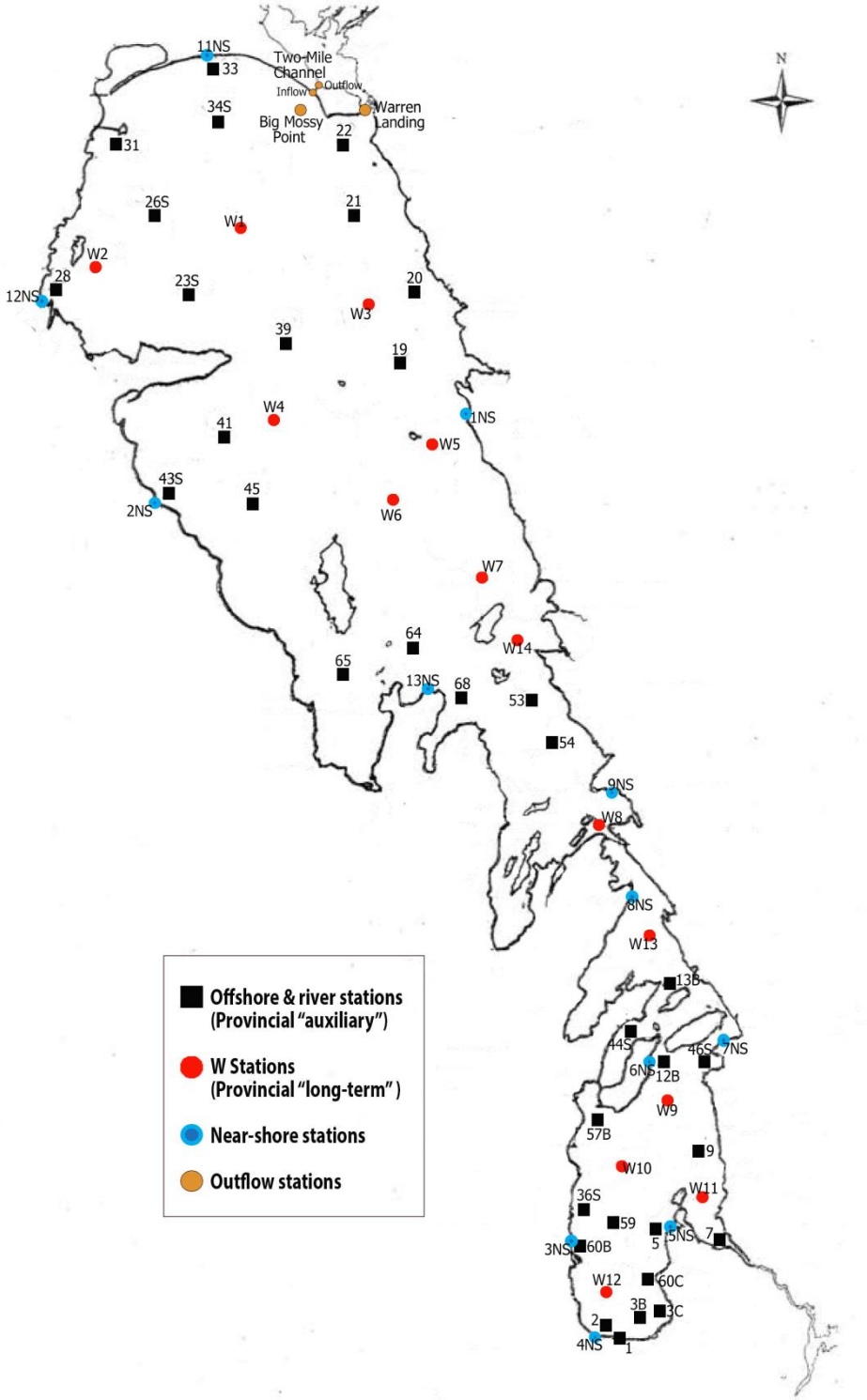
Scott Forbes

Department of Biology, University of Winnipeg

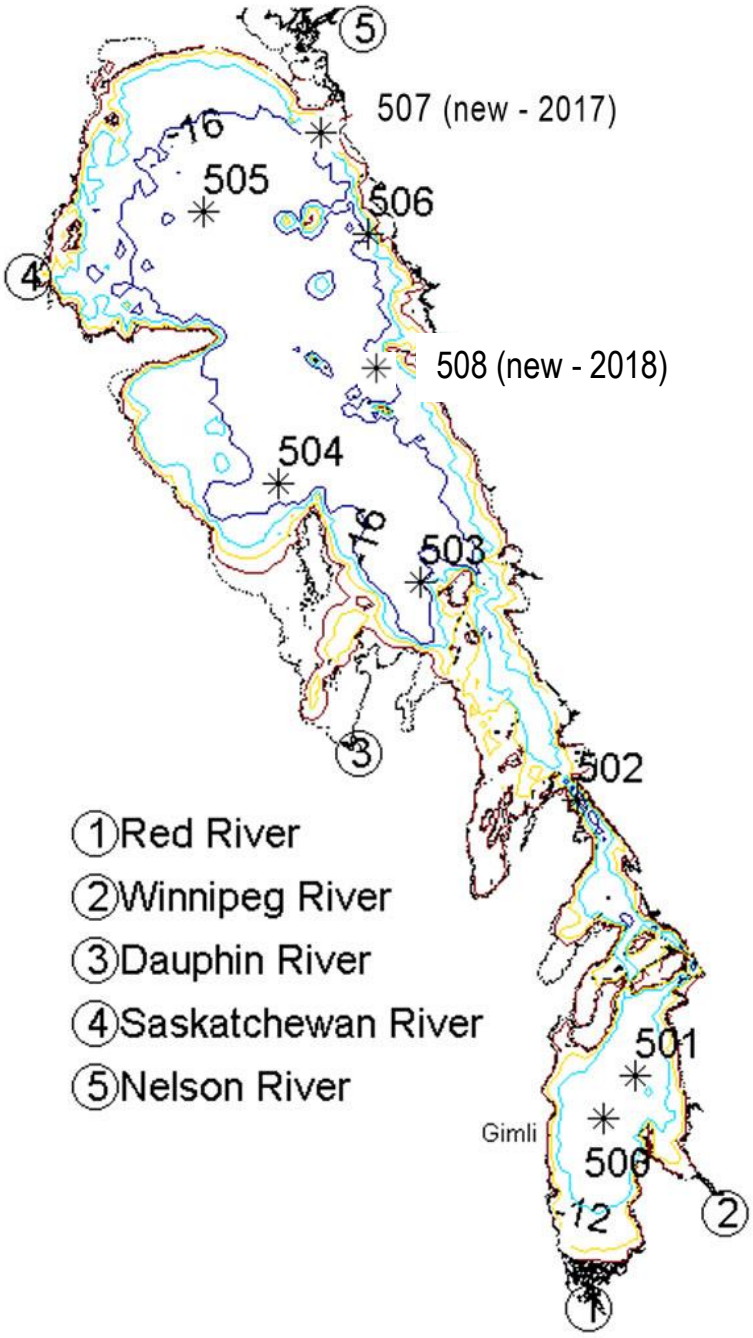
Commercial fisheries for sauger (*Sander canadensis*) have existed for more than a century in both Canada and the United States, the bulk of the catch being taken on six

large lakes: Lakes Erie, Huron and Superior in the Laurentian Great Lakes and Lakes Winnipeg, Manitoba and Winnipegosis in Manitoba. The commercial harvest of sauger on all six lakes showed a similar pattern of a multi-decade decline and eventual collapse. On five of the six lakes, sauger are commercially extinct if not extirpated. The only remaining commercial fishery exists on Lake Winnipeg, where the most recent commercial harvests are roughly 4% of the peak harvest seven decades earlier. On all six lakes, sauger we taken in multispecies percid fisheries, alongside smaller yellow perch (*Perca flavescens*) and larger walleye (*Sander vitreus*). The fisheries were conducted primarily with gill-nets using a combination of small mesh (≤76 mm for perch) and ≥89 mm for walleye. Female sauger recruited to the smaller mesh perch nets likely at sizes before maturity; the larger mesh walleye nets meant that sauger reached sizes large enough to escape harvest. Though multiple factors have potentially contributed to the decline and extirpation of commercially harvested sauger, including invasive and introduced species; eutrophication, pollution and habitat change, especially on the Great Lakes and Lake Winnipeg, the only common causal factor across all lakes is overfishing. That sauger have escaped extirpation on Lake Winnipeg may be due to historic differences in regulation of the fishery in the lake's three main basins: until recently, the use of small-mesh nets (≤96 mm) on the lake's north basin has been prohibited, creating a sauger refuge. Recent changes to regulation allowing meshes as small as 89 mm, with pressure for even smaller mesh sizes from commercial fishers, imperil Lake Winnipeg sauger.

Appendix A. Offshore, nearshore and outflow stations



Appendix B. Mooring locations



Appendix C – Research and Monitoring Activities Conducted (MV *Namao* or *Fylgja*) during the 2018 Open Water Season

Agency	Lead	Project	Spring	Summer	Fall	Details
Manitoba Sustainable Development	Burton	Long-term water quality monitoring of Lake Winnipeg	X	X	X	**All offshore, nearshore and outflow stations** - nutrients, chlorophyll a, other routine chemical parameters*****, vertical depth profile measurements of light, temperature, dissolved oxygen, turbidity, and conductivity (Seabird), *E. coli*. **14 long-term stations** – as above with metals and major ions, whole water phytoplankton for identification, enumeration, and biovolume estimates, macroinvertebrate samples (in triplicate, spring only), and surface sediment samples (summer only) for metals, nutrients, organic content, and particle size analysis (percent sand, silt, and clay). **Three stations nearest the inflow of the Red, Winnipeg, and Saskatchewan rivers** - pesticides (summer only starting 2013). **Blooms** - microcystin-LR and cyanobacterial cell counts
	Burton	Nearshore water quality monitoring	X	X	X	**Nearshore station transects at 1m, 2m and 3m depths - g**eneral chemistry, N and P (total particulate and dissolved), chlorophyll, TSS, turbidity, PAR, calcium
	Janusz	*Bythotrephes* monitoring		X	X	Two vertical zooplankton hauls taken at all stations - 64 µm mesh size - composited. Samples taken from 1 m off the lake bottom
	Janusz	Zebra mussel veligers and adults	X	X	X	Veliger sampling at all narrows and NB stations (14 m) - offshore and nearshore; substrate samplers at Princess Harbour, George Island and Macbeth

Agency	Lead	Project	Spring	Summer	Fall	Details
Environment and Climate Change Canada	Valipour, Depew, Leon	Physical lake model - assessment of hydrodynamics and model-based nutrient status	X		X	Deploy & recover moorings: 500, 502 (N&S), 503, 504, 505, 507, 508 (new)
	Yerubandi	Water quality monitoring;	X	X	X	Seabird vertical depth profiles taken on the downcast - temperature pH, DO, %sat DO, turbidity, conductivity & PAR – all stations Prov WQ/LWRC sampled
	Matson, Zastepa & Davis	Impacts of zebra mussels on phytoplankton community composition		X	X	Lab-based feeding experiments; phytoplankton characterization using microscopy & flow cytometry
	Matson, Zastepa & Davis	Harmful algal blooms and nutrient cycling		X	X	Algal bloom sampling – north and south basins
	Depew & Leon	Ecological Modeling		X	X	Summer & fall – water & zooplankton (stable isotopes) at 28 stations; Fall – triplicate sediment (ponar) at 39 stations, 250 µm mesh
	Depew	Internal phosphorus loading		X	X	Sediment cores 6 stations; surficial sediment 21 stations
	Koehler	Changes in foodweb structure & function due to zebra mussels	X	X	X	DIC/DOC/NO3; phytoplankton, zooplankton, benthos; C and N isotopes – all stations
Fisheries & Oceans Canada;	Enders	Forage fish trawl		X	X	43 offshore stations

Agency	Lead	Project	Spring	Summer	Fall	Details
	Stainton	Algal metabolism	X	X	X	Continuous monitoring of net photosynthesis and respiration, chlorophyll, algal group composition, CDOM and transparency (AOA); in transit – MV *Namao* & *Fylgja*
U. Manitoba	Hann	Zoobenthos	X	X	X	W stations - one sample per site - 200 µm mesh
U. Manitoba	Hann	Zooplankton community	X	X	X	Vertical haul; W stations – 70 µm mesh
U. Manitoba	Kuzyk (student) & Yurkov	Anoxygenic phototrophs – role in biochemical cycling and toxin tolerances	X	X	X	Stations W9, 7NS, W10, W9 and 57B
U. Manitoba	Tim Papakyriakou	Lake carbon dynamics	X	X	X	Characterize components of lake C system - select stations surface & bottom waters
U. British Columbia	Murch	BMAA algal toxin	X	X	X	Water samples from algal blooms (unprocessed)
Manitoba Hydro	Chaze	CAMP		X	X	Warren Landing, Two-Mile Channel (inflow and outflow), Mossy Bay (sediment) and station 22

Appendix D. Motor Vessel *Namao* Drydock – June 4th to July 10th, 2018

(Prepared by Ryan Johnson, Superintendent of Marine Operations)

The MV *Namao* was successfully hauled out of the water in Hnausa on June 4th, 2018. The vessel departed Gimli sailing on a temporary permit issued by Transport Canada allowing a single voyage from Gimli to Hnausa for drydocking. The vessel was positioned so that the bow was over the first airbag and the tow eye could be attached. The 100-foot tow line was attached to the tow eye with a 30-ton rated shackle and the other end attached to the winch line. The air bag was inflated, and the winch line was tightened. The ship rolled on the airbag as the winch line was hauled in. As the ship was coming out of the water the majority of the vessel's weight was being carried by two air bags, these air bags sunk into the mud of the dry dock slipway and the winch was not able to move the vessel any further. A third airbag was inserted under the ship and two excavators were connected to the ships mooring bits on the bow with the ships mooring lines. With the extra support of the third airbag and the extra pulling force exerted by the two excavators the ship began to move out of the water. As the ship exited the water and was entirely supported by the air bags it was winched into position. When the ship was in position timber blocking was placed under the hull using the newly developed blocking plan to ensure adequate support and to prevent damage to the ship from insufficient or misplaced blocking. Approximately eight hours elapsed from the time the ship entered the dry-dock slipway to have the tow line attached to the tow eye to the time the ship was securely on the timber blocks.

The air bags were removed from under the ship to allow access for the contractor to wash the hull with high pressure and hot water pressure washers. A preliminary inspection found the hull to be rather clear of zebra mussels except for the ships main sea water intakes and showed no significant signs of damage. During the preliminary inspection it was found that the starboard propeller had significant cracking at the periphery of the propeller blades and

would require replacing the propeller. The port propeller had minor damage on one of the propeller blades and it was decided to replace the propeller with the spare in storage. The starboard propeller which was in storage was sent out for repair prior to the ship being dry-docked and would be used to replace the damaged starboard propeller. The preliminary inspection also indicted that there was significant wear on the rudder shaft and mounts as the rudders had excessive "slop".

The high-pressure cleaning of the hull took four days to complete. The contractors surrounded the ship's hull in tarps to contain the debris from sandblasting and painting. The hull was abrasive blasted in any area where bare metal was exposed during the high pressure washing. The remainder of the hull was brush blasted to prepare the surface for coating. The hull was coated with the same coating which was used in 2010. Extra protection was applied to the sea water intakes to minimize the buildup of zebra mussels.

While the ship's hull was being cleaned another contractor was disassembling all valves connected directly to the ship's hull for inspection. The valves were inspected, the valve seats were lapped, and the valves were reassembled after being inspected by a Transport Canada Marine Inspector. The contractor was also removing the rudders, propellers and propeller shafts. When the rudder shaft and pintails were removed and measured it was found they were at the minimum diameter for continued service and would require replacement. The propeller shafts, rudders and components were shipped to the contractor's facility in Selkirk. During inspection of the propeller shafts it was found the starboard shaft had a slight bend in it. The contractors performed a cold straightening of the shaft and brought the straightness back into specification. The contractors fitted the replacement propellers to the propeller shafts ensuring adequate contact between the taper of the shaft and the taper of the propeller. The contractor also sourced material to fabricate new bushings, shafts and pintles for the rudders.

A through visual inspection of the ship's hull was carried out both internally and externally with ultrasonic thickness measurement readings taken. During this inspection 2 areas were found with thinning of the hull plating in way of damaged areas. One area near the bow of the ship in the area of the forepeak and forward void space, the other area being in the ship's engine room and shaft compartment. The thinning of the hull plating in the two areas is not due to external damage and the watertight integrity for the vessel is not compromised. The thinning of the hull plating is due to internal corrosion. These two areas will be required to be repaired before the ship sails next season. To complete the repairs the ship will need to be dry-docked again. It has been estimated the repairs will require approximately four to five weeks to be completed. There are other areas of the hull which have been damaged in the past and will require repair, however due to the fact there is no thinning of the hull plating in these areas they do not require immediate repair and will be monitored with annual inspections.

The contractor installed the propeller shafts and couplings and prepared for the Transport Canada Marine inspector to witness the non-destructive test of the shaft keyways for cracking as well as the contact fit for the propellers to the propeller shafts. The contact fit and non-

destructive inspection passed, and the propellers were reinstalled. The new components for the rudders were inspected by the Transport Canada Marine Inspector and certified for installation. The rudders were reinstalled with the new components. The contractor doing the painting returned and painted both rudders.

A final inspection of the hull and sea valves was carried out by the first and second engineers. Everything was found to be in good condition and reassembled to be watertight. The dry-dock crew prepared the airbags under the ship for launching. The airbags were inflation and the blocking was removed. The ship was started down the dry-dock ramp with the assistance of 2 excavators. The ship was rolling smoothly until the air bags entered the water and like when the ship was being hauled out the air bags sank into the mud and the ship would not roll into the water. The dry-dock crew tried pulling the ship with the excavators and pushing the ship with the excavators. The excavators did not have enough power to move the ship and a large Bulldozer was brought in. The large bulldozer was able to skid the ship over the stuck airbags and get the ship to move. Once the main sea water intakes were under water the Port ships generator was started. When started it was noticed that the generator was not getting enough seawater and it was asked if the bulldozer could push the ship a little further into the water. This was not possible as the dry-dock crew had already sent the bulldozer away. We were forced to start the ships main engines with limited cooling water and back off the drydock under our own power. The ship backed off the drydock and tied up to the main dock in Hnausa. Another check was made to ensure the ship was watertight, once satisfied the ship was watertight a request was made to Transport Canada to allow a onetime sailing to Gimli to finish our annual inspection. The ship departed Hnausa and sailed to Gimli

The Annual inspection was carried out in Gimli and the Ship was granted the certificates need to sail.

Appendix E. Science Workshop Agenda

FINAL AGENDA
Science Workshop
Lake Winnipeg Research Consortium Inc.

March 19th & 20th, 2019
Qualico Family Centre – Tamarack Room, Assiniboine Park, Winnipeg

DAY 1 - March 19th (Full Day)	
8:00 a.m. to 8:30 a.m.	**Registration & Coffee**
8:30 a.m.	**Presentations**
Welcome – Opening remarks	K. Scott
Lake Winnipeg Basin Program – Update	S. Reedyk[1], U. Holweger[1]
Lake and watershed modeling – Update	L. Leon[1]
Substrate mapping of Lake Winnipeg	T. Rudolfsen[2], D. Watkinson[2], C. Charles[2], C. Kovachik[2], E. Enders[2]
Federal Nearshore Program – Update	E. Watchorn[1]
Mid-Morning Break	
Provincial Long-Term Water Quality Monitoring Program – Update	A. Burton[3]
Quality of groundwater and surface water in the Assiniboine Delta Aquifer area	S. Danielescu[1], V. Morand[1], F. Barbecot[1]
Historical variability & future changes in temperature precipitation & snow in the Assiniboine-Red Basin	R. Shrestha[1], B. Bonsal[2], A. Kayastha[1], Y. Dibike[1], C. Spence[1]
Temporal changes (1929-2015) in emergent vegetation cover in Netley-Libau Marsh	G. Goldsborough[4], E. Watchorn[1], P. Kowal[4], C. Hudon[4]
Noon	**Lunch (Workshop registrants only)**
1:00 p.m.	**Presentations**
Provincial AIS Program – Update	L. Janusz[3]
Temporal and spatial variation in densities of *Bythotrephes* 2012-2017	B. Hann[4], W. Jansen[6], L. Janusz[3]
Lake Winnipeg zebra mussel distribution – Update	D. Depew[1], K. Rattan[1], L. Leon[1]
How do changes in climate and wetlandscape hydrology contribute to algal blooms, L. Wpg? – MINI	F. Fendereski[7], I. Creed[7], C. Trick[7]
BMAA toxin study – Update	S. Murch[8], S. Lauren Bishop[8]

Mid-Afternoon Break	
Impacts of dreissenid mussels on phytoplankton community composition	P. Matson[9], T. Davis[9], A. Zastepa[1]
Remote sensing bloom indices: a status update and comparison with historical monitoring data	C. Binding[1]
Steps toward a methane budget for Lake Winnipeg	T. Papakyriakou[4], D. Capelle[4], R. Mandryk[4]
Preliminary results of Lake Winnipeg bottom and suspended sediments	M. Goharrokhi[4], D. Lobb[4], G. McCullough[4], P. Owens[5], S. Clark[4]

DAY 2 - March 20th (Half Day)	
8:00 a.m. to 8:30 a.m.	**Registration & Coffee**
8:30 a.m.	**Presentations**
Food web Isotopic study	G. Koehler[1]
Common Carp movement and habitat use in the Lake Winnipeg Basin	D. Watkinson[2], C. Charles[2], E. Enders[2]
Walleye movement patterns in Lake Winnipeg	N. Turner[10], M. Rennie[10], E.Enders[2], D.Watkinson[2], C. Charles[2], G. Klein[3]
Genomics and movement in the Lake Winnipeg walleye (*Sander vitreus)* – MINI	M. Thorstensen[4], J. Jeffrey[4], K. Jeffries[4]
Mid-Morning Break	
Indigenous Inland Commercial Fisheries Initiative (IICFI) – resource management & business development	B. Galbraith[11]
Updates from the Pelagic and Littoral Fish Survey Monitoring Programs	E. Enders[2], A. Caskenette[2], C. Lumb[2], D. Watkinson[2]
The collapse and extirpation of sauger in commercial fisheries: is Lake Winnipeg next?	S. Forbes[12]
Wrap up – Seabird data, 2019 field season, IAGLR	K. Scott

Noon Post-workshop meeting (~10 min) – Lake Winnipeg Special Issue JGLR

Affiliations	
[1]Environment and Climate Change Canada	[7]University of Saskatchewan
[2]Fisheries and Oceans Canada	[8]University of British Columbia
[3]Province of Manitoba	[9]Bowling Green State University, Ohio
[4]University of Manitoba	[10]Lakehead University
[5]University of Northern British Columbia	[11]Indigenous Services Canada
[6]North South Consultants	[12]University of Winnipeg

Appendix F. Science Workshop participants and affiliations

Name	Agency
Ayles, Burton	Freshwater Institute, Fisheries and Oceans Canada - retired
Binding, Caren	Environment and Climate Change Canada, Burlington
Burton, Andrew	Manitoba Sustainable Development
Capelle, David	University of Manitoba
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Depew, David	Environment and Climate Change Canada, Burlington
Dibike, Yonas	Environment and Climate Change Canada, Saskatoon
Fendereski, Forough	University of Saskatchewan
Forbes, Scott	University of Winnipeg
Galbraith, Bill	Indigenous Services Canada
Geisler, Marianne	University of Winnipeg
Gladu Kanu, Daniel	Lake Winnipeg Indigenous Collective
Goharrokhi, Masoud	University of Manitoba
Goldsborough, Gordon	University of Manitoba
Grosshans, Richard	IISD-ELA
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Hanson, Mark	University of Manitoba
Harland, Michelle	Environment and Climate Change Canada, Winnipeg
Herbert, Claire	University of Manitoba
Heuring, Laura	Manitoba Sustainable Development
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Hughes, Elizabeth	University of Manitoba
Hutchison, Dale	Manitoba Hydro
Janson, Wolfgang	North/South Consultants Inc.
Janusz, Laureen	Manitoba Sustainable Development
Johnson, Ryan	Lake Winnipeg Research Consortium
Kanu, Alexis	Lake Winnipeg Foundation
Klein, Geoff	Manitoba Sustainable Development

Name	Agency
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Kuzyk, Steven	University of Manitoba
Leon, Luis	Environment and Climate Change Canada, Burlington
Lobson, Chelsea	Lake Winnipeg Foundation
Lumb, Chelsey	Manitoba Sustainable Development
Mandryk, Rachel	University of Manitoba
McCullough, Greg	University of Manitoba
North, Gina	Manitoba Hydro
Page, Elaine	Manitoba Sustainable Development
Paterson, Michael	International Institute of Sustainable Development - ELA
Penner, Wes	Manitoba Hydro
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Rodenberg, Andreas	Lake Winnipeg Research Consortium
Rodgers, Katelyn	University of Manitoba
Rudolfsen, Tyana	Freshwater Institute, Fisheries & Oceans Canada, Winnipeg
Scott, Karen	Lake Winnipeg Research Consortium
Shrestha, Rajesh	Environment and Climate Change Canada, Saskatoon
Stratton, Desiree	University of Manitoba
Swanson, Gary	Manitoba Hydro
Thorstensen, Matt	University of Manitoba
Toews, Jay	Toews Environmental Ltd.
Turner, Nicole	Lakehead University
Warren, Kyla	National Indigenous Fisheries Initiative
Watchorn, Elise	Environment and Climate Change Canada, Winnipeg
Watkinson, Doug	Fisheries and Oceans Canada
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