Lake Winnipeg Research Consortium Inc.

2017 / 2018 Annual Report

Science and Education Programs

March 2018

Report prepared by Dr. Karen J. Scott

Programs Coordinator

TABLE OF CONTENTS

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 a dedicated research platform, the Motor Vessel (M.V.) *Namao*, to its science members, and by convening those members annually at a 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. This report summarizes the main activities associated with LWRC's Science and Education Programs, as well as additional relevant contributions to other agencies' programs.

SCIENCE PROGRAM

Background

Since 2002, the LWRC has offered three, whole-lake surveys annually aboard the M.V. *Namao* - spring, summer and fall – that cover an established network of sampling stations. For the first 10 years of the LWRC's existence, roughly 65 stations comprised the "offshore" station network on Lake Winnipeg.

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 M.V. *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 2016, the LWRC launched a second vessel, M.V. *Fylgja*, a 12.8 m touring boat converted for research purposes. Her full history can be found on the LWRC's website. With a mere one metre draft, M.V. *Fylgja* complements the M.V. *Namao*'s capabilities by further facilitating special projects closer to shore in the south basin and narrows of Lake Winnipeg.

M.V. *Namao* Dry Dock Challenges

The M.V. *Namao* requires an out of water inspection every five years. Prior to 2015, this inspection took place at the dry dock in Selkirk; however, this facility is now closed.

Consequently, the M.V. *Namao* has been operating on an exemption from Transport Canada since 2015, the last scheduled dry dock, although many of the Transport Canada requirements that are normally inspected during the dry dock have been carried out (with the ship in the water). To service its barge, the *Poplar River*, the Freshwater Fish Marketing Corporation has constructed and operates a new dry dock facility in Hnausa. The M.V. *Namao* is scheduled to use this facility after ice-out in the spring of 2018, which may or may not impact the scheduling of Programs depending on the timing of the spring melt.

Field Program - Open Water Season 2017

Three research surveys were carried out during the 2017 open water season on board M.V. *Namao*. The spring survey ran between May 31st and June 17th; the summer survey between July 24th and August 8th; and the fall survey between September 18th and October 5th. Only two days were lost to weather – one each during the spring and fall surveys. A total of 2875 nautical miles were travelled during these three surveys. One survey was carried out on board M.V. *Fylgja* in between the M.V. *Namao*'s summer and fall surveys.

Appendix A provides a summary of the research and monitoring carried out during the 2017 field season on board M.V. *Namao* and *Fylgja*. Appendices B and C contain maps of the station network and mooring locations, respectively.

Science Workshop

The annual Science Workshop was held on February 13th and 14th, 2017 at the University of Manitoba in Winnipeg (Appendix D – Agenda; Appendix E - list of workshop participants). In contrast to the 2015 Special Science Workshop (*Lake Winnipeg: State of the Science II - Toward the Integration of Lake Science and Management*), which developed a draft whole ecosystem Science Plan, this year's Workshop aimed to simply provide an opportunity to update the larger on-lake science community on previous and ongoing studies, as well as future planning of new projects. It was deemed an opportune time for such a format since a number of important initiatives are either nearing an end (State of the Lake report) or just starting (5-year Lake Winnipeg Basin Initiative).

Abstracts of the workshop presentations are below. If no abstract was submitted, a brief summary of the presentations was prepared for this report.

ECCC's Activities and Program in the Lake Winnipeg Basin

Ute Holweger

Environment and Climate Change Canada, Winnipeg

No abstract was submitted. The federal water mandate shows an increased desire for interdepartmental cooperation (ECCC, DFO and CCG) and working with orders of Government to protect Canada's freshwater, including Lake Winnipeg. This is evidenced by a renewal of the Lake Winnipeg Basin Program 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 funding breakdown is roughly: $8.3M in support of a Science Plan; $8M for application–based funding for nutrient reduction actions ($4.05M), collaborative governance ($1.97M) and indigenous engagement ($1.97M); $1.2M for nutrients (directed); and $7.4M for salaries. A call for Letters of Intent went out February 1st and successful candidates will have the opportunity to submit Project Proposals before March 26th, 2018.

The Lake Winnipeg Basin Program: Science Update

Ram Yerubandi

Environment and Climate Change Canada, Burlington

No abstract was submitted. This presentation provided an overview of the science component of the LWBP III and updates on the status of projects comprising the science program. Many of these projects were presented at the Workshop and are described below in more detail. The overall science plan objectives are to:

- Evaluate effectiveness of actions in reducing nutrient additions to local tributaries;
- Demonstrate progress in reducing nutrients reaching the lake;
- Demonstrate progress in establishing an ecologically sustainable nutrient balance in the lake; and
- Develop and report on ecological indicators and the State of the Lake.

Seasonal Hydrodynamics and Water Quality in Lake Winnipeg – Field Observations and Three-Dimensional Numerical Modeling

Reza Valipour, Luis Leon, David Depew, J. Zhao and Ram Yerubandi

Environment and Climate Change Canada, Burlington

No abstract was submitted. This presentation provided the objectives for the lake modeling effort, progress to date, future plans and data needs. Lake Winnipeg modeling objectives include: the development of an integrated modeling framework for the U.S. and Canadian watersheds discharging into Lake Winnipeg to replicate and predict water

movement patterns and water quality in the horizontal and vertical directions; identifying sources of nutrients triggering algal growth and propose management objectives to seasonally mitigate algal growth at the local and lake-wide scales; predicting the lake's response to potential nutrient loading reduction actions to improve water quality by connecting a watershed model to a lake model; and integrating dreissenid mussel effects on phosphorus cycling into models in order to assess the relative importance of direct and indirect effects on algal growth. Thus far, 10 years of field measurements (from 2007 to 2018) have been conducted and will continue in 2018. A number of hydrodynamic models are developed or are pending development or validation, including: ELCOM - 2km, 21 layers (developed, calibrated, and validated); ELCOM and Tuflow - 250m and 500m, 21 layers (validations for 2016 – 2018 pending); and ELCOM ICE model (to be developed). In addition, the development of the water quality model CAEDYM with mussels (2km) is planned and will help understand the effects of dreissenid mussels on phosphorus cycling. Ultimately, connecting a watershed model to the lake model will better predict the lake's response to potential nutrient loading reduction actions to improve water quality.

Substrate Mapping of Lake Winnipeg to Predict Zebra Mussel Colonization "Hot Spots"

Tyana Rudolfsen, Colin Krovachik, Doug Watkinson, Eva Enders

Freshwater Institute, Fisheries and Oceans Canada

The Zebra Mussel (*Dreissena polymorpha*), an invasive aquatic species known to outcompete native mussel species and alter food webs, was discovered in Lake Winnipeg in 2013. Due to Lake Winnipeg's large size and complex community structure, it is challenging to predict the degree to which Zebra Mussels might impact the lake's ecology. Using a hydroacoustic sonar and benthic sediment samples, Fisheries and Oceans Canada is developing a map that will depict depth and sediment types across Lake Winnipeg. With this understanding, we can better identify suitable habitat for Zebra Mussels and predict their potential impact on community structure. This information will also be used as data input into Environment and Climate Change Canada (ECCC)'s nutrient cycling model for Lake Winnipeg and serve as habitat maps for the Lake Winnipeg Fish Movement Study.

Long-Term Water Quality Monitoring on Lake Winnipeg

Elaine Page

Water Quality Management Section, Manitoba Sustainable Development

Since 1999, the Water Quality Management Section has conducted chemical and biological monitoring from a network of offshore stations on Lake Winnipeg. The objective of the monitoring program is to determine the impact of anthropogenic activities on water quality and aquatic life, to provide information to support and protect

the health of the lake, and to help assess change in water quality over time. Beginning in 2014, twelve nearshore stations were added to the long-term water quality monitoring network to characterize conditions in the littoral areas of the lake. This presentation will provide an overview of results to date focusing on nutrients, algal biomass and microcystin concentrations in the offshore and nearshore areas of the Lake Winnipeg.

Watershed Modeling (Red and Assiniboine Basins)

Luis Leon, Isaac Wong, Agnes Richards, Chris Spence, Rajesh Shrestha, Yonas Dibike and Barrie Bonsal (presented by Ram Yerubandi)

Environment and Climate Change Canada, Burlington

No abstract was submitted. The status of a number of watershed modeling initiatives was described. **Integrated modeling**: the objectives of the integrated modeling are to integrate the existing Water Quality Analysis Simulation Program (WASP model) for Lake Winnipeg and the Soil and Water Assessment Tool (SWAT model) for the LaSalle, Boyne and Little Saskatchewan basins with various nutrient load reduction scenarios and assess the impacts on the lake and watershed. In addition, integrated modeling will provide decision support system tools to model a suite of BMPs in SWAT to meet the load reduction scenarios. **SPARROW model**: will be improved by developing a Bayesian framework that will integrate with lake models to quantify nutrient loads, identify source hot-spots, estimate uncertainty, and inter-annual variation, such as wet and dry years. **Red and Assiniboine rivers watershed models**: will be developed using SWAT by setting up a hydrologic and nutrient transport model to improve understanding and prediction of nutrient dynamics and transport to Lake Winnipeg under climate variability and BMP scenarios, including non-contributing areas. **Climate change**: will also be evaluated in terms of hydroclimatic variability, drivers, and indicators, such as precipitation, temperature and various moisture indices impacting water availability and nutrient fluxes over the Red-Assiniboine watershed.

Significance of groundwater contribution to N&P loading of surface water in LWB

Serban Danielescu[1], Dale vanStempvoort[2] and F. Barbecot[3]

[1]Environment and Climate Change Canada and Agriculture and Agri-Food Canada, Fredericton; [2]Environment and Climate Change Canada, Burlington; [3]GEOTOP and Département des sciences de la Terre et de l'atmosphère, Université du Québec

The contribution of groundwater to the nitrogen and phosphorus loading to surface water in the Lake Winnipeg Basin (LWB) is currently unknown. Several studies have been conducted in the past with respect to the sources of nutrients that have potential to contribute to groundwater loading; however, there are significant gaps regarding the fate and transport of these nutrients in the subsurface, as well as to their dynamics and magnitude in groundwater. Consequently, the nutrient fluxes delivered to the surface water bodies (i.e. Lake Winnipeg and tributaries) by groundwater discharge is currently

unknown. Hydrogeological conditions in the LWB vary widely, with the unconfined sand and gravel aquifers playing a particularly important role in the subsurface mobilization of nutrients due to susceptibility of contamination from both point and diffuse sources. These aquifers have high hydraulic conductivity and storage capacity when compared to other surficial materials (e.g. clay-rich glacial deposits and lacustrine clays) present in the LWB. As a first attempt at investigating the significance of groundwater inputs to the LWB nutrient balance, a five year pilot project focused on the Assiniboine Delta Aquifer (ADA, 3800 km^2), an area where groundwater discharge to surface water is suspected to play a significant role, started in April 2017. This project will provide detailed information about fluxes of nitrogen and phosphorus from groundwater to surface water in the LWB, and it is anticipated that the techniques involved and the research outcomes will provide valuable support for investigation of these processes in other areas of the LWB.

Agricultural Practices for the Lake Winnipeg Basin

Henry Wilson, Alan Moulin, Mohammad Khakbazan, Jason Vanrobaeys, Steve Sager, Scott Duguid, Stella Fedeniuk, Larry Braui, Erin Zoski and Ute Holweger

Brandon Research and Development Centre, Agriculture and Agri-Food Canada

This presentation will provide an update on the Agriculture and Agri-Food Canada (AAFC) project "Research, development, and transfer of knowledge for sustainable and climate change resilient agricultural management practices to mitigate nutrient runoff from agricultural landscapes in the Lake Winnipeg Basin." Interactions between agricultural management practices and weather variability associated with climate change will become increasingly important due to the potential impacts on runoff generation, crop production, and ultimately the economic viability of farming systems in the Lake Winnipeg Basin. Identification of key nutrient source areas within fields and watersheds and the prediction of potential for nutrient transport on the scales at which farm management decisions are made (field, farm, and small catchment) remain significant knowledge gaps within the Lake Winnipeg Basin due to the complexity of source dynamics with snowmelt, highly variable weather patterns, dominant movement of agricultural nutrients associated with dissolution rather than with erosion of soil, and the uneven distribution of runoff sources that characterize the landscape. The research completed with this project will result in the development of agricultural management practices and tools to target conservation efforts that increase efficiency of P and N use and retain these valuable nutrients on agricultural land.

Use of Suspended and Bottom Sediment of Lake Winnipeg to Determine the Source of Materials Being Exported Out of the Lake

Masoud Goharrokhi[1], David Lobb[1], Greg McCullough[2], and Phil Owens[3]

[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

Suspended mineral sediments in Lake Winnipeg ultimately derive from major tributary inflows (mostly the Red River, which cuts through glacio-lacustrine deposits to the south) and from massive erosion of glacial deposits along the north shore. At any given time, the more proximate source of suspended sediments have been resuspended locally from the bottom. We collected significant quantities of suspended sediments by continuously centrifuging and filtering more than 4 million liters of lake water in transit and at stations during 2016 and 2017 cruises. To assess the efficiency of a high-volume, continuous-flow centrifuge system and a high-volume, continuous-flow filtration system in collecting suspended particles under different levels of sediment concentration, weather conditions, and operating durations, samples were collected of the ambient lake water as well as from the outlets of these devices. The nature and distribution of suspended sediment in the water column, in inflows and outflows, and in eroding banks will be quantified. In conjunction with this study, more than 50 bottom sediment cores were also obtained from selected stations and along two transects running southward from north shore of the Lake. We will use sediment fingerprinting techniques to discriminate north shore versus tributary sources of sediment in these cores and in the outflow of the lake to determine the source of materials being exported out of the Lake.

Sedimentation Monitoring – Coordinated Aquatic Monitoring Program

Russ Schmidt

Manitoba Hydro

The Coordinated Aquatic Monitoring Program (CAMP) conducted sedimentation monitoring on Playgreen Lake in 2013 and along the length of the upper Nelson River in 2016. The presentation will summarize the monitoring programs with a focus on flows entering Playgreen Lake from Lake Winnipeg which entailed installing up to ten continuous multi-parameter (turbidity, temperature, dissolved oxygen and conductivity) sensors. Ongoing work related to estimating sediment loads from continuous turbidity data and mapping of sediment concentrations from satellite imagery will also be presented.

State of the Lake Report Update

Kevin Jacobs[1] and Elise Watchorn[2]

[1]Water Quality Management Section, Manitoba Sustainable Development
[2]Water Quality Monitoring and Surveillance, Environment and Climate Change Canada

Environment and Climate Change Canada and Manitoba Sustainable Development continue to lead the production of a second State of Lake Winnipeg technical report, covering the period 1999 to 2016. Participants include numerous scientists and managers who have conducted research, monitoring and other work in Lake Winnipeg and its watershed. The report will include updated data analyses throughout, chapters on new subject areas, and an expanded exploration of many topics included in the first report. This talk will provide an update on the status of the report, the anticipated timeline, and the targeted release date.

Canadian Watershed Information Network Update

Claire Herbert

[1]Centre for Earth Observation Science (CEOS), University of Manitoba, Winnipeg

No abstract was submitted. The Canadian Watershed Information Network (CanWIN), as it is now known, was first developed by Environment and Climate Change Canada to act as a collaborative web-based platform to collect and share research related to the Lake Winnipeg Basin. In 2012 it was transferred to the University of Manitoba and its scope was expanded to link or share research conducted within the Nelson River watershed, into Hudson Bay and the Arctic. CanWIN's mandate is two-fold - support research and education, and support management, policy and evidence-based decision-making. A number of recent updates were described. Funding from LWBP III has been allocated for the ongoing support of CanWIN.

Update on the Pelagic Fish Survey Monitoring Program

Eva Enders, Amanda Caskenette, Doug Watkinson, Chelsey Lumb

Freshwater Institute, Fisheries and Oceans Canada

The continuation of the Pelagic Fish Survey Monitoring Program in Lake Winnipeg that has been conducted since 2002 provides a unique opportunity to study the impact of recent introductions of aquatic invasive species such as Zebra Mussel (*Dreissena polymorpha*) and Spiny Water Flea (*Bythotrephes longimanus*). In addition, it provides a yearly status update on the prey fish community that supports important fisheries species, an early indication of the Walleye (*Sander vitreus*) year class strength as well as samples for food web analyses. Fish trawls are conducted during spring, summer, and fall lakewide surveys from the M/V Namao (Lake Winnipeg Research Consortium) to better understand patterns of temporal and spatial variation of fish assemblages in the offshore waters of Lake Winnipeg. Trawl stations occur parallel to a systematic water quality

program using a network of long-term monitoring stations. Preliminary results from the 2017 survey data revealed that native Emerald Shiner (*Notropis atherinoides*) and Cisco (*Coregonus artedi*) continue being the dominant species in the South Basin and Channel. Until recent years, the prey fish community in the North Basin was dominated by the non-native Rainbow Smelt (*Osmerus mordax*), however, in 2017 not a single Rainbow Smelt was captured. The impacts of aquatic invasive species on population trends and time-lagged responses (e.g., over generations) are planned to be analysed using modelling approaches. Results from the pelagic fish survey monitoring program are useful to aid in evaluating the relative importance of top-down and bottom-up regulations in the Lake Winnipeg food web, which has implications for fisheries and water quality management.

Lake Winnipeg Fish Movement Study

Doug Watkinson[1], Colin Charles[1], Colin Kovachik[1], Doug Leroux[1], Mark Pegg[2], Henry Hansen, Geoff Klein[3], Jamison Wendel, Todd Caspers, Ken Jefferies[4], Jason Treberg, Darren Gillis[4], Mike Rennie[5], Paul Blanchfield[1], Eva Enders[1]

[1]Freshwater Institute, Fisheries and Oceans Canada; [2]University of Nebraska, Lincoln, Nebraska; [3]Wildlife and Fisheries Branch, MB Sustainable Development; [4]University of Manitoba, Winnipeg, Manitoba; [5]Lakehead University, Thunder Bay, Ontario

Fisheries and Oceans Canada in partnership with the University of Nebraska, Province of Manitoba, State of Minnesota, State of North Dakota, University of Manitoba, Lakehead University and Lake Winnipeg Foundation is conducting an acoustic tagging fish movement project in the Lake Winnipeg Basin. To date, 530 fish have been tagged, represented by Common Carp (n=40), Lake Sturgeon (n=45), Bigmouth Buffalo (n=80), Channel Catfish (n=161) and, Walleye (n=204). A total of 247 receivers are currently deployed to detect tag transmissions in the Lake Winnipeg Basin, including the US portion of the Red River. The goals of this project include the evaluation of movement and habitat use of species at risk, river connectivity (fish passage past dams), fisheries management, understanding shared fisheries with the USA, fishing mortality, theoretical – receiver spacing, wetland use by Common Carp, markers and indices of metabolic function and disruption, transcriptomic responses to environmental stress, and fishery hazards to non-target species. Preliminary results, after one year of study, suggest connectivity of fish population tagged in the Red River to the US portion of the watershed and extensive movements with Lake Winnipeg.

Provincial Commercial Fisheries Update

Geoff Klein, Kevin Casper

Sustainable Fisheries Unit, Wildlife and Fisheries Branch, MB Sustainable Development

No abstract was submitted. Two provincial fisheries updates were provided. The first was on the Negginan (Poplar River) fall whitefish fishery collaborative stock assessment. In an effort to move toward achieving sustainable fishing certification, fishers in Poplar

River undertook an index netting program in collaboration with provincial fisheries biologists. The second presentation provided an update on the provincial index netting program, which includes spawn testing and index netting for sauger and walleye. In 2018, the department implemented a maximum mesh size in order to protect the spawning population.

Southeast Resource Development Council: Commercial Freshwater Fish Market Opportunity

David MacKay

South East Resource Development Council

No abstract was submitted. With the legislated provincial withdrawal from the federal mandate of the Freshwater Fish Marketing Corporation, new opportunities for commercial fishers may be possible. This presentation described a proposed initiative for fishers in Manitoba, or the Prairies, similar to existing federal Aboriginal fisheries programs such as the Atlantic, Pacific and Northern Integrated Commercial Fisheries Initiatives (AICFI, PICFI and NICFI respectively).

Fish Mercury in Lake Winnipeg – A Brief Perspective

Wolfgang Jansen

North/South Consultants Inc.

The monitoring of mercury concentrations in fish from Lake Winnipeg dates back to 1969. At the time, the Federal Department of Fisheries and Forestry detained all fish originating from the Saskatchewan River system, including Lake Winnipeg in response to a report that fish from the river contained up to 10 ppm mercury. Results for commercial catches from Lake Winnipeg to August 1970 indicated that concentrations in up to 63% of composite samples from some predatory species exceeded the 0.5 ppm Health Canada standard for retail fish, although very few samples had concentrations >1.0 ppm. Species with higher concentrations included Yellow Perch, Freshwater Drum, Sauger, and Northern Pike, whereas species such as Lake Whitefish, Cisco, Whites Sucker, and Burbot generally had concentrations of less than 0.35 ppm. Also, fish from the south basin contained more mercury than fish from the north basin. After being closed from 1970-1972, the commercial fishery of Lake Winnipeg re-opened with some limitations on predatory species. Mercury concentrations of more than 5000 individual fish of 13 species and 19 locations in Lake Winnipeg have been measured as part of scientific studies and monitoring efforts by the Canadian Food Inspection Agency and the Province of Manitoba until 2011. Since 2010, systematic, 3-annual monitoring of mercury in Lake Whitefish, Northern Pike, Walleye, and young Yellow Perch from the north basin at Mossy Bay has continued under the Coordinated Aquatic Monitoring Program (CAMP) by the Province of Manitoba and Manitoba Hydro. Results from Mossy Bay and a near-by location with historic monitoring data indicate that fish mercury concentrations have

decreased somewhat since the 1970s. Current (2016) concentrations in whitefish (0.02 ppm), pike (0.17 ppm), and Walleye (0.12 ppm) are very low for the species compared to other locations in Manitoba and Canada.

Dreissenid Mussels in the Great Lakes and Changes to Nearshore Nutrient Ecology: Is it Relevant to Lake Winnipeg?

Robert Hecky[1] and Harvey Bootsma[2]

[1]Department of Biology, University of Minnesota, Duluth; [2]School of Freshwater Sciences, University of Wisconsin, Milwaukee

Invasive dreissenid mussels have modified phosphorus cycling in the Laurentian Great Lakes both nearshore after the zebra mussel invasion and offshore with establishment of quagga mussels. Benthic algal blooms are common nearshore on the invaded lakes while offshore clarity has increased as well while offshore P concentrations have fallen in these already oligotrophic lakes. However, several large shallow eutrophic embayments have not been significantly altered and valued fisheries have been relatively stable. Lake Winnipeg has similar characteristics, e.g. shallow, high nutrient content and turbidity, and high algal abundance, to these large, eutrophic coastal embayments. Consequently, algal abundance and fisheries in Lake Winnipeg may not be strongly impacted by mussel invasion.

Lake Winnipeg Nearshore Monitoring Overview

Elise Watchorn[1] and Amanda Caskenette[2]

[1]Environment and Climate Change Canada, Winnipeg; [2]Fisheries and Oceans Canada

No abstract was submitted. The nearshore environment will likely be most susceptible to change due to zebra mussels, followed by changes in the offshore over a longer time period. To monitor these potential changes, ECCC initiated a nearshore pilot program in 2009, but it was not continued. As part of LWBP III, and in collaboration with DFO, ECCC resumed this program starting in 2017. There are 9 road accessible sites, which will be sampled three times a year at 1 and 3 metre depths for a number of water quality parameters, phytoplankton, and biota, including zooplankton, benthic macroinvertebrates, and fish (seining).

Lake Winnipeg Indicators

Dorothy Lindeman[1] and Kevin Jacobs[2]

[1]Environment and Climate Change Canada, Winnipeg; [2]MB Sustainable Development

Manitoba Sustainable Development and Environment and Climate Change Canada continue to work on production of a suite of indicators to track and report on ecosystem health in the Lake Winnipeg basin. A formal process has been established to coordinate

the indicators project. Further description of this process and an update on indicators currently in development will be provided.

2017 AIS Watercraft Inspection and Monitoring Results

Laureen Janusz

Aquatic Invasive Species Program, Fisheries Branch, Manitoba Sustainable Development

No abstract was submitted. The Province introduced watercraft inspection stations for aquatic invasive species in June, 2017. Six stations were located at strategic pinch points on provincial highways and at high volume boat launches. In addition, Manitoba and partners monitor a total of 95 water bodies, prioritized based on risk of introduction (i.e. proximity) and likelihood of establishing once introduced. High risk water bodies were sampled for zebra mussel veligers, adults and environmental DNA. In water bodies such as Lake Winnipeg, where zebra mussels are already established, monitoring continues to determine the extent of spread northward. In 2017, veligers were found at all 11 stations in the Narrows (compared to 7 and 2 in 2016 and 2015, respectively). The minimum number in a sample was 4 and the maximum was 1040 (compared to 1 and 642 in 2016): adults were observed on infrastructure at Princess Harbour and a substrate sampler at McBeth fishing station. In the North Basin, veligers were found at three stations at the south end of the north basin only, and no adults were observed on the north basin ODAS buoy or substrate samplers at George Island.

Population and Composition of Aerobic Anoxygenic Phototrophs in Lake Winnipeg's South Basin

Steven Kuzyk, Xiao Ma, Vladimir Yurkov

Department of Microbiology, University of Manitoba, Winnipeg

Lake Winnipeg has been under scrutiny over recent decades due to eutrophication. Studies have focused on impact to higher-level organisms and chemical content. However, information gaps remain for the microbial composition, their influence on nutrient loading, and importance as primary producers for this fresh water ecosystem. Therefore, we have initiated a microbial ecology study that focuses on aerobic anoxygenic phototrophs (AAP), but also encompasses other groups. AAP are photoheterotrophs that grow aerobically and use phototrophy as an auxiliary energy source without producing oxygen. They are abundant in many aquatic habitats, while their niche in such environments remains poorly investigated. This population study includes the identification of AAP species, determination of temporal and spatial variations, and defining capacity to affect chemical cycling within Lake Winnipeg. Six sampling trips to the lake during spring, summer, and fall of 2016 and 2017 have focused on the enumeration and diversity of phototrophic microbes. These include AAP, purple non-sulfur bacteria (PNSB), and aerobic oxygenic phototrophs (cyanobacteria and algae). Ten sites were chosen from the south basin for study; five from littoral zones, and the

others from limnetic zones. Liquid and sediment samples were taken for analysis from each shore site. The limnetic heterotrophic population peaked in the spring, and had lowest counts during the summer. Conversely, littoral microbial numbers peaked in the summer, and had lowest counts during the fall for both years. Although we observed less pigmented colonies from littoral sites than limnetic sites, a higher proportion of aerobic strains contained bacteriochlorophyll *a*, indicative of being AAP. Interestingly, water pH trends were similar for limnetic and littoral sites with a maximum in the summer, and predominant decrease in the fall. Chlorophyll *a* concentrations in 2016, indicating aerobic oxygenic phototrophs, showed little variation in the limnetic zones between seasons, while littoral zones showed increase during summer and decrease during the fall. Paired with information for metal and nutrient concentrations from each site, and community 16S rDNA analysis, it will be possible to evaluate the diversity, distribution, functional role and seasonal fluctuations of phototrophs in Lake Winnipeg.

Lake Winnipeg Phytoplankton Update: Current Phytoplankton Biomass and Composition

Hedy Kling

Algal Taxonomy and Ecology Inc.

This presentation will briefly show current north and south basin mean summer phytoplankton biomass and composition compared to historic data. Dominant taxa during this period were still N fixing Cyanobacteria such as *Aphanizomenon flos-aquae* complex, *Dolichospermum mendotae*, *D. flos-aqua*/*spiroides*, *D. fuscum*, and *D. lemmermanni* in the north basin while in the south basin Crytophytes and Chlorophytes were more important but *Aphanizomenon flos-aquae* complex as well as some of the same species of *Dolichospermum* were prevalent depending on location. The presentation will also briefly show biomass and composition at some of the near shore stations for 2017.

N-β- Methylamino-L-Alanine and its Naturally Occurring Isomers in Cyanobacterial Blooms in Lake Winnipeg

Stephanie Bishop, Jeff Kerkovius, Frederic Menard and Susan Murch

Chemistry, University of British Columbia, Kelowna

Cyanobacterial blooms have affected Lake Winnipeg since the mid-1990s due to an increased phosphorus loading into the lake, which has been exacerbated by stressors such as climate change and eutrophication. 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). We hypothesized that the cyanobacterial bloom in Lake Winnipeg produces BMAA and/or its naturally occurring isomers. Samples of

cyanobacteria were collected by the Lake Winnipeg Research Consortium from standard sampling stations and blooms in July and September of 2016 and were analyzed for BMAA, DAB, AEG and BAMA using previously published validated analytical methods. BMAA and BAMA were found in the highest concentration in the center of the north basin, the deepest and lowest-nitrogen zone of the lake, at an average concentration of 4 μg/g (collected in July and September 2016) and 1.5 mg/g (collected in July 2016) respectively. AEG and DAB were found in the highest concentration in cyanobacterial blooms from the near-shore region of the north basin, the slightly shallower and more nitrogen-rich zone of the lake, at 2.1 mg/g (collected in July 2016) and 0.2 mg/g (collected in July and September 2016) respectively. These 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.

Lake Winnipeg Harmful Algal Blooms

Jerome Compte, Arthur Zastepa, David Depew

Environment and Climate Change Canada, Burlington

Lakes are commonly viewed as integrators of changes that occur in the surrounding catchment basin. In this regard, Lake Winnipeg is experiencing excessive nutrients contributing to widespread harmful algal blooms (HABs). Action plans are in place to identify the sources and reduce phosphorus loadings from tributaries. Part of ECCC's Lake Winnipeg Basin Initiative is to identify the factors that drive cyanobacterial and algal blooms in Lake Winnipeg. To this end, samples at different locations across the two basins will be collected and analyzed for bacterio/phytoplankton composition using current techniques (microscopy/flow cytometry/genomics) to maintain consistency with previous years and develop/validate other measures (remote sensing, fluorescence, genomics). In particular this work would allow extending ECCC-GRDI initiative to Lake Winnipeg to develop, validate and apply genomics to archived and newly collected plankton samples, to establish a long term monitoring tool and provide a community-based measure of spatial/temporal shifts in plankton and toxigenicity in response to nutrient loadings and climate. Collaborative studies on zebra mussels and internal phosphorus loadings will further shed light on the impacts of invasive species on the disruption of Lake Winnipeg food web and the contribution of internal phosphorus loading to the maintenance of HABs respectively. The objectives and approaches of this multi-year research program will be detailed during this presentation.

Zoobenthos Community Variability in Lake Winnipeg

Brenda Hann

Department of Biological Sciences, University of Manitoba

Zoobenthos community composition and density in the offshore region of Lake Winnipeg were examined (2000-2016). Sampling protocols employed by Manitoba Water Stewardship and by Lake Winnipeg Research Consortium on behalf of Brenda Hann differed greatly with respect to gear, mesh size for sieving, number of stations sampled, sampling frequency, and sampling seasonality. Data will be shown to evaluate the influence of these factors on determination of zoobenthos community composition and density in Lake Winnipeg.

Lake Winnipeg: Foodweb Modeling

Keith Hobson[1], Geoff Koehler[1] and David Depew[2]
Environment and Climate Change Canada, Saskatoon[1] and Burlington[2]

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 presentation briefly described food web research to date and research planned for LWBP III, through an evaluation of changes in foodweb structure and function in response to the three aforementioned stressors.

LWRC's Honours and Graduate Student Scholarship

In the 2011 - 2012 fiscal year, the Science Program introduced an *Honours and Graduate Student Scholarship* to encourage and promote research initiatives by young scientists on Lake Winnipeg. A generous initial contribution of $20,000 over five years by the Manitoba Government and General Employees' Union allowed the establishment of the fund, and subsequent smaller contributions are being made to help maintain the fund.

The 2017 - 2018 recipient of the LWRC's Honours and Graduate Student Scholarship was Masoud Goharrokhi from the Department of Soil Science, University of Manitoba. The main purpose of Masoud's research is to determine the relative contribution of sources of suspended sediments being exported from Lake Winnipeg to the Nelson River. Sediment fingerprinting techniques will discriminate north shore versus tributary sources of sediment in cores and in the outflow of the lake to determine the source of materials being exported out of the Lake. Masoud received a $3,000 scholarship for stipend support.

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.

Lake Ecology Field Program

The LEFP was offered in the spring of 2017 between May 23rd and May 29th, during which time 183 students and chaperones participated in the Program. In addition, students from the School for the Deaf joined the science team for a full day in the fall of 2017.

The LEFP is a unique hands-on learning opportunity on board M.V. *Namao*, offered to students from grades eight to university level. Students set sail from Gimli, Manitoba on a half-day excursion in the south basin of Lake Winnipeg to sample and analyze various components of the lake ecosystem including *E. coli*, plankton, macroinvertebrates, turbidity and most recently plastics, microcystin-LR and even how to tie knots. In addition to field and lab work, students are responsible for taking accurate field notes, including drawing specimens, and completing an on-board written assignment. Prior to the field excursion, all students are required to view several on-line presentations describing the lake ecosystem and changes imposed on it by multiple stressors. These on-line resources are updated on a regular basis to reflect the most recent lake and watershed science and in response to student and teacher feedback on their effectiveness.

"LWRC Water Award" - Manitoba Schools Science Symposium

Jakob McKenna was the 2017 – 2018 Water Award recipient for his project entitled "*The bioremediation of nitrate in fertilizer-contaminated soil*".

The LWRC offers a *Water Award* at the Manitoba Schools Science Symposium (MSSS) in support of junior, intermediate and 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 research vessel *Namao* during the summer research survey.

Other Contributions

The LWRC continues to offer presentations to the general public on changes in the Lake Winnipeg ecosystem and to contribute to other initiatives, such as: the "Story Paddle Project", Buchanan School Aboriginal Committee; Gimli Museum display (lake science advisor); Blue Flag program (jury); State of the Lake report (steering committee); workshops and special sessions; and other agencies' efforts related to Lake Winnipeg.

APPENDICES

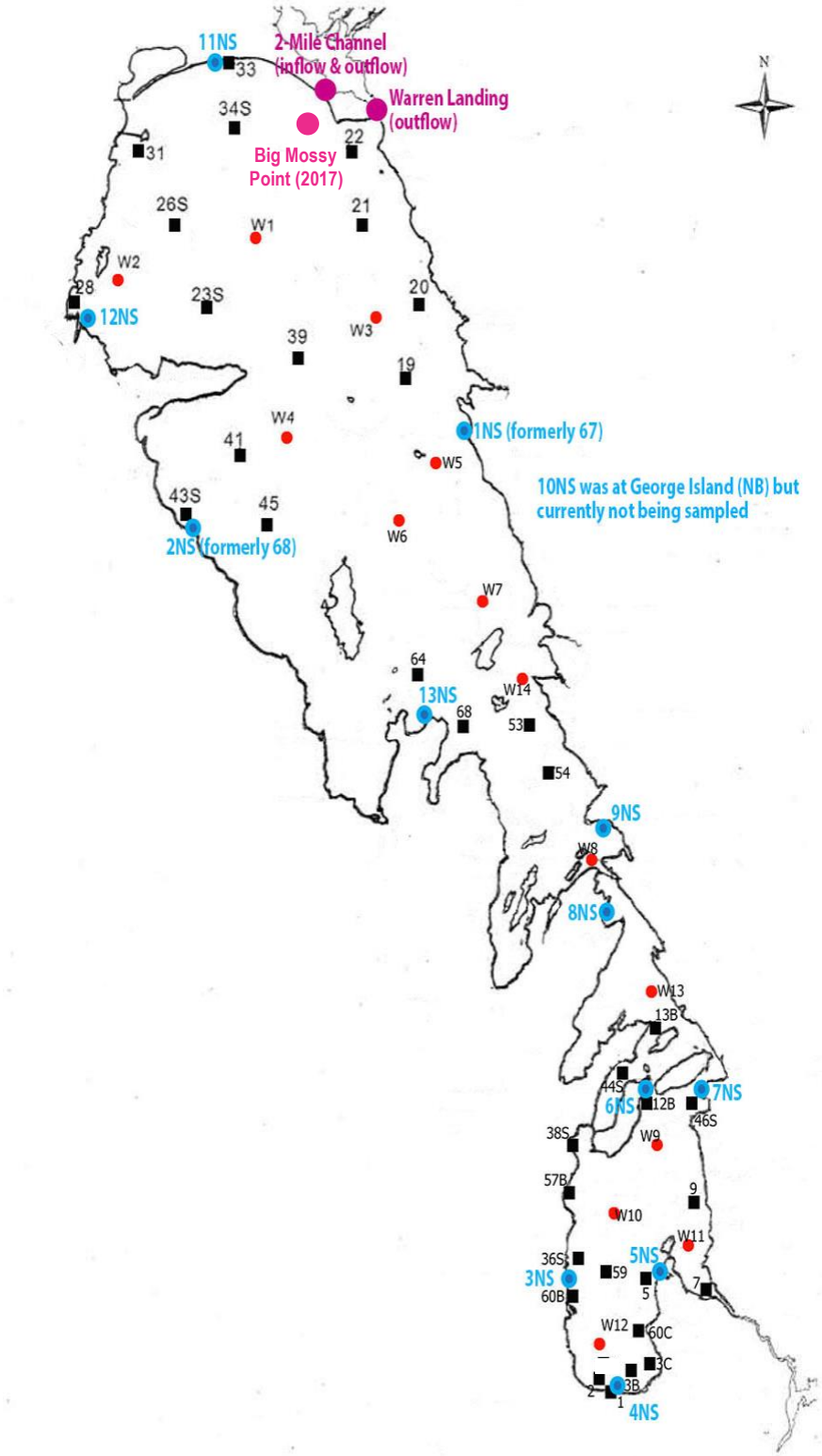
Appendix A – Research and Monitoring Activities Conducted off the Motor Vessels *Namao* and *Fylgja* during the 2017 Open Water Season

Agency	Lead	Project	Spring	Summer	Fall	Details
Manitoba Sustainable Development	Jacobs	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
	Jacobs	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

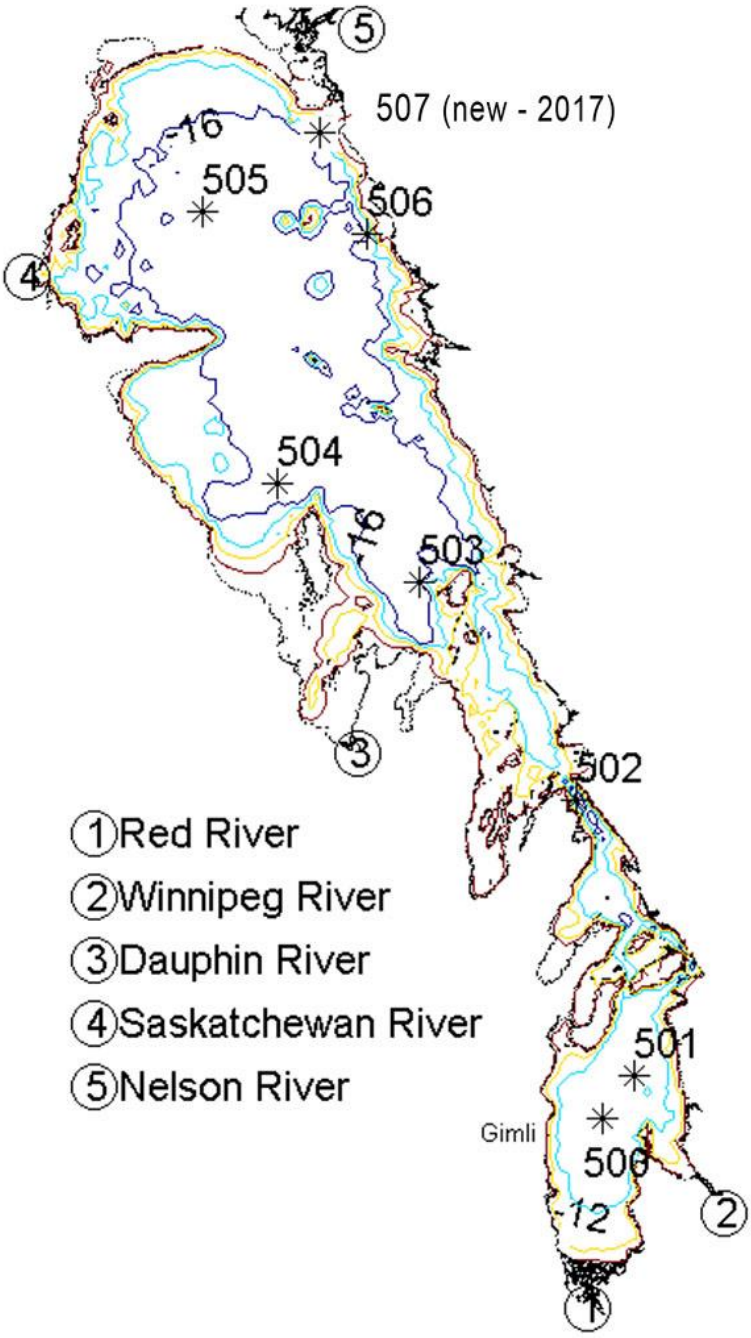
Agency	Lead	Project	Spring	Summer	Fall	Details
Environment and Climate Change Canada	Yerubandi	Physical lake model -assessment of hydrodynamics and model-based nutrient status	X		X	Deploy & recover moorings: 500 (1), 502 (4), 505 (1), 507 (4); install climate station George Island
	Yerubandi	Water quality 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
	Comte & Zastepa	Spatial heterogeneity in cyanobacterial and algal blooms, diversity & toxicity			X	*In situ* water chemistry; pigment fluorescence; plankton net cast at 15 offshore & 2 outflow stations
	Depew & Leon	Ecological Modeling		X	X	Summer & fall – water & zooplankton (stable isotopes) at 28 stations; Fall – triplicate sediment (ponar) at 30 stations, 250 µm mesh
Fisheries & Oceans Canada;	Enders	Juvenile fish trawl	X	X	X	43 offshore stations, all surveys
	Watkinson, Enders, Caskenette	Bathymetry and substrate surveys	M.V. *Fylgja*			Single beam echosounder mounted on a tow body; 7 x 7 m grid; south basin
	Stainton	Algal metabolism	X	X	X	Continuous monitoring of net photosynthesis and respiration, chlorophyll, algal group composition, CDOM and transparency (AOA); in transit – M.V. *Namao* & *Fylgja*
U. Manitoba	Hann	Zoobenthos	X	X	X	All offshore and nearshore (at 1 m) stations - one sample per site - 200 µm mesh

Agency	Lead	Project	Spring	Summer	Fall	Details
U. Manitoba	Hann	Zooplankton community	X	X	X	Vertical haul; 29 stations along N/S transect – 70 µm mesh
U. Manitoba	Goharrokhi (student) & Lobb	Sediment sources	X	X	X	Filter suspended sediment in transit
U. Manitoba	Kuzyk (student) & Yurkov	Anoxygenic phototrophs – role in biochemical cycling and toxin tolerances	X	X	X	Stations W9, 7NS, W10 and 57B
U. Manitoba	Stratton (student) & Goldsborough	Relationship between algal toxins & chemical, physical, and biological parameters	X	X	X	Algal blooms
U. British Columbia	Murch	BMAA algal toxin	X	X	X	Water samples from algal blooms (unprocessed)
Manitoba Hydro	Chaze	CAMP	X	X	X	Warren Landing, Two-Mile Channel (inflow and outflow), Mossy Bay (sediment) and station 22

Appendix B. Offshore, nearshore and outflow stations



Appendix C. Mooring locations



Appendix D. Science Workshop Agenda

AGENDA
Science Workshop
Lake Winnipeg Research Consortium Inc.

February 13th and 14th, 2018
St. John's College
Common Room
University of Manitoba
Winnipeg, Manitoba

Workshop Objectives: To convene active Lake Winnipeg science and management agencies in an effort to communicate scientific findings and future plans, as well as to discuss persisting/emerging science gaps and management needs on Lake Winnipeg.

DAY 1	
8:10 AM	**Registration, coffee**
8:30 AM	**Presentations**
Welcome	Karen Scott (LWRC)
Lake Winnipeg Basin Initiative Phase 3: science, ongoing work, expectations (Update)	Ram Yerubandi (ECCC)
Seasonal hydrodynamics and water quality in Lake Winnipeg – field observations and three-dimensional numerical modeling	Reza Valipour, Luis Leon, D. Depew, J. Zhao, & R. Yerubandi (ECCC)
Substrate mapping of Lake Winnipeg to predict Zebra Mussel colonization "hot spots" (Update)	Tyana Rudolfsen, Colin Kovachik, Doug Watkinson, & Eva Enders (DFO)
Long-term water quality monitoring on Lake Winnipeg	Elaine Page (MB Water)
Break	
10:30 AM	**Presentations**
Watershed Lake Model	Luis Leon (ECCC)
Significance of groundwater contribution to N&P loading of surface water in the LW Basin	Serban Danielescu (ECCC, AAFC)
Overview of the Agricultural Practices Program for the Lake Winnipeg Basin	Henry Wilson (AAFC)
Use of suspended and bottom sediment of Lake Winnipeg to determine the source of materials being exported out of the Lake	Masoud Goharrokhi (UM)
Sedimentation monitoring – Coordinated Aquatic Monitoring Program	Russ Schmidt (MB Hydro)
Lunch – Provided	

Science Workshop Agenda Continued – DAY 1

1:00 PM	**Presentations**	
	State of the Lake Report (Update)	Kevin Jacobs (MB) & Elise Watchorn (ECCC)
	Canadian Watershed Information Network (Update)	Claire Herbert (UM)
	Pelagic Fish Survey Monitoring Program	Eva Enders, Amanda L. Caskenette, Doug A. Watkinson, and Chelsey E. Lumb (FWI, DFO)
	Lake Winnipeg Fish Movement Project	Doug Watkinson, C. Charles, C. Kovachik, D. Leroux, M. Pegg, H. Hansen, G. Klein, J. Wendel, & others
	Break	
3:00 PM	**Presentations & Discussion**	
	Provincial Commercial Fisheries	TBA (MB Fish)
	Indigenous Commercial Fishery Initiative	David Mackay (SERDC)
	Mercury in fish	Wolfgang Jansen (NSC)
	Discussion – Inventory of forgotten data sets & samples	
4:30 PM	**Wrap up Day 1**	

Science Workshop Agenda Continued – DAY 2

DAY 2		
8:10 AM	**Registration, coffee**	
8:30 AM	**Presentations**	
	Nearshore phosphorus shunt and recent work and experience in the Great Lakes	Robert Hecky (U. Minnesota-Duluth, Emeritus)
	Federal Nearshore Sampling Program overview (Update)	Elise Watchorn (ECCC)
	Indicators (Update)	Dorothy Lindeman (ECCC), Kevin Jacobs (MB Water)
	Provincial Aquatic Invasive Species Program (Update)	Laureen Janusz (MB Fish)
	Break	
10:30 AM	**Presentations**	
	Algal metabolism (Update)	Mike Stainton (DFO Emeritus)
	Population and composition of aerobic anoxygenic phototrophs in Lake Winnipeg's south basin	Steven Kuzyk, X. Ma, X., & Vladimir Yurkov (UM)
	Lake Winnipeg phytoplankton: current biomass & composition (Update)	Hedy Kling (AT&E)
	N-β-Methylamino-L-Alanine and Its Naturally Occurring Isomers in Cyanobacterial Blooms in Lake Winnipeg (tele-conf)	Stephanie Bishop, Jeff Kerkovius, Frederic Menard, & Susan Murch (UBC)
	Lunch - Provided	
1:00 PM	**Presentations & Discussion**	
	Nutrients and Harmful Algal Blooms (HABS) (tele-conf.)	Arthur Zastepa & Jerome Compte (ECCC)
	Zoobenthos community variability in Lake Winnipeg	Brenda Hann (UM)
	Food web isotope study	Geoff Koehler (ECCC)
	Discussion – What is missing in terms of lake monitoring and research that will enable managers to more effectively evaluate and respond to changes in the lake ecosystem due to multiple stressors? (Near-shore indicators, lake whitefish index netting, denitrification/N_2 fixation etc.)	
3:00 PM	**Wrap up workshop**	

Appendix E. Science Workshop participants and affiliations

Name	Agency
Asadzadeh, Masoud	University of Manitoba
Ayles, Burton	Freshwater Institute, Fisheries and Oceans Canada - retired
Blicq, Andy	4th Avenue Productions
Caskenette, Amanda	Freshwater Institute, Fisheries & Oceans Canada, Winnipeg
Chaze, Ainslie	Manitoba Hydro
Compte, Jerome	Environment and Climate Change Canada, Burlington
Danielscu, Serban	Environment and Climate Change Canada, Fredericton
Depew, David	Environment and Climate Change Canada, Burlington
Enders, Eva	Freshwater Institute, Fisheries & Oceans Canada, Winnipeg
Geisler, Marianne	University of Winnipeg
Gillis, Darren	University of Manitoba
Goharrokhi, Masoud	University of Manitoba
Guildford, Stephany	University of Minnesota, Duluth
Hann, Brenda	University of Manitoba
Hanson, Mark	University of Manitoba
Harland, Michelle	Environment and Climate Change Canada, Winnipeg
Hasler, Caleb	University of Winnipeg
Hecky, Bob	University of Minnesota, Duluth
Hedges, Kevin	Fisheries and Oceans Canada, Winnipeg
Herbert, Claire	University of Manitoba
Hesslein, Ray	Fisheries and Oceans Canada - retired
Heuring, Laura	Manitoba Sustainable Development
Higgins, Scott	International Institute of Sustainable Development - ELA
Holweger, Ute	Environment and Climate Change Canada, Winnipeg
Jacobs, Kevin	Manitoba Sustainable Development
Janson, Wolfgang	North/South Consultants Inc.
Janusz, Laureen	Manitoba Sustainable Development
Klein, Geoff	Manitoba Sustainable Development

Name	Agency
Kling, Hedy	Algal Ecology and Taxonomy Inc.
Koehler, Geoff	Environment and Climate Change Canada, Saskatoon
Kristofferson, Al	Lake Winnipeg Research Consortium Inc.
Kuzyk, Steven	University of Manitoba
Leon, Luis	Environment and Climate Change Canada, Burlington
Lindeman, Dorothy	Environment and Climate Change Canada, Winnipeg
Lumb, Chelsey	Manitoba Sustainable Development
McCullough, Greg	University of Manitoba
McKay, David	South East Resource Development Council
Murch, Susan	University of British Columbia
Page, Elaine	Manitoba Sustainable Development
Paterson, Michael	International Institute of Sustainable Development - ELA
Ramlal, Patricia	Freshwater institute, Fisheries and Oceans Canada
Reedyk, Sharon	Environment and Climate Change Canada, Edmonton
Rudolfsen, Tyana	Freshwater Institute, Fisheries & Oceans Canada, Winnipeg
Schmidt, Russ	Manitoba Hydro
Scott, Karen	Lake Winnipeg Research Consortium
Shead, Justin	Freshwater Institute, Fisheries & Oceans Canada, Winnipeg
Stainton, Michael	Fisheries & Oceans Canada, Winnipeg - retired
Stratton, Desiree	University of Manitoba
Swanson, Gary	Manitoba Hydro
Toews, Jay	Toews Environmental Ltd.
Valipour, Reza	Environment and Climate Change Canada, Burlington
Watchorn, Elise	Environment and Climate Change Canada, Winnipeg
Watkinson, Doug	Fisheries and Oceans Canada
Wilson, Henry	Agriculture and Agri-Food Canada, Brandon
Yerubandi, Ram	Environment and Climate Change Canada, Burlington
Zastepa, Arthur	Environment and Climate Change Canada, Burlington