Lake Winnipeg Research Consortium Inc.

2013 / 2014 Annual Report

Science and Education Programs

November 2014

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Programs Coordinator

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INTRODUCTION

The Lake Winnipeg Research Consortium (LWRC) Inc. is a charitable organization that was founded in 1998 to address the need for scientific studies on Lake Winnipeg following evidence of water quality deterioration related to the 1997 Red River flood. Much has changed since the early 2000s when the LWRC began its annual, whole lake, multi-season research surveys, which more clearly revealed the ecological status of Lake Winnipeg. Among those changes, there is a growing number of organizations "advocating" for Lake Winnipeg. There is greater awareness and dialogue among the public, albeit sometimes misinformed due to the casual use of coined descriptors, such as "dying", "choking" and "most threatened", which have no scientific basis. There is now considerable momentum in the watershed to address nutrient loadings: in the form of research, with the establishment of two Research Chairs at the University of Manitoba; Provincial legislative changes; and funding priorities of the federal Lake Winnipeg Basin Initiative. Perhaps the greatest change, or more accurately game-changer, is the most recent invasive species, the zebra mussel, which was first detected in Lake Winnipeg in the fall of 2013.

Aquatic ecology aside, the economic costs of zebra mussels can be considerable. The cost of zebra mussels in Ontario is estimated to be between $73 and $90 million annually. Alberta's draft economic assessment estimated zebra mussels could cost that Province $75 million annually. From an ecological perspective, changes can be profound, albeit not as conveniently quantified. Research on the Laurentian Great Lakes has demonstrated the importance of the near-shore area, where impacts associated with zebra mussels, notably increased water clarity and nutrient concentrations, were greatest and manifested most quickly. This includes increased benthic algal productivity and near-shore macrophyte growth. High bacterial growth has also been associated with this excess near-shore benthic primary productivity, due in part to the protection from UV radiation that they afford to bacteria. Over time, changes in nutrient cycling in the near-shore increase impacts to the offshore areas of the lake, and ultimately these changes are reflected higher up the food web.

Due to the profound impacts of zebra (and quagga) mussels in the Laurentian Great Lakes, research and monitoring programs have increasingly incorporated near-shore processes. To date, most of the research and monitoring effort on Lake Winnipeg has been directed at the offshore area of the lake, where the LWRC's research ship, **Motor Vessel *Namao***, can safely travel. Also, in recent years, the LWRC has sampled on behalf of an increasing number of its science member agencies due, in part, to their inability to send personnel of their own. With routine cut-backs to government departments, such as Fisheries Branch of Manitoba Conservation and Water Stewardship, and, very little participation by Academia, the on-lake Science Program is diminishing in its capacity to address the increasing number of stressors on Lake Winnipeg, most recently zebra mussels, which will require a greater near-shore effort.

This "new reality" was the topic of discussion at the annual **Science Workshop** where results derived from the on-lake research and monitoring are presented by the respective

member agencies to gain an improved understanding of the status of Lake Winnipeg. This year's Science Workshop also included an entire Session on zebra mussels with two guest speakers, Drs. Scott Higgins and Michael Rennie, who shared their expertise on the potential impacts of zebra mussels on the ecosystem and on lake whitefish, respectively. All workshop presentations are summarized in this report and are available on the LWRC's website.

In 2013, the LWRC acquired a new vessel, the ***Fylgja*** ("Guardian Angel"), a 42' touring boat that was received as a charitable donation. Once outfitted for research purposes, this vessel will be particularly well suited for near-shore work and will serve as a valuable complement to the M.V. *Namao*'s offshore capabilities. The acquisition of the *Fylgja* is timely since it coincides with the arrival of zebra mussels, which, as previously described, will have the most profound impacts in the near-shore area, if it is able to thrive in the lake. Additional acquisitions in 2013 intended to enhance the on-lake research effort are also described.

In a small effort to support student research and to attract more members of the academic community, the LWRC's Science Program created an annual **Scholarship** in 2011 for honours and graduate students interested in studying Lake Winnipeg and its watershed. The 2013/2014 recipient was Marianne Geisler for her work entitled "*Forecasting the potential effects of invasive dreissenid mussels on habitat occupancy & production of walleye (Sander vitreus) in Manitoban & northwestern Ontarian lakes*".

The LWRC has a formal **Education Program** aimed primarily at Grades 8 to 12, but includes Grade 2 up to fourth year University. Most noteworthy is the **Lake Ecology Field Program,** which takes place in the spring and fall on-board M.V. N*amao.* This hands-on learning opportunity includes the use of a variety of sampling and analytical equipment, as well as microscopes and taxonomic keys. For teachers who wish to introduce Lake Winnipeg into the classroom environment without leaving the classroom, the LWRC Education Program is developing a series of "out of the box" **Web-based Resources**, as time and funding permit. Lastly, the LWRC has a **Special Projects Program** designed to facilitate or provide support to water-related grassroots initiatives, in both the arts and sciences. Future programming will include a two-day Workshop for teachers on-board the M.V. *Namao.*

The LWRC website (www.lakewinnipegresearch.org) continues to serve as the primary repository for information related to both the Science and Education Programs. As well, the website is populated with information suitable for the general public, such as the **Image Library** and **Satellite Image Blog**, found at www.lakewinnipegresearch.org/blog. This resource is intended to explore the Lake Winnipeg ecosystem through imagery, including satellite images, aerial photographs, microscopy, student art, and data.

This report summarizes the activities of the Science and Education Programs during the 2013 - 2014 fiscal year, including the Science Workshop presentations and discussion, the 2013 on-lake Field Season, new Science Program acquisitions, the LWRC Scholarship recipient, and the various components of the Education Program.

SCIENCE PROGRAM

Science Workshop

The annual Science Workshop was held on February 18th and 19th, 2014 at the Siobhan Richardson Field Station, Fort Whyte Centre in Winnipeg. As in recent years, the venue, being somewhat remote and self-contained in nature, was chosen deliberately in an effort to promote participation and dialogue among invitees (Appendix A – Workshop participants) both during and between workshop sessions.

Workshop Structure

Four Sessions comprised the Science Workshop, followed by a discussion (Appendix B – Agenda). The first Session on Day 1 was intended to provide big picture updates, including the Provincial water quality monitoring program, the Federal integrated modelling effort, and the University of Manitoba (UM) Lake Winnipeg data portal. The subsequent two Sessions – Watershed/Rivers and the Food Web - included more specific projects from within the watershed to the lake ecosystem, from fisheries to primary productivity. The final session (Day 2) began with an update presentation on the Federal-Provincial initiative to develop a suite of eutrophication indicators. The remainder of the session was devoted entirely to zebra mussels and included two guest speakers from Fisheries and Oceans Canada who have considerable experience with this invasive species.

A brief summary of each of the workshop presentations is below. The full presentations are posted on the LWRC's website, with one exception, which was too large to post. (Discrepancies between titles below and those on the Agenda are due to last minute changes by the authors.)

The Workshop wrapped up with a discussion on the "new reality" of moving forward toward an improved understanding of the Lake Winnipeg ecosystem despite diminishing scientific capacity on the lake. In an effort to provide some structure to the discussion, the following guiding questions were sent to workshop participants prior to the workshop.

- Is the current on-lake research and monitoring effort adequate to evaluate the consequences, if any, of remedial land management strategies on lake productivity?
- Is the current on-lake research, monitoring and modelling effort adequate to detect and predict potential changes in the status of Lake Winnipeg due to zebra mussels? (*Bythotrephes*? Other stressors?) Should near-shore parameters be considered in the current suite of eutrophication indicators?
- How can the LWRC further enhance the capacity of its Science Program to facilitate both offshore and near-shore research and monitoring on Lake Winnipeg?

Science Workshop Session One - Big Picture Updates

Lake Winnipeg State of the Lake: an update – E. Page
Manitoba Conservation and Water Stewardship, Water Quality Management Section

Elaine Page provided an overview of the Provincial water quality monitoring objectives, the historical and current monitoring effort, as well as an overview of future plans. The data presented included a summary of the annual means for nutrients (total nitrogen and phosphorus), chlorophyll-a, and microcystin for the open water season (May to October) from 1999 to 2013, as well as river flows and nutrient loads to the lake between 1994 and 2012.

Total nitrogen (mg/L) annual means by basin showed considerable year-to-year variability with no apparent trend over time. Moreover, the concentrations do not appear to follow peak inflows or loading years, which is perhaps related to other in-lake microbial processes such as nitrogen fixation and denitrification, neither of which is currently being studied by any agency working on the lake. Total phosphorus concentrations (mg/L) were two to three times higher in the south basin than the north basin, which is not surprising given that the Red River is the single largest contributor of phosphorus to the lake. There was no apparent increase or decrease over time; however, no formal trend analyses had been conducted either. Similarly, there was no clear trend for chlorophyll-a (μg/L). Of note was the 2006 peak, which has been attributed to the dry, warm conditions that were preceded by the high flow year in 2005 that brought in high levels of nutrients. The Provincial microcystin monitoring program includes both offshore sampling (from the M.V. *Namao*) as well as beaches in the south basin. Microcystin concentrations were higher in the near-shore areas of the lake but, overall, remain low with levels typically at or near detection (<0.2 μg/L). One surprising result from 2013 included an offshore sample in the north basin (near Poplar River) that measured 85 μg/L. This exceeded the recreational water quality objective of 20 μg/L and is considered a very rare occurrence for the north basin.

The mean annual flow (m^3/sec) for the Red, Winnipeg, Saskatchewan and Dauphin rivers is highly variable from year to year based on a 20-year time series. The year 2011 experienced some of the highest flows on the Red, Saskatchewan and Dauphin rivers. The nutrient load (t/year) delivered by these rivers to Lake Winnipeg has tended to be elevated during high flow years, with the Red River typically contributing the greatest loading. Of note was 2005 and 2011 – the former was a year with both high flows and high concentrations of total phosphorus in the lake, whereas 2011 had some of the highest loads but not correspondingly high in-lake concentrations. An interpretation of these results is still required but may be related to the proportion of flow originating from the Assiniboine River, variability in river concentration, and possible differences in methodologies between jurisdictions.

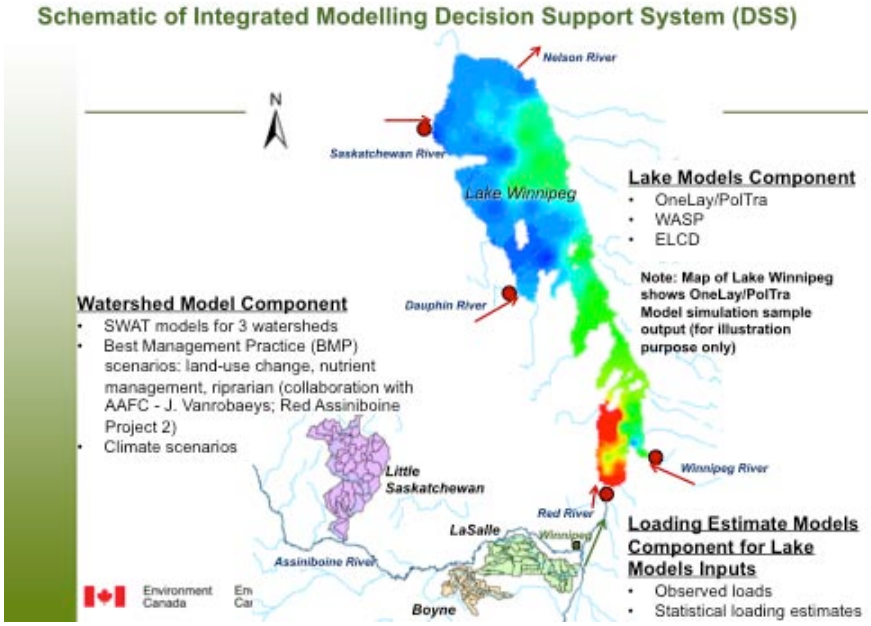
Future Provincial initiatives include an update to the State of Lake Winnipeg Report, a multi-agency report published in 2011 that summarized the physical, chemical and biological characteristics of the lake between 1999 and 2007. The update is planned for 2016 and will

include eight years of additional information collected by the various agencies working on the lake and its watershed. Manitoba is also contributing to the development of a suite of eutrophication indicators, an initiative lead by Environment Canada (see Session 4) intended to describe and report on the ecological health and status of Lake Winnipeg over time. Lastly, Manitoba continues to refine the long-term ecologically relevant Nutrient Objectives for Lake Winnipeg with the use of a WASP model that was originally developed by Environment Canada (see next presentation). Currently, Manitoba is committed to reducing phosphorus in the south basin of Lake Winnipeg by 50%, or to 0.05 mg/L.

Lake Winnipeg Basin Initiative: Modelling – R. Yerubandi, I. Wong, W. Zhang, J. Zhao, L. Leon, C. McCrimmon, P. Fong and B. Booty
Environment Canada (Burlington, ON)

The integrated modelling framework being developed by Environment Canada is an ambitious project aimed at combining numerous models (land, lake ecosystem and loading) that currently exist for various purposes. Although changes and ultimately challenges in personnel have resulted in some delays in the development and implementation of the integrated modelling system, some progress is nevertheless being made. This presentation provided an update on that progress.

From the big picture modelling perspective, there are two ways to approach the challenges in managing Lake Winnipeg and its watershed. The first is to model potential actions taken in the watershed (SWAT model) to determine how the lake ecosystem might respond, and the second is to establish targets in the lake and how they might be achieved via actions in the watershed. The integrated modelling framework allows both approaches.

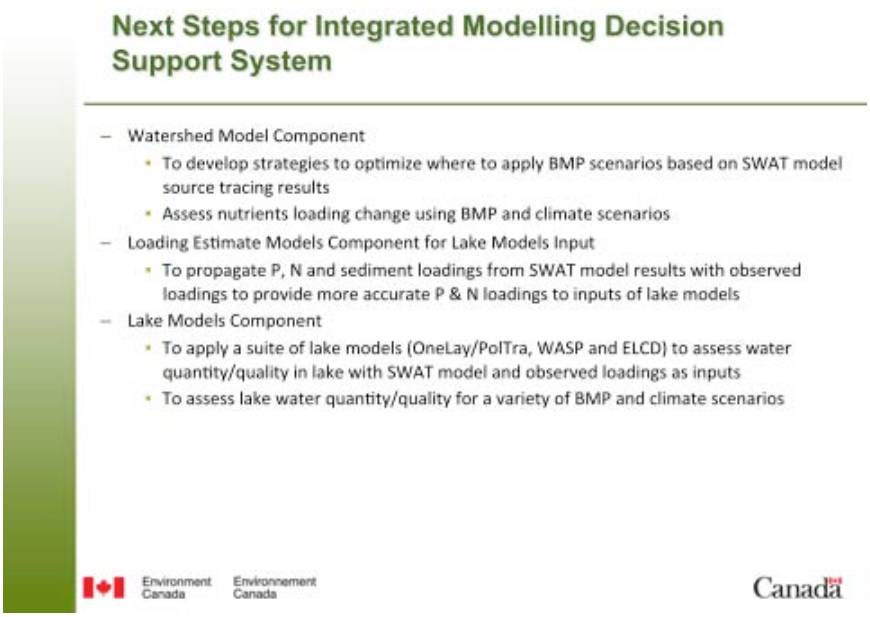


The watershed model component includes SWAT models for three watersheds within the Red/Assiniboine basin: the LaSalle, Boyne and Little Saskatchewan. Other loads entering the system must be estimated. Various fictional best management practices (BMP) scenarios concerning land use changes and nutrient and riparian zone management have been successful. The next steps will include: developing strategies to optimize where to apply the BMP scenarios based on the SWAT model output for source tracing; assessing nutrient loading changes using BMPs and climate scenarios; including SWAT into the framework; and making it available on the web portal (described in the next talk).

The OneLay/PolTra lake model is based on a 2-D grid and 2 km grid bathymetry with daily output. Its proof of concept simulated one ice-free period from June to October, 2002. The simple multi-segment WASP ecosystem model is being used for developing nutrient objectives for Lake Winnipeg. This model currently includes two nutrient cycles (nitrogen and phosphorus) and three functional phytoplankton groups: non-cyanobacteria; nitrogen fixing cyanobacteria (*Aphanizomenon* and *Anabaena*); and non-nitrogen-fixing cyanobacteria (*Microcystis*). It was calibrated between 2002 and 2008 with validation runs completed for 2009/10 and is now being extended for 2010/11. The 3D Hydrodynamic model (ELCOM) for Lake Winnipeg has horizontal resolution of 2 km and vertical resolution of 1 m in 21 levels. Model simulations of water levels, surface currents, and temperature structure are good. Further, the model reproduces the stratification development and the distribution of water isotopic tracers.

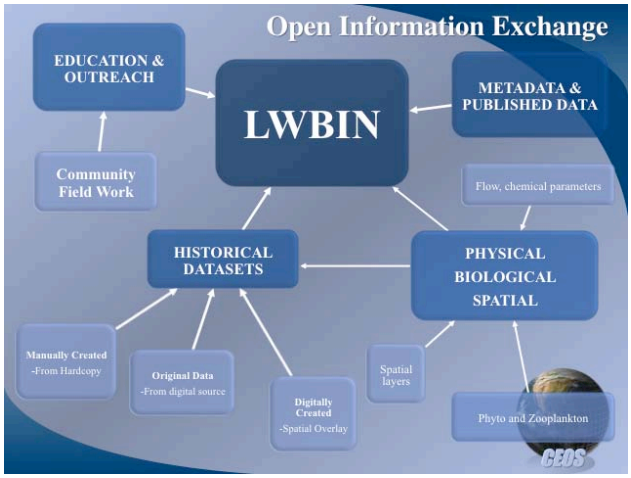
A number of initiatives are in progress including tests for a lake ice model (implemented in ELCOM), climate change impacts on lake physics, and the calibration and validation of ELCOM coupled with CAEDYM, a biological model, to predict the potential impacts of zebra mussels on nutrients and phytoplankton.

The future direction of the Integrated Modelling effort is summarized in the slide below.



Lake Winnipeg Basin Information Network – C. Herbert
University of Manitoba, Center for Earth Observation Science

Claire Hebert, coordinator for the Lake Winnipeg Basin Information Network (LWBIN), described the purpose and status of the web-based data and information network created by Environment Canada as part of the Lake Winnipeg Basin Initiative under Canada's Action Plan on clean water. In 2012, ongoing development and management of the network transferred to the Center for Earth Observation Science (CEOS) at the University of Manitoba.



An important goal of the LWBIN is to "facilitate sharing of water quality data and information for the lake and its contributing watersheds" by serving as a central hub for the distribution of data, information, knowledge, expertise and tools.

The LWBIN enhances research, education and decision-making in the watershed by: 1) enabling networking and collaboration among researchers, decision makers, government agencies, organizations and the public by acting as a portal for open-source data, metadata and information; 2) acting as a central hub where decision-makers and managers share access to current scientific information to guide and evaluate water and land management policy and programs; and 3) facilitating Citizen Science and public Education and Outreach throughout the basin through tools such as Know Your Watershed.

For more information, visit the website and join Twitter.

Website: http://lwbi.cc.umanitoba.ca

Twitter - @LWpgBIN

Phosphorus release from flooded soils

G. Amarawansha[1], D. Kumaragamage[1] and D. Flaten[2]
[1]University of Winnipeg; [2]University of Manitoba

Many agricultural areas in Manitoba (MB) are prone to flooding during spring snowmelt and heavy rains. Recent evidence has shown that prolonged flooding, and resulting anaerobic conditions, can increase phosphorus (P) release to flood waters. Thus, holding water back on agricultural land may contribute to increased P loadings from watersheds to lakes. From a management perspective, identifying soils with a high risk of P release to flood water is important in determining proper soil, fertilizer and water management practices. The research presented here looked at the issue of P release under flood conditions with the following questions. Does P released from MB soils increase with flooding and anaerobic conditions? Does the increase depend on soil type? What types of soils are more prone to release P when a soil is flooded? Could we use soil characteristics to identify those soils?

Three studies were conducted to explore these questions: 1) Field ponding study (summer 2011) conducted at Glenlea with Scanterbury heavy clay. Three treatments – unamended, manured and fertilized; 2) Laboratory incubation study using 12 surface soils with a wide variation in soil properties (covering four soil orders) that were collected in the fall of 2011 from different locations in MB including the Red River Basin and Interlake. Two treatments – unamended and manured; and 3) Field ponding study (summer 2013) with 12 soils from the same geographical location, but collected in 2013. Soils were brought into one common site at the University of MB for the study. Surface flood and soil pore water were sampled once a week and analyzed for dissolved reactive P (DRP), pH, total dissolved Ca, Mg, Fe and Mn. Soil samples were analyzed before and after flooding for water extractable P, Olsen P, P adsorption capacity at 150 mg P L^{-1} and Mehlich-extractable P, Ca, Mg, Fe and Mn.

Initial findings showed that the P released to flood water was not consistent across soils, but rather varied substantially from one soil to the other. Similarly, after becoming anaerobic, P released to flood water ranged from a small decrease to over 10-fold increase in soluble P, depending on the soil type. Manured and unamended soils showed similar responses to flooding. Results from the incubations and field ponding studies suggested that other factors in addition to clay content affect P dynamics in flooded soils. Overall, this work suggests that the P release from flooded soils to surface flood water can be predicted using simple soils parameters measured prior to flooding.

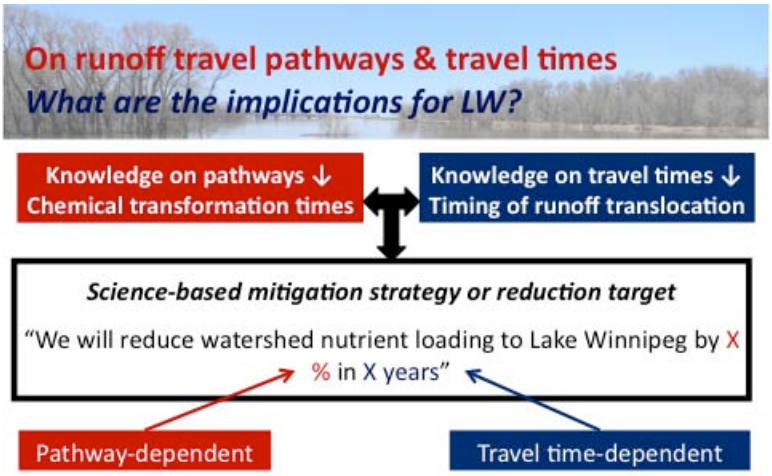
With funding from the Lake Winnipeg Basin Initiative, this study will continue to investigate P release under flood conditions to ultimately develop predictive tools based on soil properties. The predictive tools will need to be validated in the field using a greater number of different soils, including heavy clay soils. Moreover, model validation should also be carried out under different temperature regimes, such as spring melt when soil reducing rates would be much lower due to decreased microbial activity.

From the watershed to the lake: do we know enough about runoff travel pathways and travel times? – G. Ali, H. Petzold, A. Penner, C. Ross, S. Randall and D. Lobb
University of Manitoba, Watershed Systems Research Program

The Watershed Systems Research Program (WSRP) was established in 2010 by the Province of Manitoba with the aim to enhance the quality of water resources in Lake Winnipeg and its basin with an emphasis on nutrients. This Program is based at the University of Manitoba and includes a multitude of research interests and network of collaborators. Some of the major research questions being explored by the WSRP and pertaining to nutrient export from the watershed to Lake Winnipeg include: How much water is available to run off the landscape? Where will it end up? Which routes will runoff take to reach streams and rivers? How long will it take? What are the implications for water quality? To address these questions, very intensive data collection is being carried out in multiple sub-watersheds from the Prairie pot-hole region, escarpment, Lake Winnipeg and Catfish Creek. Ultimately, enhancing the predictive ability of models to answer these questions is desired, provided of course that complex dynamics can be modelled in a simple deterministic manner (another question of interest to the WSRP).

This presentation focused specifically on the 2013 results from the Catfish Creek watershed, the closest of the study sites to Lake Winnipeg, and addressed the following research questions pertaining to runoff travel pathways and travel times. 1) Do neighbouring watersheds behave alike in response to snowmelt or rainfall? 2) When does subsurface water flow from land to stream? 3) Can we predict the spatio-temporal variability of water quality at the watershed scale? 4) Are our conclusions biased by our sampling strategy?

The implications of this work on Lake Winnipeg are considerable since without better estimates of run-off travel pathways and travel times, it will be very difficult to demonstrate that reduction targets over given time periods are science-based. In essence, they are required for setting the targets in the first place.



The "Xs" are still unknown....

Stable isotopic compositions of nitrate and sulfate in the Assiniboine and Red River watersheds – G. Koehler

Environment Canada (Saskatoon, SK)

The first phase of this research used isotopic "fingerprinting" to examine the whole isotopic framework within the lake, including the Winnipeg, Saskatchewan and Red rivers. The study revealed that the Red River was an important source of nitrate (NO_3) derived from animal waste, both manure and sewage treatment plants.

The primary objective of the next phase, presented here, aims to use isotopic fingerprinting to discern where some of these nitrogen sources are coming from within the Red and Assiniboine basins – a few hotspots or more broadly diffused throughout the watershed. In addition to nitrogen isotopes, the isotopic compositions of sulfur (S) and sulfate (SO_4) are also being examined to determine if the spatial distribution of $\delta^{34}S$ values of dissolved SO_4, as reflected in the $\delta^{34}S$ values of fish, is related to differences in watershed input or in-lake processes.

Data analysis and interpretation from the first year of sampling is ongoing; however, preliminary results indicate that the NO_3 in the Red River was more a mixture between inorganic fertilizer and manure sources, whereas the Assiniboine River tended to have greater manure and sewage treatment plant sources. The Red River spring run-off also seemed to experience pulses of agricultural fertilizers, over the baseline of the manure/sewage treatment plants signature.

The watershed isotope work will continue in 2014 with increased sampling, including from sewage treatment plants in Brandon and Winnipeg, and with a specific focus on the Assiniboine River watershed. In a related study lead by Dr. K. Hobson, linkages between the watershed and lake food web will be examined by following nutrient inputs up the food web. The objective of the Food Web Dynamic study is to "use stable isotopes ($\delta^{13}C$, $\delta^{15}N$, $\delta^{2}H$, $\delta^{34}S$) to assess food web consequences and spatio-temporal changes in nutrient sources to Lake Winnipeg via the Red and Assiniboine watershed". In 2013, in-lake sampling included: forage fish and bulk plankton, which were collected off the M.V. *Namao* at river mouths and from the central basins (north and south); and basin level sampling for multi-trophic level fish. Two post-doctoral fellows, pending approval, will join Hobson and Koehler at the Stable Isotope Hydrology and Ecology Laboratory in Saskatoon. In addition, methods development using state of the art laser spectrometry is ongoing.

Nelson River Stable Water Isotope Monitoring Network (SWIMN): update

T. Stadnyk, A. Smith and A. Wall
University of Manitoba, Civil Engineering

The Nelson River Stable Water Isotope Monitoring Network (SWIMN) Program is in collaboration with Manitoba Hydro and, as its name suggests, is focused primarily on the

Nelson River, which contributes 75% of Manitoba Hydro's total power generation. The overall goal of the Program is to improve flow-forecasting capabilities on the lower Nelson River system through the development of different watershed models and calibration of those models using stable water isotopes. Ultimately, having the ability to forecast how much water there will be in the future is key to developing climate change adaptation strategies for power generation as far as 100 years into the future.

The overall approach to the project includes setting up the WATFLOOD™ watershed model of the Nelson River watershed, including the Nelson Churchill system, followed by model calibration using hydrometric data and stable water isotopes. There are only 10 hydrometric stations within the 90,000 km^2 SWIMN, thus additional sources of data are needed for model calibration. Without proper calibration that includes both total flow and sources of flow, the model would not accurately forecast future conditions, hence the need for stable water isotopes. Thus far, over 1,000 stable water isotope samples have been collected over a three-year period. In addition to the above, a Hydrologic Assessment study within the lower Nelson River is being carried out by Ph.D. student A. Smith using isotope data to determine different sources. Lastly, everything will be combined in a calibrated hydrologic model to simulate future flow-forecasting scenarios, which in essence equates to more confidence in predicting future power production.

An early result from this project indicated that flux-weighted surface water samples showed distinct river regimes upstream (Upper Nelson) and downstream (headwater river basins, including the Burntwood) of the Kelsey Generating Station. The Upper Nelson was most enriched, with progressive depletion downstream, and showed inconsistent seasonal patterning with ice-on enrichment and ice-off depletion. However, the Burntwood (headwater river) was more consistent with northern boreal systems, and had ice-on depletion (due to the influence of groundwater and snow melt in the spring) and ice-off enrichment (due to evaporation). Given that the Upper Nelson is connected with Lake Winnipeg, there was interest in determining to what extent, if any, Lake Winnipeg was contributing to these differences between headwater rivers and the Upper Nelson.

In brief, preliminary data from one year of sampling based off the M.V. *Namao* at and near the outflows of Lake Winnipeg (Station 22, 23B, 2-Mile Channel and Warren Landing) indicated that Lake Winnipeg's influence is responsible for Upper Nelson shifted seasonal mixing patterns and that headwater-mainstem source separation is possible in the spring/summer in the Upper Nelson region but not in the fall when the tributaries are not distinguishable from the mainstem. These preliminary findings are positive in that they will allow mixing model applications to be done.

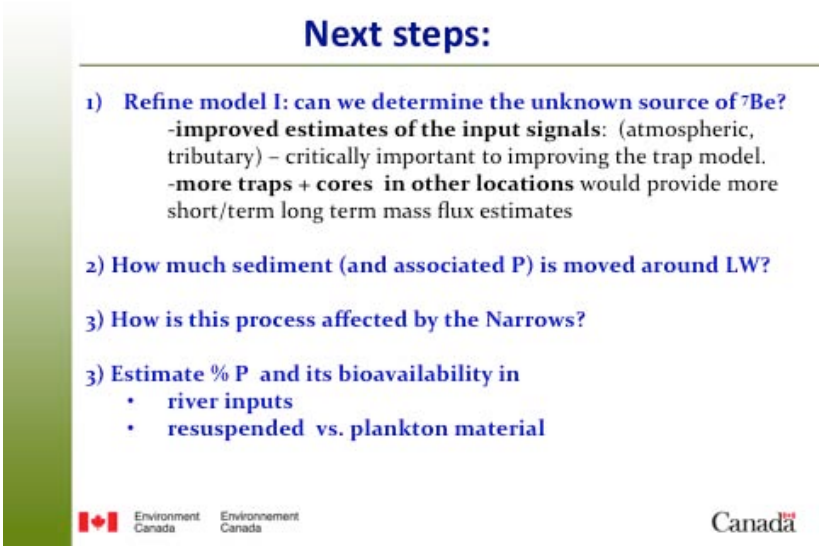
The Nelson River isotope sampling will continue for another four years. The Lake Winnipeg outflows sampling off the M.V. *Namao* will continue for another two years to confirm seasonal patterns and cycling under various hydrologic conditions.

Sediment influx and re-suspension in Lake Winnipeg – S. Watson, G. Matisoff, J. Guo
Environment Canada (Burlington, ON)

This multi-year project aims to characterize the nature and behaviour of Lake Winnipeg sediment and describe the associated implications for other processes such as internal and external phosphorus loading and bioavailability. Early results showed significant differences in surficial sediment composition across Lake Winnipeg, with higher percent clay in the south basin, and silt in the north basin. There were also distinct gradients in sediment particle size from north to south, east to west and inshore to offshore. Moreover, smaller particle size was associated with higher bioavailability of phosphorus, while there was little relationship between grain size and total phosphorus.

In this presentation, Dr. Watson explained the most recent phase of this project, which estimated, through various field measurements and models, a number of parameters including: the external or "new" sediment inputs from tributaries and the atmosphere; total suspended sediment across the north and south basins; the percentage of resuspended ("old") vs. new water column sediment; the associated phosphorus with the different sources of sediment; and the transport of sediment and associated nutrients spatially.

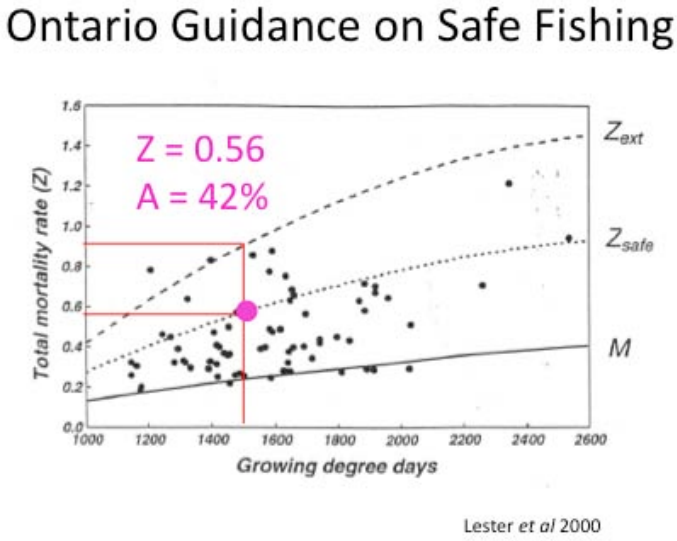
The methodology tested during this research included: sediment trap mass balance model; $^{7}Be/^{210}Pb$ Ratio Model; ^{210}Pb model; and ^{137}Cs System Time Averaging (STA) model. With the exception of the sediment trap mass balance model, the various methodologies appeared to be consistent over the two years of data collected, and suggest that the suspended matter in the water column does not resemble the sediment characteristic of the Red River and is likely recycled from the bottom of the lake. Indeed, it was estimated that 96 to 98% of the suspended matter was derived from resuspension. In addition, estimates suggest that accumulation rates are 2 to 4 times higher in the south basin than the north. This project is ongoing and future plans are presented in the "Next steps" slide.



Lake Winnipeg: Better all the time! – G. Klein
Conservation and Water Stewardship, Fisheries Branch

This presentation provided an update on the stock status of the three commercial quota species in Lake Winnipeg – whitefish, sauger and walleye - as well as an update on the eco-certification of the fishery.

The ***walleye*** stock status update was encouraging with five years of data from the current index-netting program. This is significant because it allows for better estimates of mortality rates, and defensible mortality rates are required for eco-certification. Based on the Ontario Guidance on Safe Fishing, a little more than two times the natural mortality (M) is considered a safe level of fishing (Zsafe). After five years of data collection, it appears that the total mortality rate for walleye is 0.56, or 42%: a safe level of fishing that is now supported by data. The Maximum Sustainable Yield (MSY) for walleye in Lake Winnipeg is 39%.



Lester *et al* 2000

There is no such method to determine mortality rates for ***sauger*** in this manner. However, M can be estimated in various ways, and doubling this value is a generally acceptable means to approximate the total mortality rates (Z) at MSY. The two methods that were presented to calculate M were Pauly (1980) and Hoenig (1983), both of which resulted in very similar natural mortality rate estimates of 0.33 (A=28%) and 0.37 (A=31%), respectively. MSY for sauger would occur at a total annual mortality rate of 57%. The current rate of mortality is 50%. Thus, it appears that sauger is also being harvested at a sustainable rate based on the five years of data from the current index-netting program.

The importance of these data cannot be overstated if the Lake Winnipeg fishery is to be evaluated by a third party certifier and ultimately eco-certified. This designation would allow fishers to sell into eco-certified markets, which are becoming increasingly important as large

companies like Walmart and Sobey's choose to sell only seafood that is sustainably harvested.

The stock status update for ***whitefish*** was understandably brief as no new data for lake whitefish has been collected since 2000 when the whitefish index-netting program ended. As has been noted in previous reports, very little is known about lake whitefish in Lake Winnipeg despite its importance as a sentinel species. As a bottom feeder, lake whitefish will likely be among the first species to be affected by changes in the benthic community, as well as by the presence of zebra mussels and spiny water flea, two recent aquatic invasives in Lake Winnipeg.

Eco-certification is a third party certification indicating that a fishery is being harvested in a sustainable manner. It is essentially the private sector attempting to encourage sustainable fishing in the absence of effective governance for sustainable fisheries management. Thus far, the Provincial success story for eco-certification by the Marine Stewardship Council (MSC) is Waterhen Lake, which has a progressive group of fishers. Waterhen Lake walleye and northern pike commercial gillnet fishery announced full assessment in December 2012 – the first freshwater lake fishery in North America to enter into assessment against the MSC standard.

Lake Winnipeg is considerably further behind in the eco-certification process as illustrated below using criteria for Seafood Watch (SW), which is similar to the MSC but only as a recommendation, not actual certification. It is used here for its more visual scoring display. Whitefish stock status ranks poorly due to the lack of data. Whitefish is also a bycatch in the walleye and sauger fisheries, hence the red rankings in that category. There is also no management plan in place. All told, the fishery would receive a ranking of AVOID if evaluated for eco-certification.

Species/Stock	Fishery	Impacts on the Stock Rank (Score)	Impacts on other Species Rank (Score)	Management Rank (Score)	Habitat and Ecosystem Rank (Score)	Score	SFW Ranking
Lake Whitefish	Gillnet	Red (1.73)	Yellow (3.15)	Red (2)	Green (3.61)	2.54	AVOID
Sauger	Gillnet	Green (3.83)	Red (1.65)	Red (2)	Green (3.61)	2.63	AVOID
Walleye	Gillnet	Green (4.28)	Red (1.65)	Red (2)	Green (3.61)	2.70	AVOID

Even a weak management plan that follows the eco-certification criteria for the quota species and not the bycatch species would result in a ranking of GOOD ALTERNATIVE. If stock data were collected on whitefish and the harvest was sustainable, walleye and sauger

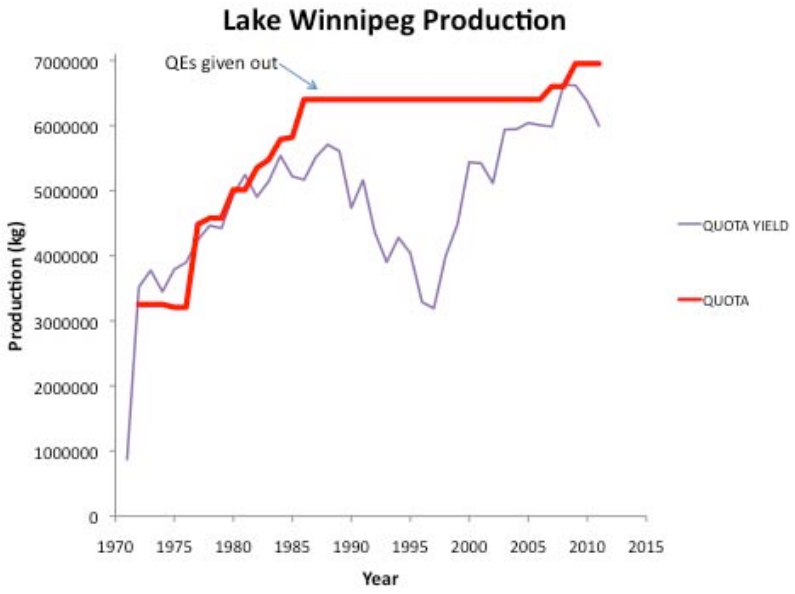
would be ranked as BEST CHOICE and whitefish as a GOOD ALTERNATIVE. To effectively move forward toward eco-certification, greater co-operation among Fisheries Branch, the Freshwater Fish Marketing Corporation and Lake Winnipeg fishers is needed.

"If this is eutrophication, bring it on!" – C. Lumb[1], D. Gillis[2], and G. Klein[1]

[1]Conservation and Water Stewardship, Fisheries Branch; [2]University of Manitoba

(Quote from a Lake Winnipeg Commercial Fisher, The Nature of Things)

The second presentation graciously made by Geoff Klein began with a brief review of the Lake Winnipeg commercial fishery since the 1970s, pointing out two notable time periods: the early 1980s when the harvest by fishers could keep pace with increasing quota and the 2000s onward when the harvest steadily increased again and quota was again increased to keep up. This latter period is of particular interest as it corresponds with the increasing nutrient loads to the lake.



As a first attempt to correlate total phosphorus to walleye productivity, the natural logs of total phosphorus and walleye landings were plotted from 1980 to 2005. This time period was chosen because it appears to best represent a period of unconstrained fishing. In addition, the data were lagged four years to represent when the fish likely entered the fishery. The preliminary relationship that emerged was strong and warranted further exploration of other possible influences and biological hypotheses. This presentation outlined the process of model building and selection for the best explanatory power of the observed patterns.

Long-term changes in benthic invertebrates in Lake Winnipeg

B. Hann[1], M. Wishart[1] and S. Watson[2]
[1]University of Manitoba, Biological Sciences; [2]Environment Canada (Burlington, ON)

Dr. Brenda Hann provided an update on the zoobenthos sampling program in Lake Winnipeg for data collected between 2002 and 2012. Samples collected in the spring, summer and fall of 2013 had not yet been analyzed.

In brief, lake-wide benthic density has increased, most notably in the north basin and in the spring and fall, compared with data collected during the 1969 surveys of the whole lake. Highest densities of *Diporeia* were found in the narrows and along the east side of the north basin, perhaps due to the deeper, colder water in that part of the lake. There is no evidence yet of a decline in densities. The distribution of *Diporeia* between 1969 and 2002 shows both years with high concentrations in the narrows. However, there appears to be a broader distribution in the north basin in 1969, especially around the shoreline north of Long Point. This was considered unusual, as this is not typically their preferred habitat.

Collection of benthos will continue in 2014 at all stations within the LWRC station network.

Response of zooplankton to changing diet in the summer – M. Fetterly and B. Hann

University of Manitoba, Biological Sciences

This student project examined how Lake Winnipeg zooplankton respond to changes in cyanobacteria biomass by comparing the zooplankton and phytoplankton communities in the lake in years of high and low cyanobacteria. In addition, an in-depth study of the diet of *Daphnia mendotae*, an important filter-feeder and the largest *Daphnia* in the lake, was also undertaken.

Four years of data, each representing different levels of phytoplankton, were used for the study: 1969 with low cyanobacteria and no blooms; 2003 with moderate cyanobacterial blooms; 2006 with significant cyanobacterial blooms; and 2012, a low cyanobacteria year. The phytoplankton data varied for each of these years (taxonomy, chlorophyll-a, algal on-line analyzer) and datasets were therefore correlated. Zooplankton samples were identified to species (cladocerans) and as either calanoid or cyclopoid copepods. Their densities were determined by lake region – south basin, north basin and the narrows.

Findings from the study indicated that important changes in zooplankton densities occurred in the north basin but not the south basin or narrows. In addition, it appears that *D. mendotae* was replaced by *D. longiremis* in the north basin in 2006, a high phytoplankton year. Lastly, large cladocerans (filter-feeders) and total cladocerans showed significantly lower densities in 1969 (low phytoplankton year) than in all other study years.

Lake Winnipeg phytoplankton (summary 2014) – H. Kling[1], S. Watson[2], B. Parker[2], G. McCullough[3], C. Herbert[3], M. Stainton[4] and E. Watchorn[5]
[1]Algal Taxonomy and Ecology Inc.; [2]Environment Canada; [3]University of Manitoba, CEOS; [4]Fisheries and Oceans Canada and [5]Conservation and Water Stewardship

Abstract provided by the author

Under-ice algae, zebra mussels and floods have the potential to significantly influence the open water season nutrient and productivity balance of a lake, and these phenomena have recently gained considerable interest in relation to Lake Winnipeg (LW). This presentation includes a short summary of some recent LW phytoplankton data, focusing on the under-ice populations, open water bloom periods and two mid-late summer seasons from samples in the near-shore south basin where the mussels have been recently reported.

Under-ice algae have been studied sporadically since 1969 and can sometimes reach bloom proportions. The size and taxonomic composition of this under ice algal population are highly dependent on the ice thickness and snow cover between February and ice-off. What happens under the ice may also influence the open water season.

With the recent appearance of zebra mussels in the lake and the implication for the near shore region, the current status of the inshore phytoplankton populations during the open water season is important to establish the current, pre-dreissenid conditions. This is essential if the impacts of these invasive species are to be fully tracked and understood.

Finally, we present summer data from periods following the recent severe flooding on the Assiniboine and Red rivers, where subsequent summers of maintained high water levels were accompanied by a decrease in mean phytoplankton biomass - so much so that people were asking "what happened to the blooms?".

Lake Winnipeg Harmful Algal Blooms (HABS): a polyphasic approach

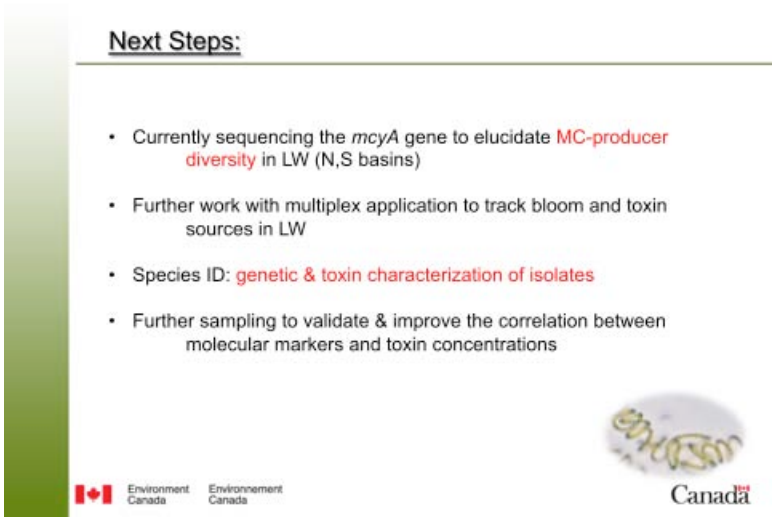
S. Watson[1], T. Davis[1], H. Kling[2], P. Zimba[3] and A. Chiu[3]
[1]Environment Canada (Burlington, ON); [2]Algal Taxonomy & Ecology Inc.; [3]U. of Texas

The term *polyphasic approach* refers to combining multiple methods to characterize harmful algal blooms (HABs), such as traditional taxonomy, physiological, biochemical and molecular metrics. This approach allows for a better understanding of what species are present, the extent of their toxicity, how toxins vary spatially and temporally, the role of internal regulators and external changes, including on a large scale in response to changing hydrology, management actions, zebra mussels and climate.

This presentation provided a brief overview using this polyphasic approach to characterize HABS in Lake Winnipeg, including the value and limitations of each method and some corresponding recent data. The three broad areas within the polyphasic approach included: *macroscale* (remote sensing), which allows for a near real-time and historic spatial-temporal

analysis and describes bloom intensity, timing, aerial coverage and high-risk areas, but low or no taxonomic and toxigenic resolution; *microscale* (microscopy, fluorescence, and biochemistry), which allows for taxonomic, biochemical *or* toxigenic resolution; and *molecular scale* (Multiplex qPCR / sequencing) for genomic *and* toxigenic resolution.

The molecular scale research using Multiplex qPCR is new to Lake Winnipeg and holds promise as a powerful diagnostic tool. In 2013, it was used to determine gene copies of three toxins: microcystin, cylinderspermoxin and saxotoxin. This project is on-going – the next steps were summarized.



Photosynthetron 2.0 - Monitoring Lake Winnipeg photosynthesis and respiration

S. Higgins[1], M. Holoka[1], S. Page[1], T. Papakyriakou[2], M. Stainton[1], S. Watson[3]
[1]Fisheries and Oceans Canada; [2]University of MB; [3]Environment Canada (Burlington, ON)

Abstract provided by the author

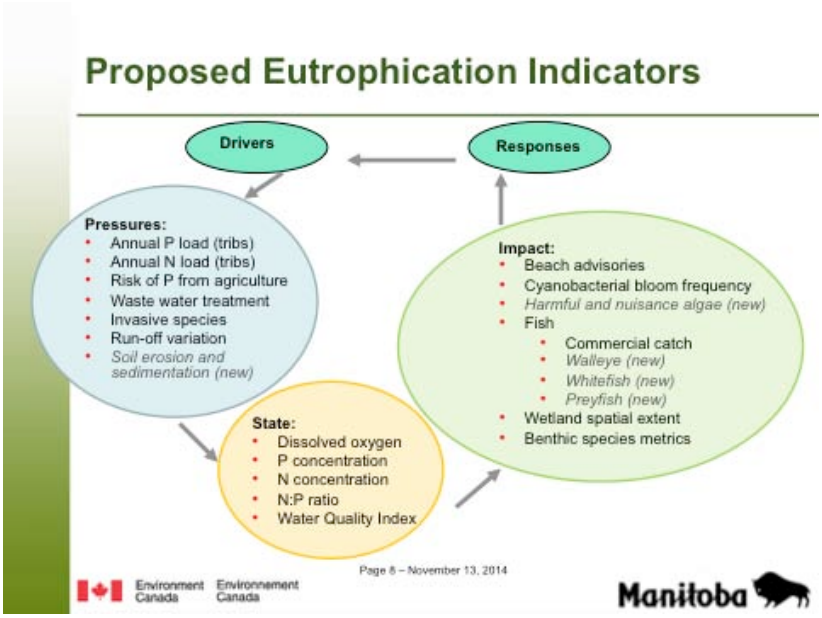
In 2013, we were able to deploy instrumentation on the *Namao* that monitored Net Photosynthesis (Net PP) and Respiration (R) at hourly intervals (approximately every 10 knots) during cruises 2 and 3. The instrument system consisted of three incubation chambers that could be independently programmed for: incubation time, light level (0, 33%, 66%, 100%) and light quality (white or red/blue LEDs). Algal metabolism was monitored as changes in O_2 levels. The equipment was used to monitor Net PP and R and test the relative efficiency of white vs red/blue LEDs, incubation time and light level. Algal chlorophyll and community composition was simultaneously monitored using an "Algal Online Analyzer". Instrument hardware and software performed flawlessly producing 700+ estimates of Net PP and R. When the *Namao* was on station for prolonged periods (hours to days) ship-board estimates of Net PP and R tracked rates observed *in situ*. Tests of light quality seem to show the Red/Blue LED light source to be less efficient than the White LED source, particularly in turbid waters. A good correlation between monitored chlorophyll and Net PP was observed suggesting that ship-board monitoring of Net PP may be useful for calibrating satellite imagery that can then map whole lake algal productivity.

Eutrophication-related indicators review: Lake Winnipeg and its watershed

K. Farmer
Environment Canada (Winnipeg, MB)

Kristina Farmer (Water Science & Technology Branch) provided an update on Environment Canada's (EC) efforts to develop *Eutrophication Indicators* for Lake Winnipeg. This important initiative began in 2010 with the development of an initial list of 35 indicators by TriStar, a consulting company commissioned to prepare the report by EC. The following year, representatives from Canada and Manitoba further refined the list to 18 indicators based on a literature review and consultation with internal experts. The framework within which these key indicators were selected and evaluated is known as the *Driver-Pressure-State-Impact-Response (DPSIR) model**. In 2012, EC prepared an internal draft report describing the development of individual draft indicator profiles and assessment criteria for indicator prioritization.

In an effort to assess the proposed ecological indicators through a peer-review process, a workshop entitled "*Lake Winnipeg Eutrophication Indicators Workshop*" was held in Winnipeg in October 2013. The purpose of the workshop was to review, evaluate and rank the 18 existing indicators and any new indicator proposals. There were roughly 30 participants from various agencies, including government, academia, resource agencies, NGOs and others. The workshop summary report was completed the following spring.



The next phase of this initiative will include working with the Province to develop an action plan by March 2015 to link data collection and indicator reporting on a selected sub-set of indicators and to identify who will lead the reporting on specific indicators. How exactly to report on the indicators will also have to be determined to ensure that information is

relevant, timely and presented in a clear, accessible, and flexible format. There was no plan to establish goals or targets for each indicator or to allocate resources for monitoring them over time.

*This conceptual model recognizes that *Driving* forces (D), such as societal and economic developments, can exert *Pressures* (P) on the environment, such as wastewater loadings, which may lead to changes in *State* (S) (chemical, physical, biological) and result in *Impacts* (I) to the system. These impacts may, in turn, promote a societal or human *Response* (R), which may then feed back on the driving forces, pressures, or directly on the states or impacts. The DPSIR framework allows decision-makers to understand the linkages between the condition of the ecosystem, pressures on the ecosystem, and how human activities are related.

Provincial strategy for the zebra mussel in Lake Winnipeg – L. Janusz
Conservation and Water Stewardship, Fisheries Branch

Laureen Janusz, Fisheries Branch, provided background information and status updates on two invasive species, spiny water flea and zebra mussels, with emphasis on the latter.

Bythotrephes, or the spiny water flea, was first detected in Traverse Bay on the east side of Lake Winnipeg in September 2011. Monitoring by the Province continued off the M.V. *Namao* during scheduled research surveys. By the fall of 2012, its distribution covered the entire lake and by 2013 it was found in near-shore samples from Playgreen Lake. Samples collected from the 2013 open water season from the offshore areas of Lake Winnipeg had not yet been analyzed at the time of the workshop.

Zebra Mussels were first confirmed in Lake Winnipeg on October 11th, 2013, after a specimen was removed from a recreational water craft moored at Boundary Creek Marina located on the west side of the south basin of Lake Winnipeg. The Province initiated a Rapid Response Protocol, including the establishment of a Science Advisory Committee. After determining the extent of its distribution and gathering other relevant data, the conclusion reached was that it was an early stage of infestation, with low densities contained to five harbours. Determining the level/extent of the infestation was achieved through intensive sampling while diving and/or snorkeling and by taking plankton tows both within and outside of the harbours.

At the time of the workshop, the proposed management considerations included: *eradication* within the harbours to apply downward pressure on the population and reduce the spread of zebra mussels from the harbours; *containment* via various means to reduce the spread within and to other lakes; *legislation changes* of various degrees; *monitoring* and surveillance; and *enhanced communications, education and outreach* to increase awareness of aquatic invasive species and what can be done to reduce the spread to other water bodies.

Based on the recent national risk assessment conducted by DFO, zebra mussels have a high level ability to establish in Manitoba waters due to high calcium. In a report by Marbek (2010) the mean annual cost of zebra mussels in Ontario is between $73 and $90 million. Alberta has just finished a draft economic assessment for their province and estimated zebra mussels could cost $75 million annually. The ecological cost is difficult to put a dollar figure to; however, based on other systems, it will be profound if they are able to establish themselves in Lake Winnipeg.

Impending changes in Lake Winnipeg: discovery of the dreaded zebra mussel (*Dreissena polymorpha*) – M.E. Geisler[1], M.D. Rennie[2] & D. Gillis[1]
[1]University of Manitoba, Biological Sciences; [2]Fisheries and Oceans Canada

An important change observed in many water bodies impacted by zebra mussels is an increase in water clarity. This is due to the high filtration rates of these organisms, which can reach one litre per day per individual. At densities over 100,000 individuals/m^3 the cumulative impact on water clarity can be considerable on the rest of the ecosystem.

This graduate research project looked at the potential impacts of water clarity on walleye habitat and productivity in Manitoba lakes, including Lake Winnipeg. This was being achieved (not yet completed) through the development, use and evaluation of suitable predictive models using pre-invasion Secchi depth and select lake morphometric characteristics, the Thermal-Optical Habitat Area (TOHA) Model, and the Morphoedaphic Index (MOI) Model. Forecasting how invasive dreissenid mussels affect walleye production is particularly important for Lake Winnipeg where walleye comprise the majority of the commercial catch. Ms. Geisler anticipates defending her Master's thesis in the spring of 2015.

Changes in lake whitefish diet, growth and behaviour following dreissenid establishment – M.D. Rennie
Fisheries and Oceans Canada

Guest speaker, Dr. Mike Rennie, presented research related to his graduate and post-doctoral work, as well as some ongoing investigations with collaborators from Trent University. On the Great Lakes, lake whitefish is a valuable commercial species. It was apparent that, coincident with the arrival and establishment of dreissenids, there was a decline in lake whitefish body condition and growth rate in most water bodies. This work looked at potential mechanisms driving these observed declines. In addition, there was a brief discussion on what one might expect for Lake Winnipeg and recommendations on future research.

Based on research in South Bay, Lake Huron, benthic community changes associated with dreissenids included a decline in total abundance at profundal sites, related primarily to declines in *Diporeia*, a key food source for lake whitefish, as well as an increase in the abundance of near-shore benthos. Consequently, there was a corresponding shift in resource use by lake whitefish, with an increase in the reliance on near-shore benthos. There is strong evidence to support that these conclusions apply to other Great Lakes as well, with the exception of Lake Superior. Evidence of benthification - that is, a greater proportion of the energy in the system generated from benthic production in dreissenid-invaded systems than before their arrival - is reflected in patterns observed in stable isotopes in benthos and fish, specifically benthivores.

Based on these findings, anticipated outcomes for Lake Winnipeg might include: an increased reliance on near-shore, benthic productivity; slower growing lake whitefish in poorer condition; and an increased catch of lake whitefish. Recommended steps forward in terms of research to better understand the post-invasion ecosystem response include: isotopic or growth analysis on archived ageing tissues to establish pre-invasion condition of Lake Winnipeg whitefish; expand the provincial fishery-independent index-netting program to include lake whitefish in an effort to estimate population densities and monitor diet composition; and conduct stationary hydroacoustics studies to determine current movement rates of whitefish and monitor over time with expanded establishment of zebra mussels.

Two important points were made regarding the recommendation to expand the provincial index-netting program to include whitefish. First, as Klein had mentioned in his presentation, whitefish data are necessary for eco-certification. Second, in terms of ecosystem indicators, having data on a species that could comprise a considerable proportion of the total fish biomass, regardless of its value as a commercial species, is critical information when attempting to understand an ecosystem, and its response to stressors, including eutrophication and the impacts of invasives like zebra mussels and spiny water flea.

Ecosystem impacts of dreissenid mussels: implications for research and monitoring of Lake Winnipeg – S. N. Higgins
Fisheries and Oceans Canada

With over 700 lake and river systems invaded by dreissenid mussels across North America, there is now considerable information in the form of hundreds of published studies on the ecological impacts of these mussels. This presentation provided an overview synthesis of many of these studies.

Conceptually, it is believed that zebra mussels consume phytoplankton near-shore and produce pseudo-feces, thereby increasing both water clarity and nutrients at the sediment-water interface, respectively. Thus, there is an overall diversion of energy from the pelagic-profundal to the benthic-littoral pathway, and a consequent re-structuring of the food web. In the lower food web, the biomass of most phytoplankton groups (based on chlorophyll or

microscopy) was significantly reduced resulting in overall declines in areal photosynthesis. However, in some eutrophic lakes, improved water clarity led to increased areal productivity. The south basin of Lake Winnipeg could potentially be a candidate for such a response. Moreover, in some systems, such as the western basin of Lake Erie, zebra mussels can promote harmful algal blooms (HABs) through selective grazing of green algae, which gives a competitive advantage to *Microcystis*. Although this is not consistent among lakes, the similarities between Lake Erie and Lake Winnipeg are notable and warrant close monitoring. Other useful indicators to monitor include both phytoplankton and periphyton, as they are the primary source of fixed energy and nutrients for higher trophic levels, and changes here will likely be reflected higher up the food web.

In general, most zooplankton groups were reduced. The response of zoobenthos seems to depend largely on where they are located, in the littoral or profundal zone. In general, the total biomass of benthos in the littoral zone tended to increase, especially among those with larger body sizes, while most profundal zoobenthos tended to experience a decline. Particularly susceptible to declines, regardless of locale, are the freshwater unionids and sphaeriids. The abundance of freshwater mussels has shown declines of about 90% within ten years of a zebra mussel invasion, and could, therefore, represent an important sentinel group to monitor in and around Lake Winnipeg.

Much of the research and monitoring effort on Lake Winnipeg is directed at the pelagic area of the lake; however, the near-shore area is where impacts associated with increased water clarity and nutrient concentrations in other systems have been highest and manifest most quickly. This includes greater benthic algal productivity and increased near-shore macrophyte growth. High bacterial growth has also been associated with this excess near-shore benthic primary productivity, due in part to the protection from UV radiation that they afford to bacteria. As a heterogeneous and high energy environment, near-shore monitoring has its challenges and a combination of approaches was recommended including: instrumented near-shore index stations; transects using the LWRC's new vessel *Fylgja* equipped with flow-through sensors; moorings; and even water intakes. Monitoring should also include both benthic and water column indicators.

The magnitude of the impact of zebra mussels will depend on their densities and the filtration pressure they impose on the ecosystem. The filtration capacity of zebra mussels will be a function of the population and the size of the water body. The substrate to which mussels adhere is an important factor in determining densities – mud and sand tend to support lower densities than harder, rocky substrates. Different substrates pose sampling challenges as distributions can be patchy and difficult to sample. The experience of the Great Lakes in this regard will be invaluable to optimize sampling on Lake Winnipeg. The development of substrate maps, especially in the near-shore areas of Lake Winnipeg, will also be important for estimating total density and spatial variations in density, as well as projecting worst case scenarios for modelling purposes. In addition to substrate type, temperature and anoxia can also affect the variation in density. However, Lake Winnipeg does not have a large hypolimnetic zone, nor does it experience frequent, persistent anoxia.

Another important consideration for Lake Winnipeg is the difference in character between the north and south basins. Indeed, Lake Winnipeg has been described as two lakes, the north and south basins, separated by a river, the narrows. Will Zebra mussels colonize offshore sediments in southern and northern basins? Thus, in addition to inshore-offshore considerations, each of these distinct regions of the lake could respond differently. This includes the narrows as zebra mussels have had dramatic impacts on phytoplankton in river systems (~90% reduction). The narrows would also provide a favorable rocky substrate for colonization.

Science Workshop - Discussion

Among the first indications that Lake Winnipeg was changing were the large algal blooms witnessed by some fishers 15 odd years ago. Since then, the eutrophication of Lake Winnipeg has gained considerable attention, from school children to environmental groups to politicians. Furthermore, the reduction of nutrients, notably phosphorus, has become the main focus of decision-makers and funding agencies tasked with addressing the problem: the assumption presumably being that the desired outcomes (as defined by management) are largely predictable and attainable through such actions.

But is this the case? Can we distinguish between the lake's response to change that is driven by management actions and change driven by other, less predictable, manageable or understood factors, such as climate or invasive species? Is the on-lake Science Program adequate to evaluate the success or failure of management actions undertaken in the watershed? Is there a need to refocus sampling, research or funding priorities to better evaluate remedial outcomes? In an effort to provide a loose framework for the discussion, the following guiding questions were developed by the LWRC's Science Program Coordinator and sent to workshop participants prior to the workshop.

1) Is the current on-lake research and monitoring effort adequate to evaluate the consequences, if any, of remedial land management strategies on lake productivity?

2) Is the current on-lake research, monitoring and modelling effort adequate to detect and predict potential changes in the status of Lake Winnipeg due to zebra mussels? *Bythotrephes*? Other stressors) Should near-shore parameters be considered in the current suite of eutrophication indicators?

3) How can the LWRC further enhance the capacity of its Science Program to facilitate both offshore and near-shore research and monitoring on Lake Winnipeg?

Three important points shaped the discussion. 1) Zebra mussels are in Lake Winnipeg, and, if they are able to thrive, have the potential to fundamentally change the lake ecosystem. 2) Change will first be manifested in the near-shore area of the lake. 3) There is very little littoral/near-shore data and currently no formal near-shore science program. Thus, regardless of the answer to Question 1, the answer to Question 2 is no, the current Science Program is not adequate to detect and predict potential changes in the status of Lake Winnipeg due to zebra mussels. Consequently, the ensuing discussion focused largely on

sampling the near-shore area and how this can be accomplished most efficiently and cost-effectively given the increasingly limited resources, both in terms of funding and personnel, that most agencies are facing, especially the Province of Manitoba. Ideas put forward during the discussion were synthesized and summarized below based on topic.

Re-evaluate the On-lake Sampling Strategy

Currently, 67 stations comprise the LWRC's station network on Lake Winnipeg including two near-shore stations that were introduced in the north basin in 2012. Five stations are quite close to shore or at river mouths, and, therefore, require the use of a workboat for sampling, but the majority of the station network is considered "offshore". Each station is visited three times a year during the spring, summer and fall research surveys, and has been, for the most part, since 2002.

The issue of re-evaluating this station network has been discussed and largely ignored for many years. Indeed, a station optimization study was conducted in 2009 (Beveridge *et al.*, JGLR 2012, v38, p174) but it was limited to water quality and no follow-up was initiated. The reasons for this are numerous. There are diverse research and monitoring interests on the lake and changing the station network may optimize one group's efforts while adversely affecting another. Moreover, some initiatives, such as modelling, require long-term datasets, while others do not. Of course, interruptions to long-term datasets diminish their quality and value. Nevertheless, in light of the arrival of zebra mussels, the immediate need for a near-shore effort and general lack of additional resources, new approaches must be explored if effective science is to be accomplished. It should be noted that the LWRC does not do science, but rather, it *facilitates* science for its member agencies, hence Question 3 above. A synthesis of the suggestions put forth by those member agencies on how to move forward with a re-evaluation of the sampling strategy included:

- Keep the 14 Provincial stations as the offshore index stations;
- Evaluate the remaining offshore stations and re-direct redundancies toward establishing a near-shore station network; and
- Direct more effort to automated instrumentation that samples in between offshore stations. For example, the algal on-line analyzer has had success at estimating chlorophyll and distinguishing algal groups (cyanobacteria, diatoms etc). This point recognizes that some analytical methodology has improved in the last 10 years. Once integrated into the on-lake program, automated instrumentation will not only provide better, more timely data, but could also cut costs associated with lab analyses

The next steps will include forming a sub-group of science representatives to move forward on the above discussion in preparation for the 2014 open water season.

Establish Stronger Academic Partnerships

The establishment of two Research Chairs at the University of Manitoba by the government has certainly aided the watershed research effort in recent years; however, there is no

research chairholder working on the lake itself. Indeed, the academic community is largely absent from the on-lake research effort, with the majority of studies being led by government agencies.

An effective model that was used in the Great Lakes was described and proposed as a possible means to address the absence of academia on Lake Winnipeg. It was an academically driven project, funded through an NSERC strategic grant, with strong federal and provincial partnerships providing important in-kind contributions – a synergistic partnership that allowed for some of the resource-related problems to be overcome. Ultimately, a lot of process-related work in the near-shore was accomplished, which in turn informed modelling efforts.

In the longer term, a more formal, integrated relationship may need to be established with the University of Manitoba to ensure the participation of the academic community, which increasingly is taking over the role of government in conducting research in Canada.

Near-Shore Sampling Program and Near-Shore Indicators

As previously noted, the biggest changes associated with zebra mussels will most likely be seen initially in the near-shore areas of the lake, which is also the area that the public sees and interacts with the most. Thus, in terms of public perception, it may be beneficial to have a near-shore indicator related in some way to changes associated zebra mussels. However, in terms of the science, establishing background data to which changes can be compared is necessarily the priority.

Comments pertaining to the development of a near-shore program are listed below. The Province of Manitoba has an established Science Advisory Committee to inform their zebra mussel sampling program, among other things.

- Substrate mapping – to quantify habitat suitability
- A few index stations at key locations - to begin to characterize the near-shore areas of the lake. For example, the narrows might be an ideal place for them given the hard substrate and high flows
- Consider instrumentation other than point sampling (moorings, current velocity, chlorophyll sensors)
- Limnocorrals in the harbours – to experimentally evaluate the effect of zebra mussels on suspended material, light, primary productivity
- Substrates are likely a more effective and economical means than veliger sampling to evaluate the degree of infestation. Deploying PVC substrates (or another material) with a consistent design in harbours and on buoys around the lake would provide good spatial and temporal coverage as well as an opportunity to engage the public in "citizen science". Another citizen science opportunity is using "Apps" to contribute information on zebra mussel distribution

- Use Macbeth Point and George Island as study sites to capitalize on the diverse habitats (sandy beaches, Precambrian Shield vs limestone) and safe harbours for the *Namao*

On-Lake Research - Open Water Season 2013

The 2013 open water program consisted of three research surveys and the fall Lake Ecology Field Program (LEFP). The spring LEFP was cancelled due to a persistent ice sheet that blocked the *Namao*'s exit from Gimli Harbour.

The spring research survey ran from May 29th to June 17th, the summer survey from July 22nd to August 4th, and the fall survey from September 16th to October 4th. Details of the studies are included in Table 1 below. The fall survey was followed by the LEFP, which ran from October 7th to October 11th. The total number of sailing days for Science and Education were 14, 14 and 22 days for the spring, summer and fall, respectively. In addition, 5.5 days were lost to weather.

The LWRC continues to sample on behalf of an increasing number of agencies that are unable to provide their own on-board personnel to carry out their programs. That sampling included: benthos and zooplankton; pelagic trawls (summer and fall surveys); outflow water chemistry; stable water isotopes (north basin); bulk plankton and forage fish stable isotopes; and the deployment and retrieval of POCIS. In addition, the LWRC deployed and retrieved moorings and assisted in the routine operation of the Seabird since Environment Canada no longer has a dedicated technician on board to oversee its operation.

The *North Basin Near-Shore Sampling Program* continued in 2013 with no additional sites added. The original purpose of this new program was to enable member agencies to commence the characterization of the near-shore environment prior to the arrival of zebra mussels. In its first two years, few agencies took advantage of the opportunity to access the near-shore. Nevertheless, additional sites will be added in 2014 now that zebra mussels have been detected in the lake. As originally described in the LWRC's 2011 Workshop Report, *State of the Science*, and again emphasized in this report, most of the data on Lake Winnipeg describe the pelagic area of the lake. Consequently, knowledge of the near-shore area is lacking. Characterizing the near-shore areas is of value as this is where the predominant effects of zebra mussels will manifest.

Table 1 – Research and Monitoring Activities Conducted off the Motor Vessel *Namao* during the 2013 Open Water Season

Agency	Lead	Project	Spring	Summer	Fall	Details
Conservation & Water Stewardship	Lumb & Heuring	Lakewide offshore trawl surveys for status and trend monitoring of pelagic fish		X	X	LWRC sampled on behalf of MB. Reduced network in the fall (21 stations - 2, 36S, 6, 60, W9/10A, W11, 12B, 49S, 53, 68, W8, 18, 21, 28, 34S, 39, 45, 64, 65, W5, W7)
	Watchorn	Long-term water quality monitoring of Lake Winnipeg	X	X	X	**All lake stations** - nutrients, chlorophyll a, other routine chemical parameters*, vertical depth profile measurements of light, temperature, dissolved oxygen, turbidity, and conductivity. **14 long-term stations** - 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). Microcystin-LR and cyanobacterial cell counts where nuisance algae blooms occur.
	Janusz	*Bythotrephes* monitoring		X	X	Two vertical zooplankton hauls to be taken at each station - 76 µm mesh size - composited. Samples taken starting two metres off the lake bottom.
University of MB	Hann	Zoobenthos	X	X	X	One sample per site - 65 sites - 200 micron mesh; LWRC sampled in absence of student
	Hann	Zooplankton community	X	X	X	Vertical haul; LWRC sampled in absence of student; 30 stations along N/S transect
	Fetterly & Hann	Response of zooplankton (primarily *Daphnia*) to a changing diet in the summer		X		Sampling zooplankton and phytoplankton at the 30 zoop sampling stations on the lake. Zoop samples - densities of major zoop taxa to be determined and compared with values form other years with high cyanobacteria biomass. Gut contents of zooplankton to be determined.
	Stadnyk	Development of a Stable Water Isotope ($\delta^{18}O$ and $\delta^{2}H$)	X	X	X	LWRC to sample - stations 22, 23B, Warren's Landing and Two-Mile Channel OF. Water samples are being analyzed

Agency	Lead	Project	Spring	Summer	Fall	Details
		Monitoring Network (SWIMN) in the Nelson River Basin. Examining changes in isotopic signature with lake turn-over over open-water season				for stable water isotopes ($\delta^{18}O$ and $\delta^{2}H$). Stations 22, 23B - profiles at 3-4 m intervals. Warren's Landing - composite sample and Two-Mile Channel outflow composite. We are looking for changes in isotopic signature with lake turn-over, so ideally we would like to capture spring, summer and fall conditions to capture any seasonal evolution.
	McCullough	Sediment incubations to determine the extent of phosphorus release from sediments		X		On-board until end of survey
UM; University of Winnipeg	Hanson & Wong	Characterize a suite of 11 algal toxins in the surface waters		X	X	Toxins - microcystin-LR, -RR, -YR, -WR, -LA, -LY, -LW, and –LF, as well as anatoxin-a. POCIS deployed and retrieved at weather buoys by LWRC
Environment Canada	Yerubandi	Physical lake model - assessment of hydrodynamics and model-based nutrient status	X		X	LWRC to deploy & retrieve moorings
	Bibeault	Water quality monitoring;	X	X	X	Vertical depth profiles taken on the downcast - temperature pH, DO, %sat DO, turbidity, conductivity & PAR – all stations Prov WQ/LWRC sampled
	Watson, Guo, Davis, Chiu	Sediment, lower food web, microbial genetics.	X	X	X	Fluoroprobe profiles, nutrients, suspended sediment and DNA. Possible collection of surficial sediment at each station.
	Hobson & Koehler	Stable isotope analyses - forage fish, bulk plankton		X		LWRC to run trawl & sample bulk plankton. Summer - bulk plankton & forage fish community (15 x each species) - central north (Stn W1) and south (Stn W12) basins plus river mouths (RR, WR, SR).
	Binding	Validation of satellite methods for remote sensing of algal blooms on Lake Winnipeg	X	X		Profiling spectro-optical instrumentation to measure *in situ* optical properties and coincident WQ information to validate and further develop methods for satellite detection of algal blooms. Two profilers - an AC9 (winch deployment) and a free-falling Satlantic radiometer (deployed by hand)

Agency	Lead	Project	Spring	Summer	Fall	Details
	Guo & Watson	Origination of suspended sediments (Be:Pb isotopes)	X			Suspended sediment via bag filtration while in transit; cores at most stations
EC; Algal Taxonomy & Ecology Inc.	Watson & Kling	Pico/bacterio-plankton, phytoplankton	X	X	X	Net haul (10 um) - 14 long-term stations + blooms - live with subsample preserved. Surface water (0 to 0.5 m) all stns (biomass & composition) - preserved.
EC; Fisheries & Oceans Canada; UM	Watson, McCullough & Stainton	In lake nutrient processing & trophic indicators.	X	X	X	NB buoy (chlorophyll, phycocyanin); on board (chl, C-DOM, algal groups); TP, part P, DOP, SRP, ammonium, NO23, TKN, part N, fluroprobe, phycocyanin, chlorophyll, turbidity
DFO	Stainton	Carbon metabolism study Install and operate equipment that automatically measures Net Primary Production and Respiration at 60 to 120 minute intervals along the ships track.		X	X	Surface Sample from CTD/Rosette, filtration for particulates (C,N,P, Chl) and filtrate. In transit, instruments monitor, R, Net PP, pCO2, O2, Conductivity, GPS, Total Chlorophyll, Algal Group Chlorophyll, %T, CDOM and T. Ship at anchor for a 24-hour period; measurements at hourly intervals with use of CDT
MB Hydro	Chaze	Same chemistry as Province	X	X	X	Warren's Landing only – LWRC/Prov to sample
Near-shore	Watchorn, Lumb, Kling	Characterize near-shore NB Two new sites: near George Island (east) and near station 43S (west).			X	Seining (Fisheries Branch); nutrients, chl, turbidity, DO, conductivity, temperature PAR (Prov WQ); phyto & periphyton (AT&E Inc.)

Science Program Acquisitions

The LWRC's Science Program acquired a number of pieces of new equipment to further enhance its capacity to facilitate science on Lake Winnipeg for its member agencies. This equipment includes: a dead-weight towing vehicle with 2 kHz standard calibration sphere to facilitate hydroacoustic studies; Biosonics Visual Analyzer and Habitat processing software; an aluminum crankup tower; a sample storage fridge; and four marine radios. The Science Program also contributed toward the development of an on-board, in-line incubator.

In 2013, the LWRC received a new vessel, the *Fylgja* ("Guardian Angel"), as a charitable donation from Barbara and Jens Nielsen (Appendix C). This vessel will be particularly well-suited for near-shore work and, once re-fitted for research purposes, will serve as a valuable complement to the M.V. *Namao*'s offshore capabilities. The acquisition of the *Fylgja* is timely since it coincides with the arrival of zebra mussels, an aquatic invasive species that will have the most profound impacts in the near-shore area of the lake.

The LWRC's Board of Directors established the following preliminary Terms of Use for the 2014 open water season, if the requisite upgrades are completed. The Board will review and refine the Terms of Use following input from potential user groups.

- The *Fylgja* will be offered to potential users at an initial *per diem* rate of $250 per berth based on four berths over a 30 day season
- The *per diem* is inclusive - Captain and deckhand, safety equipment, zodiac, food, fuel, bedding
- Anticipated fundraising revenues and extra revenues generated from bookings beyond the 30 days will be used to reduce the $250 per diem charge
- Operations will take place between the spring, summer and fall pelagic surveys conducted off the M.V. *Namao,* and possibly between the completion of the *Namao*'s fall Programs (Science & Education) and retrieval of the weather buoys

Honours and Graduate Student Scholarship

As part of its Science and Education programming, the LWRC created an *Honours and Graduate Student Scholarship* in 2011/12 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 (MGEU) allowed the establishment of the fund, and subsequent smaller contributions were made.

Marianne Geisler, University of Manitoba, was the 2013/14 LWRC Scholarship recipient for her project entitled "*Forecasting the potential effects of invasive dreissenid mussels on habitat occupancy & production of walleye (Sander vitreus) in Manitoban & northwestern Ontarian lakes*". This research involves the development of a thermal-optical model to predict the potential effects of dreissenid mussels, including the zebra mussel, on walleye. Zebra mussels have a very high filtration capacity, which may lead to greater water clarity and light penetration into the water column. These conditions could in turn result in decreased walleye habitat and lower

productivity. Given the very recent arrival of zebra mussels in Lake Winnipeg, Marianne's work is particularly timely and relevant to both the commercial and recreational walleye fishery. Marianne received a $2,500 Scholarship from the LWRC to help cover costs associated with attending a conference to present her research findings.

EDUCATION PROGRAM

The LWRC's Education Program has two main components, the *Lake Ecology Field Program* (LEFP) and the development of *Web-Based, Mixed Media Resources*, both of which are aimed primarily at public and high school teachers and their students. The overall goal of the Education Program is to contribute to greater environmental literacy through the study of Lake Winnipeg. Below is a summary of the activities that took place in the 2013/2014 fiscal year.

Lake Ecology Field Program

The LEFP has evolved from an 'education component' of the Science Program, whereby students simply came aboard the research vessel M.V. *Namao* and watched scientists at work, to a stand-alone program with dedicated ship time for schools. The LEFP is a unique program that provides students with the opportunity for field-based, hands-on learning about aquatic ecosystems.

The LEFP takes place on board the M.V. *Namao* in the south basin of Lake Winnipeg, and is aimed primarily at grades 8 to 12 students. All field trips are preceded by the compulsory viewing of a number of on-line presentations, which aim to provide an overview of the lake and research, link the field trip to in-class activities, and put the issues facing Lake Winnipeg into a global context. In addition, one of the on-line presentations discusses ways in which students can reduce their impact on water with decisions they make on a daily basis. Students are also given a pre-trip reading assignment that is intended to reinforce some of the new concepts and issues that were introduced during the overview presentations.

Programming on board M.V. *Namao* focuses on the sampling and analyses of various components of the lake ecosystem (water, bacteria, plankton, benthos) using a variety of field and analytical equipment. In addition, students have the opportunity to discover the microscopic and macroscopic world of a lake using microscopes and taxonomic keys, and are encouraged to record observations using technical drawings and accurate and detailed field notes. Near the end of the field trip, students record their newly acquired skills, knowledge, and results on video to take back to their schools as a resource for other initiatives that will extend their experiences and new knowledge about water beyond the ship and into the community.

The LEFP integrates extremely well with the Provincial science curriculum including the Grade 8 Water Systems unit, Grade 10 Science, and advanced Grades 11 and 12 courses, such as Aquatic Sciences, Environmental Sciences, Advanced Placement Biology, and Conservation of Biodiversity. Interestingly, teachers of other subjects, such as Math and Social Studies, are using the LEFP to support their teaching outcomes as well. In addition to complimenting the Provincial curriculum, the LEFP supports a number of recommendations as advocated by the Lake Winnipeg Stewardship Board. These include Recommendations 1.1 through 1.5, 1.9, and 2.1 through 2.5.

In 2013, the spring LEFP was cancelled due to a persistent ice-sheet in Gimli Harbour that prevented the M.V. *Namao* from leaving harbour. Interestingly, the rest of the south basin was ice-free. The fall Program ran as scheduled following the fall research survey. Appendix D includes a summary of participating schools and how the LEFP contributes to their curricular outcomes. Schools participating in the LEFP were also engaged in other meaningful activities that promoted water stewardship, often beyond the classroom and into the larger community. As an inspiration to other teachers, some of those activities are included in Appendix E.

Web-Based, Mixed Media Resources and Special Projects

The development of Lake Winnipeg web-based, mixed-media resources for schools is an on-going initiative aimed at providing accurate, up-to-date science-based resources to schools, that also support existing Provincial curricula. Although targeted at schools, resources are suitable for a wide range of audiences, including the general public and special interest groups.

YouTube Videos - Currently, there are five videos on-line that explore the watershed, lake ecosystem, common Lake Winnipeg descriptors, what you can do, and the LEFP. These resources are not in the public domain and their use is limited to the LEFP and special interest group requests. Students from the Manitoba School for the Deaf worked on an in-class project to add closed captioning to some of the LWRC's on-line resources. Their initiative will help promote scientific study in the deaf community.

LWRC Image Library and Satellite Blog - Within the public domain, the LWRC website continues to be the primary repository for both the Science and Education Programs. The most recent addition is an image library and blog that can be found at www.lakewinipegresearch.org/blog. This image library contains the satellite image archive from 2003 to present, photomicrographs of different species of phytoplankton and zooplankton, as well as student art derived from the LEFP and Special Projects. In addition, there is a 'satellite blog' to which one can subscribe to receive updates on new satellite imagery postings.

Science Teachers Association of Manitoba - An ongoing collaboration continues with the LWRC's Education Coordinator, Dr. Karen Scott, and Grade 10 teacher Cheryl Boguski, the lead person who developed the Grade 8 Lake Winnipeg unit for Manitoba Education. In an effort to encourage teachers to adopt this new unit in their classrooms, Scott and Boguski have united to present annually at the Science Teachers Association of Manitoba. Scott focuses on the ecology of Lake Winnipeg and hands-on learning opportunities with the LEFP, while Boguski reviews some of the resources she has developed. In addition, a booth was manned to provide teachers who were not able to attend the presentation with information pertaining to the LEFP and Lake Winnipeg, including resources on zebra mussels, the latest invasive species to enter the lake.

Manitoba Schools Science Symposium (MSSS) - On an annual basis, the Save Our lake (SOUL) group from the Grindstone Cottage Owners' Association (an LWRC member) offers a Lake Winnipeg award valued at $300 at the MSSS event. In addition to the financial award, the LWRC offers a trip on the M.V. *Namao* during one of the scientific research cruises to each recipient of the prize. This award provides a very unique opportunity for individual students to experience real fieldwork and research, for which they have already demonstrated an interest and ability through their MSSS science projects. The 2013 recipients were a team from Ecole River Heights, Wynonna and Alexandra, for their project entitled "How do chemicals affect the growth of algae?"

Non-curriculum linked activities included participation in the Blue Flag Beaches Workshop (Grand Beach), the Fisher River Watershed Planning Workshop (Fisher River) and Federal-Provincial Eutrophication Indicators Workshop (Winnipeg), as well as presentations to Manitoba Parks staff (Camp Morton), the First Nations and Inuit Health Branch Water Monitors, Manitoba Government and General Employees' Union (Health and Safety) and the Social Justice League.

Future programming of the LWRC's Education Program will depend on the success of fund-raising initiatives by the LWRC's Board of Directors to support the Program. Although considered a unique learning opportunity, it is recognized that the LEFP is limited in its ability to reach a large number of students. For this reason, the development of a 2-day "Teachers' Workshop" on board the M.V. *Namao* is being considered. This workshop would be offered during the summer and would aim to provide teachers with first-hand experience and accurate resources to confidently introduce Lake Winnipeg into their classrooms.

APPENDICES

Appendix A. Science Workshop participants and affiliations

Name	Agency
Ali, Genevieve	University of Manitoba
Armstrong, Nicole	Manitoba Conservation & Water Stewardship
Chaze, Ainslie	Manitoba Hydro
Clarke, Heather	Manitoba Conservation & Water Stewardship - Fisheries
Farmer, Kristina	Environment Canada, Winnipeg
Geisler, Marianne	University of Manitoba
Gillis, Darren	University of Manitoba
Greenberg, Tracie	Environment Canada, Burlington
Gurney, Sharon	Manitoba Conservation & Water Stewardship
Hann, Brenda	University of Manitoba
Herbert, Claire	University of Manitoba
Hesslein, Ray	Independent
Higgins, Scott	Fisheries and Oceans Canada
Janusz, Laureen	Manitoba Conservation & Water Stewardship - Fisheries
Kline, Geoff	Manitoba Conservation & Water Stewardship - Fisheries
Kling, Hedy	Algal Taxonomy and Ecology, Inc.
Koehler, Geoff	Environment Canada, Saskatoon
Kumaragamage, Darshani	University of Winnipeg
Kristofferson, Al	Lake Winnipeg Research Consortium Inc.
Long, Jeff	Manitoba Conservation & Water Stewardship - Fisheries
McCullough, Greg	University of Manitoba
Page, Elaine	Manitoba Water Stewardship
Parker, Brian	Manitoba Conservation & Water Stewardship - Fisheries
Rennie, Mike	Fisheries and Oceans Canada
Rutherford, Les	Environment Canada, Winnipeg
Scott, Karen	Lake Winnipeg Research Consortium Inc.
Shead, Justin	Manitoba Conservation & Water Stewardship
Smith, Aaron	University of Manitoba
Stadnyk, Tricia	University of Manitoba
Stainton, Mike	Fisheries and Oceans Canada
Swanson, Gary	Manitoba Hydro
Tipples, Mo	Lake Winnipeg Research Consortium Inc. (Board Member)
Watchorn, Elise	Manitoba Conservation & Water Stewardship
Watson, Sue	Environment Canada, Burlington
Yerubandi, Ram	Environment Canada, Burlington

Appendix B. Science Workshop Agenda

FINAL AGENDA
Lake Winnipeg Research Consortium
Annual Science Workshop
February 18th and 19th, 2014

Siobhan Richardson Field Station, Fort Whyte Centre
1961 McCreary Road, Winnipeg

General Schedule

Wake up (coffee, tea, snacks etc provided on site)	8:00 AM to 8:30 AM
Morning Presentations	8:30 AM to ~Noon
Lunch (provided on site)	~Noon to 1:00 PM
Afternoon Day 1	1:00 to ~4:30 PM
Afternoon Day 2	1:00 to ~3:00 PM

– DAY 1 –

Intro & Welcome – K.J. Scott

Big Picture Updates

- State of Lake Winnipeg: update – E. Page[1]
- Update on integrated modelling – R. Yerubandi[2] (Burlington)
- Lake Winnipeg Basin Initiative Information Portal – C. Herbert[3]

Watershed / Rivers

- Phosphorus release from flooded soils – G. Amarawansha[4], D. Kumaragamage[4] & D. Flaten[3]
- From the watershed to the lake: do we know enough about runoff travel pathways and travel times? – G. Ali[3], H. Petzold[3], A. Penner[3], C. Ross[3], S. Randall[3] & D. Lobb[3]
- Stable isotopic compositions of nitrate and sulfate in the Assiniboine and Red River watersheds (mini) – G. Koehler[2] (Saskatoon)
- Nelson River Stable Water Isotope Monitoring Network (SWIMN): update (mini) – T. Stadnyk[3], A. Smith[3] & A. Wall[3]
- Sediment influx and re-suspension in Lake Winnipeg – S. Watson[2], G. Matisoff[2] & J. Guo[2] (Burlington)

Lunch
Food Web

- Stock status update – G. Klein[1]

- Walleye landings and phosphorus (mini) – G. Kline[1]
- Patterns in benthos in Lake Winnipeg – B.J. Hann[3], M. Wishart[3] & S. Watson[2]
- Response of zooplankton to changing diet in the summer – M. Fetterly[3] & B.J. Hann[3]
- Lake Winnipeg phytoplankton (summary 2014) – H. Kling[5], S. Watson[2], B. Parker[1], G. McCullough[3], C. Herbert[3], M. Stainton[6] & E. Watchorn[1]
- Molecular diversity of HNAB-forming and potential microcystin-producing phytoplankton in Lake Winnipeg (mini) – T. Davis[2] & S. Watson[2]
- Photosynthetron 2.0: monitoring Lake Winnipeg photosynthesis and respiration – S. N. Higgins[6], M. Holoka[6], S. Page[6], M.P. Stainton[6] & S. Watson[2]

– DAY 2 –

Indicators and Zebra Mussels

- Eutrophication-related indicators review: Lake Winnipeg and its watershed: – Kristina Farmer[2] (Winnipeg)
- Provincial strategy for the zebra mussel in Lake Winnipeg – L. Janusz[1]
- Impending changes in Lake Winnipeg: discovery of the dreaded zebra mussel (*Dreissena polymorpha*) – M.E. Geisler[3], M.D. Rennie[6] & D. Gillis[3]
- Potential effects of zebra mussels on lake whitefish diet and growth – M.D. Rennie[6]
- Ecosystem impacts of dreissenid mussels: implications for research and monitoring of Lake Winnipeg – S. N. Higgins[6]
- LWRC Science Program Updates – K.J. Scott[7]

Lunch
Discussion – Guiding Questions

- Is the current on-lake research and monitoring effort adequate to evaluate the consequences, if any, of remedial land management strategies on lake productivity?
- Is the current on-lake research, monitoring and modelling effort adequate to detect and predict potential changes in the status of Lake Winnipeg due to zebra mussels? (*Bythotrephes*? Other stressors?) Should near-shore parameters be considered in the current suite of eutrophication indicators?
- How can the LWRC further enhance the capacity of its Science Program to facilitate both offshore and near-shore research and monitoring on Lake Winnipeg?

Affiliations: [1]MB Conservation and Water Stewardship; [2]Water Science & Technology Directorate, Environment Canada (various locations); [3] University of Manitoba; [4]University of Winnipeg; [5]Algal Taxonomy and Ecology Inc.; [6]Fisheries and Oceans Canada; [7]Lake Winnipeg Research Consortium Inc.

Appendix C. Specifications for the *Fylgja*

The *Fylga* ("Guardian Angel")

- 42' length overall
- 12' beam
- 3.5' draft
- Steel hull & cabin
- Aluminum wheelhouse
- Detroit diesel motor (3 cylinder, 53 cu. In.)
- Horsepower
    - 73 Continuous Shaft hp (at 2400 rpm)
    - 92 Rated Shaft hp (at 2800 rpm)
    - 101 Rated Brake hp (at 2800 rpm)
- Cruising speed 8 knots
- S-L 555 windlass & chain (manual)
- No winch but could be installed
- 150 L fresh water tank
- Sleeps six

Appendix D. Lake Ecology Field Program (2013) (successful applicants) and curriculum linkages

School	Grade & Subject	Curriculum Link
Fort Richmond Collegiate, Winnipeg	10 – 12 Extra-curricular	The Lake Ecology Field Program will contribute to both the grade 10 Science and the Biology 40S teaching outcomes. Grade 10 - ecosystems, food chains/webs, population studies and limiting factors, and invasive species are all concepts that are covered in the course and can be related to the Lake Winnipeg ecosystem. Biology 40S - the diversity of living things is a large component of the course that can be related to the organisms living in or around the lake. Participating in the Lake Winnipeg ecology field program would both reinforce and expand on the water systems ecology knowledge FRC students have received through their Kelburn training. In turn they will be able to pass on their knowledge and enthusiasm for the environment to the visiting elementary and junior high students with whom they work. Kelburn pothole lakes link up and feed into the Red River, which flows into Lake Winnipeg. The Lake Winnipeg field study program will reinforce the connection between the two water bodies and promote introspection of how the activities on or around the pot hole lakes may affect Lake Winnipeg and ultimately may encourage FRC students to consider pursuing research in this area.
St. George School, Winnipeg	7/8 Science, Math, Social Studies, ELA	As the core of this project is to provide a community of learners, authentic science based learning opportunities that allow them to develop first-hand scientific and technological habits, as well as to have them utilize this information to communicate their findings to both their community and peers, it is our intention to utilize this experience with the Lake Ecology Field Program to underscore our learning as we study the Manitoba water system within the context of Lake Manitoba Water Stewardship curriculum resource. The Lake Ecology Field Program will thus ultimately allow us to consider not only where our water goes, but will provide the societal context for the need for ongoing water-related research. The Lake Ecology Field Program experience will also act as a significant stepping stone in terms of moving our project forward as it will provide context to the understanding that students must not only be ready to understand the socio-cultural, environmental and economic factors facing the world and province they live in, but must also be prepared to provide potential solutions to these challenges.
Mennonite Brethren Collegiate Institute	8 Science	Part of the grade eight science curriculum is water systems. The lake ecology field program will enhance our study of water systems in Manitoba and how we are affected by them.
Manitoba School for the Deaf, Winnipeg	11 Current Topics in Science	We are doing water sampling to learn about microhabitats. We are also doing CoCoRaHS to record daily precipitation - report as part of the Floodwatch Program.
7 Oaks Met School, Winnipeg	9 & 10 Science & Geography	We are exploring different types of eco-systems. Students are also working on their scientific method skills, and this experience would expose them to proper sampling, using a microscope, fieldwork, and how to analyze experiments/samples/results. Seeing and hearing about Lake Winnipeg's Ecology through hands-on learning is extremely important because our school is about holistic hands-on and relevant to the real world learning.

School	Grade & Subject	Curriculum Link
Gimli High School, Gimli	11/12 ITS 40S; Current Topics in Sciences 30S	The hands-on opportunity afforded by this program is outstanding. Being able to see what scientists do makes it real. It is exactly the kind of education needed to encourage sustainability-focused mindsets in students! The ITS course focuses upon LW and world water issues. The CTS course focuses upon ecology. This is an excellent opportunity to engage students in real lake science. This program addresses significant areas of content for this course and is applicable to other course outcomes, such as Science 20S and Bio 40S.
St. John's-Ravenscourt School, Winnipeg	12 Global Issues	This experience will provide students the opportunity to fully understand how all systems are connected via issues associated with drainage basins. They will identify how their actions and inaction contribute essentially, to the death of an ecosystem. Furthermore, they will realize that solutions to these issues are multi-dimensional, where a variety of skills and bodies of knowledge are required. My hope is that students will be inspired, through the development of a new ecological literacy, to take political action.
Long Plain School, Portage la Prairie	5 – 9 Environmental Reduction Impact Program	This program will provide students with a wider range of how mans' influence on the environment is affecting the earth, specifically the water supply as well as fish environment. This in turn should translate reasons to protect the Assiniboine River, which runs through Long Plain First Nation, and the effect contamination has on the food supply. By being able to participate in this program, the students will get a much better idea of what is happening to the large lakes being fed by the surrounding streams and rivers that drain into these water basins.
Sterling North Stonewall Campus	10 Science	The study of ecosystems and eutrophicaiotn of lakes. Importance and value of reducing waste products. Allow students a hands-on experience that allows them to see what scientists do. Our school has gone in the past. Students have always felt that it is one of the best field trips they've ever had. My current grade 10s are anxious to experience the oppportunity.
Springfield Collegiate	11 & 12 Marine Science	It will provide the "hands on" portion to the theory we will be learning in class. For example, we will be looking at various methods of water sampling in the class, then on the ship we will actually do them.
Concordia University, Minnesota	4th year Limnology	By driving through the landscape from Moorhead to Lake Winnipeg, they see the changes in the landscape and can begin to understand how alterations can impact the entire watershed. By being able to collect the data on Lake Winnipeg themselves, they will be able to observe differences and similarities that exist in regional water quality parameters. Reading about phosphorus pollution helps students understand the basic chemistry behind an algae bloom. Seeing the blooms and hearing stories from individuals helps students make the connection between what nutrient pollution means to a community, it helps them to understand how pollution impacts the environment and economy of a region.
Woodlands School	8 Science and ELA	The Lake Ecology Field Program will bring to life the ideas we have been studying in class. If the students see that there are researchers studying water quality, they will see that it is indeed something of importance. It will also expose students to different career opportunities where they can use science. We will also have the opportunity to compare water clarity, and benthos of Lake Winnipeg to Lake Manitoba and Shoal Lake. Students will use their findings as part of their Power Point Presentations that they share with their community.

Appendix E. School water stewardship activities

- The members of the extra-curricular Kelburn Farms wetlands group act as leaders during field trips to the divisional wetlands site, Kelburn Farm. Students develop and facilitate activities that introduce elementary and Junior High students to wetlands ecology (invertebrate sampling and identification, as well as water and soil testing). Prior to volunteering at Kelburn Farms, the High School students participate in training sessions that prepare them for their leadership roles.
- Grade 7 and 8 students currently monitor and conduct water quality testing of the local Seine River as part of a collaboration with the local Save Our Seine River Environment Inc. and the national water monitoring action group G3E as part of their Adopt-a-River initiative. The goal of the Adopt a River programming is to involve youth and the community in working for water, and involves having students take part in monitoring, observing and conserving aquatic ecosystems. A major component of this programming is to have students "take action"; that is, once a diagnosis of the river's health has been made, students are to come up with actions that can help improve conditions in the ecosystem. During our time at the river, students continually made note of how much garbage there was on the shoreline. As a result, students partnered with the Save Our Seine's Green Team and led a group in charge of cleaning a section of the Seine River during the "Great Canadian Shoreline Cleanup". This is a conservation initiative of Vancouver Aquarium and World Wildlife Fund and is one of the largest contributors to the International Coastal Cleanup. Students not only ran and completed the cleanup, but collected data on the type of debris for submission to Vancouver Aquarium where it is further tallied and submitted to the International Coastal Cleanup for tracking of worldwide results. Based on our results of collecting 319 shopping bags, the students are also planning to take part in Bag Up Manitoba - Plastic Bag Roundup Challenge, a program of Take Pride Winnipeg!
- Students have a number of relevant projects planned and in progress, including a water day event with early years students in late May, and a water activity day for senior students which is being set up this semester to run in October 2013. We will do water sampling and assessments in some local areas. Some of our students have been working towards providing a composting toilet for a northern/remote community where water infrastructure is lacking. Others are working towards informing members of our broader community about their concerns and want to provide positive, doable ideas for individuals, families and groups about how we can care for LW and water in general.
- Some of our students will be attending an Earth Day Environmental Conference for Youth in Costa Rica in April in order to broaden their understanding of what water and watersheds mean to others. As a result of this conference, our plan is to make connections that can facilitate local and global projects and co-operation.
- Our class is learning about water filtration and participated in a water filtration activity through Engineers Without Borders. We are relating the water filtration activity with a geography aspect - looking at how land, economy and society affect water quality. We also had a guide from the Fort Whyte center come and show us some water testing methods with retention pond water and Red River water. In addition, we have students that are involved in raising money for clean water in developing countries – this opportunity would allow them to see the importance of water quality. Other students are

raising money for wells for water through the "walk 4 water" foundation. In previous years, they have done this through awareness campaigns and one of the reasons they want to do the LEFP is so that they can relate it to their peers on how important water is. One of the initiatives that they are raising money for is through "Free the Children" foundation, their initiative this yr is "water for a year".

- We have just started the Water Systems unit. As part of our unit we will be studying the differences between water sources and wastewater disposal in Winnipeg compared to rural communities in the Interlake. Students will inquire about their home water systems (where their water comes from, and where it goes after it is used). We will be testing water and benthos from several local sources including Lake Manitoba, Shoal Lake and local dugouts, for clarity, pH, and nitrogen levels. Students will create a water cycle model, and also design and create a water filtering device.
- In ELA we will be reading about water issues around the world including Lake Winnipeg. We will be viewing and responding to The Nature of Things 'Save My Lake' video. I have invited a local Aboriginal student group from Teulon Collegiate to come in to do a presentation about water issues on First Nations reserves. Following the presentation, students will make a Power Point Presentation about water issues in the world with an emphasis on how they can help. They will show this Power Point to the other classes at school, and also to parents during student led conferences in hopes that the community will become more aware of the impact we can have on our water systems.
- In my class we do a unit on water quality. In this unit we will perform several activities to discover what water quality is such as: Diversity Stream Study (Environmental Impact Simulation) – where students study a simulation of a cattle farm's effects on a river based on the changes in aquatic invertebrates found at 3 sampling sites.They will learn how to use the Simpson' Diversity Indices and write an Environmental Impact Assessment; Chemistry lab testing amount of Dissolved Oxygen in water samples; Oak Hammock Marsh to do their Wetland Ecology program; LEFP on the *Namao* will give the students the 'real' version of how to sample water and look for indicators of water quality and it will help them put information they have learned into practical use. At the end of the year, the students have a practical exam where they teach the grade 5 students in the surrounding communities about water and the ocean – Ocean Fest.
- As part of this course, students learn about river ecology and lake ecology. Students perform a water quality assessment of a local lake, which they present to the regional Lake Association or Department of Natural Resources. The trip to the city of Winnipeg and Lake Winnipeg is part of a two day field trip, where we learn about water quality issues of the Red River of the North and consider how the land use surrounding the Fargo-Moorhead area ultimately impact the downstream waters. As part of this trip, we study the ecology of the region at Oak Hammock Marsh, take a tour of water control structures in and around the city of Lake Winnipeg, see how the health and water quality of Lake Winnipeg is assessed by many agencies, discuss water quality changes in Lake Winnipeg with area scientists and get the hands-on experience of collecting water quality data themselves. We compare these differences to regional lakes.
- Students participate in two service-learning activities throughout the semester, including creating and presenting the water quality assessment of a local lake and volunteering at the RiverKeepers Water Festival - a resource that impacts approximately 1600 4th grade

students from around the region. This trip helps students make the global-local connection, to understand how complex water management can be, particularly when looking at an international water body.

- This year a group of students have been studying the effects of pollution and improper disposing of trash is having on the environment. Within the program, the students are also learning of the responsibility First Nations groups have on protecting Mother Earth. This includes understanding that pollution affects water supplies which ultimately affect plant growth and animals that rely upon the water, sun etc. They have created a video which has been shown to their classmates, peers, and community members. It has also been provided to AANDC who funded this learning experience for them. This project has led the students to neighbouring communities such as Portage la Prairie and Winnipeg where they have learned of issues that are not only affecting the rural areas but urban centres as well. A video was created and is being shared with other groups, which include school and government on the need to dispose of materials in environmentally friendly ways and the need to not litter and pollute. This in turn is leading to students and community members making their recycling bins for the community.
- As part of our course, students have been tasked with completing a Praxis, or action, project. Through this inquiry process, many students within our group have chosen to do research based on fresh water issues associated with wetlands, ELA and Lake Winnipeg. Our focus has been on establishing an understanding of systems thinking so that we can improve our ecological literacy. Through our weekly seminars and project work, our primary motivation has been to see how we are all connected to the biosphere and each other. Most of the activities we do are in the public sphere. Our latest assignment, dealing with the concept of the Good Life, can be viewed via our bog by the entire world: http://hendersonsjr.blogspot.com. I believe that authenticity provides a natural rigour to the learning process. Based on this, not only do our Praxis projects aim to provide real solutions to immediate dilemmas, but there is an understanding that what we do in class is more important than marks