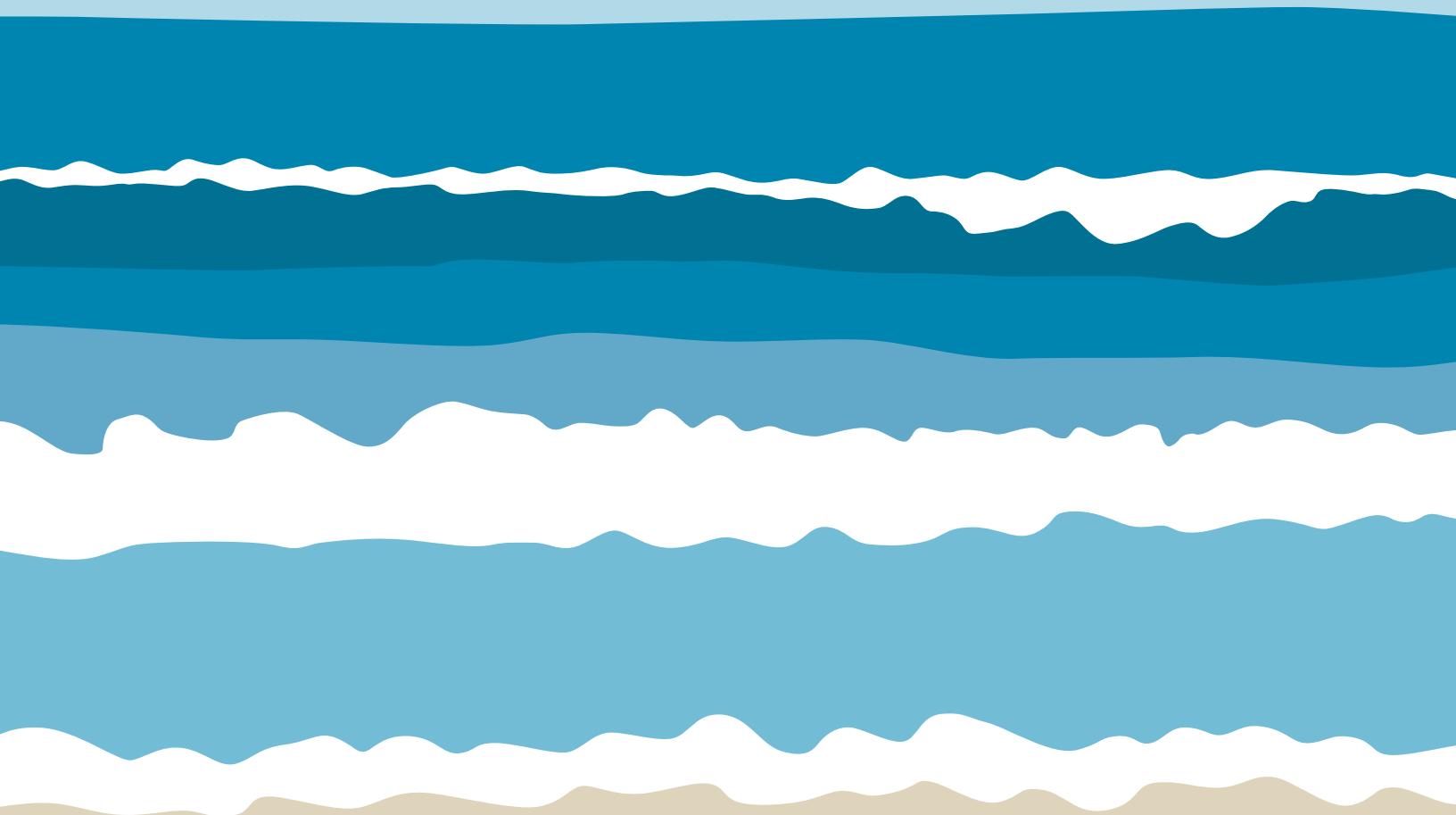
2020

Focusing on the Future



IAGLR

International Association for Great Lakes Research

63rd Annual Conference on Great Lakes Research • Online

ABSTRACTS

63rd Annual Conference on Great Lakes Research

June 9–11, 2020

International Association for Great Lakes Research
4840 South State Road
Ann Arbor, Michigan 48108
iaglr.org

Cover design and conference logo by Jenifer Thomas

SESSIONS

ABSTRACTS

A listing of abstracts presented online at the 63rd Annual Conference on Great Lakes Research (IAGLR 2020 Virtual), grouped by session and organized alphabetically by first author. Presenters are underlined.

1. Linking soil biogeochemical processes with nutrient export into waterways

A. ALAMANOS, University of Waterloo, WATER Institute; R. BROUWER, University of Waterloo, Water Institute. **The cost-effectiveness of wetlands as a nature-based solution to reduce phosphorous runoff.**

Wetlands provide valuable ecosystem services. However, many wetlands have been destroyed or are degraded due to land use intensification. Recently, wetlands are increasingly considered a low-cost nature-based solution to solve water challenges like eutrophication. We review almost 4 decades of literature focusing on the role of wetlands to reduce nutrient runoff. Almost 60 studies are identified that assess the cost and effectiveness of different types of wetlands across Canada to reduce phosphorous runoff into surface and groundwater. Regression models are estimated to identify key driving forces behind the observed variation in the cost-effectiveness of wetlands to retain phosphorous and prevent their runoff. Drivers include wetland type, size, and geographical location. The results from this meta-analysis provide policymakers with important insights in support of future wetlands conservation and restoration as a cost-effective nature-based solution for sustainable watershed management.

C.A. ARNILLAS, C. YANG, S. ZAMARIA, A. NEUMANN, A. JAVED, D. PAREDES, Y. SHIMODA, University of Toronto Scarborough, Department of Physical and Environmental Science; B. BASS, Environment and Climate Change Canada, Great Lakes Issue Management and Reporting Section; G. ARHONDITSIS, University of Toronto Scarborough, Department of Physical and Environmental Science. **Surfing or drifting on uncertainty? Or how to build BMP decision making tools on sand.**

Agricultural and urban Best Management Practices (BMPs) have been proposed to reduce the impact of human pollution on rivers and water bodies. Despite several model predictions and the extensive application of BMPs, Lake Erie is still severely affected by harmful algae blooms. We hypothesized that large sources of uncertainty are partially responsible for the mismatch between model predictions and present trends. We reviewed 12 BMPs prioritized by Canadian decision-makers and 11 models commonly used to represent watershed processes and BMPs. We identified strengths and weaknesses of the 11 models to represent BMPs, with particular emphasis on sources

of uncertainty, BMP ageing, and biochemical mechanisms not captured in the models. We identified potential strategies to address these limitations, building on the strengths provided by each model, and discussed these results with decision-makers involved in the Canadian side of Lake Erie. Here we synthesize the results of that experience.

T. BRANNON, J. MYERS, S. NEWELL, M. MCCARTHY, Wright State University. **Temporal Changes in Water Column Ammonium Cycling Rates in the Maumee River.**

External nutrient loading causes eutrophication and cyanobacteria blooms in Lake Erie's western basin. The Maumee River accounts for about half of N and P loading to the western basin, but internal nutrient processing also occurs within the river. We measured ammonium uptake, regeneration, and nitrification rates at four sites from Defiance, Ohio, to the river discharge into Maumee Bay from October 2018 to October 2019. Regeneration rates were generally similar to uptake rates, suggesting rapid organic N turnover. Regeneration, uptake, and chlorophyll a (chl a) concentrations followed a seasonal trend, with peak rates in summer. These processes affect the amount and form of N available to fuel cyanobacteria blooms and demonstrate how loading estimates can be a poor indicator of bioavailable N. Future models aimed at informing watershed management in agricultural watersheds should consider N cycling rates and pathways occurring within tributaries prior to discharge to receiving waters.

K. FRIESEN-HUGHES, N. CASSON, University of Winnipeg; H. WILSON, Agriculture and Agri-Food Canada. **Controls on Nitrogen in Southern Manitoba Agricultural Streams.**

Agricultural lands in cold regions are getting warmer and experiencing shifts in precipitation patterns resulting in reduced snowpack, more extreme climate events, and higher proportions of summer rainfall. Using data from southern Manitoba agricultural streams from 2013-2018, the goal of this research was to assess the seasonal and hydrological coherence of stream nitrogen patterns. Snowmelt discharge was the main driver of nitrogen transport in spring, but transport in the summer was not linked with discharge, suggesting other drivers. Spring was dominated by inorganic nitrogen, while summer was dominated by organic nitrogen, which tracked more strongly with organic carbon dynamics. This suggests seasonal shifts in nutrient ratios, which may be important for downstream water quality. Understanding controls on stream nutrient patterns is increasingly important as warming temperatures and shifting precipitation patterns alter nutrient cycling dynamics in affected streams and lakes.

J. LIU, H. BAULCH, University of Saskatchewan, School of Environment and Sustainability; J. ELLIOTT, Environment and Climate Change Canada; D. LOBB, University of Manitoba, Department of Soil Science; M. MACRAE, Univ. of Waterloo; H. WILSON, Agriculture and Agri-Food Canada. **Phosphorus in Cold Agricultural Regions: Soil Processes, Phosphorus Transport and Management Options.**

Phosphorus (P) is a limiting nutrient which drives eutrophication in many large lakes. In cold climate regions, P transport from agricultural landscapes to surface waters is controlled by snowmelt and rainfall runoff. This raises challenges for management options that have been developed solely for rainfall runoff. In this presentation, we discuss hydrological and biogeochemical processes controlling P transport in cold agricultural regions (e.g., snowmelt processes and freeze-thaw of soils and vegetation) and discuss the efficacy of various soil, nutrient and crop management options in reducing P losses. We will discuss how these management options affect hydrology (surface runoff and subsurface drainage), P availability and mobility in the soil and its transfer from soil to water, to inform our understanding of how management options may be affected by changing climate. We will also propose a framework, the "CUPCAKE" approach, for managing agricultural water quality in variable and changing climates.

L.N. SUAREZ, The University of Akron, Integrated Bioscience; A. LOPA, D. PERRY, The University of Akron, Chemistry. **Stop HABs at the Source: Closing the Loop on Nutrient Runoff with Shallow Subsurface Soil Spectroscopy.**

Several strategies are available to control agricultural nutrient runoff that drive harmful algal blooms: precision agriculture fertilizer application, fertilizer injection into soil, buffer zones between fields and waterways, new drainage ditch designs, and creation of retention ponds or mini-wetlands. What is not known is the effectiveness of a given strategy after implementation. Our plan is to evaluate the effectiveness of nutrient traps by determining the accumulated nutrients in the soil combined with measurements of nutrient content of runoff water. These two measurements provide information, based on which a strategy can be judged successful or changed as needed. With accumulated experience, best practices for a variety of agricultural situations will become evident. We have developed the S4 Shallow Subsurface Soil Spectroscopy method for producing 3-dimensional maps of the nutrient content in the soil. A probe is inserted into the ground to record the diffuse reflectance of the soil in the visible and near infrared region of the spectrum. The soil is probed on a grid pattern to yield a 3D dataset that is subjected to a chemometric analysis.

A. VÁZQUEZ-ORTEGA, Bowling Green State University, School of Earth, Environment and Society; S. PELINI, Bowling Green State University, Biological Science; R. BRIGHAM, Bowling Green State University, School of Earth, Environment and Society. **Dredged Sediments as Farm Amendments to improve Soil Health and reduce Nutrient Loss.**

This study aims to 1) identify the appropriate native soil to dredged material ratio to achieve the best crop yield, 2) determine nutrient and metal release into soil solution, and 3) determine metal and microcystin bioaccumulation in crops from farm soils amended with dredged material. Dredged material provides organic matter and supplies essential plant nutrients to agricultural soils that can further reduce fertilizer application costs. We expect dredged sediments to improve soil bulk density and crop yield and minimize nutrient loss into waterways. Dredged blends can be categorized as the

right source since they might positively benefit the biological, chemical and physical health of a farm soil. We envision that nutrient management specialists from the Ohio Department of Agriculture can use the results from this project and make recommendations to farmers about the incorporation of dredged blends as part of their agricultural best management practices.

2. Social-ecological benefits of Great Lakes coastal wetlands

E. GONDWE, P. MUHONDA, A. BENNET, Michigan State University, Department of Fisheries and Wildlife. **Understanding Drivers of Fish Consumption: A Food Security Perspective**.

The important role that fish plays in food and nutrition security especially in fishing regions such as those in the Great Lakes is highly understood. Current debates on fish and food security highlight the imperative need for holistic discourses of fish and its role in contributing to food and nutrition security such as policy, economic and social actions addressing demand, access, supply and nutrition. Using a socio-economic lens, we employ econometric models to determine factors affecting amount of fish allocated to households by fish value chain actors in Lake Malawi, an African Great Lake. Our findings suggest the amount of fish allocated to households is positively correlated with being a male fisher and processor. We observe differences amongst tribal groups, suggesting the potential influence of cultural backgrounds on fish consumption. Our results enforce the need of understanding social compounding factors to improve the role of fish to food security in fishing communities.

S. HICKEL, M. LIBERATI, D.R. PEARSALL, K. ROBINSON, S. SIMOWSKI, G.M. ANNIS, The Nature Conservancy, Conservation Science. **Blue Accounting: Identifying Socioeconomic Metrics for Great Lakes Coastal Wetlands.**

Measuring the contribution of Great Lakes coastal wetlands to human socioeconomic wellbeing has been challenging. These benefits have not always been quantified in a rigorous way that would aid decisionmakers on Great Lakes issues. Blue Accounting (BA) is working to ensure that timely and relevant information on socioeconomic benefits of coastal wetlands is available by identifying socioeconomic indicators that align with the BA's goal, that people "recognize benefits of, and engage in the protection, restoration and conservation of coastal wetlands." We are using a structured decision-making process that considers the relevance of socioeconomic indicators to coastal wetlands and human quality of life. Potential indicators are ranked based on relevance, resonance, realism and data-richness. This process breaks down indicator selection into discrete components and iterative steps that allow everyone involved to clearly see the assumptions, potential biases and tradeoffs associated with any selection. Selected socioeconomic indicators will be published on the BA information hub and used to clearly quantify the benefits of coastal wetlands.

D.R. PEARSALL, M. LIBERATI, S. HICKEL, K. ROBINSON, S. SIMOWSKI, G.M. ANNIS, The Nature Conservancy, Conservation Science. **Restoring coastal wetlands to benefit people: patterns from the Blue Accounting database.**

Great Lakes coastal wetlands provide ecosystem services that benefit people across multiple domains of human well-being (HWB), and conservation projects intended to improve ecosystem extent or condition often also enhance these benefits to people. However, project managers do not often recognize or promote these benefits in project descriptions. The Blue Accounting Coastal Wetland team has compiled data for over 200 coastal wetland protection, restoration and enhancement projects across the basin since 2010. An initial assessment revealed that 25% of project descriptions asserted an intent to benefit people (HWB projects), predominantly in the Work and Leisure domain. Funding for HWB projects averaged 46% higher than the overall average ($1.11M vs $0.76M per project). Having increased the number of projects, we re-examined the database for patterns in geographic distribution, funding amount and source, recipient type, and project type. We also interviewed managers of HWB projects to assess the pros and cons and lessons learned; e.g., why did you promote HWB and did it affect project outcomes? Our findings will inform project managers and funders.

N. STOTT, J.G. MINER, Bowling Green State Univ., Dept. Biological Sciences, Biology. **If you build it, will they come? Northern Pike recruitment bottleneck in Lake Erie coastal wetlands.**

Wetland restorations in Lake Erie have aimed to reconnect diked wetlands and restore existing systems. A main objective is to provide critical habitat for native species like Northern Pike, *Esox lucius*. In spring 2017-2019 we assessed early life stage Northern Pike production in six Ohio coastal wetlands. Northern Pike often use these wetlands for spawning (generally in water < 0.5m deep), but no larvae/two juveniles were captured in these wetland complexes in 2017 and 2018. A large seiche occurred in both years (1.1m in 2017, 0.75m in 2018) during egg incubation. In 2019, no seiche occurred and 22 juveniles were captured. Age analysis from 106 adults suggests highly variable recruitment with strong year classes being related to low numbers of wind driven seiches during the egg incubation period ($P < 0.05$). Thus, we point to these seiche-driven influences and their timing as critical factors in Northern Pike recruitment. Currently, many restored systems may act as ecological sinks as opposed to sources when seiche activity occurs. Therefore, restoration of near-lake wetlands should evaluate water level fluctuations to optimize ecological benefits.

3. Great Lakes shoreline changes during recent extreme water levels

P. LAWRENCE, E. KOSTECKY, University of Toledo. **Assessing Impacts of 2019 Record High Water Levels on Great Lakes Parks and Protected Areas.**

In 2019, all five of the Great Lakes experienced record high water levels that surpassed previous levels held since 1985/86 or earlier. Limited previous studies conducted following earlier events documented that impacts that associated flooding and erosion had on many parks and protected areas located along the shorelines of the Great Lakes. As a follow-up to that previous research, a short survey consisting ten questions was sent via Survey Monkey to forty federal and state/provincial parks to examine the 2019 events and impacts. The results highlights operations and facilities that were directly impacted by shoreline flooding and erosion, including visitor access and services, damages to infrastructure, changes to education programs, additional operating costs, plus initial assessment of immediate and subsequent direct and in-direct financial costs and associated planning issues, both current and future.

K. LEDERLE, Michigan Department of Environment, Great Lakes, and Energy, Water Resources Division. **Shoreland protection in Michigan: a regulatory perspective.**

Michigan's Great Lake coastline is 3,288 miles long. Home sites along the coast are highly valued and much sought after. The Department of Environment, Great Lakes, and Energy is charged with regulating development in coastal dunes and along highly erodible shorelines. The current high water levels present additional challenges to protecting the coastal resource for all citizens and mitigating the hazard of structures falling into the lakes. Michigan regulatory staff have responded to the increased permitting load for shore protection while maintaining littoral processes as much as possible. Contractors and property owners have numerous ideas of how to stop erosion, not all of which are feasible. Our primary message is to move the structure landward whenever possible rather than installing shore protection. Local units of government have the power to write zoning ordinances and could play a pivotal role in protecting their coastline.

4. Fluxes of carbon and nutrients across aquatic boundaries from land to ocean

M. ALAM, University of Toronto Scarborough, Department of Physical and Environmental Sciences; A. ZASTEPA, Environment and Climate Change Canada, Canada Centre for Inland Waters; M.B. DITTRICH, University of Toronto Scarborough, Department of Physical and Environmental Sciences. **Phosphorus recycling in Lake of the Woods: Reactive-transport modeling across spatial and temporal scales.**

The dynamics of sediment phosphorus (P) remobilization and recycling of P in both hypoxic and anoxic areas in many polymictic system undergoing extensive changes due to distinct external loading conditions is less understood. Here, we used multifaceted approach of quantifying sediment P binding forms and corresponding metal contents in sediment cores down to 30 cm from eight different locations at Lake of Woods (LOW) in three different seasons, measured pH, redox potential and dissolved oxygen uptake across the sediment-water interface and the concentration of

nutrient and metals in pore water at different depths. Additionally, we applied a reaction-transport diagenetic model to investigate sediment P dynamics in LOW. The summer diffusive fluxes of P ranged between 3 and 83 *u*mol m-2 d-1 whereas the winter fluxes are lower ranged from 0.1 to 0.35 *u*mol m-2 d-1. P recycling efficiency are 13% to 77%. The model supports the experimental finding that P is bound substantially to ferric Fe in surface sediments, and P release is mostly driven by the diagenetic recycling of redox sensitive and organic bound P.

S. COLLINS, T. BRANNON, Wright State University, Dept Earth & Environmental Sciences; E. JEPPESEN, Aarhus Universitet, Institut for Bioscience; M. MCCARTHY, Wright State University, Dept Earth & Environmental Sciences. **Effects of Climate Warming and Nitrogen Loading on Ammonium Cycling in Shallow Lake Mesocosms.**

Harmful algal blooms impact lakes worldwide and are caused by excess nitrogen (N) and phosphorus loading from watersheds. Warmer temperatures and extreme precipitation/drought are projected to worsen eutrophication. We examined climate warming and nutrient loading effects on N cycling in shallow lake mesocosms. N loading to some mesocosms ceased in June 2018 and resumed in June 2019. Ammonium (NH4+) uptake, regeneration, and nitrification rates were evaluated. Nutrient additions generally had a larger effect on rates than temperature changes, and macrophytes versus phytoplankton dominance was also important in determining NH4+ dynamics. NH4+ uptake rates were generally higher in light incubations than dark, but non-photoautotrophs also contributed substantially to NH4+ uptake. NH4+ regeneration could support about 44% of potential microbial NH4+ demand, and even before resumption of N loading to high nutrient mesocosms, internal NH4+ regeneration sustained primary producer biomass.

N. KAO, Ecohydrology Research Group, Ecohydrology Research Group; M. MOHAMED, Environment and Climate Change Canada; R. SORICHETTI, Ontario Ministry of the Environment and Climate Change; A. NIEDERKORN, P. VAN CAPPELLEN, University of Waterloo, Ecohydrology Research Group; C. PARSONS, Environment and Climate Change Canada. **Phosphorus mitigation on the Thames River, Ontario: Influence of a dammed reservoir on P loads and speciation.**

The Thames River is the largest Canadian tributary source of phosphorus (P) to Lake Erie's western basin. Yet, the effects of dams on P flow and speciation remain poorly characterized. We estimated the annual and seasonal retention efficiencies (RE) of different P pools (DRP, DUP and TP) by the largest dammed reservoir (Fanshawe) on the Thames River using a mass balance approach based on two years of sampling data (2018-2019). Four load estimation models were used to quantify P loads. Results show that on an annual basis, Fanshawe Reservoir was a P sink (RE: 29 to 46%) with no significant changes to outflow DRP:TP ratios. However, loads, RE, and DRP:TP ratios showed systematic seasonal variations. For TP, retention was the highest in winter and fall (RE: 49 to 69%), while the reservoir acted as a source during the summer and one of the spring

seasons (RE: -25 to -110%). Furthermore, the dam's outflow DRP fraction increased during the summer, ostensibly driven by stratification and internal P loading. Our results show that Fanshawe Reservoir exerts a major influence on the flow and speciation of P and, thus, represents a potential point of intervention for P mitigation.

R. MANDRYK, D. CAPELLE, T. PAPAKYRIAKOU, University of Manitoba, Department of Environment and Geography. **First estimates of diffusive methane flux from Lake Winnipeg.**

Freshwater lakes are increasingly recognized as potentially significant sources of atmospheric methane (CH_4). Lake Winnipeg, as the eleventh largest freshwater lake by surface area globally, has been the subject of several studies as it suffers from anthropogenic eutrophication and invasive species, while providing large commercial fisheries, recreation opportunities, and a natural hydroelectric reservoir. With CH_4 samples from summer, fall 2018, and winter 2019, we provide a preliminary examination of the diffusive CH_4 flux from Lake Winnipeg during the open water season. We found spatial and temporal variability, with noticeably higher concentrations near river inflows, as well as higher concentrations on average in the summer relative to the winter and fall. Continued sampling will confirm these results and will add to our understanding on regional variation on the production and emission characteristics of CH_4 within the lake, and how these patterns vary across season and between years.

K. RODGERS, G.K. MCCULLOUGH, University of Manitoba, University of Manitoba, Department of Environment & Geography; D. BARBER, University of Manitoba, Centre for Earth Observation Science. **Land cover effects on nutrient loading from small tributaries to the Upper Manitoba Great Lakes**

The Lake Winnipeg watershed (LWW) includes a series of interconnected large lakes ("the upper MBGL"), which feed, via the Fairford River, into Lake Winnipeg and via the Nelson River into Hudson Bay. Current knowledge on water quality in the major rivers have a greater influence by the upstream lakes rather than the surrounding land use. Two sub-watersheds (Winnipegosis and Manitoba) within the LWW were selected for water quality sampling. These sub-watersheds consist of developed agricultural land in the southern portion and relative pristine wetland-forested areas in the northern portion. This presentation will discuss year one results for the water quality and nutrient loading in four small tributaries, ranging from pristine wetlands to mixed forest, wetland and agricultural development within these sub-watersheds.

L. SETHNA, T. ROYER, Indiana University; J. TANK, University of Notre Dame. **Winter cover crops may reduce harmful algal bloom frequency and intensity in agricultural watersheds.**

Agricultural streams in the Midwestern U.S. contribute the majority of dissolved nitrogen (N) and phosphorus (P) loads to the Gulf of Mexico; however, studies have shown agricultural land use decreases the export of dissolved silica (DSi), an essential nutrient for diatom growth. The

resulting stoichiometric imbalance among N, P, and DSi fosters the formation of harmful algae blooms (HABs) and contributes to the loss of ecosystem services and declines in water quality. Winter cover crops (WCC) reduce N and P losses from fields by increasing nutrient retention, yet their effect on DSi concentrations and stoichiometry is unknown. In this study, we analyzed concentrations and loads of dissolved N, P, and DSi in subsurface tile outlets draining fields with and without WCC in a small watershed in northwestern Indiana. We found WCC had little effect on N:P:DSi; however, seasonal variation in nutrient loads indicate temporal variation in the risk of HAB formation throughout the year.

P. WEIDMAN, T.J. MAGUIRE, S.O. MUNDLE, University of Windsor, Great Lakes Institute for Environmental Research; J.W. MOORE, K.A. CHEZIK, Simon Fraser University, Earth 2 Oceans Research Group; D.T. SELBIE, Fisheries and Oceans Canada, Cultus Lake Salmon Research Laboratory. **Industrial Atmospheric Emissions and Watershed Export of Dissolved Ions in Pacific Coast Streams.**

Watershed-scale impacts of atmospheric acid deposition on tributary concentrations and watershed exports of major nutrients and ions were quantified for the Kitimat River Watershed, north coastal British Columbia. The Kitimat watershed is impacted by emissions from an aluminum smelting facility at the river estuary. Concentrations of sulfate (SO4), fluoride, nitrate, and chloride were significantly higher in six impacted tributaries compared to three reference sites. Watershed export was calculated using bootstrapped stratified estimates of discharge. A Bayesian approach was used to improve model parameters using uncertainty of export estimates. Export of SO4 and calcium (Ca) increased significantly with proximity to smelter emissions. The impacted area for SO4 and Ca was 100 and 45 km2, respectively. SO4 export was due to excess S being flushed from watersheds. Ca export resulted from impacts of S deposition on soil pH and cation exchange. Industrial development in the region is expected to increase atmospheric acid emissions, which is a concern for benthic stream communities and locally important juvenile Pacific salmon.

B. WOLDEGIORGIS, H. BAULCH, University of Saskatchewan, School of Environment and Sustainability; A. BAJRACHARYA, University of Manitoba, Department of Civil Engineering; T. STADNYK, University of Calgary, Department of Geography. **Improving calibration strategies for hydro-biogeochemical models - A case study of HYPE in the Red-Assiniboine.**

Human activities can cause excessive nutrient loadings that endanger the health of water bodies. Hydro-biogeochemical (BG) models are useful tools to quantify the pollution load discharged into water bodies and identify mitigation options. Adequate simulation of the baseline scenario is a pre-requisite for scenario investigations. In this regard, calibration of a BG model is often performed after optimizing the hydrological model. While some studies have demonstrated this does not support an optimum BG model, joint hydrological and BG optimization remains relatively rare. Here, we compared the BG efficiency of the sequential and joint calibration of the

HYPE model applied to the Red-Assiniboine basin - an agriculturally-dominated part of the Lake Winnipeg basin. We demonstrate that joint hydrological and BG calibration improves the BG model efficiency over sequential calibration approaches. Growing evidence is suggesting a joint calibration approach can improve BG simulation models.

Y. YEZHOVA, D. CAPELLE, University of Manitoba, Department of Environment and Geography; M. STAINTON, Freshwater Institute; T. PAPAKYRIAKOU, University of Manitoba, Department of Environment and Geography. **Carbon dioxide fixation and remineralization by the pelagic community in Lake Winnipeg.**

Lakes are important sites for carbon fixation and carbon dioxide (CO_2) exchange with the atmosphere. The CO2 fixation rates have never been published for Lake Winnipeg, but they are important for quantifying the lake's role in the regional carbon budget. Additionally, it is important as biomass production in the lake is the foundation of the system's food web, and its degradation affects lake oxygen status with implications on heterotrophs, including commercial fish species. This study aims to measure net community production across the lake using an automated, custom-built incubator onboard the *MV Namao* over a 3-year period (2017 to 2019). Quantification of gross oxygen production and consumption, and net community production allows for quantification of the gross and net carbon fixation and remineralization by the pelagic community. The study also identifies key moderating factors that underpin spatiotemporal variability in net community production in Lake Winnipeg.

5. Assessing nutrient biogeochemistry of sediments in agricultural drains

I. CRUMRINE, J. MYERS, M. MCCARTHY, S. NEWELL, Wright State University. **Potential for Nitrogen Removal by Maumee River Sediments**.

Lake Erie experiences annual cyanobacterial blooms that affect the biotic community and regional economies. The Maumee River contributes anthropogenic nutrients to the lake, and excess nitrogen in river discharge allows for Microcystis proliferation, which can produce microcystin and disrupt ecosystem services. The role of Maumee River sediments as an ammonium source or sink was evaluated using sediment cores collected throughout 2019. Ammonium uptake and regeneration rates across the sediment-water interface were measured and extrapolated to represent net ammonium flux through three distinct zones of the river. The river acted as a net sink for ammonium, but when compared to annual nitrogen loading from the river, sediments extracted only a small fraction of total nitrogen inputs. Maumee River sediment ammonium uptake was balanced to a large degree by internal regeneration, highlighting the need to develop management strategies aimed at reducing nitrogen loads to receiving waters.

E. KINDERVATER, M. OUDSEMA, M. HASSETT, A.D. STEINMAN, Annis Water Resources Institute, Grand Valley State University. **Optimizing phosphorus retention in agricultural drainage through engineered solutions.**

Sediment and nutrient loadings are an issue of concern for the Macatawa Watershed in West Michigan. Comprising 45% of the land use in the watershed, agriculture has been acknowledged to be a major source of these nonpoint source pollutants. Two-stage ditches, with constructed floodplain benches, were introduced in 2015 and analyzed for phosphorus (P) and sediment retention in 2016. While these systems did slightly reduce P at baseflow and have the potential to retain a considerable amount of P within their soils, the retention time was not long enough to make a significant impact. Iron slag filters installed to receive tile drainage effluent are now being studied to determine if a more engineered solution will be more effective at reducing P in agricultural drainage. Initial results show that that these systems can retain bioavailable and total P, as well as reduce turbidity.

S. SPEIR, J. TANK, U. MAHL, University of Notre Dame. **Quantifying denitrification following floodplain restoration via the two-stage ditch.**

In agricultural streams, the construction of two-stage ditch floodplains has been shown to enhance nitrate (NO3) removal via microbial denitrification, reducing export to downstream ecosystems. At the Shatto Ditch Watershed (Indiana, US), we quantified the direct impact of restoration efforts on both stream and floodplain denitrification following the construction of an additional 6.4 km of floodplains in 2017-2018. We found denitrification on unconsolidated stream sediments was minimally impacted by stream dredging during two-stage construction. In contrast, denitrification on floodplain soils was below detection one year post-2017 construction. As predicted, stream sediment denitrification was driven by water column NO3 concentration, while organic matter was the limiting for floodplain denitrification. The two-stage ditch can increase NO3 removal by >27% in agricultural watersheds, representing an effective ecological engineering solution to combat downstream eutrophication.

T. VAN STADEN, University of Waterloo; K. VAN METER, University of Illinois at Chicago, Ecohydrology; N. BASU, University of Waterloo, Civil and Environmental Engineering; C. PARSONS, Environment and Climate Change Canada; P. VAN CAPPELLEN, University of Waterloo, Ecohydrology Research Group. **Phosphorus Legacies and Water Quality Risks in Southern Ontario.**

Excess phosphorus (P) loading to lakes can increase the frequency of harmful algal blooms (HABs). Efforts to reduce P inputs to Lake Erie were successful in the 1970s, but HABs returned in the 2000s. One possible contributing factor is the export of legacy P accumulated in the watershed from historical inputs, *e.g.* due to fertilizer use in excess of crop needs. Here we present a large-scale assessment of Canadian Lake Erie watersheds which locates and quantifies anthropogenic P inputs

from 1961 to 2016. The Net Anthropogenic P Input model (NAPI) was used to delineate areas with P surpluses. Due to intense agricultural activity, southwestern Ontario received the largest P surplus over time. The cumulative P surplus map was combined with soil erosion potential maps to construct risk maps that identified areas with the greatest potential for erosional P export or soil P accumulation. We identified a higher risk of legacy P accumulation in soils along coastal areas of Lake Erie, areas which may thus serve as long-term sources of P to the lake. The risk maps may help inform nutrient management and abatement strategies and the targeted implementation of conservation practices.

7. Invasive species

P. ALSIP, Cooperative Institute for Great Lakes Research, University of Michigan; H. ZHANG, Eureka Aquatic Research, LLC.; M. ROWE, E. RUTHERFORD, D.M. MASON, NOAA Great Lakes Environmental Research Laboratory; C. RISENG, University of Michigan, SEAS; Z. SU, Michigan Department of Natural Resources, University of Michigan - Institute for Fisheries Research. **Modeling the effects of mussels, climate, and nutrient loads on Lake Michigan's suitability for bigheaded carps.**

Anthropogenic stressors affect the vulnerability of lakes to bioinvasions. In Lake Michigan (LM), strategic phosphorus (TP) abatement, Dreissena, and climate change have altered its biophysical character. LM is 76 km from the invasion front of bigheaded carps (BHC), and currently contains habitat suitable for their growth. Understanding how climate, mussels, and TP loads affect LM's suitability for BHC can clarify the historic trend and future trajectory of invasion risk. We applied a BHC growth rate potential (GRP) model to a 3D simulated environment for nine scenarios, which differed in climate (cool, reference, warm), TP loads (None, 2010 loads [3300 MTA], and High Loads [5600 MTA]), and the presence of Dreissena. We found that a warm climate decreased food competition between mussels and BHC. High loads increased annual growth 8-40% compared to 2010 loads. In sum, LM's suitability for BHC has declined since the 1980s but could be improved by climate change and future P enrichment.

M.E. BOHLING, Michigan State University Extension, Sea Grant; K. BROLICK, B. CLAWSON, Michigan State University Extension; M. COWALL, Land Information Access Association; K. WALTERS, Michigan Department of Environment, Great Lakes, and Energy. **MI Paddle Stewards: Linking citizen science with aquatic invasive species early detection & rapid response.**

Non-motorized watercraft continue to be popular ways for residents & visitors to traverse the state's many waterways in search of tranquility or adventure. However, recreational paddling can also increase the spread of aquatic invasive species. MI Sea Grant & our partners secured funding from the Michigan Invasive Species Grant Program to enlist those paddlers in a fight to protect the

waters they love through MI Paddle Stewards. We've teamed up with Clean Boats, Clean Waters, MI Dept of Environment, Great Lakes, & Energy, Land Information Access Association and over a dozen local organizations to offer workshops to help paddlers become allies in the fight against aquatic invasive species. Professionals from partner organizations train participants how to identify & report aquatic invasive species, with an emphasis on MI *Watch List Species* & reporting in MISIN. Paddlers also learn from how to properly clean their watercraft to avoid giving invaders a free ride. These citizen scientists become extra sets of trained eyes searching for new invaders, aiding in the state's ability for early detection & rapid response.

T.J. FIRKUS, C. MURPHY, Michigan State University, Department of Fisheries and Wildlife; G. FISCHER, University of Wisconsin - Stevens Point, Northern Aquaculture Demonstration Facility; F. GOETZ, National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center. **Effects of sea lamprey parasitism on reproduction of two morphotypes of Great Lakes lake trout.**

Sea lamprey have had serious negative impacts on lake trout populations since their introduction into the Great Lakes. 45-75% of lake trout survive a sea lamprey attack, but little is known about the health of parasitism survivors. Lake trout that have survived a sea lamprey attack are likely to suffer health repercussions that may cause the fish to divert energy from normal physiological processes, including reproduction. We examined the sub-lethal effects of sea lamprey parasitism by allowing sea lamprey to parasitize individual lake trout (lean and siscowet) for four days. Following parasitism, we monitored reproduction-related endpoints and growth. Parasitized male lake trout from both morphotypes displayed reduced sperm concentrations, while siscowet females with A-type wounds skipped spawning more frequently than controls or females with B-type wounds. Parasitism status did not affect egg production for leans. The results suggest parasitism could affect lake trout populations via growth and reproduction and that life history shapes this impact.

M.E. GRUWELL, N.C. MOORE, Penn State University, Biology; E. DOBRY, Penn State University, Department of Plant Science; K.A. DELOE, Penn State University, Biology; A.A. CANGELOSI, Penn State University; M. BALCER, Independent Contractor; I.T. KNIGHT, Penn State University. **Early Detection of Ship-Mediated Aquatic Invasive Species (AIS) Through Environmental DNA (eDNA).**

eDNA is gaining acceptance as a means of monitoring AIS, however signal duration ranges widely. We designed mesocosm experiments using the Great Lakes invader, Hemimysis anomala, recently discovered in Pennsylvania. We used four control tanks and four exposure conditions (5 tanks each): high and low biological oxygen demand and presence or absence of organisms in exposed lake water. Ten mL water samples were filtered from each tank, 1) prior to organism inoculation, 2) immediately after inoculation, and 3) at regular intervals for 15 days post inoculation.

Genomic DNA was extracted and the presence of eDNA was detected through PCR and gel electrophoresis of CO1 mtDNA. During the first 4 days post inoculation the number of eDNA positive tanks declined for all 4 treatments. For the duration of the experiment, eDNA signal was sporadically positive in all tanks and no significant difference in eDNA signal between treatments was observed. Although these methods were effective in detecting H. anomala DNA, the persistence of eDNA signal extends beyond two weeks. Future experiments, with longer duration are needed to determine the extent of signal persistence.

J. HOLTSWARTH, E. LARSON, University of Illinois, Department of Natural Resources and Environmental Science; J. TIEMANN, Illinois Natural History Survey; P. WILLINK, Illinois Chapter of American Fishery Society. **Genetic analysis of the rapid expansion of banded killifish in the Great Lakes Region**.

Banded killifish range from the Atlantic coast through the Great Lakes and upper Midwestern states. The eastern subspecies occupies the Atlantic coast and inland to Lakes Ontario and Erie, whereas the western subspecies ranges from Lake Erie west through the upper Midwest. Western banded killifish were often collected in kettle lakes in the southern Lake Michigan basin, but declined throughout the 1900s. Since the early 2000s, an expansion of banded killifish into the Illinois and Mississippi rivers prompted investigations into which subspecies is causing the spread. We have morphological and mtDNA analyses that suggest the non-native eastern subspecies has expanded its range. The invasion of eastern banded killifish could negatively impact the native western subspecies through mechanisms including hybridization and competition. It is important to protect the native western subspecies while understanding how this invasion could influence aquatic communities in the Great Lakes region.

E.K. LOWER, Michigan Sea Grant. **The Hateful 8: Characterizing the Impacts of the Great Lakes' Top Invasive Species.**

This poster identifies the top eight aquatic invasive species determined to have the most significant environmental and socio-economic impacts in the Great Lakes basin, and examines what characteristics these species share that make them so harmful. Using an organism impact assessment developed in conjunction with the Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS), we determined that no particular taxon, place of origin, or vector of introduction seems to be especially common among these highest-impact species: instead, the traits they share are primarily behavioral, including aggressive competition with native species for food and habitat, direct predation, and behaviors that damage recreation, aesthetics, and economic activities. Highlighting these "most unwanted" species also fulfills an ongoing communications need among Great Lakes science educators by ranking which AIS in the region are most harmful.

A.S. MCNAUGHT, Central Michigan University, Biology. **Exotic species in the Great Lakes: the anomalous case of the bloody red shrimp.**

A recent Ponto-Caspian invader, the predatory crustacean *Hemimysis anomala*, exhibits behavioral and life history characteristics that may enable it to substantially alter the food web by either (1) feeding on lower food web organisms and reducing energy flow to higher trophic levels, or (2) serving as a new resource for fish, thus creating an energy pathway between primary/secondary production and higher trophic levels. We conducted small scale (500 mL) and meso-scale (1000 L) experiments to determine the degree to which *Hemimysis* reduce zooplankton abundance. To determine if nearshore fish consume *Hemimysis*, we examined stable isotope signatures of round goby, rock bass, and likely prey. We also conducted laboratory feeding trials with age-0 Lake Trout. Results from the field and lab indicate that *Hemimysis* is a voracious predator whose effects are likely limited by low zooplankton densities in the Great Lakes. Fish readily feed on *Hemimysis* and feeding increases with mysid density. Therefore, *Hemimysis* may have the ability to temporarily lengthen the food webs and supplement fish diets in systems where they are abundant.

R. STURTEVANT, Michigan State University, Michigan Sea Grant; E.K. LOWER, Michigan Sea Grant; F.A. MARTINEZ, NOAA National Centers for Coastal Ocean Science; A. ELGIN, NOAA Great Lakes Environmental Research Laboratory, Lake Michigan Field Station. **Exploring Geographic Niches of Aquatic Invasive Species with the GLANSIS Map Explorer.**

In late 2018, GLANSIS (https://www.glerl.noaa.gov/) launched a new utility, Map Explorer, that allows users to overlay habitat layers available through the Great Lakes Aquatic Habitat Framework (https://www.glahf.org/) with GLANSIS records of established aquatic nonindigenous species. The map layers can also be downloaded into GIS tools such as ARCGIS and R. In a pilot project designed to explore the tool's capabilities, we examined the distribution patterns of a small set of species representing a diversity of taxa and invasion histories by mapping AIS locations onto GLAHF's Aquatic Ecological Units (AEU - Riseng et al 2018) and mapping shoreline AIS (e.g., Phragmites) locations onto GLAHF's shoreline classification. We then extracted values using the extract tool in ArcGIS to generate a summary of habitats in which each species occurred. Here we present preliminary results of the species distribution analysis to illustrate AIS species spread and habitat suitability, and to inform where additional monitoring efforts may be needed.

E.M. WEISE, K.T. SCRIBNER, O. BOEBERITZ, Michigan State University, Department of Fisheries and Wildlife; J.V. ADAMS, USGS Great Lakes Science Center; A. JUBAR, USFWS Ludington Biological Station; G. BRAVENER, Fisheries and Oceans Canada, Sea Lamprey Control Centre; N. JOHNSON, USGS, Great Lakes Sci Center; J. ROBINSON, Michigan State University. Department of Fisheries and Wildlife. **Assessing the effectiveness of sea lamprey control using population genomic data and pedigree analysis.**

Barriers have been a primary method of sea lamprey since the 1950s. Sea lamprey larvae are occasionally found above barriers but estimating associated numbers of spawning adults (N_b) is difficult. We used population genomic approaches to estimate N_b in multiple streams where larvae were present upstream of barriers. Larvae were separated into age cohorts using a Gaussian mixture analysis. SNP data were used to estimate effective number of breeding adults, calculate extrapolated estimates of the total number of spawning adults (N_s), and evaluate the influence of sample size on estimates. N_b and N_s were small in all cases, indicating that escapement above barriers was low. Pedigree-assigned families included individuals from multiple cohorts estimated using mixture analyses, highlighting limitations of the mixture analysis approach for separating cohorts by size. The sample size evaluation showed moderate upward bias in estimates for the smallest sample sizes, but accuracy was high for samples of 100 or more individuals Collectively, results illustrate the utility of genetic estimates of spawning abundance for evaluating sea lamprey populations.

8. Great Lakes Fish Biology and Ecology

L. CARTWRIGHT, K. BARNES, R. PORTISS, Toronto and Region Conservation Authority; J. MIDWOOD, Fisheries and Oceans Canada. **Fish community response to wetland restoration at Tommy Thompson Park, Toronto, Canada.**

Tommy Thompson Park is an artificial landform on the Toronto waterfont created by millions of cubic metres of concrete, earth fill and dredged sand deposited at the site throughout the twentieth century. We used electrofishing data collected over the past 30 years to examine changes in fish communities at Cell 1, Cell 2 and Embayment D that have undergone aquatic habitat restoration (e.g. carp exclusion, aquatic vegetation plantings, log cribs). The fish community appears to have shifted post-restoration towards the desired fish community targeted through restoration actions (improved forage/piscivores, carp exclusion) although there were losses/declines for several native cyprinids including Spottail Shiner and Bluntnose Minnow. Restoration efforts are achieving fish habitat goals although further consideration may be needed to sustain non-target species.

K.E. CUNNINGHAM, Trent University, Department of Environmental and Life Sciences; E.S. DUNLOP, ON Ministry of Natural Resources, Trent University. **Lake Whitefish (*Coregonus clupeaformis*) recruitment dynamics in Lake Huron.**

Lake Whitefish (*Coregonus clupeaformis*) are an ecologically and commercially significant species across the Laurentian Great Lakes. Recent assessments in Lake Huron show reduced numbers of young Lake Whitefish, but the reasons for this decline are unknown. In this study, larval fish were sampled from the Fishing Islands region in the main basin of Lake Huron, an important spawning shoal for Lake Whitefish. Larval fish were collected throughout the spring hatching period during two time periods: a historical period (1976-1986) when abundances were higher and a recent period (2017-2019) when abundances are declining. The seasonal patterns of larval growth rates, densities,

and effects on year class strength are examined. We expect lower current growth rates and survival of larvae than historically due to reduced food availability from dreissenid mussels. We also expect larval densities to correspond with variation in overwinter conditions, such as water temperature and ice cover.

T.J. FIRKUS, C. MURPHY, Michigan State University, Department of Fisheries and Wildlife; G. FISCHER, University of Wisconsin - Stevens Point, Northern Aquaculture Demonstration Facility; F. GOETZ, National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center. **Effects of sea lamprey parasitism on reproduction of two morphotypes of Great Lakes lake trout**.

Sea lamprey have had serious negative impacts on lake trout populations since their introduction into the Great Lakes. 45-75% of lake trout survive a sea lamprey attack, but little is known about the health of parasitism survivors. Lake trout that have survived a sea lamprey attack are likely to suffer health repercussions that may cause the fish to divert energy from normal physiological processes, including reproduction. We examined the sub-lethal effects of sea lamprey parasitism by allowing sea lamprey to parasitize individual lake trout (lean and siscowet) for four days. Following parasitism, we monitored reproduction-related endpoints and growth. Parasitized male lake trout from both morphotypes displayed reduced sperm concentrations, while siscowet females with A-type wounds skipped spawning more frequently than controls or females with B-type wounds. Parasitism status did not affect egg production for leans. The results suggest parasitism could affect lake trout populations via growth and reproduction and that life history shapes this impact.

O.T. GORMAN, J. LYONS, L. EVRARD, U.S. Geological Survey Great Lakes Science Center. **Diversity of Ciscoes of Lake Superior: More than Koelz Imagined?**

In contrast to other Great Lakes, Lake Superior retains an intact cisco complex. Back in the 1920s Walter Koelz described 7 forms of ciscoes (genus *Coregonus,* subgenus *Leucichthyes*) in Lake Superior: *artedi artedi, artedi albus, hoyi, kiyi, zenithicus, reighardi dymondi*, and *nigripinnis cyanopterus*. Several of these forms were absent from surveys in the later 20th century, and speculation arose as to whether they ever existed. Since 2001 all these forms have been collected, although it is not certain that recent examples of *reighardi* and *nigripinnis* match those of Koelz. Besides these 7 species, other variants of *artedi* and deepwater ciscoes have been collected. Morphological and genetic analyses from extensive collections made since 2012 are currently underway to describe the diversity of cisco forms in Lake Superior. We will provide a pictorial overview of the morphological diversity of Lake Superior ciscoes and outline ongoing research that seeks to characterize these forms and their ecology and evolution.

M. HERBERT, The Nature Conservancy; M. VINSON, O.T. GORMAN, D.L. YULE, L.L. EVRARD, C.L. ROSINSKI, U.S. Geological Survey Great Lakes Science Center. **Spawning Assessment of Lake Superior Kiyi to Inform Potential Restoration Efforts.**

Kiyi (*Coregonus kiyi*) only occur in Lake Superior, after being extirpated from Lakes Michigan, Huron and Ontario in the 20th century. There is growing interest in rehabilitation of Kiyi in the Great Lakes. However, there are major gaps in our knowledge of Kiyi spawning timing and behavior. Therefore, the feasibility for effectively being able to collect Kiyi during spawning for rehabilitation efforts is in question. To help address this knowledge gap, we worked with a commercial fisher to collect Kiyi from late November through mid-January in Southeast Lake Superior over three years. Catch-per-unit-effort was compared across depths and sampling times. We evaluated the spawning status and the gonadosomatic index for these fish with Kiyi collected throughout the rest of the year in standard USGS monitoring efforts to better understand the timing of Kiyi spawning. Kiyi were effectively collected at depths greater than 450 feet. Our preliminary results suggest that Kiyi have a distinct spawning season that begins in mid-December. Our results indicate that Kiyi can be readily collected during spawning, but weather conditions may prohibit collection in some years.

J. JONAS, B. TURSCHAK, Michigan Department of Natural Resources; D. WARNER, U.S. Geological Survey. **The relationship between Growth of coho and Chinook salmon in Lake Michigan and alewife recruitment.**

Chinook and coho salmon are important components of a multi-billion dollar sport fishery. Linkages between the abundance of alewife and growth rates are particularly strong as both species utilize alewife primary prey. We developed cohort based growth models for both species. Model fits to data were strong. There was strong evidence of inter-annual variability in fish size (weight). Seasonal growth patterns were compared at for a given age on Jan 1 and on Sept 15. The greatest change in size occurred for both species at age 1 and changes in size were less pronounced for older fish. Likely due to energetic demands associated with maturing and reproduction. Age 1 alewife abundance was not correlated with the size of Chinook salmon at any age. The size of age 2 coho salmon was strongly correlated with the abundance of age 1 alewife explaining 73% of variation providing a reasonable metric for evaluating year-class and recruitment of alewife to age 1.

S. KOENIGBAUER, Purdue University; T. HÖÖK, Purdue University, Illinois-Indiana Sea Grant. **Intraspecific egg size variation in three Great Lakes fishes.**

The size of eggs a fish produces is related to a balance between potential fecundity and individual offspring provisioning. This balance is expected to vary depending on environmental conditions and life-history strategies. Not surprisingly, intra-specific fish egg size has been observed to vary at population and individual levels, including for some populations in the Laurentian Great Lakes. Between 2018 and 2019, we collected egg samples from spawning cisco (Coregonus artedi),

walleye (Sander vitreus) and yellow perch (Perca flavescens) from Great Lake and smaller inland lake (< 1,000 ha) populations, and compared mean length-adjusted egg diameters intraspecifically among populations. In all three species, we observed variation in egg size across Great Lake populations. We also found that females of smaller inland systems produced larger eggs than conspecifics in Great Lake populations, which suggests that system size may influence egg size variation.

T.E. PITCHER, C. LAJOIE, University of Windsor, Great Lakes Institute for Environmental Research; K. LOFTUS, T. DREW, Ontario Ministry of Natural Resources and Forestry; M.T. ARTS, Ryerson University; R. WEHSE, USFWS. **Differences in egg quality between hatchery-reared and wild-origin bloaters.**

Deepwater cisco species, such as the bloater (*Coregonus hoyi*), were once abundant in Lake Ontario and served as an important prey source for Lake Trout (*Salvelinus namaycush*). In the 1950s, bloaters had been presumably extirpated from Lake Ontario and as such, recent efforts have been made to re establish a self-sustaining population using hatchery-reared bloaters. It is possible that individuals reared in captivity and released in the wild may hinder restoration efforts as they may be maladapted for the wild and have lower reproductive success than wild individuals. In this study, we aim to compare egg quality traits between hatchery reared bloaters and wild-sourced bloaters. Overall, this research will not only help contribute to the restoration of bloaters in Lake Ontario but may also provide insight into the potential reproductive success of hatchery-reared individuals which are frequently used in conservation efforts.

B. TURSCHAK, Michigan DNR; H. BOOTSMA, University of Wisconsin-Milwaukee. **Dietary Niche of Lake Michigan Salmonines as it relates to Alewife Population Structure.**

We explored the niche area and position, diet, and potential for niche overlap of Lake Michigan salmonines from 2014-2016 using stable C and N isotopes. Diet proportions were estimated using Bayesian mixing models and isotopic niche area and overlap were assessed by fitting Bayesian ellipses to the data. From 2014-2016 preferred alewife prey abundance declined while size structure shifted to smaller individuals. Diet and niche responses to changes in Alewife population structure appear to be asymmetric and species specific. Some species appeared to occupy a small niche area across years suggesting specialist feeding behavior whereas other species exhibited large shifts in niche area and overlap. The asymmetry of diet and niche responses among predators suggests that this predator community may be able to partition available resources in the absence of preferred prey.

9. Dual challenge: Nearshore nutrient enrichment and offshore productivity declines

M.J. BURROWS, International Joint Commission, Great Lakes Regional Office; R.E. HECKY, University of Minnesota-Duluth, Biology Department and Large Lakes Observatory; J.F. BRATTON, LimnoTech; J.V. DEPINTO, Retired; M. CHILD, International Joint Commission.
Understanding Declining Offshore Productivity - Findings, Recommendations and Research Implications.

The International Joint Commission's Science Advisory Board completed its report on declining offshore productivity in January 2020. The goal of the study was to confirm and improve understanding of the phenomenon of declining offshore productivity while the Great Lakes are at the same time experiencing symptoms of nearshore nutrient enrichment. This report is a unique compilation of all available information about declining offshore productivity in one document that shows this is a significant issue. Setting targets for nutrient reductions requires an ecosystem-level analysis. Water quality managers must partner with fishery managers to break down information silos and adopt an adaptive management framework that considers the upper and lower food webs. Complex factors that contribute to the observed decline in fish populations are presented. There is not yet a complete explanation for the relationship between the declines in nutrients and offshore fish populations. The SAB-SPC identifies knowledge gaps and recommends an ecosystem approach to solve this puzzle.

D. RUCINSKI, T. REDDER, D. SCHLEA, LimnoTech. **Development of a 3-Dimensional Unstructured Finite Volume Ecosystem Model for Lake Erie.**

Harmful and nuisance algal growth has increased in Lake Erie over the past 15 years, in large part due to high levels of nutrient loading, that are delivered to the lake during spring storms. *Microcystis* blooms in the western basin, "dead zones" in the central basin, and *Cladophora* growth in the eastern basin are threatening drinking water quality, recreation, tourism, and Lake Erie's fishery. As part of Annex 4 of the Great Lakes Water Quality Agreement, the United States and Canada agreed to significantly reduce phosphorus loading to the lake, based on previous modeling studies. However, continued assessment of the ecosystem response on a whole lake basis is needed. Here we develop a state of the science, unstructured finite volume ecosystem model, which will allow investigation of cyanobacteria, hypoxia and benthic algae responses to management scenarios. The model is based on the FVCOM hydrodynamic model, which is linked with an advanced aquatic ecosystem model. Initial calibration performance and model outputs will be presented in the context of management scenarios.

D. SCHLEA, T. REDDER, LimnoTech; Y. HUI, J.F. ATKINSON, University at Buffalo, SUNY; R.S. LAMBERT, D. RUCINSKI, LimnoTech. **Model development for nutrient dynamics in Lake Ontario.**

A whole-lake, linked hydrodynamic-eutrophication model has been developed for Lake Ontario to support future management decisions by providing quantitative evaluation of the relative benefits of potential abatement strategies. The Lake Ontario Ecosystem Model (LOEM) was constructed to provide spatially and temporally resolved cycling of nutrients within the entire lake, including utilization in the nearshore by *Cladophora* and *Dreissenids* and exchange between nearshore and offshore waters. The LOEM was calibrated to water quality data primarily from Cooperative Science Monitoring Initiative (CSMI) efforts in 2013 and 2018. Initial model evaluations performed include whole-lake phosphorus mass balance analyses, sensitivity to tributary nutrient loading, and assessing the impacts of *Dreissenids* on water quality and the lower food web. This presentation will summarize this modeling effort, which was motivated by top priorities for Lake Ontario management, including improving nearshore water quality, dealing with oligotrophic conditions offshore, reducing harmful and nuisance algal blooms, and enhancing coastal resiliency.

H.A. VANDERPLOEG, E. RUTHERFORD, J.F. CAVALETTO, P. GLYSHAW, D.M. MASON, NOAA Great Lakes Environmental Research Laboratory; D. WELLS, University of Michigan, CIGLR. **Effects of Dreissenid-mediated changes in Light and UV Radiation on the Pelagic Food Web.**

Oligotrophication of the Great Lakes from nutrient load reductions and invasive mussel filtration has led to increased light and likely higher relative concentrations of plankton in the metalimnion and below. We hypothesized that increased UV radiation (UVR) also may explain current diel vertical migrations and distributions of organisms. We determined fine-scale diel depth distribution of PAR, UVR, and food web components at offshore sites in Lake Huron and Lake Michigan using a variety of technologies and contrasted our results with vertical distribution of PAR, UVR, and zooplankton and larval fishes determined during the 1980s. In addition to decreased densities of zooplankton and larval fishes, their movement away from near-surface waters is consistent with increased photic depth of UV-A radiation and the higher concentration of plankton in deeper water, where PAR is high enough to support primary production as well as visual predation by larval fish but not Bythotrephes.

X. ZHOU, P. XUE, M.T. AUER, Michigan Technological University, Civil & Environmental Engineering. **Offshore P-forcing of Cladophora growth in the Lake Michigan nearshore: a 1D modeling approach.**

Nuisance conditions of Cladophora growth occur in the Lake Michigan nearshore, absent forcing by local P enrichment. It has been hypothesized that nuisance conditions would be insensitive to control of P discharges to the nearshore because quagga mussels, with access to

offshore particulate P (PP) reserves, could supply the soluble P (SRP) required to support prolific algal growth. We developed a model for quagga mussel - phosphorus dynamics to simulate the impact of offshore - nearshore PP transport on mussel SRP excretion and attendant water column concentrations. In a well-mixed, 1D framework, the model successfully reproduces published mussel biomass, filtration, and SRP excretion rates. The model is applied for conditions at Good Harbor Bay, Lake Michigan, a system with nuisance levels of Cladophora but no local P source. Results indicate that offshore PP supply cannot support rates of SRP excretion required to support nuisance levels of Cladophora growth.

10. The role of monitoring in research

R. SNIDER, A.L. JAMES, Nipissing University, Geography; H. YAO, Ontario Ministry of Environment, Conservation and Parks. **Chloride and total phosphorus budgets for Lake Nipissing and the French River tributary of Georgian Bay, Lake Huron.**

Water quality of major inflows to Lake Nipissing, the seventh largest inland lake in Ontario, are only available from the mid-1960s to 1990s. During 2015-2018, we conducted monthly water quality surveys of inflows and have generated nutrient budgets for chloride (Cl^-) and total phosphorus (TP). Trend analyses indicate decreasing TP concentrations, but select inflows continue to exhibit concentrations above provincial objectives, including provincially unmonitored inflows. Surveys also showed higher average Cl^- concentrations than historical records for some inflows. Increasing Cl^- trends for winter (Oct-Apr) and summer (May-Sept) periods suggest that road salt application in this region may be affecting streamflow throughout the year. Water and nutrient budgets indicate that while specific runoff ($l/s/km^2$) is quite similar across catchments, select high yield catchments with urban and agricultural activities exist where Cl^- and TP are disproportionate sources to the lake. We anticipate this first effort to quantify annual nutrient budgets of Lake Nipissing will be of value for regional water resource managers.

A. RITZENTHALER, G. CUTRELL, E. VERHAMME, LimnoTech **Use of NuLab Instruments in the Great Lakes Region for Real-Time Nutrient Monitoring.**

Traditional nutrient monitoring programs are labor and resource intensive. Just one monitoring event can sometimes require two or more days of effort by one or more staff members in order to collect and analyze samples. The use of autonomous instruments can transform a monitoring program by allowing for continuous, in-situ nutrient monitoring, providing results in real-time. This presentation will discuss three recent case studies where nutrients were monitored in lake and riverine systems via autonomous instruments (i.e NuLabs), using well-established wet chemistry methods, in order to provide water resource managers real-time data.

11. Physical processes in lakes

J.A. AUSTIN, University of Minnesota, Duluth, Large Lakes Observatory; C. HILL, University of Minnesota Duluth, Mechanical and Industrial Engineering; G.L. WEBER, K. WEISS, University of Minnesota, Duluth, Large Lakes Observatory, Physics; J. FREDRICKSON, University of Minnesota, Duluth, Large Lakes Observatory. **Radiatively Driven Convection in a deep lake: the 2019 field season**.

A field campaign was carried out in May-July 2019 in order to better characterize spatial and temporal scales of variability during radiatively driven convection. The moored assets deployed consisted of a large 2-dimensional mooring, carrying 18 thermistors arrayed along a 180-long headline as well as 5 vertical lines suspended from the headline with another 30 thermistors; a meteorological buoy carrying instrumentation to carefully measure surface heat and momentum fluxes; a spar buoy carrying 6 more thermistors close to the surface; and an ADCP mooring with an upward-looking 5-beam ADCP. The field site was in western Lake Superior, approximately 50 km from the nearest coast, and in a region of relatively featureless bathymetry with a depth of approximately 180m. Upon deployment in May, the water column was inversely stratified with a surface mixed layer on the order of 80m thick. By early June, the water column became homogeneous, and the lake formed stable positive stratification in early July. Comparison of the vertically integrated heat content and surface heat flux suggest that advection plays an insignificant role in variations in temperature.

J. FREDRICKSON, J.A. AUSTIN, University of Minnesota, Duluth, Large Lakes Observatory.
Horizontal temperature variability during radiatively driven convection in Lake Superior.

Prior to positive stratification, Lake Superior undergoes a period of radiatively driven convection (RDC) following ice cover when the water mixes fully vertically. While horizontal scales are traditionally assumed to be large compared to vertical scales, previous data has suggested the opposite during the RDC period. To address this variability, a "horizontal mooring" was employed with temperature recorded laterally every 10 meters on a headline at a depth of roughly 34 meters. Correlation analysis of the temperature measurements suggests decorrelation scales on the order of tens of meters with significant day-to-day variability. Propagation of warmer water packets along the headline indicate potential convective cells traveling past the headline, and bi-directional behavior could indicate internal seiches. Finally, meteorological data collected nearby indicates shortwave radiation drives temperature variability rather than wind forcing during the fully mixed, RDC period.

L. GIRIHAGAMA, University of Toronto Scarborough, Department of Physical and Environmental Sciences; E.T. HOWELL, Ontario Ministry of Environment, Conservation and Parks, Environmental Monitoring and Reporting Branch; K. LI[1], M. WELLS, University of Toronto

Scarborough, Department of Physical and Environmental Sciences. **Physical circulation in the coastal zone of a large lake controls the benthic biological distribution.**

There are gradients of conductivity and major ions in the coastal zone of Eastern Georgian Bay of Lake Huron that appear to limit the spatial distribution of invasive *Dreissena* mussels. Rivers flowing into Georgian Bay from the Canadian Shield are relatively low in conductivity compared to the main body of Lake Huron, and so there is an observed gradient of solutes near the river mouths. The field observations show a strong positive correlation between conductivity and calcium concentration. Thus, we use conductivity to infer the solute concentrations required for successful growth of *Dreissena*. We find that no mussels exist for specific conductivities less than 140 mS/cm. We use field observations to examine the hydrodynamics features of these freshwater estuaries ("*freshtuaries*") which account for the calcium gradients that determine mussel distribution. Our results suggest that a weak solute gradient across the coastal zone, indicating intrusion of open bay waters in to the shallow embayments is favourable for growth of mussels. In contrast a strong solute gradient with broader onshore-offshore gradients of low calcium inhibit and limit growth of dreissenid mussels. The dynamic character of these solute gradients help account for the varied occurrence of *Dreissena* which has strong implications for adverse impacts of this invasive species on nearshore ecology and on human infrastructure

T. HOLLENHORST, EPA Mid-Continent Ecology Division; S. MOEN, Minnesota Sea Grant; R. STERNER, University of Minnesota Duluth, Large Lakes Observatory; N. LANGSTON, Michigan Technological University. **Early Studies of Lake Superior Nutrients, Productivity, and Currents 1956-1961. St. Louis River Summit, Superior, WI, March 5-6, 2019**.

In 1956 the Minnesota Department of Health asked the School of Public Health of the University of Minnesota to conduct a limnological study of Lake Superior. The original planning of the project was conducted in conference with individuals now widely recognized as early leaders in the fields of limnology, oceanography and environmental health. These included Dr. Athelstan F. Spilhaus, who conceptualized the National Sea Grant Program; Dr. Gaylord W. Anderson, the first dean of the UMN School of Public Health; and Dr. Alfred C. Redfield of Woods Hole Oceanographic Institute and the discoverer of the Redfield ratio (which describes the ratio between nutrients in plankton and ocean water). Dr. Redfield acted as a consultant to the project and provided a detailed memorandum regarding the development of a limnological institution for the continuous long-term study of Lake Superior. Since 1994, the Large Lakes Observatory at UMD has performed cutting-edge science on Lake Superior and other large Lakes of Earth, a mission rooted in Redfield's recommendation. Dr. Theron O. Odlaug, founding member of the UMN Department of Biology, also prepared a bibliography and abstracts of Great Lakes literature extending as far back as 1829. This poster will highlight the studies initiated in 1956, their results, and their relevance for current Great Lakes research. This presentation reviews some historical research conducted on Lake Superior. Much of it has the potential to inform current work EPA-MED conducts in the Great

Lakes and Lake Superior in particular. Reviewing this work, the type of sampling and locations may provide some useful comparisons and relevance for our current research efforts.

S. LIN, L. BOEGMAN, R. MULLIGAN, Queen's University, Department of Civil Engineering; S. SHAN, Royal Military College of Canada, Department of Physics and Space Science. **Predictive simulations of physical processes and water quality of Lake Erie.**

With the proliferation of data online in real-time, the real-time and forecast models can be setup without a need to work closely with the agencies that collect data. To enhance public safety and water resource management, we applied the AEM3D model in realtime and forecast mode to Lake Erie, driven by high resolution (10 km and 25 km) meteorological boundary forcing data from Regional Deterministic Prediction System (RDPS) and Global Deterministic Prediction System (GDPS), respectively. Hydrodynamic lake processes were resolved on a 500 m horizontal grid. By enabling the water quality module within AEM3D, the model is being developed to provide forecasts of harmful algae blooms, hypoxic events, and distributions of fish habitat, as well as other key water quality indicators required for management.

J.B. MCINERNEY, A. FRIEDRICHS, A.L. FORREST, University of California Davis, Department of Civil and Environmental Engineering; Tahoe Environmental Research Center; J.A. AUSTIN, University of Minnesota, Duluth, Large Lakes Observatory. **Autonomous measurements of turbulence associated with radiatively-driven convection in Lake Superior.**

Radiatively-Driven Convection (RDC) causes significant mixing in large lakes in cold climates through volumetric heating at temperatures below the temperature of maximum density (3.98 °C). This process is typically initiated with ice cover present and continues following ice-off independent of mixing driven by wind shear. Previous observations of RDC in Lake Superior have been made by mooring and autonomous underwater gliders, indicating the chimney-like structures expected by convection cells down to significant depths (>100 m). In June 2019 we deployed a buoyancy driven Autonomous Underwater Vehicle (e.g. Slocum glider) equipped with a MicroRider package to collect measurements of the radiatively-driven convection structure and turbulence kinetic energy dissipation associated with the resulting mixing. Our glider completed repeat transects along a 6 km north-south line in Lake Superior.

A. SAFAIE, H. FIROUZEH, A.P. JAMAAT, Sharif University of Technology, Department of Civil Engineering. **The effect of Caspian Sea water-level drop on physical processes of coastal wetlands associated with the lake.**

Water levels on the Caspian Sea, which is the world's largest inland lake, are on the dramatic decline with the rate of 3 inches per year. Dropping Caspian Sea Levels have had significant impacts on coastal wetlands associated with the lake. Anzali Lagoon in the southern part of the Caspian Sea represents one of the most extreme cases reported in recent years. The aquatic ecosystem of the

wetland is endangered due to climate changes and anthropogenic activities and climate changes. In this project, we attempt to explore the physical processes involved in this issue using a detailed three-dimensional hydrodynamic model combined with remote sensing observations. Results show that a wave breaker of the wetland built into the lake plays a very important role in controlling the flow pattern and sediment transport of the wetland. Moreover, the wetland area has been decreasing as the Caspian Sea water level decreases, and less water enters the wetland from the lake than leaves it.

J. TUYISENGE, Energy Development Corporation Limited, Lake Kivu Monitoring Programme; S. MACINTYRE, University of California Santa Barbara, Department of Ecology, Evolution and Marine Biology; A. VAN DAM, G. GETTEL, IHE-Delft Institute for Water Education, Department of Water Science and Engineering. **Assessment of the temporal mixing and stratification in Lake Kivu, East Africa.**

Vertical mixing, stratification and indices of water column stability were described for upper 100 m of Lake Kivu in 2015-2017, using the surface meteorological and the CTD data. Indices were calculated from temperature and density data. A seasonal signal, observed from May to August, was mainly characterized by a decrease of the relative humidity to ~ 70% and that of longwave radiation to ~ 370W/m^2. The mixed layer was nearly isothermal in the morning conditions and stratified in afternoons as a result of sun heat accumulation. The seasonal mixing reached ~55m depth when the water column was cool with 23.4°C. The Chlorophyll fluorescence and the dissolved oxygen remained high and shallow during stratification. The pH varied significantly at 60m, chi sq=34.409, d.f.=3, $p < 0.001$. The hypolimnetic temperatures, showed a warming trend of 0.016°C/year. High buoyancy frequency (18cph) and Schmidt stability (11kJ/m^2) were observed during the stratification period. The Wedderburn number ranged from 1 to 22. The mixolimnion of Lake Kivu is weakly stratified during the dry-mixing season and moderately stratified during the wet-stratification period.

K. WEISS, University of Minnesota, Duluth, Large Lakes Observatory, Physics; J.A. AUSTIN, University of Minnesota, Duluth, Large Lakes Observatory; E.J. ANDERSON, NOAA, Great Lakes Environmental Research Laboratory. **Observations of large-scale advective events in Lake Superior.**

Between 2009 and 2011, several moorings spanning the full water column measured temperature at various locations in Lake Superior. During fall months, the moorings recorded events of sudden and total restructuring of the water column. In a dramatic case, water with temperature characteristic of 30-50m depth rapidly appears at 350m. Simultaneous changes in local heat content suggest large-scale advection of warmer water. In certain cases, stratification remains heavily modified until winter homogenization. The events generally occur 48hrs after high winds, preferentially in regions of irregular bathymetry, and independently at mooring locations. To further explore the internal structure of the lake surrounding these phenomena, numerical model output

(FVCOM) is employed. Model output suggests conditions favorable for such restructuring events: significant horizontal variability in vertically integrated heat content at the 10-100km scale that can persist and migrate for multiple weeks.

M. WELLS, Y. KUAI, University of Toronto Scarborough; D. WEBBER, S. SMEDBOL, VEMCO.
Influence of thermal stratification upon acoustic telemetry range in large lakes.

Vertical Speed of sound gradients can influence lateral sound propagation, thus influencing the functioning of acoustic telemetry arrays used to monitor fish. The speed of sound in lakes is primarily a function of water temperature. The seasonal thermal stratification in the Great Lakes represents the strongest speed of sound gradients in any aquatic system. These speed of sound gradients can act the refract sound waves (via Snell's law), leading to greater divergence of acoustic signal, and hence more rapid attenuation. We interpret data from an acoustic telemetry array in Lake Ontario so show that changes in acoustic detection range correlate strongly with changes in stratification.

12. Phytoplankton research in the Great Lakes

E.E. ALEXSON, H.A. WELLARD KELLY, E.D. REAVIE, L.R. ESTEPP, M.N. ALIFF, University of Minnesota Duluth, Natural Resources Research Institute. **What is it and what does it mean? Challenges in Great Lakes diatom taxonomy.**

Because of their utility as environmental indicators, diatoms play an important role in the management of the Great Lakes. Accurate taxonomy = accurate environmental information, but challenges remain in diatom taxonomy despite extensive work. Analyst artifacts and confusion around the taxonomy of cosmopolitan species remain prevalent. We hope to resolve these issues with progressive scrutiny of diatom taxonomy and other phytoplankton comprising the critical primary producer community. Recently, we examined a group of small cyclotelloids and confirmed an undescribed species, Pantocsekiella laurentiana sp. nov., that is prolific in summer assemblages, especially in warmer, stratified surface waters resulting from atmospheric warming. Now, we investigate several common species of Synedra: S. radians, S. ostenfeldii, and S. filiformis and its questionable variety exilis. High-resolution microscopy along with a morphometric analysis were conducted, and analyses reveal differences in valve morphology that allow us to distinguish the species and provide documentation of these complex, yet abundant, species.

A.J. BRAMBURGER, Environment and Climate Change Canada, Watershed Hydrology and Ecology Research Division; E.D. REAVIE, University of Minnesota Duluth, Natural Resources Research Institute. **Resolving the Variability of Phytoplankton Stable Isotope Signatures in the Great Lakes.**

When trophic ecologists create food web ordinations using stable isotope data, the phytoplankton are often represented by a single point, usually surrounded by enormous error bars for both ^{13}C and ^{15}N axes. These error bars bely the fact that "phytoplankton" is a catch-all terms for a group that, particularly when including other sexton, harbors more taxonomic and functional diversity than the rest of the food web combined. Here, we used phytoplankton collected during USEPA Great Lakes Biological Monitoring Program and CSMI cruises to explore spatial, temporal, and size fractionated patterns of algal stable isotope composition. We found marked lake-to-lake and seasonal differences in both ^{13}C and ^{15}N signatures, as well as differences between seston of different size classes (3.0 um, 0.22 um) at single sites. Typically, the smaller size fraction showed a more enriched ^{15}N signature and a more depleted ^{13}C. Differences in ^{15}N between size fractions within a station could be up to a whole trophic level. These results indicate that the taxonomic makeup and function of the phytoplankton can have a profound influence on stable isotope signatures.

A. CHIANDET, Severn Sound Environmental Association. **Climate change, invasive species and nutrients, oh my! Drivers of algae dynamics in Severn Sound.**

A clear regime shift occurred in the mid-90s in Severn Sound, Georgian Bay, marked by dramatic increases in light penetration and reductions in ambient total phosphorus caused by the introduction of dreissenid mussels and reduced phosphorus loading from watershed sources. Long-term monitoring indicated that this shift impacted biomass and community composition of phytoplankton communities. Since the 1970s, and particularly immediately after the shift, phytoplankton biomass declined dramatically, and species composition shifted to include increasing dominance by Chrysophytes and a decrease in diatoms. Since the mid-90s, year-to-year variability in community structure has increased while total biomass has been stable or in some cases has increased. Factors such as water temperature and nutrients are examined along with food web interactions. The impact of changes in taxonomists on interpretations of long-term biological datasets is also discussed. Results will improve understanding of the current ecological state of Severn Sound, and the implications of future changes due to climate change and continued shifts in the lower food web.

C. GOLTZ, University of Winnipeg, Geography; A. CHICOINE, University of Saskatchewan; H. JAEGER, University of Missouri; H. JOVANOVIC, Wilfrid Laurier University; H. KEY, E. KINZINGER, University of Missouri; H. BAULCH, University of Saskatchewan, School of Environment and Sustainability; N. CASSON, University of Winnipeg, Geography; R.L. NORTH, University of Missouri, School of Natural Resources; J.J. VENKITESWARAN, Wilfrid Laurier University, Department of Geography and Environmental Studies; C. WHITFIELD, University of Saskatchewan. **Impacts of nitrogen on cyanobacterial harmful algal blooms in eutrophic water bodies.**

Cyanobacterial harmful algal blooms (cyanoHABs) in surface waters are a global problem caused by anthropogenic nutrient loading to water bodies. Cyanobacteria produce cyanotoxins such as microcystin, which can be extremely harmful to aquatic life within the lake as well as to the surrounding organisms. The magnitude of cyanoHABs and the production of cyanotoxins is influenced not only by total nutrient loading, but also by the form of N present in water bodies. How the form of nitrogen (N) influences cyanotoxin production has become particularly pressing given shifts in agricultural practices towards urea-based fertilizers. The purpose of this research was to evaluate how different forms of nitrogen (nitrate, ammonium, urea) affect algal biomass and the production of microcystin in North American water bodies. Water samples were collected from 5 eutrophic water bodies in different geographic locations, and were incubated under ambient light and temperature regimes for 9 days. The results indicate that chlorophyll a and microcystin concentrations depended both on the initial conditions at the various study sites as well as the forms of N added.

N. JANATIAN, Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences & Department of Evolutionary Biology, Ecology and Environmental Sciences, University of Barcelona; P. NÕGES, Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences. **Atmospheric stilling offsets the benefits from reduced nutrient loading in a large shallow lake**.

Yet another climactic phenomenon that has received less attention than warming is the 'atmospheric stilling.' To look into the effects of this stilling on phytoplankton in Lake Võrtsjärv, we applied the Nonmetric Multidimensional Scaling (NMDS) ordination on the 54-year (1964–2017) phytoplankton community composition time-series. The NMDS results distinguished three periods in which transitions matched with the jumping points in wind and/or water level time series. We demonstrate that stilling caused a decline in the suspended sediment levels in the lake, which created a "light niche," that was capitalized and filled by the shade-tolerant phytoplankton community. We suggest that wind stilling is another global factor, supplementary to climate warming, which may counteract measures of eutrophication abatement in lakes and can represent a new challenge for reaching the good ecological status of light-limited shallow lakes.

A. KNIGHT, University of Guelph, School of Environmental Sciences; X. ORTIZ, Ontario Ministry of Environment, Conservation and Parks, Environmental Science and Standards Branch; S. BHASVAR, Ontario Ministry of Conservation and Parks; R.S. SHAHMOHAMADLOO, P.K. SIBLEY, University of Guelph, School of Environmental Sciences. **Transgenerational development of microcystin toxin tolerance in Daphnia magna.**

The increased frequency and severity of harmful algal blooms (HAB's) has had devastating impacts on water quality and ecosystem health in aquatic ecosystems globally. Zooplankton species may be impacted by the release of microcystin toxins during these blooms, affecting reproductive

output, growth, and survival. To better understand the impacts of prolonged exposure, a multi-generational reproductive study was conducted with Daphnia magna and M. aeruginosa to study the effects of five generations of cell-bound microcystin exposure in chronic and acute exposures. Results displayed a gradual improvement of fitness and survival in Daphnia progeny with previously exposed mothers, indicating the evolution of a toxin tolerance through maternal transfer. Concurrent exposure to a non-toxic M. aeruginosa strain also appeared to provide a competitive advantage for *Daphnia*, contrary to other observations in the literature. Our research provides insight to better estimate the future and long-term impacts of HAB's on zooplankton community composition and abundance

J. HAMPEL, University of Southern Mississippi; M. STEFFEN WURCH, James Madison University; M. MCCARTHY, S. NEWELL, Wright State University, **Resource scarcity: heterotrophic bacteria aid in Microcystis dominance.**

Large, shallow lakes are commonly afflicted with seasonal, cyanobacteria-dominated, harmful algal blooms (HABs). Relationships between cyanobacteria and co-occurring, heterotrophic bacteria are documented, and the physiology of Microcystis colonies, in particular, lends itself to tight associations with heterotrophic bacteria. Here, we present community and kinetic ammonium uptake rates from HABs in large lakes Taihu (China), Erie and Okeechobee (USA), and Peipsi (Estonia). We compare these data with uptake kinetics from axenic Microcystis cultures, co-cultures, and bacterial isolates from Microcystis-dominated blooms. Results suggest that bacterial partners with high affinity for ammonium may increase the competitiveness of Microcystis. HABs in every system investigated were nitrogen-limited and dominated by non-nitrogen-fixing taxa, despite high rates of ammonium regeneration. Thus, microbially-mediated nitrogen recycling represents an important nitrogen supply fueling HABs.

P. PILKINGTON, Brock University, Earth Science; A. KRUEGER, Brock University, Biological Sciences; C. GARNER, Brock University; F. MCCARTHY, Brock University, Earth Sciences; K. KORNECKI, Griggs-Lang Consulting Geologists and Engineers, P.C.; M. Katz, Rensselaer Polytechnic, Earth and Environmental Science. **Algal and cyanobacterial palynomorphs as proxies of environmental change in the Great Lakes.**

Vegetative and resting stages of green algae, dinoflagellates, and cyanobacteria are common in macerations for pollen analysis. Taxonomic and taphonomic challenges limit their exploitation as paleolimnological proxies, however. Recent investigations in Lake George, NY have attempted to identify all non-pollen palynomorphs in lakebed and core sediments using various phycological and palynological resources. Palynological assemblages in lakebed sediments were related to the phytoplankton in the water column and in sediment traps, and to measured variations in water quality across the basin of this large, narrow lake. Comparison with better-understood microfossils (diatoms and testate amoebae) in sediments confirms that the acid-resistant remains of

phytoplankton reflect limnological conditions in the water column and on the lakebed. Abundant eutrophic taxa, such as *Botryococcus*, *Anabaena, Microcystis* and *Peridinium* spp., in *Ambrosia*- rich sediments in a core near the DFWI monitoring station off Tea Island, record recent anthropogenic impact in southern Lake George, including evidence of a 19th C mass wasting and 20th C fire events.

E.D. REAVIE, K.E. KOVALENKO, University of Minnesota Duluth, Natural Resources Research Institute. **Phytoplankton communities are prone to analyst error. What is the impact on environmental interpretations?**

Inter-operator differences in taxonomy and counting techniques are the primary sources of uncertainty in taxonomic assessments of algae. Great Lakes phytoplankton communities are complex in space, time and overall diversity, and so consistency in phytoplankton assessments can be problematic without taxonomic harmonization among analysts. Paired comparisons of community analyses from 235 Great Lakes phytoplankton samples revealed an average Bray-Curtis similarity of 83% between analysts, meeting the USEPA requirement of 60% similarity. Similarities were poorer in more diverse phytoplankton samples. Application of an algal-based model to infer lakewater P indicated no effect of analyst error on inferred water quality. Analyst dissimilarities were much smaller than ranges in phytoplankton abundance observed in long-term changes in the monitoring program, indicating that analyst bias has little impact on our ability to track changes. Substantial analyst training and taxonomic harmonization is critical to ensure consistency in phytoplankton assessments, but current protocols appear to meet the needs of a program to support lake management.

13. Exploring Great Lakes diversity: Using traditional and genetic approaches

S.M. BERGSON, M.D. RENNIE, Lakehead University, Biology; A. THOMSON, Lakehead University, Natural Resource Management; M. CRISTESCU, McGill University, Biology; M.J. PATERSON, IISD Experimental Lakes Area. **Abundance, Transportation, and Preservation of *Mysis diluviana* eDNA in Freshwater Ecosystems.**

Environmental DNA (eDNA) has proven to be a useful tool in the detection of rare or invasive species, particularly within the Great Lakes and surrounding systems. Recent work has shown that eDNA in lake sediment (lake sedDNA) can demonstrate changes in community composition, and potentially be used to provide restoration guidelines for impacted ecosystems. In this study, we determined the effectiveness of both water eDNA and lake sedDNA sensitivity to Mysis diluviana, a small freshwater crustacean that inhabits the Laurentian Great Lakes and many deep cold-water lakes across North America. Mysis sedDNA are extracted from gravity and freeze cores collected from three lakes at the IISD- Experimental Lakes area in Northeastern Ontario. Sections of the cores are tested using quantitative polymerase chain reactions (qPCR) to evaluate

preservation and down-core activity of extracted Mysis eDNA. To determine seasonal variation that may affect sedDNA distribution, water samples from the corresponding lakes and outflowing streams are also assessed. Preliminary results show presence of Mysis within the top sediment layers of cores in lakes where Mysis are present.

S. CREVECOEUR, Environment and Climate Change Canada, Canada Centre for Inland Waters; J. COMTE, Institut National de la Recherche Scientifique, Centre Eau Terre Environnement; L. WATSON, Environment and Climate Change Canada; A. DOVE, A. ZASTEPA, Environment and Climate Change Canada, Canada Centre for Inland Waters; T.A. EDGe, McMaster University, Biology. **Spatial and temporal variation of the aquatic microbiome along the Thames River-Lake St. Clair-Lake Erie corridor.**

Lake Erie is heavily impacted by urban and agricultural nutrient loading and face recurring events of cyanobacterial harmful algal blooms (cHAB). Measures of nutrients and total phytoplankton biomass alone seem to be poor predictors of cHABs. Therefore, a more integrated approach at the watershed scale assessing the linkages between Lake Erie and the surrounding watershed microbiomes may improve our understanding of the conditions that lead to bloom formation. Here we used high-throughput DNA sequencing to characterize the spatial and temporal variation of the aquatic microbiome in the Thames River - Lake St-Clair - Lake Erie corridor. We found that the microbiome was structured along the flow path, dominated by the same main bacterial phyla. However, there was a clear shift in the cyanobacterial community, which changed from being dominated by Planktothrix in the Thames River to Microcystis and Synechococcus in Lake St. Clair and Lake Erie. Ultimately, the results will improve our comprehension of the origin and composition of the aquatic microbiome in the Lake Erie basin and will provide new perspectives on how to better predict the occurrence of cHABs.

S.E. DANIEL, L. BURLAKOVA, A. KARATAYEV, SUNY Buffalo State, Great Lakes Center; P.D. HEBERT, Centre for Biodiversity Genomics; M.E. PFRENDER, University of Notre Dame, Department of Biological Sciences & Environmental Change Initiative; D. LODGE, Cornell University; A. TREBITZ, U.S. EPA, ORD/NHEERL/MED. **Great Lakes DNA Barcode Reference Library: Mollusca, Annelida, and Minor Phyla.**

DNA-based tools have been improved greatly in recent years and can increase the scope of diversity surveys and detection of aquatic invasive species compared with traditional approaches. The development of complete species-specific libraries of DNA signatures is an essential step to enable taxonomically rich and spatially extensive species surveillance and monitoring. The Great Lakes Center at SUNY Buffalo State aims to expand the taxonomic coverage of The Barcode of Life Database (BOLD) DNA library and has assembled a collaborative team including leading barcoding and taxonomic experts for targeted taxa. By preliminary estimations, 70% Annelida, 34% Bivalvia, and 56% Gastropoda, and 70% minor phyla known from the Great Lakes lack barcodes.

Collaborators have identified nearly 1000 specimens that have been plated and sent in for genetic barcoding. This presentation will focus on identifying possible cryptic species, and describing shortcomings and difficulties in genetic barcoding. Additionally, we will discuss progress made by our partners from Cornell.

V. ITSKOVICH, Limnological Institute of the Siberian Branch of the Russian Academy of Sciences.
Endemic sponges of Lake Baikal – evolution and stress response.

Endemic sponges are dominant components of the benthos community in Lake Baikal. Two families of freshwater sponges inhabit the lake: Lubomirskiidae, an endemic family, and Spongillidae with a world-wide distribution of many genera. Species identification of Spongillidae and Lubomirskiidae are complicated due to the limited number of morphological features and lack of information employed for taxonomy. The extant Lubomirskiidae currently comprise four genera, 14 species and 2 subspecies. The aim of this research was to study the variability of internal transcribed spacers (ITS) of rDNA in the families Lubomirskiidae and Spongillidae to determine the effectiveness of using ITS sequences to differentiate species and study the evolution of sponges in Lake Baikal. ITS1 and ITS2 were analysed for 28 samples of Spongillidae. Phylogenetic reconstructions revealed monophyly of genera Eunapius and Radiospongilla,and species Ephydatia fluviatilis, Ephydatia muellery, and Spongilla lacustris.

14. Great Lakes plastic pollution: Addressing knowledge gaps and informing action

E. ANDERSON, Ocean Wise Conservation Association, Great Canadian Shoreline Cleanup.
Taking action on plastic pollution in the Great Lakes.

Since 1994, the Great Canadian Shoreline Cleanup has engaged more than 850,000 Canadians and removed over 1.7 million kg of litter through volunteer-led shoreline cleanups. This national cleanup is a conservation partnership of Ocean Wise and WWF-Canada and is one of the largest direct-action conservation programs in Canada. From the long-term data our volunteers have collected in major Canadian cities situated along the Great Lakes, we see that most items fall within the category of single use plastics. Plastic negatively impacts various species in the Great Lakes as a result of ingestion, entanglement or habitat destruction. With the citizen science data collected through our program, we can play a role in developing long-term solutions to this issue. For example, our program was used to support a draft resolution urging stakeholders to act on plastic pollution, contributed to monitoring efforts for various campaigns, and has also been used to help governments target specific types of single-use plastics for reduction or banning. By reviewing the policy actions implemented in response to the data, it is time to consider whether the response is enough.

B.E. BODENBENDER, A.E. OLGERS, A.F. VAIANA, Hope College, Department of Geological and Environmental Sciences. **Wrack and ruin: Plastic litter and microplastic on four beaches along southeastern Lake Michigan.**

We characterized microplastic and plastic litter on four beaches between Holland and Saugatuck, MI, including groomed public and private sites and ungroomed nature preserve sites, to assess sources, transport, and deposition of plastic debris. At each, we sampled visible plastic litter along 7 1-m wide transects perpendicular to the shoreline and collected ~500 ml sediment samples from swash zone, lower beach, wrack zone, upper beach, and/or foredune locations to process for microplastics. At all sites, industrial nurdles suggest distant sources for some plastic and 93-99% of plastic and microplastic pieces float in water. Litter and microplastics are most abundant in wrack zones (max. 128.7 litter pieces/m^2 and 31.9 microplastics/kg vs. max. 21.7 and 10.0 respectively for other zones), with highest accumulations on ungroomed beaches. Beach wrack may indicate depositional areas on the shore or may facilitate accumulation of plastics that would otherwise blow or wash lakeward or inland.

K.M. CHOMIAK, Rochester Institute of Technology, Thomas H. Gosnell School of Life Sciences; M.J. HOFFMAN, Rochester Institute of Technology, School of Mathematical Sciences; N. EDDINGSAAS, N. CLARK, Rochester Institute of Technology, School of Chemistry and Material Sciences; C. TYLER, Thomas H. Gosnell School of Life Sciences. **Impact of microplastics on benthic ecosystem metabolism and nutrient regeneration.**

A growing body of literature illustrates the prevalence of plastic pollution in Lake Ontario and transport models predict that many plastics may sink to the bottom. Among the most common plastics found in Great Lakes sediments are polyethylene terephthalate (fibers; PET), polyvinylchloride (particles; PVC), and styrene-butadiene rubber ("crumb rubber"; SBR). These materials can promote lethal or sublethal effects on organisms, but impacts on benthic biogeochemistry is largely unknown. We used a microcosm approach to evaluate the impact of these three plastic polymers on benthic ecosystem function, using sediments from Irondequoit Bay, a major embayment of Lake Ontario. Following a 30 d incubation of sediments with and without plastics, we measured fluxes of oxygen and nutrients, benthic chlorophyll, and potential denitrification. PET has a significant negative impact on benthic metabolism, suggesting cascading impacts on the regeneration and removal of nutrients. These interactions are a key component to achieving a more complete understanding of transport, impact and fate across the microplastic life cycle in the freshwater environment.

J.M. DAILY, M.J. HOFFMAN, Rochester Institute of Technology, School of Mathematical Sciences; C. TYLER, Thomas H. Gosnell School of Life Sciences; N. EDDINGSAAS, Rochester Institute of Technology, School of Chemistry and Materials Science. **Modeling Three-Dimensional Microplastic Distribution and Deposition in Lake Erie.**

Mass estimates of plastic pollution in the large bodies of water based on surface samples differ by several orders of magnitude from what is predicted by production and input rates. This indicates the importance of accounting for vertical mechanisms driving movement for improved mass estimates. Additionally, as plastic moves away from the surface, it is likely accumulating at lower depths or in the benthos, dictating which organisms are exposed, yet the vertical distribution remains not well understood. Here we present a three-dimensional modeling effort in the Great Lakes to incorporate vertical diffusion and non-neutrally buoyant particles representing different polymer types. This work allows for improvements to existing mass estimates in Lake Erie and a first pass sediment deposition rate. Additionally, we include a first pass model for biofouling of particles and investigate the impact on distribution of particles through the water column.

A. EARN, K. BUCCI, C. ROCHMAN, University of Toronto, Department of Ecology and Evolutionary Biology. **A critical review of the literature on plastic pollution in the Great Lakes and its effects on freshwater biota.**

Plastic pollution is ubiquitous in freshwater systems worldwide and the Laurentian Great Lakes are no exception. We conducted a systematic review to synthesize the current state of the literature on plastic pollution in the Great Lakes. Thirty-three publications were used in our systematic review. Within this data, we found microplastic contamination of the surface water, sediments and beaches of the Great Lakes with maximum surface water abundances comparable to those in the ocean's garbage patches. We used citizen science data to reveal the abundance of macroplastic debris on the Great Lakes shorelines: 3 million pieces of plastic litter were collected over two years across the shorelines of the five lakes. We completed a second systematic review of the literature on plastic pollution and its impact on freshwater ecosystems to inform how plastic in the Great Lakes may impact wildlife. From this data, we found 390 tested effects, 234 (60%) of which were detected and 156 (40%) that were not; most effects (>98%) were tested on microplastics. Finally, we identify the gaps in scientific knowledge and discuss how the state of science can inform management strategies.

H. MCILWRAITH, University of Toronto; M. DIAS, Queens University; K. BUCCI, University of Toronto, Department of Ecology and Evolutionary Biology; K. GEILS, Lakehead University; A. HARRISON, Queens University; M.J. HOFFMAN, Rochester Institute of Technology, School of Mathematical Sciences; N. MALLOS, Ocean Conservancy; M.J. PATERSON, IISD Experimental Lakes Area; J. PROVENCHER, ECCC; M.D. RENNIE, Lakehead University, Biology; E. TEBOUL, D. ORIHEL, Queens University; C. ROCHMAN, University of Toronto, Ecology and Evolutionary Biology. **Assessment of microplastic contamination at the IISD-ELA along a gradient of anthropogenic activity.**

Microplastic contamination is ubiquitous across the globe, even in remote locations. Still, the mechanisms of microplastic transport to such locations are largely unknown. To investigate microplastic contamination and transport in a remote location, we investigated microplastics in several lakes at the IISD-Experimental Lakes Area. In Summer 2019, we sampled surface water, atmospheric fallout, and sediments from four to nine lakes. Lakes were selected based on three levels of anthropogenic activity: low, medium, and high. We aimed to test the relationship between anthropogenic activity and microplastic contamination. If we found a positive correlation, then local anthropogenic activity is a likely source. However, if there is no relationship, atmospheric transport may be a greater source of microplastics to these remote boreal lakes. Preliminary results suggest a lack of correlation. Results to date will be provided here, increasing our understanding about the global fate and transport of microplastics.

K. SMYTH, J. DRAKE, University of Toronto, Department of Civil and Mineral Engineering; C. ROCHMAN, University of Toronto, Ecology and Evolutionary Biology; E.N. PASSEPORT, University of Toronto, Departments of Civil Engineering & Chemical Engineering and Applied Chemistry. **Efficiency of a bioretention cell for microplastics removal from stormwater.**

Most microplastics research focuses on the marine environment, however upstream sources specifically stormwater have received little attention. Furthermore, only one study to date evaluates bioretention cell efficiency to remove microplastics from stormwater. The present study identified microplastic concentrations and polymer types at the inlet and outlet of a bioretention cell at the Kortright Centre for Conservation in Vaughan, Ontario. Over the summer and fall of 2018 and 2019, stormwater samples were collected from 23 rain events. Samples were size fractioned, density separated and visually counted before Raman spectroscopy analysis. Statistically significant decreases in microplastic concentration and loads were observed between the inlet and outlet of the bioretention cell, from 196 +/- 190 at the inlet to 57 +/- 33 particles/L at the outlet. As the size range of microplastics decreased from > 1mm, 500 um - 1 mm, 300 um - 500 um, to 106 um - 300 um, the microplastics concentration increased. Samples consisted primarily of microfibers. Overall, bioretention cell results showed efficient microplastic removal from stormwater.

16. Oil spills in freshwater and estuarine systems: The need for specific knowledge in an often-overlooked scenario

A. GUTTORMSON, M. STANLEY, University of Manitoba, Biosystems Engineering; V. PALACE, IISD Experimental Lakes Area; R. GROSSHANS, International Institute for Sustainable Development; D. LEVIN, University of Manitoba, Biosystems Engineering. **Optimizing plant and nutrient ratios to enhance floating wetland remediation of freshwater oil spills.**

Intracontinental transport of crude oil gives rise to the risk of an accidental release into freshwater systems. Conventional cleanup methods for such spills may cause additional negative

effects on the impacted areas, creating a need for less invasive techniques. Research at the IISD Experimental Lakes Area (IISD-ELA) is investigating the use of engineered floating wetlands (EFW) for enhanced oil degradation as a minimally-invasive spill remediation method. EFWs - vegetated platforms which provide extensive root mass for microbial biofilm growth - may improve the degradation of oil constituents via enhanced microbial metabolism. In order to optimize EFW design, a series of crude oil treated mesocosms will receive EFWs planted with varying ratios of Typha sp. and two Carex spp. and augmented with varying nutrient ratios. These experiments will identify the impacts of different plant and nutrient ratios on shifts in EFW microbial communities and the degradation of oil. Pathways for EFW optimization may be used to guide the implementation of this method in spill response plans as a less-invasive alternative to conventional technologies.

S. MICHALESKI, IISD Experimental Lakes Area; A. BARTLETT, Environment and Climate Change Canada; L. TIMLICK, IISD Experimental Lakes Area; M. BARRON, United States Environmental Protection Agency; G. TOMY, University of Manitoba; V. PALACE, IISD Experimental Lakes Area. **Fun in the sun: Interactive effects of UV radiation and diluted bitumen on Hyalella Azteca.**

Diluted bitumen, the major product of the oil sands region, is a combination of bitumen and natural gas condensates and synthetic crudes that are added to reduce viscosity so that the product can be transported in pipelines. The rate of diluted bitumen spills has declined over the past decade, but the risk of spills into aquatic environments is still a concern. Previous studies have evaluated the toxicity of diluted bitumen, but many overlook the potential for photo-enhanced toxicity of oil constituents in environments with UV exposure. To examine the interactive effects of diluted bitumen and UV radiation, *Hyalella azteca* were exposed to three water accommodated fractions of diluted bitumen, under low (10%) and high (90%) UV exposure. When exposed to diluted bitumen and UV radiation in combination, *Hyalella azteca* had significantly increased mortality suggesting that the potential for photo-enhanced toxicity should be considered when examining the potential effects of dilbit spills in freshwater environments.

M. STANLEY, A. GUTTORMSON, University of Manitoba, Biosystems Engineering; V. PALACE, IISD Experimental Lakes Area; R. GROSSHANS, International Institute for Sustainable Development; D. LEVIN, University of Manitoba, Biosystems Engineering. **The role of plants on floating wetlands for enhanced biodegradation of oil spills in freshwater lakes.**

Crude oil is a non-renewable energy source, extracted and transported across landscapes that intersect freshwater systems, creating risk for accidental release. While there are current methods for oil spill remediation, there is a need to understand impacts of oil spills in freshwater and for improved methods of oil recovery. Projects at the IISD Experimental Lakes Area (IISD-ELA) have responded to this research need by investigating the effectiveness of minimally invasive, secondary

remediation options for oil spills in freshwater shorelines. Engineered floating wetlands (EFW), vegetated platforms with a dense root zone for microbial development, are being tested as a remediation strategy. Microorganisms can naturally degrade oil compounds but can be limited by environmental conditions. This research explores the role of EFWs in enhancing microbial degradation of hydrocarbons through both in-lake research at the IISD-ELA and laboratory studies on the role and function of plants. Results will be communicated to spill responders and environmental managers, with potential to influence response plans, reduce impact and improve oil recovery.

S.S. STOYANOVICH, University of Ottawa, Biology; J.L. RODRIGUEZ-GIL, IISD Experimental Lakes Area; R. FARAGHER, Environmental Climate Change Canada; M. HANSON, University of Manitoba; B. Hollebone, Environment and Climate Change Canada; F. MIRNAGHI, Environmental Climate Change Canada; D. ORIHEL, Queens University; V. PALACE, IISD Experimental Lakes Area; K. SHAH, Z. YANG, Environmental Climate Change Canada; J.M. BLAIS, University of Ottawa, Biology. **Exploring the physical and chemical fate of diluted bitumen in a boreal lake: A limnocorral study at the IISD-ELA.**

Despite environmental concerns and the importance of pipeline expansion projects in Canada, very little is known about the environmental effects of a dilbit spill in a freshwater setting. The BOREAL project was commissioned to carry out large-scale controlled dilbit spills in lake 260 at the IISD-Experimental Lakes Area. Utilizing a regression design, 7 independent spills ranging in volume from 1.5 - 180 L were carried out during the summer of 2018. This presentation will document important behavioural changes of the dilbit that occurred throughout the 80-day study, highlighting it's ultimate fate: submergence. We will also report the hydrocarbon contamination that followed each spill, focusing on concentrations of PAHs in the water column and sediments. These results are important for our understanding of dilbit's behaviour in the environment across a wide range of possible spill sizes and the potential impacts it can have on important environmental media such as the water column, the sediments and the surrounding biota. It is our hope that our findings will help inform evidence-based management strategies for the transport of dilbit in Canada.

L. TIMLICK, IISD Experimental Lakes Area; J. DEARNLEY, University of Manitoba; J.M. BLAIS, University of Ottawa, Biology; M. HANSON, University of Manitoba; B. HOLLEBONE, Environment and Climate Change Canada; D. ORIHEL, Queens University; J. RODRIGUEZ-GIL, University of Manitoba; V. LANGLOIS, INRS; V. PALACE, IISD Experimental Lakes Area.
Effects of model diluted bitumen spills on wild small-bodied freshwater fish at IISD-Experimental Lakes Area.

Controlled field studies on the effects of diluted bitumen (dilbit) spills in freshwater are an important complement to data from real-world spill sites. In order to study the potential toxicity of dilbit in freshwater, the Boreal lake Oil Release Experiment by Additions to Limnocorrals

(BOREAL) project began in 2018 at the IISD-Experimental Lakes Area (Ontario, Canada). Spills ranging from 1:100,000 to 1:1,000 dilbit:water were modelled in seven 10 m diameter limnocorrals (~1.5 m deep). Two untreated limnocorrals and fish from the open lake serve as references. Male and female finescale dace (Phoxinus neogaeus) were added to the limnocorrals 21 days after oil addition. Here we report the effects of chronic exposure on these wild fish. Assessed metrics include gonadal and liver somatic indices, hepatocyte volume indices, condition factor, gill basal epithelia width, and histology of the gonads. Fixed wavelength fluorescence analysis of the bile was used to confirm the fish were interacting with dilbit. Results indicate that lower exposures (< 1:10 000) cause no clear health effects but higher exposures (>3:10 000) correlate with significant mortality.

19. Remote sensing, visualization, and spatial data applications for the Great Lakes

L.H. ELLIOTT, P. LANDISCH, University of Minnesota, Forest Resources; W. SEVERUD, University of Minnesota; M. NELSON, U.S. Forest Service; J. VOGELER, Colorado State University; J. KNIGHT, University of Minnesota, Remote Sensing and Geospatial Analysis Laboratory. **Assessing watershed condition and coldwater fish distribution using forest inventory and remote sensing data.**

Species distributions are driven by spatiotemporal distributions of landscape characteristics such as land use, land cover, forest disturbance, and riparian areas. We assessed these characteristics across US Great Lakes basins with attributes from the NLCD, a tree canopy cover dataset, Landsat time series-based canopy disturbance data, and the Forest Inventory and Analysis database. Riparian areas comprise 14% of Great Lakes basins, and 16% of forest land is located within riparian areas. We applied these metrics in models of brook trout (*Salvelinus fontinalis*) distribution within a Minnesota study area. Land cover in the study area's 12-digit hydrologic unit code (HUC12) watersheds is 83% forested, of which >17% has experienced disturbance at least once (1975-2018). Brook trout were found in 49% of 158 surveyed HUC12s. The novel datasets we have constructed will be used to identify and prioritize watersheds for restoration and can inform distribution models of other species and taxa.

H. GARCIA, University of Michigan, School for Environment and Sustainability, Department of Civil and Environmental Engineering; S. BRINES, University of Michigan, School for Environment and Sustainability; B. WONG, University of Michigan, Department of Civil and Environmental Engineering; C. BROWN, University of Michigan, School for Environment and Sustainability; A. GRONEWOLD, University of Michigan, School for Environment and Sustainability, Department of Civil and Environmental Engineering. **Incorporating remote-sensing data to improve conceptual floodplain modeling in Southeast Michigan.**

Understanding how surface and coastal waters move across a watershed's landscape is necessary for effective regional water resources management, land use planning, and infrastructure resilience. In this study, the authors created hydraulic models from multiple sources of available high-resolution LiDAR data and water level data in two watersheds in Southeast Michigan. A conceptual floodplain model was built for the North Branch Clinton River watershed using a 1D steady-state HEC-RAS model to convey how increased inland development may alter floodplain extents in future storm events. In Monroe County, along the western coast of Lake Erie, ArcGIS spatial analysis was used to examine the impacts of coastal flooding around highway infrastructure. With predicted increases in precipitation and development in the Great Lakes region, remote-sensing data can improve floodplain modeling to help inform regional flood management, planning, and infrastructure decisions.

R. MALBURG, US Army Corps of Engineers / Detroit District; J. MCNINCH, US Army Corps of Engineers Engineer Research and Development Center, Field Research Facility. **Nearshore Sediment Transport and Shoreline Change Observations during 2019 High Water at Leland, MI**.

The Radar Inlet Observing System (RIOS) is a technology developed by the US Army Corps of Engineers Field Research Facility. This technology allows for continuous observations of breaking wave parameters during energetic storm events using x-band radar. These observations can then be used to derive nearshore sediment transport patterns. The RIOS technology was positioned on the shoreline at Leland, MI from June to October 2019 to monitor the transport of approximately 10,000 cubic yards of dredged material placed as beach nourishment. Physical observations using RIOS were used to understand shoreline change, development and migration of the subaqueous nearshore bar, and evolution of the beach nourishment promontory under high water conditions. Utilization of this technology provided hourly observations during energetic storm events, which would otherwise be unsafe to collect using hydrographic survey techniques.

20. Improve model predictions via coupled system, data assimilation, machine learning

Q. LIU, University of North Carolina Wilmington, Physics and Physical Oceanography; M. ROWE, NOAA GLERL; E.J. ANDERSON, C. STOW, NOAA Great Lakes Environmental Research Laboratory; R. STUMPF, NOAA; T. JOHENGEN, CIGLR, University of Michigan. **Probabilistic forecast of microcystin using satellite imagery, in situ observations and numerical modeling.**

Lake Erie has experienced a resurgence of microcystin-producing cyanobacterial harmful algal blooms (CHABs) since the early 2000s. Microcystins can cause liver and kidney disease. Prediction of microcystin concentrations is challenging due to the complex association between cyanobacteria densities and toxin concentrations. We developed a forecast system to predict the

spatially- and temporally-varying probability of exceeding a public health advisory level (PHA, 6 ?g/L) of microcystins in the western basin of Lake Erie. The system combines satellite-derived CHABs distributions, hydrodynamic model, particle tracking model, and *in situ* chlorophyll-a and microcystin concentrations derived from weekly sampling in Lake Erie. We calibrated and assessed the model in 2014-2016, and further assessed the model in 2017, a year that was outside the calibration period. Evaluation of the system's performance demonstrated that this approach provides potentially useful information to stakeholders.

D.M. WRIGHT, University of Michigan, Climate and Space Sciences and Engineering; E.J. ANDERSON, P. CHU, NOAA, Great Lakes Environmental Research Laboratory; A. FUJISAKI-MANOME, CIGLR, University of Michigan; C. JABLONOWSKI, University of Michigan, Climate and Space Sciences and Engineering; B.M. LOFGREN, NOAA/GLERL, Great Lakes Environmental Research Lab; G. MANN, NOAA, NWS. **Using a Coupled FV3SAR-FVCOM Modeling System to Improve Lake-Effect Snowfall Forecasts.**

Most numerical weather predictions of lake-effect snowfall use temporally static lake surface characteristics that can lead to poor forecasts for longer forecast horizons or in cases of rapidly evolving lake conditions. To improve simulations, an asynchronous iterative coupling of NOAA's FV3SAR, a regional atmospheric modeling framework in the Unified Forecast System, with a lake hydrodynamic and ice model (FVCOM) is used to provide more realistic lower boundary conditions, both spatially and temporally, for the atmospheric model. FV3SAR is run at a horizontal resolution of 3km to begin to explicitly represent lake-effect snowfall bands, while FVCOM is run on an unstructured grid with higher horizontal resolution near the coasts. Simulations show a significant improvement in both lake surface temperature and ice cover when using FVCOM data compared to default initialization. These improvements generate improved snowfall intensity and band placement when compared to gridded observations. Results will be compared to a similar coupling between the High Resolution Rapid Refresh model (HRRR) and FVCOM.

21. Unraveling the code: Exploring freshwater ecosystems in the age of genomics

P.T. EUCLIDE, University of Wisconsin Stevens Point, Department of Natural Resources; B. DIXON, University of Waterloo; M. FAUST, Ohio Department of Natural Resources, Division of Wildlife; L. MILLER, Minnesota Department of Natural Resources; W. STOTT, Michigan State University, USGS Great Lakes Science Center; K.T. SCRIBNER, Dept. Fisheries and Wildlife, Michigan State; C.C. WILSON, ON Ministry of Natural Resources and Forestry, Trent University; W. LARSON, U.S. Geological Survey. **Genomics provides a more nuanced picture of walleye population structure in the Great Lakes.**

Walleye support a large recreational and commercial fishery in the Great Lakes and are intensely managed. There are ongoing efforts to restore walleye populations that have been negatively impacted by overfishing and poor water quality; many of which use hatchery propagation to provide a demographic boost to populations. However, naturally reproducing populations remain intact. To help guide management and understand the evolution and genetic structure of walleye, we developed a 100,000 marker restriction-site associated DNA capture panel (RAD-capture or Rapture) and genotyped 1,200 walleye from the Great Lakes. We found that walleye have extensive fine-scale genetic structure, including in Lake Erie where descriptions of genetic structure has previously been inconsistent and difficult to define. The improved power of our approach provided a more nuanced description of population structure than previously possible using microsatellites and suggest that walleye populations may be more structured than previously thought.

J.E. LITTLEFAIR, Queen Mary University of London; L.E. HRENCHUK, IISD-Experimental Lakes Area; M.D. RENNIE, Lakehead University, Biology; P.J. BLANCHFIELD, Fisheries and Oceans Canada; M. CRISTESCU, McGill University, Biology. **Plumbing the depths: Seasonal lake stratification and species detection with environmental DNA.**

Significant advances have been made in developing molecular methods for detecting species using environmental DNA (eDNA), but we are missing information about the "ecology" of eDNA, including temporal and spatial distribution and influence of abiotic and biotic processes. We sampled eDNA depth profiles in dimictic lakes during stratification and turnover and used acoustic telemetry to validate habitat use for cold water fish. We found that eDNA of fish becomes stratified into layers during summer, reflecting thermal niches of the species. During summer, lake trout eDNA was only detected at the deepest parts of lakes while minnow DNA was more abundant above the thermocline. During turnover, the fish species assemblage was homogeneous in the water column as detected by eDNA. These findings enhance our understanding of eDNA ecology within lake ecosystems, illustrating how seasonal water movements interact with thermal niches to impact our design of appropriate biomonitoring schemes.

R.S. SHAHMOHAMADLOO, University of Guelph, School of Environmental Sciences; D.B. SIMMONS, Ontario Tech University, Faculty of Science; P.K. SIBLEY, University of Guelph, School of Environmental Sciences. **Shotgun proteomics reveals sub-lethal effects in Daphnia magna exposed to microcystins produced by Microcystis**.

Microcystins that are cell-bound within *Microcystis* have demonstrated the ability to cause lethal and reproductive impairment in *Daphnia*. This study examines the effects of cell-bound microcystin exposure in *Daphnia magna* as a function of dose and time with shotgun proteomics in order to measure and provide insightful evidence describing functional mechanisms from, and relationships between, protein populations in response to toxic *Microcystis aeruginosa*. We further characterize the life-history fitness of *D. magna* in the presence of toxic exposure by measuring

somatic growth rate. Chronic dietary exposure to cell-bound microcystins reduced the somatic growth rate of *D. magna*. Through proteomics analysis, we identified a significant increase in abundance of proteins related to reproductive success and development, removal of superoxide radicals, and motor activity in *D. magna* parents exposed to cell-bound microcystins at sub-lethal concentrations. We also identified a significant decrease in abundance of proteins related to apoptosis, metabolism, DNA damage repair, and immunity in *D. magna* neonates.

23. Great Lakes innovative technology forum

J.F. BRATTON, E. VERHAMME, LimnoTech; S. RUBERG, NOAA - GLERL; P.C. ESSELMAN, U.S. Geological Survey; T. NETTESHEIM, U.S. EPA, GLNPO; R. MILLER, University of Michigan – CIGLR. **Developing an Interagency Common Agenda for Use of Advanced Survey Technologies in the Great Lakes.**

USEPA, NOAA, and USGS, with input from other agencies and organizations, are developing a strategic plan for interagency cooperation on the use of advanced survey technologies to validate models, answer priority research questions, and fulfill monitoring needs. A group of experts is identifying a set of technologies and developing a process to achieve common goals. Participating agencies are (1) preparing an inventory of the availability and operational status of existing advanced survey technologies at Great Lakes agencies; (2) identifying high-potential technologies for building regional capacity; and (3) developing a plan for transitioning from research and development to full-scale operations. The result of the plan and agency commitments will be coordinated acquisition and use of advanced technologies, including greater efficiencies in data management and visualization, deployment and recovery of survey platforms, and training and staffing of technical support teams.

M.B. HERZOG, Cleveland Water Alliance. **Smart Citizen Science - Leveraging Technology to Accelerate Non-Expert Data Collection.**

The Lake Erie iteration of Great Lakes One Water (GLOW), a collaboration between community foundations across the Great Lakes Region, is focused on enabling Smart Citizen Science. Our collective aim is to position Lake Erie and its communities as a trailblazer in community-led solutions for water monitoring by embracing new technology and data that are trusted, transparent, and tied to regional policy and education. The effort will launch in seven targeted communities represented by our Lake Erie Basin community foundations and be led at the regional level by Cleveland Water Alliance (CWA). The initial rollout of the program will focus on synthesizing existing citizen science, new technology, and strategic communications into a highly coordinated regional monitoring network for nutrient pollution. The effort will be driven at the local level through investments in "Smart Citizen Science Hubs," existing citizen science organizations with deep roots in their local community.

E. VERHAMME, GREG CUTRELL, JOHN BRATTON, LimnoTech. **Next Generation Wireless Sensor Networks for Great Lakes Scientists/Managers.**

The emergence of low-cost open access wireless networks provides a unique element to the Smart Lake concept. Previously researchers that wanted to transmit data from the field in real-time had to invest in cellular, satellite, or individual radio system to transmit data to the internet. Most researchers with a defined set of research questions and budget did not incorporate real-time telemetry unless it was absolutely necessary. The next generation wireless sensor network will utilize low power wide area network technology (LPWAN) and builds off the Semtech LoRa standard. Open access gateways will be deployed in Milwaukee, Detroit, Toledo, Sandusky, and Cleveland by LimnoTech, University of Wisconsin-Milwaukee, Wayne State University, Bowling Green State University, University of Toledo, and NOAA GLERL. A single gateway to relay deployed sensor node data to the internet can support between 300 and 1000 devices transmitting data from up to 10 miles away (potentially 20 miles given line of site) using a very small amount of data and power. This presentation will describe the 2020 pilot efforts, how you can access the network.

24. The state of global lakes

A. ACHIENG, University of Eldoret; O. OSANO, University of Eldoret; B. KAUNDA-ARARA, J. IVES, University of Windsor. **Land use changes: Toxic to Lake Victoria**.

Lake Victoria suffocates from multiple stressors that threaten its sustainable use. Most of the stressors originate from land use changes at river catchments which are sources of nutrient loads from subsistence, commercial agriculture and agro-chemical industries, organic pollution from urban runoffs, municipal waters and food processing industries and toxic anions and cations from manufacturing companies along the river basins. Excluding the transboundary rivers, Kenya contributes the largest discharge from rivers and surface water inflow into the lake. A recent study on most of Kenyan rivers titled Toxic Flow: Rotting from the deep, identified the lake as a receptacle of filth and contamination; dirty lake and muddy shoreline with suspended nonbiodegradables. We investigated this through satellite images and land use maps from February 2019 to date, analyses nutrient and heavy metals at the lake shores and river mouths which and observed deteriorating lake condition.

M.K. AGELI, Great Lakes Institute for Environmental Research; G.D. HAFFNER, Great Lakes Institute for Environmental Research; P.B. HAMILTON, Canadian Museum of Nature; P. WEIDMAN, Great Lakes Institute for Environmental Research. **Benthic-pelagic state changes in the primary trophic level of an ancient tropical lake**.

While most ancient lakes show long-term planktonic dominance, Lake Towuti, Indonesia is currently dominated by benthic diatom species and completely lacks centric frustules. We investigated whether the lake has always been a benthic-dominant system. Two sediment cores, each

over 100 m deep, have been counted for relative and absolute abundances of diatoms. Our results show major switches between benthic and planktonic dominant diatom communities. Planktonic phases were dominated by Aulacoseira spp., with valve densities of around 1.5 x 10^9 valves/ g, while the benthic phases were primarily dominated by Cymbopleura spp. Canonical distribution analyses of the diatom phases and sediment chemistry showed relatively different chemical environments in benthic and planktonic layers. Lake Towuti has experienced major changes in its primary production over such long periods of times, demonstrating the capacity of lakes to return to previous states after thousands of years.

G. CHAVULA, University of Malawi, The Polytechnic., Civil Engineering. **Lake Malawi/Nyasa/Niassa Basin: Preliminary Assessment of Impacts of Climate Change on Fisheries.**

The discussion in this paper focuses on the current state of Lake Malawi/Nyasa/Niassa in light of preliminary findings of impacts of climate change on the lake and its fisheries resources, and further proposes anticipatory adaptation strategies to manage fisheries resources under climate change scenario. Projections of temperature and rainfall for the lake were inferred from results obtained for the lakeshore area using statistically downscaled General Circulation Models following the procedure recommended by the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), and those obtained by the Intergovernmental Authority in Development (IGAD) and ICPAC (IGAD Climate Prediction and Application Centre) of 2007. Increases in temperature are expected to increase fish stress whereas severe floods are likely going to destroy fish spawning grounds. Climate change scenarios are further discussed in light of their effects on fisheries resources in the basin and appropriate anticipatory adaptation strategies that should be implemented in order to counter the adverse effects.

M.A. FABRICE, Institut Superieur Pedagogique de Bukavu & Catholic University of Bukavu, Chemistry & Environmental Sciences. **Current status of Lake Kivu resource management and ecosystem health.**

Lake Kivu (2370 km^2 surface area, 485 m maximum depth) is a meroctimictic deep lake of East Africa. It is located at the border between the DR Congo and Rwanda. The limnological patterns of the lake are characterized by a permanent physical and chemical stratification caused by subaquatic discharges of salty waters. Lake Kivu is famous for its high and hazardous amounts of dissolved gases (60 km^3 of CH_4 and 300 km^3 of CO_2 STP), thus the lake bears an important risk of limnic eruption similar to that of Lakes Nyos and Monoun (Cameroon). Lake Kivu main resources include Fisheries (based essentially on *Limnothrissa miodon*), hydropower energy production (72 MW installed and 487 MW planned) at the outflow as well as methane resource in development. The lake resource conservation is currently facing a number of environmental problems (like water pollution

of the littoral zone, invasive species and climate change effects), weak fisheries management and lack of harmonization of transboundary resource management policies.

N. FILATOV, N. KALINKA, M. ZOBKOV, N. BELKINA, Northern Water Problems Institute of the Karelian Research Center, Russian Academy of Sciences. **The Modern State and Changes of Lake Onego Ecosystems.** (No abstract.)

C.M. GITHUKIA, Kenya Marine and Fisheries Research Institute (KMFRI), Department of Aquaculture and Fisheries; K.O. Obiero, Kenya Marine and Fisheries Research Institute, Research. **Cage Culture and Environmental Impacts: Current Status and Policy Implications in Lake Victoria**.

Lake Victoria is an important resource regionally as a livelihood source. However, over the years the lake has been subjected to several anthropogenic challenges causing deterioration of water quality and reducing fish yield. The reduction in fish catches spurred cage fish farming in Lake Victoria attracting many investors in their quest to fill the gap between fish demand and supply due to its high rate of intensification. However, fish feed used in the cage is a source of nutrient load in the lake especially phosphorus and nitrogen which is detrimental to the already eutrophied water body. This study therefore seeks to review the existing literature on the impact of cage fish farming in Lake Victoria on the water quality. This is paramount in safeguarding this shared resource and in ensuring environmental sustainability. The paper will also focus on the current status of the lake and propose policy geared towards safeguarding the fragile ecosystem. The study will recommend the possible lakes' cage carrying capacity, cage sizes, stocking densities and feeds usage, taking in to account other livelihoods dependent on the resource.

A. JANSSEN, Wageningen University & Research. **Nutrient pollution and critical thresholds for Large lakes: Some examples from China**.

China has gone through a vast development of economy, human population and society. Whilst this vast development has strengthened China's international position, it has also resulted in environmental issues including eutrophication of lakes resulting in many Chinese lakes with toxic cyanobacteria blooms. These cyanobacterial blooms are detrimental to ecosystem services such as the provisioning of water for drinking. A large variety exists in the responses within lakes to eutrophication, especially within large lakes. Therefore, critical nutrient load also varies within the lake complicating restoration. Here we assess the current and critical nutrient loads of large Lake Taihu, a large shallow lake that is located in southeast China. We show critical nutrient loads with spatial heterogeneity. Our results show that 50-90% of the current nutrient load to Taihu has to be reduced to reach sufficient water quality. We compare this output with findings for other large Chinese lakes.

Y. KAO, Michigan State University. **Effects of climate and land-use changes on fish catches across lakes at a global scale**.

We assessed effects of climate and land use changes on fish catches in 31 lakes across five continents by analyzing data between 1970 and 2014. Results showed that fish catches could respond either positively or negatively to climate and land-use changes. At one level, we found that effects of a climate or land-use driver (e.g., air temperature) on lake-environmental factors (e.g., water temperature) were relatively consistent in directions. However, the effects of a changing lake-environmental factor (e.g., warming water temperature) could have either positive or negative effects on fish catches across lakes. A subsequent correlation analysis indicates that reductions in fish catch was less likely to occur in response to potential climate and land-use changes if a lake is located in a region with greater access to clean water. This suggests adequate investments for water-quality protection and water-use efficiency can provide additional benefits to lake fisheries and food security.

J.M. MATUNGURU, University of Burundi Doctoral School, Integrated Management of Fisheries and Wetland Ecosystems; H. NAKIYENDE, National Fisheries Resources Research Institute, Uganda, Capture Fisheries and Biodiversity Conservation; M. MULONGAIBALU, Universite Officielle de Bukavu, Hydrobiologie; O. WEMBO, Universite Officielle de Rwenzori, Biologie; G.O. MUKABO, Universite Officielle de Bukavu, Hydrobiologie; V.M. NSHOMBO, Centre de Rercherche en Hydrobiologie d'Uvira, Icthyologie; J. MICHA, Universite de Namur, Biologie, Unite de Recherche en Biologie de l'Environnement et Evolutive; G. NTAKIMAZI, Universite du Burundi, Centre de Recherche en Sciences Naturelles et de l'Environnement. **Status of Lake Edward Fisheries: Exploitation, threats and strategies for sustainable management.**

Lake Edward, located in the western arm of the great rift-valley at an altitude of 920 m above sea level and covering a surface of 2 325 KM^2 is the smallest of the Great African Lakes shared between the DRC (71%) and Uganda (29%). Fishing is a major source of food, livelihoods and income for riparian inhabitants and contribute significantly to the economies of both countries. From a provisional list of 50 species, only 29 species are known (92% are endemic) with only 7 commercialized species (Ex. *Bagrus docmak, Oreochromis niloticus*, etc.). However, several threats are affecting this ecosystem and its resources. Applying scenarios must guarantee their sustainable exploitation: (1) Lack of control measures fishery, decline in fish production; (2) Rate of sustainable exploitation, maintaining production the longest; (3) Unsustainable exploitation rate, drop in production after a few years and (4) forced reduction of exploitation rate leads to high economic and environmental costs.

M.M. MUTILI, Kisii University, Aquatic and Fishery Science Department; R. OMONDI, Kisii University, Aquatic and Fishery Science; J. MALALA, Kenya Marine and Fisheries Research

Institute, Turkana Station, Fisheries Department. **Significance of Protected Areas on Lake Ecosystems: A case study of Lake Turkana.**

Lake Turkana is the world largest desert lake located in northern Kenya. The lake has enormous potential of aquatic resources, especially fish. The eastern side of the lake is within a protected area, Sibiloi national park; where apart from occasional poaching fishing is prohibited. The western side of the lake is, however, under open access fishery. Higher catches of fish are reported on the eastern than on the western side of the lake. Zooplankton, on the other hand, have lower densities on the eastern than on the western side of the lake. The higher numbers of fish in the park area could be attributed to controlled fishing activities. The high abundance of fish, however, leads to lower zooplankton densities due to predation. Key words: Protected areas, Lake Turkana, fish, zooplankton, protected areas

K.O. OBIERO, Kenya Marine and Fisheries Research Institute, Research; J. MALALA, Kenya Marine and Fisheries Research Institute, Turkana Station, Fisheries Department; J. ATALITSA, Kenya Marine and Fisheries Research Institute; M. WAKJIRA, Jimma University, Ethiopia, College of Natural Sciences; A. GETAHUN, Addis Ababa University; J. KOLDING, University of Bergen. **The State of Lake Turkana.**

Lake Turkana is the world's largest desert and alkaline lake spanning a large part of northwestern Kenya and Ethiopia's southwestern highlands. Like other great lakes in the world, the lake's resources have been adversely affected by multiple anthropogenic and environmental stressors which negatively affect the biological, ecological, economic, and socio-political aspects of these vastly important resources. For decades, the lake has generated the least interest and attention compared to the other Great Lakes of Africa. However, recent developments in the region including the construction of cascading dams on River Omo; the "umbilical cord" of Lake Turkana, massive irrigation projects along the river basin, oil discovery and exploration, construction of African largest wind power plant attest to a changing environment amid great concerns of potential impacts on long term viability of ecosystem benefits. This paper documents emerging threats and challenges to Lake Turkana and also highlight opportunities for transboundary research partnerships and collaborations to develop long-term conservation-oriented actions and solutions.

N. SALMASO, Research and Innovation Centre, Fondazione Edmund Mach, Italy. **The large lakes south of the Alps: Current limnological status, with a special focus on Lake Garda**.

The large lakes south of the Alps (DSL: Garda, Maggiore, Como, Iseo and Lugano) are one of the most important lake districts in Europe. In the last decades, the DSL showed a tendency to oligotrophication, warming of the water column, decrease in the frequency of full mixing episodes followed by a lower supply of nutrients to the upper layers. In Lake Garda, the decrease of nutrients caused a decline of the mesotrophic cyanobacterium Planktothrix rubescens (microcystin producer), which was partially replaced by Tychonema bourrellyi (anatoxin-a producer), a "new" species

identified in 2014. The discovery of Tychonema can be considered a paradigmatic example of the unknown biodiversity in the DSL. To solve this gap, high throughput sequencing has been recently used to analyze bacteria, cyanobacteria, protists and fish. The new approach has been extended to the whole Alpine region within the EU Alpine Space project Eco-AlpsWater (www.alpine-space.eu/projects/eco-alpswater).

P. VERBURG, National Institute of Water & Atmospheric Research, New Zealand; S. GUILDFORD, R. HECKY, University of Minnesota Duluth; A. Albert, National Institute of Water & Atmospheric Research, New Zealand. **Increased P limitation of algal growth in Lake Taupo and no change in algal biomass following increased nitrogen concentrations.** (No abstract.)

25. State of large lakes of North America - SoLLNA: Managing ecosystem stressors

M.W. MURRAY, National Wildlife Federation, Great Lakes Regional Center; D. ALLAN, University of Michigan, Sch. For Environment and Sustainability; M. CHILD, International Joint Commission; J.F. BRATTON, LimnoTech; J.M. DALEY, LimnoTech, University of Michigan. **Potential Importance of Interacting Stressors in the Great Lakes.**

Recognizing that the interaction of multiple stressors in the Great Lakes is poorly understood, the International Joint Commission's Science Advisory Board undertook a review and exploratory analysis. The project included a facilitated expert workshop and review and assessment of the literature, focusing on 11 stressor pairs considered to be of importance for the Great Lakes. The project considered literature from the Great Lakes and beyond that addressed interaction concepts, including additivity, synergy, and antagonism, and identified their frequency in studies of aquatic ecosystems. Stressors often interact and their combined effect often is greater than that of a single, dominant stressor, but the review found both synergistic and antagonistic effects to be more common than simple additive effects. These effects are context dependent and are likely to vary spatially, and implications for further research and in particular management will be discussed.

T. CONNOLLY, X. ZHU, B. MALLEY, Fisheries and Oceans Canada, Arctic and Aquatic Research Division; M.S. EVANS, Environment and Climate Change Canada, Watershed Hydrology, Ecology and Research Division. **Ecological Drivers of Spatial Patterns of Zooplankton Community Composition in Arctic Great Lakes.**

Zooplankton community characteristics can be affected by within-lake and lake-river interactions including lake morphology, depth-specific thermal stratification, and river-inflow turbidity. We hypothesized these ecological drivers would be correlated with spatial patterns, species richness, and abundance of zooplankton communities for the typical oligotrophic lake, Great Slave

Lake (GSL), Northwest Territories, Canada. To assess, data was collected from 106 randomly-selected grids across the main basin of GSL (6 fisheries management areas, 245 grids at 86.49 km^2 /per) during summers 2012-2015. Depth-specific vertical net tows revealed zooplankton samples predominately comprised of Calanoida (IRI=52%) and Cyclopoida (IRI=29%), with Mysidae and various Cladocera also present. Detrended correspondence analysis (DCA) revealed sampling depth, pH, conductivity, chlorophyll a, and turbidity to be primary forces in determining zooplankton composition along environmental gradients. This study emphasizes the benefits of combining multiple statistical techniques to explore ecological drivers of low-trophic community composition.

O.T. GORMAN, U.S. Geological Survey; M. VINSON, USGS-Great Lakes Science Center; T. PRATT, Fisheries and Oceans Canada. **Status of the Lake Superior Fish Community.**

Much of Lake Superior remains deep, cold and unproductive for fishes, limiting the number of species (including invasive species) that can be successful. As a result, food webs remain relatively simple and relatively un-impacted by invasive species with the exception of Rainbow Smelt. Energy is moved between nearshore and offshore areas through both pelagic and benthic pathways, primarily by the macroinvertebrate *Mysis*, the pelagic fish planktivore Cisco, and the top fish predator Lake Trout. The vast majority of fishes in Lake Superior have declined since a period of high abundance and biomass in the mid-1980s through mid-1990s, concurrent with a recovering Lake Trout population. Evidence indicates that Lake Trout have recovered and reached carrying capacity, leading to reductions in prey fishes. There are real concerns that climate change is affecting native fishes and encouraging the spread of invasive species; recent warming trends have coincided with widespread recruitment failure in Lake Superior's cisco species and there are reports of increasing spatial extent of dreissenid mussels.

B. MARCEK, The Ohio State University Department of Evolution, Ecology and Organismal Biology; S.A. LUDSIN, Aquatic Ecology Lab, The Ohio State University. **Effects of Temperature, Dissolved Oxygen, and Harmful Algal Blooms on Lake Erie Fish Abundance.**

In Lake Erie, temperatures have increased, the extent and severity of bottom hypoxia has worsened, and toxin-producing harmful algal blooms (HABs) have expanded, yet their independent and combined effects on fish populations remain poorly understood. Herein, we examined how these habitat changes influenced the distribution and abundance of common sport, forage, and introduced fishes in central and western Lake Erie. To do so we analyzed spatially explicit bottom trawl data collected by Lake Erie agencies during June through October, 2000-2018. We found that fish abundance generally increased with increasing temperature and decreased rapidly below ~4.5 mg O_2/L. Our analyses also suggest a negative effect of HABs on fish abundances in the west basin and positive effect in the central basin, although these patterns were not significant, with the exception of round gobies for which a decrease in abundance with increasing HAB severity was apparent in the western basin. Ultimately, our findings indicate a need for additional research to

improve our understanding of the potential impacts of these stressors, especially HABs, on fish populations.

M. MUNAWAR, Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences; I. MUNAWAR, Plankton Canada; M. FITZPATRICK, H. NIBLOCK, Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences; H.J. KLING, Algal Taxonomy & Ecology Inc., Algal taxonomy. **Changing microbial-planktonic food webs of Lake Superior and Lake Ontario: Structure, Function and dynamics.**

Fisheries & Oceans Canada has been conducting lake-wide phytoplankton surveys in the Laurentian Great Lakes since the early 1970s. Lake Superior was sampled 6 times from 1973-2011 and Lake Ontario was surveyed 7 times from 1970-2018. Most of these surveys included phytoplankton biomass/composition, primary productivity, and -since 1990- microbial loop (bacteria, picoplankton, hetertrophic nanoflgellates, ciliates). Long term assessments of Lake Superior show it continues to be ultra-oligotrophic (TP: < 3 ug/l; Chlorophyll a: < 1 ug/l, phyto biomass: 0. 7 g/m3. Lake Ontario is undergoing oligotrophication in the offshore, (TP: 8 ug/l; Chlorophyll a: 1.5 ug L, and phyto biomass: 0.4 g/m3). Both lakes appear to be operating at different stages of oligotrophy, and the microbial food web seems to be oscillating between periods of autotrophy and heterotrophy. A comparison of the structure and function of MFW of the two lakes will be presented.

D. STINSON, Incite Planning. **A preliminary Rural-Urban Transect analysis of Phosphorus-loading within the Lake Simcoe Watershed.**

The suburban pattern of development has created many deleterious impacts. The Rural-Urban Transect has been a useful tool in analysing them, such as different CO2 emissions across development patterns. This study used a similar method to assess P-loading of Lake Simcoe. Public policy has created a remediation plan for the watershed, as P has increased since settlement. Sport fishing is important to the local economy, but the hypoxia from P-levels has limited fish populations. Current analyses highlight P-loading from farms, roads, sewage, the air, and "urban" runoff. Though useful in remediation, public policy has failed to address the importance of urban types on pollution. The use of the Transect in this preliminary study reveals: the overwhelming extent of "suburban" development patterns, the disproportionate impact of this pattern for P-loading, the predominant suburban contribution to the P-problem on a watershed and household basis, and urbanism as a possible solution.

H. ZHANG, Eureka Aquatic Research, LLC.; E. RUTHERFORD, NOAA Great Lakes Environmental Research Laboratory; D.M. MASON, NOAA GLERL; B. WEIDEL, USGS, Great Lakes Science Center, LOBS; L. RUDSTAM, Cornell University Bio Field Station, Dept. of Natural Resources, Natural Resources; M. KOOPS, Fisheries & Oceans Canada, Great Lakes Laboratory for

Fisheries and Aquatic Sciences; T. STEWART, Ontario Ministry of Natural Resources, Lake Ontario Management Unit; T. JOHNSON, Ontario Ministry of Natural Resources; M. HOSSAIN, Fisheries and Oceans Canada; K. HOLECK, K... FITZPATRICK, Cornell University; J. WATKINS, Cornell University, Natural Resources; J. HOLDEN, OMNRF; M. YUILLE, Queens University; M. CONNERTON, NYS DEC; B.F. LANTRY, U.S.G.S., Lake Ontario Bio Station; C. CHU, Ontario Ministry of Natural Resources and Forestry. **Effects of total phosphorus and bigheaded carp on the Lake Ontario food web.**

Lake Ontario (LO) is undergoing rapid changes due to invasive species, climate change, development in watersheds and management actions. To understand how these factors singularly or interactively affect the LO ecosystem, we used an Ecopath with Ecosim model to evaluate the effects of total phosphorus (TP) and bigheaded carp (BHC) on LO's food web. TP ranged from 20% of current level to 540% (historic high). Simulation scenarios were: TP levels with/without BHC. Biomass of most model groups increased with increases in TP, but the increases were smaller when TP was 2*current level. BHC biomass increased with increases in TP, but their biomass was negligible under the 20% of TP scenario. TP had much stronger effects on the food web than BHC. BHC consumption of plankton had negative effects on zooplankton and zooplanktivores, but positively affected Smallmouth Bass, Lake Whitefish and Yellow Perch. BHC showed strongest negative effects under scenarios of 100% or 140% of current TP.

26. Lake Winnipeg: The emerging view after 15 years of whole-ecosystem science

D. DEPEW, E. KRUTZELMANN, Environment and Climate Change Canada; K. WATCHORN, Environment & Climate Change Canada, Water Science & Technology Directorate; E.C. ENDERS, A. CASKENETTE, Fisheries and Oceans Canada. **Distribution of the exotic zebra mussel (*Dreissena polymorpha*) on natural substrates in Lake Winnipeg.**

The invasive zebra mussel (*Dreissena polymorpha*) was initially detected in several harbours of Lake Winnipeg in 2013, raising concerns about economic and ecological consequences of a subsequent invasion and colonization of Canada's sixth largest lake. Here we document lake-wide sampling efforts to assess the initial stages of invasion with respect to mussel abundance and biomass and distributional patterns over 2017 - 2019. Preliminary results indicate a divergence from colonization patterns in other large lakes, perhaps due to the physical features and predominantly soft substrates dominating Lake Winnipeg. Patterns in distribution and abundance will be discussed with a perspective toward projecting potential ecological impacts of an established dreissenid population in Lake Winnipeg.

K. WATCHORN, Environment & Climate Change Canada, Water Science & Technology Directorate; G. GOLDSBOROUGH, University of Manitoba, Department of Biological Sciences;

C. HUDON, Environment & Climate Change Canada, Water Science & Technology Directorate. **Wetland vegetation in Netley-Libau Marsh: temporal changes in cover related to Lake Winnipeg level & Red River flow.**

Netley-Libau Marsh, Lake Winnipeg's largest coastal wetland and the delta of the Red River, has experienced a trend of emergent vegetation loss, degrading its wildlife habitat and limiting its ability to mitigate nutrient loads to a eutrophic system. A time-series of classified vegetation cover maps were produced for Netley-Libau Marsh to evaluate its current state and investigate relationships between hydrology and cover. Late-summer Landsat imagery was used to delineate and classify open water area, emergent vegetation, wet meadow, and upland within the marsh from 1990-2013. Temporal changes of the area and distribution of marsh vegetation were related to Lake Winnipeg level and Red River discharge, as well as with connectivity and bathymetry of the marsh. Periods of extremely low water as short as one year induced a marked expansion in emergent vegetation cover that persisted over the next ten years despite higher water levels. Rather than being gradual, changes in the spatial extent of Netley-Libau Marsh vegetation appeared to proceed by fits and starts, wherein periods of relative stasis were disrupted by major changes in abundance.

27. The Lake of the Woods watershed

W. GREENWOOD, Trent University; C. EIMERS, Trent University, School of the Environment; A. WILLIAMS, Trent University. **Hydrology of the Lake of the Woods watershed: basin storage and streamflow response to extreme weather.**

Nutrient export from rivers and streams can vary greatly depending on flows; therefore, nutrient budget estimates for the Lake of the Woods (LOW) require reliable flow data and a strong understanding of the local basin hydrology. The sheer size and complex nature of the LOW basin makes monitoring costly and exemplifies the importance of efficient monitoring program design. Here we compare the flow regimes of rivers draining the southern Agassiz clay plain to those on the northern Canadian Shield during two back-to-back years with very different hydroclimatic conditions (2018 and 2019) in order to assess a) whether or not the pattern of flashy, more variable flow on the Agassiz clay-plain vs. relatively subdued, stable flow on the Canadian Shield persists and b) how these rivers may or may not respond differently to weather extremes (e.g., different snowpack and snowmelt dynamics and extreme summer rainfall events). This information may be used to inform future monitoring design and evaluate potential sensitivity to climate change.

28. Addressing Great Lakes science and policy at the IISD Experimental Lakes Area

L.A. MOLOT, York University, Faculty of Environmental Studies; T. MUDGE, ASL Environmental Services; J.J. VENKITESWARAN, Wilfrid Laurier University, Department of

Geography and Environmental Studies; H. BAULCH, University of Saskatchewan, School of Environment and Sustainability; S.L. SCHIFF, University of Waterloo, Department of Earth and Environmental Sciences; M. LARSEN, Wilfrid Laurier University, Department of Geography and Environmental Studies. **Rapid Formation of N-fixing Cyanobacteria Blooms in Two Lakes Fertilized only with Phosphorus.**

Weekly additions of phosphoric acid without nitrogen began June 6, 2019 to oligotrophic Lake 303 (shallow, polymictic) and Lake 304 (thermally stratifies) at the IISD Experimental Lakes Area in northwestern Ontario. Large blooms of N-fixing *Dolichospermum* dominated both lakes within 10 weeks of P additions. Dissolved P increased about 2-fold from 2.4 to 2.9 ug/L in mid-May to 5 to 6 ug/L after P additions began although dissolved P reached 21 ug/L in L303 in early July. Chlorophyll *a* in L304 increased from < 4 ug/L to > 20 ug/L by mid-August and in L303 from < 10 to > 50 ug/L by early September. Cyanobacteria dominated the phytoplankton community by mid-August in L304 (86% of biomass, 3.1 mg/L wet wgt) and L303 (50%, 1.6 mg/L wet wgt). Cyanobacteria biomass in L303 reached a maximum of 28.4 mg/L in early September. Formation of large blooms of N-fixing cyanobacteria in these lakes when only P was added suggests that removal of anthropogenic N in wastewater treatment plants that already remove P will not contribute to bloom prevention effectiveness.

29. A science strategy for water management in the Great Lakes

J.F. BRATTON, LimnoTech; M.R. TWISS, Clarkson University, Dept. of Biology & Great Rivers Center; J. RIDAL, St. Lawrence River Institute of Environmental Sciences; L. WANG, International Joint Commission. **IJC Assessment of Great Lakes Connecting Channels and their Monitoring Infrastructure.**

An IJC advisory team reviewed issues facing St. Marys, Mackinac, Huron-Erie, Niagara, and St. Lawrence channels. Priorities noted were legacy contaminants, sewer overflows, habitat degradation, and flow/load monitoring. The Huron-Erie Corridor is monitored and studied most intensively. Data management is good, but accessibility could be improved. Gaps include habitat usage by resident/transient species, restoration trajectories, water level and flow regulation influence on habitats, and ice dynamics. Impediments include inadequate coordination of monitoring, insufficient funding for sustained monitoring, and suboptimal monitoring equipment and vessels. Recommendations include more investment in monitoring and support systems, an improved mix of reference stations and experimental monitoring, expansion of real-time monitoring, better linkage of monitoring to modeling, and more consistent attention to channel issues in Lakewide Action and Management Plans and in the Cooperative Science and Monitoring Initiative cycle. The monitoring capacity of Indigenous groups should also be enhanced.

J.F. BRATTON, E. VERHAMME, LimnoTech; S. RUBERG, NOAA - GLERL; P.C. ESSELMAN, U.S. Geological Survey; T. NETTESHEIM, U.S. EPA, GLNPO; R. MILLER, University of Michigan – CIGLR. **Developing an Interagency Common Agenda for Use of Advanced Survey Technologies in the Great Lakes.**

USEPA, NOAA, and USGS, with input from other agencies and organizations, are developing a strategic plan for interagency cooperation on the use of advanced survey technologies to validate models, answer priority research questions, and fulfill monitoring needs. A group of experts is identifying a set of technologies and developing a process to achieve common goals. Participating agencies are (1) preparing an inventory of the availability and operational status of existing advanced survey technologies at Great Lakes agencies; (2) identifying high-potential technologies for building regional capacity; and (3) developing a plan for transitioning from research and development to full-scale operations. The result of the plan and agency commitments will be coordinated acquisition and use of advanced technologies, including greater efficiencies in data management and visualization, deployment and recovery of survey platforms, and training and staffing of technical support teams.

A. GRONEWOLD, University of Michigan, School for Environment and Sustainability, Department of Civil and Environmental Engineering; H.X. DO, University of Michigan, School for Environment and Sustainability; L. BRILEY, Great Lakes Integrated Sciences and Assessment; R. ROOD, University of Michigan, Climate and Space Sciences and Engineering. **Research needs to address hydrologic impacts of climate change.**

Over the past decade, hydrologic conditions across the Great Lakes have gone through a significant transition. From 1998 through 2013, water levels were predominantly at or below average, while from 2014 through 2020 water levels have risen sharply leading to record-high conditions. There is a clear and pressing need to differentiate the hydrologic and climatic drivers behind the changes observed during this period, and doing so requires a new perspective on research objectives and priorities. In this talk, we explore some of the recent advancements in regional hydrological and climatological modeling and forecasting, and how they align with observations and current conditions across the basin. We also discuss the role of existing monitoring infrasctructure in the region, and how its utility might be improved in light of increasing investments in high-resolution global data sets.

P.R. JOHNSON, Great Lakes St. Lawrence Governors & Premiers. **An Overview of the Regional Body and Compact Council's New Science Strategy.**

On December 11, 2019, the Regional Body and the Compact Council adopted a new Science Strategy. This Science Strategy addresses the research needs to assist the Regional Body and Compact Council to their implement Great Lakes water management obligations. The Science Strategy highlights a variety of needs and challenges related to improved water quantity data

collection; improved tools for management decisions regarding water use consumptions, conservation and efficient use; and overarching issues such as climate change, indigenous engagement and outreach. In addition, the Science Strategy also identifies priority actions that include a focus area for each of the next three years. This presentation will focus on the history of the development of Science Strategy, the content of the Science Strategy, the importance of the updated Science Strategy to the region, and plans for implementing the Science Strategy.

R.A. SMAIL, Wisconsin Department of Natural Resources. **Remotely-sensed water budgets for Wisconsin agriculture.**

Much of the land cover in the Great Lakes basin is agricultural and therefore likely to impact regional water budgets. Understanding these effects requires empirical observations of precipitation and actual evapotranspiration (ETa). This study compared the results of two gridded evapotranspiration products on cropland in the upper Midwest of the United States, SSEBop and MOD16A2, against observations at 13 proximate Ameriflux eddy covariance sites. While both products were within 10% of Ameriflux bserved annual ETa, MOD16A2 observations more closely reflected ETa in all years and at all sites. Gridded PRISM precipitation and MOD16A2 were then used to calculate 2004-2018 monthly potential infiltration and runoff for agricultural 2,966,248 ha Wisconsin. Agricultural management features such as crop rotation and irrigation as well as physical features such as soil drainage and hillslope gradient were compared to identify differences in monthly water budgets.

30. Great Lakes, wicked problems: Research across science-policy-public interfaces

J.H. HARTIG, University of Windsor, Great Lakes Institute for Environmental Research; G.B. Krantzberg, Engineering and Public Policy, Program, McMaster University; J.C. AUSTIN, The Brookings Institution; P.D. MCINTYRE, Loracs Design LLC. **Great Lakes Revival: How Restoring Polluted Waters Leads to Rebirth of Great Lakes Communities.**

Since 1985, governments and stakeholders have been developing and implementing remedial action plans to restore uses in Great Lakes Areas of Concern (AOCs). Initially, progress was slow because of complexity of the problems, lack of clarity on use of an ecosystem approach, time commitments for effective stakeholder involvement, evolution of management programs, and limited funding. Over time, many of these constraints have been overcome. As of 2019, seven AOCs have been delisted, two have been designated as AOCs in Recovery, and 79 of 137 known use impairments in Canadian AOCs and 90 of 255 known use impairments in U.S. AOCs have been eliminated. Although progress has been made, much remains to be done to restore all uses in all AOCs. IAGLR and partners have undertaken a three-year study of what has been achieved and learned from more than 30 years of restoring AOCs. As part of this study, 10 AOC case studies

were prepared of how cleanup has led to reconnecting people to waterways that has led to community and economic revitalization. These case studies illustrate the benefits of AOC cleanup and make a powerful case for sustaining funding and help revive communities.

L. STARR, Wright State University. **Summertime sources and cycling of methylmercury in western Lake Erie tributaries.**

Little is known about the sources and cycling of bioaccumulative methylmercury (MeHg) in Lake Erie, despite the lake having a world-renowned sport fishery. We examined concentrations and fluxes of total mercury (Hg) and MeHg to western Lake Erie from the Detroit, Sandusky, and Maumee Rivers. Average total Hg concentrations were similar in the Detroit (5.4 ± 0.8 pM) and Sandusky Rivers (5.3 ± 0.9 pM) and less than in the Maumee River (11.6 ± 2.8 pM). Similarly, MeHg was lower in the Detroit (0.38 ± 0.25 pM) and Sandusky Rivers (0.24 ± 0.13 pM) than in the Maumee (0.63 ± 0.46 pM). The mean fraction of total Hg as MeHg in water was comparable among the rivers (~5%), suggesting similar biogeochemical cycling. Estimated river fluxes of MeHg were much greater from the Detroit River (200 mmol day–1) than from either the Maumee (1.5 mmol day–1) or Sandusky Rivers (0.05 mmol day–1). These preliminary results suggest the Detroit River is a large fluvial source of MeHg to western Lake Erie.

E. ZEEMERING, University of Georgia. **Evaluating the Intergovernmental Performance of the Great Lakes Restoration Initiative (GLRI) in Illinois.** (No abstract.)

32. Traditional ecological knowledge and the Great Lakes basin

C.M. Febria, University of Windsor, GLIER & Integrative Biology. **Co-production as a critical tool in community-based Great Lakes research.**

How can we ensure that scientific research in the Great Lakes best serves society, Indigenous rights-holders and future generations? Here I present a framework and set of tools used in research that places communities at the centre of the research process. Using examples from here in the Great Lakes and beyond, I present examples of actionable science, translation ecology, collaboration and science communication that are all forms of co-produced research. To further ensure that freshwater sustainability, honour the Truth and Reconciliation Act of Canada, and fully restore the vitality of the Great Lakes and their watersheds, I discuss the benefits of normalizing co-production in research teams.

C. JACOBS, Bkejwanong Territory/Walpole Island First Nation; C. DONALDSON, J.T. IVES, University of Windsor; C.M. FEBRIA, University of Windsor, GLIER & Integrative Biology. **Traditional Ecological Knowledge and the Great Lakes: A field course experience.**

To bridge the gap in understanding and strengthen connections between science and indigenous ways of knowing, we co-designed a summer field course that took place across Bkejwanong Territory (Walpole Island First Nation). Here, students and university faculty gathered on the unceded territorial land of the Anishnaabe people in the heart of Lake St. Clair and the Laurentian Great Lakes basin. Each day, scientists and indigenous knowledge holders collaborated to co-produce learning experiences that exposed students to varied ways of knowing Nature, to see the Great Lakes from the Anishinaabe perspective, and share in the experience of building community through community-based scientific research. Here we share our experiences from the course and selected reflections from the students who engaged in the learning experience.

D. YUNUS, IISD Experimental Lakes Area Inc. **Building Relationships: Lessons from a Western science facility located in First Nations territory.**

Where do we begin to build meaningful relationships in a time when bridging Western science and Traditional Knowledge has become critical in addressing some of the most pressing environmental crises facing our world? The story of Canada's most unique scientific research facility has plenty to teach us. Located in Treaty #3 traditional land, IISD-ELA has seized upon a unique opportunity to work more closely with Indigenous communities to look at how the two ways of knowing can work together and benefit each other. During this session, Dilber Yunus, IISD-ELA's outreach officer, will explore what IISD-ELA has learned along the way, including the importance of individual connection with respect and honesty; understanding communities' needs; and incorporating the preservation and revitalization of Indigenous culture and language into collaboration efforts. She will explain where IISD-ELA needs to go from here, and what the lessons IISD-ELA has learned could mean for other scientific facilities who want to engage with Traditional Knowledge in a meaningful way.

33. Great Lakes education, outreach, and communications

B. DOLGAN, Turnstone Strategies. **A year in scicomm: Aquatic invasive species, coastal ecosystems and marketing Chicago Wilderness.**

Strategies is a marketing/communications firm founded in 2018 with a focus on Midwest land and water conservation. Founder Bob Dolgan reviews three successful communications/storytelling efforts from the past year: 1) Great Lakes Protection Fund's 30th anniversary, including research and stories about aquatic invasive species and the launch of a $17B ballast water treatment industry; 2) "Monty and Rose," an integrated marketing campaign featuring a pair of endangered piping plovers that became the first of the species to nest in Chicago since 1955; 3) Nature Loves Chicago, a storytelling project focused on nature and nature enthusiasts of Illinois and Indiana during the Covid-19 pandemic. Turnstone Strategies is a new conference sponsor and eager to connect with other conference attendees.

S. SMITH, Zephyr Mangata. **Climate and water education: Too much, too little, too dirty.**

This session shares information on new curricula and tools used to engage students in climate change education, with local and global water as a central theme. The impacts of climate change manifest in water-related impacts: flooding (too much), drought (too little) and pollution (too dirty). We will discuss how to engage youth in climate education through the lens of water, through newly developed lesson plans and educational kits that focus on ecological footprints, clean water for all and climate action. The lessons tie in both the North American Great Lakes and the East African African Great Lakes, with students considering both local and global impact and actions to solve problems at different scales.

S. SMITH, Zephyr Mangata. **Turn up the volume for youth voice in water issues.**

How can youth voice and action be better engaged and amplified to create change? In connecting water and climate education to local and global geographies and impacts, youth can learn what's needed to make a difference in the world, yet more is needed to translate this into action. This session explores insights gleaned from developing tools to foster youth as agents of change for water and climate.Amidst a rise in youth environmental leaders (notably in climate change), there is still a gap for many youth who strive to make a difference, but lack tools and connections to do so - particularly in the middle school and early high school range. And while youth climate leadership is growing visibly, what are the tools youth interested in water issues need and can use to grow into water leaders? Find out how to better connect youth change agents to each other, their communities and the systems they strive to understand and impact.

S. SVOBODA, Great Lakes Now, Detroit Public TV. **Ace the Interview: Pointers for talking to print, radio or tv reporters.**

(Back from 2019!) Being a credible, effective communicator with reporters is not a one-size-fits-all protocol for all media platforms. Print journalists have different needs from their sources than radio hosts or tv producers do. Digital work and social media also offer opportunities for controlling the public conversation about research and Great Lakes issues. Starting with a comparison of how scientists and journalists are alike and different in their workflow and approaches to "content," we will review how and where researchers and reporters can help each other work effectively. With examples from the presenter's 30-year communications career, session participants will learn skills and strategies they can immediately use to help their work be understood, valued and correctly represented in the media and to the public and other stakeholders.

35. Climate impacts on Great Lakes and watersheds: Model applications

Y.B. DIBIKE, Environment and Climate Change Canada, Watershed Hydrology and Ecology Research Division; A. MUHAMMAD, Government of Saskatchewan, Water Security Agency; R.R.

SHRESTHA, C. SPENCE, B. BONSAL, L. DE RHAM, Environment and Climate Change Canada, Watershed Hydrology and Ecology Research Division; J. ROWLEY, University of Victoria, Department of Geography; G. EVENSON, The Ohio State University, Department of Food, Agricultural and Biological Engineering; T. STADNYK, University of Calgary, Department of Geography. **Variable Contributing Area for Modelling Hydrologic Response of the Assiniboine Watershed to a Changing Climate.**

The effect of representing variable contributing area (VCA) dynamics in modelling streamflow in the pothole dominated Assiniboine watershed is investigated using a modified version of SWAT with enhanced representation of wetlands. The fill-and-spill processes are captured using a physically-based approach with a volumetric threshold to reduce the computational demand. Despite the challenges in accurately simulating the prairie pothole hydrology, the modified approach improved model performance in replicating the observed streamflow over the calibration/validation periods. The implications of this modelling approach on future hydrologic projections are also investigated using statistically downscaled CMIP5 GCMs, under two emissions scenarios. End of century projections indicates increases in annual precipitation and temperature and decreases in summer precipitation relative to the 1976-2005 baseline period. Compared to the standard SWAT setup without VCAs, the modified model is found to be more responsive to these changes with relatively larger projected increases in seasonal and annual flows for most of the evaluated stations.

H.X. DO, University of Michigan, School for Environment and Sustainability; A. GRONEWOLD, University of Michigan, School for Environment and Sustainability, Department of Civil and Environmental Engineering; L.M. FRY, NOAA Great Lakes Environmental Research Laboratory, Office of Great Lakes Hydraulics and Hydrology; J. SMITH, Cooperative Institute for Great Lakes Research. **Impacts of hydro-climate variability to the recent surge of water levels across the Laurentian Great Lakes.**

Water levels of the Laurentian Great Lakes have recently shown a rapid transition from extreme lows to extreme highs, indicating a potential impact of climate change and variability on the hydrologic cycle across the region. To assess the drivers of changes in water levels, we developed a new record of seventy-year long monthly water balance using the Large Lake Statistical Water Balance Model, which was encoded in a Bayesian framework. To explore the connection between changes in water levels and stochastic variabilities of net basin supply variables, the damping effect of connecting-channel flows was removed from our analysis. Across the Great Lakes, the coincidence between unusually high conditions of lateral runoff and over-lake precipitation is likely the mechanism driving the recent water level surge since 2014.

Y. LIN, University of Michigan; A. FUJISAKI-MANOME, CIGLR, University of Michigan; J. WANG, E.J. ANDERSON, NOAA, Great Lakes Environmental Research Laboratory. **Does a hotspot(s) of ice formation exist in the Great Lakes?**

Knowledge of the processes of ice formation over a large freshwater body (e.g. lake) is essential to understand how the ice-lake system will respond to a changing climate. In the polar regions, latent-heat polynyas are well known, ice-free areas near the coastal region or the edge of shore-fast ice. Over a typical latent-heat polynya, ice is continuously formed and exported toward offshore by winds, serving as a hotspot of ice production. The Great Lakes, the world's largest freshwater lake system, are partly frozen each year, and yet the preferences of ice formation locations remain unclear. For instance, is there a similar mechanism of polynya associated with shore-fast ice in Great Lakes to generate lake ice? If so, where are these hotspots located in Great Lakes? Do these hotspots reappear in the same regions? The goals of this study are to improve the parameterization of shore-fast ice of Finite-Volume Community Ocean Model (FVCOM) coupled with the unstructured grid version of the Los Alamos Sea Ice Model (CICE) in the Great Lakes and use it to simulate the processes of ice formation in the Great Lakes to address the above mentioned questions.

F. SEGLENIEKS, A. TEMGOUA, Environment and Climate Change Canada, National Hydrological Services. **Future climate and water levels on the Great Lakes basin based on CORDEX simulations.**

Changes in the future hydro-climate regime of the Great Lakes are an important area of study at Environment and Climate Change Canada (ECCC), as these changes will have significant impact on the environment, economy, and overall quality of life of the region. Regional climate model (RCM) results are crucial in properly simulating the unique nature of the Great Lakes given the large percentage of lake area in the basin. The climate simulations are based on CMIP5 scenarios driven by various members of the Coordinated Regional Climate Downscaling Experiment (CORDEX) for both the RCP4.5 and RCP8.5 scenarios. For this study, current and future climate simulations of temperature and precipitation are used to run the hydrological model WATFLOOD. The results of the hydrological model are examined on a monthly basis in terms of differences between the current climate and future climate simulations. The hydro-climate variables examined include: temperature, precipitation, lake ice, streamflow, snow water equivalent, evaporation, soil moisture, and Great Lake water levels.

R.R. SHRESTHA, B. BONSAL, Environment and Climate Change Canada, Watershed Hydrology and Ecology Research Division; A. KAYASTHA, University of Victoria; Y.B. DIBIKE, C. SPENCE, Environment and Climate Change Canada, Watershed Hydrology and Ecology Research Division. **Projecting snowpack response in the Lake Winnipeg watersheds under global warming.**

We present a modelling study on future snow water equivalent (SWE) responses for two sub-watersheds of the Lake Winnipeg watershed (Assiniboine and Red). We use a process-based snow model driven by an ensemble of statistically downscaled GCMs to project future changes

under 1.0?C to 3.0?C global mean temperature increases above the preindustrial period. Results indicate consistent seasonal and annual temperature increases, with greater warming in winter months. Precipitation projections show wetter winters and springs, and drier summers, while autumn could get either drier or wetter. Consequently, under the global warming thresholds from 1.0?C to 3.0?C, the basin will experience successively shorter snow cover duration, slower snowmelt, smaller monthly SWE and maximum SWE and earlier maximum SWE occurrence. Further, parts of the basin would transition from snow-dominant to rain-snow hybrid regime. These changes will have implications on water quantity and quality of the region.

36. Large lakes' interaction with climate on seasonal to multi-millennial scales

D.K. HALL, University of Maryland College Park, ESSIC; D.S. O'LEARY, University of Maryland College Park, Geographical Sciences; N.E. DIGIROLAMO, SSAI; W. MILLER, Brigham Young University, Civil and Environmental Engineering; D. KANG, University of Maryland College Park, ESSIC. **Influence of climate change on the dramatic decline of the Great Salt Lake, Utah.**

The Great Salt Lake (GSL) in Utah has been shrinking over the last ~170 years because of upstream water diversions causing a decline of ~3.6 m in surface-water elevation (SWE). Though the SWE fluctuates considerably, there is a trend of continued desiccation that is exacerbated by climate change. The lake is very shallow so lowering of the SWE leads very quickly to decreased area and increased salinity, with negative environmental consequences. We use MODIS satellite data products along with meteorological data to study climate-related factors that are associated with the lake's decline. To the east of the lake in the GSL basin in the Wasatch and Uinta mountains, air temperature has been increasing, while snow depth has been decreasing. Furthermore, snow in the GSL basin is melting ~10 days earlier since 2000. Earlier snowmelt, and higher air and surface-water temperatures are associated with increasing evaporation, thus accelerating water loss from the lake.

B.M. LOFGREN, NOAA Great Lakes Environmental Research Laboratory. **Progress on Global Climate Modeling Including 3-dimensional Lake Models.**

Direct linkage of a 3-dimensional lake circulation model to a global climate model (GCM) in lake-covered portions of the domain will conceptually improve the energy, moisture, and momentum exchanges between the lake surface and atmosphere, compared to 1-dimensional lake models. It will reduce the number of linkages that must be used to drive simulations of lake circulation. Progress is being made on a coupling of the Finite Volume Community Ocean Model (FVCOM) configured for the Laurentian Great Lakes with NOAA Geophysical Fluid Dynamics Laboratory's (GFDL) Climate Model version 4.0 (CM 4.0). This system will directly simulate lakes' horizontal circulation, upwelling and downwelling, and ice transport interaction with freezing and melting—all processes that are inaccessible to 1-dimensional lake models. The accompanying

surface fluxes of energy, moisture, and momentum are important drivers of both the lake and the atmosphere, and are expected to be more realistic using a 3-dimensional model. Results of simulations to date will be presented in the talk.

F. MCCARTHY, J. PENTESCO, Brock University, Earth Science; E. PAPANGELAKIS, University of Western Ontario, Geography; A. SARVIS, District School Board of Niagara. **The role of climate in the Lake Superior basin on the hydrology of lakes in the Huron-Michigan basin.**

Most of the hydrologic input to Lake Huron-Michigan is outflow from Lake Superior. Because the sill along the St. Mary's River is shallow, the water balance in the driest part of the Great Lakes basin greatly impacts the quantity and quality of water in Lake Huron-Michigan, affecting humans since the Early Holocene. Hydrologic closure of Lake Superior allowed rapid drawdown (up to 1mm/day) during the Early Holocene drought, isolating lowstand lakes in the Michigan, Huron, and Georgian Bay basins more rapidly than pollen-derived reconstructions of climate in the Huron-Michigan basin would suggest. The negative water budget increased the concentration of dissolved ions, recorded by testate amoebae and ostracods in sediments and in the oral traditions of the Ojibway people. Lake levels rose quickly in response to the large-scale changes in atmospheric circulation that signaled the beginning of the Middle Holocene Epoch, rapidly transgressing to Nipissing levels. This illustrates the sensitivity of the Great Lakes to climate and the importance of using a basin-wide approach to understanding the response of individual lakes to projected climate change.

37. General

C. GODWIN, Cooperative Institute for Great Lakes Research, School for Environment and Sustainability, University of Michigan; J. ZEHNPFENNIG, Institute for Great Lakes Research, Department of Biology, Central Michigan University; D. LEARMAN, Institute for Great Lakes Research, Department of Biology, Central Michigan University. **Biotic and Abiotic Mechanisms of Manganese (II) Oxidation in Lake Erie**.

Seasonal hypoxia in Lake Erie's central basin causes elevated manganese (Mn) in the hypolimnion, creating a problem for drinking water intakes. The persistence of dissolved Mn in the water is determined by multiple redox mechanisms, but the balance of these processes is poorly understood. Here we show that homogenous oxidation by molecular oxygen is negligible, but abiotic mechanisms involving mineral surfaces play a large role in oxidizing Mn (II), particularly in the light. Reactive oxygen species exhibited antagonistic roles: hydrogen peroxide acted as a net reductant for Mn oxides and completely masked oxidation of Mn by the superoxide free radical. Mn oxidation rates were much higher in the western basin than the central basin. These findings show that multiple mechanisms may exert control over the fate of Mn and suggest that Mn released from

sediments during hypoxia can potentially remain dissolved in the water for an extended period of time. DOI: 10.3389/fenvs.2020.00057

K. MCKEEHAN, A. ARBOGAST, Michigan State University, Department of Geography, Environment, and Spatial Sciences. **Repeat Photography of Lake Michigan Coastal Dunes: Expansion of Vegetation and Human Impacts Since 1900.**

Coastal dunes are a prominent feature of the Lake Michigan shoreline, especially along the Lower Peninsula of Michigan. The long-term geomorphic history of these dunes has been researched in recent years, demonstrating how these systems respond to climatic variability and lake levels. Less is known about how these dune systems change on shorter temporal scales. Using repeat photography, we attempt to demonstrate how these dunes are changing in the historic record. Hundreds of photographs of Lake Michigan coastal dunes were collected from archives and citizen scientists. Rephotographs were taken at over 80 of these locations, replicating the original images. The changes between dune conditions in the original photographs and in the 2019 rephotographs show a general conversion of bare sand to vegetation. Human development has played a role in reshaping the coastal dunes as well, but the most pronounced difference between historical dunes and current conditions is the advent of vegetation. Here, we present photographs most representative of these changes and discuss likely causes, including the increase in precipitation in Michigan in the last 80 years.

M. BEZOLD, S. NEWELL, J. MYERS, M. MCCARTHY, Wright State University. **Sediment microbial nitrogen dynamics in an agricultural settling pond during the non-growing season**.

Constructed wetlands are used for reducing excess nutrient loading by anthropogenic activities and are often paired with settling ponds for sedimentation, but whether these ponds act as a net nitrogen (N) sink, and what the major N removal pathways are, remains uncertain. Additionally, sampling is often limited to warm months, making pond dynamics during colder seasons a major knowledge gap. We examined sediment N dynamics from Oct 2019-May 2020 in an agricultural settling pond connected to a constructed wetland in Ohio. Intact sediment cores were amended with 15N for continuous flow incubations to determine denitrification and N fixation rates from dissolved gas measurements. Denitrification was stimulated when 15N-nitrate was added, suggesting substrate limitation. N fixation rates increased in winter, while denitrification rates increased in warmer months. These results offer new insights into improving agricultural nutrient control practices on a year-round basis.

R. EVELEENS, University of Windsor, Great Lakes Institute of Environmental Research; C.M. FEBRIA, University of Windsor, Great Lakes Institute of Environmental Research & Department

of Integrative Biology. **Can a community save a species? Using species interactions to restore unionid species at risk.**

Delays in species recovery following conservation or restoration efforts suggest that current approaches need improvement. One avenue is the use of species interactions to inform recovery actions targeting desired species. In the Great Lakes, 14 of 35 unionid mussel species in Southern Ontario are federally at risk. Unionids interact with multiple trophic levels, including relying on fish hosts during parasitic juvenile stages, feeding on algae and organic matter, and interacting with other filter-feeding species. It is unclear how multi-trophic interactions are considered in restoration, but it may be a critical aspect. Here we present a global literature review investigating current restoration success and when community interactions have been included. Preliminary results suggest efforts using community interactions are few but results are promising. Sequenced approaches to managing abiotic and biotic aspects should be considered particularly if coordinated at appropriate scales.

E. HOLLIDAY, C. HAMMERSCHMIDT, S. NEWELL, M. MCCARTHY, Wright State University. **Phosphorus Fluxes from sediments in the Maumee River in 2019**.

Excess nutrients (P and N) into the western basin (WB) of Lake Erie are related to cyanobacteria blooms and hypoxia events. For example, a toxic cyanobacterial bloom in 2014 shut down the water treatment plant in Toledo, Ohio. The Maumee River inputs ~5% of the water load into WB but ~50% of the average total phosphorus (P) load. We quantified seasonal P flux from sediments in the Maumee River in 2019. Upriver sediments were, on average, a P sink all year (23.2 ± 5.34; all rates in μmol m-2 h-1). At the river mouth, sediments were a P source in April (91.0 ± 17.5), shifting to a P sink in August through October (10.1 ± 7.5). In Maumee Bay, sediments were a P source in May and October (21.0 ± 7.3) but a sink during summer months (3.0 ± 2.1). These suggest that upriver sediments perform a valuable ecosystem service by removing P that otherwise could fuel cyanobacterial blooms in WB, but the effects of both downriver and nearshore Maumee Bay sediments on WB P dynamics are less clear.

Y. HONG, University of Michigan, Cooperative Institute for Great Lakes Research; L. FRY, E.J. ANDERSON, NOAA, Great Lakes Environmental Research Laboratory; L. READ, A. RAFIEEINASAB, National Center for Atmospheric Research. **Evaluating Precipitation for National Water Model Prediction over the Great Lakes.**

The development and evaluation of gridded meteorological forcings data is a critical component of total water prediction at the continental scale. NOAA has invested significant effort in developing an Analysis of Record for Calibration (AORC) forcing dataset for the continental United States and parts of Canada. The AORC dataset will serve as the primary forcing dataset for NOAA's National Water Model (NWM) as of version v2.1, which will include calibration over the transboundary Great Lakes basin. Limited work has been conducted to evaluate precipitation products over the Great Lakes and in Canadian portions of the basin for use in calibration and

retrospective simulations by the NWM. This presentation highlights research evaluating CaPA and AORC over the Great Lakes region by comparing daily gridded precipitation from both products with station data. \n

C. KITCHENS, C. GODWIN, Cooperative Institute for Great Lakes Research, University of Michigan. **Timing and Rates of Hypoxic Manganese Flux from Lake Erie Sediments**.

Seasonal occurrences of hypoxia in the central basin of Lake Erie can cause the sediment to release manganese (Mn) into hypolimnetic waters. These Mn-enriched waters can result in yellow-tinted drinking water that is potentially harmful to both distribution systems and human health. The precise redox conditions required for the onset of release are uncertain, as are the rates of Mn flux under various dissolved oxygen (DO) conditions. We conducted an experiment using intact sediment cores to estimate timing and rates of Mn flux from Lake Erie sediments as a function of temperature and DO content in the overlying water. Results show that sediments are a net sink for dissolved Mn while the overlying water is oxygenated, but flux of Mn from the sediments to the water begins when DO falls below 2 mg/L. These results have important implications for predicting when and where hypoxia may lead to elevated Mn in the hypolimnion in Lake Erie.

J. MCANDREWS, A.T. FISK, T.E. PITCHER, S. LAROCQUE, A. MOKDAD, University of Windsor, Great Lakes Institute for Environmental Research; K. LOFTUS, Ontario Ministry of Natural Resources & Forestry; T.B. JOHNSON, Ontario MNRF, Glenora Fisheries Station; C. BROWN, Macquarie University, Biological Sciences. **Effects of in-hatchery environmental enrichment on the post-release behaviour of Atlantic Salmon.**

In-hatchery enrichment is a tool used in conservation biology that provides life skills to improve behavioural deficits and survivorship in hatchery-reared fishes; however, it is often not utilized in production-oriented fish stocking programs. In an effort to improve the reintroduction efforts of Atlantic Salmon (*Salmo salar*), a native top predator in Lake Ontario, we incorporate enrichment (live food, live predators, and in-tank structure ten weeks prior to their release) into a production-oriented fish hatchery. Using acoustic telemetry, we examine the differences between the post-stocking performance of conventionally reared and enriched *S. salar* in Duffins Creek, ON. All 60 acoustically tagged fish were detected in the array and at least two control and five enriched fish migrated out of the creek within two weeks of stocking. We will discuss movement and behaviour between control and enriched fish, which has implications for fish restoration strategies

A. MOLINA-MOCTEZUMA, K. KAPUSCINSKI, A. MOERKE, Center for Freshwater Research and Education, Lake Superior State University. **Restoring long lost hydrological connectivity in a Great Lakes connecting channel, the St. Marys River**.

In the Great Lakes, habitat has been extensively altered resulting in destroyed habitats. In particular, the St. Marys River lost over 50% of its historic rapids habitat over the past century. In

2016, the Little Rapids Area in the St. Marys River was restored. The goal of this study was to evaluate ecological responses to restoration of the Little Rapids area. Habitat and biological data were collected prior to the restoration and compared to post-restoration data. Pre-restoration, velocities were below target flows of 0.24 m/s, whereas following restoration, 70% of the habitat was above the target flows. Benthic macroinvertebrate abundance and richness was reduced following restoration. In larval fish we observed an increase in CPUE, and richness two years post-restoration. In adult fishes, the proportion of lotic species increased throughout the study area. In general, the physical and biological conditions of the area changed to conditions typical of rapids habitat.

J. MYERS, S. NEWELL, Wright State University; L. CLECKNER, Finger Lakes Institute at Hobart and William Smith Colleges; M. MCCARTHY, Wright State University. **Internal nitrogen and phosphorus loading supports harmful algal blooms in a shallow, temperate lake**.

Honeoye Lake is a shallow lake (New York, USA) characterized by an increasing frequency of harmful algal blooms (HABs). Nitrogen (N) and phosphorus (P) from external and internal loading often control algal growth in lakes. Sediment processes contribute to nutrient removal (e.g., denitrification) and internal loading (e.g., N fixation). To investigate sediment nutrient dynamics in Honeoye Lake, sediment cores were collected (May–October) from two sites and incubated using bottom water with no amendments (control) or 15-N stable isotope. Sediment cores were sampled daily for nutrients (ortho-P, NH4, NOx, urea) and dissolved gases (O2, N2). Sediments were a net source of both N and P. Chemically reduced N forms dominated the N pool, and nitrate limited N removal via denitrification. N and P from sediments is mixed to the surface by weather events, promoting HABs. Effectively reducing external and internal loads of N and P is necessary to reduce occurrences and toxicity of these blooms.

A. NEUMANN, University of Toronto Scarborough, Department of Physical and Environmental Science; A. RICHARDS, Environment and Climate Change Canada; D. KIM, K-Water Research Institute, Department of Physical and Environmental Science; A. JAVED, G. ARHONDITSIS, University of Toronto Scarborough, Department of Physical and Environmental Science. **Data-Driven Bayesian SPARROW Modeling Framework: A Piot Study in Georgian Bay, Ontario, Canada.**

Georgian Bay coastal embayments frequently experience poor water quality due to total phosphorus (TP) inputs, which are the main driver of algal blooms. There is an urgent need to develop models that can iteratively assimilate tributary monitoring data to perform sources apportionment, quantify nutrient export coefficients (EC), and allocate nutrient hot-spots. The applied SPARROW model corroborated existing TP EC for forests in the Precambrian Shield. Agricultural areas demonstrated troublesome twice higher TP losses per unit area compared to Southern Ontario. Source tracking identified three critical source areas: 1) multiple upstream

catchments which delivered > 90% of TP inputs in coastal embayments, 2) wetlands which contributed ~ 30% to the delivered TP from forests, and 3) agricultural areas with ~ 40% share in anthropogenic TP budget. The developed framework can be extended for nutrient loading assessment in other Precambrian Shield areas, such as Lake of the Woods basin

S. PACZUSKI, K. MARGESON, Oak Ridge Associated Universities. **Decision Support for the Beneficial Use of Dredged Material**.

Dredging work to maintain shipping channels and subsequent material management in port cities across the Great Lakes can benefit remediation, restoration, and revitalization. Each year, over 25,000 miles of navigation channels are dredged for regular operations and maintenance, producing millions of cubic yards of material that must be managed through either disposal or beneficial reuse. This research aims to understand the roles and perceptions of diverse groups of stakeholders while increasing transparency in the decision-making process. By reviewing existing beneficial reuse cases and working with stakeholders to identify current and future project alternatives, we have built up a suite of criteria relevant to considering beneficial reuse. Initial results indicate that there are five categories or dimensions of criteria for decisions; governance, biophysical environment, built environment, economy, and social criteria.

D. PLOUCHART, S. MARKOVIC, G. ARHONDITSIS, University of Toronto Scarborough, Department of Physical and Environmental Science; A. ZASTEPA, Environment and Climate Change Canada, Canada Centre for Inland Waters; M.B. DITTRICH, University of Toronto Scarborough, Department of Physical and Environmental Sciences. **Phosphorus biogeochemical transformations at the sediment water-interface in Lake Erie.**

Despite considerable efforts to reduce external phosphorus (P), water quality problems including harmful algal blooms (HABs) are still recurrent issue in Lake Erie. Recently, new studies and models have shown that HABs are promoted by sediment phosphorus reflux (internal P loading). Interestingly, phosphate diffusion through sediments is controlled by long-term storage of P and by redox conditions at the sediment-water interface (SWI) on shorter time scales. Therefore, we aimed to investigate the sediment biogeochemistry at the SWI and quantify the internal loading rates from sediments of western and central basins of Lake Erie. We then compared the profiles in summer where a large peak of cyanobacteria occurs to early fall where stratification and anoxic zones took place. The combining methods of depths-profiling (micro-electrodes: pH, oxygen, redox potential), porewater (dissolved reactive P, ferrous iron, alkalinity), and sediment analyses (porosity, P fractionation) would allow us to quantify the rates of P, trace metals recycling and retention process at the SWI to untangle the mechanisms playing on phosphorus reflux.

M. PUZYREVA, D. ROY, International Institute for Sustainable Development. **Water Quality Trading: Blessing or Curse?**

Lake eutrophication is a global problem and in cases like Lake Winnipeg and the Great Lakes involves addressing point- and non-point loading of nutrients. There is widespread interest in applying water quality trading (WQT) to enable point- or non-point dischargers facing higher pollution control costs to meet regulations by purchasing environmentally equivalent pollution reductions from lower-cost actions in the watershed. While the overall logic and intention of WQT may be clear and appealing, the implementation of WQT programs are often complicated. This presentation will showcase analyses and case studies related to WQT programs across the globe and provide insights on key elements of WQT design and implementation such as the need for clear regulatory limits, up-front institutional investments, clarity of intent, scale, supply and demand and discuss how water quality improvements can be achieved realistically through this mechanism. Ultimately, careful consideration of relevant design elements and the potential of WQT can help policymakers avoid policy implementation paralysis and attain regional water quality objectives.

M. SEPP, Estonian University of Life Sciences; T. KÕIV, Estonian University of Life Sciences; S. NEWELL, M. MCCARTHY, Wright State University. **Variation in dissolved organic matter (DOM) quantity and quality in temperate lakes**.

The main sources of dissolved organic matter (DOM) in lakes are allochthonous inputs from the catchment and autochthonous production. We investigated variation in DOM quantity and quality in 11 Estonian lakes during 2015-2019. DOM quantity was measured as dissolved organic carbon (DOC) and colored dissolved organic matter (CDOM), latter representing the catchment-derived DOM. The quality of DOM (molecular weight and aromaticity) was characterized using different spectral parameters based on absorbance and fluorescence measurements. DOC ranged from 3.9 to 53.0 mg/L in the studied lakes. DOC and CDOM were strongly correlated ($r = 0.95$, $n = 220$), indicating the mainly allochthonous origin of DOM. However, in oligotrophic lakes with low inputs from the catchment or eutrophic lakes, DOC increased with the relative contribution of autochthonous DOM. Understanding the drivers of DOM variation will help to predict responses of lake DOM to climate change and effects on the global carbon cycle.

D.R. UZARSKI, University of Windsor, GLIER; T. JOHNSON, Ontario Ministry of Natural Resources; A.T. FISK, University of Windsor, GLIER. **Utilizing carbon and nitrogen stable isotopes to assess lower trophic relationships in Lake Ontario.**

While the relationships between organisms residing in the higher trophic levels of Lake Ontario's food webs are relatively well understood, the linkages between invertebrate species tend to be understudied. Zooplankton and benthic invertebrate samples collected from 50 stations across Lake Ontario in 2012 and 2013 were analyzed for stable isotopes (13C and 15N) to determine trophic relationships. Niche size was determined for each species and niche overlap between species was calculated using the SIBER package in R statistical software. The strong tendency of

zooplankton to be omnivorous and the variance in isotope signatures of the habitats sampled has led to a high rate of overlap among species in the lower trophic levels of Lake Ontario.

D.P. ZIELINSKI, Great Lakes Fishery Commission; R. MCLAUGHLIN, University of Guelph; T. PRATT, Fisheries and Oceans Canada; A. GOODWIN, U.S. Army Engineer Research and Development Center; A.M. MUIR, Great Lakes Fishery Commission. **Selective connectivity for ecosystem management**.

Barrier removal is the most recognizable solution for reversing aquatic ecosystem fragmentation, yet restoring connectivity can have unanticipated benefits for undesirable species (connectivity conundrum). Selectively moving desirable taxa while restricting the movement of undesirable taxa (selective connectivity) could provide a solution to the connectivity conundrum. The challenge of selective fish passage is fundamentally one of sorting an assortment of things, but engineered, multi-attribute sorting systems for live organisms do not exist. For this reason, we developed an approach to selective fish passage that integrates ecology and biology of targeted fish with engineering designs, and is modeled on the single-stream recycling process that involves material collection, disintegration and conditioning, sorting, and fate. Using the case study of sea lamprey control, we will discuss how key aspects of recycling processes could be applied to fish passage phases (approach, entry, passage, and fate) to achieve selective connectivity. Our industry inspired vision of selective connectivity could help resolve the connectivity conundrum.