global lake ecological observatory network

Poster Session Abstract Book

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Poster Abstracts

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#Ponding - Mixing and stratification

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Currently we are #PONDING (Pond Observation aNd Discovery IN GLEON) both old datasets and newly collected data from more than 50 ponds around the world. The goal is to see how ponds differ from lakes and from the common misconception that ponds are fully mixed due to their shallow water column. Recent studies have emphasized that ponds exhibit a diverse suite of very dynamic mixing and stratification patterns. Many ponds stratify during the day, typically followed by partial or full convective mixing at night. While the stratified period in ponds is often short, it can be pronounced and have important implications. Surface water dissolved oxygen can be as high as 400 % super-saturated, while waters below the thermocline can be hypoxic or even anoxic. Other ponds are covered by emergent or floating leaf vegetation resulting in darkness and hypoxia in the entire water column. Low availability of oxygen below the thermocline is a result of respiration processes dominating, this releases nutrients and CO2 and lowers pH. Under hypoxic or anoxic conditions bacterial metabolism can reduce metal ions and form sulphide and methane. When a pond mixes, oxygen could temporarily be resupplied to the bottom waters while nutrients, CO2 and methane are transported to the surface waters. The addition of DIC and nutrients stimulate continued productivity while methane might be oxidized or escape to the atmosphere.

A better understanding of the drivers of mixing and stratification is therefore key to gaining a better understanding of how our smallest and most numerous water bodies function.

2. *Maggie ARMSTRONG[1], Elisabeth Ruijgrok[2], Guus Kruitwagen[2], Lisette de Senerpont Domis[1]*

The People Behind The Process: Water Manager Socioeconomic Decisions in the Implementation of the Water Framework Directive

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Eutrophication and climate change have been identified as key drivers of water quality deterioration worldwide. Mitigating the compound effects of these stressors requires preemptive, multidisciplinary management measures. Given the diversity of ecological, social and meteorological parameters around the world, there can be significant variations to the inventive approaches that water managers take while pursuing preventative and/or restorative actions towards mitigation of negative impacts on ecosystem functions and services.

The European Union's Water Framework Directive is an international law, which requires all ground and surface waters in the EU to be in good ecological status. Within the context of the EU-WFD, we are assessing the approaches of water managers in implementing rehabilitation plans, particularly with how they evaluate their rehabilitation plans in terms of socio-economic benefits. Due to the influence that the availability of ecosystem services have on stakeholders and society at large, we hypothesize that water managers are also integrating these values into their rehabilitation plans. We are therefore inventorying what type of socio-economic appraisal techniques water managers are using in the development of rehabilitation plans.

In order to test this hypothesis we are collecting data from water management organizations throughout Europe using online surveys as well as in-depth qualitative interviews. We will analyze these data for trends in approaches towards improving the ecological status and the inclusion of socioeconomic values. By sharing the common practices of approaches taken towards fulfilling the WFD, the results of our study can inform water managers in Europe and beyond on the most effective approach for developing benefit-oriented rehabilitation plans.

3. *Louis ASTORG[1], Simon Thibodeau[1], Alison Derry[1]*

Freshwater zooplankton community response to experimental road salt exposure in a pristine Laurentian lake

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Freshwater ecosystems provide crucial services for human societies such as drinking and irrigation water, food, climate regulation and recreation. These lake ecosystem services are dependent on the health and integrity of freshwater populations and communities in aquatic food webs. While the effects of exposure to certain pollutants, such as heavy metal and pesticides, have received much attention in aquatic ecosystems, the ecological effects of other pollutants, such as increased salinity as a result of runoff from road salt application, are less understood. This is despite that road-salt runoff can cause major changes in the abundance and composition of aquatic invertebrate assemblages, which provide food for higher consumers such as fish. In this study, we experimentally exposed naive planktonic communities of a freshwater boreal lake to a gradient of elevated NaCl concentration (0-1200 $mg.L^{-1}$) in *in-situ* lake mesocosms. We measured changes in the composition and taxon-specific abundance of crustacean zooplankton and rotifer communities as a response to the different levels of salt concentration. We found that elevated NaCl concentration had large negative effects on many species of crustacean zooplankton and rotifers. However, certain small cladocerans, such as *Bosmina*, had higher resistance to the stressor than other zooplankton. Contrary to our expectations, rotifers were sensitive to salt exposure, suggesting a potential for region-specific responses in aquatic communities. Overall, however, our findings support that runoff from road salt applications can have devastating effects on naive freshwater zooplankton communities, even at what is considered sublethal concentrations by guidelines for water quality standards.

4. *Karen S. ATKINS[1], Scott H. Hackley[1], Shohei Watanabe[1], S. Geoffrey Schladow[1]*

Long Term Trends of Periphyton Biomass in an Oligotrophic Lake

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Periphyton, algae attached to the bottom of freshwater environments, play vital rolls as the base of many aquatic food webs and as an indicator species. The amount of periphyton biomass at a specific location is dependent on many physical, chemical, and ecological functions making it particularly difficult to predict. Researchers have monitored periphyton levels in Lake Tahoe, USA since 1982. Here, our goal is to employ statistical methods to better understand long term periphyton trends and processes. We analyze spatial and temporal patterns of periphyton at sampling stations around the lake and the influence of lake level fluctuations on periphyton levels with Mann-Kendall Tests. Additionally, we used the Kruskal-Wallis Test to examine biomass trends associated with shoreline levels of human development. To further characterize processes responsible for periphyton growth we implemented a Bayesian Hierarchical Model strategy. Through this method, we created multiple layers of conditional models to address spatial and temporal influences to periphyton. We input light, nutrients, grazing, and sloughing field data to clarify the relative influence on periphyton biomass. Results will be used to inform a periphyton biomass model for Lake Tahoe.

5. *Abdou Rachid BAH[1], Ronaldo Carhuaricra[2], Patty Arunyavikul[2], Shaun Pollard[2], Ryan Chen[2], Hamid Norouzi[2] and Reginald Blake[2]*

Studying Global Lakes Surface Temperature Variability at the Basin Level-Scale Using Remote Sensing Observations

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Even though lakes make up a small percentage of the water bodies on the global land surface, natural lakes and impoundments provide critically important ecosystem services that include drinking water, fisheries, recreation, and irrigation. Unfortunately, however, several lake surface areas around the globe have been changing with many of them dying due to climate variability and local mismanagement at the basin-scale level. Lake Surface Water Temperature (LSWT) is recognized as a critical indicator of climate change.

This project focuses on the application of remote sensing to investigate the changes in lake surface water temperatures and their relationship with their surrounding land cover type in a bid to identify the main driving factors of these changes. In this study, 394 global major lakes have been investigated. An analysis of temperature variation over these lakes has been conducted using daily observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) from year 2002 to 2018 over the lakes and their surrounding land areas. Preliminary results show that 45.67% of the studied lakes are warming, and about 54.32% of them are cooling. Furthermore, 62.94% of the lakes are shrinking while 29.69% of them are growing. The relationship between the rates of LSWT change and other lake characteristics such as lake depth, salinity level, geographical location, and size were also investigated. A clear latitudinal relationship was discovered in temperature changes with increasing LSWT rates from north to south. This study, therefore, provides insights about LSWT variability on a global scale.

6. *Alexandre BAUD[1], Pierre Francus[2], John Smol[3], Irene Gregory-Eaves[1]*

Eastern Canadian spatio-temporal analysis of geochemical change

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In collaboration with the LakePulse Network Program, this research project constitutes a comprehensive inter-regional assessment of geochemical change based on analyses of sediment cores from across Eastern Canada. For this large-scale research project, continuous sediment cores have been collected across 40 lakes and analyzed using new high-resolution instruments to provide insights into the magnitude and direction of geochemical change across four ecoregions in Eastern Canada. We will explore whether lakes most heavily impacted by land-use transformation in their watershed and lakes closer to metallic mines show the greatest magnitude of change through time. We will also explore the direction of the geochemical change of each lake by classifying their trajectory across different categories. Investigating lakes' temporal geochemical trajectories will help us understand to greater details the factors shaping the regional geochemical change experienced by Eastern Canadian landscape since the Industrial Revolution.

7. *Jennifer A. BRENTRUP[1], Nicole K. Ward[2], Cayelan C. Carey[2], Kathryn L. Cottingham[1], Denise A. Bruesewitz[3], David C. Richardson[4], Kathleen C. Weathers[5]*

A comparison of three winters of under-ice ecosystem metabolism estimates reveals high variability in under-ice net ecosystem production

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The challenges of winter sampling in lakes have prevented many multi-year comparisons of under-ice ecosystem metabolism estimates. In oligotrophic lakes, increases in the magnitude and variability in gross primary production (GPP) and respiration (R) may be a sensitive indicator of the impacts of warmer winters on carbon cycling. We compared ecosystem metabolism estimates in an oligotrophic lake from the winter of 2007-2008 to metabolism estimates from 10 years later during the winter of 2017-2018 and 2018-2019. During the 2018-2019 winter, we deployed two dissolved oxygen (DO) sensors to compare metabolism estimates below the ice at 1.5 m to just above the sediments at 8 m. For all three winters, mean net ecosystem production (NEP) was heterotrophic, but the magnitude of heterotrophy varied. The lowest mean NEP occurred at 8 m, which was 2.75x lower than surface NEP estimates. The rate of oxygen consumption under ice at 8 m was 6x greater than at 1.5 m. In addition, GPP and R estimates at 8 m were significantly more variable than estimates from 1.5 m as soon as ice formed. During the latter two winters, R increased throughout the under-ice period with the highest rates occurring immediately before ice-off, which differed from the first winter, when the highest R occurred after ice-on. GPP estimates were low under-ice until rapidly increasing just before ice-off in the most recent winter. The variability in ecosystem metabolism estimates across different years and depths may improve predictions for how carbon cycling will change as winters warm.

8. *Sarah H. BURNET[1], Frank M. Wilhelm[1]*

Predicting the occurrence of harmful algal blooms resulting from wind-related metalimnetic entrainment of high phosphorus hypolimnetic water

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Wind is a primary factor influencing the physical translocation of packets of water, and the nutrients in them, in lakes and reservoirs. If phosphorus (P) derived from internal loading in the hypolimnion reaches surface waters it can alter the nitrogen:phosphorus (N:P) ratio that determines the species composition of algal communities. Low N:P ratios are known to promote the occurrence of blooms of toxic cyanobacteria called harmful algae blooms (HABs). We aim to test the hypothesis that it is possible to predict the timing and occurrence of HABs from relationships between wind speed, time of year, depth of thermal stratification, and the water column phosphorus concentration. We plan to use Willow Creek Reservoir (WCR) in Heppner, OR as a case study to quantify the load of P transferred to surface waters by wind mixing events, given it currently experiences severe annual hypolimnetic anoxia and high hypolimnetic P loading that are hypothesized to result in HABs. Additionally, we aim to understand the physical drivers of these processes including the duration and strength of a wind event needed to cause metalimnetic entrainment. The potential to predict the occurrence of algae blooms will benefit lake managers that are responsible for managing lake access and ensuring the health and safety of the public.

9. *Elisa CALAMITA[1], Davide Vanzo[2], Bernhard Wehrli[1,2], Martin Schmid[2]*

The impacts of a large tropical dam on river water quality: a modelling approach.

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The fast growing population of Africa is pushing the exploitation of water resources to ensure water supply, food and energy production. Consequently, African river basins are experiencing major anthropogenic changes. The ongoing boom of large dam constructions will affect water quantity and quality and will increase pressure on aquatic environments. Particularly, the increased hydrologic residence time imposed by dams and the potential for stratification of their reservoirs affect downstream river water quality. However, the scarce data availability and limited modelling efforts result in limited knowledge about their impacts on downstream aquatic ecosystems.

In this study, we focus on the Zambezi River Basin (southeaster Africa), one of the most dammed African basin. Using the one dimensional General Lake Model, we reproduced the internal dynamics of Kariba Lake, the world largest artificial lake by volume, created by damming the Zambezi River at the border between Zambia and Zimbabwe. Through this modelling approach, we assessed and quantified the impact of the reservoir on downstream water temperature and dissolved oxygen concentrations. Moreover, we investigated how different management opportunities potentially allow to reduce these water quality alterations in the downstream Zambezi River, reducing the consequences for the entire river ecosystem.

10. *Maria Caldero Pascual[1], Eleanor Jennings[1], Elvira de Eyto[2], Mary Dillane[2] and Valerie MCCARTHY[1]*

The role of nutrient availability and allochothonous carbon contributions in determining zooplankton dynamics in Lough Feeagh

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Dystrophic lakes, also called humic or brown lakes, have naturally low levels of inorganic nutrients and high concentrations of humic matter. This gives a typical brown colour to the water and generally originates from terrestrial ecosystems and has been shown to be related to dissolved organic carbon (DOC) concentrations. The characteristic brown colour of humic matter in dystrophic lakes increases attenuation of solar radiation, which has been associated with a natural reduction in primary productivity. In contrast, this terrestrial carbon source tends to promote higher bacterial production, which In turn alters the energy and chemical flows through the aquatic food web.

The role that changes in physico-chemical and biological dynamics have in determining plankton diversity, biomass and community structure in Lough Feeagh, an Irish dystrophic lake in the west of Ireland was investigated. Primary productivity was found to be driven principally by physical factors such as water temperature, light and wind speed. On the other hand, changes in nutrient elemental composition of zooplankton seston food supply was found to have a role in influencing zooplankton community structure. High zooplankton biomass during the winter period, when primary productivity was very low, suggested that primary consumers also take advantage of allocothonous organic carbon sources during this time. A better understanding of the relative importance of autochthonous versus allochthonous carbon contributions and its implications for planktonic food webs is required. This is particularly important in a dystrophic lake such as Feeagh, where primary consumers are highly adapted to high carbon to nutrient ratios and poor carbon quality (high recalcitrant compounds and low essential fatty acids composition) originating from the surrounding terrestrial ecosystems.

11. Cayelan C. CAREY[1], Alexandria G. Hounshell[1], Kaitlin J. Farrell[1]

Integrating simulation modeling into undergraduate aquatic ecology courses increases students' understanding of global change on lakes

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Environmental scientists are increasingly using simulation models, based on large datasets of sensor observations, to predict the effects of global change on aquatic ecosystems. Despite the increasing importance of ecosystem modeling, however, undergraduate aquatic ecology curricula rarely include hands-on modeling activities. Through Macrosystems EDDIE (Environmental Data-Driven Inquiry & Exploration), we are developing a suite of hands-on, inquiry-based modules to teach macrosystems ecology to undergraduate students at a range of experience levels. Modules combine high-frequency data from GLEON (Global Lake Ecological Observatory Network) and NEON (National Ecological Observatory Network) with lake ecosystem simulation models to teach students macrosystems ecology through the lens of limnology. Assessment data from general ecology and aquatic ecology courses at seven universities demonstrate that completing Macrosystems EDDIE modules significantly increases student self-reported proficiency, confidence, and likelihood of future use of simulation models, as well as student ability to correctly interpret complex model output. Importantly, our data show that students' system thinking skills significantly increased as a result of completing a module. Moreover, using models to develop and test hypotheses increased students' perceptions of the value of running multiple different simulations to study and predict potential effects of climate change on lakes. Consequently, our results suggest that integrating simulation modeling into undergraduate aquatic ecology courses will improve students' abilities to predict and understand the potential effects of global change on aquatic ecosystems.

12. Irene CARAMATTI[1], Frank Peeters[1], David Hamilton[2], Hilmar Hofmann[1]

Modeling the water exchange in Lower Lake Constance and its alteration due to climate warming

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Three-dimensional (3D) hydrodynamic models can be useful to investigate currents and circulation patterns in lakes that have distinct topographic features, such as a sill-separated basin. Additionally, they can forecast how the lake hydrodynamic would answer to climate warming.

Here we present a multi-year hydrodynamic study of an alpine lake with complex morphology (Lower Lake Constance, LLC) using the three-dimensional (3D) model AEM3D. LLC is subdivided into three basins (Gnadensee, Zeller See and Rheinsee) which differ in depth, morphological features, hydrodynamic conditions, and ice cover phenology and thickness. Gnadensee is the most enclosed sub-basin and it is connected to the rest of the lake via a shallow sill (average water depth of 2.5 m), that limits the horizontal exchange with the other basins.

AEM3D was used to quantify the water exchange between GS and the rest of the lake and to understand the influence on the exchange of the seasonal lake thermal structure. The setup of numerical tracer studies permitted to understand the role that the main river inflow and the surface water in the Mixed Layer play in the water exchange. Moreover, the study investigated the alteration of water exchange induced by climate warming.

13. *Kaelin CAWLEY[1] and Keli Goodman[1]*

Lake Ecosystems are part of the National Ecological Observatory Network (NEON)!!

[1]National Ecological Observatory Network (NEON) operated by Battelle, Boulder, CO, USA

The National Ecological Observatory Network (NEON) is a national-scale research platform distributed over 20 ecoclimatic domains from Alaska to Puerto Rico. Over the next 30 years, NEON will collect data that enables a better understanding of how ecosystem structure and function are impacted by climate change, land-use change, and invasive species on a decadal scale. Standardized instrumentation and field protocols are used to collect data at 34 freshwater aquatic sites, including seven lakes. Lake instrumentation includes a riparian meteorological station, buoy-mounted meteorological station, in situ nitrate, PAR, and profiling water quality sonde. Field protocols cover a range of chemical, physical, and biological parameters, which include algae, zooplankton, fish, macroinvertebrates, nutrients, inorganic and organic solute concentrations, and lake bathymetry.

The lakes span a wide range of geographic, morphometric and water quality conditions: surface area ranges from 10 to 150 ha, maximum depth from 1.6 to 26 m, Secchi disk depth from 0.1 to >5 m, and conductivity from 5 to 6000 µS/cm. In addition to serving open data (https://data.neonscience.org/home), NEON infrastructure supports additional research activities through the assignable assets program (https://www.neonscience.org/resources/information-researchers). Data coming out of this monitoring network will be available for answering a wide range of scientific questions, such as the environmental drivers of community structure change over time, or how lakes are impacted by disturbance events such as hurricanes. NEON data will add to the existing GLEON community lake data to aid in understanding how lakes respond to a changing environment.

14. *Rosaura J. CHAPINA[1], Brian O'Malley[2], Jason Stockwell[1]*

How complete is benthic-pelagic coupling by Mysis?

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Mysids play vital roles in lake food webs because their extensive diel vertical migration (DVM) couples pelagic and deep-water benthic habitats. Mysids are omnivorous and serve as a primary food source for many pelagic and benthic fishes, thus mysids have the potential to transport nutrients up and down the water column. The literature indicates that small Mysis may suspend in the pelagic zone during the day especially over deeper waters, suggesting incomplete benthic-pelagic coupling for part of the population in certain regions of deep lakes. We propose a standardized, collaborative field effort in 2020 that spans north-temperate lakes to test the hypotheses that 1) greater lake depths and sufficiently low light levels allow Mysis to stay suspended during the day; 2) pelagic-caught individuals that remain suspended during the day are smaller than individuals caught at night; and 3) smaller individuals remain suspended due to predation risk from cannibalism by larger individuals on the bottom, and thus feed on pelagic resources with high nutrient concentrations to grow faster and reduce predation risk. Data to be collected at each lake include day and night Mysis whole water column samples over a gradient of bathymetric depths, secchi depth, and light intensity at the surface. The data will be used to develop a model that will help determine the leading factors in Mysis decisions to remain in pelagic habitat during the day.

15. Manqi CHANG[1,2,], Sven Teurlincx[1], Donald L. DeAngelis[3], Jan H. Janse[1,4], Tineke A. Troost[5], Dianneke van Wijk[1,2,6], Wolf M. Mooij[1,2], Annette B.G. Janssen[6]*

A Generically Parameterized model of Lake eutrophication (GPLake) that links field-, lab- and model-based knowledge

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Worldwide, eutrophication is threatening lake ecosystems. To support lake management numerous eutrophication models have been developed. The established models are based on three key approaches: the empirical approach that employs field surveys, the theoretical approach in which models based on first principles are tested against lab experiments, and the process-based approach that uses parameters and functions representing detailed biogeochemical processes. These approaches have led to an accumulation of field-, lab- and model-based knowledge, respectively. Linking these sources of knowledge would benefit lake management by exploiting complementary information; however, the development of a simple tool that links these approaches was hampered by their large differences in scale and complexity. Here we propose a Generically Parameterized Lake eutrophication model (GPLake) that links field-, lab- and model-based knowledge and can be used to make a first diagnosis of lake water quality, i.e. chlorophyll-a level. We derived, parameterized and applied GPLake. The derivation of GPLake provides the model with a solid mechanistic foundation from consumer-resource theory. In the parameterization, the generic parameters were found to scale in comparable manner across data sources. Finally, we show that GPLake can provide lake managers with a first diagnosis of the limiting factor and lake water quality, using only the parameters for lake depth, residence time and current nutrient loading. Hence, we conclude that GPLake provides a versatile and simple tool for lake management.

16. *François CLAYER[1], Jan-Erik Thrane[1], Uta Brandt[1], Peter Dörsch[2] and Heleen A. De Wit[1]*

Quantifying carbon fluxes in a typical boreal catchment: a coupled field-based and modelling approach

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Headwater lakes and streams are key components of the climate system through their role of emitters of greenhouse gases (GHG), i.e., CO2 and CH4, and intensive processors of terrestrial carbon (C). Yet, they are not fully represented in Earth System Models partly because significant uncertainties remain within their C budget. Several studies suggest that including lateral C fluxes, i.e., dissolved organic and inorganic C (DOC, DIC) lateral export and GHG release, can reduce the land C sink by up to 27%. There is thus a clear need to better quantify C flux within headwater catchments.

In this presentation, we combine the analysis of high-frequency sensor data and field measurements of GHG concentrations and fluxes to the atmosphere from the long-term monitored Lake Langtjern (Norway) and connected streams to gain insight into the C cycling of a typical boreal catchment. This dataset enables us to acknowledge the role of the lake and streams as emitters of GHG at the catchment level and discuss their significance in counteracting the land C sink. The output of previous and new lake modelling on DOC processing using Low-Frequency (1986-2015) and High-Frequency (2014-2016) data are also used to provide lake C budgets and compare the various flux estimates with field-based measurements.

17. *Kristen A. COLEMAN[1], Joshua R. Thienpont[1] and Jennifer B. Korosi[1]*

Understanding lake response to thawing permafrost in the subarctic

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Aquatic ecosystems at the southern limit of permafrost are highly sensitive to climate warming through dramatic alterations of the landscape resulting from the thawing of permafrost. In the southern Northwest Territories (NT), permafrost is typically restricted to peat plateaus that are elevated above the surrounding wetland complex. As mean annual air temperatures approach 0°C, permafrost thaw can result in the collapsing of these peat plateaus and waterlogging of the trees. These landscape changes can impact aquatic ecosystems by altering the connections between water bodies and altering the amount of terrestrial organic matter that enters these ecosystems, contributing to the "browning" of lakes, which in turn can affect important aquatic ecological processes. Understanding how lakes in the southern NT have been responding to the acceleration of permafrost degradation over the past few decades can be challenging as monitoring records are scarce in these remote regions. The field of paleolimnology offers an indirect way to reconstruct long-term environmental change, by using chemical, biological, and physical proxy data preserved in lake sediment cores. My research uses paleolimnology to answer questions about ecosystem responses of small subarctic lakes to permafrost thaw. Specifically, I am interested in the spatial and temporal variability of lake response and how hydrological connectivity might be driving the sensitivity of lakes to browning. This research will contribute important advancements in our understanding of how permafrost thaw impacts aquatic ecosystems near the southern limit of permafrost and how they will change in the future as the permafrost boundary moves northward.

18. CULPEPPER, Josh[1,2], Chandra, Sudeep[2], and Schumer, Rina[1]

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Land to lake: Connections between winter snowpack, ice-out date, and spring turnover

Decreasing ice cover duration owing to climate change may affect traditional perspectives on lake mixing. Increasing air temperatures continue to alter snow content in high-altitude environments, which decreases ice cover duration. Recent modeling suggests that more than 90,000 lakes may experience winters without freezing in midlatitude and polar regions by as early as 2080. Other suggest that some lakes will lose ice cover completely before the end of the century, fundamentally altering their physical mixing behavior, and by extension, their ecosystems. We have observed fluctuating ice breakup dates at Castle Lake (z=30 m), California, in recent years. Ice cover is correlated with summer warming trends, summer average primary productivity, and more, indicating that winter conditions influence lake behavior in other seasons. We use high temporal resolution temperature and oxygen sensors to ask if ice breakup affects spring mixing patterns. Instead of classical dimictic behavior, mixing is intermittently incomplete in Castle Lake. We suggest that conditions such as intermittent ice cover, earlier ice breakup, and low spring melt inhibit full mixing in the hypolimnion. Castle Lake only mixed to the depth of the metalimnion (z=10 m) in spring of 2017, after low winter precipitation (~1671 mm). Sensors in the hypolimnion at twenty and thirty meters showed limited oxygen concentration and temperature changes throughout the spring but showed increased oxygen concentration and isothermal behavior during fall mixing at the full thirty meters. We use these data to establish context of winter climate characteristics that may alter spring mixing regimes.

19. *Elvira DE EYTO[1], Alo Laas[2], Amir Reza Shahabinia[3], Angela Baldocchi[4], Ankur R. Desai[4], Anna Lupon[5], Annalea Lohila[6], Blaize Denfeld[7], Brian Doyle[1,8], Cayelan C. Carey[9], David Bastviken[10], David Reed[11], Eva-Ingrid Room[2], Francois Clayer[12], Gesa Weyhenmeyer[3], Hannah Chiemel[13], Hans Peter Grossart[14], Heleen de Wit[12], Iestyn Woolway[8], Ilga Kokorite[15], Jan-Erik Thrane[12], Janis Bikse[15], Jim Rusak[16], Jorge Encinas[17], Ludmila Brighenti[18], Matthias Koschorreck[19], Mika Aurela[6], Rafa Marce[20], Rita Adrian[14], Robyn Smyth[21], Ryan P. McClure[9], Biel Obrador[22], Steve Sadro[23], Sarian Kosten[24], Nathan Barros[24], Thomas Hintze[14], Philipp Keller[19]*

DC-FLUX – a GLEON initiative to measure CO2 fluxes in the still of the night, across the world.

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DC-FLUX is a GLEON working group initiative that started at the G18 meeting in Lunz, Austria in 2016. Our group was motivated by a shared interest in the measurement of GHG (greenhouse gas) emissions from lakes, and specifically in the use of relatively cheap CO2 sensors in small do-it-yourself (DIY) flux chambers. Several GLEON members had already started using this technology or were planning on using them in the near future. We decided that the GLEON community infrastructure was ideally-suited to utilise and test this technology to address two linked hypotheses: 1) CO2 fluxes are higher at night due, in part, to turbulent convective mixing, and 2) diel differences in CO2 fluxes are greater in lakes with a more pronounced gradient between surface water and air temperatures. By addressing these two hypotheses, we aimed to extend the range of waterbodies for which GHG fluxes had been quantified, and explore how CO2 fluxes vary between day and night over a latitudinal gradient. After agreeing on a common fieldwork protocol, sampling took place at 21 lakes and reservoirs around the world between 2016 and 2018. In total, 42 sampling expeditions were carried out, in which CO2 flux was measured 7 times over a 27-hour period, at 4-hour intervals. Data collation is ongoing. Here we present initial results and provide the context and background to the project.

20. *Kristy DEINER*[1]

Measuring biodiversity through understanding biogeochemical cycling of environmental DNA in lakes

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The biosphere is under immense pressure and we need standard measures of Essential Biodiversity Variables (EBVs) to execute regular assessments of global biodiversity. Many conventional methods will not be feasible due to their expense and time required for multiple taxonomic groups and large geographic scales – environmental DNA (eDNA) has the potential to solve this bottleneck. eDNA is DNA shed from an animal or plant into its surroundings that can be collected and sequenced to infer species presence. Precise knowledge on its fate is crucial to facilitate the paradigm shift to a powerful way to assess biodiversity using molecular methods. I will highlight how biodiversity information inferred from eDNA can benefit from collaboration between limnologists by linking our current understanding of how water movement and chemistry determines eDNA persistence. I will present a vision of interdisciplinary research leading to new ways of measuring ESVs for large spatial scales using lake water and allow monitoring biodiversity of earths ecosystems. The ERC funded project propose a collaboration available for GLEON members to participate in a global sampling effort.

21. *Oxana ERINA[1], Maria Tereshina[1], Liudmila Efimova[1], Dmitriy Sokolov[1], Valeriy Puklakov[1]*

The impact of environmental changes on internal and external nutrient loads in the Mozhaysk Reservoir

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The main driver of eutrophication around the globe remains the input of nutrients with anthropogenic sources. However, in Russia over the past 30 years, the intensity of agriculture has significantly decreased, which in turn has led to a decrease in the external nutrient load and lakes. The catchment area of the Mozhaysk reservoir, located in the central European part of Russia, was actively used mainly for agricultural purposes until the late 1980s. Our study shows, that over the past 30 years, the supply of nutrients to the reservoir has reduced significantly. Along with a decrease in human input of nutrients, the decrease in external nutrient load has been affected by changes in spring weather. In spring, 50-60% of the total annual amount of external nutrients enter the reservoir, and as a result, depending on the form of the flood, differences in the amount of incoming phosphorus can reach several tons.

Under these conditions, a significant source of nutrients in the reservoir comes from the internal load. As a result of climate change in the reservoir, there has been an increase in the duration of the period of stratification and the anoxic conditions. Consequently, the concentrations of nutrients, especially phosphorus, in hypolimnion has doubled over the past 30 years. Furthermore, in the last 10 years the frequency of extreme weather events has increased, resulting in nutrients being released from sediments and consumed by phytoplankton. Such extreme weather events followed by periods of warm weather cause the bloom outbreaks. in the reservoir.

22. *Stephanie FIGARY[1], Lars G. Rudstam[1], and James M. Watkins[1]*

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Determining zooplankton community response to changing water quality parameters in large lakes using Taxa Indicator Threshold Analysis

Regulations governing aquatic systems focus on water quality parameters as a tool for managing systems. Zooplankton community assemblages are impacted by both bottom-up (nutrients) and top-down (planktivory) forces; however, separating these factors is difficult. This project focuses on the zooplankton community response to changes in bottom-up forces using an existing dataset from a large lake system that underwent planned nutrient reductions over the past several decades and experienced zooplankton community changes during the same time period.

This project will use data from United States Environmental Protection Agency's Great Lakes National Program Office's (GLNPO) monitoring program. The GLNPO dataset includes zooplankton, chlorophyll a, and water chemistry data from 1997 to 2018 that was collected twice a year during the spring, typically April, and summer, typically August, seasons from all five Laurentian Great Lakes. This project will use zooplankton community data from 153 um net tows to a depth of 100m or two meters from the bottom of the site, whichever was deeper. Water chemistry data that varied between 1997 and 2018 will be selected for analysis. Changes in the zooplankton community will be detected using Taxa Indicator Threshold ANalysis (TITAN). TITAN determines the point along an environmental gradient where individual taxa have the largest change in abundance and frequency and then uses the community to determine if numerous taxa have a similar change point, indicating a potential ecological threshold. Results from this study will help explain the bottom-up factors contributing to zooplankton community changes in an oligo- and meso-trophic lake system.

23. *Giovanna FLAIM, Dario Ballin[2], Ulrike Obertegger[1]*

You can't always get what you want – fish, sensors and fishermen

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Fishing is an important recreational activity in Trentino with an estimated economic impact of approximately €1.5 million per year in seasonal and daily fishing licenses, without considering revenue generated by equipment, participation in fishing tournaments, hospitality, etc. In this region, anglers' expectations are geared towards trout (*Salmo truta* L) and fishing associations regularly stock brown trout to meet this demand.
For higher altitude lakes however, stocking with brown trout is no longer permitted and provincial fish management plans require replacing non-native species such as brown trout and rainbow trout (*Oncorhynchus mykiss*) with native Arctic char (*Salvelinus alpinus*). This has led to complaints from stakeholders (resident and visiting anglers, wardens, associations) about lower catches with loss of revenue for anglers' associations. While lower altitude lakes are often repeatedly stocked with brown trout, they do not always provide suitable habitats for salmonids. This is often the case where upstream water abstraction changes the hydrological regime of a lake that historically supported a trout population. Temperature sensors, such as iButtons and HOBOs, are an economical educational tool useful to illustrate the compatibility of seasonal water temperature with salmonid survival. Examples from Lakes Campo and Roncone are given.

24. Bryan FLOOD[1], Mathew Wells[1]

Influence of basin geometry and bathymetry on swash zone structure and internal wave dynamics

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The thermocline of large, stratified lakes is constantly sloshing along the sloping lake bed, creating a zone where temperature and dissolved oxygen levels can vary rapidly. The degree of variation depends upon the magnitude of the internal seiche, which is determined by wind speed and duration, strength of stratification, upper layer thickness, and basin geometry and bathymetry. The degree of upwelling is often estimated by the Wedderburn number, which implicitly assumes a constant basin depth and width (perpendicular to the wind direction). In our current study, we show that areas with reduced surface area, and/or milder bed slopes experience larger amplitude up- and downwelling events, and thus greater variability in temperature and dissolved oxygen. This area encompassed by the swash zone can be large, and has the potential to significantly impact the behavior of aquatic organisms, especially in large lakes that suffer from hypolimnetic hypoxia. Combining a detailed field study in Hamilton Harbour, Canada, during the summer of 2017 with a 3D hydrodynamic model, we document how the swash zone is modified, from the idealized predictions of the Wedderburn number, by basin geometry and bathymetry. The presence of internal seiches in practically all large stratified basins suggests our findings are transferable to a large variety of lake, reservoir and harbour systems. Insight into how basin shape modifies the internal seiche and swash zone is important for understanding aquatic habitat variability and directing habitat restoration efforts.

25. *Bryan FLOOD[1], Mathew Wells[1], Erin Dunlop[2], Joelle Young[3]*

Large amplitude internal waves drive exchange and structure coldwater fish habitat in a deep, narrow embayment

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Large amplitude internal waves driven by wind shear across the surface that develop in thermally stratified lakes are an important exchange mechanism between deep coastal embayments and the main basin. In the long, deep and narrow Kempenfelt Bay of Lake Simcoe, we observed internal wave pumping to be the dominant exchange mechanism. Long period internal waves and the associated internal currents resulted in large horizontal excursion lengths of several kilometers, resulting in effective exchange of embayment and main basin waters. In addition to driving exchange, large amplitude internal waves have the potential to dynamically alter the aquatic habitat. The strong thermal gradient across the thermocline results in a quasi two layer system, with deep, cold hypolimentic waters sitting below the warm, well-mixed epilimnion. We observed internal waves with amplitudes of up to 10 m in Lake Simcoe, which dramatically alters the amount and location of the preferred habitat of coldwater fishes, that require low temperatures and high levels of dissolved oxygen, over timescales on the order of days. Hydroacoustic survey results suggest that coldwater fishes respond to changes in their physical environment by adjusting their depth in the water column to remain in the hypolimnion, in response to internal wave oscillations. The ubiquity of internal waves in stratified systems suggests that the exchange processes and biological responses investigated in our study are present in many of the long, deep and narrow embayments found throughout the Laurentian Great Lakes and elsewhere.

26. *Vincent FUGERE1, Yannick Huot2, David Walsh3, and Beatrix Beisner1*

Multitrophic species interaction networks of lake communities across Canada

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Studies of lake communities and their response to anthropogenic stressors usually focus on 'horizontal communities' and rarely incorporate detailed compositional information across trophic levels. The Lake Pulse project, with its standardized and comprehensive sampling of ~ 680 Canadian lakes across broad biogeographic and anthropogenic gradients, provides a unique opportunity to document land use impacts on lake communities from bacterioplankton to metazoans. In this poster we illustrate a number of statistical frameworks which we will employ to integrate the various plankton community composition datasets generated within the Lake Pulse project. We also show preliminary results from our current efforts to leverage existing data on fish community composition available for Lake Pulse sites. The objective of these analyses will be to construct multitrophic species interaction networks for Lake Pulse and reveal how land use affects the structure of lake communities across Canadian ecozones.

27. Jacob A. GASKILL[1], Ted D. Harris[2], Rebecca L. North[1]

Phytoplankton Response to Changes in Light: Can Glacial Rock Flour be used to Control Cyanobacterial Blooms?

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Toxin-producing cyanobacterial blooms are increasing in frequency and magnitude across the globe. While a variety of methods to control these blooms have been developed, light manipulation is an understudied strategy that could also be used for algal bloom management. Here, we added glacial rock flour (GRF), a fine particulate that remains suspended and floats on the water's surface, to 12,000L mesocosm tanks. Our objective was to reduce cyanobacteria biomass through light reduction achieved from the addition of GRF. After GRF addition, we observed a decline in cyanobacterial biovolume and a shift from communities where the taxon with the greatest biovolume was cyanobacteria or chlorophyta, to communities where cryptophyta had the highest biovolume. Cyanobacteria biovolume declined by 33.8% while cryptophyta biovolume increased by 28.4%. Further experimentation should explore whether the community shift we observed persists, as this would suggest that reducing light may present an alternative strategy to controlling cyanobacterial blooms.

28. *Daniel P. GILLIS[1], Charles K. Minns[1], Brian J. Shuter[1]*

Forecasting the effects of climate change on fish thermal habitat in North American lakes

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Temperature is a key characteristic of lakes profoundly affecting their physical, chemical, and biological processes. Fish habitat availability is constrained by a lake's suitable thermal habitat supply, a result of its thermal regime. Several abiotic factors influence thermal regimes; therefore, to predict the influence of climate warming on fish thermal habitat supply, we must understand the relationship between climate and other abiotic factors with lake temperature patterns across a wide geographic scale. We fit a semi-mechanistic seasonal temperature-profile model (STM) to datasets of 431 morphometrically diverse North American lakes (1971-2016). Using the STM's fitted parameters for these lakes' thermal characteristics (e.g. onset date of stratification, peak summer surface temperature), we use mixed modelling to create a set of sub-models for predicting STM parameters of any lake based on abiotic factors, including climate. We will use these results to assess changes in fish thermal habitat supply over the sampling period and the sub-models to forecast future thermal habitat supply under climate change. These findings will strengthen our understanding of the factors that influence lake thermal regimes across regional gradients, and help identify lake types and regions that may be especially susceptible to climate change.

29. Max GLINES[1], Michael Kelly[1], Alo Laas[2], Christopher McBride[3], Peter Staehr[4], and Kevin Rose[1]

Understanding high-frequency variation in light attenuation in a group of GLEON lakes

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Water clarity is an important characteristic that regulates many properties of aquatic ecosystems. Historically, water clarity has been measured primarily using Secchi disks, with radiometers and remote sensing products used to a lesser extent in more recent years. These methods have been widely employed to examine variability in water clarity over seasonal and annual scales. However, many ecological processes operate at shorter time scales, where lower frequency water clarity measurements may not be informative to understand ecological patterns. As a result, the importance of short-term variations in water clarity are poorly understood. Here, we compiled high frequency (~sub-daily) light data and calculated daily estimates of light attenuation (K_d) for photosynthetically active radiation (PAR) for six lakes from the US, Denmark, Estonia, and New Zealand. Our results indicate that the median daily rate of change in K_d across all lakes was close to zero; however, occasional substantial short-term changes in K_d that match or exceed long-term seasonal to interannual patterns were observed in most lakes. Lakes with high K_d appeared to exhibit the largest short-term variations in water clarity. Additionally, measurements made throughout the year, including under-ice, indicate that short-term changes in water clarity are observed at all times of the year. We seek to add to this dataset and a global assessment of short-term variations in water clarity, and invite data contributors for other sites who have high-frequency measurements of underwater light.

30. *Sadye K. GOLDFARB[1], Jonathan Doubek[2], Ana Antão-Geraldes[3], Mireia Bartrons[4], Stella Berger[5], Jennifer A. Brentrup[6], Sandra Brucet[7,8], Sarah Burnet[9], Luciano Caputo Galarce[10], Cayelan C. Carey[11], Kirsten Christoffersen[12], Elvira de Eyto[13], Gael Dur[14], Şeyda Erdoğan[15], Oxana Erina[16], Hans-Peter Grossart[5], Martin Kainz[17], Gökben Başaran Kankılıç[18], Sami Khan[19], Barbara Leoni[20], Fabio Lepori[21], Valerie McCarthy[22], Veronica Nava[20], Jens Nejstgaard[5], Ulrike Obertegger[23], Ziga Ogorelec[29], Arda Ozen[33], Maria Pascual[22], Michael Paterson[24], Martina Patelli[20], Qianlinglin Qiu[25], David Richardson[26], Armando Sepulveda-Jauregui[27], Lorena Silva[28], Dietmar Straile[29], Barbara Tartarotti[30], Ülkü Nihan Tavşanoğlu[31], Maria Tereshina[16], Gerardo Umaña-Villalobos[32], Tim Walles[5], Heather L. Wander[11], Wayne Wurtsbaugh[34], and Jason Stockwell[1]*

The Effects of Hypoxia on Zooplankton Population Estimates and Migration in Lakes

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Many zooplankton species typically exhibit diel vertical migration (DVM), where zooplankton migrate from the hypolimnion to the epilimnion of lakes at night. Zooplankton exhibit this behavior to avoid visual predators and UV radiation by remaining in the bottom waters during the day and ascending to the surface waters to feed on phytoplankton at night. However, hypoxic conditions in the hypolimnion of lakes may

interfere with DVM and force zooplankton to increase diel horizontal migration (DHM) to find predation refuge in littoral zones. Climate change and eutrophication are expected to increase the prevalence and severity of hypoxic conditions worldwide and thereby possibly alter zooplankton migration patterns. We hypothesize that hypoxia will force zooplankton to shift their migration patterns from predominantly DVM to DHM to avoid oxygen-depleted bottom waters. To test our hypothesis, we are conducting a standardized global sampling program to test whether pelagic, full water column estimates of zooplankton are greater at night versus the day under hypolimnetic hypoxic versus oxic conditions. Participants are aiming to sample at least one lake with an oxic hypolimnion and one lake with a hypoxic hypolimnion during the thermally-stratified period at midday and midnight. With our global dataset (currently expecting about 60 lakes in 22 countries), our goal is to improve our understanding of how global change may alter zooplankton migration behavior and patterns in lakes.

31. Hans-Peter GROSSART[1,2], Silke Van den Wyngaert[1], Maiko Kagami[3], Christian Wurzbacher[4], Michael Cunliffe[5,6] and Keilor Rojas Jimenez[7]

Aquatic fungal dark matter: A key for foodweb functioning in a spatio-temporal context

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Fungi are phylogenetically and functionally diverse and ubiquitous components of almost all ecosystems on Earth, including aquatic environments stretching from high montane lakes down to the deep open ocean. Aquatic ecosystems however remain frequently overlooked as fungal habitats, even though the fungal kingdom most likely evolved from marine ancestors. In this talk, we conceptualize within a broad ecological framework, the spatio-temporal dimensions, diversity, functions and interactions of aquatic fungi. We analyze their roles in structuring aquatic foodwebs, influence on community interactions and processing of organic matter, paying particular attention to the currently enigmatic "dark matter fungi". To date, many aquatic fungi and their interactions remain "hidden" and require interdisciplinary efforts to be explored and their roles understood in an ecosystem context. Although recent methodological developments have facilitated a greater appreciation of the importance of aquatic fungal diversity, functionality and interactions, a conceptual framework is still missing. There remain obvious knowledge gaps in the multiple potential functions of aquatic fungi, moving from the microscale to the global scale. This knowledge is urgently needed since we humans strongly interfere with structure and function of natural ecosystem by permanently reshaping most of the Earth's surface and creating vast areas of novel urban habitats.

32. Mingyang GUO[1], Zeli Tan[2], Huaxia Yao[3]

Simulating lake thermal dynamics at a global scale: model evaluation and future projection

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Lakes are a critical component of earth landscapes in terms of both societal and ecological functions. Therefore, to understand how climate change would impact lakes at a global scale is of great importance. In this study, we used a one-dimensional process-based lake model, Arctic Lake Biogeochemistry Model (ALBM), to simulate the thermal dynamics of 59 lakes that vary in size, region and mixing regime under the ISIMIP2b local lake protocol. Model calibration was conducted for nine parameters using a Monte Carlo optimization method against observed water temperature. We ran simulations for both the historical period (1979-2014) and four future scenarios (piControl, rcp26, rcp60 and rcp85) based on four climate models (GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR and MIROC5) to (1) assess the model performance, (2) test model sensitivity to parameters and input data, and (3) understand the response of lake thermal dynamics to climate changes in different scenarios. The model shows overall high accuracy in reproducing both the epilimnion and full-profile water temperatures. The simulation discrepancy tends to increase for larger and deeper lakes. Our model sensitivity analysis suggested that this error dependence could be related to the parameterization of latent and sensible heat in ALBM. Our projection showed that the future changes of lakes under climate warming would be diverse and depend strongly on lake characteristics (such as lake morphology and region).

33. *Truls HANSSON*

A chimney for peatland GHGs; The CH_4 dynamics of peatland rivers and lakes

Peatlands play an important role in the global CH_4 budget, and are receiving increasing attention as climate warming alters their role. Understanding how CH_4 is transported by rivers and lakes draining peatlands is crucial to our understanding of CH_4 dynamics.
Vertical movement of CH_4 through peatland can be slow due to oxidation and the physical barrier of the peat itself. Lateral transport may therefore represent a relatively fast pathway for CH_4 to escape the peatland. Additionally, rivers and lakes may, due to the larger water surface in direct contact with the atmosphere, represent an important component of tCH_4 exchange with the atmosphere.
In this study, over a period of 6 months, sampling including repeated transects of an Irish deep humic lake (Lough Feeagh), combined with single point samples from its catchment area was carried out. The campaign captured two drought periods, each followed by a heavy rain event. We found that CH_4 originating from rivers flowing through peatlands in the lower catchment was siphoned into Lough Feeagh. Transects indicate that virtually all CH_4 was lost before reaching the lake's deepest point, where concentrations were at near atmospheric levels. This process was most easily detectable during extreme dry periods, when low flow-rates resulted in accumulation of CH_4 in the lower catchment and inflow of the lake. Heavy rain-events strongly reduced concentrations in both catchment and inflow areas. These findings suggest that peatland associated water bodies may function as a "chimney" for peat-derived CH_4 and thus could increase global atmospheric CH_4 concentration.

34. *Bruce R. HARGREAVES*[1], *Katherine Le*[2], *Beth C. Norman*[3]

Decades of water column temperature, lake level and meteorological data of Lake Lacawac, a pristine glacial lake at Lacawac Biological Field Station in the Pocono mountains, Pennsylvania USA (1992-2019)

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Lake Lacawac weather and the lake water column were monitored to observe seasonal and interannual temperature and lake level patterns in response to solar heating, wind-driven water column mixing, precipitation, evaporation, watershed runoff and seepage, and outflow (L. Lacawac has an outflow stream but no inflow stream, and is surrounded on one side by peat bogs). Several studies have shown the lake to have a slow exchange by seepage (slightly more seeping in than out except during dry months). Over the years the raft data have been used to calibrate heat flux, mixing, and evaporation models for the lake, to study zooplankton and phytoplankton distribution and dissolved organic matter flux (photobleaching in the water column, influx from the watershed, and exchange with bottom sediments) and associated UV transparency. The data have also been used to accompany experimental manipulations of lake organisms (algae, zooplankton, fish) in relation to exposure to UV radiation. More recently these lake data have been useful in developing lake indices of climate change.

35. *Josef HEJZLAR[1], Jiří KOPÁČEK[1], and Yuliya Vystavna[1]*

Empirical modelling of phosphorus retention in lakes: is a site-specific approach necessary?

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The prediction of phosphorus (P) concentration in lakes using empirical models of P-retention that are based on hydrological variables is needed in the management of eutrophication and water quality in lakes, for example for determining how to reduce external P loads to decrease their trophic conditions and achieve good ecological quality. Our study examines the relationship between P loading and P and chlorophyll-a concentrations in lakes. Based on long-term data from 20 naturally-formed lakes and man-made reservoirs situated mainly in central Europe, we show that the relationship between the P concentration in the lake input and the P in-lake concentration is not determined solely by hydrological parameters (water residence time, hydraulic loading) and/or the P concentration in the inflow, as assumed in models such as by Vollenweider (1975), Chapra (1975), OECD (1982), etc., but is fundamentally influenced by the P internal load and seasonal P regeneration. The internal load and regeneration of P is an individual characteristic of each lake and can change during the lake's development history, for example with accumulation of sediment, varied external P load, or climate change. Therefore, it appears that empirical P-retention models should be designed and calibrated for each lake individually to account for their site- and time- specific conditions.

36. *Meredith A. HOLGERSON[1], Bridget R. Deemer[2], Mikkel R. Andersen[3], Kelly Hondula[4], David C. Richardson[5]*

Exploring global carbon emissions and the importance of small water bodies

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Inland waters contribute substantially to global greenhouse gas emissions; however, there are large uncertainties in emission estimates. Here, we report on two projects aimed to increase confidence in estimates of global carbon emissions from lakes and ponds. First, we compiled the most up-to-date estimates of methane (CH4) flux (diffusion and ebullition) from 223 lakes around the world. We then upscaled these fluxes to global emissions based on lake size class. We found that lake CH4 emissions account for roughly half of all inland water CH4 emissions (93 - 256 Tg CH4 yr-1), rivaling estimates of wetland emissions. Interestingly, the majority (~66%) of lake CH4 emissions come from small water bodies (< 0.01 km2).

Our second project focuses specifically on these small water bodies (i.e., ponds) that have the highest carbon emissions of any lake size class. Specifically, we initiated a project within the GLEON #PONDING (Pond Observation aNd Discovery IN GLEON) campaign. We conducted field work and compiled existing datasets for carbon emissions in ponds worldwide. We are currently compiling CO2 and CH4 emissions from over 30 collaborators and close to 100 ponds across three continents. We are evaluating drivers of carbon emissions, including surface area, depth, DOC, and phytoplankton biomass. Ultimately, this is the first dataset of carbon emissions specific to ponds around the world and will aid scientific understanding for why ponds have the highest carbon fluxes from inland waters.

37. Alexandria G. HOUNSHELL[1], Ryan P. McClure[1], Mary E. Lofton[1], and Cayelan C. Carey[1]

Constraining methane production and surface efflux from reservoirs with oxic and anoxic hypolimnia using whole-ecosystem oxygenation experiments

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Reservoirs are recognized as important drivers in the global carbon cycle, particularly as sites for significant organic carbon burial and greenhouse gas production (CH4, CO2). Little is known, however, about how the role of these ecosystems in the global carbon cycle will change under warmer and more anoxic conditions expected in the future due to climate and land use change. To address this, we experimentally manipulated dissolved oxygen concentrations in a temperate, eutrophic reservoir using an engineered hypolimnetic oxygenation system over two summers (2016-2017). The oxygenation system increases dissolved oxygen in the hypolimnion while maintaining thermal stratification. We measured dissolved CH4 and CO2 concentrations at multiple depths and diffusive fluxes from the surface twice-weekly in the oxygenated reservoir and weekly in an upstream reference anoxic reservoir. Preliminary results suggest an order of magnitude greater hypolimnetic CH4 production in the anoxic reservoir (~140 µmol L-1) as compared to the oxic reservoir (~3.5 µmol L-1), which resulted in 6× greater CH4 efflux observed in the anoxic reservoir following fall turnover. Concentrations and fluxes increased in the summer of 2016 when epilimnion temperatures were ~1°C warmer, resulting in warmer surface waters and enhanced thermal stratification in both reservoirs. Results from the oxygenation experiments suggest that the greater extent of anoxia expected due to warming temperatures will result in substantially greater CH4 production and efflux from reservoirs. We anticipate that increasing anoxia in freshwaters will play an even greater role in the global carbon cycle as important sites of CH4 production and emission.

38. *Dexter W. HOWARD[1], Mary E. Lofton[1], Alexandria G. Hounshell[1], Bethany J. Bookout[1], Ryan P. McClure[1], and Cayelan C. Carey[1]*

Drivers and patterns of dissolved organic matter fluorescence at diel to seasonal time scales in a drinking water reservoir

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Freshwater reservoirs play a significant role in the global carbon cycle by processing and storing large quantities of dissolved organic matter (DOM). Once DOM enters a reservoir, it can either be buried in the sediments, released to the atmosphere as carbon dioxide or methane, or transported downstream. Understanding the magnitude and drivers of these DOM pathways has significance for the global carbon cycle because DOM dynamics in reservoirs may be changing due to human activities. We estimated DOM concentrations using an in situ fluorescent DOM (fDOM) sensor measuring at ten-minute intervals and determined the dominant timescales of fDOM variability from hourly to seasonal scales in a eutrophic drinking water reservoir and GLEON site located in southwest Virginia, USA. We collected weekly water samples for dissolved organic carbon as well as potential fDOM driver data, including water temperature, dissolved oxygen, chlorophyll-a, water residence time, inflow stream discharge, precipitation, and incoming solar radiation. Our objectives are to determine the drivers and dominant timescales of variability of fDOM and how differences in hypolimnetic oxygen conditions prior to reservoir turnover due to management decisions affect epilimnetic fDOM concentrations after turnover. To analyze our data, we used wavelet analysis to determine dominant timescales of variability, ARIMA time series modeling to determine dominant drivers, and a before-after-control-impact analysis to determine the effects of reservoir turnover on fDOM. Our study has the potential to inform future research on how dominant timescales and drivers of DOM processes may respond to water management decisions.

39. *Allison HRYCIK[1], Don Pierson[2], Peter Isles[3], Rita Adrian[4], Matt Albright[5], Linda Bacon[6], Ruchi Bhattacharya[7], Stella Berger[4], Hans Peter Grossart[4,8], Josef Hejzlar[9], Amy Hetherington[10], Lesley Knoll[11], Alo Laas[12], Noah Lottig[13], Cory McDonald[14], Kellie Merrell[15], Jens Nejstgaard[4], Kirsten Nelson[16], Peeter Nõges[12], Andrew Paterson[17], Rachel Pilla[18], Dale Robertson[19], Lars Rudstam[20], Jim Rusak[17], Steven Sadro[21], Eugene Silow[22], Jason Stockwell[1], Huaxia Yao[17], Kiyoko Yokota[5]*

Earlier winter/spring runoff corresponds with lower summer phytoplankton productivity

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Winter conditions are hypothesized to set the stage for aquatic communities for the rest of the year, including the severity of summer algal blooms. However, little is known about how winter physiochemical conditions influence summer phytoplankton dynamics in light of a changing climate. We expect that nutrients delivered to lakes during colder, mixed, and possibly ice-covered conditions, could be less effective at stimulating phytoplankton growth because of early loss through lake outflow, uptake by other organisms, such as heterotrophic bacteria, or uptake by diatoms which may transport nutrients to the hypolimnion. Additionally, earlier snowmelt may correspond with shorter periods of daylight, thus causing a mismatch between nutrient inputs and light levels necessary to promote phytoplankton growth. We developed an index of runoff timing using the winter/spring center of mass of stream discharge for inflows, outflows, or nearby streams for 41 lakes in Europe and North America. Each year, the runoff index is paired with an index of summer productivity using long-term chlorophyll a data for each lake. Results indicate that earlier runoff timing generally corresponds to lower summer productivity. We examined several covariates that may regulate the relationship between runoff timing and productivity, including residence time, lake area, watershed area, lake depth, dissolved organic carbon, and trophic status.

40. *Peter ISLES[1], Stuart Dennis[1], Christian Ebi[1], Thea Kozakiewicz[1], Tom Lorimer[2], Ewa Merz[1], Marta Reyes[1], Francesco Pomati[1]*

Development of a real-time, automated, in situ microscope for ecological research and forecasting phytoplankton blooms

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One of the biggest roadblocks to improving our understanding of phytoplankton dynamics in situ has been the impracticality of collecting high frequency (sub-daily), taxonomically-resolved data on phytoplankton and zooplankton populations. Without such data, which are prohibitively expensive to collect using manual microscopy and field sampling, it is difficult to address questions about in-situ growth rates, predator-prey interactions, and the role of extreme weather events in plankton community assembly. In this poster we present a new high-frequency (up to 10 frames/second), in situ, dual-magnification, dark field microscope, developed in a collaboration between Eawag and the Scripps Institute of Oceanography. We show results of two years of continuous monitoring with calibrations to traditional sampling methods (microscopy and high-frequency fluorescence measurements), and describe the operation of the instrument. We also detail the workflow for managing high volumes of image data, performing image annotation with custom-designed software, and performing automated image classification using deep convolutional neural networks (CNNs). Finally, we describe how these data are being applied to investigate species interactions and forecast phytoplankton blooms using process-based and machine-learning approaches.

41. *Robyn JONES[1], April James[1], Dan Walters[1], Andrew Paterson[2]*

Investigation of local meteorological drivers of thermal mixing and dissolved oxygen regime of a polymictic bay

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Recently, research has explored the role of extreme and seasonal weather conditions to within-lake dynamics. Callander Bay is a 12 km2, polymictic bay of Lake Nipissing, the 7th largest lake in Ontario, Canada. To determine the impact of meteorological conditions on the thermal structure and dissolved oxygen (DO) levels in the bay, we used five ice-free seasons of high-frequency lake buoy data, that include weather (e.g. air temperature (Ta), wind speed (Ws)) and within-lake conditions (DO, water temperature). The association between weather and isothermal conditions were assessed using daily averages and high-frequency values from three days prior to isothermal conditions establishing. Extreme events were selected based on > 2SD above each ice-free seasonal average. Differences in thermal stratification were observed between the ice-free seasons including the number of isothermal events which ranged from eight to 35 and ~75% of these events lasted < 24 hours. This variability in thermal structure resulted in diverse lengths of anoxia occurring near the sediment-water interface. Cooling Ta and increased Ws were associated with 78% of the isothermal periods. Rainfall was associated with 8%. Wind-related isothermal conditions dominated from May to August. September and October association with cooling Ta dominated. Episodic weather did not consistently generated isothermal conditions nor disrupt DO depletion but corresponded to weakening of water column stability suggesting antecedent water column stability mediates the within-lake response. Exploration of time scale for measurements (e.g. 10-minute versus daily averages) revealed the importance of sub-daily as daily averages captured only 24% of the total mixing events as observed via high-frequency monitoring.

42. Michael R. KELLY[1,2], Vincent W. Moriarty[2], Guillaume Auger[2], Campbell Watson[2], Harry R. Kolar[2], Kevin C. Rose[1]

Understanding the factors contributing to harmful algal bloom formation in a large oligotrophic lake: the important role of physics

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Harmful algal blooms (HABs) are a growing threat to the safety and ecology of lakes in many regions. Despite this, HABs remain difficult to predict, challenging forecasting efforts and the ability to properly manage many waterbodies. A classic view of HAB formation posits that they form in eutrophic waterbodies and emerge when conditions are favorable, typically characterized by warm surface waters and low winds. However, HABs are also prevalent in oligotrophic lakes and in seasons not classically considered "warm", indicating that other processes may regulate their formation.

We deployed a vertical profiler with high-frequency sensors, acoustic Doppler current profilers (ADCP), and weather instrumentation on Skaneateles Lake, New York, to better understand processes and conditions antecedent to HABs. Skaneateles Lake is a large oligotrophic lake that began having significant and widespread HABs in September 2017. We observed eight distinct HABs in 2018, confirmed by laboratory analyses. Our sampling, combined with weather and hydrodynamic modeling indicate that a series of sequential physical events, including breaking internal waves, Langmuir circulation, and specific weather conditions, preceded each HAB. Repetition of similar sequences and timing of processes leading to each HAB suggests an opportunity for prediction, possibly days in advance. Our results demonstrate the value of coupled ADCP data with weather and water quality profiling data for HABs monitoring and prediction. Additionally, our results demonstrate the importance of consideration toward data frequency and quantity requirements to best characterize HAB formation, and how typical deployment strategies often fail to acquire such data sets.

43. S. Kelly[1, 2], B. Doyle[1], E. de Eyto[2], M. Dillane[2], R. Poole[2], M. White[3], E. Jennings[1]*

Impacts of a record-breaking storm on physical and biogeochemical regimes along a catchment-to-coast continuum

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An overall change in climate is most readily sensed through changes in weather extremes, with effects often severe and felt across multiple ecosystem levels. This study describes and analyses the impacts of a succession of winter storms throughout December 2015, emphasising the cascade of effects from record-breaking Storm Desmond, on Burrishoole, a catchment-lake-estuarine complex on the Atlantic coast of Ireland. In-situ high-frequency sensors captured in detail the effects of an unprecedented period of rainfall, high wind speeds and above-average winter air temperatures on lake and estuarine dynamics. Immediately post-flood, turbidity and acidity increased in Lough Feeagh, the peatland catchment's largest lake. Surface heat input, due to a warm, moist above-lake air mass, was rapidly distributed throughout the Feeagh water column, fully-mixed since autumn turnover. Discharge into saline Lough Furnace was estimated to be the highest on record (since 1976), increasing the buoyancy flux by an order of magnitude and doubling the stratification strength. Entrainment of salt into the outflowing plume exported resident salt from Furnace, which in combination with attenuation of subsequent spring tidal inflows, resulted in net salt loss. The event markedly reinforced stagnant deep basin water conditions that promote deoxygenation in Furnace, whilst stratification and internal wave properties in Furnace remained fundamentally modified several months post-storm. Current profiles measured in the connecting estuarine channel allowed a first-order estimate of the total catchment-to-coast volume flux during peak flooding, with a 20-fold increase over typical fluxes. Storm impacts spanned the full catchment-to-coast continuum and these results could provide a glimpse into a potential future where more frequent and severe regional hydroclimatic events occur.

44. *Hares KHAN[1,2], Alo Laas[2], Rafa Marcé[3], Biel Obrador[1]*

Calcite precipitation, an important driver of carbon fluxes in lakes and reservoirs

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The precipitation of calcium carbonate is a relevant process in the carbon cycle of lakes and reservoirs. It can imply a significant burial of carbon into lake sediments, as well as strongly determine CO2 dynamics whereby interactions with the inorganic carbon equilibria have direct effects on the concentration of dissolved inorganic carbon (DIC) species, including CO2. Recent evidence suggests that calcite precipitation could be a major source of CO2 in lakes of high alkalinity, leading to CO2 supersaturation. In lakes calcification is tightly coupled to primary production, apparently due to a nucleation effect of picophytoplankton. While the geochemical importance of calcite precipitation as a driver of air-water CO2 fluxes is well established for marine systems, its role on carbon dynamics in freshwater systems is traditionally assumed to be negligible, under the assumption that most lakes have too low alkalinity for these processes to be relevant. This poster presents theoretical and experimental evidence that calcite precipitation plays an important role in driving carbon dynamics in freshwater systems.

45. *Jihyeon KIM[1] and Yves T. Prairie[1]*

Preliminary results of the Pan-Canadian Lake Pulse project: How much do Canadian lakes contribute to atmospheric GHGs emissions, and how much will it be affected by the impacts of land-use and climate changes in the future?

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Natural lakes comprise about 91% of all inland waters and have been recognized as important players in local, regional and global carbon cycle, in particular by emitting greenhouse gases (GHGs) to the atmosphere. These estimates, however, are poorly constrained because they are usually derived from averages from datasets lacking a sufficient geographical coverage. Therefore, providing substantial datasets and better integration of them are needed to improve our understanding in lakes GHGs dynamics and fluxes. Also, predicting how the lakes carbon emission will respond to environmental pressures such as climate changes and human impacts is essential for planning for a sustainable future. As part of the pan-Canadian Lake Pulse project, we quantified and mapped accurate air-water fluxes of the two dominant GHGs (CO2 and CH4) in 444 lakes across a wide range of environmental gradients (8 ecozones, 10 regions) in Eastern and middle Canada in 2017 and 2018. In addition, human impacts index was calculated to estimate the impacts of land-use on carbon emission. Our preliminary results showed that diffusive fluxes of CO2 and CH4 were highly variable among regions (overall mean 360.9±23.3 and 47.8±5.6 mg C/m2/d, respectively). The magnitude of CH4 fluxes was correlated with the human impacts index and surface water temperature, indicating that lakes will respond to changes of land-use and climate changes with substantial increase in carbon emissions. The changing role of lakes on the global carbon emissions will therefore constitute a significant additional source of GHG to the atmosphere under the ongoing and future environmental changes.

46. Katelyn KING[1], Mary Tate Bremigan[1], Dana Infante[1], Kendra Cheruvelil[1]

Crossing ecosystem boundaries to better understand macroscale fish diversity

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Stream and lake fishes are important economic and recreational resources that respond to alterations in their surrounding watersheds and serve as indicators of ecological stressors on aquatic ecosystems. Research suggests that fish species diversity is largely influenced by surface water connectivity, or the lack thereof. For example, lake, stream, and wetland connections support fish movement among ecosystems and provide access to refugia, food, habitat, and nesting sites. Connections and alterations that block dispersal and reduce connectivity often occur at fine-scales, but they can also exhibit regional patterns. However, few studies consider the gradient of freshwater connections and their effect on both lake and stream fish communities across broad spatial extents. Therefore, we examine the macroscale (i.e. regional) patterns of fish species diversity in lakes, reservoirs, streams, and rivers. We do so by using fish sampling data from thousands of waterbodies (natural lakes, reservoirs, streams, and rivers) across a five-state extent in the northeastern/midwestern United States. By studying a variety of freshwater types, our results inform scientific understanding of what drives variation in fish species diversity at broad spatial scales.

47. *Jen KLUG[1], Nadia Harvieux[2], Olenka Duncan[3], Teresa Sauer[1]*

Libraries Love Lakes: helping library visitors explore the importance of lakes.

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"Libraries Love Lakes" is a new project developed in partnership with NE GLEON, the Finger Lakes Institute, and Fairfield University designed to expose library patrons to the value of lakes in their lives. Libraries offer a chance to engage a wide variety of people who may have little knowledge of the ecosystems services provided by lakes. We piloted the project in 2019 at two town libraries, one in New York and one in Connecticut. At both libraries, the target audience was children ages 4-12 and their accompanying adults. We created displays of age-appropriate lake books available for them to check-out and offered adults a flyer describing the project. All library visitors were invited to respond to the prompt "Why we love lakes!" by posting on a centrally located community display. Outcomes of the pilot project were shared on Facebook and Twitter using the hashtag #LibrariesLoveLakes. Our 2019 activities were created to coincide with Lakes Appreciation Month – an awareness campaign sponsored by the North American Lake Management Society (NALMS) which promotes the importance of lakes. The project was well-received by the participating libraries and the NALMS community. In the future, we expect to expand our current summer programming to other local libraries and work with school librarians to bring "Libraries Love Lakes" into the classroom. In addition, we plan to work with interested GLEON members to develop other programming that meets the needs of libraries and library visitors in regions outside of northeastern North America.

48. *Lesley B. Knoll[1], Sapna Sharma[2], Blaize A. Denfeld[3], Giovanna Flaim[4], Yukari Hori[5], John J. Magnuson[6], Dietmar Straile[7], and Gesa A. Weyhenmeyer[8]*

Consequences of lake and river ice loss on cultural ecosystem services

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People extensively use lakes and rivers covered by seasonal ice. Although ice cover duration has been declining over the past 150 years for Northern Hemisphere freshwaters, we know relatively little about how ice loss directly affects humans. We synthesize the cultural ecosystem services (i.e., services that provide intangible or nonmaterial benefits) and associated benefits supported by inland ice. We also provide, for the first time, empirical examples that give quantitative evidence for a winter warming effect on a wide range of ice-related cultural ecosystem services and benefits. We show that in recent decades, warmer air temperatures delayed the opening date of winter ice roads and led to cancellations of spiritual ceremonies, outdoor ice skating races, and ice fishing tournaments. Additionally, our synthesis effort suggests unexploited datasets that allow for the use of integrative approaches to evaluate the interplay between inland ice loss and society.

49. *Robert LADWIG[1], Hilary Dugan[1], Paul C. Hanson[1], Jordan Rread[2], Vahid Daneshmand[3], Renato Figueiredo[3]*

New Features to the Trinity of GLM R-packages: glmtools, GLM3r and GRAPLEr

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The raising popularity and growing user community of GLM (General Lake Model, developed by the AED research group of the University of Western Australia) stimulated the development of multiple R-packages to lighten the pre- and post-processing, as well as running the model on a local machine or distributed servers. glmtools is a sophisticated toolbox to calculate physical derivatives and to plot model outputs. We have added updated visualization functions to the packages (including ggplot features) as well as options to run sensitivity and automatic calibration algorithms that help first-time users in setting up their own model environment. GLM3r is a new package, built off of GLMr, which supports model execution of GLM3.0 in the R environment. This version features support for Windows, macOS and Linux. GRAPLEr is a distributed computing system that enables users to run multiple simulations, which is especially handy for scenario analysis. Similar to GLMr, GRAPLEr has been updated and is now compatible with the GLM 3.0. Together these packages are vital tools for the GLM community and should foster modern limnological research and collaboration.

50. *Maximilian P LAU[1] and Paul del Giorgio[1]*

Reactivity and fate of dissolved organic matter in anoxic waters

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When oxygen consumption exceeds renewal, anoxic conditions can develop. The delivery of terrestrial organic matter to inland waters promotes anoxia by fueling microbial O2 consumption and increasing the resistance towards convective mixing, as observed in wetland ponds and small lakes. There, and further along its passage through the aquatic network, such dissolved organic matter (DOM) is subject to microbial processing, and the water retention time is known to be a key determinant of its ambient concentration and reactivity. However, in the absence of oxygen, the prevalent biogeochemical conditions markedly shift and so do the processes that modulate and consume organic carbon. Although anoxic waters are ubiquitous components of the land-ocean continuum, the transient residence of DOM therein has not been reconciled with the continuous downstream decrease in its degradability.

Here we present results of a study explicitly assessing the various reaction pathways and fates of DOM in the anoxic waters of two small north-temperate lakes. We found that increasing residence time in anoxic waters gradually alters the chemical, optical and redox properties of the DOM. By monitoring additional metabolism indicators including C mineralization, bacterial production and electron acceptor consumption we were able to gain an improved understanding of the factors that govern the rate of carbon processing in this environment. Our results suggest that contrary to general orthodoxy, anoxia constitutes an environment of continuous carbon turnover that possibly harbors unique DOM processing routes. The landscape factors that control the exposure of DOM to anoxia during the land-to-ocean transit will be discussed.

51. *Abigail S. L. LEWIS[1], Alexandria G. Hounshell[1], Ryan P. McClure[1], Nicholas Hammond[2], Dexter W. Howard[1], Mary E. Lofton[1], Heather L. Wander[1], Whitney M. Woelmer[1], Francois Birgand[3], Paul C. Hanson[4], John C. Little[5], Madeline E. Schreiber[2], and Cayelan C. Carey[1]*

Consequences of changing oxygen availability for carbon cycling in freshwater ecosystems

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Oxygen dynamics in lakes and reservoirs are changing worldwide. At the decadal scale, warming temperatures and increased nutrient loads are increasing the prevalence and duration of anoxia. Conversely, at the daily scale, mixing due to more powerful storms may periodically increase hypolimnetic oxygen availability. Changing hypolimnetic oxygen conditions can dramatically alter carbon cycling in aquatic ecosystems, as oxygen dynamics near the sediment-water interface regulate whether carbon inputs will be buried, respired as carbon dioxide, or respired as methane. Any changes to carbon cycling would be especially significant in reservoirs, as reservoirs bury more carbon than ocean sediments and account for 25% of the global carbon sink from all terrestrial and freshwater sources. In this four-year, multi-institutional, National Science Foundation-supported project, we are using whole-ecosystem manipulations of hypolimnetic oxygen concentrations to identify how changes in oxygen at different time scales (i.e., weeks to months) alter freshwater carbon processing, burial, and greenhouse gas emissions. Preliminary modeling results show that oxic conditions can cause mineralization of "legacy" carbon that had accumulated over years of sedimentation. Field data from the first summer of oxygenation experiments reveal that respiration rates are highly sensitive to both temperature and the history of oxygen exposure. Building off of this work, future studies will examine the role of alternate electron acceptors in carbon release from sediments, the impact of carbon quality on carbon processing under varying oxygen conditions, and the effects of future oxygen scenarios on carbon cycling in lakes and reservoirs around the world.

52. *Mary E. LOFTON[1], Jennifer A. Brentrup[2], Whitney S. Beck[3], Ruchi Bhattacharya[4], Ludmila S. Brighenti[5], Sarah H. Burnet[6], Ian M. McCullough[7], Simon Stewart[8], Jacob A. Zwart[9], Cayelan C. Carey[1], Kathryn L. Cottingham[2], Holly A. Ewing[10], Shannon L. LaDeau[11], Kathleen C. Weathers[11]*

Near-term forecasts of cyanobacterial blooms in a large, oligotrophic temperate lake: identifying sources of uncertainty

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Cyanobacterial blooms alter lake ecosystems through production of surface scums, toxins, and taste and odor issues. Near-term forecasts of blooms would help lake managers preemptively manage water quality and provide advance warning to the public of potential recreational water closures. Importantly, forecasts should include uncertainty estimates to provide a robust assessment of bloom forecast confidence. Our project, a collaboration among members of the Ecological Forecasting Initiative (EFI), the Global Lake Ecological Observatory Network (GLEON), and the Lake Sunapee Protective Association (LSPA), aims to identify the dominant sources of uncertainty to near-term forecasts of cyanobacterial densities in oligotrophic Lake Sunapee, NH, USA, which experiences blooms of the cyanobacterium Gloeotrichia echinulata. We partitioned uncertainty among model-process error, initial conditions error, observational error, and parameter uncertainty for several Bayesian state-space models predicting cyanobacterial density. Candidate models were calibrated and validated using subsets of a 14-year, ongoing time series of weekly G. echinulata densities collected from May to October. We evaluated whether candidate forecast models including wind direction and speed, thermal stratification stability, and water temperature covariates improved one-week-ahead predictions of G. echinulata compared to a random walk model. Preliminary uncertainty partitioning of the predictive intervals for our models revealed that initial conditions and process errors were the primary drivers of total prediction uncertainty. Our work suggests that more intensive G. echinulata observations and exploration of further candidate models could improve near-term bloom predictions and advance understanding of how best to forecast cyanobacterial blooms.

53. Eric MASSA[1] and Evelyn Gaiser[2]

Effects of phosphorus on network ego size in diatom assemblage networks in benthic microbial mats

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The Florida Everglades possesses extensive mat-forming microbial communities (periphyton) with a great influence on basic attributes of the ecosystem. In the Everglades, periphyton mats are a major component of the base of the food web and are responsible for as much as 50% of net primary productivity. Additionally, mats provide habitat structure and regulate the availability of nutrients and gases within the water column. Periphyton is highly sensitive to changes in nutrient availability and can dissociate as conditions change. The exact mechanism behind mat dissociation remains unknown, but it may be due to changes in co-dependencies between species. Resource limitation often determines the presence and strength of species co-dependencies. Several works by other authors have identified aspects of community dynamics that are analogous to the behavior demonstrated by complex mathematical networks and have demonstrated the ability to predict shifts in community structure in response to changes in one or more environmental variables, which has implications for environmental management and restoration projects. An ecological network analysis approach to a 10-year diatom community composition database has identified a potential indicator of community shift well before previously identified nutrient thresholds. As diatom species data is already used to measure water quality, we are exploring the use of networks constructed from diatom abundance data to accurately assess water quality trends in the Everglades.

54. *McArd Joseph MLOTHA[1], David Kahler[2], Joshua Edokpayi[3], and Kevin C. Rose[1]*

Monitoring water quality in Limpopo River Basin, Southern Africa using remote sensing.

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Monitoring the quantity and quality of inland water bodies is essential for understanding ecological processes and providing water for human use. The ability to characterize water quality enables communities, governments, and the public to plan utilization of aquatic resources and manage pollution control programs for healthy aquatic ecosystems. While in situ monitoring is common in many regions, it is often not practical in many developing countries due to factors such as cost, potential equipment losses, and technical expertise. It is with this concern that geospatial technologies like satellite remote sensing imagery provide a useful tool to monitor water quantity and quality over large areas of land. In this current study, we report the use of satellite imagery to understand spatial and temporal variability of water resources in the region, focusing on remote sensing of turbidity and chlorophyll *a* as indicators of water quality. The Limpopo Basin is characterized by water scarcity compounded by a changing climate and ongoing drought. Both mining, wastewater discharge and agricultural activities are increasing in impact, and land use transformations appear to be reducing water quality. Our research indicates that publicly available imagery, such as Landsat, is adequate to characterize land use patterns and changes and assess water quality in large rivers during wetter times of the year. However, dry conditions, which are occurring more frequently, limit the applicability of publicly available imagery due to course pixel size. Complementing this, commercially available imagery enables characterization of water quality in smaller river and lake networks.

55. *Ryan P. MCCLURE[1], R. Quinn Thomas[2], Mary E. Lofton[1], Whitney M. Woelmer[1], Ashley M. Mickens[1], and Cayelan C. Carey[1]*

Successful real-time prediction of methane ebullition in a eutrophic reservoir using temperature via iterative near-term forecasts

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Freshwaters emit considerable amounts of methane (CH4) to the atmosphere relative to their small surface area globally. Freshwater CH4 emissions are dominated by bubble fluxes from the sediments, a process known as ebullition. While ebullition is a substantial pathway of CH4 from freshwaters to the atmosphere, it is also sporadic and has been considered extremely challenging to predict spatiotemporally. As a result, there remains substantial uncertainty in ebullition estimates from freshwater ecosystems. Current approaches for estimating ebullition rates generally use models based on historical datasets, which prevents preemptive forecasts of ebullition to inform adaptive sampling during ebullition peaks. To overcome this gap, we developed iterative, near-term forecasts that predicted future ebullition rates weekly in a eutrophic reservoir. We integrated water temperature forecasts from an iterative near-term forecasting system (FLARE, Forecasting Lake And Reservoir Ecosystems) into an ebullition time series model calibrated with two years of weekly observational data. We forecasted the mean ebullition rates of four traps on a one-week time horizon during the 2019 monitoring period and updated the forecasts weekly using data assimilation. Our forecasts successfully predicted ebullition rates each week, with a root-mean-square error of 2.9 mg CH4 m-2 d-1. The forecasts successfully predicted substantial increases in ebullition rates when water temperatures at the sediment-water interface also increased. We also quantified the relative contribution of different sources of uncertainty in our forecasts and found, preliminarily, that meteorological driver data were the largest contributor of uncertainty in the ebullition forecasts. Our forecasts show that ebullition rates can be successfully predicted on short timescales in freshwater ecosystems, which has the potential to substantially inform our estimates of methane emission rates in freshwaters.

56. *Alex C. MCCLYMONT[1], Shelley E. Arnott[2]*

Effects of road salt and climate change on lake communities

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Extensive road salt use across the Northern Hemisphere is causing long-term and substantial salinization in many freshwater systems, with significant consequences for aquatic organisms and communities. American and Canadian water quality guidelines for chloride are currently based on single-species studies conducted under laboratory conditions, which do not account for community interactions or the effects of additional stressors. Concurrent with salinization, lakes are warming due to climate change. Increasing water temperatures alter lake communities, and could exacerbate the effects of increasing chloride concentrations on aquatic biota. To determine the impacts of these stressors, we conducted a mesocosm experiment using pelagic plankton communities from a lake typical of the Canadian Shield.

While warming had minimal impacts on plankton communities, the effects of chloride were significant and substantial. Increasing chloride concentrations caused a shift in zooplankton community structure and reduced zooplankton richness, biomass and abundance, even at low concentrations. Elevated chloride also led to changes in phytoplankton community composition, with higher levels of chloride fostering the dominance of cyanobacteria. Our results show that plankton communities will be negatively affected by road salt pollution, even at low chloride concentrations. To ensure the preservation of freshwater systems, Canadian water quality guidelines should be modified to better protect these crucial organisms.

57. *Michael F. MEYER, Stephanie E. Hampton, Matthew R. Brousil, Alli N. Cramer*

Quantifying changes in high-elevation lake surface area over 20 years (1995-2015) in relation to climate and human population

A changing climate and increasing population heighten the need to understand freshwater systems will respond. Aquatic systems at higher elevations have demonstrated marked sensitivity to increasing temperatures and changes in precipitation patterns, where increasing temperatures in drier climates leads to greater evaporation while lakes in warmer, wetter climates tend to increase in size. Despite foundational works documenting how high-elevation lakes respond to a changing climate, their physical isolation often hinders frequent and spatially expansive monitoring. Remote sensing, however, creates opportunity to investigate how high-elevation lake areas may be fluctuating at local-to-global spatial as well as annual-to-decadal temporal scales. In order to leverage remote sensing data to identify hotspots of high-elevation lake area change, we calculated the surface area of permanent, seasonal, and total water for 15,000+ high-elevation lakes from 1995-2015 using the Global Lake area, Climate, & Population dataset. The direction and rate of lake surface area change was highly variable worldwide. Regionally, lakes in the western United States tend to be decreasing in surface area, whereas lakes in northwest India and southwest China tend to be increasing in lake area. Basin-level temperature, precipitation, and human population as predictors of lake area suggest associations for observed lake area changes. This study provides a new global perspective on lake area changes to better evaluate the current and future linkages between lake dynamics and water quality, human use, and ecosystem function.

58. Edward E. MILLAR[1]

A survey of protocols, tools, and strategies used to support volunteer participation in citizen science water monitoring programs

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The increasing interest in citizen science as a method for monitoring lakes and streams has corresponded with a recognition in the importance of applying interdisciplinary approaches to identifying best practices for the successful retention of volunteers and the long-term success of aquatic citizen science projects. Citizen science promises a method for obtaining valuable and reliable data for mapping large-scale ecological changes, while fulfilling objectives related to public science education, public participation in science, as well as a more democratic vision of an active science citizenship. Currently, a wide range of protocols and monitoring technologies exist, including the use of bioindicators (benthic macroinvertebrates, fish, aquatic plants, cyanobacteria, birds), mobile applications in which volunteers contribute visual assessments, open source data loggers, and more expensive automated data loggers. Choices about which protocols and monitoring tools to adopt in aquatic citizen science programs have implications related to the quality of data that is collected, as well as the degree and type of participation required from volunteers. This poster will present a typology of water monitoring devices and strategies currently employed in aquatic citizen science programs, based on a survey and assessment of volunteer water monitoring programs currently in operation in North America. This research seeks to explore the degree to which automated data loggers and mobile applications are being adopted to support volunteer aquatic monitoring, and to contextualize the existing range of tools, devices, protocols, and standards within the broader theoretical discussions around public participation in science.

59. Tadhg MOORE[1], Robert LADWIG[2], Elvira de Eyto[3], Malgorzata Golub[4], Rafael Marce[5], Don Pierson[4], Wim Thiery[6], Eleanor Jennings[1]

ISIMIP2b Lake Sector: Calibrating lake models for a range of lakes with a global distribution for use in climate change predictions and the impacts it will have on lake hydrodynamics

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Freshwater lakes provide important ecosystem services, are both sensitive indicators of climate change and hot spots of biogeochemical processing. Emerging evidence indicates that lakes have been, and will continue to be affected by changing climate, with consequent changes in water temperature, thermal structure and biogeochemistry. Studying the impacts on select number of well-studied lakes provides for the validation of the global approach of modelling the global distribution of lakes (>170,000 worldwide).

Here we present results from the calibration of two 1D lake hydrodynamical models GLM and GOTM for 59 lakes with a global distribution, following the Inter-Sectoral Impact Model Inter-comparison Project (ISIMIP) Lake Sector simulation protocol, which offers a framework for consistently projecting the impacts of climate change across affected sectors and spatial scales. Calibration methodologies were based on the protocol used and the meteorological data that was available. The main assumptions for lake modelling of climate projections were 1) lake level remains constant; 2) no inflows or outflows; 3) climate forcing gridded meteorological data at daily resolution; 4) using a 1-dimensional hydrodynamical model. A constant lake level with no inflow or outflow was assumed, and the models were forced with gridded meteorological data at daily resolution. A sensitivity analysis was carried out prior to the calibration process using the one-at-a-time (OAT) and Morris method. A factorial analysis test was carried out to examine which physical and morphological attributes affected the model calibration. Preliminary results from some key sites are presented showing the impacts of the different representative concentration pathways (RCPs) on lake surface temperature, stratification period and effects on thermocline depth. Further analysis will include a multi-model comparison using an extended set of lake models.

60. *Happiness A. MOSHI[1,2] Daniel Shilla[2], Ismael Kimirei[1], Steven Loiselle[3] and Catherine O'Reilly[4]*

Citizen Science in Lake Tanganyika Water Quality Monitoring: Opportunities and Challenges.

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Meaningful public engagement in research and scientific aspects is essential to improving knowledge about the environment and supporting the sustainable use of ecosystems and natural resources. Using citizen science is quite a new introduced complementary approach to monitor water quality in Lake Tanganyika but its opportunities and constrains is still a question to the community. This study was designed to assess the opportunities and challenges raised when implementing citizen science methodology in monitoring Lake Tanganyika water quality. Individual interviews, participant observations, focus group discussions and key informant interviews were used to collect data for the study. A total of 150 participants involved in monitoring water parameters such as nutrients and turbidity were interviewed from five villages (Ilagala, Karago, Kibirizi, Ujiji and Mwamgongo) around Lake Tanganyika. It was discovered that; increasing scientific literacy, increasing environmental awareness and citizen inclusion in local issues were the main opportunities to citizens. It was found that lack of community willingness in monitoring water quality, data fragmentation and inaccuracy and limited funding were the major challenges encountered by participants in their monitoring activities. This study recommends that frequent and proper training should be given to citizens in order to increase their willingness in environmental issues, improve data accuracy as well as enough fund to support them in their monitoring activities is needed.

61. Elias MUNTHALI[1], Rafael Marcè[2], Lisette de Senerpont Domis[3]

Intensity of wastewater treatment upstream a reservoir defines resistance of its water quality to extreme climatic events

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Reservoirs play a vital role in various sectors of the society because of the broad range of ecosystem services they offer, such as potable water supply, recreational activities and flood control. Benefits such as drinking water supply and recreational activities are very sensitive to water quality characteristics, requiring a comprehensive understanding and sound management practices to sustain the supply of such services. Algal blooms are one of the nuisances that diminish the usability of a water body for water supply and recreation, and extreme events have been attributed as a cause for their proliferation.
In this study, we applied causal inference statistical methods to a dataset of climatological, hydrological and water quality variables, collected from the 1960s to present in the Ter Catchment in Spain, to compare the response of water quality to climatological and hydrological extremes, between two periods demarcated by upgrades of wastewater treatment plants in the catchment to enhance nutrient removal, in the mid 1990s. We examined how various water quality variables responded to temperature extremes (heatwaves), droughts, extreme precipitation, reservoir level and streamflow conditions. Results show stronger evidence of causality between hydro-climatological variables and water quality, in the before upgrades period than after, particularly in the hypolimnetic timeseries of dissolved oxygen, nitrate and nitrite. The analysis highlights discrepancies in response to extreme events between the upper and bottom water layers and among the spectrum of water quality variables.

62. Prisca MZIRAY[1,3], Peter A. Staehr[2], Jesper P. A. Christensen[2], Ismael A. Kimirei[1], Charles V. Lugomela[3,4], Dennis Trolle[2], Catherine M. O'Reilly[5], William L. Perry[6]

Vertical and temporal dynamics of primary production in Lake Tanganyika

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This study investigated variability in ecosystem metabolism in the oligotrophic deep Lake Tanganyika. A large buoy equipped with oxygen and temperature sensors for every 10 m down to 102 m depth, provided a three-month data with one-minute frequency. This enabled a detailed description of the temporal and vertical variability in oxygen, temperature and irradiance, from which we derived daily depth specific rates of gross primary production, ecosystem respiration and net ecosystem production. We applied a modified mass balance approach which included dissolved oxygen exchange between depth layers driven by mixed-layer deepening and eddy diffusivity derived from a one-dimensional hydrodynamic model. We hereby demonstrated that the automated in situ measurements of dissolved oxygen can be used to estimate gross primary production with high temporal and vertical resolution in a huge low productive lake. In the meromictic Lake Tanganyika, the extent of the mean daily upper mixed layer depth varied between 21-40 m and a metalimnion extending between 48-75 m and a photic zone (20-38 m depth) extending into the metalimnion on several days, providing enough light for primary production to occur at the studied location. The vertical extent of the metalimnion and gradients in oxygen were strongly related to the water column stability, which varied from variability in wind conditions and surface warming. The profiles of metabolism indicates that primary production in the metalimnion of Lake Tanganyika, to some extent, can compensate for the decreasing primary production in epiliminon if this is followed by increased water transparency.

63. Anaïs OLIVA[1], Yannick Huot[1] et Nicholas Ogden[2]

Satellite-derived and environmental determinants related to infectious disease pathogen indicators in Canadian lakes: a study in Prairies and Boreal Plains ecozones

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One of the most common morbidity and mortality cause in the world is from waterborne diseases derived from fecal contamination. Population and/or animal density with water proximity in watersheds are inherent to fecal contamination. Moreover, rise of antibiotic resistance in many pathogens is an added threat for public health concern.

Several studies have demonstrated that fecal contamination indicators in lakes is a hard and variable data to estimate and is highly related to meteorological conditions such as rainfalls and runoffs and also seasonal changes. Associated factors can be different between lakes and overtime and thus, public authorities have difficulties to keep track of water quality and monitor several lakes at the same time. However, using large datasets, satellite-derived products and potentially more stable contamination indicators, would enable a better estimate of those factors in Canadian ecozones.

This poster focuses on determining environmental determinants related to fecal contamination in lakes located in two sampled ecozones: Prairies and Boreal Plains, during the summer high-recreative season (July-August).

This study is part of the NSERC LakePulse network creating the first Canadian lake dataset for more than one hundred variables, more than 600 randomly selected lakes and after 3 field campaigns (2017-2019). We used a sample of the lakes dataset gathered in 2018 and 2019 and Generalized Linear Mixed Models (GLMM) as a preliminary approach. We compared the results for both ecozones and the overall and show the most important variables related to the microbial indicators and present future steps to improve the models.

64. Veronica NAVA[1], Martina Patelli[1], Valentina Soler[1], Barbara Leoni[1]

How climate change can influence biogeochemical cycle of Dissolved Silicon (DSi): insights from long-term monitoring (1993-2019) analysis in deep oligomictic lake (Lake Iseo, Northern Italy)

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Whereas total algal growth is primarily regulated by the availability of N and P, the relative availability of Si to N and P can influence the composition of the phytoplankton community. The lack of Si can change freshwater ecosystems from those dominated by diatoms to non-diatom based, exacerbating the already declining quality and structure of aquatic systems. Since the fundamental role of silicon, it is important to enhance the knowledge about this nutrient in freshwater systems that are directly threatened by climatic changes. We highlighted some consequences of these changes analysing a monthly long-term series (1993-2019) on Lake Iseo, a deep (258 m) south-Alpine lake in Northern Italy, which is experiencing in the last decades a substantial decreased frequency of vertical complete mixing events. Our results showed an increase of Dissolved Silicon (DSi) in all hypolimnetic layers with different rates for the different depths (e.g. increase of ~70% from 1500 µg/L to 2500 µg/L in the layers from 150 m to the lake bottom in the period 2006-2018). The concentration in the superficial layers displayed seasonal variance, but not an overall positive trend. The change of the thermal behaviour of Lake Iseo, from oligomictic to meromictic, is leading to segregation of silicon in the deepest layers. In a broader context, this will have consequences on trophic web and productivity of lakes but also, ultimately, of ocean. Future comparisons of DSi to other compounds in different lakes worldwide will give new insights about the pattern and the role of this important nutrient.

65. Žiga OGORELEC[1]

Top-down effects of whitefish (Coregonus wartmanni) and invasive three-spined stickleback (Gasterosteus aculeatus) on different trophic levels of pelagic food web.

[1]Limnological Institute, University of Konstanz

Lake Constance, the second largest European pre-alpine lake with surface area of 476 km2, and a mean depth of 100 m has around 30 species of fish fauna. The most important economically as well as ecologically as a major pelagic planktivorous fish was for centuries whitefish (Coregonus wartmanni). Anyhow, their numbers are reducing due to re-oligotrophication and recently also due to three-spined stickleback (Gasterosteus aculeatus) invasion. Although sticklebacks were firstly reported in Lake Constance already in 1950s, they massively spread in the pelagic zone in 2012-2013, where they now present more than 90% of a number and one-fourth of the biomass of all pelagic fish. Long term data demonstrate the invasion of sticklebacks is associated with an increase of small zooplankton like Bosmina spp. and Daphnia cucullata. The last was not present in the lake before, but now it presents in summer months more than 90% of all daphnids. Therefore it is speculated, that stickleback invasion might have a top-down effect on other pelagic trophic levels. In our mesocosm studies, we are using 0+ native whitefish and invasive sticklebacks to demonstrate how one or another fish species can influence the pelagic food web. Through different zooplankton selection, they affect lower trophic levels and chlorophyll-a value. Special attention is addressed also to the role of invertebrate predators (Bythotrephes longimanus and Leptodora kindtii) as an intermediate predator.

66. Oluwaseun OLUBODUN[1], Craig Williamson[1]

Challenges and Opportunities for Nigerian Lakes

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There are more than fifty natural lakes and man-made reservoirs in Nigeria which provide a major food source. Lake Chad is a prominent natural lake which is shared by 4 countries (Nigeria, Cameroon, Niger, and Chad). It is a shallow lake with only about one-tenth of its basin (60,000 sq mi) lying in Nigeria. It used to be one of the largest lakes in Africa but is now grossly affected by seasonal variations due to climate change, population growth, irrigation, and violent conflicts.

Most of the challenges faced are political and transboundary. Water quality issues have been the fore front of most research in this region. Agencies such as the Lake Chad basin authority and the Lake Chad basin Commission have focused on improving agriculture, rural development and control of river pollution with little or no consideration of the long term monitoring of these lakes.

Lack of sufficient data due to underdevelopment of human capacity for research is a gap in Nigeria. Currently, there are no earth observation systems in Nigeria and there is no real-time data collection and transmission to facilitate dissemination of data. There is also a lack of coordinated, effective and financially sustainable data for supporting strategic development decisions. Hence, the need for an improvement of the knowledge base through human capacity building to provide opportunities to assess, manage, and train water professionals to improve the level of information about Nigeria's water resources.

This study considers the state of research on Nigerian lakes, the challenges, and opportunities to encourage global network development and improve the science and practice of water resources planning and management in ways that balance quality of life, environmental sustainability, and economic growth.

67. Freya OLSSON[1,2], Ian D. Jones[3], Ellie Mackay[1], Tadhg Moore[4]

Investigating water residence time effects on in-lake temperatures and stratification dynamics of a small temperate lake

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[2]Lancaster Environment Centre, Lancaster University, Lancaster, UK

[3]Biological and Environmental Sciences, Stirling University, Stirling, UK

[4]Centre for Freshwater and Environmental Studies, Dundalk Institute of Technology, Dundalk, Ireland

Poor water quality, caused by excess nutrient addition, is a widespread issue in lakes globally. Even when improvements have been made to reduce external loads, internal sources of nutrients in the sediment can cause problems to persist. One method proposed of improving water quality, following enrichment, is the shortening of WRTs through increasing flushing rates. It is proposed that this will inhibit stratification and prevent the anoxic conditions that promote internal nutrient loading. This study aims to improve the understanding of WRT-effects on temperature dynamics in lakes and see the potential there is for WRT manipulations to be used in management.

This study utilises the General Ocean Turbulence Model (GOTM), calibrated using high-frequency data from Elterwater, a small lake in the UK. Through manipulations of the inflowing discharge, we investigate how changes to annual WRT modify the streams contribution to the lake heat budget and affect in-lake temperatures.

Results show, that due to temperature differences between the incoming stream and the resident water, in the summer the stream exerts a cooling flux and in the winter a warming flux. As WRT is shortened the size and contribution of the stream heat flux to the heat budget increases. This drives increased warming in the winter and cooling in the summer at shorter WRTs. Associated with summer cooling, caused by the stream, the length of the summer-stratified period is also reduced at shorter WRTs.

68. *Martina Patelli*[*1], *Veronica Nava*[1], *Valentina Soler*[1], *Morena Spreafico*[1], *Leoni Barbara*[1]

The pelagic food webs of deep subalpine lake and climate change: a long-term dataset analysis

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Climate change is considered to be one of the most severe threats to earth and aquatic ecosystems and the concern about the effects that global warming can have on biological communities is increasing. Even if the number of studies concerning climate change is increasing the effects of climate change are challenging to monitor and understand because of the multitude of responses within an ecosystem. In the last years, analyses of long-term data sets provide increasing evidence on the sensitivity of water bodies to climatic fluctuation. Moreover, small size and fast reproducing zooplankton organisms are key components of aquatic food webs and they are particularly sensitive to environmental change. The main aim of this study is to achieve generalized information on how climate variation can affect zooplankton population dynamics in relation to different lakes trophic evolution and how this affects the entire lake ecosystems. We combined the analysis of long term limnological dataset to paleolimnological studies to disentangle the effects of climate change and other anthropic pressure (i.e. eutrophication).

Our results suggest that in deep lakes winter climatic variability trigger a cascading effect that involves the entire lake ecosystems, modifying lake chemical, physical and biological characteristic. Climate change can mimic or reinforce the effect of eutrophication process, promoting algal development and increasing the phosphorus accumulation in the hypolimnion. The impact of global warming on zooplankton population dynamics indirectly affect the entire lake food webs and interfere with some lakes management strategies.

69. *Rachel M. PILLA, Craig E. Williamson, Erin P. Overholt, Stella Berger, Raoul-M. Couture, Heleen DeWit, Ignacio Granados, Hans-Peter Grossart, Georgiy Kirillin, Alo Laas, Jens Nejstgaard, Kevin C. Rose, Jim Rusak, Manuel Toro, Huaxia Yao*

Ice cover duration, morphometry, and water quality differentially influence winter vs. summer oxygen depletion in the deep waters of lakes

Recent trends of severe oxygen depletion in both lakes and oceans has resulted in growing concerns for ecosystem health and water quality. In lakes, periods of summer and winter thermal stratification are most likely to have deepwater oxygen depletion, and we hypothesized that shorter periods of ice cover will differentially affect the severity of oxygen depletion during these two periods. Oxygen depletion during winter is likely to be less severe over time with shorter periods of ice cover. In contrast, oxygen depletion during summer stratification will depend on the relative responses in the duration of spring mixing vs. summer stratification. Here, we have assembled high-frequency data on dissolved oxygen and water temperature from 20 dimictic lakes in the Northern Hemisphere and use a space-for-time analysis to address how the phenology of oxygen may respond to shorter ice cover duration. We found the predicted relationship between shorter ice cover duration and less deepwater oxygen depletion in winter across lakes. This relationship was not apparent, however, for summer stratification duration and deepwater oxygen depletion in summer, despite a strong indication that shorter ice cover duration results in longer summer stratification duration. Instead, lake characteristics were most important, where small, shallow lakes with high phosphorus or organic carbon were most likely to experience severe oxygen depletion during summer. Expanding the spatial and temporal use of high-frequency sensors is critical to understanding the drivers of oxygen depletion in lakes over time, with important ecological implications for habitat gradients, fish kills, and biogeochemical cycling.

70. *Joseph S. RABAEY[1], Mikkel R. Andersen[2], Meredith A. Holgerson[3], Kelly L. Hondula[4], David C. Richardson[5]*

#PONDING – Metabolism: What drives production and respiration in ponds?

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Metabolism is an important metric for lentic waterbodies, providing insight into dominant biogeochemical and ecological processes. Gross primary production (GPP), ecosystem respiration (ER), and net ecosystem production (NEP) are often calculated for lakes, with an emphasis on identifying important drivers such as dissolved nutrient concentrations, lake area and depth, temperature, and land use. However, ponds have been understudied with respect to ecosystem metabolism. It is unknown whether pond GPP and ER respond similarly to the same sets of drivers that apply to larger lakes. As ponds are globally abundant and contribute substantially to global carbon dynamics, understanding how pond metabolism responds to changing environmental factors (e.g., temperature and nutrient loads) is key to understanding the global carbon cycle. In addition, pond metabolism may provide insight into fine scale patterns of both pond productivity and pond ecology. Our goal was to measure ER and GPP in ponds and examine if the drivers of pond metabolism differ from lakes. We used free water oxygen data to calculate GPP, ER, and NEP from over 100 ponds around the world. We then compared this to chemical and physical pond characteristics that we expected to be important in regulating metabolism, including pond size, land use, macrophyte cover, and dissolved nutrients. Preliminary data suggests that ponds can have extreme rates of both ER and GPP, far exceeding typical values seen in lakes. This project is part of the suite of #PONDING (Pond Observation aNd Discovery IN GLEON) projects.

71. Jordan S. READ[1],Xiaowei Jia[2]; Jared Willard[2]; Alison P. Appling[1]; Jacob A. Zwart[1]; Samantha K. Oliver[1]; Anuj Karpatne[3]; Gretchen J.A. Hansen[2]; Paul C. Hanson[4]; William Watkins[1]; Michael Steinbach[2]; Vipin Kumar[2]

Process-guided deep learning predictions of lake water temperature

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The recent growth in environmental data is staggering, and many opportunities exist to direct water resources data and computing resources towards answering societally relevant questions. Data growth and methodological advances have introduced deep learning techniques that improve prediction accuracy and aid can scientific discovery. Hybrid models that integrate theory with state-of-the art empirical techniques have the potential to improve predictions while remaining true to physical laws. We designed a Process-Guided Deep Learning (PGDL) hybrid model to predict water temperature. The PGDL has three primary components: a deep learning model with temporal awareness, theory-based feedbacks (model penalties for violating conversation of energy), and model pre-training to initialize the network with water temperature predictions from a process-based model. We evaluated the PGDL model performance compared to a deep learning (DL) and a process-based (PB) model in conditions where training data were sparse and when predictions were made outside of the range in the training dataset. The PGDL model performance was superior for all modeling conditions (when ten or more temperature observation dates were available) compared to PB and DL models. The PGDL model also performed well when applied to temperature predictions for sixty-eight lakes in the Midwest U.S., with a median RMSE of 1.21°C during the test period (range of 0.78° to 2.39°C). This case study demonstrates that integration of scientific knowledge into deep learning tools shows promise for improving predictions of many societally- relevant environmental variables.

72. *Kaitlin L. REINL[1], Robert W. Sterner[1], Brenda Moraska Lafrancois[2], Sandra Brovold[1]*

Sources of cyanobacteria blooms in oligotrophic Lake Superior

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Lake Superior is warming rapidly and experiencing increasing numbers of extreme precipitation events. It's well known that four out of five Laurentian Great Lakes have experienced cyanobacteria blooms, but now the largest lake in the world has joined their ranks, as blooms dominated by the cyanobacterium Dolichospermum lemmermannii have been observed in western Lake Superior. We conducted experiments in 2017 and 2018 to investigate sources of these cyanobacteria blooms and characteristics of locations that are potential sources. We used a factorial design with 3 regional locations (Harbor, Rivers, and Apostle Islands), 2 nutrient conditions (high and low NP), and 3 temperatures (15, 20, and 25 °C). Cyanobacteria were most abundant from the River and Harbor regions at low N:P and 25 °C, suggesting that cyanobacteria propagules are being delivered from inland locations to the lake. We then evaluated 26 inland locations as potential sources of cyanobacteria to Lake Superior and identified similarities among sites that may be sources. We found that rivers were more likely to be sources than lakes or coastal waters, and further, that sites that were colder with high conductivity yielded the highest experimental growth rates. These results suggest propagules are transported from rivers, where conditions are less favorable for growth, to the nearshore where there are warmer temperatures and higher light availability, and then grow in abundance in the lake. If water temperatures and nutrient delivery to the nearshore in Lake Superior continue to increase, blooms may continue or worsen in western Lake Superior.

73. David C. RICHARDSON[1], Matthew J. Farragher[2], Meredith A. Holgerson[3], Margot Groskreutz[3], Kathryn K. Hoffman[3], Mikkel R. Andersen[4], Kelly L. Hondula[5]

#PONDING - What is a pond?

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Ponds represent a small proportion of lentic waterbodies by surface area (<10%) but outnumber lakes by an order of magnitude and are critically important to the global carbon cycle and biodiversity. Given how ubiquitous ponds are; seemingly everyone, those with and without training in limnology, can identify a pond when they can see it. Yet, there is no consistent definition of what a pond is and how ponds might functionally and structurally differ from lakes or wetlands. Ponds can be defined using physical characteristics: small and/or shallow with a variety of qualitative (e.g., smaller than a lake or light able to penetrate to the sediments throughout the system) and quantitative definitions (e.g., 1 m2 to 2 ha surface area). Other definitions include qualitative biological constraints. For example, a pond could be shallow enough for rooted plants to grow throughout. Additionally, there are cultural conventions for naming lentic waterbodies. For example, in the US, Great Pond, Maine has a surface area of 3,400 ha with maximum depth of 21m. However, Haseco Lake in New York (also called Mud Pond) has a surface area of 8 ha with maximum depth of 1.2 m. Our goal is to create a unified definition of ponds. We did this by synthesizing definitions of ponds from across scientific publications, grey literature, and tertiary literature to look for quantitative and qualitative commonalities. Further, we used published scientific data from self-identified 'pond' research to compile a database of pond characteristics and compared those to regional and national lake databases. Finally, we developed a social survey for limnologists, managers, anglers, and citizens on their views of what a pond is. This project is part of the suite of PONDING (Pond Observation aNd Discovery IN GLEON) projects.

74. Dale M. ROBERTSON[1], Benjamin Siebers[1], and Cory P. McDonald[2]

Modeling Metalimnetic Hypoxia in Big Green Lake, Wisconsin

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Big Green Lake is the deepest natural lake in Wisconsin, USA; maximum depth of 72m. In the early 1900's, the lake was oligotrophic, with hypoxia only occurring in the deepest part of the hypolimnion; however, increased nutrient loading has caused the lake to become mesotrophic, with hypoxia occurring in both the metalimnion and deeper parts of the hypolimnion. To document the extent of hypoxia in the lake and the factors driving the hypoxia, comprehensive water-quality sampling of the lake and its tributaries was conducted during 2017–18. The Aquatic Ecodynamics (AED) modeling library coupled to the General Lake Model (GLM) is currently being used to describe the short-term changes in the hydrodynamics and water quality in the lake and to understand the factors causing the degradation in water quality and the associated increase in the metalimnetic oxygen minimum (MOM) and deeper hypolimnetic hypoxia. GLM3-AED2 was able to simulate the summer thermal structure and deep hypoxia in the lake very well; however, the model currently underpredicts the extent of winter ice cover and metalimnetic hypoxia in the lake. Alternative routines within AED2 are currently being investigated to improve the model's ability to simulate these characteristics. The ultimate goal of the study is to provide information to guide watershed efforts to improve the water quality of the lake and reduce the MOM.

75. Jenna Robinson[1], Stephen Jane[1], Vince Moriarty[2], Matt Schuler[1], and Kevin Rose[1]

Understanding patterns of spatial and temporal variability in ecosystem metabolism

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Characterizing ecosystem metabolism is important for understanding the flow of energy and cycling of both organic and inorganic matter in freshwater systems. Recent improvements in high frequency sensors and modeling have enabled improved estimates of metabolic rates. Despite past studies, there is still limited understanding of many aspects of horizontal, vertical, and temporal variability in lake gross primary production (GPP), ecosystem respiration (ER), and the balance between these, net ecosystem production (NEP). We deployed twelve littoral dissolved oxygen (DO) sensors and two pelagic vertical profilers in a large oligotrophic lake to understand patterns and drivers of spatial and temporal variability in ecosystem metabolism. Littoral sensors were placed adjacent to stream deltas, wetlands, areas with invasive macrophytes, and control areas to estimate (1) metabolism horizontally across the lake surface over time, (2) metabolism between thermal layers over time, (3) differences in metabolism in relation to proximity to wetlands and stream deltas, and (4) how an aquatic invasive macrophyte alters metabolism. Vertical profilers enabled characterization of metabolism through the entire water column (0 to ~50m). Our results indicate substantial heterogeneity spatially among sites, with invasive macrophytes and nearby wetlands playing an important role in regulating both GPP and ER. Our results also indicate that temporal variability within sites is substantially higher among littoral sites than pelagic surface waters, which are in turn substantially more variable than deep waters. Seasonally, metabolism decreased and net heterogeneity became more prevalent, but sites became less variable spatially as stratification weakened.

76. *Amina SAEED[1,4], Peisheng Huang[1,2], Kerry Trayler[3] , Carolyn Oldham[2,4], & Matthew R. Hipsey[1,2]*

Integration of routine and high-frequency data to improve 3-D water quality model predictions

Stage 1: Analysis of high-resolution water quality sensor data and model calibrations and validation

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Supporting short- and long-term water quality management decisions in aquatic systems is a challenging task which requires a holistic view of the systems internal response to external stressors. Many approaches have been developed to simulate the water quality of aquatic systems through building models that assist with decision making. Additionally, regular monitoring programs of water quality with weekly or longer time intervals allow for tracking trends in water quality and an understanding of how systems evolves over extended periods of time. However, to improve our knowledge of the finer-scale hydrodynamic and biogeochemical processes (e.g. mixing, diel metabolism) monitoring data collected at frequent intervals (10 mins) is essential. While high-resolution sensor data offer great potential to assist with the calibration and testing of water quality models (e.g. models targeting hypoxia and harmful algal bloom issues), there remain challenges in the input of such high resolution sensor data into model prediction workflows. Resolving this challenge is expected to improve mechanistic models and offer a better understanding of drivers and controls underlying aquatic metabolism. It is envisaged that the new data streams will support further connections between data-driven and process-based model approaches, and ultimately lead to more "process-inspired" calibration opportunities of the model system. In this work, we will evaluate sensor data collected at high time resolution (10 mins) from multiple sites in the Swan-Canning estuary (Guilford, Caversham, Maylands, and COMO), and analyse weather data to explore different environmental drivers for each site. Secondly, as the first step in improving model estimations, high frequency sensor data will be used calibrate and validate our 3D coupled hydrodynamic and aquatic biogeochemical model (AED2-TUFLOW FV) with an aim to improve the current developed Aquatic Ecodynamic model (AED2) and gaining a better understanding of the science underlying estuarine aquatic metabolism.

77. *Peter SANFUL[1], Dennis Trolle[3], Yaw Agyeman[2], Karsten Rinke[7], Emmanuel Opuni-Frimpong[4], Mary Antwi[4], Adelina Mensah[5], Francis Nunoo[6], Thomas Davidson[3], Hans Thodsen[3], Torben Lauridsen[3], Anders Nielsen[3], Bertram Boehrer[7], Tom Shatwell[7], Austin Asare[4], Asha Damoah[4], Amos Asase[1], Solomon Amfoh[4], Augustine Yeboah[4], Elizabeth Kwakye[4], Sylvia Baidoo[4]*

Understanding and predicting climate forcing effects on hydrodynamics, ecosystem productivity and anthropogenic responses to enhance resilience of Lake Bosumtwi (Ghana, West Africa)

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Lake Bosumtwi is the only natural lake in Ghana and occupies a 1.07 million-year circular, meteorite impact crater. It is the oldest and deepest lake in West Africa and a UNESCO heritage site. Lying within the equatorial rainforest between the Atlantic Ocean and the Sahel desert, it is climate-sensitive on all time scales. Beginning in the 1970's, regional warming trends, strongly correlated with shifts in the mixing dynamics of the lake, have affected the timing and intensity of seasonal mixing, nutrient upwelling, ecosystem productivity and fisheries productivity. New livelihoods from adaptations to poor fish harvest are driving rapid deforestation and other harmful land use practices within the steep-sided crater with unknown consequences for the lake. With high resolution monitoring of climate, hydrodynamics, biogeochemistry, primary productivity, fisheries productivity, land use changes and livelihood adaptive strategies, the "Building Resilience of Lake Bosumtwi to Climate Change" – RELAB Project, aims to couple the hydrodynamic ecosystem model (GOTM-FABM-PC lake), fisheries model ECOSIM/ECOPATH and watershed model (SWAT) to simulate various scenarios of climate-ecosystem-watershed interactions in order to understand current and future impacts of climate and human adaptive responses on ecosystem function. Available data shows stable water column, persistently anoxic hypolimnion and incomplete mixing during the cool, windy season, evident of lake warming. Based on historical data from the 2004-2006 NSERC/LBRP Project, the GOTM-FABM-PC lake model has been setup and calibrated. Validated classified land use and land cover maps for the watershed between

1986-2018 indicates diminished lake volume (3.7 %), and displacement of closed and open forests (22.6 %) to farmlands, built-up areas and bare lands.

78. Lena A. SCHALLENBERG[1], Susie Wood[2], and Carolyn W. Burns[1]

Picocyanobacterial diversity and dynamics in contrasting New Zealand lakes

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Picocyanobacteria (Pcy) are the most abundant photoautotrophs on earth, responsible for up to up to 80% of total primary production in oligotrophic lakes. These organisms play a vital role at the base of the microbial food web, yet very little is known about their abundance, diversity and function in freshwater systems, particularly eutrophic waterbodies. Here we determine the spatial (horizontal and vertical) and temporal diversity and dynamics of Pcy in six oligotrophic and eutrophic New Zealand lakes over one year using epifluorescence microscopy and environmental DNA (eDNA) metabarcoding. Preliminary results suggest that freshwater Pcy are highly diverse, with over 63 distinct taxa found across 6 lakes. Spatial abundance was more variable than spatial diversity in the studied lakes, with higher Pcy abundances found in bays than open water sites. Pcy communities in oligotrophic lakes were generally less diverse than their eutrophic counterparts, and abundance and community composition were more stable over time. Greater variability in Pcy abundance and community composition was found in eutrophic lakes, with some lakes exhibiting boom-bust Pcy dynamics. We now have Pcy isolates from these study lakes, and ongoing work includes genome sequencing and nutrient addition experiments to determine how Pcy uptake and regulate nutrients in these different lake types.

79. *Martin SCHMID*[1]

Using lakes for heating and cooling: potential and impacts

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Lakes can be used as renewable sources or sinks of heat, for example for heating buildings or cooling infrastructure. From the ecological point of view, the limiting factor for such heat usages are the resulting changes in temperature, and as a consequence, in the stratification and mixing regimes of the lakes. The potentials of all larger Swiss lakes for heating and cooling were estimated based on basic heat budget calculations and assumed limits for the maximum allowable temperature changes. Except for some lakes in densely populated areas, the resulting potential exceeded the local demand, indicating that for many lakes economic and technical constraints rather than ecological impacts limit the application of this technology. The potential of specific lakes, and the impacts of a planned heat usage system were evaluated in more detail using the one-dimensional hydrodynamic lake model Simstrat.

80. L. SENERPONT DOMIS[1], M. Beklioğlu[2], S. Berger[3] and J. Nejsgaard[3]

AQUACOSM: Connecting freshwater and marine ecosystem-scale mesocosm approaches to ecosystem-scale questions

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To obtain mechanistic quantitative understanding of aquatic ecosystem functioning and biogeochemical processes, a range of empirical approaches have been used from laboratory to ecosystem scale, such as mesocosms. It is becoming increasingly clear that mesocosm experiments is a powerful approach to obtain such mechanistic quantitative understanding, especially when embedded in long-term observations, theoretical models and experiments conducted at other scales. However, after decades of ecosystem-scale empirical studies, there is still little standardization and collaboration across sites and biomes, especially between freshwater and marine systems. To challenge these issues, the EU-INFRAIA project INFRAIA aims to coordinate research, develop common best practices and open both freshwater and marine large-scale research infrastructures (mesocosms) for international cross-discipline participation. In addition, AQUACOSM offers scientists, students, trainees, enterprises and others transnational access to 37 mesocosms facilities in Europe.

81. Amir Reza SHAHABINIA[1], Matthew J. Bogard[2], Paul A. del Giorgio[1]

Patterns and Regulation of Ecosystem Metabolism in Lakes across Canada

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Quantification of the metabolism of lakes provides fundamental information needed to understand how materials and energy cycle within these ecosystems, as well as how lakes interact with other environments at local to global scales. Assessments of gross primary production (GPP) and respiration (R) and their net balance (NEP and P/R) for northern lakes are scarce, however, because conventional approaches require either long incubations, intensive sampling or deployment of monitoring equipment, none of which are feasible in remote northern areas. Here we present the initial results of a large-scale comparative study of lake metabolism where we are exploring the patterns and drivers of GPP, R, NEP and P/R of lakes across Canada, part of the NSERC-funded Canadian Lake Pulse Network. The study is based on measuring summer mixed-layer metabolic rates in these lakes using an oxygen isotopic (δ18O2) mass balance approach that combines ambient O2 concentration and isotopic signature, and which provides an integrative snapshot of lake metabolism. We present here the preliminary results of Year 1 of the study, which covered over 220 lakes distributed across four major ecoregions in Eastern Canada: Atlantic Highlands, Mixedwood Plains, Atlantic Maritime and Boreal Shield, encompassing wide environmental, hydrologic, and climatic gradients. GPP, R and NEP varied greatly across lakes within regions, as a function of lake size and morphometry, trophic status and local watershed properties, but our preliminary results suggest that there are also significant differences in mean lake metabolism between ecoregions, reflecting higher order drivers of lake metabolism.

Keywords: Oxygen, Lake Metabolism, Oxygen Stable Isotopes, Primary Production

82. Sapna SHARMA[1], Kevin Blagrave[1], John J. Magnuson[2], Catherine O'Reilly[3] and Ice Team

Consequential impacts of climate change on lake ice loss and human mortality

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Lake ice is a sensitive indicator of climate. Our objective was to understand the drivers of extreme intermittent ice cover events in lakes around the Northern Hemisphere (defined here as the absence of complete ice cover in some years). We assembled a database of 520 lakes with long-term records of lake ice phenology extending between 40 and 575 years. Classification tree analysis revealed the importance of air temperature, lake depth, elevation, and lake shape for the occurrence of winter lake ice. We estimated that 14,800 lakes currently experience intermittent winter ice cover; 35,300-230,400 lakes could be vulnerable with warming of 2 to 8°C. These changes in ice cover represent widespread impacts on ecosystem services for up to 656 million people in 41-50 countries. We illustrate that an extensive loss of lake ice will occur within the next generation and highlight the corresponding losses to human life. As such, we documented over 4000 winter drowning events from 10 countries around the Northern Hemisphere. We found that winter air temperatures explained approximately 50% of the variation in winter drownings. Winter drownings increased exponentially as winter air temperatures approached 0°C. Higher rates of drownings occurred late in the winter season when ice stability weakens. Children and young adults were at the highest risk of winter drownings. Beyond climate, differences in cultures, regulations, and human behaviours were important additional risk factors. In a warming world, winter drownings will increase unless climate change adaptation strategies are incorporated into winter drowning prevention plans.

83. *Michael SHIOZAKI[1], Saba Ketabchi Haghighat[1], Sam Feng[1], Vignesh Sivan[1], Alexander Wong[1,2], Ted D. Harris[3], Jason L. Deglint[2]*

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Interactive Tool for Aggregating and Visualizing Spatial and Temporal Harmful Cyanobacteria Bloom Data

With toxic algae blooms recently gaining global attention, researchers require compiled data on worldwide cyanotoxin concentrations to examine if toxin-producing blooms are increasing in frequency. The Global Microcystin Aggregation (GLEON-GMA) project focuses on microcystin, one of the most frequently detected cyanotoxins, and compiling a global spatial/temporal dataset of of freshwater microcystin and associated physicochemical water quality data. This data will allow researchers to identify global trends, examine concentrations of microcystin, and possibly help select future locations of study (i.e., areas without any cyanotoxin information). The website visualizes the data using Dash, a python plotting library. Researchers can interact with the data live, modifying parameters to allow them to pinpoint microcystin relations in specific lakes or regions.

84. Joseph STACHELEK[1], Lauren Rodriguez[1], and Patricia A. Soranno[1]

Prediction of lake depth at continental scales: spatial patterns and relationship to landform

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Lake depth is widely regarded as a critical predictor of nutrient cycling in lakes. Unfortunately, existing databases lack widespread information on this basic measure. Lack of depth data is a key impediment to effective lake nutrient prediction in thousands of lakes at regional to continental scales. Although a number of investigators have developed predictive models of lake depth based on topography surrounding a lake, predictions from such models have proved to be fairly imprecise. To improve prediction of lake depth, we compiled a database of maximum depth for more than 15,000 lakes throughout the conterminous United States and used it to develop predictive models of lake depth based on factors such as lake elevation, topography, geometry, impoundment status, and landform. We used fitted models to predict lake depth for nearly all lakes in the conterminous United States and show how our statistical models, which are stratified on lake and watershed characteristics, represent an improvement over existing models. Ultimately, our lake depth predictions could be used not only as an aid in predicting lake nutrients but also as a rough check on estimates of total lake volume used in Earth System Models.

85. *Julio A. A. STELZER[1], Jorrit Mesman[1], Alena Gsell[2], Lisette de Senerpont Domis[2], and Bastiaan Ibelings[1]*

Towards a (Comprehensive) Process-Based Assessment of Ecological Resilience

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Deterministic approaches are widely used in environmental sciences and have been responsible for outstanding achievements along the history of limnology. Yet, in front of a (every time faster) changing world, we still lack the understanding over basic ecological processes underlying ecosystem's response. Such a process-based understanding of ecological response is not only necessary to better predict consequences of long-standing environmental pressures (e.g. climate change, eutrophication), but as well to better develop self-sustained ecosystem-based management strategies.

Using the framework of Ecological Resilience, we ran a mesocosms experiment under a mechanistic approach capturing daily step-wise changes in the structure of the community (i.e. functional traits) in association with broad ecosystem response variables (i.e. phytoplankton pigments). Systems were pressed by phosphate addition and destabilized by hydrogen peroxide mimicking stochastic events in three rounds of perturbations. Future results are expected to show where and when eutrophication changes the functional structure of a natural ecological network and how it affects ecological resilience.

Here we present the first results of an experimental setup designed for observing internal feedback loops capable to sustain the ecological state of a system, while still allowing the quantification of early warning signals of regime shift.

86. Jonathan T. STETLER[1], Lesley Knoll[2], Charles T. Driscoll[3], Kevin C. Rose[1]

Understanding the nutrient stoichiometry of browning lakes: Important ecological implications of lake browning

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Widespread increases in lake dissolved organic carbon (DOC) concentrations have been observed in recent decades, but the ecological consequences are poorly understood. Observations suggest a unimodal relationship between DOC and lake productivity, with peak productivity at intermediate DOC concentrations. DOC may increase productivity via DOC-associated nutrients or decrease productivity by absorbing light. A key assumption of this hypothesis is that nutrients (i.e., Phosphorous and Nitrogen) increase at a constant stoichiometric rate as DOC increases. However, it is unknown whether DOC nutrient stoichiometry is constant across space or through time. We conducted a field survey of over 30 lakes in the summer of 2018 to understand DOC-nutrient stoichiometry. We found a positive linear relationship between DOC and different forms of nutrients suggesting constant stoichiometry across space. Additionally, using data from the US National Lakes Assessment, nutrients were correlated with DOC concentration at the national scale. However, using a long-term dataset of DOC and nutrients from NY, USA, we found that despite substantial increases in DOC concentration, nutrient concentrations did not increase, demonstrating variable stoichiometry. Other factors, such as interactions with soil chemistry or changes in climate and growing season length are likely altering long-term patterns in stoichiometry. Our findings imply that that through time, DOC may not be a substantial source of nutrients and browning ecosystems will likely be more susceptible to the negative impacts of browning (light shading) than previously believed.

87. Ena L. SUAREZ[1], Bastiaan Ibelings[1]

Planktothrix rubescens strain diversity at different physical and chemical vertical fine scale gradients in Lake Zurich, Switzerland.

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We aim to study how Planktothrix rubescens population functional and genetic diversity varies with depth, based on steep gradients in the availability of nutrients, light and temperature within the deep chlorophyll maximum (DCM) in Lake Zurich, Switzerland. We assume that sub-populations of P. rubescens that are vertically separated remain at their respective depths in the DCM for long enough to develop functional and genetic differences. We captured four different structures of the thermocline, with contrasting water column stability conditions to test how the strength of stratification affects the thickness of the P. rubescens layer. The sampling methods consisted on a micro-sampler, able to collect simultaneously 80 water samples at 8.8 cm vertical and 4.4 cm horizontal intervals, and Niskin samples. We formulated three hypotheses on the vertical P. rubescens diversity gradients within the DCM: 1) The amount of accessory light harvesting pigments (phycoerythrin) is larger for strains positioned at the bottom of the P. rubescens bloom. 2) The degree of gas vacuolation is higher for strains positioned at the bottom of the P. rubescens layer. 3) The number of microcystin producers in the P. rubescens layer decreases with depth. For the first and second hypothesis we will use flow-cytometry data on the ratio of chlorophyll a to phycoerythrin and the forward and sideward scattering, to detect the differences at each depth. For the 3rd hypothesis we will use results from qPCR analysis to calculate the ratio of non-microcystin mutants vs microcystin producers (Garneau et al. 2015).

88. Kristy L. SULLIVAN[1] and Evelyn E. Gaiser[1]

Seasonal vertical distribution of phytoplankton in a subtropical dystrophic lake

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Physical, chemical, and competitive processes can influence the vertical distribution of phytoplankton in freshwater lakes. While some phytoplankton control their buoyancy and motility with gas vesicles and flagella, others rely more heavily on the physical stratification of lake water to maintain their position in the photic zone. In DOC-rich waters, the photic zone may be limited to just a few meters, often above the thermocline where deep chlorophyll maxima typically occur. In these low-nutrient, high-OC environments, mixotrophs may be the dominant functional group. Mixotrophic algae, which combine heterotrophy and autotrophy, are able to sustain their metabolic functions under light, nutrient, or prey (bacteria, dissolved or particulate organic carbon) limitation, outcompeting strict auto and heterotrophs in stressful conditions. In subtropical dystrophic Lake Annie, mixotrophs may be serving as organizers of phytoplankton assemblages spatially and temporally. The proposed study aims to determine the influence of changing DOC and bacteria concentrations on phytoplankton species diversity, richness, and mixotrophy across vertical depths and seasons. Patterns of seasonal vertical phytoplankton distribution will be used alongside physiochemical measurements and long-term data to elucidate the potential driving mechanism(s) of mixotrophy in this subtropical lake. Preliminary results suggest diversity is greatest in the hypolimnion during stratification, while an opposite trend is observed during lake turnover. Preliminary results also suggest that species richness and diversity are greatest with higher DOC concentrations, likely due to increased resource availability for mixotrophic species.

89. Xinyu SUN[1]

Examining the interactive effects of high salinity and acute thermal stress on freshwater zooplankton communities and the influence of timing on the effects

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Freshwater ecosystems are one of the most valuable resources for humans and various species of wildlife and play an essential role in maintaining pivotal ecosystem functions. Zooplankton are an important component of freshwater ecosystems because they connect the flow of energy and nutrients between primary producers and higher trophic levels; but zooplankton communities are being altered by environmental stressors. Considerable research effort has been made to understand how different environmental stressors individually affect freshwater organisms, communities and ecosystems, whereas, in nature, ecosystems are exposed to multiple stressors, either simultaneously or sequentially. For freshwater ecosystems, elevated salinity is one of the novel disturbances brought by human activities. Meanwhile, climate change has caused a higher frequency of extreme heat wave events. However, the combination of high salinity and acute thermal stress, either occurring simultaneously or sequentially, has not been thoroughly studied in freshwater systems, particularly at the community-level, which has limited our ability to predict and mitigate outcomes of future disturbances. Therefore, during summer 2019, I conducted a mesocosm experiment to investigate this multiple stressor problem. The experiment aimed to study (1) the interactive effects of high salinity and acute thermal stress on freshwater zooplankton communities' structure (i.e. species richness, total and relative abundance) and function (i.e. biomass) and (2) if the interaction between these stressors differ when they are applied at the same time vs. when they are decoupled in time. This research would broaden our knowledge about multiple stressors and help predict impacts of future changes on freshwater ecosystem.

90. Andrew J. TANENTZAP[1], Jérémy Fonvielle[1], Samuel Cottingham[1]

The chemical and microbial diversity of European lakes

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Dissolved organic matter (DOM) is central to the functioning of lakes. But despite its importance, DOM remains poorly understood because it has been measured with little resolution for nearly 200 years. Recent technological advances using ultrahigh-resolution mass spectrometry have shown that a handful of lake water contains thousands of different molecules of varying origin and composition. A key question that now needs answering is what do all these different molecules do in aquatic ecosystems? With funding from the European Research Council, we have embarked on a 5-year project (2019-2024) to resolve this mystery. Here we present work package 1 of the Ecological and Evolutionary Importance of Molecular Diversity in Dissolved Organic Matter (sEEIngDOM) project. This work package aims to map the shared biogeography of chemical and microbial diversity across more than 100 lakes spanning the latitudinal extent of Europe. We also highlight a call for participants for a new GLEON project that we wish to undertake in 2020. This project would aim to understand how the chemical diversity of DOM varies seasonally across the world's lakes. We are especially interested in welcoming participants that could contribute monthly water samples from pelagic monitoring stations.

91. Andrew J. TANENTZAP[1], Erik J. S. Emilson[1,2], Amelia Fitch[1,3], Chloé Orland[1,4], Kurt M. Yakimovich[5,6], Nathan Basiliko[5], Nadia C. S. Mykytczuk[5], and John M. Gunn[5]

A moveable feast: coordinated experiment reveals how lake sediments respond to changing terrestrial organic matter inputs

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Inputs of terrestrially derived organic matter (t-OM) exert major control over lakes, but the ecological consequences of changes in their quantity and quality remain poorly understood. About a third of all t-OM input into inland waters is buried in lake sediments, with larger particulate material disproportionally accumulating nearshore. However, littoral sediments remain understudied relative to pelagic environments, especially in the context of future changes to t-OM. Here we describe a 3-year mesocosm study replicated across lakes with different overlying water clarity. Artificial sediments were incubated with different amounts and types of t-OM to simulate future increases in forest productivity and climate-driven shifts in forest vegetation. This experimental platform ultimately mirrored biogeochemical patterns in adjacent natural lake sediments, highlighting its potential for coordinated deployment across field conditions. After 2 months, we found both bacteria and archaeal but not fungal communities differentiated from the initial source material, resulting in different taxonomic and functional composition between lakes. After 12 months, microbial communities in the dark but not clear study lake had greater relative abundances of genes involved in t-OM decomposition. This difference potentially reflected recruitment of surrounding lake taxa pre-adapted to high-molecular weight carbon inputs. However, genes involved in t-OM decomposition generally increased over time irrespective of the lake and mineralization of t-OM was strongly associated with sediment chemistry both in the lab and field. More broadly, our results suggest that the responses of lake sediments to changes in t-OM inputs depend on overlying water chemistry and the composition of resident microbial communities.

92. Sven TEURLINCX[1,2], Dianneke van Wijk[1,3,4], Wolf M. Mooij[1,4], Robert J. Brederveld[5], Inese Huttunen[6], Manqi Chang[1], Jan H. Janse[7], Ben Woodward[2], Fenjuan Hu[8], Jan J. Kuiper[9], Annette B.G. Janssen[3]

A perspective on water quality in connected systems: modelling feedbacks between upstream and downstream transport and local ecological processes

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Food production for a growing world population relies on application of fertilizers and pesticides on agricultural lands. However, these substances threaten surface water quality and thereby endanger valued ecosystem services such as drinking water supply and recreational water use. Such deleterious effects do not merely arise on the local scale, but also on the regional scale through transport of substances as well as energy and biota across the catchment. Here we argue that aquatic ecosystem models can provide a process-based understanding how these transports by water and organisms as vectors affect - and are affected by - ecosystem state and functioning in networks of connected lakes. Such catchment scale approach is key to setting critical limits for the release of substances by agricultural practices and other human pressures on aquatic ecosystems.

93. R. Quinn Thomas[1],Renato J. Figueiredo[2],Vahid Daneshmand[2],Mary E. Lofton[3],Ryan P. McClure[3],Whitney M. Woelmer[3],Cayelan C. CAREY[3]

Near-term iterative forecasting with GLM-AED and daily data assimilation reveals the forecastability of water quality dynamics

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[3]Virginia Tech, Department of Biological Sciences, Blacksburg, VA, 24061

Freshwater ecosystems are experiencing unprecedented levels of anthropogenic stress, creating enormous challenges for managers to provision drinking water in the face of toxic phytoplankton blooms, metal contaminants, and low oxygen concentrations. Forecasts, with quantified uncertainty, can help managers anticipate these water quality impairments. Here, we apply an iterative near-term forecasting system (FLARE – Forecasting Lake And Reservoir Ecosystems) to Falling Creek Reservoir, a eutrophic drinking water reservoir and GLEON site, to generate 16-day forecasts of multiple water quality variables. FLARE uses data assimilation (Ensemble Kalman Filter) and a 1-D hydrodynamic model coupled to an aquatic ecosystem model (General Lake Model – Aquatic Ecosystem Dynamics) to generate initial conditions and calibrate parameters for 16-day forecasts. Every day, FLARE develops probability distributions for drinking water quality variables that span physical (water temperature), chemical (dissolved oxygen concentrations), and biological (chlorophyll a) processes. Over 1 year of 16-day forecasts, FLARE was most accurate at forecasting the physical variables (water temperature) and least successful at forecasting the biological variables (chlorophyll a), with the chemical variables (dissolved oxygen) intermediate. While our initial model parameter set was based on calibration with 5 years of weekly sampling data, all forecasts were improved by including real-time parameter calibration with data from high frequency sensors using data assimilation. Furthermore, we partitioned the relative contribution of different components of uncertainty and, preliminarily, found that meteorological driver uncertainty was more important for physical variables while model process uncertainty was more important for biological variables. FLARE provides an open-source forecasting framework for developing real-time forecasts, updated and calibrated using high-frequency sensors, that is both generalizable to other waterbodies in GLEON and applicable for drinking water management.

94. Seth K. THOMPSON, James B. Cotner, Sehoya Cotner

Data-driven inquiry as a course-based undergraduate research experience in limnology

Engaging undergraduates in research opportunities is imperative for cultivating a new generation of motivated scientists but offering these experiences to a large number of students in the field of limnology is often challenging. Course-based undergraduate researcher experiences (CUREs) represent a powerful training tool for preparing future researchers by providing inclusive research experiences for undergraduates and reducing the systematic biases that have led to underrepresentation of non-white and female scientists. Therefore, applying the CURE framework to engage students in limnological research experiences represents an exciting opportunity for recruiting and training a new generation of limnologists. He we present a two-semester course series developed at the University of Minnesota to expose undergraduates to research in limnology by leveraging large publicly available datasets. We discuss the underlying course structures and assessment strategies for the course as well as introduce the education research questions that will be addressed during the implementation of the limnology CURE.

95. *Jeng-Wei TSAI[1], and Cheng-Hao TANG[2]*

Ecosystem metabolism regulate seasonal bioaccumulation of heavy metals in Amano shrimp (Palaemonetes varians) in a tropical blackish wetland

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[2]Department of Oceanography, National Sun Yat-Sen University, 70 Lienhai Road, Kaohsiung, Taiwan

Aquatic communities are naturally exposed simultaneously to environments with mixture of heavy metals and varying DOM levels. Ecosystem metabolism (EM) denotes the process of production, consumption and sources of organic matters (OM) within ecosystems. We assumed that EM regulate the bioavailability and accumulation of metals, especially to the detritivore species that directly feed on the organic matters or bacteria that consume the DOM; however, how and what extend the EM determines the bioavailability and bioaccumulation of heavy metals is still not clear. This study involved field investigation for the seasonality of EM and related environmental and limnological regulators, and heavy metal level of Cu, Zn, Mn, Pb, Hg, Cr, Se and Ni in bulk water, sediment and amano shrimp (*Caridina pseudodenticulata*) population in a eutrophic wetland in tropical Taiwan. In-situ sonde and discrete field samplings were conducted to collect the environmental, limnological variables and ecotoxicological samples, respectively. Results revealed that heavy metal residues in shrimp were not significantly correlated to neither waterborne nor sedimentary concentrations, but shows significant positive or negative correlation with the GPP, R and NEP (r2 ranged from 56 to 87, $p<0.05$). This study support that EM plays as a crucial endogenous factor driving the seasonality of heavy metals bioaccumulation in aquatic population as EM reflects the quantitative feature of the waterborne DOM and metal-specific speciation bioavailability. The finding contributes to improve the temporal- and spatial -specific ecotoxicological exposure risk and human health risk assessment particularly in the context of changing climate and environment.

96. Dianneke VAN WIJK[1,2,3], Carolien Kroeze[1], and Wolf M. Mooij[2,3]

Smart Nutrient Retention Networks for good water quality and sustainable nutrient use

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Society heavily depends on fertilizers to feed a growing world population. Part of the valuable nutrients in these fertilizers end up in surface waters, causing severe water quality problems, and are eventually lost into the oceans. With global change, these problems are expected to increase further. Here, I propose Smart Nutrient Retention Networks (SNRNs) to tackle these challenges by employing the positive feedback loop between nutrient loading, water quality and nutrient retention in hydrological networks. SNRNs utilize the higher nutrient retention of clear, vegetated states over turbid, algae dominated states, to simultaneously improve water quality and recycle valuable nutrients. The project aims to result in a modelling tool for water quality managers and to contribute to achieving sustainable development goals at local and global scales.

97. Mark P. Wachowiak[1], April L. James [1], Dan Walters[1], James Rusak[2], and Krystopher Chutko[3]

Relationships and Correlations in Environmental Time Series for a Large Inland Lake System

[1]Environmental Sciences, Nipissing University
[2]Dorset Environmental Science Centre, Ontario Ministry of Environment, Conservation and Parks
[3]Department of Geography and Planning, University of Saskatchewan

Visual analytics, the science of interactive visualization to promote, complement, and enhance humans' innate abilities of analytic reasoning, is employed for analyzing a large volume of high-frequency data acquired from sensors for environmental monitoring of lake conditions. Meteorological and inlake observations from Lake Nipissing, a large, inland lake in northeastern Ontario, are collected every 10 minutes using two lake buoys with temperature and dissolved oxygen sensors located at different depths. The high frequency data is assessed with windowed cross correlation (WCC) and wavelet transform coherence (WTC) to uncover relationships, correlations, and possible evidence of causality between driver (cause) and response (effect) variables. WCC is well-suited to the short- or long-term impact of short-duration events, such as storms, while WTC, a time-frequency method, is useful for studying longer-term trends. Interesting or anomalous phenomena observed in the WCC and WTC interactive visualizations are further investigated with statistical tools. Preliminary experiments include examining air temperature, rain amount, and wind speeds as drivers of changes in water temperature and dissolved oxygen at the soil-water interface as a result of mixing events. Frequency and causes of mixing and the depletion of oxygen at depth are of particular interest in this polymictic lake because of their role in preventing and/or contributing to the transfer of phosphorus from sediment back into the water column (internal P loading). WCC and WTC tools are used with more traditional analyses to provide users with additional approaches by which to intelligently steer the analysis of high frequency data towards meaningful results.

98. Mark P. WACHOWIAK[1], April L. James[1], Renata Wachowiak-Smolikova[1], Dan Walters[1], Krystopher Chutko[2], James Rusak[3]

Analysis of High-Frequency Lake Monitoring Data Using an Enhanced Visual Analytics Interface

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[2]Department of Geography and Planning, University of Saskatchewan
[3]Dorset Environmental Science Centre, Ontario Ministry of Environment, Conservation and Parks

Visual analytics in environmental science is motivated by the rapid increase in the volume and frequency of monitoring data. Because it is often not known *a priori* what patterns or relationships are sought between measured properties, the driver/response relationship is not well defined, specifically at the short-time scale for which data are now collected Visual analytics integrates automated analysis and algorithmic approaches with users' domain knowledge and intuition. This research expands earlier work on an interactive web-based system for assessing the cumulative effects of multiple stressors (e.g. nutrient inputs, changing weather conditions) on altering aquatic ecosystem function employing high frequency observations of Lake Nipissing, a large, shallow lake in northeastern Ontario, Canada experiencing environmental challenges, including the occasional harmful algae bloom event. An intuitive online visualization system was designed to facilitate exploration, pattern recognition, and anomaly detection of large, complex monitoring data, which can be further refined with statistical methods and advanced automated analysis. New features include 3D smooth parallel coordinate plots, water temperature depth profile visualization, and improved horizon plots and small multiples. Additionally, new database features allow data from heterogeneous sensors to be simultaneously viewed and compared. Because of the importance of location-specific environmental monitoring, the web-based visual analytics interface will utilize users' natural pattern recognition capabilities to discover new patterns related to inlake processes. This poster will introduce the web-based visual analytics system for the Lake Nipissing monitoring program with the goal of promoting community involvement, scientific research, and ensemble modeling of lake conditions.

99. Qi WANG[1], Leon Boegman[1]

Simulation of western Lake Erie hydrodynamics and biogeochemistry from 1979-2015

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During the 1970s, harmful algal blooms (HABs) were common occurrences in western Lake Erie. Remediation strategies reduced total P loads and bloom frequency; however, HABs have reoccurred since the mid-1990s, likely forced by climate change. Given these concurrent changes in nutrient loading and climate forcing, there is a need to develop management tools to better understand historical changes in the lake and predict future water quality. Herein, we applied coupled one-dimensional hydrodynamic and biogeochemical models (GLM-AED) to reproduce water quality conditions of western Lake Erie from 1980 to 2015. The physical forcing was derived from surface meteorological buoys, airports and measurements of precipitation and inflow. Nutrient loads were reconstructed from historical monitoring data. The models were validated against observations of water levels, water temperature, DO, TP, PO4, NH4, NO3, total chlorophyll a (Chl a), and cyanobacteria concentration. The results indicate GLM-AED has the capacity to simulate these parameters with adjustment from default values (e.g. to the longwave formulation). We conclude that GLM-AED is able to reproduce historical water quality conditions of western Lake Erie and then we apply this model to explore the impacts of nutrient scenarios on algal bloom reductions to inform future water quality management.

100. Heather L. WANDER[1], Bethany J. Bookout[1], Jonathan P. Doubek[2], Alexandria G. Hounshell[1], Dexter W. Howard[1], Abigail S. Lewis[1], Mary E. Lofton[1], Ryan P. McClure[1], Nicole K. Ward[1], Whitney M. Woelmer[1], Cayelan C. Carey[1]

Zooplankton vertical and horizontal migration in an anoxic reservoir

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In freshwater lakes and reservoirs, zooplankton often perform diel vertical migration (DVM) or diel horizontal migration (DHM) to escape from visual predators and ultraviolet radiation. While many studies have looked at these zooplankton migration strategies separately, fewer have compared both migration types within a single lake. Additionally, it is possible that crustacean and rotifer taxa preferentially optimize DHM vs. DVM based on their functional traits. In general, DVM is considered the more ubiquitous strategy, but DHM may become more advantageous in the presence of hypolimnetic anoxia (<0.5 mg/L oxygen), especially for larger taxa with low oxygen tolerances. In this study, we measured both DVM and DHM in a reservoir with hypolimnetic anoxia during two separate sampling campaigns in summer 2019. We collected vertical net tows at pelagic and littoral sites throughout a 24-hour period to identify zooplankton distribution patterns in the presence of hypolimnetic anoxia. For DVM sampling, we collected full water column tows and oxycline tows (above ~4.8m) at noon and midnight. For DHM sampling between sites, we collected epilimnetic tows at noon, midnight, and within three-hour windows around sunrise and sunset. We found changes in density, biomass, and community composition across sites, which suggest that DVM and DHM were both occurring simultaneously, and that different migration strategies were exhibited by different taxa. Identifying which migration strategies are preferred among crustacean zooplankton and rotifers in freshwater ecosystems will advance our understanding of how zooplankton communities respond to increased hypolimnetic anoxia in the face of global change.

101. Whitney M. WOELMER[1], Mary E. Lofton[1], Ryan P. McClure[1], Bethany J. Bookout[1], R. Quinn Thomas[2], Cayelan C. Carey[1]

Looking backward to look forward: forecasting phytoplankton in a drinking water reservoir using multiple modeling approaches

[1]Department of Biological Sciences, Virginia Tech

[2]Department of Forest Resources and Environmental Conservation, Virginia Tech

Lakes and reservoirs are increasingly threatened by eutrophication, a result of rapidly changing land use and climate. Consequently, there is a growing need to assess the current and future state of freshwater ecosystems by adopting iterative, near-term forecasting. Because the field of ecological forecasting is relatively new, there is not yet a consensus as to whether empirical or process-based models perform better in forecasting freshwater ecological variables. To assess these two distinct approaches in forecasting harmful algal blooms (HABs), we compared an empirical autoregressive (AR) linear model and the General Lake Model coupled with Aquatic Ecodynamics (GLM-AED), a process-based model for Falling Creek Reservoir (FCR), a drinking water reservoir and GLEON site in Vinton, Virginia, USA. Both models were trained using four years of historical chlorophyll-a data and calibrated to produce near-term (up to 16-day) forecasts of HABs using the Forecasting Lake and Reservoir Ecosystems (FLARE) framework. Both model approaches generated chlorophyll-a hindcasts and forecasts that generally captured observed dynamics. Both AR and GLM-AED models performed better than chance when compared to a null persistence model and forecasted chlorophyll-a within 4 μg/L over a one-year time period. The dominant driver of uncertainty in forecasts for both models was process error; however, the contribution of initial condition uncertainty to GLM-AED forecasts increased along the 16-day forecast horizon. Our research provides valuable information on how best to forecast HABs, as well as advances our understanding of the drivers of HAB dynamics, which are increasing in lake and reservoir across the globe.

102. *Molly M. WOZNIAK[1], Kevin L. Kapuscinski[1], Jessica N. Wesolek[1], Zachary J. Johnson[1], Ashley H. Moerke[1], and Jonathan P. Doubek[1]*

LSSU's Center for Freshwater Research and Education: Enhancing undergraduate research at the nexus of the Great Lakes

[1]Center for Freshwater Research and Education, Lake Superior State University, Sault Sainte Marie, Michigan, USA

This year, Lake Superior State University (LSSU) is beginning construction of its new 20,000 ft2 Barch Center for Freshwater Research and Education (CFRE) along the shores of the St. Marys River. Located at the nexus of three Great Lakes and on an international border, the CFRE will be uniquely positioned to serve as a hub for ecological research and education on upper Great Lakes issues, while expanding immersive real-world learning opportunities for LSSU undergraduate students. The CFRE programs will provide community resources, including a public Great Lakes visitor center and K-12 Discovery Center to develop and deliver Great Lakes-based curricula to regional schools; adaptive scientific research facilities, including experimental mesocosms, wet labs, optics, and analytical laboratories that will be available to university and visiting researchers and students; and an expanded and renovated fish culture facility adjacent to the new construction. LSSU undergraduates fulfilling their senior theses or working on one of the ongoing research projects that CFRE faculty are pursuing will have access to these resources that are not available at all universities. The CFRE will also house partner organizations' offices (e.g., tribes, government and non-governmental agencies) and will work to develop a formalized consortium of research and educational facilities across the Great Lakes in efforts to share resources and identify innovative solutions for freshwater conservation, management, and stewardship in the Great Lakes basin.

103. Marguerite A. XENOPOULOS[1] and Aaron T. Fisk[2]

RAEON: Real-time Aquatic Ecosystems Observatory Network

[1]Department of Biology, Trent University, Peterborough, ON, Canada
[2]Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON, Canada

The Real-time Aquatic Observation Network (RAEON) is a ground-breaking new initiative led by the University of Windsor that has been made possible by $15.9 million in funding awarded by Canada's Foundation for Innovation Ontario's Ministry of Research, Innovation and Science's Research Infrastructure programs. RAEON is a multi-university partnership infrastructure program that will provide continuous, year-round, real-time data and monitor aquatic ecosystems from their abiotic (e.g., temperature, dissolved oxygen) to their biotic (e.g., chlorophyll, fish) characteristics. RAEON which began in early 2019 will allow transformative and cutting-edge research that will enable us to track and monitor ecosystem conditions and structure and their drivers, crucial for forecasting and responding to current (e.g., climate change) and future (e.g., Asian carp) threats to aquatic ecosystems. RAEON includes four mobile autonomous sub-surface vehicles (Slocum Gliders), telemetry instrumentation to track animal movement, echosounders, real-time sensory arrays that will collect continuous physical and biological data via a network of cabled and acoustically-connected sensors and *in situ* autonomous instrument pool of multi-water parameter sondes and loggers (e.g., nitrates, phosphorus, chlorophyll, CDOM, temperature, pCO_2). Please visit my poster to learn more about RAEON, our instruments, current projects, and, how you can get involved.

104. Bernard YANG[1], Mathew G. Wells[2]

Hydrodynamics beneath lake ice potentially provide a significant source of heat for melting the ice cover

[1]Department of Physics, University of Toronto, Toronto, Ontario, CA

[2]Department of Physical and Environmental Sciences, University of Toronto Scarborough, Toronto, Ontario, CA

There is enough heat beneath the surface in many lakes to melt all the ice during winter. However, due to the inverse stratification present in winter, most of this heat is not in contact with the ice surface. The presence of radiatively driven convection beneath the ice is an overlooked physical process that can liberate this deep heat, and potentially change ice-off dates in lakes. We will discuss in detail 3 years of physical studies of mixing using high frequency temperature and velocity observations in a large ice-covered lake and compare the mixing dynamics with a small ice-covered lake at a similar latitude. We found that the inverse stratification under ice is much stronger in smaller lakes and is weaker in larger lakes. We further compare the ratio of internal heat fluxes due to liberating the accumulated heat over the winter by convection to the external heat fluxes associated with solar radiation and lateral transport processes. At the same latitude, the internal heat fluxes are nearly an order of magnitude larger in the smaller ice-covered lake than in the large ice-covered lake with a weak inverse stratification. Most temperate, subarctic, and arctic lakes are experiencing thinner ice cover due to a warmer climate, thus there will potentially be increased convection under ice that can liberate heat stored in the deep hypolimnion of these lakes.

105. Qing ZHAN[1]

Mitigating negative impacts of heatwave on the internal phosphorus loading in freshwater ecosystems

[1]NIOO-KNAW Institute

A very promising way of moving lakes to an oligo/mesotrophic state is by using geo-engineering techniques that reduce cyanobacterial biomass and bioavailable phosphorus. More heatwave is expected in the context of global warming and extreme events. A deepen understanding of the negative impact of heatwave on the rehabilitated water is essential for optimizing water management, especially for the high nutrient-loaded agricultural watershed. Therefore, an experiment with before-after- control-impact (BACI) design was performed to study the effect of heatwave treatment on the Phoslock treated water. In this poster, the initial results of this experimental data will be presented. Principal response curve (PRC) is used for analysis of heatwave treatment effects in the control groups and the Phoslock treated group. The results showed that the Phoslock applied water is more resilient (PO4 below 0.2 mg/L) along time in comparison with the control groups (PO4 up to 1.5 mg/L). But the heatwave was observed resulting in the release of Phosphorus from the sediment. In addition, the Greenhaus Gases (GHG) emissions were enhanced under heating (species scores of CO2 equivalent = -2.3), which will, however, recover after the treatment.

106. *Jacob A. ZWART[1], Alison Appling[1], Samantha Oliver[2], Jordan S. Read[1]*

A broad-scale, near-term water temperature forecasting system using data assimilation

[1]U.S. Geological Survey, Integrated Information Dissemination Division
[2]U.S. Geological Survey, Upper Midwest Water Science Center

Near-term forecasts represent one of the purest forms of the scientific method: forecasters are required to synthesize their understanding of a system in the form of a model, use that model to predict the state of the system, and confront their predictions with out-of-sample observations to test their understanding. Weather forecasting performance has improved significantly over the last several decades in large part because weather forecasters generate and test hypotheses on how the world works multiple times a day at millions of locations. Unfortunately, water quality studies have either focused on predictions that cannot be tested (e.g. predictions decades to centuries into the future) or relied on historic data to test predictions, which hinders advancement in understanding contemporary water quality issues. This poster describes a new modeling workflow for producing broad-scale, near-term forecasts of lake and stream temperature, primarily focused on the Delaware River Basin, USA. We describe how we are assimilating *in situ* water temperature data with existing water temperature models, such as the General Lake Model (GLM) and Stream-Network TEMPerature (SNTemp) model, within an efficient and reproducible modeling pipeline to make probabilistic temperature predictions 10 days into the future. We present preliminary results on how our forecast accuracy changes the further into the future we forecast and how our prediction accuracy varies across different lakes and locations in the stream network. Furthermore, we present hypotheses for which modeling component contributes most to forecast uncertainty and propose methods for partitioning uncertainty within our modeling framework.

New Site Abstracts

107. *Janet M. FISCHER[1], Mark H. Olson[1], and Masaki Hayashi[2]*

New GLEON site: Canadian Rocky Mountains – resilience of mountain lakes across a gradient of glacial retreat and vegetation advance

[1]Department of Biology, Franklin & Marshall College, Lancaster, Pennsylvania, USA
[2]Department of Geoscience, University of Calgary, Calgary, Alberta, Canada

Mountain landscapes worldwide are changing rapidly as glaciers retreat and vegetation advances upslope. The objective of our research is to investigate the effects of landscape characteristics on the resilience properties (i.e., resistance and recovery) of lakes in two UNESCO World Heritage Site National Parks in the Canadian Rocky Mountains. Climate-driven changes in landscape affect lakes by modifying the type and amount of material input from the surrounding catchment, particularly glacial flour and chromophoric dissolved organic matter (CDOM). Glacial flour and CDOM both influence water transparency, a key regulator of lake ecosystem structure and function. Using a space for time substitution to represent a chronosequence of glacial retreat and vegetation advance, our research tests the overarching hypothesis that resilience of water transparency changes systematically as lake catchments shift from glaciated to rocky to vegetated. To test this hypothesis, we combine high frequency monitoring (temperature, turbidity, fDOM) and less frequent manual profiling (dissolved oxygen, light attenuation, chlorophyll, and zooplankton) in five lakes that span a gradient of glacial and vegetation coverage. Concurrent hydrological data are also being collected to better understand dynamics of turbidity and CDOM inputs and their relationships to meteorological data recorded at nearby stations. Because water transparency of mountain lakes is a powerful case study through which to communicate ecosystem-level effects of environmental change to a broader audience, we are also working on a short film describing the research.

108. Barbara LEONI[1], Veronica Nava[1], Martina Patelli[1], Valentina Soler[1]

Long-term ecological studies on Lake Iseo, a deep south-Alpine lake in Northern Italy

[1]Department of Earth and Environmental Sciences, University of Milano-Bicocca, Milano, Italy

Lake Iseo is a deep lake (surface area 60.9 km^2, max depth 258 m, volume 7.6 km^3) located in Northern Italy. It is one of the deep lakes south of the Alps (DSL: Maggiore, Lugano, Como, and Garda, all included in the Long-Term Ecological Research network, LTER-Italy), which constitute the most important water district in Italy, totaling 121 km^3 of water and about 80 % of the Italian total freshwater volume, including artificial lakes. Located in one of the most densely populated and highly productive areas of the country, Lake Iseo represents an essential strategic source of water supply for agriculture, industry, fishing, and potable use, and an important resource for recreation and tourism. Regular monthly studies on Lake Iseo have been established from 1993 for physical and chemical parameters (*e.g.,* transparency, temperature, DO, pH, EC, nutrients and major ions) and plankton analysis (phytoplankton and zooplankton). The main research topics regarding this site are the evolution of the trophic status, the dynamic of phytoplankton and zooplankton, the effects of climate change on hydrology, thermal structure, water chemistry and biological communities, paleolimnology, and ecological modelling. This site is already involved in two different GLEON projects, related to chlorophyll-a, temperature, and dissolved oxygen patterns. This long-term monitoring programme has so far provided a valuable dataset that can also allow comparison with different lakes worldwide.

109. Marguerite A. XENOPOULOS[1] and Aaron T. Fisk[2]

RAEON: Real-time Aquatic Ecosystems Observatory Network

[1]Department of Biology, Trent University, Peterborough, ON, Canada
[2]Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON, Canada

The Real-time Aquatic Observation Network (RAEON) is a ground-breaking new initiative led by the University of Windsor that has been made possible by $15.9 million in funding awarded by Canada's Foundation for Innovation Ontario's Ministry of Research, Innovation and Science's Research Infrastructure programs. RAEON is a multi-university partnership infrastructure program that will provide continuous, year-round, real-time data and monitor aquatic ecosystems from their abiotic (e.g., temperature, dissolved oxygen) to their biotic (e.g., chlorophyll, fish) characteristics. RAEON which began in early 2019 will allow transformative and cutting-edge research that will enable us to track and monitor ecosystem conditions and structure and their drivers, crucial for forecasting and responding to current (e.g., climate change) and future (e.g., Asian carp) threats to aquatic ecosystems. RAEON includes four mobile autonomous sub-surface vehicles (Slocum Gliders), telemetry instrumentation to track animal movement, echosounders, real-time sensory arrays that will collect continuous physical and biological data via a network of cabled and acoustically-connected sensors and *in situ* autonomous instrument pool of multi-water parameter sondes and loggers (e.g., nitrates, phosphorus, chlorophyll, CDOM, temperature, pCO_2). Please visit my poster to learn more about RAEON, our instruments, current projects, and, how you can get involved.

Site News Abstracts

110. François CLAYER[1], Magnus Norling[1], Jose-Luis Guerrero[1], Leah Jackson-Blake[1], James Sample[1], Uta Brandt[1], Kari Austnes[1], Raoul-Marie Couture[2] and Heleen A. De Wit[1]

New sensors at Lake Langtjern (Norway) and a new MOdel BUIlding System – MOBIUS

[1]Norwegian Institute for Water Research (NIVA), Oslo, Norway
[2]Université Laval, Québec, Québec, Canada

Lake Langtjern (60°37'N; 9°73'E) is a small (0.227 km2) humic and oligotrophic lake located in central Norway and member of GLEON since 2015. Lake Langtjern has been included in the Norwegian freshwater monitoring program since 1972 and has facilitated the emergence of key long-term datasets on acid deposition, carbon and mercury cycling, oxygen and greenhouse gas dynamics, as well as fish and invertebrate ecology. A new monitoring station at the inlet and a new pCO2 sensor at the outlet have been set up since 2015. This upgrade is now offering 5 years of high-frequency data on runoff, temperature and coloured DOM fluorescence (FDOM) at the inlet and 2 years of pCO2 data at the outlet in addition to the 9 years of high-frequency data from existing sensors, from the weather station and the on-site camera.
Using in-situ data from local monitoring and weather stations, we have calibrated two lake models (MyLake and GOTM-FABM-DOMCAST) for DOC processing. In addition, we also developed a modular modelling framework (MOBIUS – Model building system: https://github.com/NIVANorge/Mobius) that allows rapid model prototyping by combining hydrological and biogeochemical catchment models. Using MOBIUS, NIVA has already developed a range of fully integrated catchment models simulating the (reactive) transport of nitrogen, carbon, phosphorus, microplastics, sediment and more. A new model can be easily setup within MOBIUS and is equipped with a graphical user interface (GUI) and state-of-the-art facilities for calibration and uncertainty analysis (e.g., optimisation and Markov chain Monte Carlo – MCMC – based algorithms).

111. James THOMPSON[1], Yvonne McElarney[1], and Robert Rosell[1]

The first automatic high frequency monitoring of the largest lake in Ireland – Lough Neagh; nutrient and fishery management.

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Lough Neagh is the largest lake in Ireland (383km2). It is shallow, with a mean depth of 8.9m; maximum depth of 33m and a residence time of 1.3 years. The lake is hypereutrophic (2017 mean annual TP and chlorophyll a is 139 µg/L and 44 µg/L respectively) due to a history of cultural eutrophication, although nutrient loading has been reduced, the recovery is being delayed by internal loading and diffuse sources from the catchment.

Lough Neagh sustains commercially significant fisheries, most notably for the critically endangered European Eel (Anguilla anguilla) with a harvest of approx. 350 tonnes per annum worth circa $3.7 million USD.

Routine chemical and biological monitoring of the lake began in 1969 and continues every fortnight. Weekly samples are collected from the outflowing river and eight main rivers that feed into the lake. The deployment of a data buoy on Lough Neagh will compliment ongoing sampling, providing high frequency data for water temperature, conductivity, dissolved oxygen (DO), pH, nitrate, turbidity and total algae, in addition to wind speed, temperature, direction, and relative humidity.

Our goal is to monitor the chemical and physical parameters of the lake to coincide with depletion of nitrate from the water column and the onset of internal loading from sediments. In addition, the near real-time weather, temperature, and DO data collected by the buoy will be readily available to aid the fisheries management. Specifically, stock recruitment models for eels in the lake have shown improvement in accuracy on inclusion of temperature data.

112. Catherine M O'REILLY[1], Alice Q Hargrave[2], and Kendra Paitz[3]

The art of lake data

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With recent funding from the Andy Warhol Foundation for the Visual Arts, we are able to launch a new project that will use lake data to create art. The outcomes will include an exhibit at the University Galleries in Illinois, as well as the potential for the exhibit to travel to other locations. We will also be writing a book that will accompany the exhibit, providing additional context about the exhibit and theme. We are soliciting high frequency datasets, detailed water color information, and stories about your lake (e.g. how it is changing and why this is important). The exact theme and details of the exhibit and the art will emerge based on the input we receive at this GLEON meeting. Our goal is to create an exhibit that reflects the diversity and uniqueness of lakes as well as their sensitivity to environmental impacts.