global lake ecological observatory network

Poster Session Abstract Book

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Poster Abstracts

1. Lauren M. ADKINS1, Craig Williamson[1], Abby McBee[1], Tom Fisher[2]

Application of geographic information systems (GIS) techniques to identify potential public health risks from waterborne disease among lakes and reservoirs experiencing browning

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Long-term data from two lakes in northeastern Pennsylvania revealed a correlation between increasing dissolved organic matter (DOM), changes in thermal structure, and a reduction in water transparency. This lake "browning" has been observed in many lakes in both North America and Europe and is related to climate change-induced increases in precipitation, increases in ambient temperature, and recovery from acid deposition among other types of environmental change. Temperature and exposure to solar radiation are critical factors that contribute to natural disinfection of pathogenic microorganisms in surface waters. DOM also reacts with chemical disinfectants, during the water treatment processes, producing carcinogenic disinfectant byproducts. This emphasizes the need for a better understanding of the potential public health consequences of browning in the context of climate change. The purpose of this study was to test whether DOM-mediated responses of lakes to climate change are mediating potential risks to public health by reducing a lake's natural ability to control pathogenic microorganisms and retain its quality for drinking and recreation activities. The current state of knowledge regarding the effect of lake and reservoir responses to climate change and an analysis of water quality monitoring data and health outcome data is presented using geographic information systems (GIS) and R, over several spatial and temporal scales. Preliminary findings indicate lakes with higher organic matter also contain higher fecal coliform levels. This research supports ongoing efforts to better understand the water quality-related threats of climate change as a basis for the development of more comprehensive management strategies.

2. *María Belén ALFONSO[1], Josefina Zunino[1], Gerardo M. E. Perillo[1] and María Cintia Piccolo[1,2]*

Impact of water level fluctuations on plankton temporal dynamics from a managed shallow saline lake: La Salada (Argentina)

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La Salada is a shallow saline lake located in the SW of the Pampas subject to significant water management, so the primary objective was to assess whether the water input and physicochemical parameters have an impact on the plankton assemblages over a two-year period (2013 – dry and 2014 – wet). The plankton community structure and physicochemical variables showed substantial changes over the study period. La Salada hosted a plankton community characterized by low diversity and small sized organisms. The nanoplanktonic fraction organisms (2-20 µm) dominate the phytoplankton community. *Ochromonas* sp. showed the maximum abundance throughout the whole study period. The zooplankton community was dominated by rotifers, with a lack of cladocerans. Halotolerant species, e.g. the rotifer *Brachionus plicatilis* and the cyclopod *Apocyclops* sp. were the main species. The seasonal temperature and conductivity dynamics influence the plankton abundance dynamics in La Salada. The increment of nutrients and decrease of conductivity caused by the water input led to an increase in plankton biomass and shaped its composition. These findings emphasize that interactions between plankton, salinity, and nutrients are sensitive to the water input and they improve the understanding of the impact of adequate management decisions.

3. *Margaret ARMSTRONG[1,2], Vicenç Acuña[3], Miquel Lurling[2,1], Elisabeth Ruijgrok[4], Lisette de Senerpont Domis[1,2]*

Towards benefit-oriented rehabilitation to make degraded lakes more resilient to extreme events

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As the global climate continues to change, the effects of extreme events such as intensified storms and heatwaves are expected to have severe ramifications on natural and manmade habitats. Of specific concern is the effect these events will have on the provision of ecosystem services of lakes and reservoirs. From recreation to transportation, such benefits provided by functional aquatic systems may be threatened if ecosystems do not gain resilience against these impairments.

This project is part of the Management of Climatic Extreme Events in Lakes and Reservoirs for the Protection of Ecosystem Services (MANTEL) program. Research topics centers on the effects of extreme climate events on ecosystem services and the use of high frequency monitoring (HFM) to assess this interaction. Project 11 is focusing on how impaired aquatic system functioning affects the socioeconomic value of ecosystem services. Research on both the physical, chemical and biological characteristics of lakes and reservoirs in addition to socioeconomic analyses will be carried out. Attaining this holistic understanding of the water system will assist in building ecosystem resilience as a method of mitigating or preventing future extreme event effects.

Anticipated deliverables include a decision framework promoting remediation plans that optimize ecosystem services benefits. In addition, the program will provide training in technical and transferable skills to enhance future research opportunities.

4. *Margaret ARMSTRONG [1], Ana I. Ayala-Zamora[2], Ewan Geffroy[3], Truls Hansson[4], Nasime Janatian[5], Hares Khan[6], Jorrit P. Mesman[7], Elias Munthali[8], Julio A.A. Stelzer[7], Cleo N. Stratmann[1], and Michael Thayne[9]*

Management of Climatic Extreme Events in Lakes & Reservoirs for the Protection of Ecosystem Services (MANTEL)

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Extreme episodic events such as intense storms and heatwaves are predicted to become more frequent with the changing climate. These short-term events can have negative and long-term impacts on the functionality of freshwater ecosystems and the services they provide. The MANTEL Marie Skłodowska-Curie Action European Joint Doctorate Innovative Training Network (MSCA EJD ITN) aims to mentor 12 early-stage researchers (ESRs) conducting theoretical and experimental investigations on these impacts to freshwater ecosystem services. Research projects will cover a range of ecosystem topics including nutrient cycling, community functioning, lake physics, resilience thresholds, early warning signals of ecosystem functioning and socioeconomic values. Central to these projects is the use of high frequency monitoring (HFM) technology, which can capture and record sudden shifts in ecosystem states with the high temporal resolution of data. Current and historic HFM data collected from freshwater systems will be analyzed and modeled to assess the duration and severity of impairments on various ecosystem characteristics and functions. Collaborations between universities and institutes as well as with industrial partners will assist in enhancing ESRs' understanding of aquatic science and research. Specialized skill training administered through workshops, conferences and associated projects will enhance the competency of ESRs to study emerging issues in aquatic sciences. The results of the MANTEL program will be the advancement of scientific understanding of extreme climatic effects on freshwater ecosystems and the development of 12 researchers proficient with state-of-the-art technology for studying aquatic systems.

5. *Brougham, K[1], J.S. Sinclair[1], and Shelly ARNOTT[1]*

The relative importance of local environment and regional dispersal to zooplankton community structure: a multi-year assessment

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Lake communities are structured by both local (e.g. environment) and regional (e.g. spatial connections) factors. Commonly, studies have found that local factors play a more prominent role in shaping communities, however these conclusions are often based on data obtained from a single time period without considering the potential for inter-annual variation. Annual variation in weather, local water chemistry, species interactions, and dispersal could influence the relative contributions of local versus regional processes, but this has not been explicitly examined in other studies. We sampled 25 lakes in the Frontenac Arch Biosphere from 2012-2016 to determine the influence of environmental variables and spatial distance (an indication of dispersal) on the composition of crustacean zooplankton communities, and to investigate inter-annual variation in their relative importance. On average, across all years, we found that local environment explained more variation in community composition than spatial variables. However, there were some years in which spatial influences were more prominent. This suggests that, while local factors may generally be the most influential in structuring communities, the relative importance of local and regional processes can vary between years, and caution should be taken when interpreting data based on synoptic surveys conducted in single years.

6. *Guillaume AUGER[1], Eli M Dow[1], John Ma[1], Mike Henderson[1], Campbell D. Watson[1], Harry R. Kolar[1], Lloyd A. Treinish[1]*

Estimation of material exchange in Lake George, NY, with a particle tracking method

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In the last decade, unstructured numerical models (for example: SUNTANS, SCHISM) have been used to clarify the hydrodynamics in lakes. With these models, we can locally increase the resolution of the numerical grid to obtain greater details in some area of the lake with complex bathymetry (e.g., underwater channels, etc.), where increased fluxes of substances occur. We apply the model SUNTANS to clarify the exchange of material between the South Basin and North Basin through a region named The Narrows. We use a grid with resolution of 15m at The Narrows and 40m otherwise, and force the model with meteorological parameters from a weather model based on WRF at 333m resolution. We assess the exchange of material at The Narrows with a particle tracking. Lagrangian particles are released at various times over a month to represent as many weather patterns as possible. However current particle tracking methods would generate artificial clustering, affecting the assessment of particles spatial distribution. Therefore, we use a streamline method that is consistent with unstructured model for this study to avoid such clustering. In this poster, we briefly describe the particle tracking method and show the differences between the two methods of particle tracking. We conclude the poster with the influence of adding the complex bathymetry of The Narrows in the material exchange between the North and the South Basins.

7. *Sarah BARTLETT[a,b], Erin Houghton[b], Donalea Dinsmore[c], Gina LaLiberte[c], Tim Davis[d], Todd Miller[a]*

The Good, Bad and Green of Cyanobacterial Blooms in Green Bay, Lake Michigan

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Cyanobacterial harmful algal blooms (cyanoHABs) are a growing problem in freshwater systems worldwide. Toxin-producing blooms are well documented in the Laurentian Great Lakes but little is known about the environmental drivers of cyanoHAB growth and toxicity in Green Bay, Lake Michigan. Excess nutrients from urban and rural runoff, along with sediment and phosphorous loading from the Lake Winnebago and Fox River water systems into Green Bay aid in cyanoHAB formation and proliferation, which can be toxic to humans and animals. Depth discrete samples were collected from six sites in lower Green Bay, including four sites in a transect moving through the designated Area of Concern, and two eastern shorelines sites - Bay Beach and Joliet Park. In addition to assessing the diversity of twenty different cyanobacterial toxins including eleven microcystin variants, other measured variables include pigments, nutrients, and cyanobacterial taxa counts. *Microcystis aeruginosa* prevailed as the dominant taxa throughout the season and of the microcystin variants targeted, microcystin-LR and microcystin-RR were co-dominant toxins. A toxin gradient was observed with the highest microcystin concentrations measured along the eastern shore and at the mouth of the Fox River. Similarly, pigment fluorescence and several nutrient analytes followed the toxin gradient.

8. *Ben BLOCK[1], Allison Hrycik[1], Jason Stockwell[2]*

The Emerging Role of Zooplankton on Winter Freshwater Food Webs

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Winter limnology is a relatively uncharted territory. A common observation is that a majority of zooplankton enter dormancy during winter when low photoperiod and cold temperatures limit (our perception of) food availability, resulting in lower zooplankton biomass compared to summer months. However, the literature also suggests that certain species of zooplankton are active during winter months and can, in some instances, reach summer biomass levels. The degree to which zooplankton may or may not play important roles in winter food webs is unknown. In theory, overwintering zooplankton must in some way contribute to winter food webs. Thus, research is required to observe and evaluate overwintering zooplankton community composition and classify their functions during the winter months. A first step is to address key questions with existing data or easily obtained samples. For example, which functional groups are more prevalent in winter, and has this changed over time? Does winter composition influence spring composition and possibly seasonal phytoplankton succession? What are the feeding behaviors of species that overwinter, and how will they be altered by climate change? We plan to convene an *ad hoc* group at GLEON 19 to explore and identify key questions to better understand the role of overwintering zooplankton in lake ecosystems. With sufficient interest, we hope to form a working group to test hypotheses using existing data sets or coordinated field sampling.

9. *Ludmila S. BRIGHENTI[1], Peter A. Staehr[2], Luciana P.M. Brandão[1], Francisco A.R. Barbosa[1], and José Fernandes Bezerra-Neto[1]*

Light, nutrients and organic matter affecting epilimnetic primary production and respiration in tropical lakes: a mesocosm study.

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In a factorial mesocosm study conducted in a mesotrophic tropical lake, we investigated how additions of inorganic nutrients and allochthonous organic matter, and shading affected rates of epilimnetic gross primary production (GPP), respiration (R) and net ecosystem production (NEP) and the degree of light saturation and photoinhibition of GPP. The factorial design of the mesocosms experiments simulated seasonal changes previously observed for the upper mixed layer of lakes in the Middle Rio Doce region. Specifically, this concerns changes in primary production and water clarity caused by changes in temperature, stratification, and rains, which affect the input of terrestrial organic matter, and nutrients in the epilimnion of these lakes. We found that GPP rates were enhanced by additions of inorganic nutrients and organic matter and decreased with increasing mean light available (Imean). This supports previous evidence of the importance of photoinhibiton, especially during nutrient depletion and high light availability during the warmer rainy season in the epilimnion of this lake. Increased allochthonous organic matter, with high content of colored dissolved organic matter (CDOM), not only stimulated GPP rates but also reduced photoinhibition and the level of light saturation and increased NEP and R rates. R was strongly coupled to GPP, indicating that much of the respiration was related to autotrophic activity rather than a direct and independent stimulation of the heterotrophic communities.

10. *Emma C. BRUNO[1], Hailee L. Edwards[1], Kayla A. Reid[1], Abigail Lewis[2], Dejea M. Green[1], Anthony Hollander[1], Sawyer R. Mcfadden[1], Heather L. Wander[1], David C. Richardson[1]*

Co-limitation of nitrogen and phosphorus at the epilimnion, metalimnion, and hypolimnion as a bottom-up control on phytoplankton biomass in an oligo/mesotrophic lake

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Lake Minnewaska, located in a state park in New York, has been recovering over the last 30 years from acidification; concurrently, water clarity has decreased raising concern amongst park managers and visitors. Previous research identified top-down control of phytoplankton biomass; however, in this study we investigated the possibility of bottom up controls on phytoplankton by performing nutrient limitation experiments. We carried out four one week *in situ* experiments with each having four nutrient treatments (control, nitrogen (N), phosphorus (P), and N+P), and measured chlorophyll *a* (chl *a*) concentrations as a proxy for phytoplankton biomass. Two initial experiments examined epilimnetic phytoplankton only. The third experiment investigated differences in nutrient limitation across the epilimnion (1 m depth), metalimnion (5 m depth), and hypolimnion (15 m depth). The fourth experiment examined nutrient limitation at three light intensities. We saw no limitation in the first experiment and co-limitation of N and P leading to more phytoplankton growth in the second. In the third experiment, phytoplankton was also co-limited across depths but phytoplankton growth from 15 m also showed a significant, though weaker, response to P alone. The type of nutrient limitation did not differ with increased light. However, light limitation superseded nutrient limitation at the lowest light treatment. These results suggest that lowering both N and P concentrations would lead to an increase in lake water clarity. The results also challenge conventional theory that P limitation dominates freshwater lakes and indicate potential for depth-based differences in nutrient limitation.

11. *Samantha M. BURKE[1], Jonathan P. Doubek[2], Hilary A. Dugan[3], Holly A. Ewing[4], Lauren A. MacDonald[1], Ana M. Morales-Williams[5], Nicholas K. Skaff[6], Jason D. Stockwell[5], Jamie C. Summers[7]*

Global trends and drivers of lake primary production

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Climate change and other anthropogenic stressors can alter in-lake primary production. Though these effects have been well-documented, most studies have been conducted over limited spatial and temporal scales in Europe and North America, which limits the ability to draw conclusions at a global scale. We use a paleolimnological approach to 1) assess how primary production has changed in a globally distributed set of lakes over the past ~200 years, and 2) identify drivers of lake primary production on multiple geographic and temporal scales. We hypothesize that air temperature will be the main driver of primary production in remote lakes, while development-related proxies (e.g. population, land use) may be more important in non-remote lakes. Our dataset consists of paleorecords of chlorophyll *a* from ^{210}Pb-dated sediment cores from >100 lakes across North America, South America, Europe, Asia, Oceana, and Africa. Preliminary temporal trend analyses on standardized chlorophyll *a* values indicate that 79% of lakes in the dataset experienced a significant increase in primary production since 1800. Future analyses will use spatial and temporal covariate data (e.g. air temperature, land use, population, latitude, altitude, surface area, depth) to model lake chlorophyll *a* to determine the relative importance of the possible drivers across the globe. We expect results from our study to be useful in predicting future changes in lake primary production in light of globally rising air temperatures and continued development.

12. Sarah H. BURNET[1], and Frank M. Wilhelm[1]

Spatial correlations between nutrient availability and sediment particle size in Willow Creek Reservoir, Heppner, Oregon

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For many lakes, internal loading of phosphorus (P) from bottom sediments has been calculated to be a large fraction of the annual phosphorus budget and has been identified to significantly delay improvements of water quality after reducing external sources of P. To understand the dynamics of the potential release of P from bottom sediments, we will focus on the particle size composition from 30 cores collected from Willow Creek Reservoir, in northeastern Oregon. We aim to test the hypothesis that the amount of reactive P is directly related to particle size, and the abundance of binding sites presented by the presence of iron (Fe), manganese (Mn), and aluminum (Al) in the sediments. The amount of reactive P will be compared to previously measured sediment release rates from the same reservoir. If relationships exist between the two methods, then analysis of reactive P in cores could serve to replace time-consuming incubations to measure P release from sediment cores. It would also allow more expansive sampling at a lower cost to better understand the spatial distribution of P stored in sediments which is important to managers constructing a nutrient mass balance, or attempting to identify 'hotspots' that should be prioritized for any in-lake treatment. With regard to treatments, high resolution maps of P that can contribute to internal loading would allow managers to custom tailor appropriate doses for effective treatment.

13. *Wilton G. BURNS[1,2], Toby Smith[2], Bridger Banco[2], Jason D. Stockwell[1,2,] and Andrew W. Schroth[2,3]*

Similar and contrasting drivers of nutrient and cyanobacteria dynamics in two adjacent shallow, eutrophic bays in Lake Champlain

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Shallow lake systems are impacted seasonally by internal and external drivers and are also susceptible to impacts from global climate change and land-use changes. This study focuses on two shallows bays of Lake Champlain (Missisquoi and St. Albans) that experience intense cyanobacteria blooms in the late summer, primarily due to historical and current amendment of phosphorus in their catchments. The bays are within 11 miles of one another and at similar elevation, thus experience similar local weather patterns. However, the two sites differ in watershed to lake area, watershed land-use, and hydrologic connectivity to the northern Green Mountains and the mesotrophic waters of Lake Champlain's inland sea. Thus, we posit that the two sites may exhibit different biogeochemical responses to both pheneological and episodic events. We use long-term monitoring (1991-2016) data to examine the differences and similarities in nutrient and bloom dynamics between the two sites on a seasonal scale. During wet and dry summers the bays exhibit contrasting patterns of TN and phytoplankton community composition. Conversely, both bays exhibit comparable, but precipitation-distinct TP and TN:TP patterns during dry and wet summers. Using the information gleaned from the historical biweekly monitoring data, we will use conceptual models of the drivers of nutrient and phytoplankton dynamics to develop hypotheses on the impacts of pheneological and stochastic events on the two systems. These hypotheses will then be tested using recently implemented high-frequency biogeochemical and physical monitoring networks.

14. *Maria CALDERO PASCUAL[1], Eleanor Jennings[1], Valerie McCarthy[1], Elvira deEyto[2] and Mary Dillane[2]*

Resolving the links between nutrient and carbon budgets in the Burrishoole catchment

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Lake ecosystems are sensitive indicators of catchment modification. Owing to increased anthropogenic pressures and variations in climatic conditions, there is a need to understand and detect these changes by monitoring susceptible parameters at appropriate timescales. The Burrishoole Ecosystem Observatory Network 2020 (BEYOND 2020) is a multi-institute research cluster that is working to build on the existing biological and sensor monitoring programme in the Burrishoole catchment in Country Mayo, Ireland. The proposed work programme focuses on the elucidation of biogeochemical and biological pathways using sensors, metagenomics, and biosensor development. As part of the Beyond 2020 cluster this project aims to address the current gap in monitoring in the Burrishoole catchment by quantifying and investigating nutrient (nitrogen N, and phosphorus, P) cycling to gain a fuller understanding of the drivers of productivity. The project will leverage the many data streams currently being collected in the area to link carbon budgets to macronutrient fluxes through the utilisation of high frequency monitoring and the measurement of seasonal and trophic dynamics of the main carbon and nutrient pools in addition to the microbial, zooplankton and phytoplankton populations. A new *in-situ* nitrate sensor will be deployed at the main inflow to augment current infrastructure in the catchment which, in addition to weekly/fortnightly grab samples, will be used to quantify in-streams and in-lake nutrient concentrations and loadings. Isotopic and stoichiometric analysis will be carried out to determine the reliance of the ecosystem on allochthonous carbon and to determine the nutritional quality and potential implications for consumer production and internal nutrient cycling within the system.

15. *Cayelan C. CAREY[1], Renato J. Figueiredo[2], R. Quinn Thomas[3], François Birgand[4], John C. Little[5], Madeline E. Schreiber[6], Michael G. Sorice[3]*

Integrating environmental sensor networks and real-time forecasting to adaptively manage drinking water quality and build social trust

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Freshwater ecosystems around the globe are facing unprecedented levels of anthropogenic stress that are altering the provisioning of drinking water. Simultaneously, recent water contamination events have decreased the public's confidence in their drinking water systems. To ensure safe drinking water and resilient communities in the face of global change, managers need real-time environmental data and forecasts to detect and predict when water quality thresholds are crossed so they can act rapidly to mitigate threats. We are developing a smart water system by embedding a secure, wireless sensor network in Falling Creek Reservoir, a drinking water reservoir in Roanoke, Virginia, USA and GLEON site, to improve water quality, freshwater management, and community well-being. High-frequency data from novel sensor technology will be used to create real-time water quality forecasts for drinking water managers using a new model-data fusion approach that leverages the General Lake Model (GLM). These forecasts will be co-designed in partnership with Roanoke's water utility to ensure that information and visualizations successfully translate water quality model output into decision support tools useful to managers. We envision that our project will serve as a prototype for other drinking water supply lakes and reservoirs in GLEON, and we will develop a suite of new sensor, data analysis, computing, and modeling tools that will be widely shared with the network, including: new overlay network methods for connecting distributed sensors and cloud infrastructures through virtual private networking; generation of new computational methods for automated model-data fusion; greater understanding of how global change and management interact to control water quality; and improved knowledge of the factors affecting public's acceptance of S&C technology.

16. Tomotaka CHO[1]

Climate Change Affecting the Belgrade Lakes in Maine

[1]Colby College

Lakes are a $5 billion industry in Maine, including outdoor recreation, hunting, drinking water, and camping. Every summer, millions of Americans will pack their bags and drive north for the summer to enjoy the Maine outdoors. Unfortunately, the people are loving the lakes to death. By spending time at the camps and using the lakes, the collective impacts of human activity for leisure on these lakes regularly create an aquatic chemical imbalance on the Belgrade lakes. This work presents a five-year buoy data history on Great Pond, Belgrade Lakes Maine. Great Pond plays a sentinel role in defining community attitudes toward water quality in the Central Maine. In 2013 we deployed a NexSens MB300 buoy system with sensors for oxygen, temperature, light, fluorescence, and carbon dioxide. This work details general sensor performance, calibration drift, new sensor technologies, and extracted metabolism parameters from continuous open water measurements. In particular we compare regional weather patterns with observed in lake processes.

17. Julia F. DALY[1] and Wyatt McCurdy[1]

Duration of spring mixing and potential impacts on summer stratification

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With relatively shallow depths and small volumes, it might be fair to assume that most small lakes mix easily and completely in the spring following ice-out. Data collected since 2010 in over a dozen small Maine lakes show both spatially and temporally diverse behaviors. Evaluating hourly temperature data at both the surface and bottom of the lakes year-round allows us to determine the timing and extent of mixing during the spring transition from winter to summer stratification. Following ice-out, some lake surfaces warm very quickly; our data show that some years, this warming happens so quickly that spring mixing is minimized or delayed. For some of our study sites, this has resulted in spring seasons with little to no complete mixing, despite the relatively small volume of our study lakes. Spring mixing usually results in an abrupt increase in temperature in the hypolimnion if the epilimnion has warmed following ice-out. A longer delay prior to mixing could be a warmer hypolimnion if mixing drives down warmer surface water. At some sites, average July hypolimnion temperatures vary more than five degrees between years within a decade. This interannual variability could be explained by the extent and timing of mixing during the spring transition, and may have implications for the strength and persistence of summer stratification.

18. *Blaize A. DENFELD[1], Anna Lupon[2], Hjalmar Laudon[2], Ryan Sponseller[1], Jan Karlsson[3]*

Does sampling bias affect greenhouse gas emission estimates from lakes?

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Inland waters play an important role in the global carbon cycle, emitting a substantial amount of carbon dioxide (CO_2) and methane (CH_4) into the atmosphere. However, current CO_2 and CH_4 emission estimates from inland waters lack in spatial and temporal resolution— with a sampling bias toward the open water season and mid-day samples collected from the deepest points of lakes. To investigate the potential effect of this sampling bias on greenhouse gas (GHG) emission estimates, we measured spatially resolved surface water CO_2 and CH_4 concentrations and fluxes over a year in a small (3.25 ha) boreal lake in northern Sweden (64˚ 15’ N, 19˚ 45’ E). In addition, we carried out 24-hour GHG flux sampling campaigns during spring, summer and autumn. CO_2 and CH_4 concentrations were spatially and temporally variable with highest concentrations (500 and 9 µM, respectively) observed near the shore and below ice. CO_2 emissions were highest at ice-melt during the morning from 7 to 11 am (100 mmol m^{-2} d^{-1}). Overall these results suggest it is important to consider spatial and temporal dynamics in GHG emission estimates from lakes, particularly during the ice-melt period.

19. *Margaret A. DIX[1], Ovidio García[1], Michael Dix[1], Estuardo Bocel[1], Gerson Ochaeta[2], Virginia Mosquera[3], Sudeep Chandra[4], Eliska Rejmánková[5]*

Lake Atitlan, Guatemala, 2010 -2016: water quality changes, role of physical limnology and climatic factors.

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Lake Atitlan, Guatemala,(mean depth 209 m; area 126 km^2; elevation 1562 m asl) located in an endorrheic, caldera, was sampled monthly from 2010 to 2016. The lake provides drinking water for at least 90,000 people and tourism is the major income source for the population. Accelerated population growth in recent decades has increased direct nutrient input from untreated wastewater and agricultural run-off that has led to deterioration in water quality, documented by declines in Secchi transparency and increased periods of hypolimnetic hypoxia. Since 2009, cyanobacterial blooms, have appeared that are mostly dominated by *Limnoraphis robusta*, but for the past five years have been accompanied by bloom levels of *Microcystis*, *Aphanizomenon* and/or *Dolichospermum*, so far without appreciable toxin production. Because nutrient cycling and algal populations depend on lake thermal dynamics, we evaluated effects of wind velocity and direction, precipitation and air temperatures during the same period on lake stratification patterns. We found positive correlations for Schmidt stability and Birgean work with near surface lake water temperatures ($p<0.001$) and a negative correlation with wind velocity ($p<0.001$). We confirmed that Lake Atitlan is a warm, monomictic lake that stratifies during the Guatemalan rainy season from May to September, but does not mix completely every year. Average thermocline depths during the study period were 29.6 ± 18.4 m and average oxycline depths were 25.2 ± 10.6 m. Possible trends in physical variables and potential future scenarios for Lake Atitlán management and livelihood impacts are discussed.

20. *Jonathan P. DOUBEK[1], Kylie L. Campbell[1], Kaitlyn M. Doubek[1], Mary E. Lofton[1], Ryan P. McClure[1], Nicole K. Ward[1], and Cayelan C. Carey[1]*

Oxygen-induced trade-offs on zooplankton diel vertical migration: caught between fish and an anoxic place

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As a result of global change, lakes and reservoirs worldwide are increasingly experiencing hypolimnetic anoxia. Although the effects of anoxia on internal nutrient loading have been well-studied, less is known about how anoxia impacts plankton communities. Typically, zooplankton migrate to the dark hypolimnion during the day to escape visual fish predation in the well-lit epilimnion. However, due to the physiologically-stressful conditions of anoxic hypolimnia, zooplankton may remain in the epilimnion during daylight, trading oxic stress for increased predation risk. We sampled three GLEON reservoirs biweekly during the daytime in Virginia, USA in 2016 to examine how hypolimnetic oxygen concentrations impact the vertical distribution, density, biomass, and community composition of macrozooplankton and rotifers. These reservoirs varied on a gradient of hypolimnetic oxygen concentrations, from no oxygen to high oxygen during the summer stratified period. In addition, we also conducted seven 24-h sampling campaigns on the same reservoirs to examine how zooplankton were vertically distributed over day-night periods. Under anoxic conditions, zooplankton were predominately found in the epilimnion during the day and night, did not exhibit diel vertical migration, and had overall lower seasonal biomass than in reservoirs with oxic hypolimnia. Only two out of sixteen zooplankton taxa were found predominately in anoxic layers. Moreover, our data suggest that zooplankton may change their migration patterns under oxic vs. anoxic hypolimnetic conditions: zooplankton exhibit greater vertical migration in reservoirs with oxic hypolimnia, but greater horizontal migration in reservoirs with anoxic conditions. Consequently, our results suggest that hypolimnetic anoxia may alter zooplankton vertical distribution, biomass, and behavior, which may in turn exacerbate water quality degradation because of the critical role zooplankton play in freshwater food webs.

21. Julita A. DUNALSKA[1], Justyna Sieńska[1], Daniel Szymański[1]

High frequency data as a tool for water management of lake restored by hypolimnetic withdrawal

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The selective withdrawal of hypolimnetic water, the first lake restoration method in the world, was implemented in 1956 in Lake Kortowskie (Masurian Lake District – Poland). Surface outflow was dammed, and a pipe was built at the bottom of the lake. Its inlet was located in the deepest part of the lake, and its outlet – at the outflow from the water body. In 2013, Lake Kortowskie lake was equipped with buoy (YSI 6600V2-4 multisensor with 4 wiped optical probes for dissolved oxygen (DO), chlorophyll (Chl) fluorescence, turbidity, phycocyanin, sensors for water temperature and conductivity and Lufft WS-501 weather station, which measures wind speed and direction, precipitation, humidity, radiation, air pressure and air temperature). Monitoring of water parameters and meteorological data allows to control the way of outflow water from the lake (surface, by pipe or both). High chlorophyll fluorescence and high wind speed in Southwestern direction indicate the need to limit the rate flow in the pipe in favour of surface outflow. Thereby, we can remove blue-green algal scums blown into this part of the lake straight to the outflow. This is important because of a very close location of the bathing beach.

22. Lawrence W. EICHLER[1], Charles W. Boylen[1], William Hintz[1], Matthew Shuler[1], Aaron Stoler[1], Vincent Moriarty[2], Rick Relyea[1] and Sandra A. Nierzwicki-Bauer[1]

Long-term Monitoring and Assessment of Lake George, NY

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Lake George is a large (28,000 acre), clearwater, circum-neutral lake in the southeast corner of the Adirondack Park of New York State. Since 1980, the Darrin Fresh Water Institute has conducted a water quality monitoring program on Lake George. The goals of this program are to record lake ambient water chemistry, characterize any water quality degradation, and assist in finding solutions to water quality problems. Spatial and temporal changes in water chemistry in this oligotrophic lake have been impacted by development, road salt, and the 1990 Clean Air Act Amendments (CAAA). Eutrophication effects in Lake George have been demonstrated by increases in chlorophyll a concentrations, while transparency has shown little change. Chloride and sodium concentrations have increased significantly throughout the lake and are attributed to the extensive use of road salt deicing agents. Declining sulfate concentrations and increasing pH have been observed and attributed to the CAAA. Surface water temperatures have increased by approximately 1.8ºC over the past 37 years increasing the growing season by more than 2 weeks. These findings provided an impetus for The Jefferson Project; a collaboration between Rensselaer, IBM and the FUND for Lake George. Our goal is to establish a strategic partnership that becomes the global model for sustained ecosystem protection. Using an array of new tools including a Smart Sensor Network, we are monitoring, modeling, and experimenting to inform decision-makers regarding the impacts of human activities on overall water quality, including the effects of excess nutrients, invasive species, pollutants, and changing weather patterns, leading to the lasting protection of Lake George. Our hope is to serve as a global blueprint for freshwater research and protection.

23. *Elisabet EJARQUE[1,2], Samiullah Khan[1], Lisa-Maria Hollaus[1], Gertraud Steniczka[1], Jakob Schelker[1,2], Martin Kainz[1], Tom Battin[3]*

Carbon dynamics in a subalpine lake are sensitive to warming climatic conditions

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Mountain lakes are highly sensitive to warming, and therefore, are considered to act as sentinels for climate change. In this study, we aimed to thoroughly characterise carbon dynamics in an oligotrophic, subalpine lake (Lake Lunz, Austria). First, we explored the role of the lake as dissolved organic matter (DOM) transformer, and the sensitivity of this role to changing hydrological conditions. This was achieved by comparing DOM optical properties at the inlet and outlet of the lake during two contrasting years: overall exceptionally dry (2015) versus typical wetter conditions (2016). Second, we performed a time-resolved carbon mass balance during 2016 to assess the carbon dynamics in quantitative terms. For that, we monitored lateral (DOC, POC, DIC transport via inlet and outlet) and vertical (CO_2 exchange and POC sedimentation) carbon fluxes. Preliminary results suggest that warmer and drier weather conditions, as expected by global change predictions, may favour in-lake DOM reactivity over transport, thereby transforming the terrestrial character of DOM inputs into autochthonous, low-molecular weight compounds. Due to the fundamental ecological role of DOM in freshwaters, this compositional shift may have unprecedented implications for downstream ecosystems.

24. Fabian ENGEL[1], Stina Drakare[2], and Gesa A. Weyhenmeyer[1]*

Predictable shift from allochthonous organic carbon to phytoplankton driven CO_2 dynamics in boreal lakes

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In recent years, CO_2 emissions from lakes have been recognized to be a substantial CO_2 flux to the atmosphere, and an essential part of the global carbon cycle. Lake CO_2 dynamics are controlled by hydrologic inorganic carbon inflow to lakes, in-lake mineralization of allochthonous organic carbon (OC), and CO_2 uptake by primary producers. At present, it is not known in which and in how many lakes phytoplankton CO_2 uptake has a dominant influence on lake CO_2 dynamics. To answer these questions we evaluated the fraction of total organic carbon (TOC) derived from phytoplankton, i.e. the ratio C_{phyto}:TOC, and its effect on in-lake CO_2 dynamics. Using water chemistry and phytoplankton data from 128 Swedish lake sites from 1992 to 2012, we found that in lakes with a long-term median August C_{phyto}:TOC > 5 % the long-term median August lake water partial pressure of CO_2 was negatively correlated with C_{phyto}:TOC. C_{phyto}:TOC > 5 % occurred in lakes with August total phosphorous concentrations > 30 µg l^{-1}, August water temperatures > 18 °C, and water residence times > 200 days. These conditions existed almost exclusively in geographical regions with a growing season length > 220 days, corresponding to the part of Sweden located south of ~ 60° N. The all site median C_{phyto}:TOC in the studied lakes decreased significantly between 1995 and 2012. We conclude that CO_2 uptake by phytoplankton can dominate lake CO_2 dynamics not only in eutrophic but also in several (hemi-) boreal lakes.

25. Kaitlin J. FARRELL[1], and Cayelan C. Carey[1]

Macrosystems EDDIE: Introducing Undergraduate Students to Macrosystems Ecology and Simulation Modeling through Hands-On Teaching Modules

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Ecological research in the era of rapid global change increasingly requires understanding drivers and ecological responses that operate at multiple, interconnected spatial and temporal scales. To understand complex ecological feedbacks, a macrosystems approach to ecology has emerged that uses high-frequency data streams and simulation modeling to predict ecosystem responses to changes in drivers at local to continental scales. Despite the increasing use of these approaches, however, undergraduate curricula rarely include concepts in macrosystems ecology or simulation modeling and other advanced computational skills. Through Macrosystems EDDIE (Environmental Data-Driven Inquiry & Exploration), we are developing a suite of hands-on, data-driven modules that instructors can use to introduce fundamental macrosystems topics to undergraduate students at a range of experience levels. Modules combine high-frequency data from GLEON lakes and NEON (National Ecological Observatory Network) with the General Lake Model (GLM-AED) to guide students through inquiry-based lessons on macrosystems topics through the lens of limnology. Current modules include an introduction to simulation modeling where students simulate changes in lake temperatures under climate change scenarios, and an exploration of cross-scale emergence where students examine local (land use) and regional (climate) drivers of phytoplankton blooms. Modules that address other core macrosystems topics of macro-scale feedbacks, cross-scale interaction, and teleconnection are under development. Together, these Macrosystems EDDIE modules (see: https://serc.carleton.edu/enviro_data/macrosystems/index.html) will provide instructors with a set of ready-to-use teaching tools to train and empower the next generation of macrosystems ecologists.

26. *Rocio Luz FERNANDEZ*[1]

Optimizing impoundment artificial aeration based on reservoir bathymetry

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Vertical mixing of water is supressed by thermal stratification during summer in most temperate reservoirs. Air injection diffuser systems are then a common technique for enhancing water column circulation and mixing to improve DO by eliminating the vertical density gradients that lead to low dissolved oxygen (DO) concentrations in the bottom waters. The influence of morphometric parameters on the air distribution efficiency is analysed here by means of numerical modelling in a medium-sized reservoir of Argentina. Results allow to identify a series of related items that can be helpful during the design of these aeration systems. For example, the localization of diffusers should be based on the goal to reach: thermal destratification or evaporation reduction. Moreover, air diffusers evenly distributed within the reservoir may be more effective in avoiding diurnal stratification, as well as the destratification of the water column may be reached quickly with this configuration.

27. *Giovanna FLAIM[1], Ami Nishiri[2], Federica Camin[1], Leonardo Cerasino[1], Ulrike Obertegger[1]*

Lake Tovel: some long-term trends

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Climate change is already having significant effects on aquatic ecosystems with recent scenarios indicating greater change in the Alps. Climate models are predicting significant changes in precipitation patterns, with mid-altitude lakes particularly vulnerable. These lakes provide valuable ecosystem services such as irrigation, power, recreation and fishing. LTER site Lake Tovel, Italy (46.26137 N, 10.94934 E, 1178 m asl) is a small, Alpine lake located in the Adamello Brenta Natural Park. In addition to standard limnological parameters since 1995, stable isotopes of oxygen ($\delta^{18}O$) have been sampled monthly along a depth gradient since 2009. $\delta^{18}O$ can be used to successfully investigate many aspects of lake hydrology; for example Lake Tovel $\delta^{18}O$ values between -13 and -12 ‰ indicate that the aquifer feeding the lake originates at ca. 1000 m above the lake. Long term data show a reduction of N, in line with general trends in the Alps, an increase in surface water temperature coherent with other lakes in the region, but no significant change in total phosphorus. Isotope values reflect winter precipitation. Recharge of the aquifer with rain instead of snow may result in a less steady inflow with repercussions on the lake ecosystem and services provided. Isotopes can contribute to a better understanding of a changing hydroclimate.

28. Michael FORCELLA[1]

Creating a mesh sensor network using Raspberry Pi and XBee radio modules

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A mesh network is a type of network topology in which one or more nodes are capable of relaying data within the network. The data is relayed by the router nodes, which send the messages via one or more 'hops' until it reaches its intended destination. Mesh networks can be applied in situations where the structure or shape of the network does not permit every node to be within range of its final destination. One such application is that of environmental sensing. When creating a large network of sensors, however, we are often limited by the cost of such sensors. This thesis presents a low-cost mesh network framework, to which any number of different sensors can be attached. The hardware configuration is detailed in such a way that anyone with a modest understanding of technology will be able to reproduce it. The software setup required by the user has also been minimized and clearly documented. Details specific to the user's setup can be entered into a configuration file and the majority of software scripts are scheduled to run automatically via Linux Cron jobs. I conclude by outlining several potential modifications to the framework, including further automation of the software setup, inclusion of additional hardware

29. *Rachel A. FOWLER[1], Jasmine E. Saros[1], William G. Gawley[2], Shannon P. Wiggin[2]*

Using high-frequency buoy data to interpret drivers of changing water clarity in Jordan Pond, Acadia National Park

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To better understand drivers of changing water clarity in Jordan Pond, University of Maine scientists and ANP staff installed a Nexsens CB-400 data buoy in 2013, and the buoy has been deployed in Jordan Pond each ice-free season since. A weather station was mounted on the Jordan Pond House for pairing meteorological data with sensor data from the buoy. EXO2 sensor data from the 2017 season indicate that fluorescent dissolved organic matter (FDOM, a proxy for DOC) was highest in late spring and declined throughout the summer. FDOM temporarily increased following precipitation events, particularly in late spring and early summer. Magnitude and frequency of precipitation events declined in July and August and subsequent increases in FDOM were small. A large rain event (1.7 inches in 24 hours) in early September was followed by a minor increase in FDOM. These data may indicate that precipitation events in late spring and early summer cause an influx of DOC into Jordan Pond, but that limited DOC is available for transport into the lake at the end of a dry summer, perhaps due to reduced production during drought conditions. These high-resolution buoy and weather station data help explain how precipitation events and seasonal variation contribute to DOC trends observed in Jordan Pond and will be useful for predicting how water clarity may change in the future.

30. Jacob GASKILL[1], John R. Jones[1], Daniel V. Obrecht[1], Anthony Thorpe[1], Rebecca L. North[1]

Do invasive dreissenid mussels impact water quality in warm, turbid, Missouri reservoirs with anoxic hypolimnions?

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Invasive zebra mussels (*Dreissena polymorpha*) have been shown to decrease phytoplankton biomass, shift nutrients from open water areas to the benthos of the littoral zone, and alter nutrient cycling in lakes where they become established. Since their introduction to North America in 1986, these invaders have spread as far west as California and as far south as Texas. They are present in at least seven reservoirs in Missouri, a state where long-term water quality data presents an opportunity to examine the before and after effects of dreissenids. Missouri reservoirs are often turbid, resulting in light deficiency of phytoplankton communities. Since dreissenids are prolific filter feeders that increase water clarity, we hypothesize that their presence may alleviate light limitation, potentially resulting in increases in phytoplankton. Utilizing long-term (1978-2016) chlorophyll-a concentrations and indicators of transparency collected by citizen scientists, we examine the influence of dreissenids on Missouri reservoirs. These reservoirs differ from most dreissenid-impacted natural lakes due to their high turbidity, warm water temperatures, and anoxic hypolimnions. Understanding how dreissenids will influence a variety of systems will be vital to maximizing the utility of our aquatic resources as this invader continues to spread across North America.

31. *Amanda L. GAVIN[1], Sarah J. Nelson[1,2], Amanda J. Klemmer[1,3], Ivan J. Ferndandez[2,4], Kristin E. Strock[5], and William H. McDowell[6]*

Acidification and climate drive increased dissolved organic carbon in high elevation lakes

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[6]University of New Hampshire Department of Natural Resources and the Environment

Increasing concentrations of dissolved organic carbon (DOC) in the northeastern US have been attributed to two potential mechanisms: recovery from acidification and changing climate. Maine's high elevation lakes (>600m) provide unique insight into the response of surface water chemistry to declining acidic deposition and interannual climate variability. Long-term geochemical response in 29 lakes was analyzed during 30 years of change in sulfate (SO_4^{2-}) deposition and climate. All 29 lakes exhibited positive trends in DOC from 1986-2015, and 65% of lakes had statistically significant increases in DOC throughout the study period. These results illustrate a region-wide change from low DOC lakes (<5 mg/L) to moderate DOC lakes (5-30 mg/L). Increasing DOC trends were more consistent across high elevation lakes than in previous studies from lower elevation lakes in the northeastern US. Net increases in DOC concentrations were correlated with net decreases in SO_4^{2-}, and a direct comparison of high elevation and low elevation lakes in Maine revealed greater extent of acidification and larger increases in DOC concentrations in high elevation lakes. A linear mixed effects models demonstrated that SO_4^{2-} , the strongest predictor, and climate variables describe most of variability in DOC concentrations (r^2 = 0.78). Coefficient of variation of DOC in all lakes was negatively correlated with air temperature, suggesting a homogenous DOC response to increasing temperature. Due to SO_4^{2-} concentrations trending towards pre-acidification levels and projections of a warmer, wetter, and more variable climate, there is uncertainty for the future trajectory of DOC trends in surface waters.

32. Lakshika GIRIHAGAMA[1]

Nutrient Gradients Can Be Explained By Mixing Rates And River Fluxes In The Eastern Georgian Bay, Lake Huron.

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Flushing mechanisms - driven by the natural circulation - play a dominant role in understanding the impact of land-based phosphorus on the nearshore water quality of South-eastern Georgian Bay, Ontario. Georgian Bay is located east of the main body of Lake Huron and has a surface area of 15,000 km², and contains approximately 30,000 islands. Generally, the water quality is very good, but there are concerns about the impact of ongoing development upon the many inlets and bays along the eastern shore. Detailed observations of nearshore water quality (e.g. conductivity, phosphorous, chlorophyll) from Shwanaga and Moon River Island regions show pronounced gradients, presumably driven by water circulation patterns. This region experiences seasonal thermal stratification and a significant barotropic variability in currents that is tied to variability in surface water levels. Here is a strong signal of tides at diurnal and semidurnal periods, but water movements appear to be driven by the diurnal tides at these locations. This suggests a well-mixed estuarine circulation that controls the water quality gradients. FVCOM (Finite Volume Community Ocean Model) will be run to simulate dispersion of river water in a "freshtuary" where circulation is driven by diurnal winds.

33. H.P. GROSSART[1], MIBI team[1]

Bacterial interactions with dead and live surfaces in aquatic ecosystems

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Aquatic bacteria have multiple lifestyles and ranging from purely free-living to surface and organism associated bacteria, including in the extreme case endosymbionts which share a part of their genetic material with the host. Generally, aquatic bacteria are attracted by all kind of surfaces including dead surfaces (detritus) as well as living organism. Chemotaxis, attachment and biofilm formation are important bacterial adaptations supporting a surface-associated lifestyle - also reflected in their genome. Accordingly, many studies have shown that interactions between bacteria and surfaces, in particular with living organisms such as phytoplankton and zooplankton, have severe consequences for physiology and evolution of both bacteria and their host, but also for carbon and nutrient cycling at the microscale with global scale implications. In particular, bacteria-phytoplankton interactions provide ideal model systems to study the interdependencies between both partners and their ecological implications. It is obvious that the algal microbiome has the potential to affect growth and health of their phytoplankton partner in a highly spatio-temporal manner. Recent development of molecular methods has opened up exciting insights into the underlying mechanisms including gene regulation and exchange. In my talk, I will highlight a number of examples we have studied on how microbial life on surfaces affects organic matter cycling and address specific interactions between bacteria with phyto- and zooplankton. In particular, I will highlight their ecological consequences for gene exchange, organic matter and nutrient cycling by taking their environmental context into account.

34. Tobias HAHN[1], Luke Winslow[2], Taylor Leach[2], Sarah Princiotta[3], Kevin Rose[2]

***Hydrolinks*: a new R package to link aquatic data to the hydrologic network**

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There are over 304 million lakes and 90 million kilometers of streams and rivers globally. Many of these ecosystems are connected via complex networks among the lakes, rivers, and streams. However, observations of aquatic data are frequently fragmented and difficult to compare and integrate within their hydrologic networks. In order to assess network scale characteristics, it is vital to link individual sites to their respective hydrologic networks. However, existing tools for this purpose are proprietary or difficult to use. To address this gap, we have created an open-source R package to facilitate linking of aquatic data to waterbodies and streams in available hydrologic datasets. The package automates downloading and linking against the U.S. Geological Survey's National Hydrography Dataset and the the global HydroLAKES dataset. Linking data to waterbodies on a GIS layer enables the traversal of hydrological networks between streams and lakes in the continental US using a network built from NHD data. We present an example of the power of hydrologic network linking by analyzing 149,905 lake observations and 547,930 stream sites from the USGS water quality data portal. We find that at least 30 percent of lake and stream data in the federal databases represented do not correspond with mapped lakes or streams. Further, we present results of a large-scale analysis of traditional geographic versus hydrologic network correlation enabled by our new R package, *hydrolinks*.

35. *Gretchen J.A. HANSEN[1], Jordan S. Read[2], Luke A. Winslow[3], Melissa Treml[1], Patrick J. Schmalz[1], Stephen R. Carpenter[4]*

Water clarity and temperature as drivers of fish habitat: a case study of walleye population collapse

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[4]Center for Limnology, University of Wisconsin-Madison, Madison, Wisconsin, USA

Water clarity and temperature are key lake attributes that influence numerous ecological processes. Walleye (*Sander vitreus*) are an economically important top predator fish with distinct temperature and light preferences. Walleye production in inland lakes is related to the area in which the optimal thermal and optical conditions for walleye exist concurrently, known as the thermal-optical habitat area (TOHA). Lake-specific estimates of TOHA require information on lake morphology, temperature, and clarity. We evaluated the role of changing clarity and temperature in explaining the decline of a high-profile walleye fishery in Lake Mille Lacs, Minnesota. TOHA was estimated using a thermodynamic simulation model of daily water temperatures and hourly light conditions from 1980-2016. We used the safe operating space concept to analyze how sustainable harvest and optimal population size of walleye depend on TOHA. Optical habitat area in Mille Lacs is directly related to Secchi depth, with maximum optical habitat available at Secchi depths between 2 and 3.5 m. Median Secchi depths consistently fell within this optimal range prior to 1996, but exceeded this range in over 50% of years from 1996 to 2016, resulting in reduced habitat for walleye. Maximum safe harvest levels of walleye declined with declining TOHA, suggesting that walleye harvest must be reduced to accommodate increasing water clarity and to a lesser extent, water temperature. Historic and projected future changes in water clarity and temperature are likely to impact sport fish populations, and future work is underway to expand these analysis to other inland lakes.

36. Josef HEJZLAR[1], Jiří Kopáček[1], and Yuliya Vystavna[1]

Long-term trends of phosphorus concentration in a reservoir chain situated in Central Europe: the result of socio-economic changes in the catchment, phosphorus retention and climate change

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Controlling phosphorus concentration is critical to mitigating eutrophication in most lakes and reservoirs. Based on existing phosphorus data series in the Orlík and Slapy reservoirs (the upper and middle reservoirs, respectively, of the Vltava River Cascade, Czechia) and their main tributaries, we reconstructed P inputs to the reservoirs from the catchment during 1961–2016 and compiled empirical models of P retention in the reservoirs. P concentrations in both reservoirs increased from the 1960s to 1991 and then declined, with the Slapy Reservoir having a significantly increased year-on-year variability. The rate coefficients of P-retention were site- and time-specific and were related to the P loading. Hence trends in the increase and decrease of P concentrations reflected the socio-economic development in the Vltava river basin, in particular wastewater discharges, fertilizer application, livestock, and fishpond fisheries, and varied P retention. In the Slapy reservoir after 1991, the P concentrations increased during wet summers and supported growth of phytoplankton, whereas in dry summers they decreased to mesotrophy. Climatic and hydrological processes have in the recent decades apparently begun to compete with a generally decreasing P pollution and to support eutrophication despite the drop in P loads from the catchment.

37. *William D. HINTZ[1], Matthew S. Schuler[1], Aaron B. Stoler[1], Devin K. Jones[1], Kayla D. Coldsnow[1], Lovisa Lind[1], and Rick A. Relyea[1]*

The impacts of road salt salinization on freshwater lake food webs

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The salinization of freshwater lakes is occurring in colder regions because of the application of road deicing salts. Chloride-based salts such as sodium chloride (NaCl), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$) are used worldwide, with NaCl being the most common. After decades of use, many lakes in developed catchments exceed the chronic and acute chloride thresholds established by countries like the United States and Canada for the protection of freshwater biota. However, the impacts of road salts on lake food webs are poorly understood. We conducted a series of large-scale mesocosm experiments to identify the impacts of road salt on experimental lake food webs. We found that fish predation combined with the presence of high road salt concentrations can trigger a trophic cascade leading to elevated phytoplankton blooms. Among the experiments, cladoceran and copepod grazers, amphipods, and filamentous algae were the most susceptible to high road salt concentrations ($\geq$250 mg Cl^-/L). However, zooplankton grazers like *Daphnia* can also evolve a tolerance to NaCl road salt, which may mitigate a salt-induced trophic cascade. Alternatives to Cl^--based road salt also have negative effects. We found microbial activity likely transformed unusable phosphorus from the organic additives into usable phosphorus, which increased the abundance of phytoplankton. Our results suggest dramatic changes to lake food webs may result from road salt salinization. In-situ experiments, whole-lake manipulations, and long-term monitoring of ecological responses to salinization are needed to fully understand the impacts of road salts in aquatic ecosystems.

38. Meredith A. HOLGERSON[1] and Peter A. Raymond[2]

Limnology Underdogs: Why Small Ponds Matter to Global Freshwater Science

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Small ponds are globally abundant, with over 90% of all ponds and lakes being less than one hectare in size. However, small ponds are understudied in limnology. We know little about their carbon, oxygen, and nutrient dynamics relative to larger lakes. Our research aims to fill this void and understand how small ponds function in comparison to larger systems. We've found that small ponds are biogeochemical hotspots and operate differently than larger lakes in several key aspects. First, we found that small ponds play a disproportionately large role in greenhouse gas emissions. While small ponds only account for about 9% of lakes and ponds by area, they contribute ~15% of CO_2 and ~41% of diffusive CH_4 emissions from inland freshwaters. Secondly, we found that gas exchange velocities (*k*) are low but highly variable in small ponds. We also found that *k* increases and becomes even more variable with lake size, a finding that is not currently included in global carbon models. Lastly, we found that gas exchange in small ponds is highly sensitive to overnight cooling, which can lead to short bursts of increased *k* at night, with implications for greenhouse gas emissions. Overall, small ponds are a critical part of freshwater science and global biogeochemical cycling, and understanding small pond ecosystems is an important research priority for the field.

39. *Anthony J. HOLLANDER[1], Dejea M. Green[1], Emma C. Bruno[1], Hailee L. Edwards[1], Sawyer R. McFadden[2], Kayla A. Reid[3], Heather L. Wander[1], David C. Richardson[1]*

Intermediate trophic level loss affects ecosystem structure and function in Lake Minnewaska, NY

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Trophic level loss, especially intermediate ones, from lake food webs, could have radiating effects on the surrounding food web and ecosystem structure and function. We tested this idea using Lake Minnewaska, a historically fishless and oligotrophic lake in New York State, USA. Minnewaska has experienced the introduction of Golden Shiners (GS), a small minnow, in 2008, followed by Largemouth Bass (LMB) in 2011. The introduction of fish caused a trophic cascade, resulting in algal blooms and a decrease in water clarity. GS were extirpated between fall 2013 and spring 2014. Following the loss of this intermediate trophic level, we predicted major changes to the lake ecosystem with some return to pre-fish oligotrophic conditions. From 2014-2016, zooplankton communities, Secchi depth, and dissolved oxygen profiles were collected through each ice-free season. Algal biomass decreased resulting in mean summer Secchi depth almost doubling. Conversely, hypolimnetic anoxia has significantly increased throughout the lake. The result of this is likely due to the accumulating organic matter in the lake sediments during 2010-2012. Average zooplankton density has decreased from 23.4 to 4.7 individuals/L but the average individual size of some taxa (e.g., Daphnia) has increased, suggesting that larger zooplankton are more abundant once free from direct predation. These results help elucidate the importance and effects of the recent changes to the ecosystem. We can use this data to determine if recovery to conditions prior to fish introduction will take place naturally and if any management needs to take place.

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[16]Cornell Biological Field Station, Department of Natural Resources, Cornell University, Bridgeport, New York, USA
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Effects of changes in winter/spring runoff timing on summer productivity in lakes

We hypothesize that earlier late-winter/spring runoff of a similar quantity, associated with climate change, will lead to reduced productivity and phytoplankton biomass during the summer stratified period. We expect that nutrients delivered to lakes during colder, deeply mixed, and possibly ice-covered conditions, could be less effective at stimulating phytoplankton growth because of early loss through lake outflow, sedimentation, 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. To test this hypothesis, we developed an index of winter/spring runoff timing using the center of mass of stream discharge for inflows, outflows, or nearby streams for approximately 25 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. We expect our results to provide new insights into the diverse effects of climate change on lakes, with an emphasis on understanding processes that occur in late winter and early spring that set the stage for the growing season. We plan to examine several other covariates that may influence productivity as well, including ice cover, snowfall, water temperature, light climate, DOC, and nutrients. This GLEON project is currently in the green phase, and additional collaborators are welcome.

41. Peter D. F. ISLES[1], Ann-Kristin Bergström[1], Don Pierson[2]

Measuring and modeling the effect of ice cover on the retention of snowmelt nutrients in Swedish lakes along a climate gradient

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Winter conditions are changing rapidly at high latitudes as a function of anthropogenic climate change. This will result in more frequent periods with mean daily temperatures above 0˚C and more frequent rain-on-snow events, resulting in more water and nutrient inputs during winter periods. When surface water snowmelt inputs are close to 0˚C, they are likely to intrude in the cold, narrow surface layer immediately below the ice, a substantial fraction of nutrients input to this layer may be exported from lake outflows before mixing into the deeper water column, potentially resulting in a low "effective residence time." In this study, we will explore the effects of variable winter runoff conditions on the retention of snowmelt water and associated nutrients in lakes along a climate gradient from northern to southern Sweden. We will measure the retention of nutrients delivered to 2 ice-covered lakes using biogeochemical and water-isotope data, and will model the retention of snowmelt water in a variety of idealized lake sizes along a climate gradient from sub-arctic to temperate using historical weather and discharge data from warm and cold winters.

42. Stephen F. JANE[1], Kevin C. Rose[1]

Climate warming and increasing DOC: potential interactive effects on ecosystem respiration

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Ecosystem respiration (ER) is an important driver of lake dissolved oxygen levels and influences the role of lakes in carbon cycling. Dissolved organic matter (DOM) within lakes influences ER rates because it is a primary source of reduced carbon for microbes. Though ER generally increases with DOM concentration, it is also temperature dependent, increasing as temperatures increase. Kinetic theory suggests that DOM pools dominated by more complex compounds should require more energy for organisms to break down and utilize. Such DOM pools should therefore have a greater temperature dependence than more labile DOM pools. Though many studies have examined the effect of DOM quality on the temperature dependence of respiration in soils, there have been relatively few studies in aquatic systems. We used a labile DOM source from the deep chlorophyll maximum of Lake George, NY, and a refractory DOM source from a humic bog to test the effect of DOM source on the temperature dependence of ER. 17 L mesocosms (twelve total) were monitored at ten minute intervals using high frequency DO and temperature sensors. After 32 days, we calculated daily ER rates and analyzed the response of ER to temperature and DOM source. A significant interaction between DOM source and temperature suggests the temperature dependence of ER was greater for the humic DOM source, supporting the predictions of kinetic theory. Our results suggest that respiration rates in lakes dominated by refractory, terrestrial organic matter will increase more with future warming than in lakes with more labile DOM.

43. *Eleanor Jennings1, Valerie McCarthy1, Fiona Regan2, Jens Carlsson3, Paulo Prodöhl4, Martin Llewellyn5, Philip McGinnity6, Elvira de Eyto7, Russell Poole7, Mary Dilliane7 and Mikkel R. ANDERSEN1*

BEYOND 2020 (Burrishoole Ecosystem Observatory Network 2020)

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A new multi-institute research cluster focused on the Burrishoole catchment, will conduct innovative science by developing technology, sharing and interpreting historical and new high frequency environmental and biological data, linking to next generation ’omic science, to understand, predict and communicate the role and response of aquatic ecosystems in a changing global environment. Specifically, it will maximize and enhance current capabilities at the Marine Institute facility Burrishoole through:

- undertaking new data analysis on lake physics and aquatic metabolism.
- modelling key environmental variables in the recent past and near future.
- developing Burrishoole as a testbed for new chemical and biological sensors.
- undertaking new aerial observations using drone and satellite technology to inform on marine-freshwater links.
- harnessing genotyping science to understand, predict and communicate the role and response of aquatic ecosystems in a changing global environment.

The interdisciplinary cluster will build human and intellectual capital to ensure development of future expertise and enable the establishment of an infrastructure to provide a testbed for new theory, novel instrumentation, emerging models, thus acting as a sentinel index site in Europe and globally. This goal will be enabled by establishing in BEYOND 2020 a unique team of scientists and engineers from DkIT, DCU, UCC, UCD, NUIM, QUB Mary I (UL) and UoG. The team comprises chemists, engineers, bio-geochemists, limnologists, bio-engineers, molecular biologists, quantitative biologists, evolutionary ecologists, microbiologists, climate modelers, ICT practitioners with expertise in high powered computing (HPC) and bio-informatics within an integrated ecosystem observation science program, focusing on ecosystem responses to environmental variability.

44. Philipp S. KELLER[1], The dryflux Team

Dryflux – greenhouse gas emissions from dry freshwater systems

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Globally, numerous lakes, reservoirs, and streams are subject to temporary drying. The emission of CO_2 from these dry freshwater systems represent a so far overlooked process in the global carbon cycle. Recent research indicates that drying and rewetting of freshwater sediments creates hot spots of carbon mineralization and thus CO_2 emissions. However, existing knowledge is scarce and mainly based on regional studies from e.g. USA or Spain, investigating specific systems (either lotic or lentic). Habitats with exposed sediments include ponds and ephemeral rivers as well as shallow sediments of lakes and the drawdown area of reservoirs with large water level fluctuations. Dryflux is an initiative of researchers with the aim of collecting CO_2 emission data from several sites around the globe. The 44 contributing partners perform measurements using a closed chamber approach. The coordinated measurements at several sites shall answer the following questions: (1) What is the magnitude of CO_2 emissions from dry aquatic systems? (2) Are CO_2 emissions from dry aquatic systems relevant on a global scale? (3) What are the basic drivers of emissions: Temperature? Sediment moisture? Organic matter content? Currently we have 225 sites in 18 countries on 6 continents included. Systems comprise reservoirs, streams, kettle holes, lakes, ponds, meadows, and swamps. We will present first results from already performed measurements and reflect and evaluate the applied techniques. Furthermore, we will give an outlook on the prospective plans and the future scope of the dryflux project.

45. *Patrick T. KELLY[1], María J. González[1], William H. Renwick[2], and Michael J. Vanni[1]*

Biotic and abiotic factors provide resilience against reversing eutrophication in an agriculturally-impacted reservoir

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High external nutrient loads to lakes are a primary cause of eutrophication, a pervasive environmental problem that often reduces important ecosystem services. As such, management activities in the watersheds of heavily impacted systems have increased to reduce nutrient supply to lakes and coastal waters with high phytoplankton biomass. Although management efforts are often successful, eutrophication resilience may be maintained by a variety of different drivers of phytoplankton biomass. We used a 21-year dataset to examine the responses of Acton Lake, a eutrophic agricultural reservoir, to improvements in agricultural practices in its watershed, specifically a marked increase in conservation tillage designed to reduce sediment and nutrient loads to the lake. Despite declining nutrient concentrations in the load from the watershed, phytoplankton (chlorophyll concentration) has increased in Acton Lake over this time. Time series modeling suggests two primary drivers of increased phytoplankton: 1) increased nutrient excretion by detritivorous gizzard shad (*Dorosoma cepedianum*), and 2) declining sediment loads from the watershed that has reduced phytoplankton light limitation. Structural equation modeling also points to climate and stream discharge as being possible sources of ecosystem resilience, contributing to high loads of nutrients even if concentrations in the load have declined with better management. These results show that internal nutrient cycling and abiotic drivers can confer resilience against reversing eutrophication. More broadly, this suggests a more nuanced view of management efforts to reduce eutrophication may be necessary, taking a whole-ecosystem view of the interaction between internal nutrient sources, climate variation, and changes in light availability.

46. Seán KELLY[1,2], Elvira de Eyto[2], Mary Dillane[2], Russell Poole[2], Gemma Brett[1] and Martin White[1]

Hydrographic maintenance of deep anoxia in a tidally-influenced saline lagoon

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Low dissolved oxygen concentrations are of increasing concern in aquatic ecosystems, particularly at the interface between freshwater and marine environments. Oxygen depletion occurs naturally in many perennially stratified systems and it remains to be seen how climate change will impact upon these habitats. This is, in part, due to a lack of high-resolution, long-term data describing inter-annual variability in dissolved oxygen concentrations within stratified basins. Physicochemical parameters for Lough Furnace, an ecologically important tidal lagoon, were assessed using daily measurements (2009-14) from an undulating CTD profiler and observations of tidal exchange flow. Continuous vertical saline stratification existed, with anoxia (< 0.1 mg l^{-1}) typically persisting below 6 m. Tidal inflows were generally restricted, with deep-water renewal events by intrusions of denser spring tidal water occurring episodically (3 times in 6 years), following prolonged periods of low freshwater input. While wind forcing alone was not sufficient to generate basin-scale mixing, the conditions that led to deep-water renewals may also be conducive to wind-driven upwelling events in nearshore areas. These findings have wider application to larger scale two-layered stratified systems with deep anoxia as the ability to forecast such dynamic events is important for assessing the ecological implications of dissolved oxygen depletion.

47. Michael R. KELLY[1], Eli M. Dow[1], John Ma[1], Vincent W. Moriarty[1], Michael L. Passow[1], Michael E. Henderson[1], Harry R. Kolar[1]

Building a high-frequency, integrated, and autonomous observational sensor network for watershed-scale research and environmental model development

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Lake George is a freshwater oligotrophic lake in upstate New York with generally deep Secchi transparency (~9m). In depth studies are enabled by a new observational sensor and intelligent computing network. This advanced cyberphysical system accompanies ongoing traditional scientific experimentation and data collection. Resulting data and analyses drive integrated computer models for weather, runoff, circulation, and the food web, and provide a validation mechanism for these models. Better understanding of these processes around and within the lake will enable more informed decision making and long term preservation of this valuable resource. High frequency measurement recording on vertical profilers, Acoustic Doppler Current Profilers, tributary monitoring stations, and numerous weather stations on and around the lake is the core of this observational network. Internet-of-Things sensor platform-based real-time collection, analysis, and communications both within the network and with external data sources provide opportunities to maximize system and endpoint resources providing the most, and most useful observational data possible. Autonomous control capability at each endpoint provides further data collection robustness under conditions of limited power and communications. The resulting observational data provides validation and tuning opportunities for the high resolution modeling of weather, runoff, and hydrodynamics, over a range of time scales. Advanced visualization techniques of both the observational data and model outputs provide further opportunities for a deeper understanding of the natural system. Example data showing the benefits of the system are exhibited, including event-driven, high resolution vertical profiling, as well as weather model driven tributary monitoring.

48. Bomchul KIM[1] and Kiyong Kim[1]

Short-term variation of phytoplankton biomass measured by a chlorophyll sensor in a reservoir, Lake Soyang, Korea.

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Phytoplankton standing crop in lakes and reservoirs can change both in long term and short term temporal scale. The seasonal variations of phytoplankton standing crop have been widely monitored for a long time compared with short term daily variation. In vivo fluorescence was monitored by a sensor in a reservoir for a year. The seasonal variation of chlorophyll showed significant increase after summer monsoon possibly due to phosphorus loading via storm runoff, resulting in “Monsoon blooms”. A remarkable feature of the daily variation was that chlorophyll showed two episodes of drastic decrease down to 1/3 within a few days, which could not be detected with traditional weekly survey. The mechanism of decrease is not clear; possibly, the change of mixing depth and vertical distribution, or substantial decrease of standing crop due to biological process, such as virus infection and zooplankton grazing.

49. *Brian S. KIM[1], Abigail Lewis[2], Hailee L. Edwards[3], Heather L. Wander[3], Alex E. Taylor[8], Noah Poulin[9], Sarah Princiotta[7], Kiyoko Yokota[4], Courtney Wigdahl[5], Kevin Rose[6], David C. Richardson[3], Denise A. Bruesewitz[1]*

Patterns of nutrient limitation in sixteen northeastern US lakes

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Increased anthropogenic loading of nitrogen (N) and phosphorus (P) to aquatic systems has resulted in an increase in the frequency and intensity of harmful algal blooms. However, the role of each macronutrient (N and P) in limiting freshwater phytoplankton productivity remains unresolved. P was traditionally identified as the primary limiting nutrient in most freshwater ecosystems. However, there is spatial and temporal variation in limitation patterns, with evidence for both nitrogen (N) limitation and co-limitation in addition to P limitation. In this study, we performed standardized nutrient limitation experiments in 16 lakes across four different states using the geographic distribution of lakes in NE GLEON (northeastern North American region). After one-week *in situ* incubations, we measured chlorophyll *a* as a proxy for phytoplankton biomass in each of four nutrient treatments (Control, N, P, N&P). Preliminary results show that within the northeastern United States, lakes show variation in nutrient limitation, with co-limitation occurring in 50% of study lakes. Cases of both N (19%) and P (25%) limitation occurred in similar proportions of lakes. These results challenge the conventional theory that P limitation dominates primary productivity in freshwater lakes. Given the observed spatial variation, there is a need to increase focus on the factors that determine nutrient limitation type to prevent the ecological and health consequences of toxic phytoplankton blooms.

50. *Kiyong KIM[1], Yunkyoung Lee[1], Jai-Ku Kim[1], Sungmin Jung[1], Jaesung Eum[1], Bomchul Kim[1]*

Assessment of water quality and trophic state using developed Korean water quality index

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Generally, various parameters are used for evaluation of water quality and trophic state in lakes and reservoirs. However, each parameter has different meanings when the parameters are used to assess the water quality and trophic state. Also international trophic state index (TSI) are suitable only for natural lakes but not for artificial lakes which is dominant number in South Korea. Artificial lakes have some unique features (short residence time, frequent water level fluctuation) in comparison to natural lakes. Therefore there is certain need to develop useful index which evaluates integrated water quality and trophic level in South Korea. In this study, a model for the integrated water quality index was developed for lakes and reservoirs in Korea. Water quality parameters were analyzed and measured. Also phytoplankton data was acquired. We selected 36 lakes, two natural lakes and 34 artificial lakes. Intensive field surveys were conducted in each season. Four parameters (total organic carbon, chlorophyll-a, total phosphorus, and turbidity) were selected for creating proxy index of water quality after statistical analysis among the parameters. Korean Lake Water Quality Index (LQI) ranging from 0 to 100. The results of this study can provide a relative evaluation system for lake and reservoir in South Korea.

51. Katelyn KING[1], Kendra Cheruvelil[1], and Amina Pollard[2]

How does ecosystem health differ across lakes, streams, and wetlands at the continental US scale?

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Ecosystem 'health' is a common classification system that was developed as a way to assess ecosystem state and quantify the effects of stressors on an ecosystem. Ecosystem health can also be used to compare the state of individual ecosystems to many ecosystems, as well as across regions. However, health is usually applied to one ecosystem type at a time (e.g., to lakes, wetlands, or streams). Our research is studying health for surface waters by incorporating all three freshwater ecosystem types. We will use biological, chemical, and physical measures of these ecosystems to investigate patterns of ecosystem health at the contiguous continental US scale. We have compiled data from the US Environmental Protection Agency's National Aquatic Resource Surveys. The EPA data includes 1,038 lake sample sites, 1,924 river and stream sites, and 438 freshwater wetland sites. We examine the spatial patterns of different indicator variables used to determine ecosystem health, including total phosphorus, total nitrogen, chlorophyll-a, dissolved oxygen, pH, macrophytes, macroinvertebrates, and riparian vegetation, within and across ecosystems types. We expect that patterns found during this research can help determine appropriate spatial scales for effective monitoring and management, as well as increase recognition that freshwater ecosystems form an integrated surface-water landscape.

52. *Jennifer KLUG[1], D.C. Richardson[2], L. Borre[3], D.A. Bruesewitz[4], S.D. Princiotta[5], C. R. Wigdahl-Perry[6], K.C. Weathers[3], K. Yokota[7], S.E. Arnott[8], H.A. Ewing[9], K.C. Rose[10], J.A. Rusak[11], J.E. Saros[12], R.L. Smyth[13], J.D. Stockwell[14]*

NE GLEON (Northeastern North America GLEON): a model for undergraduate engagement in limnology and buoy science.

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NE GLEON (Northeastern North America GLEON) was born at the G16 All-Hands' meeting in Québec, Canada out of a desire to increase interactions among scientists in this lake-rich region and to engage undergraduates in team science. Our network of ~14 lab groups is led by an informal planning committee and our activities over the past 3 years have resulted in increased undergraduate participation in buoy science, several funding initiatives, and exciting cross-site experiments. Our signature event is an annual 2-day conference for 25-35 undergraduates, graduate students, and primary investigators held at the Cary Institute of Ecosystem Studies, NY, USA each April. Our meeting structure was modeled on the GLEON All-Hands' meetings and includes opportunities for participants to present their research and participate in topical working groups, a professional development mixer, and workshops designed to give students the technical skills needed to work with high-frequency data. One outcome of the first conference was a protocol for conducting cross-site mesocosm experiments to assess algal nutrient limitation across a broad gradient of lake productivity. In field experiments in 2016 and 2017, participants found these easy-to-build and deploy systems useful for engaging undergraduates and high school teachers. Part of NE GLEON's success comes from support and participation from other projects with overlapping goals including the GLEON Fellowship program, GLEON Student Association (GSA), the State University of New York Lakes Ecological Observatory Network (SUNY LEON) and Project EDDIE (Environmental Data-Driven Inquiry and Exploration). Overall, feedback from participants has been overwhelmingly positive, and we are excited about future activities.

53. Katie L. KNAPP[1] and Bopaiah Biddanda[1]

Carbon Metabolism across Muskegon Lake – a Great Lakes estuary

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Lakes account for a small percentage of Earth's surface, but are hot spots for carbon cycling. Muskegon Lake is a mesotrophic model drowned river mouth Great Lakes estuary along the east coast of Lake Michigan, which is an Area of Concern (AOC) as designated by the EPA. The *in situ* sensor-based Muskegon Lake Observatory (MLO) buoy established in 2011 provides high frequency weather and water quality data that have enabled the tracking of seasonal productivity cycles, surface blooms and bottom water hypoxic conditions from 2011-2017 (www.gvsu.edu/buoy). I have investigated the spatial and temporal variation in rates of carbon metabolism using *in situ* dissolved oxygen data from the MLO and additional sensor moorings in the lake's 3 sub-basins from 2011 – 2016 and hope to determine if a lake is a source or sink of carbon. In earlier discrete sampling studies, during spring, summer and fall months Gross Primary Production (GPP) was higher than Respiration (R) resulting in positive Net Ecosystem Production (NEP), and during the winter R was slightly higher than GPP – suggesting the lake ecosystem alternates between net carbon sink and net carbon sink roles. Using time-series observatory data, I will test these notions of seasonal variability along with spatial variability in carbon cycling, and identify driving variables. Observatory-based findings can better quantify carbon flux in lakes and advance our understanding of its variability over time and space.

54. Lesley B. KNOLL[1], James B. Cotner[2], Timothy J. Griffis[3], Forest Isbell[2, 4]

Future GLEON Sites in Minnesota: Cedar Bog Lake, Elk Lake, and Lake Itasca

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Three lakes in Minnesota will be instrumented with automated buoys and micrometeorological towers. Buoys will be instrumented with a complete suite of sensors and the micrometeorological towers will allow for measurements of carbon dioxide and methane. Two of the lakes, Lake Itasca and Elk Lake, are in Itasca State Park and near the University of Minnesota Itasca Biological Station and Laboratories in the northern part of the state. The other lake, Cedar Bog Lake, is within the University of Minnesota Cedar Creek Ecosystem Science Reserve. Lake Itasca is the Headwaters of the Mississippi River and Elk Lake has been extensively studied by paleolimnologists and more recently, the Minnesota Department of Natural Resources has identified it as a 'Super Sentinel' lake for the state. One of the most significant contributions to the aquatic sciences and in the larger field of ecosystems science was performed in Cedar Bog Lake by Raymond Lindeman.

55. *Timon LANGENEGGER[1], Dominic Vachon[1], Daphné Donis[1], Daniel F. McGinnis[1]*

What the composition of sediment bubbles teaches us about whole-lake methane dynamics

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Methane is of growing concern as atmospheric greenhouse gas concentrations continue to rise. Methane produced from anoxic sediments of freshwaters contributes about 20% of the total global emissions to the atmosphere, of which half is emitted via bubbles. However, ebullitive methane fluxes are difficult to estimate due to their high temporal and spatial variability. Therefore, common methods to estimate ebullition, e.g. funnel gas traps and hydroacoustic surveys, require unrealistically large numbers of installations and time, respectively, to achieve accurate estimates. In our work, we present an alternative method to estimate methane emissions from measured gas composition of sediment bubbles released at depth. Our approach exploits the fact that ebullition depletes dissolved porewater gasses of atmospheric origin in the sediment, while at the same time considers the effect of depth on sediment bubble gas composition. Our physical sediment model relates three components of sediment methane dynamics: 1) sediment methane production, 2) sediment diffusive emissions and 3) sediment ebullition with a simple mass balance approach. We show how all components of the mass balance are resolved by any one measured component, and how these can be estimated by simply measuring the gas fractions of freshly released sediment bubbles. We applied the approach to a productive lake in the Swiss Plateau (Lake Soppen) and found good agreement between model estimates and measurements of methane production, diffusive and ebullitive fluxes. Our approach is dependent on the dissolved sediment porewater gasses, which reflect the integrated effect of the highly intermittent ebullition. As the model approach also resolves methane production and diffusion, we believe this method is a promising, and relatively simple technique to better constrain methane budgets and emissions from natural waters. Our sediment-based approach to resolved methane fluxes, coupled with a water column turbulence and bubble model, will provide an important tool to gain new insights into whole lake methane dynamics, and predict their response to future climate and eutrophication scenarios.

56. Monika LAPLANTE[1], Vivienne Sclater[2], Evelyn Gaiser[3], Hilary Swain[4]

Utilizing CUAHSI's HydroServer for GLEON Lake Data

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[3] Florida International University
[4] Archbold Biological Station

HydroServer is a data management tool and repository created by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI). This tool was recommended and reviewed at a workshop held at the 2014 GLEON All Hands meeting in Canada as a potential tool that could be used for GLEON lakes. HydroServer is designed for high frequency time series sensor data, making it a potential candidate for lake and buoy data, although it has not been used extensively for these before. Although sample lake data were uploaded from other GLEON sites, Lake Annie at Archbold Biological Station remains the sole GLEON member to have uploaded several full year's data (2008 - 2016) to HydroServer. The poster will review HydroServer's capabilities and utility for lake and buoy data, as well as the tool's obstacles, resolutions, benefits, and possibilities that were discovered with the Lake Annie data upload process. It will also explore HydroServer's compatibility with other analysis software. The presentation will include live demonstrations of Lake Annie data on HydroServer during the poster session.

57. T.M. LAVENDER,[1], Scordo, F.[2,3], Perillo, V.[4], Seitz, C.[2,5], Brendel, A.S.[2,3], Rusak, J.A.[1], Arnott, S.E.[1], Wemple, B.C.[6], Perillo, G.M.E.[2], Piccolo, M.C.[2,3], Caicedo, M.I.V.[7]

Improving the Natural Capital Project's InVEST Seasonal Water Yield model by incorporating seasonal cryospheric conditions to improve conservation decision-making

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Aquatic ecosystems are experiencing increased pressure and stress due to changes in land use, land cover, and climate change which can increase stress by altering flow regimes, nutrient and sediment loading, and water temperature. One way to reduce the impact of these changes is to manage them under the framework of ecosystem services. That is, to prioritise parcels of land for conservation based on the services they perform. Selectively conserving parcels of land based on their relative contributions to base flow (ground water regeneration) and quick flow (surface run off) is one way of managing these systems to reduce stress. Thus, tools that are able to model the partitioning of flow across a landscape are in demand. The Natural Capital Project's InVEST Seasonal Water Yield model has been developed to provide an ecosystem services approach to making conservation decisions based on flow partitioning; however, periods of freezing temperatures and snow accumulation are not accounted for by the model. As a result, spring runoff (quick flow) and groundwater recharge (base flow) are inadequately modeled. By incorporating snow accumulation and spring thaw conditions into the model predictions, seasonal contributions to base and quick flow will be improved. We modified the InVEST Seasonal Water Yield model to incorporate freezing temperatures, snow accumulation and spring freshet. We then compared the results to those from the unmodified model across three diverse watersheds to demonstrate the relevance of the models across ecosystems, as well as their utility for assessing changes in aquatic ecosystem services.

58. John D. LENTERS[1], Peter Blanken[2], and Christopher Spence[3]

The Great Lakes Evaporation Network (GLEN): Building an Integrated Observing System for Great Lakes Flux Measurements

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The Laurentian Great Lakes underwent a regime shift in the late 1990s toward higher summer evaporation rates and lower water levels, in conjunction with a period of warmer summer water temperatures and reduced winter ice cover. More recently, cold, high-ice winters such as 2013-14 remind us of the large interannual variability in the Great Lakes system and the continued need for long-term observations. A growing ensemble of measurements, including offshore eddy flux towers, buoy-based sensors, and vessel-based platforms, are being deployed through a bi-national collaboration to reduce uncertainties in the Great Lakes water balance, provide a more robust basis for short- and long-term projections, and fill a significant gap in over-lake flux measurements and related meteorological data. Here, we provide an overview of this project, known as the Great Lakes Evaporation Network (GLEN). Although the network was initiated to provide improved estimates of evaporation, it is intended to be of utility for a wide range of applied and basic research needs. We provide an overview of the data collection efforts, the array of instrumentation and platforms, and the network of heat, moisture, and CO_2 flux measurements and associated meteorological observations that are available to the scientific research community, Great Lakes mariners and emergency management officials, and the general public.

59. Lizhen LIU, Qi Huang, Yongming Wu, Daishe Wu, Hailin You

Studied on the fluorescent characteristics of chromophoric dissolved organic matter in Poyang Lake with three-dimensional excitation-emission matrix spectroscopy combined with parallel factor analysis.

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Three-Dimensional Excitation-Emission Matrix spectroscopy (EEMs) combined with Parallel Factor Analysis (PARAFAC) was applied to investigate the fluorescence characteristics in Poyang Lake, the largest freshwater lake, and further to explore the relationships between fluorescent coponents and nitrogen and phosphorus nutrition. The results indicated three fluorescence components were identified by PARAFAC, including two humic-like components C1 (245/391 nm); C2 (255, 340/453 nm), and one tyrosine-like component C3 (275/304 nm). The contribution rates to the total fluorescence intensity of microbial humic-like, terrestrial humic-like organic substances, and tyrosine-like substances were 40.8%, 30.8%, and 28.4%, respectively. Humic-like and tyrosine-like substances showed different characteristics at extreme hydrological conditions. The fluorescent intensities and contribution rates of humic-like substances were lowest at dry water level period, whereas were highest at flooding period. However, those of the tyrosine-like substances showed the oppositive phenomenon. The fluorescent intensities of all components showed the differences among the hydrological conditions, and showed similar characteristics under the same condition. The fluorescent indices indicated that the chromophoric dissolved organic matter (CDOM) in Poyang Lake showed allochthonous and autochthonous sources, and showed allochthonous characteristics at dry level poeriod. The fluorescent intensities of all components were significantly and positively correlated with total nitrogen (TN) and disolved total nitrogen (DTN), and tyrsosine-like component was significantly related to total phosphrus (TP).

60. *Mary E. LOFTON[1], Ryan P. McClure[1], Shengyang Chen[2], Charlotte W. Harrell[2], Jonathan P. Doubek[1], Nicole K. Ward[1], Madeline E. Schreiber[3], John C. Little[4], Cayelan C. Carey[1]*

Storms can both stimulate *and* inhibit phytoplankton communities: lessons from a whole-ecosystem lake mixing experiment

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Increasing water temperatures and thermal stratification associated with climate change are expected to lead to more frequent cyanobacterial blooms in lakes and reservoirs. However, the effects of other aspects of climate change on phytoplankton community composition are less certain. For example, predicted increases in storm severity throughout much of North America may mitigate blooms and favor other phytoplankton taxa. To improve our understanding of phytoplankton community response to storm events, we conducted whole-ecosystem storm simulation experiments in a small, eutrophic drinking water reservoir. We used an epilimnetic mixing system to simulate two storms of different durations and intensities while monitoring phytoplankton community dynamics, and then compared these data to a nearby reference reservoir. We found that seasonal timing and intensity of storm events can substantially alter phytoplankton community response to mixing. Specifically, we observed that a short (<6 hrs), intense mixing event early in the season, when stratification was weak, led to increased turbidity and epilimnetic phosphorus concentrations by disturbing littoral sediments, thereby stimulating the biomass of green algae, cyanobacteria, and cryptophytes. A less intense, longer (24 hrs) mixing event that occurred after stratification increased did not stimulate phytoplankton biomass. These results undermine our current expectations of how climate change will affect the prevalence of cyanobacteria in lakes and reservoirs. Thus, our study emphasizes the importance of considering the seasonal timing of storm events as well as mixing effects on nutrient dynamics when predicting climate change impacts on phytoplankton communities.

61. *Gregorio A. LÓPEZ MOREIRA[1,2], Marco Toffolon[1], Darren Giling[3], Franz Hölker[2], ILES Consortium[4]*

An integrated reduced-complexity model to study the effect of artificial light at night on the metabolic rates of lake ecosystems

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[4]ILES project (Illuminating Lake Ecosystems) funded by the Leibniz Association, Germany (SAW-2015-IGB-1 415)

Artificial light at night is one of the most significant global-scale human-induced environmental changes of our time. It has been recognised as a major threat to both terrestrial and aquatic biodiversity. It is, however, one of the least studied ecosystem stressors, especially when it comes to its impacts on aquatic productivity. Through the development and application of an integrated, vertically-layered one-dimensional reduced-complexity model, we study the effects of artificial light at night on metabolic rates of lake ecosystems by modelling the oxygen dynamics of vertical enclosures that were subjected to three different controlled intensities of skyglow, one of the forms light pollution can take, in a mesocosm experiment conducted in 2016 at the IGB LakeLab in Lake Stechlin (Brandenburg, Germany). Oxygen concentration is modelled by means of a diffusion-reaction equation, where diffusive fluxes are modelled in a process-based manner using Fick's laws of diffusion, with a variable vertical turbulent diffusivity that is estimated by means of an empirical expression based on the Richardson number, dynamically recalculated at each time step as a function of the density gradients and the wind-induced shear. On the other hand, reaction terms, which account for oxygen production by primary producers and consumption by all living organisms of the ecosystem, are estimated based on empirical expressions used in previous studies, whose parameters were calibrated statistically using a Bayesian Markov chain Monte Carlo approach.

62. *Marco Toffolon[1], Gregorio A. LÓPEZ MOREIRA[1,2], Luca Adami[1], Marina Amadori[1], Mariano Bresciani[3], Sandro Carniel[4], Hendrik A. Dijkstra[5], Francesco M. Falcieri[4], Alessandro Farinelli[6], Francesco Fatone[7], Giacomo Gerosa[8], Claudia Giardino[3], Alfredo Marzocchi[8], Edie Miglio[9], Sebastiano Piccolroaz[5], Marco Pilotti[10], Nico Salmaso[11], Giulia Valerio[10], Dino Zardi[1]*

Cluster Garda: a scientific task force to study the largest lake in Italy

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Lake Garda is one of the most attractive sites in Italy, where natural beauty tightly interacts with history and culture. Caressed by regular breezes and framed by a majestic mountain setting, the lake is visited by more than 20 million tourists every year and stores about 50 km^3 of water, used both for recreational purposes and water supply. The rapid natural and anthropogenic changes to which it is subjected are exposing this system to several threats, challenging the management and preservation of this important resource. Lake Garda has been the subject of scientific research since the 18th century, with pioneering contributions concerning its genesis, morphology, lake seiches and winds. In the last decades, significant research has been carried out on the status of the lake ecosystem and on the effects of climate change. However, only few studies explored the hydrodynamics and the transport processes in the lake, making the current knowledge lacking of the fundamental connection between ecological and physical dynamics. In order to overcome this knowledge fragmentation, a group of researchers from seven universities and three research institutes launched the scientific task force "Cluster Garda". They also signed an agreement ("Carta di Verona") with the aim of improving the knowledge on Lake Garda and making their competences available to local decision makers, as a support for an efficient and sustainable management of this precious resource. This is the first tangible step fostering the collaboration and coordination between scientists from different disciplines, backgrounds, and institutions.

63. Evanthia MANTZOUKI[1], Bastiaan Ibelings[1]

European Multi Lake Survey; an international group science effort to better understand the direct and indirect effects of eutrophication and climate change on cyanobacterial blooms

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Global warming and eutrophication are identified as major threats to lake ecosystem functioning. Although modelling studies clearly hint at a potential synergistic interaction between nutrients and temperature in promoting harmful cyanobacterial blooms, convincing support from the natural environment is lacking. The European Multi Lake Survey initiative (EMLS) sought to harness the power of group science by establishing a network of early career lake scientists from 26 European countries. Using standardized sampling protocols, we collected data on cyanobacteria and their eukaryotic competitors from lakes of different climatic zones, trophic status and depth, over a large geospatial gradient, during the locally warmest two-week summer period. Dedicated central laboratories analyzed the key survey parameters, such as nutrients, phytoplankton pigments and DNA, as well as cyanobacterial toxins, to secure an integrated, intercomparable dataset. We used HPLC analyzed pigments as a robust indicator of phytoplankton biomass and group level diversity. Our analyses reveal that in an unusually hot summer like 2015, the normally cooler Boreal regions develop significantly higher algal concentrations than the warm Mediterranean regions, under comparable nutrient availability. Temperature and nutrients not only had direct effects on phytoplankton development, but indirect too, for example by intensifying water column stability in deeper systems and altering the light climate in shallower systems, respectively. In extreme cases such as in hypereutrophic, warm lakes, nutrients interacted synergistically with temperature in explaining differences in abundance and distribution of cyanobacteria or eukaryotic algae. Exploring the observed patterns in lake characteristics and phytoplankton ecology we provide potential management measures that would maintain a diverse phytoplankton community in European lakes, also in a warmer future.

64. Shin-ichiro S. MATSUZAKI[1], Kazuhiro Komatsu[1], Ayato kohzu[1], Noriko Tomioka[1], Ryuichiro Shinohara[1], Koichi Shimotori[1], Ryuhei Ueno[1], Natsuko Kondo[1], Haruyo Yamaguchi[1], Taku Kadoya[1], Haruko Ando[1], Megumi Nakagawa[1], Kumiko Totsu[1], Akio Imai[1], and Noriko Takamura[1]

Long-term monitoring of Lake Kasumigaura, Japan: a 40 year legacy and looking to the future

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Lake Kasumigaura is the second largest lake in Japan. This lake is a relatively large (220km^2), quite shallow (max depth 7 m), and super-eutrophic lake. The National Institute for Environmental Studies (NIES) has been monitoring Lake Kasumigaura since 1976. Over the past 40 years, we have researched and collected many variables, including physical condition, water quality, phytoplankton, primary production, zooplankton, protozoa, bacteria, benthic macroinvertebrate, and fish. Although Lake Kasumigaura is registered as a core site of JaLTER (the Japan Long-Term Ecological Research Network, which is a part of ILTER), our monitoring data has not been frequently used for international comparative/macroecological studies. To promote data availability and increase data users, we have created the English web database (http://db.cger.nies.go.jp/gem/moni-e/inter/GEMS/database/kasumi/index.html) and published four data papers (Takamura et al. 2012 a, b, 2016, 2017 Ecological Research). Along with the long-term monitoring activities, we are also trying to improve our monitoring methods by applying new tools, such as environmental DNA (eDNA), and trying to identify causal interactions using a recently developed method, convergent cross mapping (CCM). Furthermore, we have conducted nation-wide lake assessments of freshwater fish diversity (45 lakes; Matsuzaki et al. 2016) and inland fishery resources (23 lakes; Matsuzaki and Kadoya 2015). In this presentation, we will introduce our current monitoring activities and related research projects. We hope that GLEON19 will be a good opportunity to register Lake Kasumigaura as a new GLEON's site.

65. Chris G. McBRIDE[1] and D.P. Hamilton[2]

Modelling water quality of a eutrophic, intermittently closed and open coastal lake

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Te Waihora (Lake Ellesmere) is a large (198 km^2), supertrophic coastal lake which transitioned to a persistently turbid, phytoplankton-dominated state following a severe storm in 1968. The lake is intermittently opened to the ocean by artificial barrier excavation to manage water level and reduce inundation of surrounding land. A lack of any ability to control the duration of lake opening results in wide fluctuations in lake salinity, with cascading effects on benthic macrofauna and macrophytes, which may in turn affect the resilience of the lake to nutrient loadings (via, for example, denitrification) and phytoplankton blooms (via sediment resuspension). Here we present model simulations of barrier opening and closure based on empirical data and use the model to develop alternative hypothetical regimes of 'trigger' thresholds for barrier excavation. The barrier model was coupled to a process-based one-dimensional hydrodynamic-biogeochemical model (DYRESM-CAEDYM) to achieve a simultaneous water and salinity balance for the lake, and to reproduce nutrient and phytoplankton dynamics. Multiple scenarios of barrier opening threshold regimes and nutrient load changes are presented to assess potential hydrodynamic and biogeochemical effects.

66. Ryan P. MCCLURE[1], Leah J. Finegold[1], Mary E. Lofton[1], Kathryn M. Kruger[3], Shengyang Chen[2], Madeline E. Schreiber[3], and Cayelan C. Carey[1].

Oxygenation and mixing increase methane bubble fluxes in a eutrophic drinking water reservoir

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Freshwater reservoirs contribute a considerable source of methane (CH_4) to the atmosphere, especially via ebullition (bubble flux). Despite their importance, the controls of CH_4 ebullition patterns remain poorly understood, especially in reservoirs managed for drinking water. Throughout the stratified period of 2017, we measured ebullition rates at 20 sites in Falling Creek Reservoir, a small eutrophic reservoir and GLEON site in Virginia, USA. During the monitoring period, the reservoir experienced multiple whole-ecosystem manipulations, including epilimnetic mixing (EM) and hypolimnetic oxygenation (HOx) management. Ebullition rates across the reservoir remained low in the spring until the EM was initiated in late April, after which ebullition rates in the reservoir rose dramatically with water temperatures, and continued to increase until the fall. Contrary to previous studies that observed the highest ebullition rates occurring in the shallowest sites of waterbodies, we observed elevated ebullition rates in the deepest site of the reservoir, likely due to HOx operation. Activation of the HOx system mixed the sediments at the deep hole, likely releasing ebullition bubbles stored in the anoxic sediments that were able to rise to the surface. Thus, while oxygenation systems are generally thought to decrease CH_4 ebullition by promoting CH_4 oxidation, our results suggest that in some reservoirs, oxygenation may actually *stimulate* ebullition. As reservoir construction and management increases globally, it is imperative to understand how their drinking water management may affect CH_4 emissions in the future.

67. Kevin MELMAN[1], Brian P. O'Malley[1], and Jason D. Stockwell[1]

Global analysis of rotifer guild ratio in relation to *Daphnia* abundance across 51 lakes

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Zooplankton community structure is influenced by many forces, including food quality and quantity. Competition for food plays an important role in determining which species will dominate in a system at a given time. The size-efficiency hypothesis predicts that larger organisms will outcompete smaller organisms vying for similar food items. Among freshwater zooplankton, *Daphnia* are large, efficient, herbivorous filter feeders that often outcompete smaller herbivorous zooplankton, such as some rotifers. Numerous studies have found that while *Daphnia* abundance tends to negatively relate to microphagous (i.e., herbivorous) rotifer abundance, predatory rotifer populations remain relatively uninfluenced because they target different food sources. The rotifer guild ratio (GR') describes the proportion of predatory to microphagous rotifer biomass in lakes. Previous work suggests that as the percent biomass of cladocerans increases in a system, GR' increases as predatory rotifer biomass increases relative to microphagous rotifer biomass, likely because *Daphnia* outcompete microphagous rotifers. Our hypothesis is that in more eutrophic systems, pelagic primary productivity is high enough to dampen competition between *Daphnia* and microphagous rotifers, and thus we expect competitive influence of *Daphnia* on rotifer community structure to decrease as lake productivity increases. We compiled rotifer and zooplankton data from 51 lakes and reservoirs of varying trophic state across 14 countries, and tested our hypothesis. Preliminary results indicate that GR' in highly productive systems tends towards greater dominance of microphagous rotifers in the presence of *Daphnia*, suggesting that highly productive systems dampen the competitive influence of *Daphnia* on GR', and therefore, rotifer community structure in general.

68. Kellie C. MERRELL[1], Jennifer Stamp[2], Janice Alers-Garcia[3], Britta Bierwagen[4], Susan Jackson[5], Katie Hein[6], Pete Jackson[7], Mihaela Enache[8] and Hilary Snook[9]

Building a Regional Lake Monitoring Network and Sediment Diatom Voucher Flora for Northeastern Lakes in the United States: Applying the GLEON Collaborative Model to State and Federal Lake Monitoring Efforts

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In the United States, state agencies are responsible for monitoring lakes for compliance with the Clean Water Act. States do this with guidance, oversight and funding from the United States Environmental Protection Agency. Most states have well established lake monitoring programs that focus on determining if lakes are being impacted by nutrient pollution and aquatic invasive species. Some monitor the extent of atmospheric pollution, nearshore habitat destruction and cyanobacteria blooms, but very few have monitoring tools that allow them to identify and measure changes in lake condition associated to multiple stressors and/or temporal scales. In addition, states have limited monitoring capacity. Two efforts are currently underway to maximize the information states gain from their long-term monitoring efforts. States in the Northeast and Upper Midwest regions of the United States are working towards establishing a regional lake monitoring network. We are currently developing the criteria for lake selection, identifying and standardizing the field methods and determining the appropriate frequencies for sampling. The second effort underway is to establish a lake sediment diatom voucher flora for the Northeast. The voucher flora is a compilation of species, their associated descriptions and taxonomic assignments to be used by diatomists as main reference. We expect this voucher flora will promote consistency in lake diatom identification and contribute to the long term goal of developing a sediment diatom index that can be used across the Northeast to assess whether lakes are meeting the aquatic life use support requirements of the Clean Water Act.

69. Tadhg MOORE[1], Eleanor Jennings[1] and Elvira de Eyto[2]

Assessing the optimal input data frequency for the GOTM Lake Physical Model

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Dynamic water quality models are dependent on the physical lake model. The GOTM (General Ocean Turbulence Model) physical lake model requires high quality and high resolution meteorological data to increase the accuracy of this model. The PROGNOS project aims to develop a predictive water quality model. This model will take data in near real time from high frequency monitoring buoys and runs the water quality model using weather forecast data and outputs water quality information. The focus is to predict Dissolved Organic Carbon (DOC) and algal blooms. Information that is relevant to water resource managers is how to make this process most efficient and a key part of this identifying the temporal frequency that is the most cost-effective but still maintain a high degree of accuracy with the model. The impact of differing temporal resolution of meteorological input data and water temperature validation data was assessed with recommendations for optimal performance for water quality forecasts.

70. C.C. NDIMELE[1]; Chukwuka, K.S.[1]; Ndimele, P.E.[2] and Pedro, M.O.[2]*

Heavy metal accumulation in organs of *Oreochromis niloticus* (Linnaeus, 1758) from industrial effluent-polluted aquatic ecosystems in Lagos, Nigeria

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Some physico-chemical parameters and heavy metal content of water, sediment and organs (muscle, gill, intestine and brain) of *Oreochromis niloticus* from a section of Lagos Lagoon complex were studied for ten months (July, 2012 – April, 2013). Three sampling stations (Ologe, Ijon and Etegbin) were chosen based on proximity to effluent discharge points from Agbara Industrial Estate and human activities. Four heavy metals (Cu, Zn, Pb and Fe) and ten physico-chemical parameters (temperature, pH, conductivity, TDS, TSS, salinity, dissolved oxygen, BOD, COD, and alkalinity) were studied. The four heavy metals showed significant ($p<0.05$) monthly, seasonal and spatial variation in sediment and tissues of *Oreochromis niloticus*. Values of copper and iron obtained in this study have exceeded the limits recommended by World Health Organisation, Nigeria's Federal Environmental Protection Agency and United States Environmental Protection Agency. This study shows that concentrations of copper and iron in Ologe, Ijon and Etegbin are increasing. Therefore, there is need for regular monitoring of heavy metals in these water bodies to promptly detect sudden increases and take necessary steps to prevent their harmful effects on man.

71. *P.E. NDIMELE, Clarke, E.O.; Mekuleyi, G.O. and Disu, M.O.*

The Socio-Ecological impacts of Sand Mining in Lagos Lagoon Complex, Lagos, Nigeria: a Preliminary Assessment

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An assessment of the socio-ecological effects of sand mining in Lagos Lagoon Complex, Lagos, Nigeria was carried out because of the importance of the water bodies to the socio-cultural and eco-economic well-being of the people. The livelihood of the people is tied mainly to these aquatic ecosystems and the services they provide. These include fishing, cultural essence, sand mining etc. Until recently, sand mining was done to supplement income from fishing, which was the main source of livelihood. However, the combine effects of population pressure, poverty and social insecurity have caused an astronomical increase in sand extraction activities in Lagos State in the last ten years. Despite the importance of aquatic ecosystems to the riverine population, the social and ecological effects of sand mining in these areas have not been a major research topic in literature. Four sampling stations (3 sites with varying degree of sand extraction and one which is relative pristine and would act as control) were selected from Lagos Lagoon Complex using the following indices; intensity of sand mining activities, hydrology and presence of fishing operation. Physico-chemistry, selected heavy metals (Cu, Zn, Fe, As, Cd, Pb), aquatic macrophytes and benthic macro-invertebrate survey were done for 12 months. Fish population dynamics and biodiversity study were also be carried out. Socio-economic survey of the riverine population was assessed as well as an inventory and valuation of the ecosystem services provided by these aquatic ecosystems. The results provide basis for the development of a management tool for sustainable sand mining operations in Lagos State, Nigeria.

72. Melanie M. PERELLO[1], Broxton Bird1, Yanbin Lei[2], Pratigaya Polissar[3], Lonnie Thompson[4], Yao Tandong[2]

Changing Indian Summer Monsoon Intensity throughout the Holocene at Galang Co, Southeastern Tibet

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40% of the world's population is dependent on the Indian summer monsoon (ISM) as the primary freshwater source, however, future projections suggest that this system is becoming more infrequent and undependable due to changing climate. Communities need more information about future climate conditions in order to plan for resiliency, but paleoclimate records from the region are low-resolution. This collaborative project is providing transects of lake paleoclimate records that focus on changing precipitation and lake levels through the Holocene. Galang Co is a new record that we are developing from the southeastern Tibetan Plateau. This small, low elevation lake is uniquely situated in the Lhasa River watershed and is currently used as a water resource for the local community. Historically, the watershed was the home of the regional Galang Dynasty for which there is limited archaeological information. In 2015, we collected three surface and two Livingstone cores from this lake along with surface sediments, water, and vegetation samples. Initial results show that this lake has underwent significant changes in lake level as indicated by organics and grain sizes. We interpret these changes as indicating strong vs. weak monsoon conditions. Future research will utilize leaf wax isotopes, geochemistry, and diatom communities to assess precipitation and human land use.

73. *Erin L. PETTY*[1], *Daniel V. Obrecht*[1], *Rebecca L. North*[1]

Out of the Shadows and into the Light: Missouri (USA) Reservoirs Demonstrate a Gradient of Light Limitation of Phytoplankton Communities

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With harmful algal blooms increasing in frequency and intensity around the globe, interest is mounting to further understand the role of nutrients and light in controlling phytoplankton communities within freshwater reservoirs. Part of a larger project seeking to demonstrate the interaction between light and nutrients on algal biomass and productivity, this study examines the range of light availability to- and deficiency within-phytoplankton communities in 66 reservoirs located within the central state of Missouri, USA, during the summer of 2017. These reservoirs are representative of a range in land-use and trophic status, and we hypothesize that phytoplankton will be responsive to this range, exhibiting a gradient in light deficiency. In order to determine the *in situ* availability of light, we calculated the mean daily mixed layer irradiance and then compared those values to previously established indicator thresholds to assess light deficiency of phytoplankton. Preliminary data suggests a wide range of light availability in these reservoirs with the majority indicating light sufficiency. During the initiation of summer stratification, 8% of reservoirs sampled were already indicating light deficiency and another 11% were nearing deficiency. When not subject to periods of light deficiency, it is assumed that phytoplankton growth is under nutrient control. These assessments have critical implications within central U.S. watersheds where the landscape tends to be dominated by agriculture. They will be instrumental in developing and implementing regional management practices for controlling phytoplankton biomass and gross primary production, as well as harmful algal blooms.

74. Alexander R PEZZUOLI[1], Jeremy L Farrell[1,2,], Michael R Kelly[3], Sandra A Niezerwicki-Bauer[1,2]

Assessing factors structuring zooplankton DVM behavior in Lake George NY by integrating high frequency chemistry monitoring, acoustics, and traditional sampling techniques

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Diel Vertical Migration (DVM) of zooplankton is structured by competing and continuously changing environmental cues and drivers. This study explores DVM at three locations in Lake George using backscatter data from 600kHz Acoustic Doppler Current Profilers (ADCP). The DVM identified based on the ADCP data is explored in conjunction with data from vertical profilers at each site. Zooplankton samples collected with a Schindler-Patalas trap every two weeks at one of the sites during both the day and night were used to ground truth DVM and identify zooplankton species that were present. The high-frequency data collections supported by the zooplankton samples revealed a diel migration pattern of Daphnids and Mysids throughout the water column. Two primary drivers of zooplankton depth selection observed in this study were surface light intensity and thermocline depth. While light and thermal stratification are typically linked, differences between overcast and clear days demonstrated how daily changes in light intensity may affect zooplankton over short timeframes. Additionally, chlorophyll concentrations were related to zooplankton density. However, even when the deep chlorophyll maximum was below the daytime zooplankton peak, density migration higher in the water column still occurred. These results will help identify the tradeoffs made during DVM, on both daily and seasonal scales.

75. Don. C. PIERSON[1]

A Robust Underwater Temperature Monitoring System for Long-Term Year-Round Deployment.

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The effects of climate change are most pronounced at higher latitudes where lake ice plays an important role in regulating the ecology of lakes, but at the same time adds logistical challenges to lake monitoring programs. Often the monitoring of ice covered lakes is interrupted in winter, especially at the time of ice loss, due to the need to avoid damage during ice movement at this time.

In order to provide continuous year-round lake temperature monitoring we developed a cabled underwater monitoring system that has the following characteristics

- Moored 1m below water surface to avoid contact with lake Ice
- Cabled connection to land provides power and allows near real time data transfer and monitoring
- Vertical chain of 50 thermocouple sensors, which have long-term stability and an accuracy of ~0.01 C
- Accessory port that allows connection of other water quality sensors

The system was deployed in Lake Erken Sweden during June of 2017. Here we provide information on its design and performance.

76. Rachel M. PILLA[1], Craig E. Williamson[1], and others

Global Temperature Sentinels Project: Long-term patterns in lake thermal structure (Climate Sentinels Working Group)

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Lake temperatures serve as a structural ecosystem driver that can affect the vertical distribution of oxygen, nutrients, and habitat availability, and are a valuable signal of environmental change. Changes in lake physical characteristics related to temperature can compromise the ecosystem function and services, including their value as drinking water sources. We have compiled the most complete database to date of long-term vertical temperature profiles in lakes across the world to understand changes in whole-lake thermal structure. The geographic span of the 100 lakes analyzed covers five continents and 18 countries, with lakes ranging widely in surface area, depth, latitude, elevation, transparency, and trophic status. At a global scale, the rates of change of lake temperature and stratification in lakes are highly variable. As expected, most lakes show epilimnion warming, with the most consistent trends in northeastern North America and northern Europe. Similar to epilimnion temperature trends, trends in strength of stratification across the globe are mostly increasing, and are sensitive to both epilimnion and hypolimnion temperature trends. Geographic trends in hypolimnion temperature are overall less consistent, and do not clearly mimic the trend found for epilimnion temperature within the same lake or region. Trends in hypolimnion temperature also show high variation in both the direction and magnitude in lakes very near to one another. These changes in strength of thermal stratification and deepwater temperature can have important ecological consequences related to mixing patterns, the availability of oxygen and nutrients, and thus vertical habitat gradients for aquatic organisms.

77. Stephen M. POWERS[1] and Stephanie E. Hampton[1]

Ice duration drives winter nitrate accumulation in north temperate lakes: implications for oxygen dynamics and stoichiometry

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Active biological processes occur beneath lake ice. Little is known of how changing ice phenology may affect biogeochemical transformations in lakes. To address this frontier we examined winter nitrogen(N) dynamics, oxygen dynamics, and nitrogen-oxygen coupling under ice using a 30+yr dataset from seven north temperate lakes. In five oligotrophic/mesotrophic lakes, nitrate accumulated during winter and was strongly related to the number of days since ice-on. Exogenous inputs accounted for <3% of nitrate accumulation in four lakes, suggesting net nitrification regulates N form and the timing of chemical conditions. Winter nitrate accumulation rates at middle depths were ~1.0 μg nitrate-N L-1 d-1. To produce the nitrate via in-lake nitrification, substantial oxygen consumption by ammonium oxidizing microbes would be required. Among lakes and depths that experienced DO depletion, stoichiometric nitrifier oxygen demand ranged from 1 to 25% of the DO depletion rate. These estimates of nitrifier-driven DO decline are likely conservative because we did not account for algal nitrate uptake or denitrification. In two bog lakes with winter DO concentrations <1.0 mg/L, nitrate accumulated near the ice surface in late winter, suggesting nitrification depends on biogenic oxygen from photosynthesis. This research suggests the number of ice-covered days can be useful for predicting winter limnological conditions, while models of under-ice oxygen dynamics may be advanced through consideration of nitrification and nitrogen-oxygen coupling. Further, we may expect changes in the form and amount of inorganic N, and altered dissolved nitrogen: phosphorus ratios, during winters with shorter ice duration.

78. *Dale M. ROBERTSON[1], Paul F. Juckem[1], Eric D. Dantoin[1], and Luke A. Winslow[2]*

Effects of water level and climate on the hydrodynamics and water quality of Anvil Lake, Wisconsin, a shallow seepage lake

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Interannual differences in water quality of Anvil Lake, WI, were examined to determine how water level and climate affect the hydrodynamics and trophic state of shallow lakes, and their relative importance compared to anthropogenic changes in the watershed. Anvil Lake is a relatively pristine seepage lake with hydrology dominated by precipitation, evaporation, and groundwater exchange enabling the typically subtle effects of water level and climate to be evaluated. Groundwater and hydrodynamic models were used to describe lake water and phosphorus budgets and how its hydrodynamics are affected by water level and air temperature. Decreases in water level should cause Anvil Lake and other shallow lakes to stratify fewer days, and have warmer bottom temperatures and more deep-mixing events. Increasing air temperatures should cause these lakes to have shorter ice cover, a longer period for stratification and warmer bottom temperatures. How water level affects water quality depends on how nutrient loading and lake volume vary: during drier, low water years, lakes with large interannual decreases in loading should have better water quality whereas, lakes with small changes in loading should degrade slightly. Anthropogenic changes in Anvil Lake's watershed over the past ~100 years were about 1.5 times the effects of changes in water level when levels were low, but the effects were similar when levels were high. Climate warming is expected to increase productivity in shallow lakes because warmer air temperatures should increase bottom temperatures increasing sediment phosphorus release and deep mixing events enabling this phosphorus to reach the surface.

79. Amber M. ROCK[1, 2], Jessica D. St-Pierre[1], Nicole M. Hayes[3], Michael J. Vanni[1], and María J. González[1]

Digestion resistance and food quantity regulate producer-herbivore energy transfer under varying light and nutrient supply

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The producer-herbivore link is critical for regulating energy transfer through aquatic food webs. Energy transfer at this trophic coupling is generally low due to a mismatch between producer and herbivore tissue stoichiometry, which can induce nutrient limited growth of herbivores. Herbivore growth can also be nutritionally limited by low essential fatty acid content of their food. Additionally, herbivore growth can be energy limited if carbon availability is low or if producer species are difficult to manage and/or resistant to digestion. Growth limitation by any of these mechanisms could further reduce energy transfer from producers to herbivores, decreasing the energy available to higher trophic levels as well as overall food chain efficiency. In this study, we used lab bioassays to mechanistically evaluate the factors limiting growth of *Daphnia*, an important aquatic herbivore, when feeding on algal communities raised under varying light and nutrient supply conditions in two mesocosm experiments. We then examined whether growth limitation of *Daphnia* results in decreased food chain efficiency in the associated mesocosm experiments. In the lab bioassays, *Daphnia* growth was most often energy limited. In one experiment, *Daphnia* growth was limited by food quantity, while digestion resistance limited growth in the other experiment. Additionally, we found that these effects carried up the food chain, as carnivore production in the mesocosm experiments was also energy limited. This study demonstrates the importance of energy limitation in constraining energy transfer between trophic levels and especially highlights the effects of digestion resistance on herbivore growth.

80. J.A. RUSAK[1], A.J. Tanentzap[2], J.L. Klug[3], K.C. Rose[4], S.P. Hendricks[5], E. Jennings[6], A. Laas[7], D. Pierson[8], E. Ryder[6], R. Smyth[9], D.S. White[5], L.A. Winslow[10], R. Adrian[11], L. Arvola[12], E. de Eyto[13], H. Feuchtmayr[14], M. Honti[15], V. Istvánovics[15], I.D. Jones[14], C.G. McBride[16], S. Schmidt[17], D. Seekell1[8], G. Zhu[19]

Automated sensing of chlorophyll fluorescence to assess within and among-lake drivers of algal dynamics.

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15.MTA-BME Water Research Group, Hungarian Academy of Sciences, Budapest, Hungary
16.Environmental Research Institute, University of Waikato, Hamilton, New Zealand
17.Department of Biology, Chemistry and Pharmacy, Free University of Berlin, Berlin, Germany
18.Department of Ecology and Environmental Science, Umeå University, Umeå, Sweden
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Algal biomass regulates key aspects of freshwater ecosystems including fish production and water quality, yet the variability, and subsequent predictability, of phytoplankton biomass is poorly understood. For the first time, we quantified within-lake variation in chlorophyll using high-frequency temporal fluorescence data from 18 lakes around the globe and tested how variation at monthly, daily and hourly scales was related to high-frequency measurements of wind speed, surface water temperature and solar radiation as well as spatial lake productivity, geography, and morphometry attributes. Daily variation in biomass increased with lake trophic status, spatially, and hourly variability in wind speed, temporally. Monthly variation in biomass similarly increased with hourly and daily variability in wind speed and had the largest variability overall. We then tested whether our high frequency relationships were expressed in long-term monitoring data from a subset of our lakes. Our results suggest that future meteorological changes, potentially associated with a warming climate, as well as widespread ongoing cultural eutrophication, have the potential to substantially alter the predictability of algal biomass and the services it provides in freshwater ecosystems.

81. E. Ryder[1], E. de Eyto[2], M. Dillane[2], Adam Mulvihill and Donncha O' Catháin.*

The role of stratification on plankton community structure richness and diversity in Lough Feeagh, Ireland

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A Global Lake Ecological Observatory Network (GLEON) project, Spring Blitz, represents a coordinated effort from eleven lakes around the world to link changes in water stability during the onset of stratification to plankton diversity. This work uses measurement and analysis of aquatic ecosystems at fine temporal and spatial resolutions, traditional limnological field sampling and laboratory analysis to test whether lakes with strong stratification in spring develop higher plankton diversity in the water column. Results from Lough Feeagh indicate that abiotic disturbance is important in driving the plankton succession during the spring-summer period, with the onset of stratification occurring during the first week in June 2013, after a period of decreased wind speed. There was little variation between Chl *a* concentration at each depth over the sampling period. Reduced phytoplankton richness and diversity was observed in Lough Feeagh during the onset of stratification, indicating that stratification is an important driver of the plankton succession during the spring-summer period.

82. *Andrés Mauricio Munar SAMBONI[1], J Rafael Cavalcanti[1], Carlos Ruberto Fragoso Jr. [2], David da Motta Marques[1]*

Modeling the water surface temperature and heat fluxes dynamics in a large subtropical shallow lake: A comprehensive assessment of cold fronts impacts on lake processes

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Water Surface Temperature (WST) is an important indicator of climate variability, which governs most physical, chemical and ecological processes in aquatic ecosystems. Most conventional methods to evaluate WST are carried out using *in situ* measurements, which is expensive, time consuming, and difficult to apply to large areas. Recently, the synergy between numerical modeling and remote sensing techniques has been used successfully in lakes and reservoirs to estimate the short-term scale variations (i.e. diurnal, weekly) on WST, allowing a better comprehension in the process linkages and to assess different thermal processes, under different meteorological conditions (e.g., cold fronts passages). We assessed the spatial and temporal variability of water surface temperature and heat fluxes in the Mirim Lake for the period 2001- 2010, using *in situ* measurements, MODIS land surface temperature (LST) data, and coupling a large-scale distributed hydrological model (MGB-IPH) with a hydrodynamic/water quality model (IPH-ECO). Out findings indicated that the main heat losses in the Lake Mirim are due to latent heat flux (i.e., increase in the evaporation rates an atmospheric saturation), where the shallow waters due to the low thermal mass, respond more quickly to the atmospheric forcings (e.g., wind stress, relative humidity, air temperature, shortwave radiation) when compared with deep regions.

83. *Matthew S. SCHULER[1], William D. Hintz[1], Eli Dow[2], Matt Klawonn[1], Rick A. Relyea[1]*

Food-web monitoring and niche modeling: Using machine learning to understand the effects of invasive species on lake ecosystems

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Understanding food webs is a critical element for understanding human impacts on lake ecology and overall water quality. In 2015, we established 30 benthic sampling locations in Lake George to monitor macroinvertebrate abundance and diversity. Each year, we collect a benthic sample from each location in June, July, and August, and identify all macroinvertebrates captured to the lowest taxonomic unit. We then use abiotic data from each site (e.g. nitrogen, phosphorus, temperature, chlorophyll A, etc.) to explain turnover and variance in macroinvertebrate abundance and diversity. Additionally we survey the fish at nearby locations, and quantify the diet of each fish species captured, to build a complex, spatially explicit food web. Across the lake, the non-native banded mystery snail (*Viviparus georgianus*) makes up the majority of the biomass for each benthic sample, and is an important food resource for fish. To understand the drivers behind the prolific nature of this species, and understand the effects it has on other organisms, we are using machine-learning algorithms to build and test more accurate and predictive niche models. Machine-learning algorithms will better express complex relationships and feedback loops between environmental factors and biotic interactions than classic niche models, allowing us to better assess the drivers of a species' niche. These algorithms will also allow us to make accurate, high-resolution predictions about a species' abundance and distribution. Future research efforts will focus on newly invading species, and attempt to predict potential movements of invasive species across landscapes.

84. Anne E. SCOFIELD[1], James M. Watkins[1], Lars G. Rudstam[1]

Trends in deep chlorophyll layer formation across the North American Great Lakes from 1996 to 2016.

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Deep chlorophyll layers (DCLs) are common features in deep mesotrophic to oligotrophic lakes with a stratified water column, including the North American Great Lakes. Over the past several decades, oligotrophication of the Great Lakes system and growth of invasive *Dreissena* mussel populations have led to greater water clarity and decreased epilimnetic chlorophyll concentrations across the lakes. Formation of DCLs may offset some of the observed losses in epilimnetic production, and a long-term perspective of trends in the vertical structure of chlorophyll distribution is important for understanding ecosystem change. This study builds on prior DCL work in the Great Lakes by investigating long-term patterns in DCL formation across all five lakes using data collected through the US Environmental Protection Agency's Great Lakes National Program Office (GLNPO) long-term monitoring program from 1996 through 2016. Preliminary results indicate that all lakes except Lake Erie form DCLs with high frequency, and the particulate organic carbon content within the DCL is comparable to or greater than those in the epilimnion. Significant trends over time were not observed for DCL depth except in Lake Michigan, where the DCL has gotten significantly deeper ($p < 0.001$, slope = 0.485 m/year). Overall, the depth at which the DCL occurs is highly correlated with euphotic depth, and differences in transparency largely explain differences in DCL depth across lakes.

85. Facundo SCORDO[1,2], M. Cintia Piccolo[1,2], and Gerardo M. E. Perillo[1,3]

Response of lake surface area in Patagonia to variations in river discharge and austral climate modes

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There are contradictory results regarding the effects produced by local climate factors, Southern Oscillation Index (SOI) and Antarctic Oscillation (AAO) over the Argentine Patagonian lakes and rivers between 45-50 °S. Musters (deep lake) and Colhué Huapí (shallow lake) are located in the Argentine Patagonian plains region (45° 34' S). This study aims to analyze the fluctuations in the areas of both lakes related to meteorological variables and river discharge in the period 1998-2015. The relationships of those variations with the SOI and AAO fluctuations are also analyzed. A multiple regression was estimated between annual series of the lake area, as the dependent variable, and series of total annual discharge, precipitation over the lakes and evaporation from the lakes, as independent variables. Finally, wavelets analysis was performed to study the effect of the regional climate events (AAO and SOI) over the discharge which finally affects lake area. The results showed periods in which the area of the lakes changed from a dry to a wet condition. The model showed that discharge is the main driver of lake area variation. Cross-spectra showed high squared coherence (> 0.7) over an annual and interannual (3-5 years) periods between discharge and both AAO and SOI. Wavelet analysis showed that discharge in this area was highly influenced by AAO over an annual to biannual period, and by SOI over an interannual period.

86. Margot SEPP[1], Toomas Kõiv[1], Alo Laas[1], Peeter Nõges[1], and Tiina Nõges[1]

Temporal variation in dissolved organic matter (DOM) in a large and shallow eutrophic lake during growing season revealed by high-frequency spectroscopic measurements

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Dissolved organic matter (DOM) plays an important role in the biogeochemistry of lake ecosystems; however, its dynamics in lakes is largely unknown. We investigated temporal variation in DOM in a temperate large and shallow eutrophic Lake Võrtsjärv during one growing season (April-October 2016) using automatic spectrometer, and discrete water sampling along with laboratory analyses. We assessed the spectral characteristics of light absorption by DOM at a 2-hour interval with In Situ Spectral Analyzer (ISA, GO Systemelektronik GmbH) deployed in the lake. In the laboratory, absorption spectra were measured from monthly taken filtered water samples using UV-VIS spectrophotometer (UV-1700, Shimadzu); in addition, DOC was measured. Absorption spectra from *in situ* and laboratory measurements were well correlated, assuring that the results from the automatic spectrometer were reliable. Spectral Absorption Coefficient at 254 nm (SAC254) was used to assess the content of DOM in lake water from high-frequency measurements. DOM content decreased in spring, increased in the beginning of summer and decreased again for about one month. From mid-July to the second half of August, DOM did not have a definite trend, yet varied on a large scale. DOM content was lowest in the second half of August and then started to increase again. According to discrete water sampling, average DOC concentration was 12.1 mg C L^{-1}, DOC was lowest in August and highest in May and September. Our results show, that monthly taken water samples did not capture the large variation in DOM content during summer months.

87. Sapna SHARMA[1], John Magnuson[2], Derek Gray[3], Catherine O'Reilly[4], Jordan Read[5] and Stephanie Hampton[6]

On thin ice: are lakes feeling the heat?

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Lake summer surface water temperatures are warming rapidly. Ice may be a key mediator of the worldwide changes in temperature. Shorter ice duration, earlier ice breakup, and later ice formation have been observed throughout the Northern Hemisphere over the last century. In particular, earlier ice break-up may have the strongest effects on lake warming. We found that summer surface water temperatures have increased at rates of 0.34°C per decade between 1985-2009, with ice-covered lakes warming twice as fast as the global average. Warming lakes may lead to a 20% increase in algal blooms. We are proposing a new collaboration and invite collaborators to test mechanisms and biological impacts of lake warming. Our goals of the synthesis project are to: 1) To gain a better understanding of the mechanisms that drive lake warming by testing the hypothesis that decreasing winter severity (i.e., earlier ice break-up and shorter ice duration) is leading to higher summer surface temperatures in lakes; and 2) To explore the potential biological impacts of warming by testing how productivity and water clarity have changed as lakes have warmed.

88. *Nicholas K. SKAFF [1,2], Philip M. Armstrong[3], Theodore G. Andreadis[3], and Kendra S. Cheruvelil [1,4]*

Wetland characteristics linked to *Cs. melanura* abundance and eastern equine encephalitis virus infection

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Eastern equine encephalitis virus (EEEV) is an expanding mosquito-borne threat to humans and domestic animal populations in the northeastern United States. Outbreaks of EEEV are challenging to predict due to spatial and temporal uncertainty in the abundance and viral infection of *Cs. melanura*, the principal enzootic vector. EEEV activity may be closely linked to wetlands because they provide essential habitat for mosquito vectors and avian reservoir hosts. However, wetlands are not homogeneous and can vary by vegetation, connectivity, size, and inundation patterns. We investigated associations between wetland characteristics and *Cs. melanura* abundance and infection with EEEV at multiple spatial scales in Connecticut, USA. Our findings indicate that wetland vegetative characteristics have strong associations with *Cs. melanura* abundance. Deciduous and evergreen forested wetlands were associated with higher *Cs. melanura* abundance, likely because these wetlands provide highly suitable subterranean habitat for *Cs. melanura* development. In contrast, *Cs. melanura* abundance was negatively associated with emergent and scrub/shrub wetlands, and wetland connectivity to streams. The effects of wetland characteristics on EEEV infection in *Cs. melanura* were generally weak. Finally, we found that wet hydrological conditions during the transmission season and during the fall/winter preceding the transmission season were associated with higher *Cs. melanura* abundance and EEEV infection, indicating that wet conditions are favorable for enzootic amplification of EEEV. These results expand the broad-scale understanding of wetland effects on EEEV transmission. Given the uncertainty associated with EEEV activity, our landscape-level study may help to more precisely identify the location and timing of outbreaks.

89. *Melanie Perello[1], Robyn SMYTH[2], Lisa Borre[3], Karen Baumert[2], Chelsea Weirich[4], Sarah Bartlett[4], Jennifer Klug[5], Dave Johnson[6], Ishmael Kimirei[7], and Gerardo Perillo[8]*

Differences and similarities in perceived threats to North American lakes by scientists, managers, and stakeholders

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The Reservoirs and Lake Management Working Group of the Global Lake Ecological Observatory Network (GLEON) developed an online State of the Lakes survey to assess perceptions of ecological threats and management of lakes globally. The survey was distributed to GLEON members and affiliates in February 2016 yielding assessments of 146 lakes on 6 continents. Climate change (CC) was the most commonly perceived threat followed by eutrophication, harmful algal blooms, and invasive species. The threat of CC was more often perceived by respondents that identified themselves as scientists (87% affirmative) while only 70% of managers and 58% stakeholders perceived CC as a threat to their specified lake. Managers and stakeholders more often perceived eutrophication and invasive species to be threats to lakes than CC, but they were a small number of total respondents. To further explore differences in threat perception between scientists, managers, and stakeholders, we distributed the survey through NALMS (North American Lake Management Society) in October 2016 and received 104 responses for North American lakes. NALMS respondents perceived eutrophication and invasive species to be threats more often than CC. Both GLEON and NALMS respondents concerned with CC were most concerned with increasing surface water temperatures followed by changes in the intensity and frequency of precipitation. Ecologically, GLEON respondents were most concerned with changes in aquatic community structure while NALMS respondents cited increasing nutrient and sediment pollution with precipitation changes. Such differences in CC threat perception have been found in other contexts and may have important implications for lake management and CC resiliency planning.

90. Joseph STACHELEK[1]

The Effect of Lake Connectivity, Climate, and Land-use Cover on Phosphorus Retention in Lakes

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A comprehensive understanding of the complex interactions between lake characteristics and biogeochemical cycles is essential for understanding and predicting lake nutrient retention and eutrophication. Previous studies have demonstrated that phosphorus (P) retention is strongly related to water residence time at very high and very low residence times. However, P retention in lakes with intermediate residence times vary greatly in P retention and the causes are unclear. Factors which may influence P retention in these lakes include lake connectivity, climate, and land use. Lake connectivity, in particular, has not been considered in previous models of lake P retention. To address this knowledge gap, I use an empirical mass-balance approach to model P retention in hundreds of lakes.To more fully examine the causes of differing P retention among lakes, I tested three model formulations including one that estimated a global first-order removal rate constant (k), one that estimated a separate k for each connectivity class, and one that estimated a separate k for each connectivity class, land-use cover class, and climate region. I found that modeling a separate estimation of k for each connectivity class led to the largest decrease in prediction error. While this suggests that lake connectivity is a useful factor to include in P retention models, it is likely that connectivity per se does not control P retention. Rather, it serves as a proxy for unmeasured factors such as organic matter quality and lability that themselves are related to P retention.

91. Simon D. STEWART[1], David P. Hamilton[2], W. Troy Baisden[3], Piet Verburg[4], Ian C. Duggan [1]

Seasonal variations in consumer nitrogen recycling in an oligotrophic lake: A stable isotope study

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Consumer nutrient recycling (CNR) is an important component of lake nutrient cycles but remains poorly understood. The importance of CNR for sustaining primary production is expected to vary in space and time. For warm monomictic lakes such as Lake Taupō, CNR likely becomes an important source of nutrients for pelagic phytoplankton during summer stratification when nutrients are depleted to severely limiting levels in the surface mixed layer. Quantifying CNR by traditional methods such as nutrient pool assessments has limitations as CNR demonstrates "high flux–small pool" dynamics with extended periods of stratification. Measuring the $\delta^{15}N$ stable isotope values of nitrogen pools within a lake is a promising method to investigate the significance of CNR. Recent stable isotope analytical advances now allow $\delta^{15}N$ determination from low-concentration ammonium and nitrate pools. In this study we performed a comprehensive stable isotope survey of nitrogen constituents in Lake Taupō over a complete annual cycle to investigate the significance of CNR as a nutrient source to phytoplankton. We tested if CNR is a ^{15}N-deplete nitrogen source by examining consumer excretion in incubations. Correlations of ammonium $\delta^{15}N$ values with zooplankton excretion $\delta^{15}N$ values suggested a significant contribution of zooplankton excretion to ammonium pools. A seasonal, whole-lake survey demonstrated that CNR contributed most to nutrient pools and phytoplankton nutrient uptake during the summer stratified period. These are discussed in the context of possible responses of Lake Taupō to changes in climate and the lake food web.

92. *Jason STOCKWELL[1], Orlane Anneville[2], Vijay Patil[3], Rita Adrian[4], Laurence Carvalho[5], Chun Wei Chang[6], Gaël Dur[7], Chih-Hao Hsieh[6], Marc Lajeunesse[8], Aleksandra Lewandowska[9], Stéphan Jacquet[2], Shin-Ichiro Matsukzaki[10], James A. Rusak[11], Nico Salmaso[12], François Schmitt[13], Torsten Seltmann[4], Sami Souissi[14], Dietmar Straile[15], Stephen Thackeray[16], Patrick Venail[17]*

GLEON Storm-Blitz: An update from the GEISHA group on the links among storms, lake physics, and phytoplankton community dynamics

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"Storm-Blitz" is a project within The Theory Working Group (TTG) of GLEON, and is related to the effects of physical disturbances and water column stability on plankton communities. Storms are expected to become more intense and more common as a result of climate change. Extreme storm events represent significant environmental disturbances which will alter phytoplankton niche-space (e.g., temperature, light, nutrients) and thus community dynamics. However, our understanding of linkages among storms, lake physics (e.g., turbulence), phytoplankton traits and ecosystem function is limited. The international collaboration "GEISHA" (Global Evaluation of the Impacts of Storms on freshwater Habitat and structure of phytoplankton Assemblages), a smaller group of collaborators within the "Storm-Blitz" framework, have met for three externally-funded workshops to compile and conduct analyses on traditional long-term and novel high-frequency datasets from lakes across the globe to better understand the patterns, physical and biological mechanisms, and ecological implications of storms on phytoplankton communities (see www.geisha-stormblitz.fr). Here, we present a conceptual model to frame a working definition of 'storm' in relation to attributes of lake physics relevant to the biology of phytoplankton. The model uses interactions between storm features, such as wind and rain, and lake features, such as morphometry and watershed characteristics, to generalize expectations of storm impacts on phytoplankton community dynamics across a gradient of lake types and conditions. We also provide updates on assembled data sets and preliminary analyses on links between storms and phytoplankton trait-responses using the framework of our conceptual model.

93. *Sara STORRER[1], Lori Froehlich[1], Justin Zimmerman[1], Emily Kinne[1], Paul Brown[1], Kevin Rose[2], and Karen Moore[3]*

Optical Sensor Performance in a Low-Carbon System

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Optical proxies for dissolved organic matter (DOM) provide a rapid, low-cost approach to characterizing DOM in surface waters. The New York City Department of Environmental Protection (DEP) has invested in YSI EXO fluorescent dissolved organic matter (fDOM) sensors to monitor contributions of DOM from watershed and reservoir sources and evaluate the suitability of using fDOM as a surrogate for both dissolved organic carbon (DOC) and disinfection by-product formation potential (DBPFP). Disinfection by-products (DBPs) form when natural organic matter is chlorinated. The DEP is evaluating sources and sinks of DOC and DBP precursors in two reservoir basins (Neversink and Cannonsville). These locations serve as test sites for monitoring and modeling DOC and DBPFP with the aim of guiding monitoring and providing input to water supply operations in the future. As a first step in evaluating sensor performance in these low-carbon systems, we compared field measurements for three fDOM sensors (one YSI EXO and two Turner Designs Cyclops) to laboratory measurements of filtered absorbance at 254 nm (UV_{254}, an established proxy for the fraction of organic matter that produces DBPs) and 440 nm (a spectrophotometric measurement of color). The results of this short-term study revealed that sensor performance was similar between different sensor models and fDOM was a good predictor of DOC and UV_{254}. Spatial patterns identified high concentrations of fDOM in forested headwater sites in the Neversink watershed for a snapshot in time during snowmelt runoff.

94. *Cleo N. STRATMANN[1], Rafael Marcé[2], Miquel Lurling[3,1] and Lisette N. de Senerpont Domis[1,3]*

Mitigating negative impacts of extreme events on the sustained provision of lake ecosystem services

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This poster presents early stage researcher (ESR) project 10, embedded in the MANTEL (Management of Climatic Extreme Events in Lakes & Reservoirs for the Protection of Ecosystem Services) Marie Skłodowska-Curie Action European Joint Doctorate Innovative Training Network (MSCA-EJD ITN), which aims to investigate the effects of weather extreme events on freshwater bodies, specially, the negative effects on the services they provide (biodiversity, recreation, drinking water supply, etc.) through a combination of modeling and experimentation. In times of a rapidly changing climate, extreme weather events (heatwaves, storms) are projected to occur more often. This trend is predicted to continue in the future. Impacts of such extreme weather events on freshwater ecosystems range from increased water temperature to enhanced organic matter and nutrient loading of the water body. Consequences include harmful cyanobacterial blooms, perturbations in lake stratification and eutrophication, which most likely have negative effects on the continued provision of ecosystem services. On a wider scale this affects also the strategies for water management and freshwater rehabilitation techniques. Using time series modelling of high frequency measurement (HFM) data, large-scale mesocosm experiments (1000L) and field studies we will assess the water quality and resilience potential of lakes and reservoirs to gain a much-needed deeper understanding and to identify mitigation approaches of effects of extreme weather.

95. Maria TERESHINA[1], Oxana Erina[1]

Simulating Snail Lake mixing regime under various pumping schedules and weather conditions

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Snail Lake, located in Minnesota, USA, is a small lake (190 acres) with watershed area of 987 acres and maximum depth of about 30 feet. The lake has been known to have a steadily dropping water level, and in 1993 the new augmentation system was introduced, with water from Sucker Lake pumping into the Snail Lake. In 2007 pumping was stopped due to an invasive mussel species threat, and restarted in the end of 2009. In years 2011 and 2013–2016 no water was pumped as water level was maintained by precipitation. One-dimensional General Lake Model was used to simulate Snail Lake's vertical thermal structure and mixing regime over the period of 2005–2016. With water temperature and specific conductance vertical distribution data from Minnesota Pollution Control Agency and EPA National Aquatic Resources Survey the model was calibrated and validated to create better compliance with real conditions. Information on water pumping rates was provided by City of Shoreview Engineering Department. Patterns in forming of lake stratification were defined for periods with active lake augmentation and periods with no pumping. Differences in lake water temperature and mixing regime associated with different pumping schedules and weather conditions are described. Lake Analyzer tool was used to calculate key mixing indices for different conditions. With lake mixing and stratification being key factors of all temperate water ecosystems functioning, results of this research can be used in connection with biogeochemical studies to gain further knowledge of Snail Lake ecology.

96. *Sven TEURLINCX[1], Wolf MOOIJ[1,2], Nienke VERMEER[1,3], Tirza ALLIJN[1,3], Lisette de SENERPONT DOMIS[1,2]*

Feeding matters: urban water quality deterioration by allochthonous food input for waterfowl

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Preventing eutrophication in aquatic systems can take on many forms. In urban lakes and ponds artificial feeding (e.g. bread) of waterfowl may account for high loading of phosphorus and nitrogen to the water system. This feeding has a threefold effect on the water quality: (1) direct addition of organic material to the system, (2) excretion of nutrients by birds and (3) attraction of extra birds by increased food availability. Scientific underpinning of the effect on the whole lake ecosystem of these combined processes is currently lacking. Meanwhile, management on feeding is currently being carried out, but has potential for societal backlash due to the nature-education value of 'feeding the ducks'. Here, we quantified the effects of artificial feeding using a combination of experimental data, field observations and modeling exercises with an extended version of the ecosystem model PCLake. We gathered information on feeding behavior of people and analyzed food items commonly fed. Combined with literature data we used this to determine plausible ranges of food input. Empirical relationships of waterfowl nutrient excretions were used to determine the added loading to the system from the bird population. By using these data to extend the PCLake model we were able to determine the effects of artificial feeding on the state of the ecosystem, i.e. turbid or the desired clear state. This allows us to test the feasibility of prohibiting artificial feeding as a preventative or restoration strategy for our urban waters.

97. R. Quinn THOMAS[1], Cayelan C. Carey[2], Renato J. Figueiredo[3], Arianna I. Krinos[2], Mary E. Lofton[2], Ryan P. McClure[2], Kaitlin J. Farrell[2]

Sensitivity of near-term water quality predictions to uncertainty in weather forecasts

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Freshwater ecosystems that provide drinking water to communities are experiencing constant variability in water quality due to weather conditions, such as heat waves, that can stimulate potentially toxic algal blooms or promote anoxia. Developing the capacity to forecast future water quality will enable water resource managers to anticipate, prepare for, and potentially mitigate the effects of these adverse weather conditions to protect drinking water supplies. To date, researchers have rarely included near-term weather forecasts in developing water quality projections for management that include probability distributions of future conditions. Here, we quantify the contribution of uncertainty in weather predictions at the 14-day time scale on predictions of water quality. As part of a newly funded project to develop a water quality forecasting system in Falling Creek Reservoir, a GLEON site and drinking water reservoir in Roanoke, Virginia, USA, we quantified the variability in predictions of water temperature at the 6-hour to 14-day timescale. By combining the General Lake Model (GLM) with 21 ensemble members from NOAA's Global Forecasting System, we are able to present uncertainty in predictions due to weather uncertainty at the time of reservoir fall mixing. Overall, this study provides context for the importance of weather forecast uncertainty when predicting water quality and – when combined with the assimilation of high frequency observations into the GLM – provides the foundation of a forecasting system that is scalable to other GLEON lakes and reservoirs.

98. *Jeng-Wei TSAI[1], Chih-Yu Chiu[2], Tim Kratz[3], Jim Rusak[45], Hou-Chi Lin[2], Jones Jack[6], Wan-Yu Shih[7]*

Prolong effect of annual droughts on Inter-annual carbon flux in two subtropical Asian lakes (Taiwan) with contrasting trophic status

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Lentic freshwater ecosystems contributed obviously to global carbon cycling and storage. Lakes in subtropical Asia are vulnerable to climate changes, because they are small, shallow and regularly experience intensive monsoons and typhoons. How do lakes carbon fluxes (GPP, R, CO2 efflux) react to annual precipitation variations in subtropical regimes are poorly understood. Goals of this study aim to (1) investigate the response of the inter-annual and seasonal carbon fluxto annual low rainfall in two subtropical small lakes, (2) test the hypothesis that the effects of drought on lake carbon flux is mediated by tCDOM, via changes in waterborne nutrient, light and liable organic material availability and their interactive effects and (3) to assess and compare the sensitivity of such responses in trophic- and color-contrasting lakes. Results show that lakes were autotrophic CO_2 sinks or neutral during the dry year (2014), but rapidly shifted towards net heterotrophic CO_2 emitters in the subsequent normal year (2015). Change in carbon fluxes were more sensitive in the mesotrophic clear lake, due to the greater effect of inter-annual CDOM fluctuations on nutrient and light availability, and lake acidity under different precipitation patterns. The loads of terrestrial CDOM serves as a proxy for understanding the response and sensitivity of ecosystem carbon flux to variation in inter-annual precipitation.

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

Visual Exploration of High-Frequency Lake Monitoring Data An Interactive Visualization Platform for "Thinking With and Beyond Watersheds"

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In recognizing the cumulative effects of multiple stressors on altering aquatic ecosystem function, limnologists have become increasingly interested in capturing high frequency observations of lake conditions. This practice has led to a demand for novel ways to visualize and analyze the wealth of data to further understand critical abiotic and biotic processes, and meet policy and management goals. Lake Nipissing, a large, shallow lake in northeastern Ontario, Canada, is home to a new high frequency monitoring buoy network for weather and water conditions with the aim of understanding multiple environmental challenges, including eutrophic conditions and occurrence of harmful algal blooms. To facilitate exploration of the large, complex monitoring data, a web-based visual analytics and data analysis system has been developed through an interdisciplinary collaboration of physical geographers, limnologists, and computational scientists. Visual analytics (VA), the science of analytical reasoning assisted by interactive user interfaces, is being used to study lake conditions, and is available to researchers, government agencies, and the general public through an intuitive web-based interface, part of Nipissing University's Integrative Watershed Research Centre (https://iwrc.nipissingu.ca). As environmental monitoring is increasingly recognized to be location-specific, this web-based interface is intended to utilize users' natural pattern recognition capabilities in revealing trends and discovering patterns related to in-lake processes. This poster will introduce the web-based visual analytics system for the Lake Nipissing monitoring program with the aim of promoting further scientific collaborations and translating high-frequency limnological data into knowledge.

100. Heather L. WANDER[1], Hailee L. Edwards[1], Emma C. Bruno[1], Dejea M. Green[1], Kayla A. Reid[1], Philesha W. Teape[1], David C. Richardson[1]

Cross lake differences in zooplanktivorous fish affects the spatial zooplankton density, size, and diversity

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The Sky Lakes on the Shawangunk Ridge have differing food webs despite close proximity (~10 km). In 2008, Golden Shiners (GS) were introduced into a fishless lake, Lake Minnewaska, without the knowledge of park management. Largemouth Bass (LMB) were subsequently introduced in 2012, and as of 2014, the GS had disappeared due to predation by the LMB. Lake Awosting is acidic and fishless while Mohonk Lake has been regularly stocked with fish. The differences in predators could affect the rest of the food web, especially the zooplankton community. Zooplankton were sampled multiple times from different depths (1m, 5m, 8m, and 15m) in the three study lakes and were analyzed for density, individual size, and community diversity. Lake Awosting exhibits the smallest migration behavior; there is no difference in size distribution at these depths, and the greatest density is at 5m. Mohonk has the greatest migration; the largest size and greatest density is at the bottom of the lake to avoid both cold and warm water fish. Larger zooplankton travel below the deep chlorophyll maximum to 8m in Minnewaska to avoid predation during the day. The presence of LMB-only direct predators of zooplankton as juveniles-results in more zooplankton deep in the hypolimnion and just above the thermocline. Diel vertical migration of zooplankton has not been studied in these lakes, but can explain the vertical distribution of the zooplankton communities. This research has implications for understanding the effects of the addition or loss of fish on the lake food web.

101. Nicole K. WARD[1], Bethel Steele[2], Kathleen C. Weathers[2], Kathryn L. Cottingham[3], Holly A. Ewing[4], Paul C. Hanson[5], Robert Wood[6], June Fichter[6], Cayelan C. Carey[1]

Bringing together citizen scientists, high-frequency sensors, and ecosystem modeling to improve lake water quality in the face of global change

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Oligotrophic lakes provide valuable ecosystem services due to their high water quality. However, land use change and resulting eutrophication are degrading oligotrophic lake water quality at an alarming rate globally. To maintain high water quality in oligotrophic lakes, decision-makers need actionable science recommendations, with a process-based understanding of specific watershed management steps, rather than nebulous nutrient load targets. Here, we address two questions: 1) How do land use and land cover interact to affect water quality in an oligotrophic lake over three decades? and 2) How can we turn modeling results into usable information for citizens to achieve water quality goals? Using long-term data from a GLEON site, Lake Sunapee, New Hampshire (USA), collected primarily by citizen scientists, we calibrated a lake ecosystem model for 30-year simulations. We ran a suite of scenarios testing in-lake responses to increasing inflow volumes related to increasing impervious surface area versus the response to increasing nutrient concentrations as related to varying land management. We found that annual maximum chlorophyll *a* magnitude responds more rapidly to proportional changes in inflow nutrient concentration than to increasing inflow volume. Thus, watershed management steps focused on inflow nutrient concentrations, such as installation of swales, reduction in fertilizer use, and other appropriate best management practices, will likely have the greatest effect in water quality improvement in Lake Sunapee. Our study demonstrates the feasibility of informing on-the-ground management with modeling scenarios developed using data streams from heterogeneous sources and highlights the importance of including research design feedback from citizen scientists.

102. Kate A. WARNER[1] and Jasmine E. Saros[1]

Evaluating changes in epilimnion thickness and phytoplankton community structure from an extreme precipitation event

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Across the northeastern U.S. extreme precipitation events have increased by 60-70% since the 1950's and may exert a stronger effect on lake ecosystems than gradual climate change. Links between extreme events and changes in lake thermal structure are becoming increasingly studied and are important for aquatic ecosystem structure and function. Thermal structure affects light and nutrient availability and may have subsequent effects on phytoplankton community structure. We evaluated changes in lake thermal structure by calculating epilimnion thickness before and after an extreme precipitation event across a set of six Maine, USA lakes. Temperature loggers measured temperature every fifteen minutes throughout the open water season in 2015 at 1-meter intervals. Epilimnion thickness increased after the storm events in lakes with a mean depth of 9-meters and greater. Phytoplankton community structure was also measured before and after the same extreme precipitation event and will be discussed. Evaluating physical and biological changes to lake ecosystems as a result of extreme precipitation events is important for adaptation and management strategies as these events are predicted to continue to increase in frequency and severity.

103. Tanner J. WILLIAMSON[1], Michael J. Vanni[1], William Renwick[2]

How will increasing storm severity and frequency alter nutrient cycling and lake metabolism?

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Climate change is expected to increase the variability, frequency and severity of storm events over the next century. Effects will be pronounced in aquatic ecosystems, where externally supplied resources (e.g., nutrients, organic carbon) drive key ecosystem processes. We know surprising little about how storm events affect fluxes of these resources and thus may modulate ecosystem function. To address this knowledge gap we deployed an array of synchronous dissolved oxygen probes coupled with high-resolution nutrient sampling in Acton Lake, a hyper-eutrophic reservoir with an agricultural watershed. Findings suggest that storm events produce strong, yet surprisingly ephemeral and spatially explicit effects on both nutrient and metabolic dynamics. Increases in limiting nutrients (e.g., phosphorus) are restricted to areas near the stream inlets and return to pre-storm baseline within days. We also found declines in both net ecosystem production and ecosystem respiration during storm events, potentially due to a reduction in algal biomass flushed from the lake during the storm event. Again, this effect was strongest near inlets, and dissipated within several days. Understanding how storm events influence metabolism and nutrient cycling is paramount to preserving ecological integrity and vital ecosystem services of lakes under future climates.

104. Man Xiao[1,2], Matthew P Adams[3], Anusuya Willis[1], Michele A Burford[1,2], Katherine R O'Brien[3]

Variation within and between cyanobacterial strains affects competition: implications for phytoplankton modelling

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Microcystis aeruginosa and *Cylindrospermopsis raciborskii* are two harmful cyanobacterial species which co-occur and successively dominate in freshwaters globally. Within-species strain variability affects cyanobacterial population responses to environmental conditions, and it is unclear which species/strain would dominate under different environmental conditions. This study applied a Monte Carlo approach to a phytoplankton dynamic growth model to identify how growth variability of multiple strains of these two species affects their competition. Pairwise competition between four *M. aeruginosa* and eight *C. raciborskii* strains was simulated using a deterministic model, parameterized with laboratory measurements of growth and light attenuation for all strains, and run at two temperatures and light intensities. 17 000 runs were simulated for each pair using a statistical distribution with Monte Carlo approach. The model results showed that cyanobacterial competition was highly variable, depending on strains present, light and temperature conditions. There was no absolute 'winner' under all conditions as there were always strains predicted to coexist with the dominant strains, which were *M. aeruginosa* strains at 20°C and *C. raciborskii* strains at 28°C. The uncertainty in prediction of species competition outcomes was due to the substantial variability of growth responses within and between strains. Overall, our study demonstrates that within-species strain variability has a potentially large effect on cyanobacterial population dynamics, and therefore this variability may substantially reduce confidence in predicting outcomes of phytoplankton competition in deterministic models, that are based on only one set of parameters for each species or strain.

105. Guangwei ZHU[1], Mengyuan Zhu, Boqiang Qin, Hai Xu

Daily nutrient variation and seasonal phytoplankton succession in Lake Taihu, China

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On the GLEON site at Lake Taihu, we measured daily nutrients concentration during 2012, include total and dissolved nitrogen, total and dissolved phosphorus, and nitrite, and recording the high frequency dissolved oxygen, chlorophyll a, and temperature with YSI sonde sensors. The phytoplankton community also was recorded by weekly interval. The result showed that both nutrients and phytoplankton biomass were highly variable year around. *Microcystis* bloom was driven mainly by temperature increase, not nutrient variation. The research suggest that high frequency monitoring is very important to catch the key ecological process.

New Site Abstracts

1. *Carmen CILLERO[1], Jordi Dado[2] & Ricardo Vázquez[3]*

The Abegondo-Cecebre Reservoir, a new GLEON Site in an instrumented Atlantic Catchment of Southern Europe.

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The Abegondo-Cecebre (A-C) reservoir, in NW Spain, (20.9 hm^3; 355 ha; Z_{max}=17.8 m; Zz_{mean}=5.9 m; CA:LA=72.6) constitutes the source of drinking water to the city of A Coruña and neighbourhood (~400.000 inhabitants). It is managed by the public company EMALCSA, being also used for flood control. The increasing water demand challenges its supply capacity being especially acute in hydric-stress situations when the water quality is adversely affected by a number of hypolimnetic processes (anoxia, increased metal concentration, etc.) or by episodic algal blooms. Worth noting also is the presence in its headwaters of the Meirama lake, a ~147 hm^3 artificial lake arisen after flooding open pit of a former lignite mine.

In recent years the A-C reservoir, Meirama Lake and the associated river courses have been the target of specific studies aimed at gaining a better understanding of the processes affecting water quality. A real-time water quality & quantity monitoring network (profiler, multiparametric probes, weather station, flow meters) has been implemented for these purposes. The available instrumentation and the fact of being the southernmost GLEON Site in Europe provides with a wealth of opportunities for scientific collaboration.

At present, we are involved in developing a methodology to support reservoir management and decision making process focused on problems with high social and economic impact (eutrophication, harmful algal blooms). This is based on high-resolution, spatially-explicit modelling of relevant water quality parameters (transparency, chl-a, phycocyanin, CDOM and T) by integrating multispectral satellite (Sentinel 2) and UAV imagery and continuous high-frequency water quality data.

2. *James B. COTNER[2], Lesley B. Knoll[1], Timothy J. Griffis[3], Forest Isbell[2, 4]*

Future GLEON Sites in Minnesota: Cedar Bog Lake, Elk Lake, and Lake Itasca

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Three lakes in Minnesota will be instrumented with automated buoys and micrometeorological towers. Buoys will be instrumented with a complete suite of sensors and the micrometeorological towers will allow for measurements of carbon dioxide and methane. Two of the lakes, Lake Itasca and Elk Lake, are in Itasca State Park and near the University of Minnesota Itasca Biological Station and Laboratories in the northern part of the state. The other lake, Cedar Bog Lake, is within the University of Minnesota Cedar Creek Ecosystem Science Reserve. Lake Itasca is the Headwaters of the Mississippi River and Elk Lake has been extensively studied by paleolimnologists and more recently, the Minnesota Department of Natural Resources has identified it as a 'Super Sentinel' lake for the state. One of the most significant contributions to the aquatic sciences and in the larger field of ecosystems science

3. *Oxana ERINA[1], Valeriy Puklakov, Dmitriy Sokolov, Valeriya Koliy, Maria Tereshina, Yuri Datsenko, Liudmila Efimova, Maya Zaslavskaya, Marina Ershova, Maria Grechushnikova, Alexander Goncharov, Konstantin Edelshtein*

Mozhaysk reservoir long-term monitoring: potential GLEON site

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Mozhaysk reservoir is a medium-size (30.7 sq km) valley reservoir located in central European part of Russia. It was filled in 1960–1962 and has average depth of 7.7 m, maximum depth of 22.6 m and retention time of about 180 days. Mozhaysk reservoir has features of a typical temperate dimictic lake with stable thermal stratification forming during summer and winter. It can be classified as eutrophic with algal blooms occuring once every 3-5 years.

Krasnovidovo limnological station of Lomonosov Moscow State University is serving as a site of long-term monitoring of Moscow region reservoirs, primarily the Mozhaysk reservoir. The station began operation in 1965 and now has collected more than 50 years of observation data, composed mostly of physical parameters in the beginning with focus shifting to biological and chemical characteristics in 1980s. The list of regular monitoring parameters now includes Secchi depth, water temperature, conductivity, dissolved oxygen content, pH, major ions, total and mineral phosphorus and silicon content, organic matter content indices (true water color, COD, Permanganate index), chlorophyll concentrations. Meteorological data is available for Mozhaysk city located 15 km from station.

Full set of parameters is measured annually in the beginning and end of summer at 19 stations during hydrological surveys, and in some years additional surveys are conducted once per month. More frequent data on Secchi depth and vertical distribution of water temperature, conductivity and dissolved oxygen are available for a buoy station, with automatic temperature sensors data covering all ice-free periods since 2010.

4. *Henrietta HAMPEL[1,2], Pablo Mosquera[3] and Raúl Vázquez[2]*

Park of the lakes: Cajas (Ecuador)

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The Cajas National Park (CNP) is situated in the south of Ecuador, within the elevation range 3150 - 4460 m above the sea level (a.s.l.), nearby Cuenca, the third biggest city of Ecuador. It is part of the UNESCO Biosphere Reserve of the Cajas Massif (CM). Its regional geomorphology was shaped by glacier activities; when the ice retreated, it left about 13 km^{-2} of lakes-dominated landscape. Annual precipitation ranges between 900 - 1600 mm with contrasting seasons and highly variable from year to year. Temperature varies between -2 °C and 18 °C. The vegetation in 91% of its total extent is herbaceous with a dominating presence of the genera Stipa and Calamagrostis. The number of water bodies in it is about 3812 among which 179 have areas larger than 1 ha. Until 2013 limnological studies were carried out only in 3 out of them. Hereafter, the project "Limnological characterisation of the lakes in the Cajas National Park" financed by the University of Cuenca (UC) and ETAPA EP, aims to provide baseline information on 202 sampled lakes including bathymetry, morphological and chemical characterisation of the lakes, stratification processes and identification of their biological communities (phytoplankton, micro and macrocrustacean, macrophytes). The Laboratory of Aquatic Ecology (LEA) of the UC also supports other international projects on paleolimnology to assess the magnitude of recent climate impacts on the diatom communities or to estimate the climate variability in the south-west of Ecuador during the last 2000 years, etc.

5. *April L. JAMES[1], Dan Walters[1], Krystopher Chutko[2], Mark P. Wachowiak[1], Renata Wachowiak-Smolikova[1], Chris McConnell[3], James A. Rusak [3], Andrew Paterson[3], Huaxia Yao[3]*

High-Frequency Monitoring of Weather and Water Conditions for a Large, Shallow Canadian Shield Lake in Northeastern Ontario, Canada

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Lake Nipissing is a large, shallow lake in northeastern Ontario, Canada (the sixth largest inland lake outside of the Great Lakes) and is experiencing multiple environmental challenges, including eutrophic conditions, occurrence of harmful algal blooms, a stressed walleye population, and invasive aquatic species. With general concern over the state of Lake Nipissing and its embayments, an integrated and timely monitoring program has been developed. Early seed funding was provided by a suite of provincial and federal programs, and research on the lake is supported by a broad collaborative group including University researchers, the local Conservation Authority and provincial government scientists. High frequency monitoring of weather and water profile conditions during the ice-off season began in 2013 and has evolved to include multiple sites. Each data buoy includes a water quality sonde (temperature, conductivity, pH, dissolved oxygen, turbidity, chlorophyll, blue green algae) at 1m depth, a thermistor string (1m interval), and additional dissolved oxygen sensors at depth. Processes of lake mixing, thermal stratification and development of low oxygen conditions (e.g., below 2 mg/l) within the water column in response to seasonal and episodic (rain/wind) events are of particular interest, due to links with delivery mechanisms of phosphorus from lake sediments into the water column. Recent additions of water profile and sediment sampling is aimed at generating more direct evaluation of this internal loading. This short presentation will introduce Lake Nipissing as a new GLEON site.

6. *Scott Girdner[1], Mark Buktenica[2], Jeremy MACK[3]*

New Site: Crater Lake, Crater Lake National Park

[1]Lake Biologist
[2]Aquatic Ecologist
[3]Data Manager

Crater Lake National Park started its Long-term Limnological Monitoring Program (LTLMP) in 1983, after a study in 1982 indicated that lake clarity may be declining. U.S. Congress mandated a 10-year follow-up study and additional funding has permitted the LTLMP to continue beyond its initial time frame and expand the scope of monitoring efforts. The LTLMP operates with the following goals:

- Develop a reliable database for the lake to be used for comparisons of future conditions.
- Develop a better understanding of physical, chemical, and biological processes occurring in the lake.
- Investigate the possibility of short- and long-term changes in the lake.
- And if changes are found, and human-caused (e.g., pollution), recommend mitigation techniques.

Crater Lake's LTLMP has spanned 33 years (1983-2016) and has amassed more than 25 datasets. Researchers from the park are interested in joining the GLEON community to provide access to the LTLMP data, collaborate on current and future projects, and connect with an international organization that shares similar goals and objectives.

7. *Rick RELYEA[1], Harry Kolar[2], and Eric Siy[3]*

The Jefferson Project at Lake George: Advancing Science and Technology to Create the World's Smartest Lake

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The Jefferson Project (JP) at Lake George was initiated in 2013 with a mission to establish a strategic partnership that becomes the global model for sustained ecosystem understanding and protection. In this brief introduction to the GLEON audience, we will review the JP's three-pronged approach to understanding and predicting lake changes over space and time that integrates monitoring, modeling, and experimenting. The monitoring effort is comprised of four types of sensor platforms deployed around the lake (weather stations, tributary stations, vertical profilers, and current profilers), which are equipped with advanced intelligence as part of the overall cyberinfrastructure. The modeling begins with high-resolution bathymetric and topographic data that serve as the basis for coupled weather, run-off, and lake circulation models that will ultimately be coupled with a food-web model. The experiments provide the mechanistic understanding of cause and effect of human activities, spanning issues related to excess nutrients, pollutants, invasive species, and global warming.

To complement these efforts, the JP has also engaged with environmental scientists who are coring the lake to understand its long-term history, multiple engineering departments who are conducting in-house sensor development, computer scientists who are working with "Big Data" issues, and artists who are developing immersive computer games to educate the public about freshwater appreciation and protection. Collectively, this multi-faceted approach is proving effective in understanding the lake and providing insights to inform decision makers regarding how to best protect it. Our goal is that this approach will serve as a blueprint for understanding lakes around the world.

8. *Courtney R. WIGDAHL-PERRY*[1]

New Site Proposal: Chautauqua Lake, NY, USA

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Chautauqua Lake is an important natural resource in western New York, serving as a key ecological and economic center in the region. Local residents and tourists use the lake as a drinking water source and also enjoy swimming, boating, and fishing on the lake. The dual-basin lake spans 5400 hectares and is approximately 32 km in length -- despite the size of this system, Chautauqua Lake is relatively shallow (average depth in North Basin = 7.9 m, South Basin = 3.4 m). The lake is eutrophic and heavily impacted by human activities, with major community concerns centered on harmful algae blooms and macrophyte growth caused by excessive nutrient loading.

In order to better understand patterns of algae growth at this site, a high-frequency monitoring buoy was deployed in the North Basin of Chautauqua Lake for the first full season in 2017. The Chautauqua Aquatic Monitoring Project (ChAMP) collects data every 15 minutes, with a YSI sonde deployed at 1 m depth. Sensors measure temperature, dissolved oxygen, pH, conductivity, and chlorophyll (chlorophyll *a* and blue-green algae), and a temperature string collects vertical temperature data every meter. A paired on-shore weather station will be deployed in 2018. Data are shared routinely with local community members, and there are a number of opportunities for scientific collaboration at this new site.