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GLEON 18 Poster Session

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The impact of cattle access and exclusion from watercourses on freshwater geochemical and microbial parameters

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Cattle access to watercourses can result in the contamination of surface waters with nutrients, sediments and faecal pathogens. This is particularly relevant to Ireland, where cattle-based agriculture is the dominant land use.

Whilst there have been several studies in the USA, Australia and New Zealand on the impacts of cattle access to water quality parameters, there have been limited studies in an Irish or European context. Despite this, measures to exclude cattle from watercourses (e.g. fencing) have been included in all Irish agri-environment schemes to date, including the current Green Low Carbon Agri-environment Scheme.

The current study is part of the project *Cattle exclusion from watercourses: environmental and socio-economic implications* (COSAINT) (EPA funded under the Research Programme 2014-2020), and is focused on the impacts of cattle access on nutrient loading, sediment loading, and indicators of faecal contamination. Cattle access points were sampled in three moderate status catchments, and two high status catchments. Sediments will be characterised upstream of and at access sites, while sediment incubations will provide information on nutrient exchange with stream waters. High resolution sampling for nutrients, motion sensor cameras to monitor cattle activity, and sediment sensors will be used to quantify the contribution of cattle in-stream activity to changes in nutrient and sediment concentrations. Sampling of sites after cattle access restriction measures implementation will allow a "before and after" comparison. Collected data will then be used in a dynamic catchment model to estimate nutrient, bacterial and sediment loadings at the catchment scale and allow for scenario testing.

2. Alex BRAIDWOOD

Code for designers workshops, generating visuals using buoy data

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Through a series of code-for-designer workshops, high-frequency buoy data has been utilized to teach art and design students a variety of techniques for developing visuals through the use of

programming. By introducing students to the fundamentals of writing code, they are able to explore these large data sets through the development of visuals generated using various points of data collected by the buoy sensors. Contemporary artists and designers spend a lot of time working out ways for their messages to connect with people using different forms of media. These channels are best explored when artists and designers have a sense for how they work and can figure out ways to build things within these systems. By providing these workshops, students have been able to overcome the steep barrier of entry and write code to produce results that at times are random and generative and others, are visualizations of large data sets. The integration of high-frequency buoy data allows students to see the value in building systems that produce visual results from massive data sets. This poster walks through the process of this workshop model.

3. Jennifer A. BRENTRUP[1], Elizabeth Ryder[2], Annie Scofield[3], William Colom-Montero[4], Werner Eckert[5], Elvira de Eyto[6], Hans-Peter Grossart[7,8], Yannick Huot[9], Peter Isles[10], Lesley B. Knoll[11], Taylor H. Leach[1], Chris G. McBride[12], Don Pierson[13], Francesco Pomati[14], Kevin C. Rose[15], Nihar R. Samal[16], Robyn Smyth[17], Peter A. Stæhr[18], Craig E. Williamson[1], Luke A. Winslow[19]

Biology or physics: What controls the formation of metalimnetic oxygen peaks?

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High-frequency profiling sensor data is opening new avenues into our understanding of sub-surface dynamics in lakes. Recent work has shown that the formation of metalimnetic oxygen peaks in lakes is governed by a combination of both biological and physical processes, rather than biological processes alone. In some lakes, physical processes contributed as much as 86% on average to the metalimnetic oxygen peak. The initial study focused on temperate lakes in one area, primarily at a single time point during the open water season. For this project, we will make use of the GLEON network of profiling buoys, and use high-frequency data collected on 14 different lakes. The initial aim of this project is to examine how widespread this phenomenon is and how the contribution of biological vs. physical processes to metalimnetic oxygen peaks may change seasonally. In lakes with metalimnetic oxygen peaks, we plan to determine the times when the sub-surface chlorophyll maximum aligns with the oxygen peak, and the times when they do not coincide and examine whether physical processes lead to this separation. Preliminary analysis in an oligotrophic lake revealed that there is closer alignment of the sub-surface chlorophyll and oxygen peaks earlier in the growing season, and as the season progresses, these peaks begin to diverge. The chlorophyll peak was consistently deeper in the water column than the maximum dissolved oxygen peak. This may have important implications for the metabolic balance of many lakes if the location of maximum primary production occurs below the oxygen peak and autotrophic production is underestimated.

4. Samantha M. Burke[1], Jonathan P. Doubek[2], Hilary A. Dugan[3,4], Holly A. Ewing[5], Lauren A. MacDonald[1], Ana M. Morales-Williams[6,7,8], Nicholas K. SKAFF[9], Jason D. Stockwell[8], Jamie C. Summers[10]

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 applicability of the results to draw conclusions at a global scale. In this ongoing study, we plan to assess global trends in freshwater primary production over the past 150 years to better understand how climate and other local drivers influence primary production. We are using a paleolimnological approach because long-term monitoring data on whole-lake production are sparse. Fossil pigments, such as chlorophyll *a*, are preserved in lake sediments and can be used as a proxy for primary

production. We are amassing data from sediment cores that have been ^{210}Pb-dated, and have had chlorophyll *a* analysis completed, either through high performance liquid chromatography or visible-near infrared reflectance spectroscopy. To date, we have collected data from ~60 lakes spanning North America, South America, Europe, Asia, and Africa. Sediments from understudied areas are being collected and analyzed using visible-near infrared reflectance spectroscopy. Our target dataset will include over 100 globally distributed lakes and will be used to analyze global trends in lake primary production. We expect results from this study to underscore the potential for future changes in lake ecosystems with continued climate warming and land development.

5. Laura Seelen[1,2], Giovanna Flaim[3], Eleanor Jennigs[4], and Lisette DE SENERPONT DOMIS[1,2]

Tapping the power of Citizen Science

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The European Water framework Directive (WFD) is a framework for community action in the field of water policy. European citizens play a key role in the implementation of the WFD. Citizen science, in which scientists and non-scientists work together on scientific projects, is recognized to be an important tool for public participation and engagement. To be able to tailor citizen science projects to water quality issues, we first investigated the water awareness of people by an online survey. Through snowball sampling, we have spread the survey throughout Europe and the rest of the world. We targeted both citizens as well as scientists with our sampling regime. First results show that there is a discrepancy between people's perception of their water awareness and their actual water awareness. Interestingly, this discrepancy holds true for both citizens as well as scientists.

6. Jonathan P. DOUBEK[1], Kevin A. Bierlein[2], Kylie L. Campbell[1], Alexandra B. Gerling[1,] Kathleen D. Hamre[1], Ryan P. McClure[1], Zackary W. Munger[3], Renato J. Figueiredo[4], Paul C. Hanson[5], and Cayelan C. Carey[1]

Hypoxia-induced trade-offs on zooplankton vertical distribution and community structure in reservoirs

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As a result of global change, hypolimnetic hypoxia is increasing in lakes and reservoirs worldwide. Although the effects of hypoxia on internal nutrient loading have been well-studied, less is known about how hypoxia impacts plankton communities, especially zooplankton. Typically, zooplankton migrate to the dark hypolimnion during the day to escape visual fish predation in the epilimnion. However, due to the physiologically-stressful conditions of hypoxic hypolimnia, zooplankton may remain in the epilimnion during daylight, trading oxic stress for increased predation risk. We sampled five reservoirs weekly to biweekly in southwestern Virginia, USA in summers 2014 and 2015 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 anoxic to oxic during most of the thermally-stratified period. We also conducted a 24-h sampling campaign on a reservoir with an anoxic hypolimnion to examine how zooplankton were vertically distributed over an entire day. Under hypoxic conditions, zooplankton were predominately found in the epilimnion, did not exhibit vertical migration, and had overall lower densities and biomass than in more oxic hypolimnetic conditions. *Kellicottia* and *Chaoborus* were the only taxa to be predominately found in hypoxic zones. Zooplankton play a critical role in lakes and reservoirs as the dominant grazers of phytoplankton, and our results suggest that hypolimnetic hypoxia may alter zooplankton vertical distribution and densities, which may feedback to alter water quality.

7. Jonathan P. DOUBEK[1], Samantha M. Burke[2], Jamie C. Summers[3], Sarah L. Bartlett[4], Hilary A. Dugan[5,6], Flora Krivak-Tetley[7], Nicholas Skaff[8], Kaitlin J. Farrell[9], Ian M. McCullough[10], Facundo Scordo[11], Paul C. Hanson[5], and Kathleen C. Weathers[6]

Cyanobacteria like it hot, nutrient-rich, and a little salty: increased chloride alters phytoplankton and zooplankton community structure in lakes and reservoirs

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In many regions, freshwaters are becoming saltier as a result of global changes. Increased salt in lakes and reservoirs has the potential to alter freshwater ecosystem functions and services. Although there have been laboratory and small-scale studies that examine the effects of salt on a single or a few biota, less is known about changes in community structure at large spatial scales that may be influenced by salinization. We used data collected as part of the U.S. Environmental Protection Agency's 2007 National Lakes Assessment to examine how salt affects phytoplankton and zooplankton densities, richness, and community structure in >1000 lakes and reservoirs across the continental U.S. Chloride concentrations ranged from ~0 to >10,000 mg/L. Indicator species analyses identified many green algal and diatom taxa as characteristic of lower chloride concentrations. Cyanobacteria, such as *Limnothrix*, *Phormidium*, and *Planktothrix*, which are known toxin-producing taxa, were characteristic of higher chloride concentrations. Only one

green algal taxon (*Oedogonium*) was affiliated with higher chloride conditions. Chloride concentrations also altered zooplankton community structure, with taxa such as the gelatinous *Holopedium* affiliated with lower chloride concentrations, and the halophilic taxa *Eurytemora*, *Moina*, and *Artemia* characteristic of higher chloride concentrations. Overall, macrozooplankton appeared to be more tolerant of high chloride concentrations compared to phytoplankton, and both were more tolerant of high concentrations than rotifers. Chloride thresholds for biotic changes were much lower than prescribed acute and chronic toxicity standards (860 mg/L and 230 mg/L, respectively), suggesting that even slight increases in chloride may significantly alter freshwater planktonic communities.

8. Brian C. DOYLE[1,2], Elvira de Eyto[1], Eleanor Jennings[2]

Filling in the gaps: resolving the organic carbon budget of a humic, oligotrophic lake in the west of Ireland

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Lakes play a significant role in the production, storage and mineralisation of organic carbon (OC) and are an important component of regional and global carbon budgets. Future climate scenarios for Ireland project warmer temperatures and significant changes to seasonal precipitation patterns as a result of global climate change, with drier late summers and generally wetter winters. Such changes are likely to alter the quantity and composition of allochthonous organic carbon (OC) entering aquatic ecosystems. It has been estimated that between 13% and 17% of Irish land area is peatland, containing a soil carbon stock of between 53% and 62% of the national total: this vast stock of carbon is important for current and future carbon cycling and particularly vulnerable to climate change. Allochthonous carbon is the main source of carbon fuelling all trophic levels in many freshwater systems, particularly in catchments dominated by peatland. Understanding and quantifying carbon cycling processes in peatland lakes provides important insights into OC transportation, storage and transformation mechanisms. The overall aim of this project is to resolve the OC budget for Lough Feeagh (in the Marine Institute's intensively instrumented Burrishoole catchment), including quantification of the major allocthonous inputs from surface water, groundwater, and atmospheric deposition, losses due to outflow, sediment burial and also autochothanous primary production and ecosystem respiration. This study intends to build on the considerable progress that has already been made and 'fill in the gaps' to resolve the carbon budget for Lough Feeagh.

9. Hilary DUGAN[1,2], Sarah Bartlett[3], Samantha Burke[4], Jonathan Doubek[5], Flora Krivak-Tetley[6], Nicholas Skaff[7], Jamie Summers[8], Kait Farrell[9], Ian McCullough[10], Anna M. Morales-Williams[11], Derek Roberts[12], Facundo Scordo[13], Zutao Yang[7], Paul Hanson[1], Kathleen Weathers[2]

Salting our freshwater lakes

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Worldwide, the greatest concentration of lakes is in north temperate ecosystems (Verpooter et al. 2014). As urban development and the percentage of people living in urban areas continue to grow in these regions, the potential deterioration of lakeshore habitats and urban runoff poses a threat to lake water quality. In north temperate climates, a known threat to water quality is runoff from road salt application, which can lead to the steady and long-term salinization of freshwaters.

To determine if urbanization was a leading driver of lake salinization, we amassed a global dataset of lake chloride concentrations from numerous national and local sources. Our dataset contains over 500 lakes, situated in North America and Europe, with chloride records spanning at least ten years. For each site, we calculated landscape metrics, including percent impervious surface and road density in 100 to 1500 m buffers surrounding the lake perimeter, mean temperatures, monthly precipitation, and sea salt deposition. The result of tree-based models constructed using the entire dataset, continental subsets, and a subset of semi-annual continuous data from 1985-2010 reveals that the percentage of impervious surface surrounding the lake was the most important predictor of chloride trends. In Northern Europe, this response is more muted, as long term trends were also driven by regional climate patterns. This study identifies areas of lake salinization, and draws attention to the lack of long term monitoring around the world.

10. Julita A. DUNALSKA[1], and Justyna Sieńska[1]

The impact of active recreation on the sustainability of urban lakes restoration methods

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In the past, urban lakes were the main receivers of municipal and industrial wastewater. After applying the restoration methods and sustainable improvement of the water quality, these lakes become one of the most attractive places for active recreation. The development of tourist infrastructure in the shore zone and increase the number of sites for fishing and bathing, picnic areas, jetties and aquatic equipment rentals may pose a threat to the maintenance of the positive effects of the restoration projects. Lack of control over the ichthyofauna structure by uncontrolled restocking and fishing pressure can restart the process of "internal loading" and lead to the degradation of resurgent submerged vegetation zones. Numerous, often illegal bathing sites are other sources of pollution. In this situation, the lake restoration has not been finished

only on improving water quality, but it must be treated as a process of continuous control. One of the most important factors to preserve the positive effects of the restoration is the education of the local community and the responsibility of the authorities in the rational management of water resources.

11. Elisabet EJARQUE[1,2], Jakob Schelker[1,2], Samiullah Khan[1,3], Lisa-Maria Hollaus[1,2], Gertraud Steniczka[1], Martin Kainz[1,4], and Tom Battin[5]

The dual role of lakes as buffers and amplifiers of dissolved organic matter temporal dynamics: Buffering transport and amplifying transformation

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Lakes that disrupt the flow of water and its constituents within the fluvial continuum can modify the downstream dynamics of dissolved organic matter (DOM). Potential causes of this change may include the hydrological buffering capacity of lakes relative to streams and rivers and the amplification of biotic processes. To test this hypothesis, we measured DOM quantity and quality at the inflow and outflow of sub-alpine Lake Lunz (Lower Austria) during one year. DOM quality was characterised using optical metrics indicative of the humic-like composition (fluorescence peak C), humification (HIX), and aromaticity (SUVA) degree, predominance of autochthonous components (BIX), and average molecular weight (E2:E3).

Total annual variability was found to be lower in the outflow compared with the inflow (SD_{out}:SD_{in} < 1) for dissolved organic carbon (DOC) concentration and HIX. These variables showed a minimal seasonal variation in both inflow and outflow, together with a more accentuated response to hydrology in the inflow. Mean DOC concentration was significantly higher in the outflow (1.70 ± 0.14 mg L^{-1}) than in the inflow (1.3 ± 0.25 mg L^{-1}), and this pattern was only occasionally reversed during high flow.

By contrast, the total annual variability of peak C, SUVA, BIX and E2:E3 was higher in the outflow than in the inflow (SD_{out}:SD_{in} > 1). This was due to the large seasonal variability in the outflow, which contrasted with a reduced temporal dynamics in the inflow. Combined, this created a shift from similar inflow-outflow DOM characteristics during winter, to uncoupled DOM characteristics during summer. This uncoupling consisted in a higher signal of the autotrophic origin of DOM, a lower average molecular weight, as well as a lower aromatic and humic-like content in the outflow.

Overall, these results highlight the role of the Lake Lunz as a DOC source and as a buffer of hydrological pulses of DOC export. Moreover, results emphasise the capacity of the lake to

amplify the seasonal variability of DOM quality, creating a maximum uncoupling between the inflow and the outflow during the months of increased biotic processing in the lake.

12. Irene GALLEGO, Patrick Venail, Bas W. Ibelings

Understanding phytoplankton species coexistence… Are we still living in a paradox?

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Identifying the mechanisms that drive phytoplankton species coexistence in a relatively homogenous environment has perplexed ecologists for decades. Recent studies propose reconciling niche-based and neutrality theories, since there is some evidence for self-organized coexistence of species, based on their size distributions. This research focuses mainly on answering the following questions: What is the effect of body size, as the most relevant functional trait, on phytoplankton species coexistence? Can we discern if niche processes or neutral processes predict species coexistence? Are freshwater phytoplankton size distributions mainly shaped by competition? Invasions from rare into a resident population, as well as priority effects are tested experimentally to differentiate between niche and neutral mechanisms of coexistence, using species of the same phylogenetic group – cyanobacteria– with a gradient of cell size. Additionally, freshwater phytoplankton size distributions data are compiled and analysed to test our hypotheses.

13. Thomas C. HARMON[1], Ramesh Dhungel[1], Daniel Conde[2], James Rusak[3], Brian Reid[4], Anna Astorga[4], Gerardo M. Perillo[5], M. Cintia Piccolo[5], Mariana Zilio[6], Silvia Londón[6], Maria I. Velez[7], Natalia Hoyos[8], Jaime H. Escobar[8], and Beverley Wemple[9]

Assessing Current and Projecting Future Freshwater Ecosystem Service Risks: Can GLEON Change the Paradigm?

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Aquatic ecosystems and the services they provide to humans are at risk due to local human activity and regional climatic pressures. Quantifying current and projecting future risks, is

challenging because (1) the connections between climatic change, local anthropogenic pressures and the timing and extent of ecosystem changes are complex and poorly understood; and (2) risk is inherently coupled to human perceptions about risk and society's capacity to adapt, which generally differ with cultural and socio-economic conditions. The objective of this work is to test several readily accessible human- and environment-related indices as potential predictors of the risk of losing aquatic ecosystem services. Specifically, we examined lakes, rivers and their watersheds throughout the western hemisphere in the context of the SAFER project, Our intent is to sample a broad array of aquatic systems set in different socio-environmental settings in order to test the robustness of the approach. A secondary objective of the work is to devise a rational for adding to the original set of six SAFER sites while avoiding excessive redundancies in terms of human and environmental characteristics. As a benchmark for aquatic ecosystem risks, we employed the watershed-based Riverthreat.net indices for adjusted Human Water Security (aHWS) and river Biodiversity (BD) threats. We then tested an array of indices as potential proxies for these threats using uni- and multivariate regression. These indices included World Governance Indices (WGI), Environmental Performance Index (EPI), Climate Vulnerability Index (CVI) and their underlying components. We examined 22 nations in N, C and S America for which data are currently available. The results here suggest that the aHWS index correlated well with governance indicators, while the BD index failed to exhibit significant correlation with any of the human or climatic indices.

14. Julia A. HART[1], Emily H. Stanley[1], and Paul C. Hanson[1]

Overlooked consequences of freshwater eutrophication: carbon budgets and enhanced greenhouse effects

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Current knowledge about the role lakes play in landscape-scale carbon cycling has been derived primarily from empirical studies of ecosystems with low to moderate nutrient concentrations. While the consequences of eutrophication, such as reduced clarity and increased harmful algal blooms, are well documented, the consequences for carbon cycling and the role that nutrient-rich, eutrophic lakes play in broad-scale carbon cycling have not been addressed. Current paradigm suggests that eutrophication results in net carbon dioxide (CO_2) sequestration; however, increased methane (CH_4) production due to increased substrate quality for methanogens and prolonged anoxia may offset that carbon sink. Considering CH_4 traps heat in the atmosphere nearly 21 times more effectively than CO_2, that carbon tradeoff may result in an enhanced greenhouse effect for eutrophic lakes. This study seeks to build a carbon budget by tracking seasonal changes in particulate and dissolved carbon analytes and to assess a potentially enhanced greenhouse effect by measuring CO_2 and CH_4 storage and emissions in a temperate, eutrophic lake (Lake Mendota, Wisconsin, USA). The results of this study will shed light on the lesser-known impacts of cultural eutrophication on carbon dynamics such as sequestration and greenhouse gas production.

15. Josef HEJZLAR, Jan Kubečka, and Petr Znachor

The Římov Reservoir, Czech Republic: a new potential GLEON site.

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Římov water supply Reservoir has been studied by the Hydrobiological Institute since its filling in 1979 when a permanent research station was established here. Regular monitoring in three week intervals include water chemistry, microbial world, phytoplankton, zooplankton and fish (annual periods). Since 2008 thermal stratification, temperature of the inflows and climatic parameters has been measured continnuously by automatic registration stations. The site serves as the basic reference for Czech limnological research in wide sense and is the most studied reservoir in the country. Besides regular long term monitoring the reservoir is a subject of extensive fine scale investigations and experimental and methodical studies. The reservoir serves as a good model of spatial longitudinal heterogeneity of many limnological variables in canyon shaped systems. Also the information from the lake management agency (Vltava River Basin Authority) is available. The main long term trends percieved: increase of temperature, shortening of ice cover, increase of dissolved organic matter (humic substances), decrease of nutrients and the fish stock, and shifts in phytoplankton community.

16. Amy L. HETHERINGTON[1,2], Cayelan C. Carey[1], Kelly M. Cobourn[2], Renato J. Figueiredo[3], and Paul C. Hanson[4]

Modeling Effects of Human Decision-Making on Lakes in Coupled Natural Human Systems

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Humans benefit greatly from ecosystem services provided by freshwaters; however, human activities also degrade water quality, which can lead to behavioral changes. The CNH-Lakes project (cnhlakes.frec.vt.edu) examines the linkages between land use decision-making, lake water quality, and local communities at three contrasting GLEON sites in the US (Lake Mendota, Wisconsin, Oneida Lake, New York and Lake Sunapee, New Hampshire). We are linking process-based human and natural system models to: 1) follow the effects of land-use decisions on nutrient fluxes through lake ecosystems; 2) represent how hydrological and limnological processes transform nutrient loads into changes in the water quality; and 3) determine how water quality changes feed back into human decision-making by affecting property values and collective action by citizen groups. We are leveraging new distributed

computing capacity made possible through a collaboration between GLEON and PRAGMA researchers (GRAPLE: GLEON Research and PRAGMA Lake Expedition; graple.org) to efficiently run millions of General Lake Model (GLM) simulations for the three GLEON lakes. After we integrate economics, agronomy, hydrology, limnology, hedonic, and social science models for each of the lake catchments, we will use model results to derive the essential management variables or critical drivers of human-natural system dynamics. Insights from these three lake systems will inform the study of coupled human-natural system dynamics across thousands of lakes throughout the US. Ultimately, our research will improve understanding of the relationships and feedbacks between people and lakes to inform the development of effective programs and policies to protect and enhance lake water quality globally.

17. Lisa-Maria HOLLAUS[1,2], Samiullah Khan[1,3], Jakob Schelker[1,2], Elisabet Ejarque[1,2], Tom Battin[4], Martin Kainz[1,5]

Are lake sediments mere archives of degraded organic matter? – evidence of rapid biotic changes tracked in sediments of pre-alpine Lake Lunz, Austria

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Lake sediments are used as sentinels of changes in organic matter composition and dynamics within lakes and their catchments. In an effort to investigate how past and recent hydrological extreme events have affected organic matter composition in lake sediments, we investigated the biogeochemical composition of sediment cores and settling particles, using sediment traps in the pre-alpine, oligotrophic Lake Lunz, Austria. We assessed annual sed- imentation rates using 137Cs and 210Pb, time integrated loads of settling particles, analyze stable carbon (δ13C) and nitrogen (δ15N) isotopes to track changes of carbon sources and trophic compositions, respectively, and use source-specific fatty acids as indicators of allochthonous, bacterial, and algal-derived organic matter. Preliminary results indicate that settling particles of Lake Lunz (33 m depth) contain high algae-derived organic matter, as assessed by long-chain polyunsaturated fatty acids (LC-PUFA), indicating low degradation of such labile organic matter within the water column of this lake. However, LC-PUFA decreased rapidly in sediment cores below the sediment-water interface. Concentrations of phosphorous remained stable throughout the sediment cores (40 cm), suggesting that past changes in climatic forcing did not alter the load of this limiting nutrient in lakes. Ongoing work reveals dramatic biotic changes within the top layers of the sediment cores as evidenced by high numbers of small-bodied cladocerans (e.g., Bosmina) and large-bodied zooplankton (e.g., Daphnia) are only detected at lower sediment layers. Current research on these lake sediments is aimed at investigating how organic matter sources changed during the past century as a result of recorded weather changes.

18. Allison HRYCIK[1] and Jason Stockwell[1]

Lake thermal structure variability under ice between extreme cold and warm winters

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Climate change is expected to alter thermal stratification patterns and ice cover duration in north temperate lakes, with implications for aquatic communities that persist under ice as well as community structure and function later in the year. Previous research has demonstrated that thermal structure under ice may be more variable than typically expected patterns of reverse stratification. To examine variability in thermal structure at diel and seasonal time scales under contrasting winter conditions, we compared high-frequency temperature readings from a thermistor chain deployed in Shelburne Pond, Vermont, during an extreme cold (2014-2015) and an extreme warm (2015-2016) winter. Ice cover duration in 2015-2016 was reduced by nearly two months compared to 2014-2015. Our results quantify the degree of variability across two winters with drastically different weather conditions and provide insight for changes that we may expect in winter thermal structuring with climate change.

19. Stephen F. JANE[1], Luke A. Winslow[2], Kevin C. Rose[1]

Long-term trends in dissolved organic carbon characteristics in Wisconsin, USA lakes

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Dissolved organic carbon (DOC) is a fundamental driver of many lake processes. While increasing DOC has been observed in many regions, few studies have sought to understand how characteristics of DOC (DOC *quality*) change over time. Quality can be measured by optical characteristics including the spectral slope ($S_{275\text{-}295}$), spectral ratio (S_R), absorbance at 254 nm (a_{254}), and DOC-specific absorbance (SUVA; a_{254}:DOC). We used 24 years of DOC and absorbance data for seven lakes in the North Temperate Lakes Long Term Ecological Research site in northern Wisconsin, USA to examine temporal trends in DOC concentration and quality. DOC concentration exhibited both positive and negative trends among lakes. In contrast, DOC quality exhibited trends suggesting reduced allochthony or increased degradation and S_R patterns indicate it is highly sensitive to variations in precipitation. These results demonstrate that DOC quantity and quality can exhibit complex long-term trends and are responsive to climate components, with important implications for aquatic ecosystems.

In future experiments, we plan to address how variability in the source and concentration of DOC influence ecosystem respiration. We predict that increased allochthony will increase the temperature dependence of respiration, and thus the amount of CO_2 released to the atmosphere

from aquatic systems at higher temperatures. When combined, these studies will link long-term observational data with high-frequency in situ measurements to understand how changes in the quantity and quality of allochthonous DOC inputs influence the structure and function of lakes and their role in the global carbon cycle.

20. Seán KELLY[1], Elvira de Eyto[2], Russell Poole[2], and Martin White[1]

Marine and freshwater influences on coastal lagoon ecology.

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A Marine institute - NUI Galway collaborative project has been instigated to quantify the hydrographic control on the ecology of a meromictic saline coastal lake, Lough Furnace, Co. Mayo, situated on the macro-tidal Atlantic coast of Ireland. The Lough has the shape of an upturned bowl with maximum depth 21m, and is connected to coastal waters via a kilometre long, constricted channel.

Long-term observations from a high-frequency undulating CTD profiler in the centre of the Lough reveal a permanently stratified vertical structure, with the formation and maintenance of a strong halocline driven by freshwater input from the catchment and tidal advection of saline coastal waters, principally at larger spring tides. This state of meromixis has led to the development of anoxic conditions in the deeper layers of the Lough with implications for resident ecological assemblages.

Observations are being carried out to assess seasonal variation in the Lough structure and volume fluxes in/out, with variability in freshwater input appearing to exert the greatest hydrographic control over the stability of stratification and extent of tidal intrusion. A simple salinity budget, based on summertime observations with 100% exchange between in/out flowing volumes and no mixing, suggests a minimum residence time of 3 months, which would appear to be underestimated. Further investigations are underway to determine deep water renewal rates. Subsequent work will focus on relating the hydrography of the Lough to its phytoplankton population dynamics, specifically how the composition and biomass of algal communities changes temporally and spatially with variation in exchange flows and vertical structure in the Lough.

21. Samiullah KHAN[1], Katharina Winter[1], Stefanie Danner[1], Elisabet Ejarque[1,2], Serena Rasconi[1], Tom J. Battin[3], Martin J. Kainz[1]

Lakes as organic matter upgraders – seasonal variation in biochemical compositions of in- and outflowing particles in pre-alpine Lake Lunz, Austria

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In this field study, we investigated how particulate organic matter (POM) quantity and its biochemical quality changed between lake inflow and outflow as well as within the oligotrophic, pre-alpine Lake Lunz, Austria, from 2013 to 2015. We tested the hypothesis that irrespective of seasons, stream water recharging the lake contains predominantly recalcitrant POM (>1.2 µm particle size), whereas outflowing lake water is mostly composed of more labile, algae-derived organic matter. Samples were collected at a monthly basis from the lake layers, inflowing and outflowing streams, and analysed for fatty acids as biochemical indicators of POM quality. Results showed that increasing precipitation and runoff predicted significantly increasing inflowing concentrations of POM ($r = 0.72$, $R^2=0.52$, *Sig. F*<0.001). The lake retained ~58% of total imported POM, but exported ~3X, ~8X, and ~6X more bacterial fatty acids (BAFA), and algae-derived omega-3 PUFA and omega-6 PUFA, respectively, than the inflow. Long-chain saturated fatty acids (used as proxy for terrestrial organic matter) constituted ~9% in inflow and ~6% of total SAFA in the outflow. In general, Lake Lunz exports on average 8X more labile POM (algae-derived) than the inflow. These results suggest that the oligotrophic, pre-alpine Lake Lunz is a biochemical upgrader within the fluvial network of this drainage basin and supplies highly labile and nutritional POM to consumers further downstream, irrespective of the season.

22. Donghwan KIM, Suyoung Cha, Bomchul Kim

DO change in urban streams by using auto logging sensor

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Due to regulatory controls and advances in wastewater treatment, the water quality of urban streams in Seoul have improved significantly. However, urban streams near urban and suburban areas are often negatively affected by rain events. After rain events, turbidity increases and dissolved oxygen (DO) decreases drastically. As a result, fish kills happen more frequently. Therefore, high frequency monitoring is needed in Korean urban streams.

Mokgam and Jungrang two urban streams are selected for this study to monitor long term DO variation. Hydrolab DS5X sensor and PME miniDOT sensors were installed in Mokgam Stream and Jungrang Stream, repectively.

We found that throughout the dry periods, change in DO concentration was influenced by temperature. Whereas, DO concentration was dramatically decreased during rain events and resulting in fish kills. In Jungrang Stream, it was observed that DO was decreased to 0 mg/L. During the study period fish kill was happened twice after rain events. The results of this study revealed that the fish in the urban streams could not adopt with the rapid change in DO concentration.

23. Donghwan KIM, Yoonhee Kim, Bomchul Kim

Water quality change in lower dam by temperature change of upper dam effluent

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The Lake Uiam is an artificial lake which has 80 million tons storage capacity and the residence time of Lake Uiam is very short, 6 days. The discharge quantity from two upper dam occupies 97 % of the total water discharge. Except two upper dam discharge, there are Gongji Stream and sewage from Chuncheon city as main inflowing sources of Lake Uaim. The water quality of Lake Uiam is controlled by those inflowing streams, and the spatial movement of water body is very complex depending on change in the flow rate and water quality of the inflowing streams.

In this study, we tried to focus on effluent water temperature of Soyang dam discharge, one of upper dam by using two-dimensional hydrologic model, CE-QUAL-W2 according to the temperature change. CE-QUAL-W2 model can be suitable for simulating the vertical stratification of the water body.

Soyang dam effluent is discharged through the outlet located at the middle depth. The middle depth of Lake Soyang is about 50 m, so the gap of temperature between the surface layer (5 m) and the middle layer is very big. From May to October, it is about 5-15℃. When the low temperature water of Lake Soyang is discharged, it is observed through the model that the surface water of Lake Uiam is moving reverse. In this case sewage inflow cannot move to downstream, so the phosphorus included in sewage might be increased eutrophication. After that the surface water of Lake Soyang is discharged, the water quality change of Lake Uiam was simulated by using the model.

24. Bomchul KIM, Sungmin Jung, Myoungsun Shin, Jaiku Kim, Jaesung Eum, Yunkyoung Lee, Jaeyong Lee, Youngsoon Choi

Rainfall in summer monsoon and the effects on phytoplankton in Lake Soyang and Korean reservoirs

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One of the most important hydrological characteristics of lakes and reservoirs in the East-Asian summer monsoon region is the dramatic difference in hydrologic inputs among seasons. Annual rainfall is commonly concentrated in a few heavy rain events. In this study the monthly variations of phytoplankton density were surveyed in three large deep reservoirs and seven small shallow reservoirs, and the effect of large precipitation events on phytoplankton was analyzed. During heavy rains phosphorus concentration in streams increased greatly and phosphorus

loadings into reservoirs were not continuous but episodic shock loadings. In deep stratified reservoirs, however, the concentrations of phosphorus and chlorophyll-a were much lower than expected from high TP in the storm runoffs. Inflowing storm waters laden with phosphorus flowed into metalimnetic layers because deep reservoirs showed stable stratification and the temperatures of storm waters were lower than epilimnions. The result is the formation of an ecosystem resilient to P shock loadings during monsoon. Nutrients in the metalimnion seemed to be dispersed gradually towards epilimnion and phytoplankton showed maximum densities after monsoon, which can be named 'monsoon blooms'. To the contrary, shallow reservoirs with short hydraulic residence times showed lower chlorophyll-a concentrations during the monsoon season, because high flushing rate was the major limiting factor of phytoplankton growth. In conclusion summer monsoon is the major determinant of phytoplankton density in reservoirs of the East Asian region, but their responses can be quite different depending on hydrologic characteristics.

25. Ilga KOKORITE[1], Linda Dobkevica[1], Ivars Druvietis[1], Laura Grinberga[1], Jolanta Jekabsone[1], Davis Ozolins[1], Elga Parele[1], Valery Rodinov[1], Agnija Skuja[1], Roberts Silins[2], Gunta Springe[1]

Limnological research at the Lake Engure, Latvia

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Lake Engure is a shallow (mean depth 0.4 m) lagoon-type lake in Latvia situated on the Western coast of the Gulf of Riga. Currently, it is a Charophyte lake in clear water stage. L.Engure and its surrounding are designated as a Natura 2000 site, Important Bird Area and Ramsar site. In 1842, Mersrags Canal connecting the lake with the Baltic Sea was excavated in order to lower a water level of the lake. Since then, frequent intrusions of saline water are observed in the lake. Monitoring data show that communities of benthic invertebrates in the site close to the Mersrags Canal are now typical for oligohaline to mesohaline environment. The low depth of the lake makes it vulnerable to eutrophication. Nutrient inputs from the catchment and also from the growing cormorant colony facilitate the spread of emergent macrophytes and disappearance of Chara beds.

In 1958, annual ornithological observations have started, but since 1995 frequent hydrobiological and hydrochemical monitoring is carried out by the Institute of Biology. Data on biomasses and composition of phytoplankton and benthic macroinvertebrates are available. A floating house equipped with Hanna Instruments sensors for in-situ measurements of water temperature, dissolved oxygen, conductivity, pH, turbidity as well as meteorological station Davis Vantage Pro2 Plus was installed in the middle part of L.Engure in 2015.

26. Josef Hejzlar, Jan KUBEČKA, and Petr Znachor

Římov Reservoir, Czech Republic: a new potential GLEON site.

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Římov water supply Reservoir has been studied by the Hydrobiological Institute since its filling in 1979 when a permanent research station was established here. Regular monitoring in three week intervals include water chemistry, microbial world, phytoplankton, zooplankton and fish (annual periods). Since 2008 thermal stratification, temperature of the inflows and climatic parameters has been measured continnuously by automatic registration stations. The site serves as the basic reference for Czech limnological research in wide sense and is the most studied reservoir in the country. Besides regular long term monitoring the reservoir is a subject of extensive fine scale investigations, experimental and methodical studies. The reservoir serves a a good model of spatial longitudinal heterogeneity of many limnological variables in canyon shaped systems. Also the information from Lake management agency – Vltava River Basin Authority is available. The main long term trends percieved: increase of temperature, shortening of ice cover, increase of dissolved organic matter – humic substances, decrease of nutrients and the fish stock, shifts in phytoplankton community.

27. Silke LANGENHEDER

SITES – Swedish infrastructure for ecosystem research

Uppsala University, Sweden

SITES (Swedish Infrastructure for ecosystem science) offers all researchers, regardless of affiliation, the opportunity to use the nine stations as resources in their research, which cover a wide geographic range and types of ecosystems. This includes a lake and stream monitoring program that is currently started at 7 station. Researcher may stay at one station and take measurements or perform experiments, or outsource tasks which are managed by the station. A further possibility is to use existing data collected at the stations.

28. Taylor H. LEACH[1], Beatrix E. Beisner[2], Cayelan C. Carey[3], Patricia Pernica[2], Kevin C. Rose[4], Yannick Huot[5], Orlane Anneville[6], Jennifer A. Brentrup[1], Isabelle Domaizon[6], Hans-Peter Grossart[7,8], Bastiaan W. Ibelings[9], Patrick T. Kelly[1], Stéphan Jacquet[6], James A. Rusak[10], Dietmar Straile[11], Jason Stockwell[12] and Piet Verburg[13]

Relative importance of light and thermal stratification to the structure of deep chlorophyll maxima in 100 GLEON lakes

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[9] Institute F.-A- Forel and Institute for Environmental Sciences, University of Geneva, Switzerland
[10]Dorset Environmental Science Centre, Ontario Ministry of the Environment and Climate Change, Dorset, Ontario, Canada
[11]Limnological Institute, Department of Biology, University of Konstanz, Konstanz, Germany
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[13]National Institute of Water and Atmosphere Research, Hamilton, New Zealand

The vertical distribution of phytoplankton chlorophyll in lakes and oceans frequently exhibits a maximum deep in the water column, referred to as the deep chlorophyll maximum or DCM (e.g. Fee 1976). DCM's are an ecologically important phenomenon as they can contribute substantially to primary production, influence nutrient cycling within the water column, and form important habitat gradients for consumers. Light attenuation and the location and strength of thermal gradients in the water column are frequently identified as the main abiotic drivers of DCM characteristics such as depth, thickness or amplitude. Unfortunately, because gradients in light and temperature strongly co-vary, their relative influence on these DCM characteristics has been difficult to differentiate. Further, our understanding of the importance of light vs. thermal stratification in determining DCM characteristics, or how generalized these relationships are across broad gradients of lakes remain limited. Here, we analyzed light, temperature, and chlorophyll fluorescence profiles with a dataset of 100 GLEON lakes. Using a random forest analysis, we assessed the relative importance of variables associated with light attenuation vs. those associated with thermal stratification in characterizing DCM depth, thickness, and amplitude and examined how predictor importance scaled across gradients of lake size, depth, and transparency. Our analysis suggests that DCM depth in a stratified water column is largely controlled by light-associated variables, namely the 1% PAR depths, while thickness varies as a function of lake size and density structure of the water column. In contrast, DCM amplitude was not well characterized by abiotic lake variables.

29. Kenneth T. MARTINSEN[1], Mikkel R. Andersen[1], Kaj Sand-Jensen[1]

Thermal properties of small lakes – daytime stratification and nighttime mixing

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Small lakes (<0.1 km^2) are common in the landscape and have a large combined areal cover on a global scale. Yet, small lakes are grossly understudied compared to medium and large lakes. Tight coupling to the terrestrial surroundings and their dynamic hydrology and chemistry as a direct consequence of their small size opens an avenue of new findings and surprising relationships. Studies on small shallow lakes reveal unexpected thermal dynamics and the potential development of diurnal stratification. We describe this feature in several small temperate lakes in Denmark using high-frequency monitoring equipment.

We have collected temperature and weather data for a collection of small Danish lakes (500 to 5000 m^2, max depth <2 m) from November 2015 to 2016. During spring and summer we show that a thermocline may develop during daytime and persist until nocturnal convective mixing of the water column after surface cooling. The stratification is particularly pronounced on sunny days in small lakes with submerged plants.

We present some of the data collected so far. Using LakeAnalyzer and LakeHeatFluxAnalyzer we describe the thermal properties of these small lakes.

Diurnal stratification may prove to be a prominent feature of small lakes having implications for their chemical conditions and role in global scale biogeochemical processes.

30. Ryan P. MCcLURE[1], Jonathan P. Doubek[1], Kathleen D. Hamre[1], Zackary W. Munger[2], Barbara R. Niederlehner[1], and Cayelan C. Carey[1]

Metalimnetic oxygen minima accumulate methane in the water column and alter greenhouse gas efflux phenology from a eutrophic reservoir

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As a result of anthropogenic change, oxygen dynamics in some waterbodies are changing, potentially resulting in metalimnetic oxygen minima (MM). MM may alter the C balance of a waterbody by generating redox conditions that result in methane (CH_4) production in the water column, a process that normally occurs at the sediment-water interface. Here, we conducted a whole-ecosystem manipulation of oxygen conditions using engineering systems to allow MM to form while keeping the hypolimnion oxygenated in a eutrophic reservoir. We measured depth profiles of dissolved CH_4 and carbon dioxide (CO_2) concentrations throughout the experiment, and estimated CH_4 and CO_2 atmospheric gas exchange with multiple gas flux models. We observed substantial accumulation of CH_4 within the MM, up to ~75 uM. Regardless of which gas flux model was used, the largest efflux of CH_4 into the atmosphere occurred 20 days before fall turnover during a storm, while the largest CO_2 efflux from the hypolimnion occurred during turnover. Our data indicate that the timing and magnitude of GHG fluxes may be dependent on the depth of the gases in the water column, and that the efflux of gases in the metalimnion may

be sensitive to weather events that are de-coupled from fall turnover. Consequently, if MM increase as a result of global change, lakes and reservoirs may accumulate substantial concentrations of CH_4 in their water columns, thereby altering the GHG efflux phenology from waterbodies.

31. R. Iestyn Woolway[1], Pille MEINSON[2], Peeter Nõges[2], Ian D. Jones[3], Alo Laas[2]

Strengthening of stratification in polymictic Lake Võrtsjärv – a matter of increasing temperature or weakening wind?

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Polymictic (frequently mixed) Lake Võrtsjärv (area 270 km^2; maximum depth 6.0 m; mean 2.8 m) is among most intensively investigated inland water bodies in Europe. To follow rapid changes in water quality, an automatic monitoring station was installed in the lake in 2008. We calibrated MyLake model with high resolution meteorological data from 2013-2015 to simulate thermal stratification of the lake. Further we drove the model with long-term meteorological data for summer months 1982-2009. A noticeable change towards stronger average stratification and more stratified days per year since 1996 coincided with the pattern in weakening winds. Over the period there was a significant trend also in air temperature. Re-running the model with air temperature only from 1982 but other meteorological data as observed in each year did not remove the trend in stratification showing that the observed air temperature changes had little impact on stratification. However, re-running the model with wind speed data only from 1982 but other meteorological data as observed in each year showed that the observed wind speed was the main cause of the trend in the strength and frequency of stratification.

32. Tadhg MOORE

Dundalk Institute of Technology, Ireland

Lakes and reservoirs are under continuous pressure from urbanization and agricultural intensification, and from changes in climate, including an increasing occurrence of extreme climatic events. These pressures can reduce water quality by promoting the occurrence of nuisance algal blooms and higher levels of dissolved organic carbon (DOC), two issues that can substantially increase the costs for water treatment. To monitor such changes in water quality, automated high frequency (HF) monitoring systems are increasingly being adopted for lake and reservoir management across Europe. These HF data are mostly used to provide near real time (NRT) information on the present lake state. An even more valuable tool for water management,

however, would be to use HF data to run computer models that forecast the probability of a change in lake state in the coming weeks or months. In PROGNOS, we will develop an integrated approach that couples HF lake monitoring data to dynamic water quality models to forecast short-term changes in lake water quality. This will potentially provide a greater window of opportunity over which to make water quality management decisions, and will increase the value of HF monitoring data, ensuring that their potential to guide water quality management is fully realized. This project will promote innovative solutions for water-related challenges across Europe. It will develop, demonstrate and disseminate forecast based adaptive management solutions for two specific water quality threats: nuisance algal blooms and the production disinfection by-products from DOC. The technology demonstrated here has the potential to transform water management and foster the growth of European companies that specialize in adaptive water management and water quality forecasting systems. The project consortium includes expertise from European sites that have been involved in the forefront of HF monitoring systems since the late 1990s, expertise in modelling algal blooms and DOC levels, and expertise in assessing societal benefits from changes in water management.

33. Ami NISHIRI[1], Ulrike Obertegger[2], Federica Camin[2], Leonardo Cerasino[2], Giovanna Flaim[2]

How underground inflow sets the scene in Lake Tovel

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Lake Tovel (Italy) is a small Alpine wind-shielded lake located at 1178 m above sl. The lake is divided into a shallow (~4m) and a larger deep basin (~38m). The source of water to this lake is cold groundwater (GW), upwelling in the littoral zone of the shallow basin. $\delta^{18}O$ (H_2O), -13.2 ‰ indicates that this source originates at ca. 1000m above the lake. The cold inflow (5°C) coupled with solar heating induces a strong thermal stratification in the shallow basin. The $\delta^{18}O$ signal in the deep basin is slightly heavier due to evaporation. High DIN nitrogen levels originate from precipitation and passage in the aquifer saturate inflowing water with respect to calcite but cause under saturation (~75%) with respect to DO. While the lake shows a deep chlorophyll maximum (12-25 m; dissolved oxygen > 100% saturation), dissolved oxygen in the surface is <100% saturation indicating sluggish gas exchange processes.

34. Kristen Dominguez[1], Elista Fisher[2], Lindsay Neitzel[2], Emily NODINE[3], Rebecca Doyle-Morin[2], Evelyn Gaiser[1], and Hilary Swain[4]

Influence of thermal dynamics on phytoplankton and zooplankton structure during the onset of stratification: Spring Blitz at Lake Annie, Florida, USA

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Spring Blitz is a globally-coordinated intensive sampling campaign to study how changes in water column stability influence biological community structure during the onset of stratification. This Global Lake Ecological Observatory Network (GLEON) project employed standard operating procedures at diverse lakes around the globe to examine patterns in the relationship between thermal structure and biological diversity; it is expected that strong thermal stratification promotes biological diversity by creating a heterogeneous physical habitat that provides more ecological niches, as opposed to a homogenous mixed environment conducive to competitive exclusion. Lake Annie, Florida, is a subtropical monomictic lake. In addition to the availability of high temporal resolution (15 min) buoy data, the lake was sampled every four days from early February to early April, 2013, a period of frequent mixing and intermittent stratification, to collect physical data as well as microbial, phytoplankton, and zooplankton communities. Preliminary analyses indicate there was a strong relationship between water column stability over the previous four days and phytoplankton species richness, and in turn, overall zooplankton abundance. These relationships appeared to be strongest early in the spring, and weakened as spring progressed. Zooplankton species richness was relatively constant, but fluctuations in dominance by different functional groups were apparent and will be investigated further. Comparisons with lakes around the world that are dominated by different physical and seasonal/temporal regimes are anticipated.

35. Samantha K. OLIVER[1], Sarah Collins[1], Patricia Soranno[2], Emily H. Stanley[1], Noah Lottig[1], Ty Wagner[3]

Long-term changes in lake nutrient concentrations: Where are we now?

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Despite past reductions in point sources of nutrients, many threats to water quality still exist, including diffuse anthropogenic nutrient loading and climate change. It is unclear if and how lake nutrient concentrations are changing in response to modern stresses. We used total nitrogen (TN) and total phosphorous (TP) records at the sub-continental scale to ask: how have lake nutrient concentrations changed in recent decades, and are TN and TP changing similarly? We used data from Midwest and northeastern U.S. lakes that had at least one TN (833 lakes) or TP (2096 lakes) observation in both halves of our timeframe (1990-2000, 2001-2011). A Bayesian hierarchical analysis revealed that across all lakes, TN declined at a rate of −0.67% per year (95% CRI = −0.90% - −0.46%) and TP did not change (mean = -0.02% per year, 95% CRI = −0.15 - 0.10%). For lakes with both TN and TP records (742 lakes), lake stoichiometry (TN:TP) was not changing (mean = −0.17% per year, 95% CRI = −0.46 – 0.11%), and only 18% of lakes

were changing in one or both nutrients. Our results suggest that recent reductions in lake nutrients are mainly small and limited to nitrogen.

36. Catherine M. O'REILLY[1], Sapna Sharma[2], Derek Gray[3], Stephanie Hampton[4], Jordan Read[5], Simon Hook[6], and John Lenters[7]

Understanding global patterns in lake warming

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Recent syntheses have improved our understanding of the variation in lake warming patterns. Combining both satellite and in-situ datasets allows us to use measurements from both lakes that are large and remote as well as lakes that are small and well-sampled. These syntheses have shown that lakes are warming at a global average of 0.34 degrees C per decade, with many lakes warming faster than air temperatures. Factors such as ice cover, increasing solar radiation, changes in cloud cover, and lake morphology play important roles in lakes warming rates. We are seeking collaborative partners for a new study extending our global lake temperature database and expanding our synthesis of lake warming rates.

37. Rachel M. PILLA[1], Craig E. Williamson[1]

Long-term Patterns in Global Lake Thermal Structure

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This global project extends work by the Global Lake Temperature Collaboration and other GLEON temperature sentinels projects within the Climate Sentinels Working Group by analyzing long-term patterns in temperature profile data from lakes around the world. These data are being used to assess trends in lake thermal structure, with specific focus on deepwater temperatures and thermal stratification. Using one temperature profile per year from each lake's approximate peak thermal stratification, we calculated four metrics of thermal structure: epilimnion temperature, hypolimnion temperature, mean water column temperature, and buoyancy frequency. We analyzed these thermal metrics for long-term changes using non-parametric Mann-Kendall trend tests. Across nearly 100 lakes spanning six continents, we found strong and consistent increases in epilimnion temperatures and strength of thermal stratification, which are generally similar with other studies of lake temperature trends. These trends may be a

response to warming air temperatures, though other factors are also being considered as potential drivers or modifiers of epilimnion temperature, such as precipitation, water clarity, and lake size. We found much more variable changes in hypolimnion and mean water column temperatures across lakes, as nearly half of lakes had cooling hypolimnion and/or mean water column temperatures. Further, changes in hypolimnion temperature do not necessarily mimic changes in epilimnion temperature in a lake, indicating within-lake characteristic(s) such as water clarity influence the response of hypolimnion temperature. This also suggests a more complex response of deeper water temperatures, which may be influenced by a range of lake-specific geomorphic, limnological, and/or climate-related variables.

38. Christian PREILER

The role of acidity in the measurement of particulate and total phosphorus

WasserCluster – Biologische Station Lunz GmbH

Detection of phosphorus as molybdenum blue is a conventional method in water analytics. Due to its sensitivity it is widely used in manual and automated methods.

Both, reaction time and final absorbance were found to be fundamentally influenced by the ratio of acid to molybdate. A surplus of acid leads to slow and incomplete colour formation, while too little acid causes self-reduction of molybdate which results in biased absorbance signals.
As the method can only detect PO4, for measurement of POP and TP, all phosphorus compounds must be transformed into PO4 prior to measurement. The digestion procedures involved in the measurement of TP and POP typically employ a combination of acid, oxidant and heat to break up polyphosphates and organically bound phosphorus. Preservation of samples can be another reason to introduce acid. Acidic samples cause delayed signal development which increases the overall duration of sampling processing. Moreover, incomplete reactions will result in reduced analytical sensitivity and precision.

To compensate for acid introduced with the digested sample, the acid concentration of reagent solutions should be adjusted accordingly. I present experimental data to illustrate the role of the acid : molybdate ratio on the duration and precision of the molybdenum blue method.

39. Theresa Lumpi[1,2], Karin Meisterl[1,2], Christian Preiler[1], Julia Birtel[3], Blake Matthews[3], Robert PTACNIK[1]

Phytoplankton diversity in Alpine lakes – gradients along altitude and longitude

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Alpine lakes are important elements in the landscape. Being distinct systems, they are very suitable for testing the role of spatial factors versus local environment as predictor of community assembly. In context of the debate about dispersal limitation in microscopic organisms, we analyze phytoplankton diversity in the Alpine region.

59 lakes were sampled in Switzerland, Germany and Austria spanning a longitudinal distance of 650 km. Lakes ranged from oligotrophic to mesotrophic conditions, and were located from 400 to 1600 m above sea level. Our analysis shows that lake productivity is a dominant factor for phytoplankton community composition in those lakes. Moreover, multivariate analysis revealed longitude as an important geographic predictor. Altitude, on the other hand, did not contribute much to community composition though lakes spanned a 1000 m gradient in altitude.

40. Martin SCHMID[1]

Can trends of lake surface water temperature be reliably estimated from monthly data?

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Lake monitoring, including temperature profiling, is often done once every month. This is also the case for many Swiss lakes, where sometimes even the monthly schedule is questioned with the aim to reduce monitoring costs. However, both the global lake surface temperature (LST) data recently published by O'Reilly et al. (2015) and a detailed combined modelling and data analysis for Lake Zurich indicate that the robustness of LST trend estimates decreases with decreasing sampling frequency, and that monthly sampling is hardly sufficient to reliably estimate annual and even less seasonal LST trends over three decades.

41. Anne E. SCOFIELD[1,4], James M. Watkins[1], Brian C. Weidel[2], Fred J. Luckey[3], and Lars G. Rudstam[1]

Drivers of deep chlorophyll layer (DCL) formation in Lake Ontario during 2013: Potential importance of metalimnetic production in a restructured ecosystem.

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Production in the offshore waters in Lake Ontario and other Great Lakes has declined leading to questions about the sustainability of the salmonid-alewife based food web and about the potential for restoration of native coregonids in Lake Ontario. However, there may have been an increase in the relative importance of the deep chlorophyll layer (DCL) leading us to question the extent of the decline in overall offshore productivity. During 2013, we investigated the temporal and spatial extent of the DCL during several lakewide surveys and using more intensive surveys along a nearshore-offshore transect out of Oswego, NY. The DCL was prevalent across the lake in July, dissipated in the eastern section in August and through most of the lake in September. During these times, peak chlorophyll in the DCL was 2 to 3 times higher than chlorophyll concentrations in the epilimnion. The depth of the DCL was highly correlated with the depth of the thermocline and the depth of the nitrate and silica nutriclines. The amount of chlorophyll a in the DCL was higher when the photic zone was deeper than the depth of the mixed layer. The DCL chlorophyll was correlated spatially with peaks in the beam attenuation and oxygen maxima, indicating that the DCL represents a biomass maximum that is productive. Diatoms were the main component of the DCL based on limited microscopy and more extensive fluoroprobe profiles.

42. Facundo SCORDO[1,2], Vanesa Perillo[3], Mike Lavander[4], Carina Seitz[1,5], Andrea S. Brendel[1,2]

Preliminary results: Implementing the Seasonal Water Yield model (INVEST NAT-CAP) for three different watersheds across the Americas
The impact of GLEON fellowship program on SAFER student work experience

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Global climate change is expected to have different impacts across the Americas. Understanding seasonal water flows in watersheds, in particular the partitioning between quick flow (occurring during or shortly after rain events) and base flow (slow release flow occurring during dry weather), improves our ability to more accurately assess the risk of flooding or drought events within a watershed. The objective of this study is to evaluate three geographically distinct watersheds across the Americas (Muskoka River (Canada), Winooski River (USA) and Alto Senguer River (Argentina) for risk of droughts or flooding. To answer this question, the INVEST NAT-CAP "Seasonal Water Yield model" (http://www.naturalcapitalproject.org/invest) was used to calculate quick flow and base flow in each watershed under current climatic conditions. Finally, the proportion of total flow (QF + BF) that was QF and BF was calculated using the ArcGIS 10.2 raster calculator tool. Our hypothesis is that a watershed with a lower quick flow (QF) proportion [QFp = (QF / (QF + BF)] compared to its base flow (BF) proportion [BFp = (BF / (QF + BF)], in current conditions is more resilient to changes in future conditions (QFp < BFp = more resilient). Those watersheds that have a similar QFp and BFp could be facing two different problems. Watersheds with high QF and BF will be threatened by floods while those

with low QF and BF, will be threatened by drought. The results in this study show that the Winooski watershed, despite having high QF values, has a lower QFp versus BFp. Thus, it has a low risk of water driven problems (floods or droughts). The Muskoka watershed presented high QFp, especially in the area surrounding water bodies. This watershed could be facing flooding risk if precipitation increases in this zone, as is predicted by the IPCC models. On the contrary, the Senguer watershed, despite having low values of QF, presented the largest area with high QFp. Most of the precipitation quickly turns into QF or is evapotranspirated, with little precipitation becoming BF. This watershed could be facing drought issues if precipitation decreases and the temperatures increase in this area, as is predicted by the IPCC models.

43. Ian McCullough[1], Kaitlin Farrell[2], Facundo SCORDO[3], Ana Morales-Williams[4], Derek Roberts[5], Zutao Yang[6], Hilary Dugan[7,8], Paul Hanson[7], Sarah Bartlett[9], Samantha Burke[10], Jonathan Doubek[11], Flora Krivak-Tetley[12], Nicholas Skaff[6], Jamie Summers[13], Grace Hong[14] and Kathleen Weathers[8]

Source or sink? Integrating biogeochemical, trophic, and landscape processes to model lake carbon budgets

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For years, the role of inland waters in global carbon budgets has been largely ignored, and only relatively recently has it been recognized that lakes actively process rather than simply transport terrestrially-derived organic carbon (OC). This recognition has brought forward the larger question: are lakes sources or sinks of OC? To date, most studies that have modeled OC budgets (i.e., mass balances) have focused on a single lake over a relatively short time period. Further, few effectively incorporated the full suite of ecologically relevant drivers of OC, which include surface and groundwater inflows, sedimentation, and net primary production. We are developing a dynamic, process-based OC mass balance model that incorporates these processes and applying it to six well-studied lakes in the United States, Canada, and Sweden. Our focal lakes vary widely in climate, productivity, morphometry, hydrology, and watershed composition, which permit us to ask the broad question: how do lake carbon budgets change along environmental

gradients? Although model results are preliminary, we have found that lakes fluctuate as net OC sources and sinks and that the overall carbon budgets of some lakes appear more stable than others. Ongoing work will continue to investigate 1) principal drivers of OC budgets across these six lakes, 2) the sensitivity of key drivers to climate and land use changes, and 3) how these six case studies can be used to advance our knowledge of the broader role of lakes in global OC cycling.

44. Carina SEITZ[1,2], Alejandro J. Vitale1[2], Gerardo M.E. Perillo[1,2], M. Cintia Piccolo[1,2]

Bathymetry and morphometry of Pampean shallow lakes: an approach to the origin and productivity[a,b,c]

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[b]Project SAFER funded by IAI and NSF
[c]Project PICT 2012-1065

Lake productivity is determined by three principal factors, lake morphology, climatic conditions and watershed's soil characteristic. In this study, the morphometric characteristic of two Pampean shallow lakes is analyzed. La Salada (39°27'45.27"S - 62°42'10.89"W) and La Barrancosa (37°20'13.17"S - 60° 6'33.95"W) are located in the Buenos Aires Province, Argentina. The objectives were: determine the origin of these shallow lakes based on morphometric characteristic related with regional geomorphology; analyze the dynamics between the morphometric characteristics and the external and internal factors (climatic variability, wind, etc; suspended solids, zonation, etc.); to analyze how slight differences in morphometry drives different responses in these shallow lakes which have a similar origin.

A bathymetry was made using an open source acoustic profiler installed over an autonomous small boat. The track and the acoustic profiler were recorded at 5 Hz. The bathymetric maps and morphometric analyses were made using GIS software. The morphometric analyses were made following the Hakånson (1981, 2004, 2012), Timms (1992), and Contreras (2011) criteria. The morphometric parameters indicate an eolic origin for both shallow lakes. The Barrancosa's mean depth euphotic zone is lower than La Salada. Despite this, Barrancosa is less affected by the resuspension of sediment than La Salada. The study shows that the morphologic factor is responsible for changes these shallow lakes. The results show that small depth changes could affect the ET- area and consequently the lake productivity.

45. Margot SEPP[1], Toomas Kõiv[1], Peeter Nõges[1], and Tiina Nõges[1]

Metrics of Organic Matter in the European Union Lake Monitoring

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Organic matter (OM) has numerous geochemical and ecological functions in inland waters and can affect water quality. Its content has been increasing in surface waters of the Northern Hemisphere and is expected to increase onward due to changes in climate and land cover. Organic substances have complex molecular composition and their determination is hence complicated. Aquatic OM is measured with many different methods as no single analytical tool can provide definitive structural or functional information about it. In the European Union (EU) Water Framework Directive (WFD), metrics of OM are not mandatory physico-chemical parameters, but only recommended parameters for transparency, oxygenation conditions or acidification status. Lake OM is monitored under the WFD in 15 European countries, applied parameters are biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), absorbance and water colour. Monitoring programmes should include methods that determine the properties of OM (e.g. absorbance or fluorescence spectroscopy) in addition to methods that measure its content (e.g. COD, TOC). Automatic stations for continuous measurements and remote sensing could improve the temporal and spatial representativeness of lake OM monitoring. Reliable measurement of OM is necessary to obtain an integrated view on the distribution and availability of OM in lakes and to investigate its response to climate change and the overall effect on the global carbon cycle.

46. Justyna SIEŃSKA[1], and Julita A. Dunalska[1]

Mineral aggregates as a potential material for phosphate removal – experimental study

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Existing methods of limiting the amount of phosphorus are executed by cutting off the wastewater or the introduction of expensive chemical methods. An alternative method of removing phosphate may be the sorption on natural mineral aggregates, therefore, the aim of the study was assessment the effectiveness of accumulation phosphate by the natural mineral aggregate from the group of carbonates and aluminosilicates. The study was carried out in static conditions at 10°C and 20°C. Among the group of carbonates the reduction of phosphate was obtained: 76%-calcite I, 86%-calcite II, 25%-dolomite I, 36%-dolomite II. Higher temperature (20ºC) increased the effectiveness of the process of phosphate removal (91%-calcite I, 98%-calcite II, 39%-dolomite I, 95%-dolomite II). Among the group aluminosilicate the highest efficiency was obtained after using LECA: 79%-LECA I and 94%-LECA II (in 10ºC), 81%-LECA I and 99%-LECA II (in 20ºC). Three times less reduction of phosphate was obtained after using zeolite 22% and 33%. The study has showed that the largest reduction of phosphate was obtained after using calcite II and LECA II, what was probably connected with higher content of Ca, Mg, Al and Fe in the chemical composition of mineral aggregate.

47. Karen Baumert[1], Robyn SMYTH[1], Lisa Borre[2], Melanie Perello[3], Sarah Bartlett[4], Chelsea Weirich[4], and Jennifer Klug[5]

State of the Lakes: A survey of lake researchers, managers, and stakeholders affiliated with GLEON

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An online survey about the threats and management of lakes was distributed to GLEON members and affiliates in January 2016 yielding data from 167 individuals covering 148 lakes across all continents but Antarctica. Climate change, eutrophication, invasive species, and harmful algal blooms were the most commonly reported threats to these lakes. Other threats (e.g., pathogens, bioaccumulating pollutants, over-extraction of water) were reported at lower rates but with greater uncertainty. With respect to trends, most of the identified threats are reportedly staying the same, except for harmful algal blooms, which are reportedly getting worse in 52% of the lakes where they currently occur. The results from this survey are compared to a previous study, the Lake Basin Management Initiative (2005), to gain insight about how the threats facing lakes are changing at a global scale. Climate change is perceived to be a threat at a substantial higher rate in this study compared to the LBMI study (79% (117 lakes) for this study vs. 25% (7 lakes) in prior study). We also found climate change was more of a concern for students (100%) and scientists (87%) than for lake managers (70%) and stakeholders (58%). This gap suggests a need for further outreach on the threat climate change poses to lake ecosystems.

48. Marie-Caroline TIFFAY[1], Bastiaan W. Ibelings[1]

Fine-scale mixing processes and resources gradients promote phytoplankton coexistence and biodiversity in peri-alpine lakes

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Understanding the processes that govern the diversity of biological communities has always been a fundamental challenge in ecology and even more nowadays in light of anthropogenic impacts on biodiversity and ecosystem services. In deep (peri)-alpine lakes, an increase of the water column stability has been observed due to climate warming enhancing lake heterogeneity. A key question, formulated in 1961 by Hutchinson in his paper “The paradox of the plankton” is what allows phytoplankton species to coexist in the face of strong competitive exclusion and what are the processes that maintain biodiversity? We focus in this project on one of the self-evident solutions to the paradox, i.e. that lakes are not the unstructured isotropic environments of Hutchinson`s seminal paper but are complex environments. In the water column, the contrast

between the epilimnion and the metalimnion is of interest as the physical conditions are clearly different and select for distinct phytoplankton communities. The phytoplankton studies considered in this project aim to collect high quality data on the reorganization of lake phytoplankton communities on small scale resource gradients in response to fine scale mixing processes in the water column, employing specifically designed Autonomous Underwater Vehicle and a 3D phytoplankton microsampler. Through these detailed field studies, we will then test the prediction that a more heterogeneous lake environment, resulting from climate warming, allows more detailed niche partitioning leading to enhanced coexistence of phytoplankton species.

49. Jeng-Wei TSAI[1], Chih-Yu Chiu[2], Tim Kratz[3], Jim Rusak[4,5], Hou-Chi Lin[2], Jones Jack[6], Wan-Yu Shih[7]

Precipitation patterns alter inter-annual variations in carbon fluxes in two trophic-contrasting, shallow lakes in subtropical Taiwan

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Lentic freshwater ecosystems are important contributors to regional carbon cycling and storage. They are sentinels to climate/environmental changes because they respond rapidly to changes in meteorology, hydrology and various external inputs. Lakes in subtropical Asia are expected to be vulnerable to climate changes, because they are relatively small, shallow and regularly experience intensive monsoons and typhoons. Aim of this study was to investigate how the variation of annual precipitation pattern affects the inter-annual variation in carbon fluxes in two trophic-contrasting subtropical lakes. Instrumented buoys were deployed to record free-water DO dynamics, water temperature profiles and meteorological measurements during the study course (2009-2010 and 2014-2015), which we used to estimate daily values of GPP, R, and CO_2 emission. Results show that annual droughts (2014) initially push lakes toward more autotrophic, but then shifted them to heterotrophy and be stronger CO_2 emitters in the following normal year (2015). Responses of carbon fluxes were more sensitive in the mesotrophic clear lake due to the stronger fluctuations of tDOM in correspond to annual precipitation changes. Results support our hypothesis that the tDOM acts as an effective mediator of the changing annual precipitations on lake C fluxes via altering the interaction between waterborne nutrient level, light variability, and thus liable organic materials productions and ecosystem respirations. This study contributes to the assessment of the role of

subtropical lakes play in regional carbon cycling and the prediction for the trend, magnitude and sensitivity of their response to climate changes.

50. Chaturangi WICKRAMARATNE[1], Anna Rigosi[1], David P. Hamilton[3], Leon van der Linden[1,2], Matthew R. Hipsey[4], Justin D. Brookes[1]

Varying responses of two lakes with different trophic status to effects of warming and nutrient loading

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Climate change and eutrophication remain global problems that continue to threat water quality. A 1-dimensional hydrodynamic model (General Lake Model) coupled with a biogeochemical model (Framework for Aquatic Biogeochemical Model) was used to study the impacts of increasing temperatures and modified nutrient loads on water quality, especially in relation to nuisance phytoplankton blooms. Eutrophic Mt Bold reservoir from South Australia and oligotrophic Lake Tarawera from New Zealand were used as study sites to determine the variation in responses to climate change and modified nutrient regimes as influenced by the trophic status. A matrix of scenarios under different nutrient status as controlled by both increasing and decreasing nutrient loads under rising temperatures (1-4 °C) was tested to determine the nutrient loading schemes that can offset the predicted negative impacts of climate change. Increase in nutrients had the most severe impact on the oligotrophic lake, resulting in a three-fold increase in phytoplankton biomass while the eutrophic reservoir observed a two-fold increase under both increased nutrients and temperature rise. The results showed a high sensitivity of oligotrophic lakes to nutrients and high sensitivity of eutrophic lakes to both high temperatures and nutrients. Nutrient or trophic status of lakes was found to play a key role in determining the detrimental effects of climate change and oligotrophic lakes are more resilient to the impacts of rising temperatures. Results highlighted the great challenge climate change poses for lake managers if nutrient inputs are not reduced substantially from present day values, with the possibility of traditional lake restoration techniques having to be enforced at higher intensity, and more frequently, in order to be successful under a future climate with higher air temperatures.