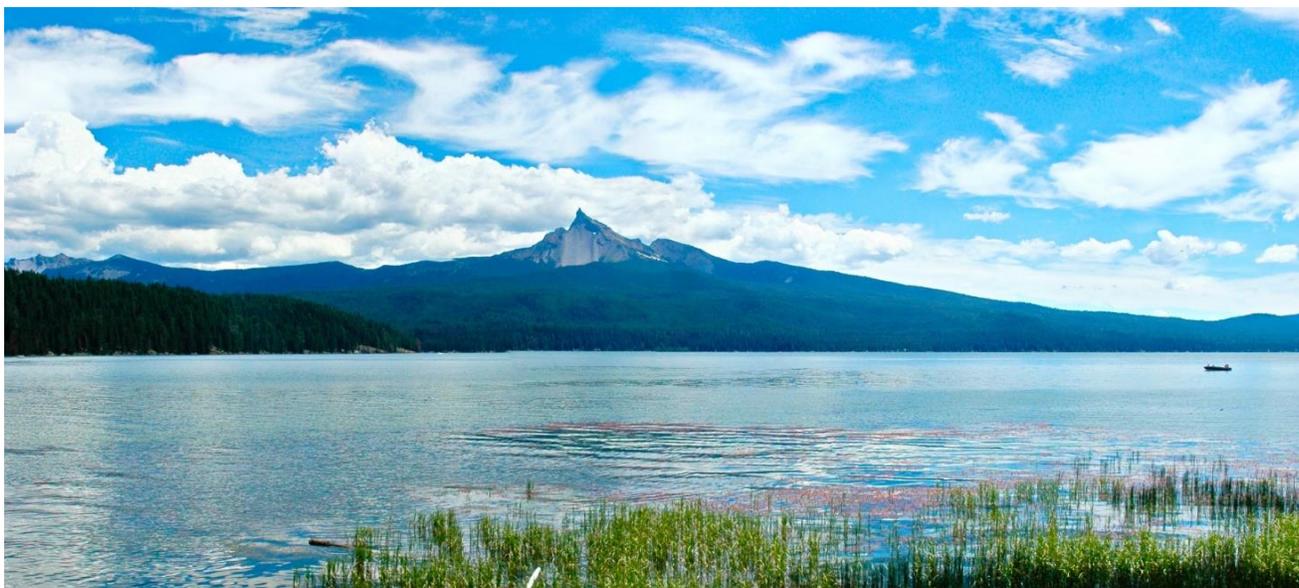


Oregon Lakes Association

2019 Conference

High Desert and Mountain Lakes of Oregon

October 25-26 at the Riverhouse on the Deschutes in Bend, Oregon



Diamond Lake and Lake Abert photos by Ron Larson

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| Friday October 25, 2019 | | |
|--------------------------------|---|---|
| 12:00 | Registration – Deschutes South at the Riverhouse | |
| Moderator: Ron Larson | 1:00 | Welcome and announcements Theo Dreher, OLA President, Oregon State University |
| | 1:05 | Outstanding Waters of Oregon: Waldo and Crater Lakes Debra Sturdevant, Oregon Department of Environmental Quality |
| | 1:25 | Replacement of a unique population of newts (<i>Taricha granulosa mazamae</i>) by introduced signal crayfish (<i>Pacifastacus leniusculus</i>) in Crater Lake, Oregon Scott Girdner, Crater Lake National Park |
| | 1:45 | Simulation of deep ventilation and ecological effects in Crater Lake, OR, 1951-2099 Susan Wherry ¹ , <u>Tamara Wood</u> ¹ , Sebastiano Piccolroaz ² , and Scott Girdner ³ ¹ USGS Oregon Water Science Center, ² University of Trento; ³ National Park Service, Crater Lake National Park |
| | 2:05 | Recent Ecological Conditions at Lake Abert, Oregon’s only Hypersaline Lake Ron Larson, Oregon Lakes Association |
| | 2:25 | Lake Abert: Recent Citizen-Science Data from a Globally-Important Waterbird John Reuland ¹ and <u>Ron Larson</u> ² . ¹ East Cascades Audubon Society, ² OR Lakes Association |
| 2:45 | Poster viewing break with light snacks | |
| Moderator: Theo Dreher | 3:15 | Legislative action on CyanoHABs Jack Zika, Oregon State Representative (District 53) |
| | 3:25 | Addressing the Third Rail for Control of Cyanobacteria Harmful Algae Blooms (cyanoHABs): Getting Serious About Remediation Wayne W. Carmichael, Professor Emeritus Wright State University and Board Member Oregon Lakes Association |
| | 3:45 | Searching for solutions to the HAB at Ross Island Lagoon Desiree Tullos, Oregon State University |
| | 4:05 | Using direct genome DNA sequencing of CyanoHAB lake samples to better understand Pacific NW blooms <u>Theo W Dreher</u> and Ryan S Mueller, Oregon State University |
| | 4:25 | Testing a new method for early detection of harmful algal blooms in Oregon lakes and reservoirs <u>Daniel J. Sobota</u> ¹ , Victoria Avalos ² , Steve Hanson ¹ , Brian Fulfroost ¹ , Smita Mehta ¹ , Sam Doak ¹ , and Lara Jansen ² ¹ Oregon Department of Environmental Quality, ² Portland State University |
| 4:45 | Ecological Design Approach to Lake Health and Algae Control, Hydraulic Flushing Manipulation and Floating Islands for Golden Alga and HAB Control Jonathan Todd, Floating Islands West, LLC | |
| 5:05 | Break - Head to 10 Barrel Brewing at 62950 NE 18th St, Bend, OR 97701 ** Space is limited and separate registration is required ** | |
| 6:00 | Ecosystem Function and Water Management in the Upper Deschutes River Basin Jason Gritzner, U.S Forest Service and Jennifer O’Reilly, U.S Fish and Wildlife | |

| Saturday, October 26, 2019 | | |
|-----------------------------------|----------------------------|---|
| | 7:00 | Continental Breakfast – Deschutes South at the Riverhouse |
| Moderator: Rich Miller | 8:00 (during breakfast) | Welcome and funding raising efforts, announcements, board elections, scholarship winner, awards Theo Dreher (OLA President), Oregon State University and OLA Board Members |
| | 8:30 | Oregon's Vision for 100-year Water Plan Theo Dreher, Oregon State University |
| | 8:45 | Collins Bay after six years of herbicide treatment for <i>Ludwigia</i> - what comes next? <u>Laura Brown</u> ¹ , Rich Miller ² , and Kurt Carpenter ³ ¹ Benton Soil and Water Conservation District, ² Portland State University, ³ US Geological Survey |
| | 9:05 | Lake and River Drawdown Use of Herbicides for Aquatic Plant Management David Kluttz, Lakeland Restoration Services |
| | 9:25 | Status and Trends of Detroit Lake Water Quality Norman Buccola and Margaret Kennedy, U.S. Army Corps of Engineers |
| | 9:45 | Enhanced Water Quality Monitoring in the North Santiam and McKenzie Rivers to Support Dam Operations and Drinking Water Management <u>Kurt Carpenter</u> ¹ , <u>Micelis Doyle</u> ¹ , <u>Holly Bellringer</u> ² , <u>Norman Buccola</u> ² , <u>Brandin Hilbrandt</u> ³ , <u>Lacey Goeress-Priest</u> ³ , <u>David Donahue</u> ⁴ , and <u>Karl Morgenstern</u> ⁴ . ¹ USGS Oregon Water Science Center, ² US Army Corp of Engineers, Portland District, ³ City of Salem, Public Works Department, ⁴ Eugene Water and Electric Board |
| | 10:05 | Poster viewing break with light snacks |
| Moderator: Wayne Carmichael | 10:25 | Hydrodynamic and Water Quality Response to Changes in the Outlet Structure for Lake Billy Chinook, Oregon <u>Joe Eilers</u> , Max Depth Aquatics and Kellie Vache, Oregon State University |
| | 10:45 | Diet reconstruction of juvenile suckers of Upper Klamath Lake using fatty acids as biomarkers <u>Julie B. Schram</u> ¹ , <u>Michael T. Brett</u> ² , <u>Jens Nielsen</u> ³ , and <u>Aaron Galloway</u> ⁴ ¹ University of Oregon; ² University of Washington; ³ National Oceanic & Atmospheric Administration, Seattle; ⁴ Oregon Institute of Marine Biology. |
| | 11:05 | Using Fatty Acid Biomarkers to untangle trophic pathways in hypereutrophic Upper Klamath Lake <u>Michael T. Brett</u> ¹ , <u>Julie Schram</u> ² , <u>Jens Nielsen</u> ³ , and <u>Aaron Galloway</u> ⁴ ¹ University of Washington; ² University of Oregon; ³ National Oceanic & Atmospheric Administration, Seattle; ⁴ Oregon Institute of Marine Biology. |
| | 11:25 | Patterns of genetic diversity in lakes of the Columbia Basin Project <u>Crysta Gantz</u> ¹ and <u>Angela Strecker</u> ² ¹ Portland State University, ² Western Washington University |
| | 11:45 | The impact of urbanization on water quality and ecosystem services provided by a major urban lake Laura Costadone and Mark Sytsma, Portland State University |
| | 12:05 | Lunch buffet and depart for field trip |

POSTER ABSTRACTS
(listed alphabetically by first author's last name)

Preliminary results and assessment of satellite data and real-time data for monitoring and detecting Harmful Algal Blooms in Oregon Lakes and Reservoirs

Victoria Avalos^{*1}, Daniel J. Sobota², Steve Hanson², Brian Fulfroost², Smita Mehta², Sam Doak², Lara Jansen^{*1}

¹Portland State University; ²OR Dept. of Environmental Quality; *Student; email contact: vavalos@pdx.edu

The current approach to Harmful Algal Blooms (HABs) in Oregon is a reactive approach, but with an increasing threat of HAB events producing cyanotoxins in drinking water supplies there is a greater emphasis being placed on understanding and predicting HABs. For my Master of Science research project, high frequency data collected from sondes in two Oregon lakes, Odell Lake and Crescent Lake, as well as weekly grab samples for cell enumeration are used to 1) perform a field verification of satellite derived cyanobacteria cell counts and eventually 2) apply techniques for HAB early warning signals that have been successfully used in Michigan Lakes (Wilkinson et al. 2018). My research aims to implement this warning system in Oregon lakes by calibrating the algorithm to be used with satellite data or the Cyanobacteria Assessment Network (CyAN) application. CyAN is an EPA developed android mobile application that can tell the user cyanobacteria cell counts in water bodies across the nation, with 55 resolvable lakes in Oregon. The preliminary results show the field verification process of CyAN will in situ cell counts in order to show the viability of using CyAN for Oregon lake management. If the CyAN app can be calibrated to be used with an early warning detection method, it will cause a shift from reactive to proactive HAB approaches. If successful, this study will offer lake managers a cost effective way to predict when a bloom will occur. This will give lake managers and other concerned stakeholders the ability to post advisories and provide educational material to lake-goers. Since CyAN is a free application, this would be useful for lakes and lake managers who do not have financial resources to perform cell counts or toxin analysis

Using Mesocosms to Monitor the Effects of Cyanobacteria Blooms on the Growth, Health, and Survival of Juvenile Endangered Suckers in Upper Klamath Lake

Summer M. Burdick¹, Danielle M. Hereford², Nathan V. Banet³, and Barbara A. Martin¹

¹U. S. Geological Survey, Western Fisheries Research Center, ²U. S. Bureau of Reclamation, Klamath Basin Area Office, ³Idaho Fish and Game, email contact: sburdick@usgs.gov

Unsustainably high mortality within the first two years of life prevents endangered Lost River suckers (*Deltistes luxatus*) in Upper Klamath Lake, Oregon, from recruiting to spawning populations. Massive blooms of the cyanobacterium *Aphanizomenon flos-aquae* and their subsequent death and decay in Upper Klamath Lake are associated with high pH, low oxygen saturation, high total ammonia concentrations, and spikes in the cyanotoxin microcystin. Poor water quality within Upper Klamath Lake is considered the most likely cause of juvenile sucker mortality, but mechanisms causing high mortality are not known. We introduced PIT-tagged age 1 Lost Rivers suckers to three mesocosms in Upper Klamath Lake to determine the timing of juvenile sucker mortality relative to environmental conditions. Sucker mortality was inferred from a lack of movement detected on remote PIT tag detection equipment located at three depths within each mesocosm. We recorded pH, temperature, and dissolved oxygen hourly near the benthos and surface. We also compared hazard rates to weekly concentrations of total and un-ionized ammonia and microcystins, sampled within mesocosms. Lower mean daily pH and temperature, that occurred after the death of cyanobacteria, were most correlated with high hazard rates. Mortality did not occur during periods of hypoxia, but hypoxia preceded periods of higher mortality at two of three sites. Mortality occurred over a protracted time and moribund fish showed signs of prolonged stress including infestations of *Ichthyobodo* sp..

Relationships between volatile organic compounds and harmful algal blooms: Can VOCs be used as time-sensitive and economical means for predicting bloom dynamics?

Lindsay Collart and Kimberly Halsey, Oregon State University, email contact: collartl@oregonstate.edu

Cyanobacteria harmful algal blooms (cyanoHABs) have a myriad of negative effects on aquatic ecology, the availability of potable and agricultural water, and the economy and health of humans surrounding these affected systems. However, the aerial environment is neglected in a majority of studies, including the volatile organic compounds (VOCs) produced during cyanoHAB events. Previous studies have suggested that VOCs produced by cyanobacteria can inhibit growth of competing organisms and decrease the potability and recreational potential of waterways. These results suggest that VOCs have complex roles in cyanoHAB ecology, but studies so far have been limited to a handful of VOCs and have not applied a temporal dimension to their practice. Here, we present first results from a two-year exploratory project that used grab-samples and cultured isolates from Upper Klamath Lake (UKL), OR and its southern irrigation canals collected between May and December in 2018 and 2019. The VOCs present in each sample were measured by proton-transfer reaction mass spectrometry, and community composition will be determined by sequencing. We are applying deep learning algorithms to analyze these data and associated environmental parameters to address two main questions: (1) Can VOC patterns be identified that predict bloom composition and succession dynamics, and (2) Can the resultant VOC patterns be used to monitor cyanoHAB development and toxicity? Preliminary data show strong correlations exist between VOCs present in UKL samples and toxin trajectories over time. These results support the idea that VOCs detected by automated sensors could provide early warning of toxic events and be used to protect the public and prevent unnecessary economic hardships associated with cyanoHABs.

Lake sediment core analysis dates the expansion of anatoxin-producing Anabaena/Dolichospermum in Anderson Lake, WA

Theo W. Dreher¹, Rolf Vinebrooke², and William Hobbs³

¹Oregon State University, ²University of Alberta, and ³WA Dept. of Ecology; email contact: theo.dreher@regonstate.edu

Anderson Lake is a 25 ha lake with mean depth of 3.7 m situated in a semi-rural setting. Land adjacent to the lake was developed for agricultural use in the early 1900s until it became a state park in ~ 1970. The lake has suffered cyanobacterial blooms since monitoring began in 2006. Anatoxin-a levels over 100 µg/L have been recorded many times and result in closure of the lake every summer; microcystins are sometimes also detected. *Anabaena/Dolichospermum* sp. WA102 has been identified as the anatoxin-a producer (Brown et al., 2016). In order to determine when cyanobacteria and anatoxin-a production became established in Anderson Lake, we analyzed a 73-cm long sediment core sample taken from the deepest point of the lake, spanning the period 2018 to the early 1700's. Pigment analysis by HPLC indicated that cyanobacteria have been present since the 1700's, but the highest flux occurred during the farming years. On the other hand, droplet-digital QPCR (ddPCR) analysis of DNA extracted from core slices showed a steep increase in cyanobacterial 16S rDNA after about 1970. Genes for anatoxin-a (*anaF*) and microcystin (*mcyE*) synthesis were detected by ddPCR, from the 1980 core slice in the case of *anaF* and at a lower level and since 1987 for *mcyE*. Based on the ratio of *anaF* to cyanobacterial 16S gene copies, the representation of anatoxin-a biosynthetic capacity increased since 1995, intensifying since 2000. This increase was also detected by 16S rDNA amplicon deep sequencing detection of *Anabaena/Dolichospermum* WA102, the extant anatoxin-a producer. Metagenome analysis of the 1995 core slice detected multiple reads corresponding to this genome, showing that *Anabaena/Dolichospermum* WA102 has been present in Anderson Lake since 1995.

Endemic annelids in two Oregon lakes

Steve Fend, Jim Carter, email contact: stevenfend@gmail.com

Although annelids may be a dominant component of lake benthos, there is little information on their occurrence and ecological function in Oregon lakes. This is largely due to difficulties in sampling and identification: they are fragile animals, and careful microscopy is required for species identification. Recent collections from two lakes in eastern Oregon (Upper Klamath Lake and Lake Abert) indicate an unusual and possibly endemic annelid fauna. The benthic invertebrates of Upper Klamath Lake have been sampled extensively in multiple studies, and the combined annelid counts (oligochaetes, leeches and the polychaete *Manayunkia* sp.) make up well over half of the macroinvertebrate density and biomass (Hazel 1969, Kuwabara et al. 2016, Stauffer-Olsen 2017). Among the more common oligochaetes, *Rhynchelmis klamathensis* and undescribed species of *Varichaetadrilus* and *Altmanella* may be endemic to the lake. Some of the common leeches (*Helobdella bowermani* and at least one other undescribed *Helobdella* species) may also be endemic. More limited sampling in saline Lake Abert (Herbst et al. 2012) has produced a single new oligochaete species that can probably be assigned to *Monopylephorus*, a genus associated with marine and estuarine habitats. The latter species has also been collected in saline lakes in Nevada; however, it does not appear in collections of *Monopylephorus* from the Pacific Coast.

Examining the drivers of harmful algal blooms-phosphorus and temperature in Cascade lakes in Oregon

Lara Jansen*¹, Angela Strecker², Kelly Gleason¹, Daniel J. Sobota³

¹Portland State University; ²Western Washington University; ³OR Dept. of Environmental Quality; * Student; email contact: ljansen@pdx.edu

High elevation-lakes are often exposed to increasing atmospheric deposition of nutrients due to surrounding industry, and in combination with rising temperatures due to a changing climate, harmful algal blooms may become more prevalent. With warm stable water and high phosphorus, bloom-forming as well as toxin-producing algae like cyanobacteria can dominate. In the Cascade Range of Oregon, many lakes are experiencing such algal blooms, but the key physical and biological factors are not well understood. The objective of our study was to quantify the natural variation of phosphorus and temperature of these mountain lakes to ultimately test if relatively higher levels of phosphorus and temperatures correlate with increasing incidences of blooms. First, we conducted a binary regression tree on pre-existing data to select lakes across a phosphorus gradient, accounting for elevation, lake size and fish stocking records. The regression showed very large lakes (>470 ha) tend to have higher phosphorus levels on average and cluster separately from smaller lakes, regardless of elevation. Small lakes (<89 ha) that are located above 4,817 ft had the lowest phosphorus levels. A survey of 29 lakes across the Cascade Range across gradients of phosphorus and elevation was conducted this summer, measuring phosphorus concentrations and temperature along with other water quality parameters. A binary regression tree was used again on the new data to see how lakes may have possibly shifted since in phosphorus levels. A similar, but separate analysis was conducted on average surface temperatures. A preliminary analysis on the relationship of phosphorus and temperature with algal blooms was a mixed effect linear model, using chlorophyll-a densities as a proxy of algal biomass.

Re-examining Shoreline Elevations at Ancient Lake Chewaucan in Central Oregon, USA

Brianna Kendrick, Pat McDowell, University of Oregon, email contact: bkendric@uoregon.edu

The Chewaucan Basin in Eastern Oregon provides a unique environment for pluvial lake geomorphology research, as lake oscillations in the last 30,000 years have formed shoreline features that wrap around the basin. Over the last century, multiple scholars have published works describing shorelines of the ancient lakes using various elevation data collection methods, including USGS topographic maps, Digital Elevation Models,

and survey equipment. By revisiting accessible shoreline sites and measuring elevations using a TopCon RTK GPS I found that topographic maps vary between 0.2 and 11 meters off and Digital Elevation Models, which are developed using the historical topographic maps, vary in accuracy between 2.5 and 12.25 meters, when compared to the TopCon measurements. These discrepancies reveal that historical elevation data needs to be evaluated when studying the geomorphology and other issues in the basin.

Early detection and monitoring of invasive aquatic plants in Oregon.

Rich Miller and Mark Sytsma, Portland State University, email contact: richm@pdx.edu

Dense growth of invasive aquatic plants (IAPs) in our lakes and reservoirs often leads to fewer native aquatic plant species, degraded water quality, sediment accretion, poor wildlife habitat, impaired recreation, and decreased property values. Because of these impacts, the Oregon Department of Agriculture's (ODA) Noxious Weed Control Program funded the Center for Lakes and Reservoir (CLR) to conduct early detection and monitoring surveys and train citizen volunteers to detect and report IAPs. Early detection of new infestations provides more effective, and often less expensive opportunities for weed management. ODA's program included 23 aquatic plant species that have been determined to be the greatest public menace and are top priorities for action by weed control programs. Examples of early detection and monitoring efforts include those targeted on flowering rush (*Butomus umbellatus*) in Columbia River reservoirs, Eurasian watermilfoil and hybrids (*Myriophyllum spicatum* and *M. spicatum* x *sibiricum*) in central and eastern Oregon waterbodies, variable leaf watermilfoil (*M. heterophyllum*) in coastal lakes, and water primroses (*Ludwigia* spp.) in the Willamette and Rogue River Valleys.

Causes of Light Extinction Based on Continuous Turbidity, Chlorophyll Fluorescence, and Meteorological Data in a Highly Degraded, Turbid Terminal Lake

Cassandra Smith¹, James Pearson², Tamara Wood³

¹U.S. Geological Survey (Bend, OR); ²US Fish and Wildlife Service, and ³U.S. Geological Survey (Portland, OR); email contact: cassandrasmith@usgs.gov

A major factor limiting aquatic health at the Malheur National Wildlife Refuge is the common carp (*Cyprinus carpio*), a nonnative species with strong direct (suspension of sediment by feeding activity) and indirect effects on water column turbidity. Data collected during 2017 and 2018 to develop a predictive light model showed that turbidity responds strongly to wind events that suspend fine bottom sediments, indicating that the biggest effect of the carp population on turbidity is through indirect effects—that is, the consumption and uprooting of aquatic vegetation, which leaves the bed sediment exposed and easily mobilized by wind stress. One framework for understanding the Malheur ecosystem is the idea that shallow lakes often have alternate stable states—one turbid and nutrient-rich state that is dominated by phytoplankton, and one non-turbid and relatively less nutrient-rich state that is dominated by macrophytes. Typically, in eutrophic systems with large external nutrient loads, the association between turbid and nutrient-rich states is driven by the growth of phytoplankton in response to those loads. At Malheur Lake, it was hypothesized that this typical relation might not hold and that turbidity would be dominated by the suspension of inorganic sediments from the bottom during wind events. While a relation between turbidity and wind events was indeed found, there was also a long-term baseline to the turbidity that varied seasonally and was correlated to wind events. The baseline turbidity appeared correlated to continuous chlorophyll fluorescence data, which indicated a robust phytoplankton population. In samples collected for microscopy analysis a large community of phytoplankton, including a substantial population of cyanobacteria, was identified. The contribution of phytoplankton to turbidity is therefore not negligible. When discussing restoration activities designed to return the lake to a non-turbid state dominated by macrophytes, factors including the role of external nutrient loads, the correlation between sediment resuspension and aqueous phosphorus concentration, the possibility of changes in nutrient storage on interannual and decadal time scales as this terminal lake changes size dramatically in response to climatic variability, and the role of nitrogen-fixing cyanobacteria need to be considered.

ORAL PRESENTATION ABSTRACTS

(listed alphabetically by presenting author [underlined])

Using Fatty Acid Biomarkers to untangle trophic pathways in hypereutrophic Upper Klamath Lake

Michael T. Brett¹, Julie Schram², Jens Nielsen³, and Aaron Galloway⁴

¹University of Washington; ²University of Oregon; ³National Oceanic & Atmospheric Administration, Seattle

⁴Oregon Institute of Marine Biology. email contact: mtbrett@uw.edu

We used fatty acid biomarker analyses to quantify basal resource contributions to the mid and upper trophic level consumers in Upper Klamath Lake in southern Oregon. Several studies have noted it is commonplace for large *Daphnia* populations to coexist with the grass-blade morphotype of *Aphanizomenon flos aquae*, and some studies have even suggested their relationship is symbiotic. We used a fatty acid biomarker based Bayesian mixing model to quantify diet contributions from four phytoplankton groups (*Aphanizomenon*, diatoms, cryptophytes, and green algae) to *Daphnia pulicaria* in Upper Klamath Lake in southern Oregon. Upper Klamath Lake is characterized by extremely high phytoplankton biomass (> 100 µg/L), very strong community dominance by *Aphanizomenon* (≥ 98% of total phytoplankton biomass), and extremely high *Daphnia* abundance (summer mean ≈ 70 individuals/L). The use of the fatty acid based Bayesian model allowed us to resolve the *Daphnia* diets at a much finer resolution (between major phytoplankton groups) than conventional isotopic methods. The fatty acid mixing model indicated that although understory phytoplankton only comprised ≤ 2% of the phytoplankton biomass, diatoms, cryptophytes and green algae comprised 65% of *Daphnia* diets (and *Aphanizomenon* comprised 35% of the *Daphnia* diets). Several fatty acids that are characteristic of *Daphnia* that have consumed diatoms (16:1n7, 20:4n6, 20:5n3) and cryptophytes (18:4n3, 20:4n6, 20:5n3) were found in high proportion in *Daphnia* from Upper Klamath Lake, despite being a very small portion of the seston fatty acid composition. These results strongly support the symbiotic hypothesis by showing intense grazing pressure by the *Daphnia* on the understory phytoplankton, and relatively speaking minor grazing on *Aphanizomenon*.

Collins Bay after six years of herbicide treatment for *Ludwigia* - what comes next?

Laura Brown¹, Rich Miller², and Kurt Carpenter³

¹ Benton Soil and Water Conservation District, ² Portland State University, ³ US Geological Survey, email contact: lbrown@bentonswcd.org

Invasive water primrose (*Ludwigia* spp.) is an aquatic invasive species that is known as the worst aquatic invasive plant in the state of Oregon. *Ludwigia* has spread along the Willamette River over the past 10 years at a rate that is rarely seen in aquatic invasive species and has changed the plant composition and degraded the quality of several backwaters, oxbows, and river channels. *Ludwigia* infested sites along the river, such as Collins Bay between Corvallis and Albany, Oregon, are treated with herbicides over long periods of time. Once treated with herbicide, mats of decaying plant matter can remain, providing substrate for native plants and new growth of *Ludwigia*. Few studies have followed the water quality responses before and after herbicide treatment, but in 2017, Benton Soil and Water Conservation District partnered with Portland State University Center for Lakes and Reservoirs, US Geological Survey, Oregon Parks and Recreation Department, and Willamette Riverkeeper to evaluate the aquatic plant and water quality conditions in four water bodies including Collins Bay. Water quality and vegetation monitoring occurred at Collins Bay in 2017 and 2019. Water quality monitoring indicated extremely high water temperatures, and extremely low dissolved oxygen concentrations in 2017. This site also stood out as having high conductance (> 1,000 uS/cm) compared to other sloughs and backwaters examined. Preliminary results for the vegetation assessment indicated reductions in *Ludwigia* since 2017, likely due to the late spring flooding of the Willamette River in 2019. Large dead mats of *Ludwigia* remained at the site, which could be causing or contributing to low dissolved oxygen. To improve water quality, Benton SWCD is exploring the feasibility of

mechanical removal, since this may be necessary even after use of herbicide, in hydrologically disconnected backwaters like Collins Bay. *Ludwigia* is a formidable plant that will require multiple strategies for control including herbicides and mechanical cut and harvest methods, but the exact balance of each, and amount of effort, will depend on the characteristics of each water body.

Status and Trends of Detroit Lake Water Quality

Norman Buccola and Margaret Kennedy, U.S. Army Corps of Engineers, email contact: norman.buccola@usace.army.mil

The Portland District Corps of Engineers oversees water management and monitors water quality in 22 Oregon reservoirs, 13 of which are located in the Willamette River Basin. Generally, lakes at higher elevations in the basin and sourced from the High Cascades are oligotrophic with relatively low nutrient levels and high water quality. However, trophic state may be changing with continuing anthropogenic pressures (land use, sedimentation, recreation, reservoir management), and recent climate change. Toxin-producing cyanobacteria blooms (harmful algal blooms; HABs) have occurred sporadically since construction of the dams, causing increasing public health hazards and complications to downstream drinking water processing. Increasing concern over the adverse health effects of HAB events has prompted recent monitoring investments and investigations in the Willamette Basin. The Corps is working to compile historical limnological and biological data into a single database to better assess current conditions as they relate to historical, long-term trends. Detroit Lake, which impounds the North Santiam River and is the primary drinking water source for Salem, Oregon (among other cities), was chosen for a water quality trends analysis. This trends analysis includes annual physical parameters from continuous monitors (i.e., maximum lake level, thermocline depth) and chemical/biological parameters as they are available periodically (nutrient levels, trophic state, predominant planktonic species, algal toxins).

Addressing the Third Rail for Control of Cyanobacteria Harmful Algae Blooms (cyanoHABs): Getting Serious About Remediation

Wayne W. Carmichael, Professor Emeritus Wright State University, Oregon Lakes Association, email contact: wayne.carmichael@wright.edu

After 50 years of renewed research into toxin producing cyanobacteria and their waterblooms many countries, states and provinces are taking serious their impact on water quality and health risk for all areas of the environment. This has been mainly demonstrated by the various sampling and monitoring programs initiated and ongoing by federal, state and local agencies, plus those from citizen efforts. Efforts towards management and mitigation are also underway. These include: 1) Physical controls •Manipulation of the intake location or depth, aerators, and mechanical mixers. 2) Biological controls •Manipulation of the lake ecology to favor cyanobacteria grazers (top-down) and increased competition for nutrients (bottom-up). 3) Chemical controls •Phosphorus treatments (e.g. lime, aluminum sulfate, lanthanum and ferric chloride), Clay particles (these are primarily used to trap cells and pull them below the photic zone), and •Algaecides (e.g., copper-sulfate, hydrogen peroxide). However, these two categories do not involve a multilevel approach and do not address the root cause of cyanoHABs, i.e. nutrient enrichment (eutrophication), design and management of water supplies and effective management of watersheds that supply those waterbodies. Just as the third rail for electric trains provides forward movement, remediation is the only way to achieve real success for control of cyanoHABs. An example of how this can be accomplished is through a multilevel approach using air/water flow, complimented with bioaugmentation that will reduce and remove lake sediments. Such reduction increases water volume, moves nutrients into food webs that are beneficial, allows competition by beneficial algae to outcompete harmful cyanobacteria and reduces sediments that would otherwise encourage growth of aquatic plants.

Enhanced Water Quality Monitoring in the North Santiam and McKenzie Rivers to Support Dam Operations and Drinking Water Management

Kurt Carpenter¹, Micelis Doyle¹, Holly Bellringer², Norman Buccola², Brandin Hilbrandt³, Lacey Goeress-Priest³, David Donahue⁴, and Karl Morgenstern⁴

¹ U.S. Geological Survey, ² US Army Corp of Engineers, ³ City of Salem, Public Works Department, ⁴ Eugene Water and Electric Board, email contact: kdcar@usgs.gov

Two of the major rivers that feed the Willamette River—the North Santiam and McKenzie—are important drinking water sources for the cities of Salem and Eugene, and they support valued and protected populations of salmon and steelhead. Streamflows in these rivers during summer have traditionally been clear and cold owing to groundwater/spring discharge from the headwaters and deep-water hypolimnetic releases from the large reservoirs. But nowadays, to improve temperature conditions for fish migration and early development, more surface water is passed downstream during summer. Discharges of warmed surface waters from these reservoirs often contain cyanobacteria during spring and summer resulting from harmful algal blooms (HABs), cyanotoxins, and compounds that cause tastes and odors, which have potential to affect the quality of source water at several drinking-water intakes downstream. A network of 5 continuous, real-time water-quality stations, managed through a new collaboration between the Cities of Salem and Eugene, and the U.S. Army Corp of Engineers and the U.S. Geological Survey, will inform operations at Detroit and Cougar Dams and downstream water treatment plants. Continuous monitors will measure water temperature, conductance, oxygen, pH, turbidity, total chlorophyll, phycocyanin, and dissolved organic matter within and downstream from two reservoirs to examine the potential impacts of HABs. Profiling systems will measure cyanobacteria pigments and photosynthesis indicators multiple times per day, at multiple depths down to 100 meters, including each of the water release points. The data stream will feed a profile analysis tool to visualize reservoir conditions and provide water treatment plant operators advance notice of a cyanobacteria bloom before it might be discharged. These complex, real-time data sets could be utilized for machine learning and other modeling techniques to gain insights into the dynamic movements and growth patterns of HABs in these systems, potentially enabling advanced warning of developing HABs.

The impact of urbanization on water quality and ecosystem services provided by a major urban lake

Laura Costadone and Mark Sytsma, Portland State University, email contact: laura.costadone@pdx.edu

The overall focus of this study is to assess how urban development can impact water quality and ecosystem services of a major urban freshwater system in a rapidly urbanizing basin. Central Puget Sound and Lake Sammamish were selected as study systems. Central Puget Sound in Washington State is one of the fastest growing regions of the United States. Lake Sammamish is a major recreational destination and a valuable natural resource as urban wildlife refuge and habitat for the native kokanee salmon. The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) nutrient delivery model was used to map phosphorus loads across the region. Values of phosphorus export (Kg/ha) generated by the InVEST models serve as inputs to a dynamic, deterministic total phosphorus simulation model developed and applied to Lake Sammamish. Three different land use scenarios that illustrate land development resulting from a range of possible management policies, strategies and plans were evaluated. Preliminary results revealed that by 2070 urbanized areas will cover about 40% of the Lake Sammamish watershed. Urban expansion will occur at the expense of forested areas that are projected to decline. The scenarios that concentrate development within Urban Growth Areas resulted in an expansion of developed areas, which increased external P inputs to the lake by more than 30%. The increased external phosphorus loading could lead to higher productivity and water quality impairment in Lake Sammamish. Under these scenarios, strict implementation of nutrient management practices will be necessary to offset the negative impact of urbanization on water quality and related ecosystem services. Estimating changes in productivity and freshwater ecosystem service provisions under different gradients of urbanization can be useful in development of sustainable watershed land-use planning.

Oregon's Vision for 100-year Water Plan

Theo Dreher, Oregon State University; contact email: theo.dreher@regonstate.edu

Oregon is launching an initiative aimed at safe-guarding the long-term sustainability of water resources that support a healthy and productive lifestyle for Oregonians and a healthy environment: the 100-Year Water Vision. With this new commitment, the Oregon House of Representatives has re-established a Water Subcommittee, chaired by Rep. Ken Helm, who recently sponsored HB 3326 to improve the State's ability to deal with CyanoHABs. Rep. Helm's view of the 100-Year Vision will be conveyed.

Using direct genome DNA sequencing of CyanoHAB lake samples to better understand Pacific NW blooms

Theo W Dreher and Ryan S Mueller, Oregon State University, email contact: theo.dreher@regonstate.edu

Just as human genome sequencing has led to breakthroughs such as personalized diagnoses based on a patient's unique genome, an inventory of the genome sequences of freshwater cyanobacterial blooms will open up new avenues for studying, monitoring and mitigating CyanoHABs. We have applied a hybrid sequencing approach using PacBio long-read and Illumina short-read sequencing to analyze standing bloom samples from the Pacific NW, without cultivation. Our studies have emphasized *Anabaena/Dolichospermum*, *Aphanizomenon flos-aquae* and *Gloeotrichia* blooms, with several goals: 1) identifying the producers and genetic determinants of toxins and taste-and-odor compounds, 2) determining relationships between morphotype and genotype, 3) determining the genetic variation in bloom-forming species within single bloom events, between succeeding years in a single lake, and at regional scales, 4) refining the taxonomy of the *Anabaena/Dolichospermum/Aphanizomenon flos-aquae* (ADA) consortium, and 5) identifying co-occurring bacteria that might constitute commensals, synergists or predators in the phycosphere. Among our results, we have determined the complete genome sequence of the *Anabaena/Dolichospermum* producer of cylindrospermopsin that was the cause of a drinking water crisis in Salem, OR, in June 2018. The same strain was present during 2016 and 2017, with toxin biosynthetic genes appearing to be present on a ~200 kbp extrachromosomal element. In both years, the most abundant co-occurring bacterium was a strain of *Opitutus* (phylum Verrucomicrobia). Our analyses have emphasized that extant CyanoHABs are members of the distinct ADA genus-level clade first identified by Driscoll et al. (2018). This is a logical group to which the now-commonly used genus name *Dolichospermum* could be applied.

Hydrodynamic and Water Quality Response to Changes in the Outlet Structure for Lake Billy Chinook, Oregon

Joe Eilers, Max Depth Aquatics and Kellie Vache, Oregon State University, email contact: j.eilers@maxdepthaq.com

Lake Billy Chinook is a 4000-acre impoundment on the upstream portion of the three-dam Pelton Round Butte Hydropower Project on the Deschutes River. Prior to 2010, water was released through a set of deep gates (275 ft). As part of an effort to facilitate return of anadromous fish above the project, Portland General Electric and the Confederated Tribes of Warm Springs installed a fish collection structure on the outlet of Lake Billy Chinook that allowed for water from the upper 40 ft of the impoundment to enter a fish collection facility while still retaining up to 60 percent flow from the hypolimnion. This Selective Water Withdrawal (SWW) allowed for warmer water to be discharged in the spring and cooler water to be discharged in the fall to the Lower Deschutes River. The attractant flow to the SWW greatly facilitated collection of smolts trying to migrate downstream. However, the change in the flow paths to the SWW resulted in unanticipated changes in water movement through portions of Lake Billy Chinook. These changes in reservoir hydrodynamics promoted additional water quality changes in the impoundment and to the Lower Deschutes River.

Patterns of genetic diversity in lakes of the Columbia Basin Project

Crysta Gantz and Angela Strecker, Portland State University, email contact: cgantz@pdx.edu

Increased development, agriculture, and large irrigation projects have strongly impacted aquatic ecosystems by contributing to habitat fragmentation and altered environmental conditions. Understanding impacts on biotic communities requires research that incorporates population genetics and landscape ecology, preferably over multiple time scales to capture historical and current eco-evolutionary processes. We have focused our study on the pelagic invertebrate *Daphnia pulicaria*, which produces ephippia that survive in sediments for decades. Our study system includes the lakes and canal system of the Columbia Basin Project (CBP) in southeast Washington State, which built 6 dams and >480 km of canals for irrigation, flood protection, and power and as one of the earliest (c. 1945) projects provides the opportunity for historical comparison of native *Daphnia* populations, which occur throughout the region. We collected sediment cores from 22 lakes within and 8 outside of the boundaries of the CBP for our analyses. Sediment cores from two lakes, one from within and one from outside of the CBP, were submitted to an independent laboratory for ²¹⁰Pb dating to determine a timeframe for sediment deposition. The upper 4 cm of sediment reflects our contemporary populations. Counts from all of the sediment cores from within the CBP are complete, but with mixed results. Some sediment cores contained sufficient numbers of ephippia for embryo genetic analysis, while others did not. Sediment cores from outside of the CBP contained sufficient ephippia for analysis. Preliminary population genetic analysis consisted of microsatellite genotyping of contemporary populations from 4 lakes within, and 3 outside of the CBP. Embryo DNA from the lower sections of the sediment cores did not amplify. I will discuss results for the contemporary populations as well as future work analyzing historical DNA. Population genetic analysis combined with environmental data collected from the study lakes will enable us to infer eco-evolutionary patterns in this system.

Replacement of a unique population of newts (Taricha granulosa mazamae) by introduced signal crayfish (Pacifastacus leniusculus) in Crater Lake, Oregon

Scott Girdner, Crater Lake National Park, email contact: scott_girdner@nps.gov

The signal crayfish (*Pacifastacus leniusculus*) was introduced to Crater Lake in 1915 and now threatens the local extinction of an endemic salamander, the Mazama newt (*Taricha granulosa mazamae*). More than a century after their introduction, crayfish have expanded in distribution to occupy nearly 80% of the lakeshore. Although newts remain in uninvaded areas, they are almost entirely absent in crayfish occupied areas. Abundance of benthic macroinvertebrates was dramatically reduced in locations with crayfish compared with areas of the lake where crayfish were absent. Isotopic signatures of newt and crayfish tissue confirm overlap in the diets of the two species and demonstrate their similar position in the Crater Lake food web. Mesocosm experiments conducted with newts and crayfish revealed that crayfish prey directly on newts, displace newts from cover, and generally alter newt behavior. Combined, this evidence suggests that further crayfish expansion likely will cause additional declines in newt abundance and distribution, and could lead to extinction of the unique population of newts in Crater Lake.

Lake and River Drawdown Use of Herbicides for Aquatic Plant Management

David Kluttz, Lakeland Restoration Services, email contact: lakeland@lakelandrs.com

Most larger lakes in the Pacific Northwest are managed for Summer irrigation and Spring flood control. Drawdown conditions in the Spring and Fall of each year allow for an opportunity to manage invasive and nuisance plants. Drawdown treatment require less herbicide vs aquatic applications. Also, less restrictions on recreation and water usage are applicable as herbicides are applied to dewatered lake bottom. GPS and bathymetric examples will be discussed and specific lake treatments will be examined. Products used and plants controlled will also be presented. Treatments will be examined on Long Lake (Lake Spokane, WA)

where 85 home fronts were treated during a drawdown. Results of drawdown treatments were so effective, many customers chose to skip summer in water treatments. Images of Biobase surveys conducted this summer were analyzed. In water treatments had varying efficacy rates (12%-90% reduction). Drawdown treatments efficacy ranged from 90%-100% on annual plants. This measurement excludes flowering rush. The Okanogan River treatment and survey will be discussed.

Recent Ecological Conditions at Lake Abert, Oregon's Only Hypersaline Lake

Ron Larson, Oregon Lakes Association, email contact: rlarson@ccountry.net

In this presentation, I will give an update on ecological conditions at Lake Abert, Oregon's 6th largest lake, and the only large lake in the Pacific Northwest with a high salt content. The lake has had an interesting history, being fresh and several-hundred feet deep in the Pleistocene, but is now often only a few feet deep. The lake's hydrology is determined primarily by inflows from the Chewaucan River, and because it lacks an outlet, from losses by evaporation. Over the past several decades, the lake reached its highest elevation around 2000, and thereafter levels dropped, reaching a minimum in 2014, when the lake was nearly dry owing to drought and upstream water diversions. Over the past 5 years, levels have varied, but are still relatively low. In 2014 and 2015, salinities reached extremes not seen since the Dust-bowl era of the 20s and 30s, causing a near-complete collapse of the ecosystem, which was replaced by hypersaline-adapted bacteria and archaea. Since 2015, salinities have remained low and the ecosystem shows signs of recovery. Several environmental groups, including OLA, are searching for a long-term solution to the lake's water shortages.

Lake Abert: Recent Citizen-Science Data from a Globally-Important Waterbird

John Reuland¹ and Ron Larson², ¹ East Cascades Audubon Society. ² Oregon Lakes Association, email contact: rlarson@ccountry.net and john.r.reuland@gmail.com

Lake Abert, located in southeast Oregon, is a hypersaline, terminal lake. It's high productivity of brine shrimp and alkali flies by midsummer in years when the salinity is moderate, provides easily-obtained food for a wide variety of waterbirds, including shorebirds, ibis, gulls, and waterfowl. This food is critical to the birds following breeding and during migration, when energy reserves are low. Numbers of birds counted at the lake have exceeded 100,000 on single dates in some years, but also have been much lower. In this presentation, we present recent data, obtained primarily by volunteers from the East Cascades Audubon Society in Bend, Oregon, showing how bird numbers have varied in relation to environmental conditions in the lake. We believe this study is a good example of how citizen science can provide critical data on how animal populations are being affected by climate change and human activities.

Diet reconstruction of juvenile suckers of Upper Klamath Lake using fatty acids as biomarkers

Julie B. Schram¹, Michael T. Brett², Jens Nielsen³, and Aaron Galloway⁴,

¹ University of Oregon; ² University of Washington; ³ National Oceanic & Atmospheric Administration, Seattle

⁴ Oregon Institute of Marine Biology. email contact: jschram@uoregon.edu

Endangered juvenile lost river and shortnose suckers experience high rates of mortality as a result of a combination of a variety of factors (e.g. predation, parasite infection, water quality). Both lost river and shortnose suckers are endemic to Upper Klamath Lake (UKL), Oregon. UKL experiences regular and severe cyanobacteria blooms (primarily *Aphanizomenon flos-aquae*) which dominate the phytoplankton community of the lake for at least six months of the year. Cyanobacteria can degrade lake water quality through release of free ammonia and cyanotoxins, while driving down the dissolved oxygen. Cyanobacteria are generally

believed to be of relatively low food quality, due in part to their lack of long-chain essential fatty acids. It has been hypothesized that low food quality of diets may be an important contributor to the suckers' vulnerability as juveniles, but little is known about wild sucker diets. We used fish and potential prey fatty acids as trophic biomarkers in a Bayesian mixing model framework to quantitatively estimate sucker diets. To parameterize prey fatty acids and variability for the modeling analysis, we made monthly collections (May – Sept 2017) of likely sucker pelagic and benthic food sources across eight sites spanning different regions and habitats of UKL. Fatty acid-based modeling indicated that overall, the most important food sources based on average prey FA profiles for suckers (median % of diet) were chironomids (55%) and oligochaetes (35%), while *Daphnia* contributed a smaller proportion (2%). These results were consistent with monthly comparisons (median % range across months) in which chironomids (44–79%) and oligochaetes (0.8–36%) contributed a relatively larger proportion of sucker diets than *Daphnia* (1–16%). Our results highlight the importance of benthic food resources in the diets of suckers in the UKL.

Testing a new method for early detection of harmful algal blooms in Oregon lakes and reservoirs

Daniel J. Sobota¹, Victoria Avalos², Steve Hanson¹, Brian Fulfroost¹, Smita Mehta¹, Sam Doak¹, and Lara Jansen²

¹OR Dept. of Environmental Quality, ²Portland State University, email contact: sobota.daniel@deq.state.or.us

Increasing public concern has prompted increased research on how to improve detection, management, and reduction of harmful algal blooms in Oregon lakes and reservoirs. A promising approach is early warning signal detection, which may help mitigate effects of blooms and provide insight on factors responsible for triggering blooms. Here we adapt a statistical approach that uses a moving window of autocorrelation and standard deviation of time series data to provide early warning signals for the onset of harmful algal blooms in lakes and apply the method to Odell Lake in central Oregon. Time series data used for the analysis included in situ monitoring water quality data (dissolved oxygen, chlorophyll a, and phycocyanin concentrations) and cyanobacteria cell counts derived from satellite imagery from June through September 2019. Odell Lake is ideal to test this method because the lake frequently experiences at least one harmful algal bloom during summer months. As a control, we also collected water quality and satellite data from Crescent Lake, which is near Odell Lake but does not experience harmful algal blooms. Odell Lake experienced a harmful algal bloom for a two-week period in late July/early August 2019. Both in situ sensors and satellite imagery captured early warning signals two weeks before the onset of the bloom in Odell Lake. The same data collected on Crescent Lake showed no signals of an algal bloom. These results suggest that increasing in situ monitoring in systems susceptible to harmful algal blooms may help identify when blooms are beginning to form several weeks in advance. Expanding the use of time series of satellite imagery may further help identify new systems vulnerable to harmful algal blooms.

Outstanding Waters of Oregon: Waldo and Crater Lakes

Debra Sturdevant, OR Dept. of Environmental Quality, email contact: Debra.Sturdevant@state.or.us

Under the Clean Water Act, states can give special designation to waters of high quality and ecological value. The Outstanding Resource Water designation provides special protection against future degradation. In 2019, the Environmental Quality Commission received a rulemaking petition to give Waldo Lake, located in the Oregon Cascade Mountains, this special designation. The Commission granted the petition and also directed DEQ to consider Crater Lake. Both lakes have exceptional water clarity. Over the next year, DEQ will conduct a rulemaking to propose designating these two lakes as Outstanding Resource Waters and to adopt policies to protect their current water quality and ecological values. In this presentation, I will provide additional background about the petition, the rulemaking process just getting underway, the special characteristics of these two lakes, and what the ORW designation will mean for Waldo and Crater Lakes and people who visit them.

Ecological Design Approach to Lake Health and Algae Control, Hydraulic Flushing Manipulation and Floating Islands for Golden Alga and HAB Control

Jonathan Todd, Floating Islands West, LLC, email contact: jtodd@ecolakesolutions.com>

East Lake in Yorba Linda, California is a 15-acre lake surrounded by 191 homes and a large clubhouse. In 2013 East Lake contracted Gold Algae (*Prymnesium parvum*), a harmful algae resulting in a total fish kill. Copper sulfate was applied to treat the infestation though minimal improvements occurred leaving the lake in a condition unable to sustain a healthy fish population. Similarly, at Lago Santa Margarita, *P. parvum* had decimated the fish population. Our Strategy: Eco Lake Solutions implemented a two-pronged strategy, beginning with Floating Islands. Floating Islands provide the matrix for beneficial plant root ecology. In this aerobic zone, the water is flushed through the roots of the plants and the associated beneficial bacteria. Observations have been made that during golden algae blooms fish move towards highly aerobic areas, where these floating islands would provide a safe haven for them. High efficiency aeration is the second component and creates "hydraulic flushing manipulation." This strategy has been proven successful in studies at Texas A&M Department of Wildlife and Fishery Science and Oceanography. At East Lake, using highly efficient aeration systems we are able to achieve the required flushing rates using three, 0.5 horsepower piston compressors with each unit pushing 12.5 million gallons per day through the treatment zones. Our hypothesis is that the not the floating wetlands up take the nutrients that cause the algae bloom. Alternately it is indicated that flushing the lake water through the healthy ecology of the root zones and associated periphyton and beneficial bacteria creates an alternative ecology that is able to out compete or displace the HAB or golden algae dominant environment. Our Impact: Three years ago, Eco Lake Solutions installed a pilot in the eastern section of East Lake to manage golden algae in that pilot zone. The pilot was significantly more successful than expected in terms of improved water quality throughout the entire 15-acre lake. Since the installation of the natural ecological system, the lake has reported Golden Algae at non-detect and the aesthetics, odor and water quality have improved dramatically and the fish population is thriving. At Lago Santa Margarita the fish population had been decimated by golden algae and nuisance algae causing odors and a high level of complaints from area residents. The installation of 22 islands and 11 diffusors was completed in December of 2018. In April 2019 the chlorophyll-a concentration readings were half of that from April 2018 providing confidence to release fish in the lake in July of 2019. As of September, the fish are healthy and recreational fishing has returned to the lake in addition to a notable improvement in the overall water aesthetics. Golden algae testing and continued observation of fish health throughout the cooler months of November and December when golden algae typically causes fish kills will be critical in our assessment of the efficacy of this approach for Lago Santa Margarita.

Searching for solutions to the HAB at Ross Island Lagoon

Desiree Tullos, Oregon State University, email contact: desiree.tullos@oregonstate.edu

The Harmful Algal Bloom (HAB) in the Ross Island lagoon (RIL) has been occurring with increasing frequency, and has led to the recent listing of the lagoon as impaired. The RIL HAB is unique due to its occurrence in river, and solutions to the HAB are complicated by environmental, regulatory, and logistical constraints. OSU faculty and students have been supporting stakeholders in identifying potential solutions for addressing the HAB, including hosting a design charrette, synthesizing current knowledge about the system, and developing hydraulic models of proposed solutions to examine their feasibility and effectiveness. Students evaluated a wide range of potential solutions, ranging from hydraulic modifications to microbial solutions (e.g. flocculents, aeration, nanobubbles, ultrasonic pontoons, barley straw floats). High-level findings include: 1) Hydraulic solutions may be effective, but a hydraulic model that represents vertical variations is needed to more fully understand the impacts of hydraulic solutions on stratification. It is not clear if the hydraulic solutions can produce enough mixing to fully suppress the bloom, or what mixing depth is actually needed to suppress the bloom. While hydraulic solutions may not fully mix the epilimnion, they should help suppress the bloom. In addition, advection of algae cells out of the lagoon may further suppress the HAB,

though the benefit of flushing cells is difficult to predict. 2) From the perspective of hydraulic drivers, the momentum from the river drives mixing through the winter. The tides drive mixing during the summer low flows. Thus, solutions that take advantage of both will be most effective, and most expensive. 3) There are some promising non-hydraulic solutions, including the ultrasonic pontoon. However, these are all generally short-term solution that would need regular application and have their own uncertainties with respect to effectiveness. Comprehensive results of the alternatives analysis and stakeholder response will be presented.

Simulation of deep ventilation and ecological effects in Crater Lake, OR, 1951-2099

Susan Wherry¹, [Tamara Wood](#)¹, Sebastiano Piccolroaz², and Scott Girdner³

¹U.S. Geological Survey, ²University of Trento; ³National Park Service, Crater Lake National Park, email contact: tmwood@usgs.gov

The frequency of deep ventilation events in Crater Lake, a caldera lake in the Oregon Cascade Mountains, was simulated in six future climate scenarios, using a 1-dimensional deep ventilation model (1DDV) that was developed to simulate the ventilation of deep water initiated by reverse stratification and subsequent thermobaric instability. The model was calibrated and validated with lake temperature data collected from 1994 to 2011. Wind and air temperature data from three general circulation models (GCM) and two representative concentration pathways were used to simulate the change in lake temperature and the frequency of deep ventilation events in possible future climates. The lumped model air2water was used to project lake surface temperature, a required boundary condition for the lake model, based on air temperature in the future climates. The 1DDV model was used to simulate daily water temperature profiles through 2099. All future climate scenarios projected increased water temperature throughout the water column and a substantive reduction in the frequency of deep ventilation events. The least extreme scenario projected the frequency of deep ventilation events to decrease from about 1 in 2 years in current conditions to about 1 in 3 years by 2100. The most extreme scenario considered projected the frequency of deep ventilation events to be about 1 in 7.7 years by 2100. All scenarios predicted that the temperature of the entire water column will be greater than 4 °C for increasing lengths of time in the future and that the conditions required for thermobaric instability induced mixing will become rare or non-existent. The disruption of deep ventilation by itself does not provide a complete picture of the potential ecological and water quality consequences of warming climate to Crater Lake. Estimating the effect of warming climate on deep water oxygen depletion and water clarity will require careful modeling studies to combine the physical mixing processes affected by the atmosphere with the multitude of factors affecting the growth of algae and corresponding water clarity. Modeling results by the time of this conference will include deep ventilation simulations of salinity and dissolved oxygen, in addition to temperature, using future climate data from twelve GCMs.

Legislative action on CyanoHABs

Jack Zika, Oregon State Representative (District 53)

Representative Zika's district surrounds the city of Bend, spanning from Redmond in the north to Crane Prairie Reservoir in the south. He was a member of the House Committee on Energy and Environment that considered HB 3326 during the 2019 legislative session. HB 3326 (introduced by Rep. Ken Helm) sought to expand the state's ability to deal with CyanoHABs. Together with Rep Marty Wilde, Rep Zika has co-chaired a continuing discussion by stakeholders (the Harmful Algal Blooms Work Group) in preparation for re-considering legislative action in the future.

