WALPA 36th Annual Conference, October 4-6, 2023, Tacoma WA

Fish and Beyond in Our Lakes

Session Schedule

Wednesday, October 4

1:00 PM – 5:00 PM Workshop: Aquatic Invasive Species

Thursday, October 5

7:00 AM – 8:00 AM Breakfast & Registration

8:00 AM – 9:00AM Welcome & Plenary

9:00 AM – 9:15 AM Break

9:15 AM – 10:45 AM Session 1: Saving Salmon

10:45 AM – 11:00 AM Break

11:00 AM – 12:30 PM Session 2: Invasive Plants

12:30 PM – 2:00 PM Lunch & WALPA Update

2:00 PM – 3:30 PM Session 3: Human Impacts

3:30 PM – 3:45 PM Break

3:45 PM – 5:15 PM Session 4: Regulations & Funding

5:15 PM – 7:00 PM Poster Presentations & Social Hour

Friday, October 6

7:00 AM – 8:00 AM Breakfast & Registration

8:00 AM – 9:30 AM Session 5: Harmful Algal Bloom Management

9:30 AM – 9:45 AM Break

9:45 AM – 11:15 AM Session 6: Lake Research

11:15 AM – 11:30 AM Break

11:30 AM – 12:30 AM Student Early Career Panel

Workshop: Aquatic Invasive Species
- Ben Peterson, *King County Noxious Weed Program*
- Brian Turner, *Washington Department of Fish and Wildlife*

This aquatic invasive species (AIS) workshop is designed to help participants learn about invasive plant and animal species that currently impact or present a threat to lakes in Washington State. The first half of the workshop will focus on plants and the second half of the workshop will focus on animals along with our State AIS management program.

Plenary: Community-Engaged Research in Lakes with Undergraduates: Bridging Basic Science, Education, and Community Needs
-James Gawel, *University of Washington Tacoma*
The University of Washington Tacoma (UW Tacoma) is a primarily undergraduate institution, with 63% students of color, 54% first in college or first to a degree, and 74% coming from Pierce, Thurston, or South King County. Most of our graduates go directly into the workplace after graduation, and thus hands-on, community-engaged experience while in college is invaluable preparation for working in the "real world." Involving undergraduates in authentic research is also a high impact practice (HIP) in education, building students' confidence as professionals and increasing their sense of responsibility for and interest in their work. At UW Tacoma we also support community-engaged research, another HIP, and since most of our students are from the region, involving them in solving problems significant for nearby communities is doubly impactful. Working with undergraduate capstone students and high school students we mapped the spatial and temporal extent of arsenic contamination in lake sediments throughout the region and statistically showed that the former ASARCO smelter was the source. That comprehensive, large-scale multi-year data collection endeavor provided the first evidence of a heightened risk to human and ecosystem health in shallow urban lakes compared to deep lakes. Through years of research with faculty collaborators and undergraduate students we have found that shallow lakes in Western Washington contaminated with arsenic pose a significant cancer risk for subsistence fishers. Collaborating with WA Dept. of Fish and Wildlife, we have learned that the risk is highest for those consuming the warm-water fish species in these lakes (e.g., sunfish and carp), not those considered sport fish. However, the number and demographics of people catching and consuming these species is not well known, and working with undergraduates we have begun to learn more about the communities at risk and how to better communicate that risk. Through involvement of lake association members in our research, we also learned of and investigated their concerns about health risk from direct contact with contaminated water and nearshore sediments. This talk will tell the story of how our work has integrated community connection, undergraduate education, and applied science over the years, and lessons I have learned in the process.

Session 1: Saving Salmon
Testing the Waters: Identifying effective methods for engaging lakefront residents towards behavioral change
-Torren Valdez, *Mid Sound Fisheries Enhancement Group*
- Coauthors: Piper Hanson, Debbie Meisinger, Amber Mikluscak, and Angela Mele
The nearshore is the last area of protection between our vulnerable lakes and the upper watershed. For the two major lakes in western Washington, a large majority of the nearshore environment is owned and maintained by private individuals. Therefore, it's critical to engage lakefront residents as partners in lake protection and conservation. Mid Sound Fisheries and King Conservation District, along with a coalition of partners, developed the "Salmon Friendly Lakes" pilot program as a tool for engaging lakefront residents in lake protection and reduction of artificial light at night. We'll present findings from

program development, including what worked and what didn't, based on firsthand experience with the Salmon Friendly Lakes program and similar campaigns and promotions and conversations with lakefront residents. Presenters will engage the audience to share ideas and experience from other efforts in order to identify tips and tools for improving effective engagement that inspires behavioral change.

Lake Sammamish Kokanee - Local and Emergency Actions on the Road to Recovery

- Alison Agness, *King County*

Once the dominant Pacific salmonid across the Lake Washington basin, kokanee that remain in Lake Sammamish, Washington are now the focus of extensive recovery efforts owing to their low abundance. Lake Sammamish kokanee once numbered in the tens of thousands of fish, but in recent years the number of returning spawners has largely hovered around one-hundred fish or less. Since 2007, the Lake Sammamish Kokanee Work Group (KWG) has been driving the collaborative effort to recover these little red fish with a focus on spawning habitat protection and restoration as well as education. The KWG includes a high-functioning group of watershed residents, local jurisdictions, agencies, and NGOs who each bring important perspectives and skills to the shared goal of kokanee recovery. In 2020, a partnership formed to implement emergency actions due to the severe decline of kokanee in Lake Sammamish. The Snoqualmie Tribe, King County and the Cities of Bellevue, Issaquah, Redmond and Sammamish signed the Kokanee Recovery Interlocal Agreement (ILA) to fund important technical studies and kokanee supplementation necessary to prevent extinction. Thanks to the collective efforts and actions of KWG and ILA partners, kokanee survive today, but recovery potential diminishes with each passing year of low abundance return. To ensure kokanee stay on the road to recovery, we are presently mobilizing our partners to adaptively manage the kokanee recovery program and expect to tackle additional threats to kokanee recovery in the near term, particularly threats in the lake environment that remain unabated, including pressures from predation, non-native aquatic vegetation, disease, lake temperature and dissolved oxygen levels, as well as, possibly, recreational fishing. Recovery partners are working together to identify new ways to collaborate and fund such additional management actions.

Quantifying the effect of Artificial Light at Night on planktivorous fish in Lake Washington, WA

- Tessa Code, *University of Washington*
- Coauthor: Dr. David Beauchamp

In aquatic ecosystems, daily light fluctuations signal periods of refuging or foraging. Artificial light at night (ALAN) is disrupting natural light cycles by extending twilight periods and increasing nocturnal light levels. ALAN threatens fish populations by mediating changes in behavior and predation mortality. Salmon predators feed primarily by sight with predation typically peaking during twilight conditions. ALAN can enhance predator foraging conditions by extending low light periods, leading to the decline of important species, like salmon. Quantifying the light environment is necessary to understanding potential predation pressure in urban waterbodies. In the pelagic habitat, fish adjust their depth to balance foraging opportunities and predation risk. Measuring fish depth distribution provides insight to how planktivores respond to in situ artificial light levels. This information can be used in an assessment of predation risk from urban light levels. Current work investigates the patterns of planktivore density and in situ light level in regions of high and low ALAN in Lake Washington, a heavily urbanized lake experiencing major declines in juvenile salmon survival.

Floating Treatment Wetland and Biomedia Module for Stormwater Treatment and 6PPD Quinone Removal

- Lizbeth Seebacher, *University of Washington*

Despite decades of estuarine and river restoration efforts, effectiveness monitoring surveys continue to document premature mortality of coho salmon (Oncorhynchus kisutch) within the streams of urbanized areas in the Pacific Northwest (PNW). Many researchers have identified stormwater inputs, especially road runoff, to be a primary cause of salmon mortality and poor recruitment while other researchers have found that certain stormwater bio-infiltration methods helped reduce mortality significantly. In December of 2020, 6PPD quinone, a previously unknown chemical derived from tire wear particles, was identified as the particularly potent contaminant responsible for killing coho salmon. Traditional biofiltration measures have been shown to alleviate the toxicity of the stormwater on salmon, however, many highly urbanized areas of Puget Sound cannot accommodate bioswales or green infrastructure for the treatment of road runoff before entering urban streams. For these sites where green infrastructure is impractical, we examined the potential of using floating treatment wetlands (FTWs) as an in-situ treatment for stormwater contaminants including 6PDD quinone. We tested a suite of wetland species for phytoremediative properties on stormwater contaminants and the ability to survive and thrive in floating wetland conditions. We also analyzed three biomedia mixes for the ability to adsorb stormwater contaminants, especially 6PPD quinone. We then investigated the efficacy of the most beneficial wetland species planted within FTWs and the most efficient biomedia mix within the FTWs on the reduction of stormwater contaminants (from this point forward including 6PPD quinone) and coho salmon survival. The results were efficacious with 100% survival and no symptoms of 6PPD quinone for any of the coho salmon in the treated stormwater. Salmon populations throughout Puget Sound and the PNW have been impaired for decades. Further deterioration of coho populations risk extinctions within those streams and rivers in high urban environments, reducing overall genetic diversity of the species.

<u>Session 2: Invasive Plants</u>

Bottoms Up! Reducing salmon predation through aquatic weed management in Lake Sammamish.

- David Kyle, *Trout Unlimited*
- Coauthor: James Bower

Lake Sammamish is home to native kokanee salmon and ESA-listed Chinook. Lake Sammamish kokanee, once the most abundant pacific salmon in the basin, are declining and at critically low numbers. Nonnative fish predation on salmonids, especially fry and smolt, is significantly impacting these populations and predator removal is being considered as a management action in the watershed. A 2019 study conducted by King County on the fish assemblage of Lake Sammamish indicated a majority of the fish abundance and biomass in the lake is from nonnative species. Many of these nonnative fishes are highly piscivorous, including smallmouth bass (Micropterus dolomieu), largemouth bass (Micropterus salmoides), and yellow perch (Perca flavescens), and utilize the nearshore lake habitat as spawning, rearing, and forage habitat.

The littoral zone of lake Sammamish and most of the larger basin is plagued with aquatic weeds. The two most prolific species are Eurasian Milfoil (Myiophyllum spicatum) and Brazilian Elodea (Egeria densa). Aquatic weed management is typically pursued to address water quality issues, navigation issues, and conflicts with general recreational use; however, these aquatic weeds create preferred habitats for yellow perch, juvenile bass, and other nonnative piscivores.

Inspired by kokanee restoration technical work of the Kokanee Work Group, Trout Unlimited and King County partnered in 2021 to conduct a pilot study in Lake Sammamish evaluating fish abundance changes in the littoral zone due to aquatic weed removal. Approximately 120 yards of aquatic weeds were removed from three sites utilizing Diver Assisted Suction Harvesting. The Treatment and paired Control sites were visually surveyed at 11 foot and 22 foot transects by SCUBA. Divers recorded fish

observations by species, size class, and abundance. In total, 9,821 individual fish observations were recorded and of those 8,020 (81.6%) fish were made in control areas while 1801 (18.3%) fish were seen in treated areas. These results have led to a second funded phase of work in Lake Sammamish in 2023.

Tahoe Keys Control Methods Test: Using data visualization tools to inform decision making
- Toni Pennington, *Environmental Science Associates*
- Coauthor: Travis Hinkelman and Kathleen Berridge

The Tahoe Keys is a residential development along the south shore of Lake Tahoe consisting of approximately 1,500 homes and 170 acres of waterways. The waterways are infested with two dominant non-native aquatic plants, Myriophyllum spicatum (Eurasian watermilfoil) and Potamogeton crispus (curlyleaf pondweed), and one native, but nuisance species, Ceratophyllum demersum (coontail). The Tahoe Keys Control Methods Test (CMT) was designed to evaluate six aquatic weed control methods implemented at multiple test sites, to determine which methods might be best suited to achieve long-term control of the three target aquatic plant species throughout the Tahoe Keys. Treatment methods being tested, both independently and in combination, include aquatic herbicides, ultraviolet light, benthic barriers, hand-pulling, diver assisted suction hand-pulling, and laminar flow aeration. The first treatment methods were applied beginning in 2022 and are planned to continue through 2024. Several approaches are being used to evaluate the efficacy of the project to determine when and whether a 75% reduction in target species biovolume is achieved. In addition to monthly hydroacoustic scans, plant rake samples are evaluated for fullness, relative abundance, frequency of occurrence, and plant health. All data are collected using field forms loaded on tablets that are connected to external high accuracy GNSS antenna. Data are routinely synced and made available to stakeholders online via a Dashboard tool developed in R Shiny. Users are able to toggle between different metrics by location, date, and follow-up treatment type. Data may be viewed by an individual rake or as a “heat map” to visualize plant density. This valuable tool has allowed decision makers to visualize data in near real time and efficiently identify follow-up treatment types and locations based on plant species and density. The intent of the three-year CMT is to inform long-term management options following full implementation, thus all results are preliminary.

Containment Approach to AIS Prevention: Stopping Starry Stonewort
- Edgar Rudberg, Ph.D., *CD3, General Benefit Corporation*
- Coauthor: Jake Utrie

The spread of Starry Stonewort is of great concern to Minnesota’s natural resource managers and lake property owners. This concern stems from Starry Stonewort’s impact on lake ecology and recreational opportunities. A public-private partnership led by Minnesota Lakes and Rivers, in partnership with CD3, responded to its introduction in Minnesota by implementing a “containment strategy” to slow or stop its spread by providing the tools to boaters to clean, drain, and dry their boats at accesses on infested waterbodies. This presentation will outline the case study and its preliminary results.

Evaluating Effects of Three Alum Treatments and the Recent Brazilian Elodea Invasion on Toxic Cyanobacteria Blooms in Green Lake, Seattle, Washington
- Rob Zisette, *Herrera Environmental Consultants*
- Coauthors: Katie Sweeney and Eliza Spear

Green Lake (Seattle, WA) was treated with buffered aluminum sulfate (alum) in 1991, 2004, and 2016 to reduce excessive phytoplankton growth and cyanobacteria blooms to meet goals established in 1990. Trophic state goals for summer total phosphorus (<25 ug/L) and Secchi depth (>2.5 meters) were met for 3 years following the 1991 treatment, but cyanobacteria blooms resulted in beach closures by 1999. The alum dose was nearly tripled in 2004 (from 8.6 to 24 mg Al/L), meeting trophic state goals but

resulting in beach closures from toxic cyanobacteria blooms after 9 years by 2012. A lower dose (8.2 mg/L) was applied for the third alum treatment in 2016, which has eliminated toxic blooms for 7 years through 2022, However, the trophic state has been increasing and exceeding goals starting in 2019 and microcystin was detected in a small scum at 15 ug/L in October 2020. Phosphorus, nitrogen, chlorophyll, and cyanotoxin concentrations and ratios are examined to explain the increasing algae biomass without cyanotoxin production.
Green Lake was invaded by Eurasian watermilfoil (milfoil) in ~1980 and rapidly expanded to cover 81 percent (210/259 acres) the shallow lake by 1991. It was managed by aquatic plant harvesting until grass carp were planted in 2001, which nearly eliminated all submersed plant populations. Aquatic plant surveys showed that milfoil cover expanded from 10 to 60 acres between 2005 and 2022. Brazilian elodea (Egeria densa) was first observed as a few fragments on shore in 2020 and found to cover 52 acres in 2022. Egeria was primarily located in the center of the lake at ~12- to 16-feet depths but did not grow with 3 feet of the lake surface, whereas milfoil grew to the surface and obstructed boat access in the nearshore region out to ~10 feet deep. Potential effects of these invasive plants on nutrient and algae conditions in the lake are examined with consideration of their ecosystem functions and recreational impacts for preparation of an integrated aquatic vegetation management plan.

Session 3: Human Impacts

Lake Washington has been surprisingly stable despite rapid urban/suburban development in the watershed

- Daniel Nidzgorski, *King County Natural Resources*
- Coauthor: Curtis DeGasperi

Lake Washington, surrounded by Seattle and its suburbs, became a well-known environmental success story with the lake's rapid, dramatic recovery after sewage was diverted from the lake in the 1960s. But the story took a turn as the lake's ecosystem showed impacts from continuing development in the watershed. Events such as a large bloom of potentially toxic cyanobacteria in 1988 foreshadowed worsening problems in the future. When the most recent set of studies were published around 2000, these impacts were expected to increase as the watershed developed further.
In this presentation, we add the latest chapter to Lake Washington's story. But instead of increasing the dramatic tension as expected, the last 25 years have found Lake Washington surprisingly stable despite continued, substantial population growth and development in the watershed. We use data from King County's long-term lake monitoring to explore this "new normal" state of the lake. This program measured depth profiles of physical and chemical parameters 1-2x/month year-round since 1993. The monitoring station was the same mid-lake station used by University of Washington researchers since the 1960s, continuing an important scientific record.
Typical seasonal dynamics in Lake Washington over the last decade (2013-2022): The main phytoplankton peak was a spring diatom bloom beginning as early as late February. As the lake stratified in April and May, the diatom bloom was gradually confined to surface waters, then interrupted briefly as nutrient depletion, zooplankton grazing, and sinking of diatoms below the thermocline (~10 m) caused the bloom to decline in late May. The lake was at the oligotrophic-mesotrophic boundary in summer, with a smaller secondary phytoplankton bloom. In late summer and fall, areas of low dissolved oxygen developed in the metalimnion (copepod respiration) and near the bottom (decomposition). In the fall, stratification weakened and waters began mixing, until a large storm in late fall mixed the lake completely for the winter.
Trends over the last 25 years (1998-2022) were stable or opposite of those expected from development impacts. The spring diatom bloom's maximum chlorophyll concentrations have decreased substantially (-24% per decade), and summer epilimnion average chlorophyll concentrations decreased as well (-4%

per decade). This in turn drove deeper summer Secchi depths (9% per decade) and higher near-bottom dissolved oxygen (22% per decade).
We are still exploring what caused the decrease in chlorophyll, but it is not a simple nutrient story. Spring epilimnion total P concentrations may have decreased slightly, by only -1.4% per decade – much less than the decrease in chlorophyll. And summer epilimnion total P may have increased slightly, by 2% per decade. This increase in summer P is the only trend we found in the direction we would expect from development impacts, but it was probably not due to development. Summer epilimnion total N decreased (3% per decade), and any development-related nutrient sources would have added both N and P to the lake, not P alone.
Understanding how Lake Washington achieved this surprisingly stable state, despite ongoing development, could help future work to protect this and other urban lakes.

Anthropogenic Wakes as a Contributor to Cultural Eutrophication in the Nearshore of Recreationally Important Lakes in Idaho

- Garret Homer, *University of Idaho*
- Coauthor: Dr. Frank Wilhelm

Eutrophication, the process by which water bodies are enriched with excess nutrients, is one of the foremost threats to water quality worldwide. When human activity is the driving force behind eutrophication, it is called cultural eutrophication. Recreational activities that generate wakes are a potential cause of sediment and nutrient resuspension in the nearshore of inland lakes, threatening the long-term water quality of these bodies of water. While wind naturally generates wake disturbances, the consequences of the unnatural frequency and magnitude of anthropogenically caused wakes is a poorly understood area of lake management. This knowledge gap is particularly concerning when a freshwater lake serves as a source water for communities along its shores. We quantified the internal loading of phosphorus (P) in the nearshore of Payette Lake, Valley County, Idaho, to assess the contribution to algal growth and the potential of harmful algal blooms. Six sites around the lake with different substrate types, fetch distances and angles, and boating traffic patterns were sampled regularly in 2023. At each site, sediment was classified at three different depths to represent the sediment profile at different lake elevations. Wind and wave activity was quantified at each site by determining wave height, while the P (total and dissolved), total suspended solids, and turbidity were quantified for each disturbance type at each site before and during natural and anthropogenic disturbances. In addition, satellite imagery was used to quantify the frequency and timing of boat activity on the lake in relation to natural wind patterns, to determine compare the natural disturbance regime with the anthropogenically introduced disturbance regime. The results of this study may be used to inform lake management professionals in Idaho on the risks associated with anthropogenic wave activity in lakes that serves as drinking water supplies, as well as important drivers of economic and recreational activity.

Resuspension of Nutrients and Metals in the Nearshore of Coeur d'Alene Lake, Idaho, in response to natural and anthropogenic waves and wakes

- Madison Schumacher, *University of Idaho*
- Coauthors: Cody Wilkin and Dr. Frank Wilhelm

Cultural eutrophication, an excess of nutrients in aquatic ecosystems input by human activity, is the most pressing threat to water quality worldwide. Wind-generated waves can result in the internal loading of nutrients from the resuspension of sediments. On lakes with high anthropogenic activity, there is growing concern that the increased nearshore interactions of waves from recreational boaters can cause unnaturally high resuspension of sediments and associated nutrients into the water column which could stimulate or contribute to harmful blooms of algae. In addition, if sediments have a high

burden of contaminants, these may also be re-introduced into the water column affecting potability and creating public health concerns for recreators. The main objective of this study was to quantify the resuspension of sediment, nutrients, and metals in the nearshore zone of Coeur d'Alene Lake in Northern Idaho, in response to natural and anthropogenic disturbances. At each nearshore study site, wake and wave activity was quantified via measurements of wave height, and velocity, while measurements of turbidity, total suspended solids, and nutrient and metal concentrations were used to quantify the severity of the disturbance. Lake-wide observational boat surveys were also completed using community-based volunteers to create a boat-use index to quantify the total lake-wide recreational disturbances on Coeur d'Alene Lake. The results of this study may be used to inform decision makers at the county level as they contemplate protecting human health and water quality via implementation of 'No Disturbance Zones' in the nearshore.

The Impact of Nearshore Recreational Activities on Arsenic Exposure in Contaminated Lakes: A Study of Sediment Disturbance and Water Quality

- Kirsti Lipphardt, *University of Washington Tacoma*
- Coauthor: James Gawel

Climate change is drawing more people to lakes to cool down, but contaminated sediments may reduce accessibility. Many lakes in Western Washington are contaminated with arsenic (As) due to a history of smelting. The sediments in these lakes contain higher concentrations of As than the water column. Prior work found As from shallow lakes is deposited into nearshore sediment, resulting in concentrations similar to deep lake sediments. We hypothesize the physical action of nearshore play may suspend As-contaminated sediments and increase As concentrations in the water column, consequently increasing As exposure through accidental ingestion of suspended sediments. Samples were collected from three lakes varying in As contamination levels. To analyze changes in As availability in the water column, we collected filtered and unfiltered water samples before and after simulated nearshore play. Surface sediment samples were analyzed for grain size and total As. We found a significant increase in As concentration after sediment disturbance in the unfiltered samples but no significant change in As concentration of filtered samples. The results suggest contaminated sediments increase the risk of As exposure during nearshore play due to the addition of As-contaminated suspended sediments. This study provides insight into the potential risks of recreational activities in As-contaminated lakes and highlights the importance of understanding the effects of sediment disturbance on water quality and human health.

<u>Session 4: Regulations & Funding</u>

Evaluating HABs for the 303(d) List in Washington State

- Justin Donahue, *Washington State Department of Ecology*

Freshwater HABs produce toxins or other environmental conditions that are harmful to humans and animals. While these blooms may be natural events, they can be worsened by nutrient inputs from human activities. The presence of HABs directly impacts the ability of humans to recreate in waters where active blooms are occurring. In an effort to evaluate and identify locations where HABs are impairing waterbodies, the Department of Ecology recently finalized a new methodology to evaluate HABs for the 303(d) list under the Clean Water Act. This methodology utilizes a combination of public health advisory information, cyanotoxin data from the Northwest Toxics Algae Database, public health assessment information, and the DOH recreational guidance to identify locations where HABs may be harmful to humans or pets. The first list of waterbodies impaired for HABs is expected in late 2024.

The Money Game - Options for Funding Lake Management

- Marisa Burghdoff, *Snohomish County Surface Water Management*

With climate change, increased development and ever spreading invasive species, the stressors to lakes in Washington are widespread and growing. Yet despite these pressures, state and federal grant funding for lake restoration is increasingly difficult to obtain. What are the options that lake communities, local jurisdictions, Tribes and others have to fund important work to restore lakes? This talk will present an overview of the funding sources for lake projects from the experience of the Surface Water Management division of Snohomish County. In addition to grants, the talk will discuss the benefits and constraints of lake management districts, surface water utility surcharges, local improvement districts and more. Through examples, we'll show how to optimize local revenue to start a long-term lake restoration project.

Session 5: Harmful Algal Bloom Management

A Lake That Flows Both Ways: Managing a HAB-impacted Floodplain Lake

- Katie Sweeney, *Herrera Environmental Consultants*
- Coauthors: Rob Zisette

Vancouver Lake in southwest Washington is considered a regional "gem" by the public but, despite decades of research and restoration efforts, the lake and its uses suffer from a variety of issues including annual toxic HABs and noxious aquatic weeds. Championed by citizen lake users, an appropriation from the state legislature was awarded to develop a Vancouver Lake Management Plan (VLMP).

Our approach for VLMP development included engaging technical experts and public stakeholders, and evaluating eight feasible management alternatives using lake modeling and cost-effectiveness analyses. The HEC-RAS 2D and WASP lake model predicted percent change in ecological endpoints from baseline conditions for each management alternative. The greatest reductions in peak cyanobacteria biomass resulted from phosphorus inactivation (58%) and algaecide (55%), followed by flushing channel enlargement (27%), lake outlet dam construction (-27%), and stormwater phosphorus treatment (-25%). The 20-year average annual cost for these alternatives ranged from $0.8M to $2M.

VLMP recommendations include: 1) flushing channel enlargement to reduce HAB formation long-term from substantial increases in Columbia River inflow, 2) increasing stormwater phosphorus treatment and sewer system expansion by enhancing existing watershed programs, 3) low-dose alum treatments for short-term HAB prevention, 4) targeted algaecide treatments in response to high-risk or beach closure events, 5) herbicide treatments to target specific noxious weeds, and 6) water quality monitoring and AIS prevention programs. To ensure VLMP success, additional components include a stakeholder involvement plan, a funding plan, and an adaptive management framework for addressing future lake issues.

Lake Cyanobacteria Management Plan Development for Lacamas, Round, and Fallen Leaf Lakes

- Jacob Krall, *Geosyntec Consultants*
- Coauthors: Ariel Mosbrucker and Steve Wall

Lacamas, Round, and Fallen Leaf Lakes are located in Clark County in southwest Washington State. Lacamas and Round Lakes have been classified as eutrophic since at least the 1980s, and Fallen Leaf Lake was found to be eutrophic in a recent study from Clark County (2021). Each lake has experienced algae blooms in recent years, with the blooms of most concern being harmful algal blooms (HABs), which are distinguished by the presence of cyanotoxin-producing cyanobacteria. Lacamas Lake has had cyanotoxin concentrations exceeding state guidelines in most years since 2018, and concentrations in Round Lake have exceeded state guidelines every year since 2019. Fallen Leaf Lake had its first recorded algal bloom in 2020.

This presentation will describe results from a year-long water quality study of the lakes and their inflows, focused on parameters relevant to understanding HABs. We will then discuss development of hydrologic and nutrient budgets, analysis of potential management options, the recommended management approach, and will touch on community outreach and stakeholder engagement. The lakes were found to be generally eutrophic, with some measurements representing mesotrophic conditions. While both internal and external loading were determined to represent a meaningful fraction of the phosphorus budget, external loading was determined to be the larger component. As such, management strategies addressing external loading are being prioritized.

Cyanotoxin production in Spanaway Lake (Pierce County, Washington) during the summer of 2021

- William Hobbs, *Washington State Department of Ecology*

Cyanobacteria (or blue-green algae) are common in many inland waters worldwide. A number of planktonic cyanobacteria species can produce toxins with potential human health and pet/wildlife impacts. Spanaway Lake in Pierce County (Washington) has a long history of cyanobacterial blooms. Here, I present an overview of sampling conducted in the summer of 2021 in Spanaway Lake. The objectives of the sampling were to (1) document the succession of cyanobacteria from May-October, (2) measure toxins and toxin-producing genes in the water column, and (3) explore associations among nutrients, cyanobacteria communities, and cyanotoxin production.

In situ profiling of the water column on a weekly basis demonstrated that by early June the water column is strongly stratified and the bottom waters contain very little oxygen; there is early summer growth of cyanobacteria in the bottom waters of the lake. In late-July and early August phycocyanin (PC; a cyanobacteria pigment) concentrations peak at a depth of 5m and subsequently PC is measured throughout the water column until October. In the anoxic bottom waters and at the sediment surface there is an increase of ammonia, iron and dissolved inorganic phosphorus from the sediments beginning in early August; at that time cyanobacteria growth has moved further up in the water column.

Microcystis aeruginosa is a small component of the cyanobacteria biomass, but likely produces the microcystin in Spanaway Lake. The expression of the Microcystin genes (Mcy) was high between July and September and dominated by genes that cover all major microcystin-producing genera (McyE) and genes that are attributable to Microcystis (McyA). The concentration of microcystin in the water has a positive correlation to McyA gene expression with a 2-3 week lag. There is a strong relationship between cyanobacteria growth (and microcystin production) and available nutrients. Cyanobacteria growth occurs mainly during periods of limited available N relative to P.

Use Patterns & Operational Efficiency of P Sequestration Agents

- Ryan Van Goethem, *EutroPHIX*
- Coauthors: Byran Fuhrmann, Ph.D.

Phosphorus sequestration is one management action utilized to address eutrophication and restore water quality in WA. Phosphorus sequestration agents have different implementation processes, and environmental compatibilities with water chemistry and waterbody characteristics. Use patterns and operational efficiencies will be compared for currently approved phosphorus sequestration products on Washington's APAM permit along with two new formulations (EutroSORB® WC and EutroSORB® SI). A better understanding of the technical fit of P sequestration products (or combinations) for a site and considering ease of implementation will allow for better water quality management decisions.

Session 6: Lake Research

Surveying Fish Consumption in Smaller Lakes for Human Health Risk Assessment and Communication

- James Gawel, *University of Washington Tacoma*
- Coauthors: Jenna Berglund, Nardoes Desta, Daniel Holycross, Jennifer Lai, Michelle Matous, Kathryn Noakes, Kenzie Sacco, Deanna Steen, Denise Drevdahl

Shallow lakes in Western Washington contaminated with arsenic pose a significant cancer risk for subsistence fishers, based on standard EPA consumption rates. However, the warm-water fish species of concern in these lakes (e.g., sunfish and carp) are not considered sport fish, and the number and demographics of people catching and consuming these species is not well known. As part of an undergraduate experiential learning class for registered nurses pursuing their Bachelors of Science in Nursing at the University of Washington Tacoma, we piloted a community-engaged research project to collect survey data from fishers at shallow lakes in Pierce and King Counties in Washington State. Students contacted fishers in person at multiple lakes and asked questions regarding frequency of visits, species caught and whether fish were consumed, information on who consumed the fish, the impact of health risk information on consumption behavior, and the best way to communicate risk to fishers. We will present our preliminary results and solicit input regarding the future expansion of this project.

Characterizing the Impacts of Arsenic Contamination on Freshwater Lake Microbiomes

- Sarah Alaei, *University of Washington Tacoma*
- Coauthors: Nyah Laureta, Sahra Jama, Alison Gardell, Jim Gawel

Microbiome structure and function are intrinsically linked modulators of host physiology, with potential to shape the ecology of the host. We hypothesize that arsenic (As) exposed environmental microbes contribute to the structure and function of primary consumer microbiomes in contaminated environments. To test this hypothesis, we collected aquatic snails and environmental samples from three lakes with differing As content and used 16S rRNA gene amplicon sequencing to evaluate microbiome composition. Our preliminary results support the notion that environmental As exposure shapes the taxonomic composition of environmental microbial communities. We found that Proteobacteria was the most abundant phylum in our reference lake, whereas the most abundant phylum in As-exposed sediment microbiota was Firmicutes. Similarly, we detected a shift from Proteobacteria dominated gut microbiota in reference lake snails to an increased prevalence of Bacteroidetes in the gut microbiota of As-exposed snails. While our sample size was small, these preliminary studies lead us to predict that environmental microbial communities, found in distinct environmental compartments, such as water, sediment, and periphyton, can influence the composition of freshwater snail microbiomes. This work is part of an ongoing effort to engage UW Tacoma undergraduate students, through coursework and independent study, in an interdisciplinary project focused on a local environmental problem. Our future studies will focus on expanding our preliminary dataset to increase statistical power and will include lab-based exposures of reference lake snails to As contaminated lake microbiota to determine the time-course and extent of microbiome modification that occurs when As is introduced.

Terrestrial-Aquatic Linkages in Debris-Avalanche Ponds Following the 1980 Mount St. Helens Eruption

- Katey Queen, *Western Washington University & Institute for Watershed Studies*
- Coauthors: Angela Strecker

The relationship between early successional terrestrial and aquatic ecosystems is still little known. Newly formed ponds and hummocks created by the 1980 Mount St. Helens volcanic eruption and landslide are still in their early successional stages and provide a natural experiment to better understand terrestrial-aquatic linkages. Zooplankton communities in these ponds may experience profound habitat and resource changes due to shifting forest plant communities and climate change. As

the terrestrial plant community shifts from deciduous-dominant forest to coniferous-dominated and climate change warms the region, an increase in terrestrial organic carbon, i.e. brownification, is expected to alter pond habitats. Eighteen mesocosms were established in 300-L cattle tanks near three perennial ponds at the Mount St. Helens National Volcanic Monument to observe zooplankton community and ecosystem changes. Using a factorial design, mesocosms were treated with a browning treatment of humic acid crossed with a leaf litter treatment, consisting of litter collected from nearby conifers (Douglas fir, Pseudotsuga menziesii, and noble fir, Abies procera), or deciduous trees (red alder, Alnus rubra, and willow, Salix salicaceae). Ponds and mesocosms were sampled weekly for five weeks over the summer to examine zooplankton diversity, biomass, and ecosystem respiration. Temperature, dissolved oxygen, pH, and nutrients (phosphorus, nitrogen, carbon) were measured or collected in ponds and mesocosms weekly. Dissolved oxygen and temperature loggers were placed in mesocosms to monitor these variables continuously. Dissolved oxygen exhibited a sharper decline in browning treatment mesocosms (average mean control = 8.28 mg/L, browning 6.42 mg/L), with the lowest dissolved oxygen levels in the browning treatments that were crossed with deciduous leaf litter (mean 2.96 mg/L). Total organic carbon in mesocosms after three weeks averaged twice as high in deciduous and browning-treated mesocosms compared to deciduous treatments alone and six-fold higher than the untreated controls, with coniferous mesocosms slightly lower than deciduous. There were differences in zooplankton community composition and biomass between the mesocosm treatments. Uncovering the terrestrial influences of plant succession and the effects of climate change in ponds can provide insight into zooplankton community structure, and ultimately, ecosystem function in this novel landscape.

Accuracy, Convenience, and Cost of using the Hanna checker for ultra-low phosphate readings in lakes for exploratory analysis by volunteers

- Sandy Williamson, *Friends of Spanaway Lake*

The $70 Hanna ULR marine checker provides volunteers a convenient and cost-effective way to do exploratory analysis of nutrient concentrations in lakes. We have analyzed dozens of samples with many comparisons to lab analyzed total P. We have found the error range to be higher than what is published, but useable if you follow procedures for repeat analysis. Spanaway Lake is phosphorus limited with concentrations in the 10 to 70 parts per billion range. Hannah's published accuracy says for readings over five parts per billion, the accuracy will be plus or minus 5% of the reading. We find that the accuracy in real world conditions to be more like 20% which is okay if we do repeat analysis. The reagent packs cost a little less than a dollar each. We repeat every test and if the two results are within 10 or 15% of each other we take the average. If the two results are more than 20% different we take a third reading. If one of the 3 results is then an outlier we take the average of the two similar results. Spanaway Lake has a significant algae blooms and nuisance aquatic plant problem. Spanaway Lake is unusual in that has a high volume of groundwater inflow and annual persistent surface water outflow. We have used a 5 gallon bucket to collect water samples out of groundwater vents. The bucket was upside down with a hose fitting in the bottom so that we could pump water coming from the vent to sample.

Poster Presentations

Using Microcosms to Estimate Internal Loading of Phosphorus in Spanaway Lake

- Mateo Schuler, *University of Washington Tacoma*
- Coauthor: James Gawel

Lake management decisions are directly impacted by whether phosphorus loading is predominantly from internal or external sources. But often internal phosphorus loading rates are estimated by indirect methods rather than direct measurements. The University of Washington Tacoma was contracted to

conduct an evaluation of Spanaway Lake sediments to measure internal phosphorus loading rates more directly for use in a refined nutrient model to inform lake management decisions. On March 30, 2023 we collected surface sediment samples by dredge (Wildco Petite Ponar) from a boat from three locations in Spanaway Lake where the water depth was greater than 6.5 m (below the seasonal thermocline). Additionally surface water was collected at one site. In the lab, we then created 30 microcosms in 1 L glass stoppered bottles with added dissolved oxygen sensor dots glued inside (PyroScience). Bottles were filled with ~350 mL of sediment and topped off with lake water. The microcosms were stored in a temperature-controlled chamber set to 13 °C, the approximate temperature of the bottom of Spanaway Lake during the summer. Once the microcosms were found to be hypoxic/anoxic, three random microcosms were sampled every other day for 14 days. The samples were transported within the required time frame to AmTest for analysis of TP, SRP, and total Mn and Fe. Our measured mean flux rate using SRP was 1.29 ± 0.70 mg P m-2 dy-1. This value is consistent with a flux estimate we calculated (1.2 mg P m-2 dy-1) using the change in hypolimnetic TP concentrations from June to July measured in 2021 by Herrera Environmental Consultants. The mean flux rate using TP in our microcosms was confounded by the presence of a non-settling solid, possibly an extracellular polymeric substance. Average total P, Mn, and Fe in the anoxic mesocosm water for the duration of the experiment (0.37 ± 0.13 mg P L-1, 0.47 ± 0.08 mg Mn L-1, and 3.64 ± 1.24 mg Fe L-1) stayed relatively constant likely due to the non-settling solid material. The previous indirect estimate of internal phosphorus loading to Spanaway Lake using an empirical relationship based on total phosphorus concentrations in sediments was 7.5 mg P m-2 dy-1, five times higher than our measured results. Therefore, microcosms may provide an accessible and more accurate estimate of internal phosphorus loading for use in nutrient budgets and lake management decision-making.

Assessment of Cyanotoxin Driven Water Quality Impairments in Freshwater Lakes of WA State

- Emese Hadnagy, *University of Washington Tacoma*
- Coauthors: Laci Bostwick, Rachel Cohn, Vinial Kumar, Isabelle Lake, Noah Melnick, Tyler Roberts, Joseph Joo

Water quality impairment due to toxins produced by harmful algal blooms (HABs) in lakes and other freshwater bodies in WA state pose a significant public health threat to people and animals. In 2023, the WA State Department of Ecology developed a methodology to assess for cyanotoxin impairment in the state's water bodies to meet its obligations to the federal Clean Water Act (CWA), specifically Section 303(d) list of impaired waters. We applied this assessment methodology to available water quality data on two cyanotoxins (Microcystins and Anatoxin-a) for 35 water bodies across the state with a range of human imprint in their watersheds, and developed category determinations of the level of impairment. With a rapidly changing climate and growing land use change, there are increasing threats to water quality of water bodies in the state. This work provides water resource planners and stakeholders an understanding of the extent of cyanotoxin driven water quality impairment and the data requirements necessary to make such determinations.

Looking Between Clouds: Examining the Efficacy of Remote Sensing as a Tool to Monitor for Harmful Algal Blooms in King and Pierce County Lakes

- Emese Hadnagy, *University of Washington Tacoma*
- Coauthors: Gopal Mulukutla, James Gawel, Joan Hardy

Satellite imagery has been widely used to assess surface water quality in marine waters and large lakes. However, operationalizing their use to study water quality in western Washington waterbodies, with the region's prolonged periods of cloud cover, can pose a seemingly impenetrable challenge. Nevertheless, we implemented peer-reviewed methods to extract three water quality indicators: chlorophyll-a, turbidity, and phycocyanin, in several lakes of western WA from multispectral imagery captured by

Sentinel-2 satellites operated by the European Space Agency. Due to these satellites' high temporal and spatial resolution (3-7 days revisit time, and 10m pixel size), statistically significant data can be captured for lakes as small as 30 acres during cloud-free periods. With initial results from a planned yearlong effort, we show that remote sensing can be an effective tool for the monitoring of harmful algal blooms (HABs) in western WA as there are many cloud-free days in the time period between April and October when blooms often occur. We will describe our planned efforts for validating satellite water quality indices with field monitoring, and our approach to assess water quality in lakes with varying trophic levels. We expect the results of this work to be of interest to the public health community, lake managers, and the science community to help anticipate the emergence of blooms, and plan for developing climate change resilient mitigation measures.

50 Years of Stream Monitoring. Statistical Analysis of Long-Term Trends in Water Quality throughout Streams in King County, WA.

- Emily French, *University of Washington Dept of Civil and Environmental Engineering*
- Coauthors: Michael Brett, Curtis DeGasperi, Jeremy Walls

Since 1980, the population of King County, WA has almost doubled. Conventional knowledge would predict a corresponding decline in water quality due to increased anthropogenic impacts. However, water quality appears to be maintaining or improving in most streams in the county. The King County Dept of Natural Resources and Parks has conducted a routine monitoring program for almost 5 decades, sampling 75 streams and rivers in the county. The program has compiled an exceptional database of stream water quality records, representing a wide variety of land cover types and stream sizes. This gives us a unique opportunity to analyze long-term trends in water quality and identify potential drivers of change. We are conducting a statistical analysis of Nitrite/Nitrate and Orthophosphate concentrations. First, we analyzed the overall distribution of trends in recent years versus their historic levels. This confirmed that the dissolved nutrient concentrations in most streams have decreased from their long-term average levels. Our next step will be to fit the recent data to statistical models that relate the recent nutrient concentrations to the proportion of developed land cover in each site's drainage basin, and the time frame of when this land was developed. We can compare these results to past studies to determine if the correlation between urbanization and water quality is as strong as previously indicated. The overall goal of this study is to explore which factors have played the most important role in the declining nutrient trend for the King County streams we assessed.