GRDA
Grand River Dam Authority

2022 ANNUAL REVIEW

ECOSYSTEMS EXPLORATIONS

Research, Conservation, and Protection

Grand River Dam Authority

The Grand River Dam Authority is an agency of the state of Oklahoma, created by the Oklahoma Legislature in 1935 to be a "conservation and reclamation district for the waters of the Grand River. GRDA is Oklahoma's largest public power utility; fully funded by revenues from electric and water sales instead of taxes.

GRDA utilizes a diverse portfolio of assets to generate, transmit and sell electricity to Oklahoma municipalities, electric cooperatives and industrial customers, as well as off-system customers across a four-state region. At the same time, GRDA manages over 70,000 surface acres of lake waters in Oklahoma, as well as the waters of the scenic Illinois River.

GRDA's Mission

We deliver affordable, reliable ELECTRICITY, with a focus on EFFICIENCY and a commitment to ENVIRONMENTAL STEWARDSHIP.

We are dedicated to ECONOMIC DEVELOPMENT, providing resources and supporting economic growth.

Our EMPLOYEES are our greatest asset in meeting our mission to be an Oklahoma Agency of Excellence.

If you are interested in learning more about the Grand River Dam Authority, please visit our website at www.grda.com or scan the QR code with your smartphone camera.

GRDA Grand River Dam Authority

GRDA's 5E's of Excellence

Electricity: We will produce low-cost, reliable electricity for our customers.

Environmental Stewardship: We will practice environmental awareness and promote conservation and reclamation of the natural resources under our control.

Economic Development: We will support economic growth and quality of life enhancement in Oklahoma.

Employees: We will be a diverse and energetic workforce, working together in a safe environment and treating each other with dignity and respect.

Efficiency: We will operate in the most efficient manner possible, to benefit our ratepayers and the people of Oklahoma.

Ecosystems Explorations - 2022 Annual Review

Table of Contents

The following is a compilation of programs, projects, and research performed and supported by the Ecosystems and Watershed Management Department of the Grand River Dam Authority. The Ecosystems and Watershed Management Department rose above many challenges in 2022 to accomplish our goals throughout the year. The work that is displayed in the following pages of this annual review represent the continued commitment that GRDA has made to be good stewards of the natural resources under our control.

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If you are interested in learning more about GRDA's research over the last 10 years, scan the QR Code with your smartphone camera.

Ed Fite, Jeri Fleming, Bill Mausbach, Courtney Stookey, Darrell Townsend, and Stephen Nikolai at the Governor's Water Conference

Ecosystems and Watershed Management

When the Grand River Dam Authority established its Office of Ecosystems Management in 2004, it did so knowing there was much work ahead. After all, the Grand Lake watershed spans four states including Kansas, Missouri, Arkansas and Oklahoma and culminates into one of the most popular recreation destinations in the region: Grand Lake.

Because Oklahoma only encompasses approximately nine percent of the watershed and the majority of Grand Lake's water supply originates from neighboring states, GRDA realized it could not face the natural resource challenges alone. Thus, the underlying theme for the department has been to build cooperative relationships to facilitate communication and efficient utilization of resources necessary to accomplish GRDA's conservation and restoration goals.

If you are interested in learning more about GRDA's Ecosystems and Watershed Management department, scan the QR Code with your smartphone camera.

Ecosystems & Watershed Mgmt.
420 Highway 28
PO BOX 70
Langley, OK 74350

Aaron Roper holding a snake found at Neosho Bottoms

GRDA staff participate in a wetland delineation class

Support for Higher Education Students

Over the years, GRDA fellowships and support programs have provided support for many students at all different levels of higher education. These fellowships have provided GRDA with valuable insight while also providing rate payers countless savings and developing the next generation of natural resources professionals, all while earning GRDA and our university partners numerous awards along the way, some of which can be seen on the next page.

Northeastern Oklahoma A&M: 18 students supported through various functions of the partnership.
Northeastern State University: 17 students supported, 17 BS.
Oklahoma State University: 13 students supported, 7 MS, 6 Ph.D.
Rogers State University: 8 students supported through senior level research projects.
University of Oklahoma: 23 students supported, 11 MS, 12 Ph.D.

Award Winning Programs and Projects

Over the last five years, the Ecosystems and Watershed Management team has received numerous awards from various state and federal entities. These awards can be seen below:

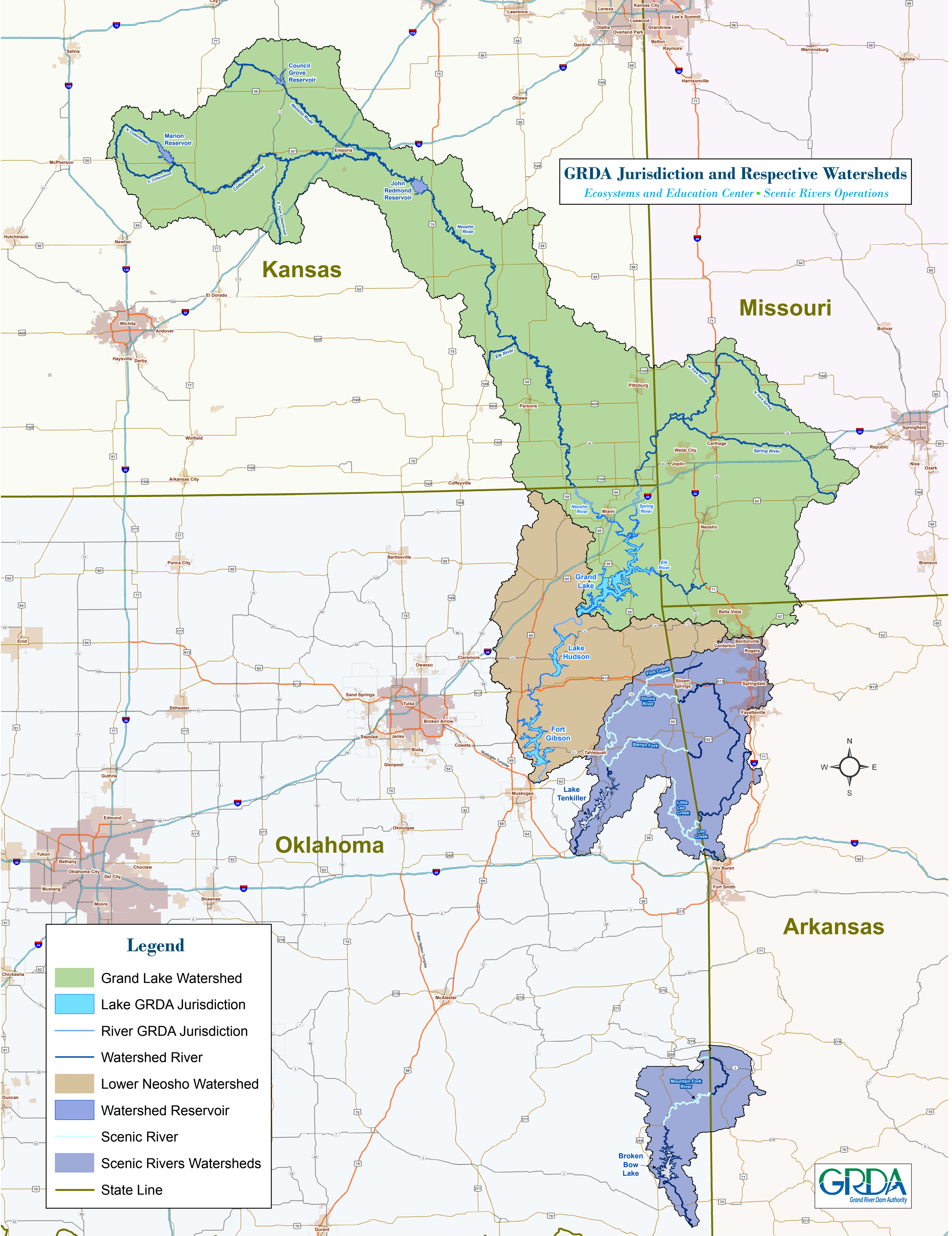
2022:
Septic Tank Remediation Program (Jeri Fleming): ***Environmental Excellence Award***: Keep Oklahoma Beautiful. November 18.
Conservation Easements (Ed Fite/Darrell Townsend): ***Outstanding Stewards of Americas Waters***: National Hydropower Association. October 20.
Jesse Rader (RSU Student)/Dustin Browning (GRDA Mentor): ***Best Biology Research Project***: Rogers State University. May 5.

2021:
Hunter Hodson (NSU Student)/Kate Wollman (GRDA Mentor): ***Outstanding Student Research Award***: Oklahoma Governors Water Conference. December 2.
Guard the Grand (Jeri Fleming): ***Best of the Environmental Best***: Keep Oklahoma Beautiful. November 19.
Guard the Grand (Jeri Fleming): ***State Government Award***: Keep Oklahoma Beautiful. November 19.
Ed Fite: ***"James R. Barnett" Public Servant Award***: Environmental Federation of Oklahoma. October 21.

2020:
Hailey Seago (RSU Student)/Dustin Browning (GRDA Mentor): ***Best Biology Research Project***: Rogers State University. May 16.
Conservation Easements (Grant Victor/GRDA-ECO): ***Leopold Conservation Award***: Sand County Foundation. March 1.

2018:
Rush for Brush: ***Certificate of Special Congressional Recognition***: Congressman Markwayne Mullin, House of Representatives. June 8.
Rush for Brush: ***Outstanding Stewards of Americas Waters***: National Hydropower Association. May 1.
Grand River Dam Authority/Northeastern Oklahoma A & M College: ***Regents Business Partnership Excellence Award***: Oklahoma State Regents for Higher Education. March 13.
Grand River Dam Authority/Northeastern State University: ***Regents Business Partnership Excellence Award***: Oklahoma State Regents for Higher Education. March 13.

2017:
Rush for Brush: ***Environmental Excellence Award***: Keep Oklahoma Beautiful. November 18.
Nick Tipton (ATU Student)/Stephen Nikolai (GRDA Mentor): ***1st Place Student Poster***: Oklahoma Clean Lakes and Watersheds Conference. April 6.



GRDA Watersheds

What is a Watershed?

A watershed is defined as an area that drains all of its rivers, streams, creeks, and runoff to a common outlet. This outlet may be the outflow of a reservoir, or the mouth of a bay, depending on your geographic location. A watershed consists of all of the surface water - lakes, rivers, reservoirs, and wetlands as well as subsurface groundwater.

The Grand River Watershed

The Grand River watershed is a collection of rivers, streams, creeks, and runoff that stretches across a roughly 10,300 square mile area and eventually flows into the Grand River in Oklahoma's northeast corner. It rests in four states, straddles two EPA regions and impacts the lives of hundreds of thousands of people.

Most of the watershed lies in the state of Kansas, with the water eventually making its way to Oklahoma by way of the Neosho River. In Missouri, another large portion of the watershed drains into our state mostly through the Spring River. The confluence of the Neosho and Spring rivers, near the heart of Ottawa County, is the beginning of the Grand River. Impounded by three separate dams, this river then gives us Grand Lake (Pensacola Dam), Lake Hudson (Robert S. Kerr Dam) and the Fort Gibson Lake (Fort Gibson Dam). Together, these lakes provide not only the "fuel" for hydroelectric generation and a valuable water supply across a large region, but also serve as a foundation for economic development tied to multiple industries, including manufacturing, tourism, recreation and more.

GRDA's Scenic Rivers Watersheds

Currently, Oklahoma has six scenic rivers that collectively extend 161 miles through six counties. The scenic river designation affords these valuable resources the highest protection and priority available through Oklahoma's environmental agencies. Specific requirements of this designation include a strict prohibition on additional pollutants, dams, and wastewater treatment plants, and a close monitoring of construction activities alongside the river.

The GRDA is invested with the power to establish minimum standards for planning and other ordinances affecting scenic rivers. As the Oklahoma Scenic Rivers Commission had done since its establishment in 1977, GRDA continues to work with communities, businesses and individuals to mitigate their impact on scenic rivers. We strive to educate the public about scenic rivers and also to provide everyone the opportunity to enjoy the features that make these water resources so special.

The partnership with Northeastern State University to create the GRDA-NSU Scenic Rivers and Watershed Research Lab is meant to help protect and better understand the Illinois River and its watershed, as well as the rest of the scenic rivers. The Ecosystems & Watershed Management department is ready to carry out the provisions of the Scenic Rivers Act through protection, preservation, and education.

GRDA's Commitment to Water Quality

The GRDA Ecosystems & Watershed Management Department opened the doors on its state-of-the-art water quality laboratory in 2010, and has been expanding and developing its capabilities and water monitoring efforts ever since. In fact, the installation of several floating water quality profilers in Grand and Hudson lakes in years past has allowed the department to make real-time water quality data readily available to interested lake stakeholders.

Currently, the department consists of two separate laboratories. The Water Quality Research Lab in Langley has 15 established sampling sites on Grand Lake, along with six on Lake Hudson and one on the W.R. Holway Reservoir. While the Scenic Rivers Watershed Research Lab in Tahlequah has 13 sites along Oklahoma's Scenic Rivers and their tributaries.

These monitoring locations are visited twice monthly during the recreation season, and once monthly during the off-season. Samples are taken more frequently and at non-established locations in the case of problem events such as blue green algae (BGA) blooms, bacteria outbreaks, and any public call out.

One goal of GRDA's water quality laboratories is to implement and conduct a long-term water quality monitoring program on GRDA's project lakes and rivers. These programs and the data that are produced when paired with agency and university partnerships will allow water professionals to make more informed and scientifically supported decisions on watershed management techniques in GRDA's watersheds. This goal of conducting long-term water quality monitoring programs ties hand in hand with supporting collaborative projects with other agencies and universities.

Both laboratories are responsible for responding to any call outs from the public concerning water quality. These can include BGA blooms, bacteria outbreaks, fish kills, and general concerns for health and public safety. These are areas that the Ecosystems & Watershed Management team take very seriously, and typically respond on the same business day.

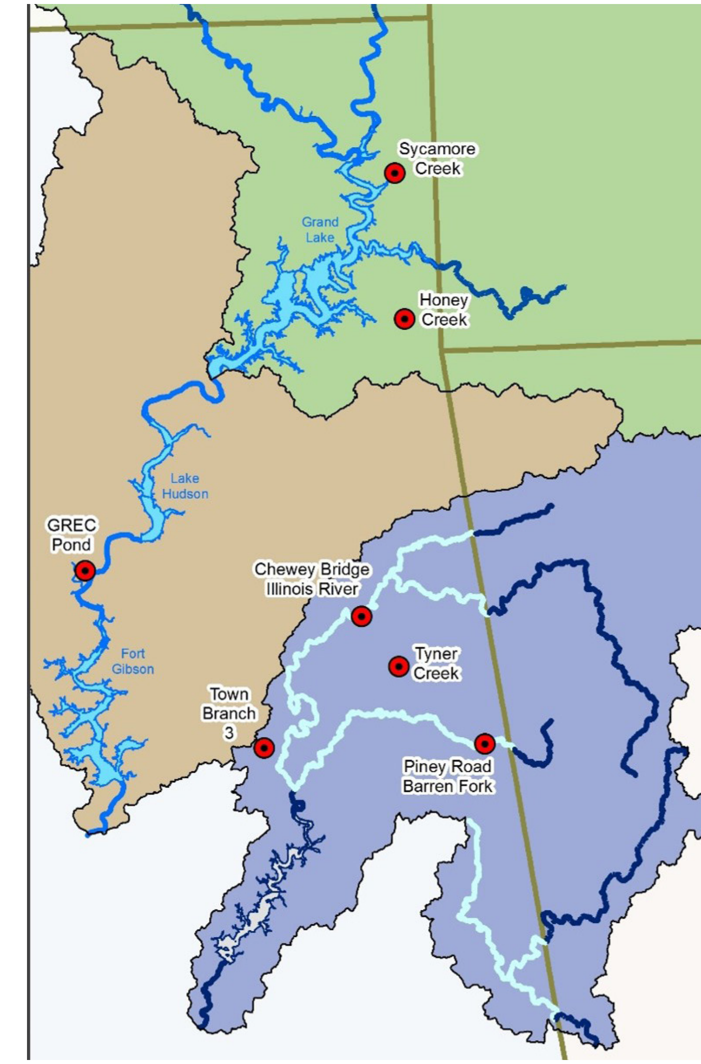
If you are interested in learning more about GRDA's water quality efforts, please visit our website at www.grda.com/environmental-stewardship or scan the QR Code with your smartphone camera.

Intern Walker John preparing a sample along the Barren Fork

A photo from a 2022 algae bloom in Ketchum Cove

Genetics Work

Many streams in the United States are listed as being impaired for high levels of fecal indicator bacteria. In Oklahoma, approximately 75% of assessed stream miles are listed as bacteriologically impaired. These impairments threaten public health and safety and contribute to the further degradation of our water resources. However, less is known about the potential sources of these bacterial impairments and how those different sources impact human health risks. To better understand this issue, GRDA has greatly expanded its microbial source tracking (MST) capabilities in recent years. MST uses genetic technologies to analyze environmental DNA found in water and lets us characterize fecal bacteria from individual sources. These sources can be from humans, cows, chickens, pigs, and many others. To date, GRDA has analyzed 43 locations on streams within our watersheds using MST. We have found that in urban areas the prominent source of pollution is humans and in rural areas the prominent source is cattle and sometimes poultry, thus linking the prominent source of bacteria in an area to that area's land use. The ability to understand the source of bacterial pollution on a case-by-case basis and in a timely manner allows us to quickly take informed mitigative action using best management practices to remediate the issue and keep our lakes and rivers healthy.



Along with this application of genetics, the Ecosystems and Watershed Management team can also use our genetic technologies to look for cyanobacteria, parasites, and infectious diseases (such as COVID-19) in surface and wastewater applications.

Microscope photos from an aphanizomenon bloom

GRDA's mobile lab van taking a stream sample

Threatened and Endangered Species

Bald Eagle Monitoring

The Ecosystems and Watershed Management team conducts aerial bald eagle surveys from a helicopter every year in January and April. Surveys are typically conducted by a GRDA pilot and at least one observer. These surveys take place 400-500 feet above the tree line at airspeeds ranging between 50-60 MPH. In the January surveys, adults, juveniles, paired eagles, and active nests are counted. Nesting locations from previous years are also inspected for new activity. New nesting locations are always noted and marked.

During the spring survey, observers look for new eagle nests and also check eagle nesting sites from previous surveys for activity and for the numbers of juveniles and adult eagles present at the time of the survey. New nesting locations are marked with a GPS and the coordinates are examined to determine if these nests are located within the project boundary. The information that is collected on these surveys is then shared with the George Miksch Sutton Avian Research Center in Bartlesville, OK, to help update their bald eagle nesting database as GRDA is an active member of their Bald Eagle Survey Team (BEST).

In 2022, Grand Lake had 12 active nests inside of the project boundary while Lake Hudson had 11.

Bat Species Monitoring

With the help of The Nature Conservancy and the United States Fish and Wildlife Service, GRDA manages three bat caves around the Grand Lake area. Two of these caves are found inland, and one is found directly on the shores of Grand Lake. These caves hold maternity colonies of the endangered cave obligate Gray Bat (*Myotis grisescens*). The shores of Grand Lake are also home to the threatened tree dwelling Northern Long-Eared Bat (*Myotis septentrionalis*).

Management activities are conducted by GRDA through agency and university partnerships. These management techniques include population estimates, nighttime counts, and White Nose Syndrome monitoring. GRDA has also written protective measures into its shoreline management plans to prevent any harm or habitat loss to these unique guests of GRDA lakes.

GRDA's Bell 407 GXI used for Bald Eagle surveys

Ice stalagmites that formed at the entrance of Jailhouse Cave

Neosho Bottoms Wildlife Management Areas

NEO A&M Partnership

In the summer of 2016, GRDA and NEO A&M formally announced a partnership agreement for pecan orchards and livestock grazing. The original plan was for GRDA to lease 1,600 acres in Ottawa County to NEO A&M for $1 per year. Since then, the original 1,600 acres has turned into around 3,000 acres available for the school's use. GRDA plays an active role in helping manage these lands by performing controlled burns and applying various best management practices.

The partnership allows NEO A&M to sublease the pecan orchards to local pecan producers and allows it to become a revenue stream for the school. These types of private-public partnerships help universities deal with massive reductions to public education budgets.

GRDA staff also work with the university to provide drone classes and other guest speaking opportunities as well as research support.

Controlled Hunts

In addition to the NEO A&M partnership, GRDA has opened around 2000 acres of this area along the Neosho River for controlled hunts, managed by GRDA. The public can register for these hunts online. Winners are selected at random with special consideration being given to those who are residents of municipal customers or public power communities.

The different types of hunts include deer, waterfowl and turkey. There are also hunting areas that have been designated for use by the Mid-America Chapter of the Paralyzed Veterans of America (PVA). In fact, around 1,000 acres has been designated for PVA hunts since 2014. This partnership with PVA has given hunting opportunities to people with impaired mobility, who would otherwise have very limited access to public hunting lands.

During the 2022 hunting seasons, GRDA hosted around 75 PVA and conventional hunters for our controlled hunts.

A food plot installed and maintained by GRDA

Seth Hembree with some rescued animals

GRDA's Guard the Grand Program

The Guard the Grand program is a watershed education program designed to involve the public in improving water quality throughout the Grand Lake watershed. Currently, the program is funded through an Environmental Protection Agency Environmental Education Grant. The grant targets three audiences: residents/lake users, educators, and businesses. Each audience receives information specific to them and ways they can easily implement some best management practices.

For residents and lake users, we were able to hold five landscaping workshops that gave away around 30 rain barrels that were installed in our watersheds. We also furthered our partnership with the Oklahoma Conservation Commission and Delaware and Ottawa County Conservation Districts in the Yard by Yard Community Resiliency Project by co-hosting workshops, giving away wildflower seeds, and talking to residents about how simple changes to landscaping can help protect water quality. Also, in furtherance of this project, we awarded a grant to Friends of Blue Thumb to develop co-branded Yard by Yard materials and for development of both a travel display for use in the watershed and a more permanent display at an area historical attraction. In addition, multiple other grants were given to various other environmental agencies.

For educators, we held our annual Riverology 101 Educator Workshop in July. We had a small group of teachers that were all from our watersheds. We were invited to present our 4th grade curriculum to the National Ag in the Classroom conference where we reached about 125 educators from across the nation to give them tools to help educate about water quality issues in their region. As a result of our education efforts with youth, we educated over 1500 students about water quality issues and how they can help protect our lake and streams.

As part of our septic remediation program, we partnered with the Oklahoma Conservation Commission, Oklahoma Department of Environmental Quality, and the Oklahoma Water Resources Board to replace 11 septic tanks and disconnect three additional tanks and connect them to city sewer. Our combined efforts were recognized by Keep Oklahoma Beautiful at their annual Environmental Excellence Awards banquet.

In partnership with the Oklahoma Conservation Commission, we were able to enroll an additional 31.8 acres in conservation easements in the Horse Creek Watershed. As a result of our partnership with OCC, the effort was recognized by the National Hydropower Association as one of the 2022 Outstanding Stewards of America's Waters.

A group photo from the Port Duncan HOA workshop

Jeri Fleming talking to the City of Cushing

GRDA's Education Program

GRDA's Ecosystems & Watershed Management department provides many educational opportunities to local K-12 schools in the watersheds. Educational outreach is an important part of GRDA's mission by teaching students about environmental stewardship. Through this outreach, students will gather knowledge firsthand from professionals and will be exposed to different career opportunities. Our team strives to promote engaging and meaningful lessons and activities that will get students excited about STEM education.

We offer two options for educational outreach – a guest speaker can come to the classroom or the class can come to our ECO facility. Schools can contact GRDA to request a guest speaker to come to their classroom to discuss water quality, water management, conservation, stream health, and much more. The speaker will bring hands-on resources to the classroom and will use them to connect the lesson to Oklahoma's Academic Standards for Science. The second option for local schools is to have a field trip to the Ecosystems and Education Center for a day of hands-on learning and to see our state-of-the-art Water Quality and Research Lab and Oklahoma's first hydroelectric facility – the Pensacola Dam. There are educational resources on-site and space to accommodate a large group of students. The center serves as a space where students can learn about ecosystems management, hydroelectric power, water safety, the history of the Grand River region, and much more. While visiting our center, students can check out the rain garden (bioretention cells), see a life-size turbine wheel, or take in the views of Grand Lake and the Pensacola Dam up close.

GRDA also hosts two youth day camps each summer – Journey to the Bottom of the Creek in Tahlequah, Okla. and A Grand Adventure in Langley, Okla. At these camps, GRDA partners with other agencies to have a day full of activities for 9–12-year-olds. The students learn about the water cycle, water pollution, erosion, what lives under the water, and how to seine for bugs and fish while wading in the creek.

Each year, GRDA participates in a couple of annual outreach events around the watersheds. The MidAmerica STEM Alliance Showcase is held in Pryor, Okla. where we set up a booth to educate 4th-6th graders on stream health while looking at macroinvertebrates under a microscope. GRDA visited with 460+ students throughout the day at this event. The Lost Creek Water Festival is in Wyandotte, Okla. and GRDA brings the mobile lab van to teach 4th-6th graders about water quality. This event allowed GRDA to meet with approximately 500 students.

In 2022, it is estimated that our team reached over 1,500 students through these outreach programs, breaking our record of the number of students reached by our team in a year! With our outreach programs continuing to grow, we hope to increase those numbers in the years to come. This year the students spanned across the Grand Lake, Lake Hudson, and the Illinois River watersheds. The students ranged from 4th grade up to 12th grade. Educating youth on environmental protection creates a direct impact on changing the behaviors and attitudes of the youth and future generations, as well as possibly influencing those around them.

To schedule outreach with our team, please email Courtney Stookey at Courtney.Stookey@grda.com.

Bill Mausbach showing GRDA's stream trailer at Earth Day

Fisheries Habitat Enhancement

GRDA's Rush for Brush Program

In the spring of 2007, the Grand River Dam Authority's Rush for Brush program made its debut on Lake Hudson, with a small workshop attended by a few volunteers. With an end goal of enhancing the lake's fishery, GRDA staff and several volunteers spent the day building artificial fish habitat structures out of materials supplied by GRDA. Simulating natural brush piles, these structures provide protection to fry and fingerlings while staying in place and lasting longer than natural brush piles. This fisheries enhancement helps GRDA to meet its mission as a good steward for the natural resources under its control.

Today, nearly 16 years later, hundreds of volunteers and dozens of workshops later, the program's end goal has not changed, even though its popularity and impact across the GRDA lakes region has grown exponentially. In fact, Rush for Brush was recognized with the "State Government Program" award from Keep Oklahoma Beautiful in 2017 and, in 2018, it was won the "Outstanding Stewards of America's Waters" award from the National Hydropower Association. To date, roughly 17,450 structures have been placed in GRDA lake waters. That is large enough to cover roughly 11 acres of lakebed with artificial habitats that continue to benefit countless numbers of fish.

At a workshop in the spring of 2022, over 40 volunteers built 450 structures, destined for GRDA lake waters.

But the program is not limited to Grand and Hudson lakes. In October 2021, GRDA and the Oklahoma Department of Wildlife Conservation (ODWC) teamed up with students from Stilwell, Okla., to place 300 artificial fish habitat structures into GRDA's W.R. Holway Reservoir, part of the Salina Pumped Storage Project, near Locust Grove. Those structures were deployed in 28 clumps to resemble large piles of hardwood trees. That took place while GRDA had lowered the reservoir for a scheduled inspection.

If you are interested in learning more about GRDA's Rush for Brush program, please visit our website at www.grda.com/rush-for-brush or scan the QR Code with your smartphone camera.


An aerial photo of the structures built in 2022


A group photo of 2021 volunteers

Conservation Easements and BMPs

One of the Grand River Dam Authority's founding objectives was to create a conservation and reclamation district. Thus, good stewardship of the natural resources under our control has always been at the core of the GRDA mission. In recent years, GRDA has begun to place extra emphasis on obtaining conservation easements along sensitive waterways. These conservation easements are legally binding although voluntary agreements, between GRDA and landowners, to restrict usage of land within the easements.

Once an easement is agreed upon, the property is designated as a protected riparian area. The landowner then works with GRDA staff and program resources to implement various conservation practices, stabilize streambanks, and manage the easement in ways that will benefit water quality in the adjacent water-bodies. These agreements include best management practices (BMPs), which are things such as stopping new construction, keeping livestock out, and optimizing agricultural production.

Having naturalized riparian areas can help to filter as much as 80 percent of pollutants such as bacteria, nutrients, and sediments before they enter streams, and are one of our best and least expensive tools to help protect water resources in these important watersheds. Since GRDA's absorption of the Oklahoma Scenic Rivers Commission in 2016, 1,726 acres have been added to the conservation easement inventory, including around 32 acres in 2022

The ultimate goal of these conservation easements and BMPs are to keep the land surrounding our precious water-bodies as close to its natural state as possible. If we are able to do this, the water quality in these areas will be better off for it.

In 2022, our conservation easement was recognized by the National Hydropower Association as one of the 2022 Outstanding Stewards of America's Waters.


Non-Easement (L) and Conservation Easement (R)


A whitetail deer using one of GRDA's easements

A Look Back at 2022 in Photos

Jesse Rader and Cheyanne Olson with an award from RSU

A GRDA truck parked in the spillways below Pensacola Dam

Joel Barrow at the Ecosystems & Education Center

Ecosystems staff after a successful mussel survey

Tate Baumert and Jesse Rader returning from a buoy retrieval

UNIVERSITY PROJECTS

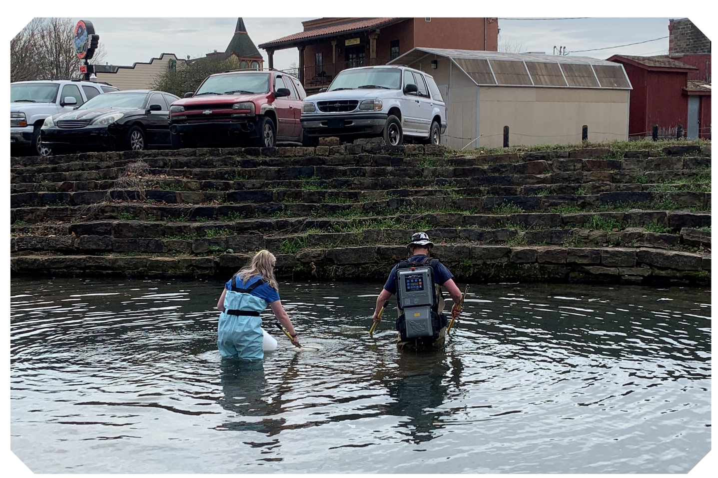
A FISH COMMUNITY ASSESSMENT OF AN URBAN STREAM, TAHLEQUAH CREEK, TAHLEQUAH OKLAHOMA

Cale Corley and Richard Zamor
Department of Natural Sciences
Northeastern State University

Rivers and streams are among the most threatened ecosystems worldwide. For many, their fish assemblages have been modified by anthropogenic habitat alteration. I compared the current fish assemblage in Tahlequah Creek against a previous fish community assessments. Previous assessments were completed in 1988, 34 years ago, which was before significant wastewater and infrastructure improvements were implemented on Tahlequah creek. These recent improvements possibly affected fish diversity over time. I surveyed seven sampling sites on Tahlequah Creek beginning at its headwaters to where it meets the Illinois River. I sampled each site for physical and chemical parameters and for habitat and substrate characteristics, including identifying and measuring all potential fish passage blockages (e.g. low-head dams) that occur along Tahlequah Creek. The first four sample sites, located in the first and second order portions of the stream, are impacted by multiple man-made structures that impede flow. The final three sites, in the third order portion of the stream are undisturbed.

I observed a total of 34 different species of fish. In the first order portion of Tahlequah creek, five total species were found. Nine total species were found in the second order sections, and a total of 33 in the third order. These species counts are lower than in historical surveys. The more abundant species in our collections are central stonerollers - *Semotilus atromaculatus* and southern redbelly dace - *Chrosomus erythrogaster*. Fish passage blockages are the biggest factor in determining the assemblage structure of the fish in Tahlequah Creek. It is important to better understand the local fish communities their distributions because Tahlequah Creek is home to a diverse fish community, but also flows into the Illinois River, a State Scenic River in Eastern Oklahoma.

Cale holding a largemouth bass caught during a survey



Sampling for fish in Tahlequah Creek

A THREE-MONTH ASSESSMENT OF LITTER LEVELS ON THE ILLINOIS RIVER

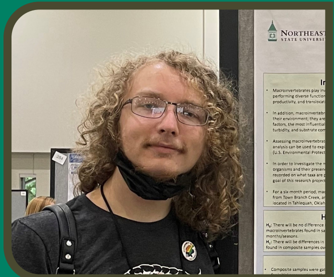
Emma Mills and Elizabeth Waring
Department of Natural Sciences
Northeastern State University

Tourism and recreational use of freshwater are important sources of economic growth for cities around the world. The Illinois River in Tahlequah, Oklahoma is no exception to the rule. Due to tourism, during the summer months, this state scenic river brings an influx of economic activity to the area. Along with the summer rise in recreational use, anthropogenic litter is increasing in volume and it is unknown the amount of damage being caused to the Illinois River. Trash and litter in freshwater systems pose serious threats to both human and environmental health. To assess the ongoing pollutant issues on the Illinois River, we quantified and categorized collected litter. Trash was collected by a paid float crew and brought to a sorting site. Upon arrival, bags of trash were weighed and individually sorted into categories: tin, aluminum, glass, plastic, styrofoam, personal items, wrappers, and misc. The items were counted and weighed in total before moving on to the next bag of litter. Averages/totals over the collection period will be used to establish what litter and how much was calculated.

In parallel to fieldwork, we incorporated human dimensions by issuing a survey/questionnaire to the public by posting QR codes at approved businesses, public access sites, and the Northeastern State University campus. Littering happens due to improper education, regulations, and management methods. Our findings and future similar assessments can direct educational outreach programs, management practices, and even bills to help protect river health and ensure the conservation of the Illinois River and other regulated waters. It also gives insight into the quality of waterways with similar regulations. Without change, the future of water will only get worse, but it is heavily relied on by humans and animals for life.

Trash collected on the Illinois River

Sorting trash after a day of collecting



MACROINVERTEBRATE COMPOSITION COMPARISON USING VARIOUS SAMPLING METHODS

Jonathan "Keegan" Stallings and Elizabeth Waring
Department of Natural Sciences
Northeastern State University

Aquatic macroinvertebrates play important roles in stream ecology. They can be primary processors of organic materials and can also be indicators of water quality health. This study focuses on the macroinvertebrate communities found in Town Branch Creek in Tahlequah, Oklahoma. During this study, the foundational macroinvertebrate communities for this creek were sampled and identified during the spring and summer seasons. This research intends to expand upon this macroinvertebrate community data by sampling the stream with varied techniques to get a stronger overall community overview. It is necessary to test out different sampling techniques so that the most effective strategies can be determined and employed. Traditionally, the stream has been sampled using the kicknet method. This is done by entering the stream with a kicknet and kicking the substrate and attached or surrounding macroinvertebrates downstream into the kicknet. The current project will additionally sample with a D-net, a Hess sampler, a rock scrubbing technique, and potentially a baiting method. The D-net sampling will be carried out by Dragging the D-net along the benthos in a sweeping-like motion to collect the above benthic and free-swimming macroinvertebrates. The Hess sampling is carried out by fixing the sampler into the substrate and letting the macroinvertebrates passively filter in through its filters throughout the water column. The rock scrubbing technique is carried out by carefully lifting rocks out of the stream bed and scrubbing the macroinvertebrates attached to them into a container. The baiting sampling method has yet to be completely determined but will involve baiting and checking the sampler for its trapped macroinvertebrates.

Contrasting sampling techniques will potentially feature differences in observed specimens. This is because macroinvertebrates develop different feeding strategies to occupy diverse niches and compete for limited resources. It will be interesting to see the different functional feeding groups and their representations across the different sampling techniques. Resource management can be difficult to implement over wide geographical ranges that resource agencies are expected to oversee. This is why it is crucial to put different techniques to the test in the field so that the most efficient sampling methods are being used in the field to accurately and time-effectively gather the data necessary for making important management decisions.

Sampling equipment on the shoreline

A mudpuppy that was collected from Tahlequah Creek

MACROINVERTEBRATE COMPOSITION STRUCTURE CHANGES DURING THE WINTER SEASON

Victoria Stallings and Elizabeth Waring
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Aquatic Macroinvertebrate communities play important ecological roles in our water resources. For this reason, over the last two years, we have been conducting macroinvertebrate composite sampling in Town Branch Creek in Tahlequah, Oklahoma to assess the foundation of what organisms are occupying this iconic scenic waterway. Macroinvertebrates have short life spans, which leads to a quick turnover within the community when a disturbance, such as the addition of a pollutant, has occurred. In addition to this, different macroinvertebrates have differing pollutant sensitivity, meaning that some species in the community may be heavily negatively affected by pollutants, such as heavy metals, while other species in the community show little to no reaction. A sudden lack of only pollutant sensitive species while pollutant tolerant species remain is a very strong indication that a waterbody may be impaired from a pollutant without the use of expensive chemical testing. Sampling is conducted with a kick net in three areas at each stie. Then the sample is taken to the lab and each macroinvertebrate is identified under the microscope to the furthest taxonomic level possible. This data makes up our knowledge of the community that will continue to be added to and used comparatively in the future.

Now that we have concrete data surrounding the spring months of late March to the summer months of late September, it is crucial to determine which organisms are present during the winter months of November through February. The next/current step in our research will be to sample during the winter months so we have year-round data on our community structure and its fluctuations. A primary reasoning for this goal was the lack of discovery of any plecopterans (stoneflies) in this creek throughout previous sampling. This is made even more complex because previous samples throughout the Illinois River System have had stoneflies. Plecopterans are known to prefer colder temperatures and inhabit and emerge from the stream during winter, so this has led to undertaking of sampling during the frigid seasons of this year to determine whether these insects have any place in the Town Branch Creek ecosystem. It will also be intriguing to see the changes in community population sizes and what other organisms are present in the samples during these months as well. It will also be intriguing and informative to see the changes in community assemblages during these months as well.

A cluster of snails found at Tahlequah Creek

Tipuliidae larvae found in Tahlequah Creek

DETERMINING RELATIONSHIPS OF FISH ASSEMBLAGES, LAND USE, AND INSTREAM HABITAT TYPE IN PARKHILL BRANCH CREEK, TAHLEQUAH, OK

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Habitat alteration can be induced by natural processes as well as anthropogenic ones. Riparian alteration can reduce canopy cover, alter stream flow, and reduce substrate diversity. Anthropogenic influences can lead to eutrophication of small streams and in return, fish species richness can decline. Understanding fish abundance and distribution within these small streams can allow us to assess the effects of land use on the fish biota and their habitat within the creek. Parkhill Branch Creek is a three-mile-long Ozark tributary stream of the Illinois River near Tahlequah, Oklahoma. Land use is varied throughout the stream's reach including natural forested areas, farm/pastureland, residential housing, and a plant nursery. We are conducting one of the first fish assemblage assessments of Parkhill Creek. In addition to characterizing the assemblage we will also investigate how fish communities change in relation to instream habitat type and land use. Monthly sampling is done by electroshocking a 100 m stretch at four sites throughout Parkhill Creek and collected fish are identified to the species level. An instream and riparian habitat assessment are done at each site.

Currently, 2317 specimens have been collected from 28 different species. Results from this study will provide a valuable assessment of the fish assemblage of Parkhill Branch Creek and any correlations between fish abundance and distribution with riparian land use, canopy cover and instream habitat.

Caleb collecting fish during a sampling event

A fish that was collected and released as part of the survey

QUANTIFYING CARBON THROUGH TERRESTRIAL AND WETLAND LANDSCAPES IN NORTHEAST OKLAHOMA

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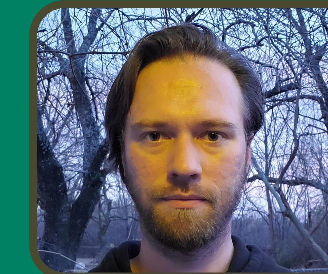

The overarching question is how much carbon is being sequestered at each of these sites and how does carbon flux differ between upland and riparian/wetland areas of land belonging to GRDA. GRDA owns lands of mixed usage. As these lands range from dry uplands to wetlands and riparian zones and all the land in between, there has been interest in knowing how much carbon is being sequestered in these various land types. We will be looking at how carbon moves through those systems using a mix of traditional forestry techniques, computer analysis of the data, and using a portable photosynthesis machine to examine how carbon is moving through plants and the soil in conservation easements owned by the GRDA.

This research will work on answering questions such as: Where is the carbon moving to and from within various properties? How does sequestration change with year to year flux of environmental variables (i.e. temperature and precipitation)?

Jon helping to harvest rivercane

Equipment used for carbon sequestration experiments

THE IMPORTANCE OF MAGNESIUM ON ALGAL GROWTH IN GRAND LAKE

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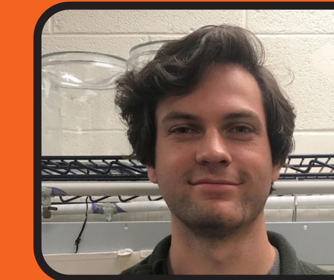
Biological growth is influenced by the availability of nearly 25 elements essential for life, that interact to form all organic and inorganic molecules in living organisms. The most abundant element in a cell is carbon and it accounts for 50% of cellular dry mass. Other abundant elements in a cell include nitrogen (N) and phosphorus (P), that are essential in building the nucleic acid backbone, and in protein homeostasis. Approximately 50% of cellular P is present in ribosomal RNA (rRNA), that catalyzes protein synthesis. Another major reservoir for P is in the "universal energy currency of the cell", adenosine triphosphate (ATP). Notably, magnesium (Mg) interacts with P and plays a crucial role in stabilizing the negative charge of phosphate in RNA and ATP molecules; thereby affecting transcription, protein metabolism, and cellular energy storage.

The role of P in enhancing algal growth and in promoting harmful algal blooms has been studied since the 1970s, but we still cannot predict algal growth in lake accurately, likely due to lack of studies on how availability of elements such as Mg affect algal growth. Since P and Mg interact with each other in several cellular processes, we predict that algal growth is affected by availability of Mg. A combination of natural and anthropogenic factors such as agricultural run-offs, sewage treatment outflows, mining activities, and geological make-up in the watershed, contribute to elemental profile and risks for eutrophication in reservoirs. Magnesium varies across lakes from ~100 to 4000 µg/L nationally and is approximately 3000 µg/L in Oklahoma reservoirs.

Grand Lake is a popular recreational facility and an economic asset to the state of Oklahoma. Due to anthropogenic activity and local geochemical features, there are spatial and temporal variations in nutrients, that leads to a distinct microbial signature in the lake. Our laboratory studies using a gradient of Mg concentrations on a model algal taxon indicate that that there is a correlation between algal growth, and availability of Mg in the growth media. In the future, we plan to test our predictions on Mg availability and algal growth within Grand Lake and across Oklahoma lakes. Such studies focusing on elemental analysis and assays on algal growth will complement our laboratory studies, and lead to a comprehensive understanding of Mg and P co-limitations on algal growth.

Algal growth assay being performed in a growth chamber

The outcome of these surveys will advance our knowledge on predicting and mitigating algal blooms, and potentially help develop improved strategies for reservoir management.



ANALYSIS OF TOTAL MICROCYSTINS USING TIME-INTEGRATED PASSIVE SAMPLING

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Cyanobacteria are a phylum of bacteria that can come to dominate algal blooms, and some species of cyanobacteria have the ability to produce toxins (cyanotoxins). Microcystins are the most common freshwater cyanotoxin and present a risk to wildlife and humans who may interact with contaminated water bodies. As a result, the USEPA has established maximum safe water concentrations of 8 parts per billion in ambient waters. Therefore, a sensitive analysis is required to detect microcystins at or below safe levels. Furthermore, detecting microcystins in the environment presents a challenge as microcystins can have heavily fluctuating concentrations due to a variety of environmental factors. Passive sampling may offer a way to improve the analysis of microcystins, especially when low or fluctuating concentrations are present. This form of sampling involves placing a sorbent receptive to the analyte (microcystins) in a water body to allow the sorbent to collect the analyte over time. Due to the continuous collection of the analyte, passive sampling offers a way to integrate potentially fluctuating or low analyte concentrations with time, which may allow for a more toxicologically relevant analysis of microcystins in the environment. However, there exist over 200 variants of microcystins, each with different chemical characteristics and toxicities. Current analytical methods associated with passive sampling of microcystins are not well suited for detecting all microcystin variants simultaneously. Furthermore, during a bloom, large portions of microcystins can be bound to cyanobacteria cells, which will alter their uptake onto passive samplers. Therefore, the purpose of this study was to explore the feasibility of coupling passive sampling with the analysis of total microcystins (all variants), and to assess the influence of cell-bound microcystins on the uptake kinetics of passive samplers. To do so, microcystins were harvested directly from cyanobacteria cultures and used to calibrate passive samplers. Both Gas Chromatography—Mass Spectroscopy (GC-MS) analysis and Enzyme-Linked Immunosorbent Assay (ELISA) were assessed as methods for analysis of total microcystins from passive samplers. While both methods had exceptional detection limits for total microcystins, ELISA was chosen as the simpler and more efficient analysis. Using the established ELISA analysis method, 3 passive sampler designs were calibrated for the measurement of total microcystins. These designs differed in their porous membrane material using either polyethersulfone (0.1 µm pores), nylon mesh (35 µm pores), or steel mesh (150 µm pores) to enclose the sampler sorbent. After calibration, the uptake of dissolved and cell-bound microcystins were then further investigated in the polyethersulfone and nylon samplers to establish how well the samplers work while some microcystins are bound to cyanobacteria cells.

All 3 sampler designs were successfully calibrated for analysis of total microcystins, indicating that they can be used for time-integrated analysis and quantification well below the USEPA safe concentrations. Furthermore, it was determined that coupling ELISA analysis with passive sampling using steel or nylon samplers could theoretically reach much lower detection limits than with singular grab sampling. Additionally, both nylon and polyethersulfone samplers were able to accurately determine the time-weighted average concentrations of total microcystins over 5-day deployments while 20% of microcystins were bound to cells. Although higher ratios cell-bound to dissolved microcystins will need to be tested, this indicates that the passive samplers work when a large portion of microcystins are bound to cells, which is likely to occur during a bloom event. As a whole, the use of time-integrated passive sampling of total microcystins can provide a more comprehensive and sensitive analysis of microcystin contamination in a water body.

BIOAVAILABILITY OF HEAVY METALS IN WATERS IMPACTED BY MINING WASTE AND THE TAR CREEK SUPERFUND SITE

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The Tri-State Mining District (TSMD), composed of the region surrounding northeast Oklahoma, southwest Missouri, and southeast Kansas, has been the major source of heavy metals entering the Grand Lake watershed since the mid-19th century, with the largest contribution of contaminants being from the area now known as the Tar Creek Superfund site. This study aims to evaluate the impact of heavy metals on fish populations in waterways impacted by mining waste surrounding the superfund site, with a specific emphasis on the development of a novel biosensor based on the fish gill cell line derived from rainbow trout (*Oncorhynchus mykiss*), the RTgill-W1. As a first step, we wanted to evaluate heavy metal bioavailability in these waters. So far, water and sediment samples have been collected from 7 sites that represent the radius of flow from bodies of water closest to the source of contamination to the southward direction, which we predict will reflect a gradient of change in the concentrations of heavy metals as they reduce. Water and sediment samples are being first analyzed for heavy metals. Additional water chemistry parameters will be used to predict bioavailability using the Biotic Ligand Model (BLM). An in vitro method for measuring cytotoxicity has been performed by directly exposing RTgill-W1 cells to the sample water. The cytotoxicity assay results have been as expected. A significantly reduced viability by as much as 80% was observed in cells exposed to the water collected from the sources closest to mining sites compared the cells exposed to water sampled further downstream and the control sites.

The preliminary data show that metal concentrations in sample water from some sites exceed EPA water quality criteria. For example, concentrations of dissolved Zn greater than 4000 µg/L were measured in samples from Tar Creek. Although the BLM data is still in progress, the cytotoxicity data confirms that the metal concentrations in those waters are elevated sufficiently enough to produce toxic effects. Interestingly, we have found that a variety of fish species and other aquatic organisms have adapted to the conditions in the most contaminated waters. This observation has led us to question what necessary mechanisms they have evolved to survive such harsh conditions and will be the focus of future investigations.

The sampling team after their sampling effort


A chat pile with drainage into a small stream

GROWTH AND IONOME-WIDE RESPONSES OF PHYTOPLANKTON TO RELATIVE SUPPLIES OF NITROGEN, PHOSPHORUS, AND TRACE METALS IN GRAND LAKE

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Harmful algal blooms (HABs) are a recurring environmental problem that are increasing in frequency and intensity worldwide. Abundance of harmful algae in freshwater systems significantly increases under favorable conditions; increasing toxin production that harm humans and pets, as well as the health and abundance of organisms (e.g., fish) found within these freshwater bodies. Both the damage on such ecosystem services and the direct adverse effects on human health make harmful algal blooms one of the key environmental problems. The Environmental Protection Agency (EPA)'s 2015 report has estimated the total management costs of algal blooms to be up to $2 billion every year in the United States. While numerous environmental factors contribute to the formation of algal blooms, the most common variable remains to be the increased loading of nutrients (such as phosphorus, nitrogen, etc.) to lakes and streams. The growth rate hypothesis partly explains this correlation based on the material demands for protein synthesis, the central anabolic mechanism underlying the production of new biomass. To support a higher rate of protein production; nitrogen (N) is required as the building blocks of proteins, whereas phosphorus (P) is required to produce rRNA to facilitate protein synthesis. While the effects of N and P on lake productivity as well as frequency of HABs are well documented, accurate predictions on algal blooms still cannot be made based on these two elements.

Aside from N and P that support protein production, protein structure and function depend on trace metal that are catalytic centers in the reactions orchestrated by a protein. N, P, and trace metal concentrations in freshwater systems can vary considerably and have increased due to anthropogenic activities (i.e., fertilizer use, mining, sewage runoff). A previous study found substantial variation in iron among Oklahoma reservoirs. In addition, iron fertilization experiments in Grand Lake did not affect total algal abundance, although it increase the abundance of bloom-forming taxa. However, this study occurred only in one location on Grand Lake. GRDA's 2020 report on Average Baseline Load into Grand Lake (SWAT Modeled, 2004-2015) shows high variation in N and P runoff from different creeks into Grand Lake. Whether such site-specific geochemical differences impact production and algal community structure have yet to be tested.

We chose to study the elemental profiles at three sites in the following creeks: Horse Creek, Honey Creek, Duck Creek, and Drowning Creek, and look for correlations between N, P, trace metal concentrations and algal abundance and community structure. Measurements were taken during three separate seasons (Oct-Mar-Jul) to also look for temporal effects over a year. At each site, particulate, dissolved, and bioavailable (using DGT passive samplers) concentrations of trace metals were measured. We also conducted bioassays with added iron (Fe) as well as an iron-binding chelator (Deferoxamine) to test for the effects of trace metal availability on algal and HAB abundance. Finally, DNA and RNA samples were also extracted from algae to generate metagenomes and explore associations between elements and algal community structures. So far, we have seen that samples with chelator-bound Fe had significantly less growth compared to the control and added Fe treatments. Furthermore, the availability of trace metals was shown to have significant effects on algae in terms of both the abundance and the processing of different elements, changing with seasonality. Such correlations based on multi-elemental effects on algal growth as well as seasonal differences have the potential to further unlock different methods of forecasting and management of algal blooms.

ASSESSING MACROINVERTEBRATE COMMUNITY ASSEMBLY AND VARIABILITY THROUGHOUT GRAND LAKE AND ITS ASSOCIATED TRIBUTARIES

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Freshwater systems host an array of insects, mollusks, and other spineless animals referred to as macroinvertebrates. These macroinvertebrate communities play a crucial role in aquatic ecosystems, serving as an integral food source for fish and waterfowl. Macroinvertebrates vary considerably in their environmental tolerance (i.e. niche breadth), their species interactions, and their dispersal capacity. These variations can help explain why certain macroinvertebrates are found in some areas and not others. Understanding how macroinvertebrate communities assemble, and how they vary, is important towards preserving and bolstering the ecosystem services that freshwater systems provide.

To assess how Oklahoma macroinvertebrate communities assemble, historic macroinvertebrate and water quality data (2001-2018) was analyzed. Utilizing data from 1363 samples, the optimal ranges of 456 Oklahoma macroinvertebrate taxa were determined for 11 environmental variables using weighted standard deviations, which were corrected and summed to approximate each genus' niche breadth. Incorporating literature values and morphological data, dispersal capacity for taxa was approximated and cooccurrence modelling was used to determine each taxa's rate of species interactions. From there, relationships between each assembly mechanism's influence on community composition and land cover gradients were compared using null community models and 4th-corner generalized linear models. These findings will help guide how to best manage an aquatic system based on its watershed characteristics.

A related, ongoing project assesses assemblage and elemental variability in macroinvertebrate communities throughout Grand Lake, focusing on the tributary-reservoir confluence zones. These confluence zones may serve as biological hotspots for macroinvertebrates, and serve as refugia for taxa in intermittent tributaries. During the summer 2022, Samples were collected from six tributary confluence zones on Grand Lake, as well as from the Neosho and Spring rivers. Preliminary findings show substantially dissimilar communities in each confluence zone, reflecting the variability of tributaries flowing into Grand Lake. Water quality and habitat data was additionally collected to examine trends between environmental conditions and community composition.

Sam sampling macroinvertebrate communities

To determine elemental variability, ubiquitous taxa and environmental samples will be collected throughout Grand Lake and analyzed using inductively coupled plasma spectroscopy. The spectrograph output will be used to show how each taxa's elemental composition varies throughout a reservoir, the factors influencing their composition, and dispersal's role in homogenizing elemental compositions across a system. These findings will not only uncover how elements flow through an aquatic food web, but also track how different taxa can transport elements throughout Grand Lake.

CAN CHANGES IN LAKE MICROBIOMES PREDICT ALGAL BLOOMS?

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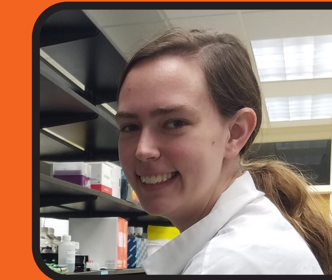

Virtually every surface and environment in the world is teeming with tiny life-forms called microbes. Although a single microbe on its own might not have the ability to affect our macro-sized world, the overall microbial community, comprised of billions of microbes belonging to thousands of species, is mighty enough to create a tangible impact. In lake environments like Grand Lake, this microbial community can help to cycle different elements to help fuel the growth and health of larger plants and animals. While the community of microbes is vital to keeping environments healthy enough to sustain larger organisms, sometimes they can also cause harm. A sudden influx of nutrients, when combined with other factors such as temperature, can cause blooms, or abrupt population explosions, of algae. Of particular interest is the blooming of Cyanobacteria, also known as blue-green algae. While Cyanobacteria normally helps within a balanced community by capturing sunlight and nitrogen for others, a bloom can quickly become dangerous. The blooming of Cyanobacteria can deplete the oxygen in the water that other organisms, like fish, need to survive, as well as cover the surface enough to blot out the light aquatic plants rely on. In addition, Cyanobacteria can produce cyanotoxins that are harmful to humans and other animals. Although we have an idea of what some of the factors that can trigger these blooms are, the blooms can be difficult to predict in real-time, making it difficult to keep the lake healthy and safe to enjoy.

We sought to characterize the microbial community of Grand Lake and observe how it changes during the time leading to a harmful algal bloom. Through repeated sampling in different locations over time, we collected data on what microbes are present, what genes they have, as well as how much of the community they make up. We sequenced both specific marker genes that can be linked to microbes' identities as well as whole microbial genomes that can help identify what types of metabolism are enriched. Armed with this data, we ultimately hoped to be able to predict when blooms will occur based on the changes of the microbial community, as they should provide signals that the nutritional profile of the lake is changing. We hypothesized that complex community trends precede a bloom, and that these trends can be predicted. To this end, we used the data we collected in machine-learning algorithms with the hope of creating an artificial intelligence program that can find the patterns leading to a harmful toxic blue-green algae bloom. Ideally, this could allow for advanced warning of a bloom, or even a window to try and correct the lake's balance and prevent a bloom, through measuring the concentrations of target lineages identified as important signals by the algorithm.

In total, we collected water samples at two depths from four sites over the period of several blooms, totaling 97 unique samples. These samples were then filtered to obtain cells, which we subsequently performed DNA extraction on. Once extracted, we performed amplification and sequencing of the 16S rRNA marker gene as well as shotgun metagenomic sequencing. After gene annotation and data preparation, our constructed machine learning algorithm was able to use the genomic information to predict bloom status with 79% accuracy. Interestingly, specific genes rather than organisms were identified as the most important contributors, suggesting overall metabolism is a better indicator than abundance of any one or combination of species. Specifically, genes related to nitrogen metabolism, biofilms, and movement served as the strongest predictors. Additional PCA analysis showed weak explained variance, suggesting that the trends are too complex for more simple analyses.

INVESTIGATING THE FEASIBILITY OF UTILIZING BIOCHAR AS A SORPTIVE TREATMENT TECHNIQUE FOR METAL IMPACTED MINE WATERS THROUGH BENCHTOP EXPERIMENTS

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A preliminary experiment has been completed on the sorptive capacity of a wood-based biochar on discharge waters from the Tar Creek underground mine pool and from mine land-impacted Elm Creek. The initial results suggest that the sorptive capacities of biochar will be unable to treat mine impacted waters effectively and sustainably. In the control using DI water, it was clear that the biochar likely released cations and increased aluminum, arsenic, calcium, potassium and sodium concentration. For mine pool treatments (discharge waters at the Mayer Ranch passive treatment system) concentrations of barium, potassium and magnesium increased with increasing biochar amounts. However, concentrations of iron and nickel decreased. The majority of iron concentration decreases were likely due to oxidation, hydrolysis and precipitation (and not sorption by biochar) since water with no biochar realized decreases from 130 to 0.5 mg/L iron. For Elm Creek waters, which were initially identified to likely be the most feasible waters to be treated by biochar, aqueous concentrations increased for aluminum, arsenic, chromium, potassium, lithium, magnesium and sodium, while concentrations decreased for calcium, manganese and zinc.

Additional plans include performing similar but expanded sorption examinations for a variety of different biochar source materials used. A column flow-through experiment will then be completed using the most promising biochar to estimate the magnitude and frequency of material replacement needs

If you are interested in learning more about the University of Oklahoma's Center for Restoration of Ecosystems and Watersheds (CREW), scan the QR code with your smartphone camera.

A soption flask experimental setup

Mine and Surface waters in flasks

EVALUATING THE EFFECT OF MINE DRAINAGE CHEMISTRY ON THE SUSTAINABLE REUSE OF MINE DRAINAGE RESIDUALS FOR PHOSPHORUS MANAGEMENT

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Eutrophication of water bodies is a considerable concern in today's society. Novel management practices are needed to decrease phosphorus (P), a common limiting nutrient which ultimately causes eutrophication and water quality degradation in receiving freshwater bodies. Innovative phosphorus-sorbing materials are being investigated as ways to decrease external phosphorus loadings into streams and reservoirs and can be divided into two general categories: i) calcium (Ca) and/or magnesium (Mg) based materials that promote P precipitation and ii) iron (Fe) and/or aluminum (Al) based materials for P adsorption. However, the cost of these phosphorus-sorbing materials can be cost prohibitive for wide-scale watershed applications.

Several studies have looked at the phosphorus removal efficiencies of different industrial waste products including mine drainage residuals (MDRs), rich in iron and aluminum oxides. These studies have found that MDRs have an elevated phosphorus sorption capacity and can be a more economical alternative to traditional Fe/Al salts. Similarly, primary treatment units in many mine drainage passive treatment systems (PTS) are oxidation ponds which accumulate iron oxide solids over time, the disposal of which can be financially burdensome and environmentally unsustainable. However, many existing studies do not consider how the originating water quality and age (and resulting mineralogy) of these solids affects sorption capacity and possible release of metals. This study analyzed MDRs from net-alkaline hard-rock mine drainage PTS (Tar Creek Superfund Site, Tri-State Lead-Zinc Mining District, USA) and from net-acidic coal mine drainage discharges and net-alkaline coal mine drainage PTS (Arkoma Basin, Oklahoma, USA). The solids were analyzed for total metals composition, percent crystallinity, specific surface area, and mineralogy. Initial sorption capacity was determined and the solids were allowed to age to determine the effects of aging on crystallinity and sorption capacity over time.

The solids collected from discharges had iron concentrations ranging from 332,000 (±9,400) mg/kg while solids collected from PTS had an iron concentration of 524,000 (±41,600) mg/kg. Results showed less crystalline (<5%) material (primarily ferrihydrite and poorly order goethite) found near discharges where precipitates were freshest, while older materials in PTS were more crystalline (more ordered goethite and hematite). Preliminary data show that all mine drainage residuals have an elevated sorption capacity for phosphate (~90 mg/g) and demonstrated minimal desorption of metals over time. This study shows that the reuse of MDRs is a sustainable and viable P management strategy that can help mitigate eutrophication in surface water bodies. However, if reuse is to be exploited and optimized in an environmentally and economically sustainable manner, more research is needed on the effects of mineralogy and age on the sorption capacity of these solids and any potential desorption.

Iron rich mine drainage at a coal mine discharge

EVALUATING IMPACTS OF LEGACY MINE WASTES AND DEVELOPMENT OF ECOLOGICALLY ENGINEERED INTERVENTIONS

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Mining impacted areas such as the Tri-State Mining District (TSMD) in the central portion of the Grand Lake watershed are often complex sources of ecotoxic metal contamination. Even when remedial efforts are underway, financial and logistical constraints often draw out these actions for decades. Due to these limitations, it is important to prioritize work in a way that will offer maintainable and acceptable water quality improvements quickly and in a budget conscious manner.

This study examines multiple hydrological, geomorphological, and geochemical factors that dictate the magnitude, extent, and kinetics of mineral-water interactions in mine waste disposal and treatment sites. It includes characterization of interactions between solid mine wastes and immediately adjacent pore waters in the context of larger watershed dynamics to determine where remediation and restoration interventions would best arrest trace metal contaminant transport. The study also evaluates current remedial actions within the TSMD with respect to their efficacy in addressing these challenges. The study is currently in the preliminary site selection and data collection process, but there are a variety of locations within the upper Spring River, Neosho River, and Tar Creek watersheds that will provide opportunities for monitoring, modeling, and further understanding of the complex interactions between water and mine waste. Future work under this project will include long term monitoring of storm-based runoff and seepage from mine waste piles within the TSMD and physical and chemical characterization of the waste to identify common attributes that promote mobility of metals from waste. Other studies will examine the movement of shallow groundwater and bedload in mining-impacted streams to further understand the hydraulic regime that governs pore water interactions with mine waste. Detailed examination of past and present projects will be used along with geochemical and contaminant transport modeling to quantify the efficacy of these projects with respect to decreasing the availability of ecotoxic metals within the ecosystem and help determine why these interventions were and/or continue to be effective. It is anticipated that the results of these studies will inform future remedial decisions in the TSMD and in similar mining districts around the world.

Water flowing over mine waste near Tar Creek

Mine waste in Tar Creek before remedial measures

COMPARATIVE ASSESSMENT OF ECOSYSTEM SERVICES VALUATION TOOLS

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Ecosystem service valuation (ESV) is one means of positioning nature's importance under the umbrella of societal value. Growing interest in characterizing and valuing ecosystem services has sparked the development of technical tools which support ESV efforts. Despite the array of opportunities supported by these tools, little comprehensive evaluation exists which provide insights into tool scope, operation, and capacity. This study addresses barriers to the widespread use of ESV by applying and evaluating the performance of these support tools. Evaluations of these ESV tools will remove a significant level of uncertainty for decision-makers and land managers, encouraging greater adoption of ESV projects. To adequately convey the value of nature to the broader public, quantitative metrics of ecosystem benefits are necessary, absent of overly specific jargon. This study aims to demonstrate how ESV tools can be applied to elicit numeric values for the quantitative analysis of ecological value. Subsequently, if basic economic theory were to be practically applied to numeric outputs, then monetary value may be derived to represent the use value of ecosystem services.

A variety of ESV support tools exist, presenting the arduous task of selecting the tool most appropriate for a given objective. This study selects and concentrates on five ESV tools that are most flexible in terms of application. Each tool is methodologically evaluated. First, a concise overview, akin to a fact sheet, is developed to outline individual tool operation, unique features, opportunities, and ultimately providing recommendations for suitable applications. Second, ESV decision support tools are compared based on their overall performance relative to specific criteria. Evaluative criteria are defined based on factors related to tool functionality, accessibility, methodology, cost, and degree of achievability. To ward off subjectivity, relevant experts are asked to rank evaluative criteria by importance, ultimately developing a weighted ranking system for comparing tools quantitatively. Third, each tool is applied to multiple ecosystems including wetlands (Lake Frances) and mine water passive treatment systems (at Tar Creek).

Insights into tool setup, data acquisition, tool application and operation are generated throughout the process. Contextualizing the functionality and suitability of selected ESV tools will help guide ESV applications by land managers, policy makers, corporate entities, and landowners. Identification of the advantages, limitations, suitable uses and relative standing will be compared to other tools to provide a starting place according to individual objectives. As ESV efforts become a more conventional practice, improvements in environmental education and appreciation are expected to manifest as increased environmentally conscious behavior. Increased conservation action will lessen environmental pressures and mitigate further degradation of ecosystem services. In the long-term, the resulting stability of ecosystem processes will feed directly back to societal stability.

Southeast Commerce passive treatment system (PTS)

UNDERSTANDING LONG-TERM EFFECTS OF DAM RESERVOIR DEPLETION ON RIPARIAN ECOSYSTEMS: A PRELIMINARY ENGINEERING WITH NATURE STUDY AT LAKE FRANCES, OK

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School of Civil Engineering and Environmental Science, University of Oklahoma

Many previous studies have focused on the ecological changes that result from dam erection and reservoir creation; however, less is known about the long-term effects on ecosystems following dam removal. A longitudinal study of the biogeochemistry and hydrology of riparian ecosystem responses and evolution following dam removal is planned at Lake Frances, Adair County, OK. The study will determine: 1) legacy sediment impacts on biogeochemical cycles within riverine and floodplain environments years to decades after dam removal; 2) in-situ legacy sediment effects on the hydrologic dynamics of a given watershed; 3) the role of legacy sediment deposits in local carbon flux and the potential implications for climate change impacts; and 4) possible nature-based solutions to address the long-term effects of legacy reservoir sediments.

Groundwater and surface water quality samples will be collected monthly to quarterly. Sediment samples will be collected at the initial site investigation and additional sediment sampling will occur on an event-driven basis (e.g., elevated river discharge, flooding). Samples will be analyzed for C, N, P, S, Si, Mg, Fe, Pb, and Cl to gain insight into the biogeochemical cycling of these elements at the research sites. Physical parameters will also be collected. Hydrogeological characterization (e.g., stratigraphy, hydraulic conductivity, porosity, groundwater gradient, stream morphology, sediment deposition, specific yield and storage) of each site will be conducted throughout the duration of the project.

The findings of this work will determine whether legacy nutrient loads continue to impact riverine ecosystems and down-gradient water quality for years to decades after dam removal. Structural hydrologic shifts could be the dominant controlling mechanism behind legacy nutrient mobilization. The influence of temperature and precipitation shifts on legacy reservoir sediments may be of importance in determining how legacy sediments may serve as a nutrient sink or source to surrounding ecosystems. Lastly, nature-based solutions may provide innovative options for management of legacy reservoir sediments. This study may lead to a shift in the dialogue on dam removal, potential long-term impacts, and their role in water cycle resiliency.

The bottomland hardwoods of the Lake Francis lakebed

An incised creek in the old Lake Francis lakebed

ENGINEERING WITH NATURE TO DEVELOP SOCIALLY SUSTAINABLE SOLUTIONS: NATURAL INFRASTRUCTURE FOR OKLAHOMA'S WATER CHALLENGES

Robert W. Nairn and Robert C. Knox
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Solving Oklahoma's water challenges requires a revolution in our thinking of the relationship between humanity and the Earth. Twentieth-century solutions – based on "gray" infrastructure driven by fossil fuels – cannot sustainably address the complexity and interrelatedness of the 21st century problems we face. Nature-based solutions, based on renewable energies and recognizing the inherent, yet oft-neglected, interdependencies of humanity and nature, hold promise for building a sustainable future. Ecological Engineering (the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both) along with related areas of inquiry including Engineering With Nature (the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration), natural infrastructure, green infrastructure, natural and nature-based features, and nature-based solutions are all based on the idea that sustainable solutions require working with natural ecological, hydrological, and biogeochemical processes and not against them. Natural infrastructure approaches to some of Oklahoma's most intractable water challenges have been the focus of teaching and research for many years. Research efforts include passive treatment of trace metals-contaminated mine waters, addressing emerging contaminants through treatment wetlands to support indirect potable reuse of municipal wastewater, amelioration of excess nutrient problems and degraded habitat through riparian conservation easements, urban stormwater low impact development best management practices, and reservoir enhancement through wetland restoration. Several formal and informal educational efforts support these applied research endeavors, including the University of Oklahoma Presidential Dream Course "Engineering the Nature of Change" in spring 2023.

The long-term partnership between the Grand River Dam Authority and the University of Oklahoma Center for Restoration of Ecosystems and Watersheds provides a solid foundation for Engineering With Nature work. Now partnering with the Engineer Research and Development Center of the U.S. Army Corps of Engineers, this partnership will lead to substantial advancements for Oklahoma's water resources. This topic was presented at the 2022 Oklahoma Governor's Water Conference and Research Symposium.

A group photo of OU's CREW team

BACTERIA IN A SULFATE REDUCING BIOREACTOR FOR MINE DRAINAGE TREATMENT

Leif Olson and Robert W. Nairn
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The Mayer Ranch passive treatment system near Commerce, Oklahoma has been n operation since 2008 and removes a variety of potentially toxic metals from mine drainage discharges, allowing clean, non-toxic water to be discharged into a nearby tributary stream to Tar Creek. Process units in the passive treatment system include vertical flow bioreactors (VFBRs), meaning that water flows vertically downwards through an organic material that hosts living organisms that remove metals from the mine drainage water via metabolic activity. At Mayer Ranch, the bioreactor substrate is a mixture of woodchips, spent mushroom substrate and limestone dust, and is several feet underwater to create anaerobic conditions. In the absence of oxygen, alternative forms of microbial respiration become predominant, including sulfate reduction, where bacteria use sulfate, which is abundant in the mine drainage water, instead of oxygen to "breathe", and to "exhale" sulfide instead of carbon dioxide. The sulfide produced binds with dissolved metals to create solid metal precipitates that effectively remove the metals from the water. These sulfate reducing bacteria (SRB) are a widespread and diverse group of microorganisms.

This project aims to identify and characterize some of the SRB and other important microbes in the Mayer Ranch vertical flow bioreactor using bacterial cultivation and environmental DNA surveys. Samples are collected and then taken back to the University of Oklahoma for further analysis and to be processed for bacterial growth. Once grown, these bacterial "isolates" are identified through genetic sequencing to determine the identity of the species. Future experiments include comparing the SRB isolated from Mayer Ranch to other strains of SRB from the same or similar species that did not originate from metal contaminated environments to see if the Mayer Ranch strains have a higher tolerance or ability to remediate metals.

The environmental DNA survey involves extractcting DNA from bioreactor samples, then amplifying genes associated with certain types of organisms and sequencing the DNA in these samples to determine the entire community of microorganisms present. These community analyses will look at the diversity of SRB present, as well as other microbes that may be important in the system, like those that can degrade complex forms of carbon into simpler forms of carbon that SRB consumes. The sample processing and analysis is in progress, but preliminary results analyzing the 16S ribosomal RNA gene, which is the standard marker for identifying bacteria and archaea, show a variety of SRB present as well as a high abundance of the genus Bacillus, a metabolically diverse group of bacteria that are known for being able to perform fermentation and degradation of complex carbon compounds. Future analysis will provide a more complete picture of the microbial community present in the bioreactor, providing insight into the complex ecology present in this nature based mine drainage remediation system.

Culturing bacteria in the anaerobic glove box

EVALUATING *ARUNDINARIA GIGANTEA* REINTRODUCTION AS A NATURE-BASED SOLUTION IN THE RESTORATION OF RIPARIAN AREAS AND WATER QUALITY

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This research focuses on evaluating *Arundinaria gigantea* reintroduction as a nature-based solution in the restoration of riparian areas and water quality in the Illinois River watershed. *Arundinaria gigantea*, or Giant Rivercane (commonly referred to as rivercane or cane), is a bamboo species native to alluvial floodplains of the Southeastern United States. Dense groups of rivercane are also referred to as canebrakes. The monopodial rhizomes of rivercane erect culms of 18 feet tall on average. Rivercane coverage has been decreased to less than two percent of its former abundance. Previous studies had shown rivercane to provide significant environmental benefits including erosion control, critical wildlife habitat, diverse fauna, and surface runoff reduction. Rivercane also serves as a culturally significant species for indigenous peoples of the Southeastern United States.

The 1,069,530 acres of the Illinois River watershed, located on the Oklahoma-Arkansas border, faces water quality concerns and an estimated fifty percent increase in population (over 1 million people) by 2045. The old Lake Frances area near Watts, Oklahoma and Siloam Springs, Arkansas provides an opportunity for studying the reestablishment of rivercane. Three studies and one review are proposed. The first study utilizes a watershed-based model, Gridded Surface/Subsurface Hydrologic Analysis (GSSHA), to examine nutrient, sediment, and bacteria loading at the study site. Data collected from the field site will be used to calibrate the model and a separate set of field data will be used to validate the model. Various watershed scenarios (e.g., land use changes, extreme weather events, rivercane reintroduction, prescribed fire, wetland restoration, deforestation) will be used to estimate pollutant loadings. The second study involves the use of a greenhouse to create batch reactor rivercane ecosystems based on field site characteristics. Physical, chemical, and biological water quality monitoring will evaluate the effectiveness of rivercane ecosystems for the treatment of various pollutant loadings (e.g., metals, nutrients, sediment, bacteria). The third study proposes the use of the U.S. Army Corps of Engineers Synthetic Environment for Near-Surface Sensing and Experimentation (SENSE) wind tunnel and rivercane. Soil, vegetation, and meteorological data from the field site will be used to prepare the experimental test bed in the SENSE wind tunnel. The growth rates, biomass change, and health of rivercane will be studied in simulated environments of current and future climate change scenarios in.

A review will be conducted after the conclusion of the three studies to evaluate rivercane reintroduction as a nature-based solution in the restoration of riparian areas and water quality based on plant establishment and pollutant uptake.

Rivercane, *Arundinaria gigantea*

CONCEPTUAL PASSIVE TREATMENT SYSTEM DESIGN TO REMEDIATE MINE DRAINAGE IN THE TAR CREEK SUPERFUND SITE

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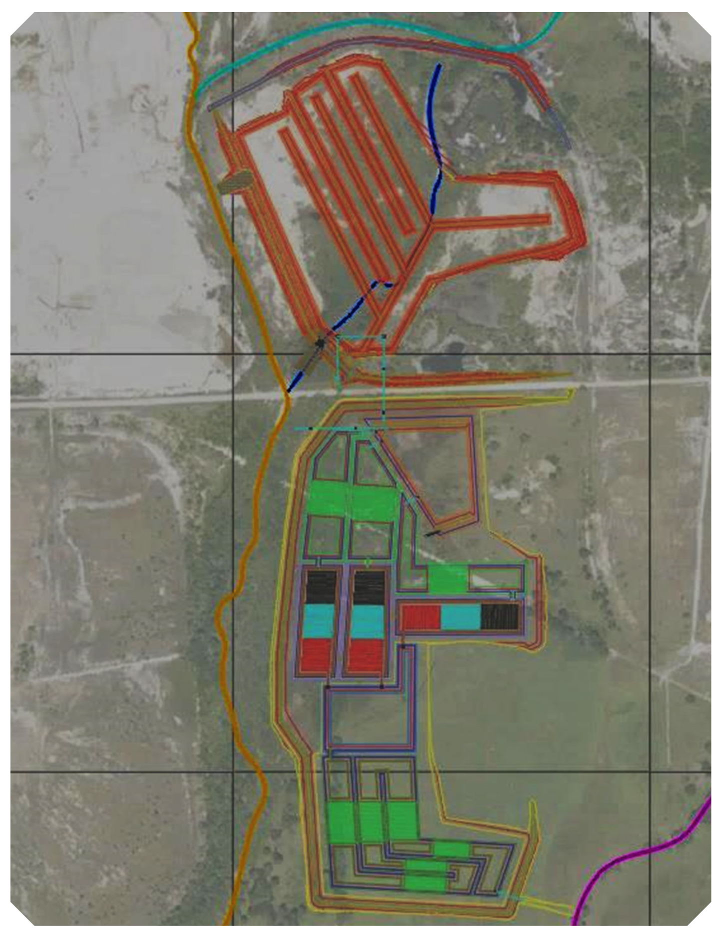
Underground mining for lead and zinc occurred in the now-abandoned Picher mining field, located on the border of Oklahoma and Kansas, USA, from the early 1900s until the 1970s. Since mining operations ceased and the last of the underground pumps were shut off, the underground workings, with an estimated volume of 80,000 ac-ft (260,680,800,000 gallons), began recharging with water. In 1979, the first artesian mine drainage (MD) discharges began to flow. To date, the largest source of MD contributing to Tar Creek, located near Douthat, remains untreated. The objective of this study was to determine if a conceptual passive treatment system design was a viable option to remediate 90% of the mine drainage by volume. The conceptual design was evaluated via an eleven-year simulation that utilized mine pool water elevation data collected at 30-minutes intervals from a USGS gage station from 2010 through 2021 to calculate the flow rates of mine drainage at each time interval. Water quality data from the discharges collected from 2018 through 2022 were used to calculate the metal loading. The simulation evaluated the change in metal loading to Tar creek if the conceptual PTS were implemented compared to the existing conditions, where untreated mine drainage from the Douthat discharges enters Tar Creek.

The conceptual PTS was designed to treat 2,150 gpm and would cover approximately 119 acres of land. The simulation showed the system would treat approximately 574,713,000 gallons of water on an annual basis and would be capable of retaining between 86% and 95% of the metals of concern (cadmium, iron, lead, and zinc), ultimately preventing these metals from entering Tar Creek and eventually Grand Lake O' the Cherokees.

Water flowing into an abandoned mine shaft in NE OK



A conceptual PTS showing the grading contours of the PTS

PHYSICAL CLASSIFICATION OF IRON OXYHYDROXIDES AND POTENTIAL REUSE FOR STORMWATER TREATMENT

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Excessive phosphorus in natural water bodies is becoming more common due to the elevated concentrations found in both urban and agricultural stormwater runoff. Eutrophication of water resources can cause devastating algal blooms. The process of removing phosphorus from natural waters can be challenging. Addressing the phosphorus in stormwater inflows impacted by nutrient dense runoff is an option to decrease eutrophication.

Iron oxyhydroxides are a residual formed during the passive treatment of metal-contaminated mine drainage. They have been shown to be particularly effective at lowering phosphorus concentration. Iron oxyhydroxide residuals remove phosphorus by adsorption, the chemical attachment of phosphorus to the particles. Finding reuse options for iron oxyhydroxides is becoming increasingly relevant in the long-term maintenance of passive treatment systems (PTS) because the rapid accumulation of iron oxyhydroxides limits their lifespan. Therefore, successfully using the iron oxyhydroxide byproduct to treat stormwater runoff with elevated concentrations of phosphorus would benefit both water quality and PTS longevity by providing a sustainable and environmentally beneficial reuse method.

Iron oxyhydroxide samples were collected at four sites in Oklahoma, two PTS oxidation ponds and two natural discharges. PTS sites included Mayer Ranch, located near Commerce, Oklahoma and treating hard rock mine drainage, and Hartshorne, located in the Arkoma Basin of Oklahoma and treating coal mine drainage. The natural discharge sites were Howe and Gowen, both untreated coal mine drainage with naturally precipitated iron oxyhydroxides. Considering previously generated data on the sorption capabilities of mine drainage derived iron oxyhydroxides, amendment options such as clean sand are being considered at varying percentages to ensure that the appropriate hydraulic conductivity is met for effective treatment. Simulated stormwater tests with varying concentrations of added phosphorus will be performed to accurately determine the effectiveness of the treatment media. These tests will not only compare the phosphorus content of water before and after being flushed through the chosen treatment media, but also ensure that the iron oxyhydroxides in the treatment media will not leach metal contaminants that may already be adsorbed to the particles.

These data are intended to aid in the second phase of this project, the engineering design of a system for the treatment of stormwater using iron oxyhydroxide residual media. An initial golf course site has been identified where both water quality and flow will be evaluated and a stormwater treatment system using iron oxyhydroxide media will be designed. The design will be prototyped and tested. If successful, it will then be implemented, and monitored long-term to verify the field effectiveness of the iron oxyhydroxide media as a treatment mechanism for phosphorus impaired water.

The laboratory testing of oxyhydroxide solids

ECOSYSTEM METABOLISM AND FUNCTION IN THE HORSE CREEK WATERSHED OF THE GRAND LAKE O'THE CHEROKEES, OKLAHOMA

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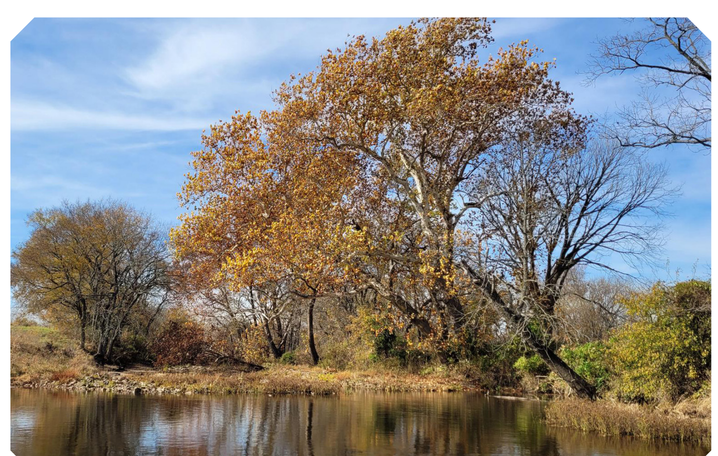
Riparian ecosystems are transitional between aquatic and terrestrial environments, providing a wide range of ecological functions such as nutrient cycling, biological productivity, and organic matter decomposition. Although traditional assessments of riparian ecosystems quantify structural components, including biotic assemblages and habitat structure, few evaluate the restoration of function gained from restoration. The focus of this study was to evaluate the impact of conservation easements in Horse Creek on functional ecosystem indicators.

Net primary productivity (NPP) was evaluated using the open diel oxygen method. No significant relationships were found between NPP and water physiochemistry, habitat, or land use parameters. A similar study was conducted on rates of decomposition in Horse Creek and Fivemile Creek, a regional reference stream. A cotton tensile strength assay was chosen to measure the relative capacity of streams to process organic matter. This method used canvas cotton strips to simulate the cellulose fibers found in leaf litter, an important source of energy for aquatic biota. Bacteria and invertebrates break down the cotton strips during a two-week incubation period. The tensile strength of the cotton strips was evaluated before and after incubation to determine the rate of loss of tensile strength, which were compared across easement and non-easement areas of Horse Creek. Cotton strips were deployed monthly at three Horse Creek sites and one Fivemile Creek site and assessed for losses of tensile strength due to incubation. Loss rates were compared to sub-watershed land use, habitat assessment, and water quality parameters to evaluate drivers behind changes in decomposition at each site. Results indicated that Fivemile Creek had the lowest rates of decomposition, followed by the conservation easement site, then the two non-easement sites in the watershed. Agricultural land use (as hay and pastureland) was strongly correlated with increases in decomposition rate, as well as levels of reactive phosphorus and riparian vegetative zone width. These results illustrate the importance of functional assessments as a tool to evaluate conservation easement success.

Deploying cotton strips in Horse Creek



A section of shoreline in the Horse Creek watershed

EVALUATION OF LAND USE, HABITAT, AND ECOLOGICAL STRUCTURE IN THE HORSE CREEK WATERSHED OF THE GRAND LAKE O'THE CHEROKEES

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Horse Creek is a small, agriculturally dominated watershed that drains into Grand Lake o' the Cherokees in northeastern Oklahoma. The Horse Creek watershed is dominated by agricultural land use, comprising 89% of the land area in the basin. Following concerns regarding blue-green algae blooms in the Horse Creek arm of the lake, cattle exclusion conservation easements were installed with the cooperation of landowners in the watershed, removing 1.1 km2 of riparian area from agricultural production.

This study conducted land use and land cover characterizations from satellite-derived data to quantify the degree of agricultural impact on the watershed and compared these land use categories to a regional reference stream, Fivemile Creek. Habitat assessments were also conducted to quantify habitat structure in three reaches in Horse Creek and a fourth reach in the Fivemile Creek basin, following Oklahoma Conservation Commission guidelines. Major impairments to Horse Creek habitat, in comparison to Fivemile Creek, include lack of flow variability and decreased riparian zone vegetative width.

Fish and macroinvertebrate assemblage data were collected and compared to land use and habitat assessment metrics to quantify the impact of riparian vegetation protection, as well as reference conditions. Results indicate that both fish and macroinvertebrate assemblage metrics respond to land use, with positive correlations to riparian vegetative zone width and stream flow variability, and negative correlations to developed land use in the watershed. These results highlight the importance of riparian vegetative zones in the improvement of biotic assemblages in the stream.

Remote sensing was also conducted using a small Unoccupied Aerial System (sUAS) to collect high-definition multispectral imagery within the conservation easement areas. The Normalized Difference Vegetation Index (NDVI) was used to calculate riparian vegetation photosynthetic vigor within the conservation easements and compared to data collected in 2020. NDVI improved at two of the sites studied by approximately 3%, but decreased at a third site by approximately 5%, likely due to exceptional drought conditions along the study reach. Digital surface models developed from sUAS data were used to estimate aboveground biomass, and indicated an approximate 2% increase in vegetation volume at all three sites, indicating that the cattle exclusion fences are succeeding in allowing vegetation to re-establish.

OU's sUAS collecting data above a stream in Horse Creek

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The 2022 Ecosystems water quality team in front of the Ecosystems and Education Center

Closing Thoughts

Throughout the proceeding pages of this 2022 Annual Review, you will find valuable information gained over the last year of research that continues to help shape GRDA's watershed management programs. We hope you find it informative and that it provides pertinent information regarding GRDA's commitment to the Environmental Stewardship of our natural resources.

As detailed throughout this publication, you will see that GRDA and our university, state, federal and tribal partners are passionate about protecting our valuable land and water resources that provide so many benefits to the citizens of northeast Oklahoma. Our commitment to these natural resources is unwaning and we will continue to seek out new solutions and develop new tools to secure a sound future for the next generation of water users.

The work featured in this publication, as well as our past publications, has helped address information gaps associated with our statutory obligations as well as addressing regulatory issues associated with our license compliance with the Federal Energy Regulatory Commission.

If you have any questions about the ongoing cooperative research programs, visit the GRDA website at www.grda.com or contact our offices at (918) 981-8473.

Aaron Roper
Manager - Neosho Bottoms

To see work that has been featured in previous years, use the QR code below to access the environmental stewardship portion of our website.

Sincerely,

Aaron Roper

If you are interested in learning more about GRDA's environmental efforts, please visit our website at https://grda.com/environmental-stewardship/ or scan the QR Code with your smartphone camera.

Ecosystems Explorations: 2022 Annual Review

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This publication was produced with input from the entire Ecosystems and Watershed Management team. All maps are property of the GRDA GIS Department. All photos and student summaries have been submitted to GRDA via project updates, and are now authorized for use by GRDA.

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Front Cover: Downstream view of the Mountain Fork River
Back Cover: Upstream view of the Mountain Fork River