ECOSYSTEMS EXPLORATIONS

Research, Conservation, and Protection

2021 ANNUAL REVIEW

GRDA
Grand River Dam Authority

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.

Mission Statement

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.

GRDA Grand River Dam Authority

-ELECTRICITY -EFFICIENCY -EMPLOYEES
-ENVIRONMENTAL STEWARDSHIP
-ECONOMIC DEVELOPMENT

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.

ECOSYSTEMS EXPLORATIONS - 2021 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 (GRDA). Although COVID-19 still lingered and presented challenges, the Ecosystems and Watershed Management Department rose above to accomplish goals throughout the year. The work that is displayed in the following pages represent the continued commitment that GRDA has made to be good stewards of the natural resources under our control.

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

(L-R) Jeri Fleming, Bill Mausbach, Steve Nikolai, Kate Wollman, Dustin Browning, and Ed Fite surveying the Illinois river

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

Grant Victor - Leopold Conservation Award

Grant Victor and his family raise 900 head of beef cattle on 2,500 acres, and grow wheat, oats, soybeans, grain sorghum and corn on another 1,200 acres. With strong influence from their ancestors, the Victor families commitment to improving water and air for those downstream and downwind is unmatched.

A photo of the Victor family

Victor Ranch hosts water and soil quality research projects and agricultural educational events. To preserve the creek and watershed's health, the Victors installed more than 27,000 feet of fencing around 178 acres of riparian area. Expanding the pecan orchards with new trees is creating quality wildlife habitat and a new income stream.

Grant has reduced soil erosion from wind and water by combining cover crops with no-till farming practices since the 1980s. With 3,000 acres enrolled in the USDA's Conservation Stewardship Program, brush management and herbaceous weed control have helped improve wildlife habitat across the ranch. With technical and financial assistance from the Environmental Quality Incentive Program, the Victors have converted 600 acres of highly erodible cropland to pasture.

If you are interested in learning more about the Victor family and their conservation efforts, scan the QR Code with your smartphone camera.

Award Winning Programs and Projects in 2021

Jeri Fleming - GRDA - Guard the Grand

At the 2021 Keep Oklahoma Beautiful banquet, Jeri Fleming and GRDA won both the State Government Award as well the Best of the Best Award. GRDA's Guard the Grand program is a watershed education program designed to involve the public in improving water quality throughout the Grand Lake watershed.

You can read more about GRDA's Guard the Grand Program on page 13.

If you are interested in learning more about GRDA's Guard the Grand program, please visit our website at www.grda.com/guard-the-grand or scan the QR Code with your smartphone camera.

Jeri Fleming speaking at the Keep Oklahoma Beautiful awards

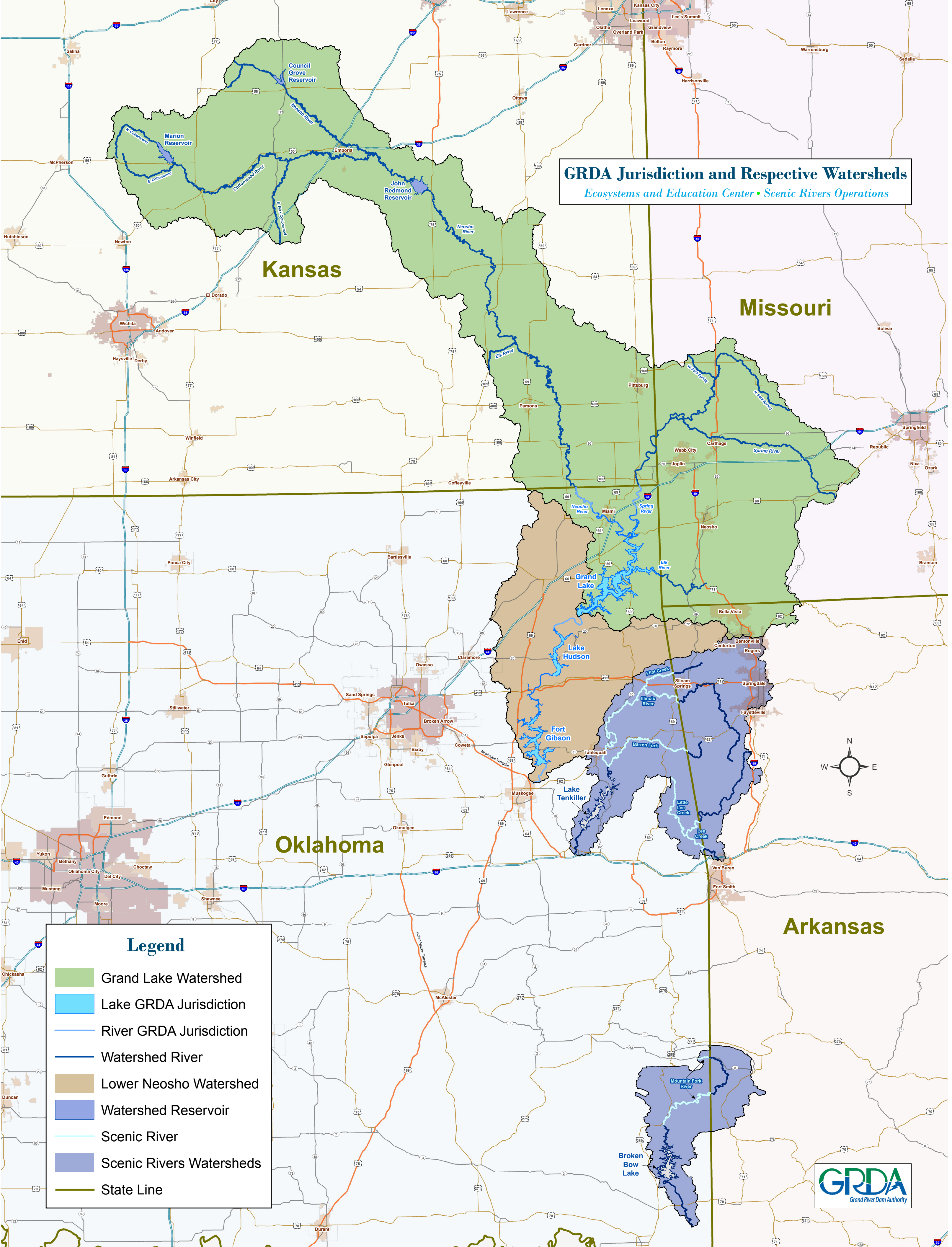
(L-R) Jacklyn, Jeri, Darrell, and Ed at the KOB awards

Hunter Hodson - NSU - Outstanding Student Water Research Poster Award

Northeastern State University student Hunter Hodson's poster titled "Comparison of Macroinvertebrate Communities Found in Invasive and Native Tree Leaf Litter" was awarded an Outstanding Student Water Research Poster Award at the 2021 Oklahoma Governors Water Conference.

You can see more of Hunter's research on page 18.

Hunter holding an award letter from Markwayne Mullin



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.

GRDA's sampling vessel

Jesse Rader sampling a stream from a bridge

2021 Algae Bloom

In 2021, the water quality team faced a significant cyano-bloom in the Horse Creek area of Grand lake. The 2021 Horse Creek bloom was an anomaly, lasting longer than the blooms of the past and keeping the water quality team on their toes with its seemingly unpredictable boom-bust cycles – about to die off one day and roaring back to life days later.

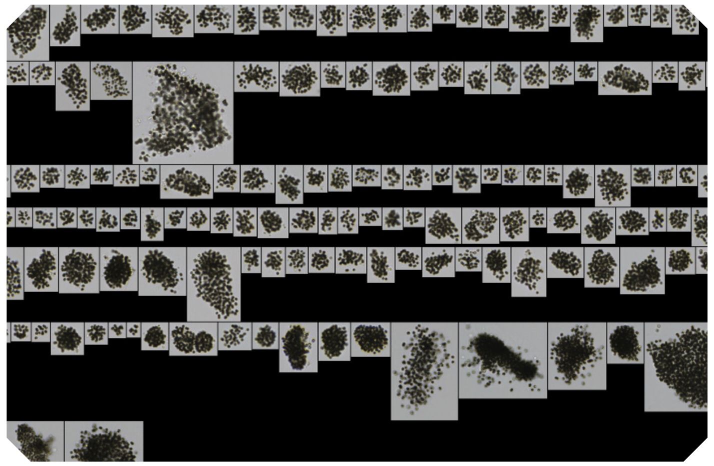
To effectively protect public health and safety while also gathering useful data, GRDA deployed an intensive monitoring program internally and called upon its university partners to help. We now know how crucial a nutrient-rich hypolimnion is to fuel a cyano-bloom, and we know that the hypolimnion nutrients can come from the benthic sediments during times of anoxia or from the watershed during rainfall events. We also learned that cyanoblooms can die-off from nutrient depletion in the hypolimnion or over-grazing by the zooplankton, *Daphnia lumholtzi*.

Moving forward, we will pre-emptively monitor the presence and condition of the hypolimnion in the Horse Creek Cove in conjunction with keeping an eye on the early warning buoys and the weather so that we can continue to keep the public aware of impending cyano-blooms. There is little that can be done to effectively manage an already active bloom, but we can make it more difficult for them to form by reducing the amount of nutrients coming into the lake from the watershed. GRDA is tackling this issue on multiple fronts such as public education through our Guard the Grand Program and through our conservation easement program, and we look forward to a time when the cyano-blooms in Horse Creek Cove become a phenomenon of the past and the clear blue waters for which Grand Lake is known are an expectation of the present.

GRDA and its university partners are hopeful that the treasure trove of data collected during the 2021 bloom will allow regional scientist to transform bloom uncertainty into potential foresight for future blooms. If you are interested in learning more about the 2021 algae bloom, check out our special edition of Ecosystems Explorations: A memoir of the 2021 algae bloom.

If you are interested in learning more about the 2021 algae blom in Horse Creek, scan the QR Code with your smartphone camera.

Algal scum on the surface of Horse Creek



Colonies of microcystis as seen on GRDA's FlowCAM

T&E 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).

GRDA's helicopter used for aerial surveys

Threatened and Endangered 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 launching their boat for a night time bat survey

Neosho Bottoms

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.

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.

A hunter with his harvested buck from Neosho Bottoms

The Neosho Bottoms team removing invasive trees

Shoreline Compliance and Cleanup

Shoreline Enforcement and Permitting

The role of the shoreline management enforcement and permitting team is to manage dock applications and inventory, vegetation management permits, and any other compliance related issues. This is accomplished by conducting regular patrols around our lakes by vehicle and aircraft to look for construction. Once construction is located, the shoreline management team works with the public to ensure compliance with state and federal regulations. If violations of these regulations occur, fines can be issued.

Aerial patrols are also used to monitor protected wetlands areas, check navigation controls on the lakes and to identify environmental incidents including fuel spills and outbreaks of blue-green algae. Because of their role in enforcing state and federal regulations, the shoreline management team will also respond to address sinking vessels, dilapidated boats & docks, sewage discharges, chemical and fuel spills.

GRDA officers prepare to conduct an aerial survey

Shoreline Cleanup

The role of the shoreline management crew (SMC) is to provide full-time employees to maintain the shores and waters of GRDA lakes by cleaning and removing trash and debris, plus assisting with volunteer clean-up programs, such as the Adopt the Shoreline program. The SMC is equipped with a barge with a hydraulic crane, skid-steer and other equipment. They have collected and disposed of over 250 tons of Styrofoam and trash from the shores of GRDA lakes since 2017. The SMC also assists the agency with the removal of dilapidated docks, submerged and abandoned vessel recovery, deceased animal disposal and the removal of navigation hazards.

The shoreline management crew also works closely with the GRDA Police Department by providing maintenance of navigation aids on the lakes. This can be a daunting task considering there are over 500 buoys and lighthouses on our lakes. This involves a variety of tasks including the recovery of broken buoys and the installation of new and replacement buoys, anchors and lights, and help maintain buoy lines in front of the dams and spillways on the lakes. Duties for the SMC also include maintaining over twenty lighthouses on Grand Lake, which can be anything from replacing lights to replacing the lighthouse structures and the large yellow navigation buoys.

The shoreline management crew installs a buoy

Watershed Education

Guard the Grand

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 practices.

Residents/Lake Users: We held six in person and one virtual workshop for residents and lake users on two topics, Landscaping for Water Quality and Boat Maintenance to Protect Water Quality. We were able give away rain barrels again this year along with a certificate for soil tests through Oklahoma State University Extension Services. We also gave out several pet waste stations to several area marinas, RV parks and the town of Disney. We have registered 16 businesses as Guardians of the Grand and have added several residents to the list as well. We are beginning to see more involvement throughout the watershed and residents and businesses share when they do something to help Guard the Grand.

Educators: We were excited to award three grants in 2020 to area nonprofits that are working to educate students and tribal members on soil health, water quality issues and nonpoint source pollution. We held our Riverology 101 educators workshop this summer and had 14 teachers join us to learn about watersheds, water conservation and what resources other state agencies have for them. Teachers left with our 4th grade curriculum specific to the Grand Lake watershed and became Project WET certified teachers. The Oklahoma Conservation Commission's Blue Thumb program, Ag in the Classroom and OSU Extension partnered with us to offer the workshop.

Other Accomplishments: GRDA staff have released a Guard the Grand app. The app provides watershed information, lake information and how bugs and fish are used to help determine water quality. All workshop videos and pamphlets are available for download on the app and interested users can join the email list. GRDA and the Guard the Grand Program were recognized in November of 2021 as the Best of the Environmental Best at the Keep Oklahoma Beautiful Environmental Excellence Awards banquet.

Harbors View Marina with their Guardian of the Grand sign

A group photo from a workshop hosted by GRDA

Conservation Easements and BMPs

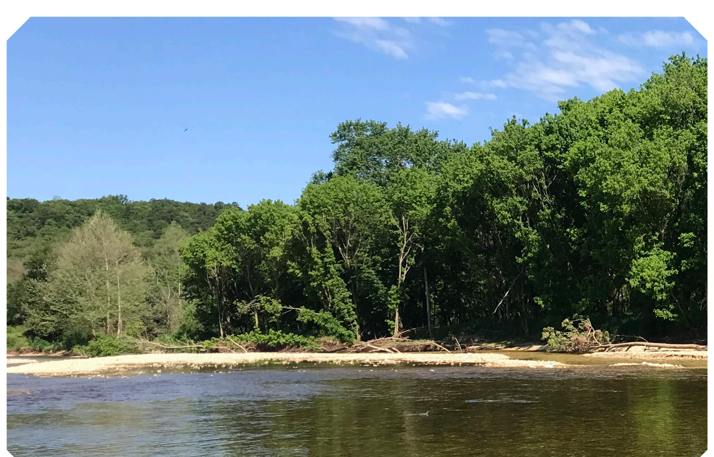
Conservation Easements

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 began 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, 1,695 acres have been added to the conservation easement inventory, including 214 acres in 2021

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.



A section of shoreline along Barren Fork Creek

The Fritts family enrolling in GRDA's easement program

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 15 years, 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 17,000 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 2021, over 50 volunteers built 600 structures, destined for GRDA lake waters. Then, in September, at another event on the shore of Lake Hudson, where it all began, 750 more structures were built.

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, Oklahoma, 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.

Volunteers posing next to structures they built

A group photo of 2021 volunteers

Photos from 2021

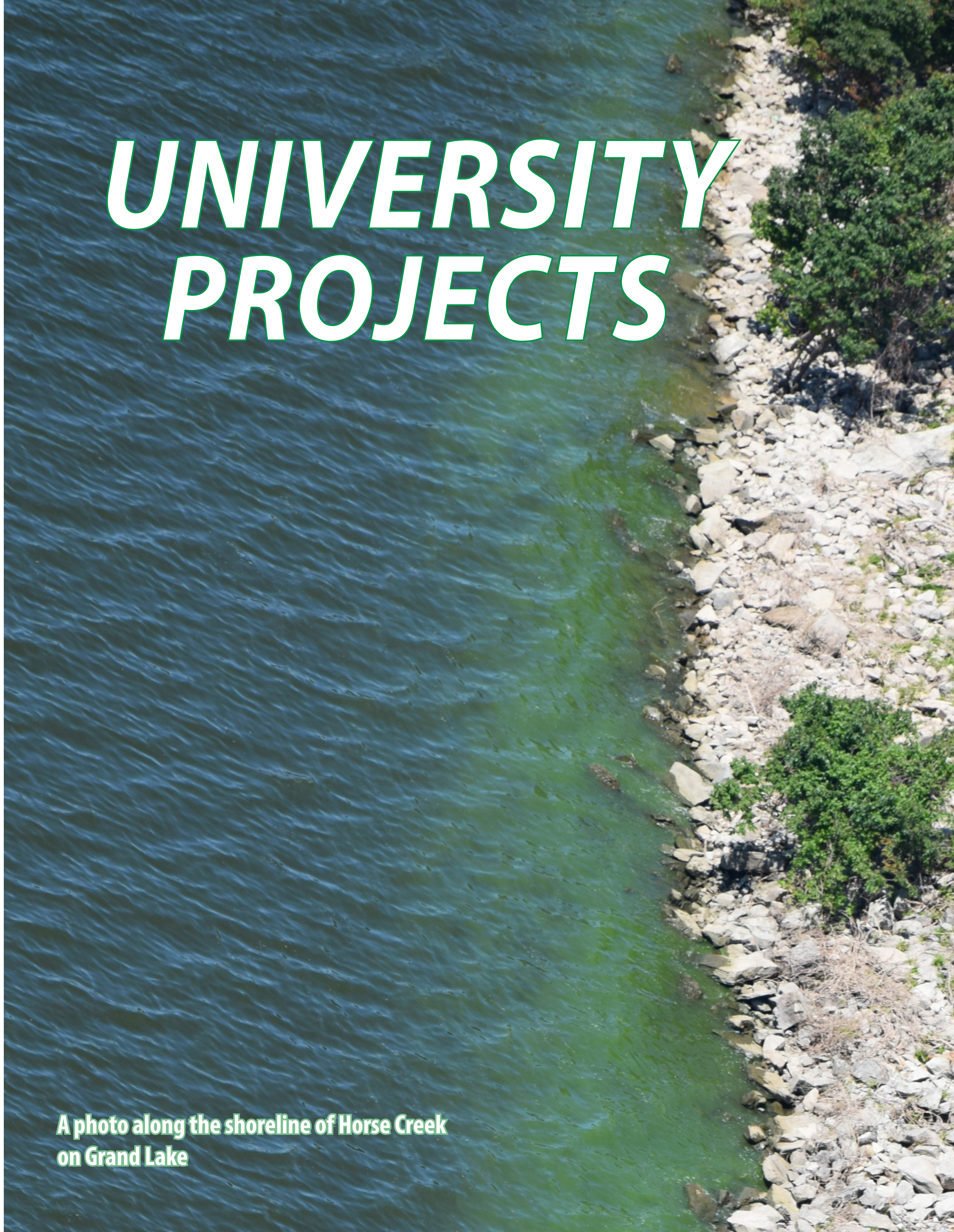

Bailye and Kate collecting macroinvertebrates


Artificial fish habitat structures built for Lake Hudson


Students learning about hydrology from GRDA's stream trailer


A rainbow arching over GRDA's Pensacola Dam


Bill and Courtney at an outreach event in Salina, OK



A photo along the shoreline of Horse Creek on Grand Lake

Northeastern State University

COMPARISON OF MACROINVERTEBRATE COMMUNITIES FOUND IN *AILANTHUS ALTISSIMA* AND *QUERCUS STELLATA* LEAF LITTER

Hunter Hodson[1], Elizabeth Waring[1], Katherine Wollman[2]
1) Department of Natural Sciences, Northeastern State University, Tahlequah, OK
2) Grand River Dam Authority, GRDA-NSU Scenic Rivers and Watershed Research Lab, Tahlequah, OK

The purpose of this research was to compare the species composition of macroinvertebrate communities found in native and non-native leaf litter in an urban freshwater stream located in Northeastern Oklahoma. Non-native *Ailanthus altissima* (Tree of Heaven (TOH)), a native to Southeast Asia, was first introduced to North America as an ornamental plant in the 18th century. Rapid growth, regeneration, and seed production allow this species to be incredibly successful in establishing itself in disturbed areas and outcompeting co-occurring species. TOH has spread to the Illinois River watershed and has led to the displacement of native plants. For this reason, it is important to understand the effects of this species copious amount of leaf litter produced has on freshwater environments. Other studies conducted over short periods have indicated that the presence of TOH leaf litter decreases macroinvertebrate activity compared with co-occurring native leaf litter. Including native *Quercus stellata* (Post Oak) litter to compare the communities found in TOH leaf litter will lead to a better understanding of how litter quality impacts the macroinvertebrates found in the Illinois River watershed.

In the months of April and May, twenty-three different species were found in the *Quercus stellata* litter bags, and twenty-six different species were found in the TOH litter bags. The Sørenson-Dice coefficient indicated that species composition between the Quercus stellata and TOH litter bags was 65.3% similar.

Hunter deploying leaf litter bags

A photo of a Caddisfly that was collected

Northeastern State University

EXAMINING SEASONAL CHANGES IN MACROINVERTEBRATE COMMUNITIES IN TOWN BRANCH CREEK, TAHLEQUAH, OK

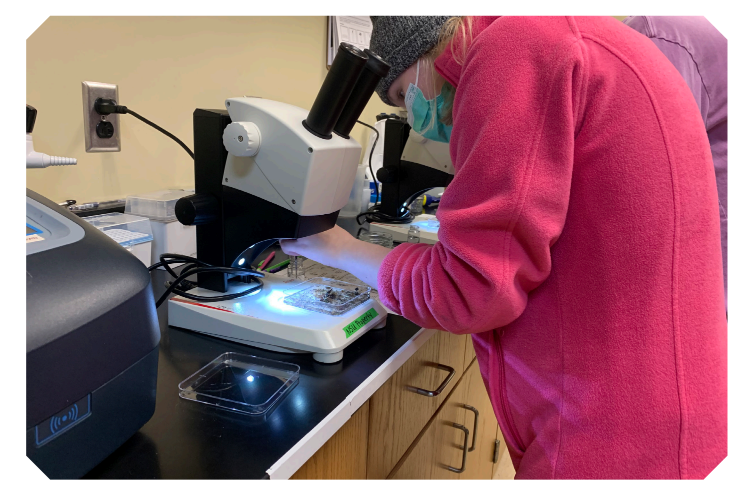
Viktoria Morris[1], Keegan Stallings[1], Elizabeth Waring[1], Katherine Wollman[2]
1) Department of Natural Sciences, Northeastern State University, Tahlequah, OK
2) Grand River Dam Authority, GRDA-NSU Scenic Rivers and Watershed Research Lab, Tahlequah, OK

Aquatic macroinvertebrates are one of the most widely used indicators of stream health. This is due to their short life span which leads to quick turnover within the community when a disturbance has occurred. This project is an examination of macroinvertebrate communities in Town Branch Creek, an urban stream in Tahlequah. We are interested in how in macroinvertebrate communities change in relation to seasonality. Composite samples were collected once a month from April to September at three different localities on Town Branch Creek. Samples were collected using a kick-net and macroinvertebrates were stored in 70% ethanol until they could be sorted and identified in the lab. Each sample was sorted randomly to a maximum of 150 individuals. If 150 individuals were not found in a sample, there was a time limit of two hours of sorting.

Currently we have sorted and identified 320 individuals from eleven different species. These findings will be value to the city of Tahlequah and other aquatic managers to see how macroinvertebrate communities change seasonally to have a better understanding of the health of Town Branch Creek and other urban streams in the area.

If you are interested in learning more about Northeastern State University's Fresh Water Science program,scan the QR Code with your smartphone camera.

A photo of a mayfly that was collected.



Students sorting and identifying macroinverebrates

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

Caleb Taylor[1], Richard Zamor[1], Katherine Wollman[2], Courtney Stookey[2]
1) Department of Natural Sciences, Northeastern State University, Tahlequah, OK
2) Grand River Dam Authority, GRDA-NSU Scenic Rivers and Watershed Research Lab, Tahlequah, OK

Natural riparian areas are associated with natural instream habitat and higher fish species richness. Riparian alteration can reduce canopy cover, alter stream flow, and reduce substrate diversity. In return, fish species richness can decline. Parkhill Branch Creek is a three-mile-long Ozark tributary stream of the Illinois River near Tahlequah, Oklahoma. Throughout the streams reach there is distinct land use surrounding it, including natural forested areas, farm/pastureland, residential housing, and a plant nursery. We are implementing the first fish assemblage assessment of Parkhill Creek and we are interested in 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, 894 specimens have been collected from 24 different species. Results from this study will provide a valuable assessment of fish communities of Parkhill Branch Creek and determine any correlations between fish species composition, abundance and distribution with riparian land use, canopy cover and instream habitat.

Caleb collecting fish during a sampling event

A banded sculpin that was collected and released

PROXIMITY TO ILLINOIS RIVER IMPACTS PHOTOSYNTHETIC LEAF TRAITS IN OAKS

Katie Worden[1], Courtney Stookey[2], Katherine Wollman[2], Elizabeth Waring[1]
1) Department of Natural Sciences, Northeastern State University, Tahlequah, OK
2) Grand River Dam Authority, GRDA-NSU Scenic Rivers and Watershed Research Lab, Tahlequah, OK

Oaks (*Quercus species*) thrive in considerably varied ranges of light availability yet possess unique moisture content in riparian and upland environments. Differing environments from riparian to upland allow oak tree health and function to be collected, quantified, and analyzed in various ecosystems. One method to determine the health of the photosynthetic systems in oaks is by measuring chlorophyll fluorescence, acquiring detailed information on the light reactions of photosystem II. Tree leaf traits varied across a riparian and upland gradient as well as between species of Quercus at ten sites along the riparian Upper Illinois River and upland Northeastern State University's campus in Tahlequah, Oklahoma. Gathering leaf traits for comparison provides an understanding of changes in leaf photosynthetic machinery, leaf shape, leaf nutrient content, and soil moisture. Photosynthetic traits and leaf traits influenced by the proximity to the river were evaluated through plant and environmental parameters. Soil moisture was measured under each tree and leaves that were in full sunlight were measured using Photosynq MultispeQ 2.0 to assess photosynthetic machinery function and chlorophyll content. Leaves were then measured for leaf area and transported to the lab to be dried and weighed for leaf specific area.

While there was no effect of species of oak on photosynthetic traits, as distance from the river increases, nonphotochemical quenching and photosynthetic rates as measured as linear electron flow increased ($p<0.01$ for both measurements). The leaf specific area of the oaks increased with proximity to the river ($p<0.0001$) indicating that leaves closer to the river are broader and thinner to allow for greater light capture. Due to the nature of the sites, riparian environments were denser than their upland counterparts, elucidating the riparian leaves' broadness and lower photosynthetic rates despite proximity to the river as a consequence of light competition.

Katie working in the field

Katie's mobile lab setup

Oklahoma State University

Measurement of Total Microcystins using Integrative Passive Sampling and Gas Chromatography-Mass Spectrometry Analysis

Ryan Grewe and Jason Belden
Department of Integrative Biology
Oklahoma State University

Harmful algal blooms can occur under certain environmental conditions, especially in water bodies receiving excess nutrients. Cyanobacteria often come to dominate these blooms, and numerous species of cyanobacteria have the potential to produce toxins (cyanotoxins). The hepatoxic microcystin is the most common cyanotoxin in freshwater systems and presents a risk to aquatic and terrestrial wildlife that are dependent on microcystin contaminated water bodies. However, there exists over 200 variants of microcystin, each with different levels of toxicity. Furthermore, detection of microcystin can prove quite difficult, as its concentrations fluctuate heavily with environmental conditions. Passive sampling may offer a way to integrate fluctuating and low concentrations of microcystin with time, allowing for a more sensitive analysis. Passive sampling involves placing a sorbent receptive to the analyte (microcystin in this case) in the water column, allowing the sorbent to collect the analyte at a continuous rate while deployed.

Once removed, the time-weighted average concentration of that analyte can be determined over the period that the sampler was deployed. Typically, however, the analytical methods associated with passive sampling of microcystins fail to detect total microcystins (using liquid chromatography). Gas chromatography-mass spectrometry (GC-MS) offers a way to detect total microcystins (all variants) simultaneously. The ADDA moiety present in all microcystin variants is oxidatively cleaved from microcystin to form MMPB. MMPB is then derivatized and analyzed via GC-MS to measure total microcystins, which is more toxicologically relevant than measuring individual variants.

The goal of this research is to couple passive sampling techniques with analysis of total microcystins. In a preliminary study, microcystin spiked passive sampler sorbents were subjected to extraction, oxidative cleavage of MMPB, and a new derivatization technique for GC-MS analysis. Results suggest that instrument quantification limits for the new derivatization and GC-MS method are sufficiently low, and from this, passive sampling should allow for much lower detection in environmental samples thanks to the continuous collection and concentration of microcystin. This data suggests that while the efficiency of the extraction and oxidation of microcystins from samplers needs to be improved, analysis total microcystins from passive samplers is feasible. The next step in this investigation will be to calibrate various passive sampler designs and estimate the analyte uptake rates. Determining consistent uptake rates will allow for the integration of low and fluctuating microcystin concentrations in the environment with time. Calibration of the samplers will require stable concentrations of microcystin, so Microcystis aeruginosa was also grown in-house to produce microcystin. This data suggests a strong correlation between microcystin prediction and growth parameters (cell density and phycocyanin content), indicating that cultivating Microcystis aeruginosa will be a valid method for producing stable microcystin concentrations for sampler calibration. Once calibration is complete, and the efficiency of the analysis of total microcystins is optimized, these methods should allow for the detection of total microcystins from passive samplers, and thus the integration of total microcystin concentrations with time while the samplers are deployed. Altogether, the coupling the analysis of total microcystins with passive sampling can provide a more simplified and comprehensive analysis microcystins in contaminated water bodies.

Oklahoma State University

Growth and Ionome-Wide Responses of Phytoplankton to Relative Supplies of Nitrogen, Phosphorus, and Trace Metals in Grand Lake

Yetkin Ipek and Puni Jeyasingh
Department of Integrative Biology
Oklahoma State University

Harmful algal blooms are one of the key environmental problems that affect water quality worldwide. In favorable conditions, algal abundance significantly increases in lake systems; compromising water quality, including the increased production of toxins that harm humans and pets. Both these direct and indirect effects also affect lake tourism and the abundance of fish in lakes; negatively affecting economies relying on such ecosystem services. 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 there are numerous environmental factors associated with the formation of algal blooms, the most common variable remains to be the increased loading of nutrients (such as phosphorus, nitrogen, etc.) to freshwater systems. The correlation between the loading of these elements and increased growth is explained by the Growth Rate Hypothesis. As an increase in algal growth would demand a higher rate of protein production; nitrogen (N) is required as the building blocks of proteins and phosphorus (P) is required in the structure of rRNA to support increased rates of protein synthesis. Faster production rates for cellular proteins are supported in the abundance of the supplies of these elements, which lead to blooms. Even though the individual effects of N and P are documented, we are still unable to accurately predict algal blooms based on these two elements. While the production of proteins depends on N and P, protein structure and function are also dependent on other elements such as trace metals, the supplies of which vary considerably. The runoff of N, P, and trace metals have increased significantly due to anthropogenic activities (i.e. fertilizer use, mining, sewage runoff). GRDA's 2020 report on Average Baseline Load into Grand Lake (SWAT Modeled, 2004-2015) showed a high variation between organic/inorganic N and P loading from different creeks into Grand Lake. Based on these values, we decided to study the elemental profiles in Horse Creek, Honey Creek, Duck Creek, and Drowning Creek sites on the Grand Lake; to test for links between trace metal concentrations and algal abundance as well as community structure. To measure bioavailable forms of trace metals, we deployed DGT passive samplers that bind to free and some bioavailable organic forms of cationic metals. We have also conducted bioassays with added iron (Fe) and metal-binding chelators, to check for comparative effects of trace metal availability on algal abundance. After measuring algal growth with a FlowCam system, we found that samples with chelator-bound trace metals had significantly less growth, compared to the control and added Fe treatments. Although this study is only starting (at least two more sampling dates planned), these findings from the initial sampling date demonstrate the potential effects of trace metals on harmful algal blooms; and have the potential to help develop effective forecasting and management of algal blooms.

The OSU team working to sample Grand Lake

Oklahoma State University

Local and regional influences on macroinvertebrate communities in reservoir tributaries of the Grand and Hudson Lake watersheds

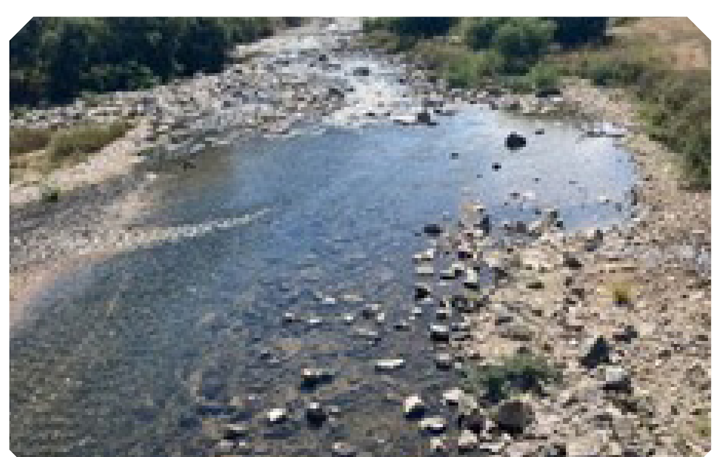
Sam Miess and Andy Dzialowski
Department of Integrative Biology
Oklahoma State University

Macroinvertebrate communities are integral components of aquatic food webs and serve as bioindicators of water quality. Macroinvertebrate communities are shaped by abiotic factors, such as water chemistry and underlying lithology, and/or biotic factors, such as vegetation and dispersal capacities. These factors can be localized (e.g. riparian vegetation, location along a stream), or exist on a broader regional scale (e.g. variation between ecoregions). Therefore, regional factors operating far beyond the bank of the stream have the potential to influence local macroinvertebrate communities. Grand Lake and Hudson Lake provide unique systems for studying local and regional influences on macroinvertebrate communities, due to their many tributaries located within different level III ecoregions. These different tributaries vary in surrounding land-use, water chemistry, and anthropogenic impact. Understanding these factors, and how macroinvertebrate communities are shaped by them, is crucial towards preserving these vital members of aquatic systems and effectively using them as bioindicators.

The current study examines how abiotic and biotic factors from tributaries to the watershed shape macroinvertebrate communities and identifies to what extent local and/or regional factors influence community structure. Investigating both local and region factors will provide a holistic view of macroinvertebrate community structure. From this, models linking factors on local and regional scales can be developed and incorporated into biotic indices, improving the accuracy of these indices in determining water quality.

We are also studying the potential relationships between macroinvertebrate communities and harmful algal blooms (HABs) as they develop in the watershed and move through tributaries into reservoirs. This study will combine field studies and mesocosms to identify how HABs impact macroinvertebrate communities, and how macroinvertebrate communities may be able to mitigate HABs. This will be accomplished by collecting macroinvertebrate and water samples from sites along a low-impacted and a high-impacted tributary, the latter experiencing frequent HABs. Simultaneously, stream mesocosms will be used to mimic stream conditions, and dynamics between macroinvertebrate communities and cyanobacteria will be explored.

Currently, site identification and sampling protocols are being finalized before starting seasonal macroinvertebrate sampling and water quality analysis of Grand and Hudson Lake tributaries. From these samples, macroinvertebrate community composition will be determined, as well as stream habitat characteristics and water quality. These data will be analyzed and compared to data collected by state and federal resource agencies from previous stream surveys


A sampling site in the Grand Lake Watershed

Oklahoma State University

Shifting Community: can changes in the lake microbiome predict algal blooms?

Chelsea Murphy and Noha Youssef
Department of Integrative Biology
Oklahoma State University

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 are seeking 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 aim to collect data on both what microbes are present as well as how much of the community they make up. We aim to sequence 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. With this data, we ultimately hope to be able to predict when blooms will occur based on the changes of the microbial community, as they should provide signals that the nutrition profile of the lake is changing. We hypothesize that complex community trends precede a bloom, and that these trends can be predicted. We aim to use the data we collect 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 would 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.

So far, we have 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. To obtain a preliminary view of the community present in the samples, we performed amplification and sequencing of the 16S rRNA marker gene. Our preliminary results show a range of Cyanobacteria concentrations corresponding to the bloom status of the sample. Principal Component Analysis (PCA) of the samples also revealed the influence of Actinobacteria and Proteobacteria on shaping the community. Depth profile of the sample appears to have an impact on the community structure, with benthic samples exhibiting a much greater Proteobacteria signal. To dive deeper into the specifics of the community makeup and metabolic expression, we plan to perform deep-sequencing on the extracted DNA samples.

Oklahoma State University

MONITORING HARMFUL ALGAL BLOOMS USING UNMANNED SYSTEMS

Abhiram S.P. Pamula[1] and David J. Lampert[2]
1) Department of Civil and Environmental Engineering, Oklahoma State University
2) Department of Civil, Architectural, and Environmental Engineering, Illinois Institute of Technology, Chicago

Nutrient transport into lakes and reservoirs can stimulate the growth of cyanobacteria and algae concentrations. Excess eutrophication can result in the release microcystins which are toxic to humans when consumed. High algal concentrations can also adversely impact the dissolved oxygen concentrations in surface water bodies. Excess algal growth that impair surface water quality are called Harmful Algal Blooms (HABs). HABs need to be monitored and modeled regularly to understand the dynamics of nutrient loadings from tributaries, releases of legacy nutrients from sediments, and algae growth rates. The Grand Lake O' the Cherokees has experienced outbreaks of cyanobacteria regularly over the past few years. The overall objective of the research at Oklahoma State University is to develop a monitoring system for surface water bodies to collect water quality data at high temporal and spatial resolutions to understand and forecast HABs. The monitoring at Grand Lake is taking place in Horse Creek Cove which is known for HAB formations.

The monitoring system at Grand Lake involve an Unmanned surface vehicle (USV) named Mobile Autonomously Navigable USV for Evaluation of Lakes (MANUEL) that can collect bathymetry and water quality data including pH, temperature, conductivity, turbidity, dissolved oxygen, chlorophyll-a, and phycocyanin concentrations at the frequency of 1 HZ. The bathymetry data collected by the USV in 2020 is compared with the hydrographic survey performed by the Oklahoma Water Resources Board in 2009 which yielded similar results. The team has observed that there is a difference in depth which resulted in the estimation of the amount of sediment accumulated from 2009 to 2020. Moreover, in-situ data collected by GRDA has been compared with high-resolution water quality data collected by MANUEL to develop remote sensing algorithms. The remote sensing algorithms to forecast HABs use statistical methods to provide gridded estimates of HABs.

Upstream of Horse Creek cove, a monitoring station is installed which includes a refrigerated autosampler that collects samples from Horse Creek regularly to monitor solids concentration and nutrients including both nitrogen and phosphorous. Beside a DIY water monitoring station has been installed close to the autosampler which collects water quality data including depth from surface, conductivity, temperature, and turbidity. Using the water quality data collected in Horse Creek, a watershed model is currently being developed. The model will simulate the watershed runoff and land management. This model will provide important insights into the non-point sources of nutrients and sediment which might be initiating the HAB events in the Grand Lake. Finally, the long-term goal of the project is to use the water quality data collected from Horse Creek to understand the HAB formation and provide HAB advisories by using statistical remote sensing tools and suggest better land management practices in the Horse Creek watershed.

OSU's Boat Autosampler

University of Oklahoma

COLLABORATIVE UNIVERSITY RESEARCH HELPS TO ENSURE SOUND SCIENCE IN WATERSHED DECISION-MAKING

R.W Nairn[1], D.E. Townsend[2], and R.C. Knox[1]
1) Center for Restoration of Ecosystems and Watersheds,School of Civil Engineering and Environmental Science, University of Oklahoma
2) Grand River Dam Authority, Office of Ecosystems and Watersheds Management

This abstract, summarizing the OU CREW and GRDA collaboration, was presented at the 2021 North American Lakes Management Society (NALMS) 41st International Symposium, Valuing Water: Economics, Ecology and Culture, Oklahoma City, OK. From 2009 to 2019, this partnership supported 15 graduate students to completion, six environmental science/ environmental engineering capstone classes, a faculty sabbatical, multiple summer internships, and an adjunct faculty appointment. In addition, 20 refereed journal publications were produced.

Multi-stakeholder partnerships are key to productive and effective watershed management. Active citizen involvement is crucial for long-term success and sustainability, but university research provides unique perspectives and contributions when working in close partnership with lake and watershed managers. The Grand Lake o' the Cherokees watershed provides jurisdictionally complex economic, ecological, and cultural issues and serves as an excellent testbed for execution of applied research collaborative partnerships. The watershed drains portions of four states (Oklahoma, Kansas, Missouri, and Arkansas) and the treaty lands of ten sovereign Native Nations. The predominantly agricultural watershed also includes the historic Tri-State Lead-Zinc Mining District and multiple Superfund Sites. The Grand River Dam Authority (GRDA; a public power utility charged with ecosystems and watershed management) established the Ecosystems and Education Center (EEC), including a state-of-the-art water quality laboratory, in 2009. That same year, GRDA entered the first of two ten-year agreements with the University of Oklahoma (OU) through the Center for Restoration of Ecosystems and Watersheds (CREW) to financially support student research. The laboratory was partially equipped by the university and the EEC provides an in-watershed research base for CREW's long-term biogeochemistry and ecological engineering research efforts.

n 12 years, over 20 graduate students, six environmental science and engineering senior capstone classes, multiple internships, and a faculty sabbatical have been supported through this partnership. Research efforts focus on water quality, including nutrient pollution and eutrophication (including harmful algae blooms) and ecotoxic trace metals, and emphasize natural infrastructure solutions to provide multiple ecosystem services and societal benefits.

Maggie from OU Crew performing a greenhouse experiment

University of Oklahoma

USING SUAS-DERIVED MULTISPECTRAL IMAGERY AND LINEAR MODELS AS TOOLS FOR MONITORING OF OPTICALLY SHALLOW SURFACE WATERS

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Collecting high-resolution spectral data across large areal extents with small Unoccupied Aerial Systems (sUAS) provides environmental monitors with the tools to estimate water quality in large optically deep bodies of water. Optically deep waters are those where light is not capable of penetrating to the depth of the substrate. Conversely, light penetrates through the water column and illuminates the substrate in optically shallow waters. The purpose of this study was to examine how scaled-down remote monitoring technologies (e.g., sUAS relative to satellite) in terms of size, cost, and complexity perform when attempting to estimate standard water quality parameters (e.g., chlorophyll-a, total suspended solids, Secchi disk depth, and turbidity), in optically shallow surface waters. Linear regression analyses revealed that reflectance bands or band ratios could accurately describe approximately 50 percent of the water quality parameters variability yet still produce statistically significant (p-value < 0.05) results. Various digital reflectance extraction techniques were also evaluated, and remote sensing limitations in optically shallow waters were verified. Verification of the developed models revealed low accuracy, moderate precision, and a rejection of the primary hypothesis that sUAS could describe water quality in optically shallow waters.

Furthermore, a novel, simple scattering correction method was developed based on the suspended sediment's physical properties within the bulk of the waterbody. The utility of this technique allows remote sensing scientists to correct for scattering using a few physical water properties. Currently, sUAS technologies are far from replacing traditional in-situ environmental monitoring and should only be used as a tool to supplement typical monitoring efforts. However, as technologies continue to improve, sUAS can substantially decrease the time, money, human-hours, and laboratory analyses required to sufficiently characterize environmental problems.


A small pond analyzed as part of this study.


Water quality sampling personell.

University of Oklahoma

IN-SITU MANIPULATIONS OF AQUATIC OPTICAL DEPTH AND ITS EFFECT ON SUAS-DERIVED SPECTRAL REFLECTANCE

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The remote collection of spectral data (e.g., multi- and hyperspectral) with sensors fixed to various platforms (e.g., satellites, occupied aerial vehicles, and small unoccupied aerial systems (sUAS)) has allowed for the estimation of several optically active constituents (OACs) common in surface waters. However, in small, complex, and optically shallow waters where multiple OACs (e.g., chlorophyll-a and total suspended solids) impact the spectral signature, these technologies have experienced significant limitations. Altering the scale at which these examinations are performed from surface waters (e.g., ponds, lakes, and reservoirs) to mesocosm systems will allow for a minute examination of the interactions between OACs and the impact of aquatic optical depth has on remotely sensed spectra. Thus, this study examines both optically shallow and optically deep water bodies at the mesocosm scale to determine the impact aquatic optical depth has on developing accurate surface-water quality models. Furthermore, the impact of bottom reflectance on the sUAS-derived spectral signature was described in two manners. Results demonstrated an accurate representation of OACs present in various forms and concentrations in optically deep mesocosms compared to optically shallow mesocosms when assessed with sUAS. Also, using an sUAS allowed for quantification of the effects of bottom reflectance. The interferences observed under these conditions (e.g., reflectance increased by 5 - 21 percent) were comparable to literature values when studying optically complex water bodies with hyperspectral data. Therefore, this study provides a basis for understanding the benefits and limitations of monitoring in-situ water quality via sUAS in optically deep and shallow waterbodies.


Mixing of optically sallow water.


Mixig of optically deep water.

University of Oklahoma

EFFECTS OF MISSION PARAMETERS ON THE ACCURACY AND EFFICIENCY OF SUAS-DERIVED MULTISPECTRAL IMAGERY AND OPERATIONS

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Data collection from afar (e.g., remote sensing) allows scientists to study natural phenomena at more acceptable temporal resolutions and greater areal extents than traditional (e.g., in-situ) environmental studies. Unfortunately, the scientific literature lacks a defined standard method for collecting small Unoccupied Aerial Systems (sUAS)-derived multispectral imagery for environmental modeling purposes (e.g., water quality estimation). The development of a proposed method must incorporate the understanding that each sUAS has system-specific constraints (e.g., battery life, flight speed, and wind stability) and collects mission-specific data (e.g., true color, multispectral, or hyperspectral imagery). Therefore, this study's goal was to provide a basis for developing an sUAS image collection standard operating procedure for environmental monitoring by examining the impact mission parameters had on imagery generated. An assessment of the spatial and spectral characteristics of the sUAS imagery was presented in a standardized manner. Evaluation of accuracy (e.g., reflectance and color) and efficiency (e.g., flight time and battery consumption) of individual sUAS missions produced a set of operational parameters to be considered in future environmental remote sensing studies. Providing a methodological approach for the development of calibrated target objects was required because no one set of parameters will work for all sUAS, target objects, or study goals. Results demonstrate the precise identification of color was heavily reliant on pixel resolutions and in-situ solar conditions during operations. Furthermore, changes in solar conditions could describe approximately 60 percent of the error observed in color identification.

Overall, the most efficient mission, in terms of flight time and image storage space, did not produce the most precise color representation, suggesting the balance between sUAS operations and data quality has yet to be achieved. Future studies must further examine the tradeoffs between changes in solar conditions (e.g., solar elevation angle), areal coverage (e.g., high altitude flights), fine spatial resolutions, and the accurate retrieval of spectra (e.g., color) while communicating in a manner that is transferable across the digital environment, ensuring future environmental remote sensing studies produce the highest quality data possible.

The different targets used in this experiment.

University of Oklahoma

USING SUAS FOR THE DEVELOPMENT AND VALIDATION OF SURFACE WATER QUALITY MODELS IN OPTICALLY DEEP MINE WATERS

Brandon Holzbauer-Schweitzer and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Remote estimation of water quality is of increasing interest to monitoring professionals. Predictive regression models have been developed using satellite and small Unoccupied Aerial System (sUAS) remote sensing techniques. Typically, these remote sensing techniques were applied to optically deep waters (e.g., the bottom was not visible), targeting traditional contaminants of concern (e.g., chlorophyll-a and total suspended solids). Therefore, by considering a water body that is shallow in terms of physical depth (e.g., water surface to substrate surface), yet optically deep (e.g., highly turbid) like many mine water systems, examinations may be made of relationships between physical and optical depth, water clarity, water chemical composition, and spectral reflectance. Thus, this study's purpose was to demonstrate novel spectral monitoring techniques for mining-impacted surface waters utilizing reflectance data from two different platforms. First, the feasibility of using sUAS-derived multispectral imagery (e.g., tens of spectral measurements) was examined to estimate in-situ metal concentrations in lead-zinc mine drainage. Results describe strong linear relationships (e.g., R2adj. > 0.74) between remotely collected multispectral reflectance and in-situ metal concentrations (e.g., Fe, Li, Mn, Pb, and Zn). Developed models could estimate mean metal concentrations within a percent of the observed value with great confidence (e.g., 70 percent confidence interval). The "success" of the non-optical metal predictions (e.g., metals not making a significant contribution to spectra – Li, Mn, Pb, and Zn) was attributed to the surface properties of the iron precipitates (e.g., high sorption affinity). Model validation at a site with waters of a different geologic origin allowed the authors to assess this phenomenon's site-specificity. Unfortunately, validation of all models developed (Mn, Ni, Pb, S, and Zn) was not possible within this study's statistical constraints (e.g., prediction within ± 25 percent of the observed value). However, two models (Fe and Li) were validated, and when other relationships were examined with site-specific spectra, significant improvements were observed.

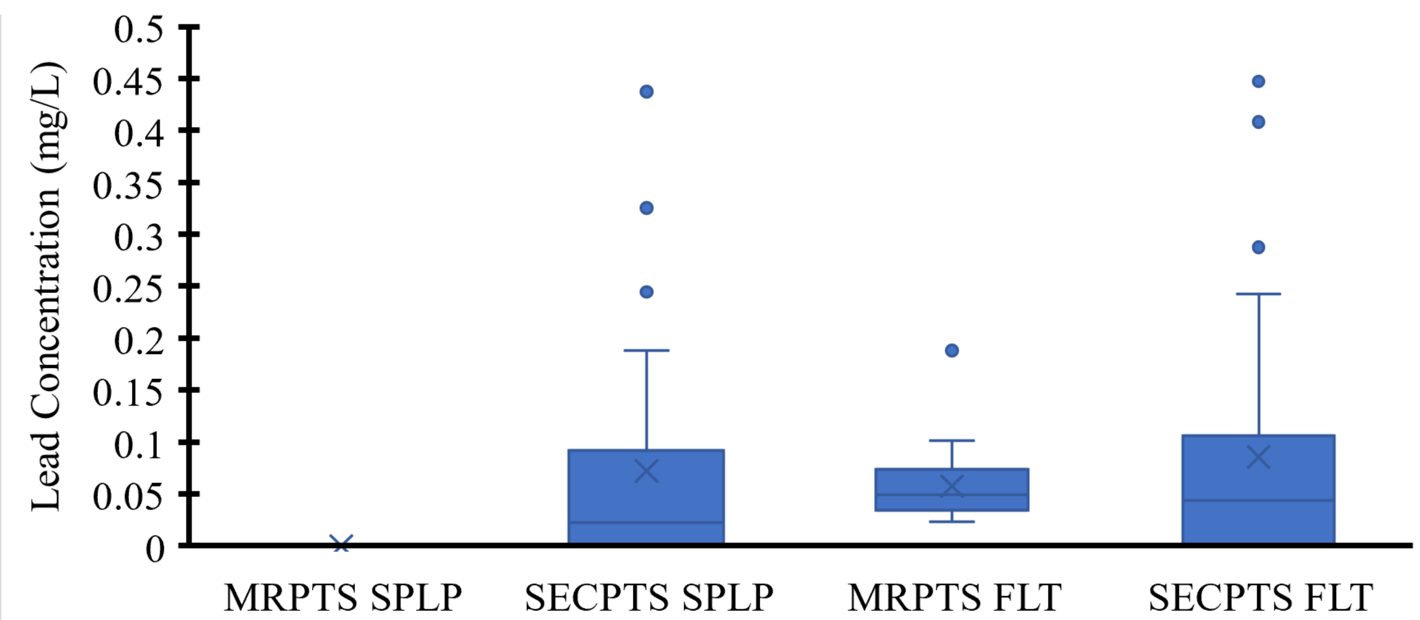
Employing hyperspectral (e.g., thousands of spectral measurements), remote sensing techniques produced a novel identification technique for optically shallow waters (e.g., the bottom was visible) and other remote sensing interferences. To do this, the exponential decay of light in water was modeled using two physical measurements (e.g., Secchi disk depth and actual depth) and sUAS-derived red band reflectance. The established level of confidence (e.g., R2 = 0.73) observed using data from two different sites suggests this model may provide environmental monitors with a means to evaluate the feasibility of using remote sensing technologies to assess water quality in mine drainage passive treatment systems. Utilizing cost-effective sUAS-derived multispectral imagery to estimate mine water quality may represent a new tool and pave the way for the next generation of environmental monitoring. Adopting this technology will advance the efficiency and effectiveness of monitoring, alter traditional environmental remote sensing strategies, and provide a glimpse into the ever-advancing future of environmental restoration.

University of Oklahoma

TRACE METALS LEACHABILITY FROM VERTICAL FLOW BIOREACTOR SUBSTRATES IN TWO HARD ROCK MINE DRAINAGE PASSIVE TREATMENT SYSTEMS

Justine I. McCann and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Vertical Flow Bioreactors (VFBRs) are an important form of biological passive treatment of mine drainage. The organic substrate in VFBRs provides an anaerobic environment for sulfate reducing bacteria, which facilitate the precipitation of metal sulfides from mine impacted waters. However, these treatment units can become clogged and require rehabilitative maintenance, such as the stirring or replacement of the organic substrate. Spent substrate from VFBRs may carry a large metal load and must be characterized before disposal to ensure appropriate handling. In this study, VFBR substrate consisting of woodchips and spent mushroom compost from two hard rock mine drainage passive treatment systems in the Tri-State Lead-Zinc Mining District were evaluated for environmental availability of metals through three leaching tests. Concentrations of metals in Toxicity Characteristic Leaching Procedure leachates did not exceed Resource Conservation and Recovery Act limits but Synthetic Precipitation Leaching Procedure and Field Leach Test leachates did exceed some Oklahoma Water Resources Board guidelines. Additionally, total metals concentrations exceeded consensus-based toxicity benchmarks for soil and sediment. These results indicate that the materials are nonhazardous, but care should be taken when developing plans for beneficial reuse to ensure the receiving ecosystem is not damaged.



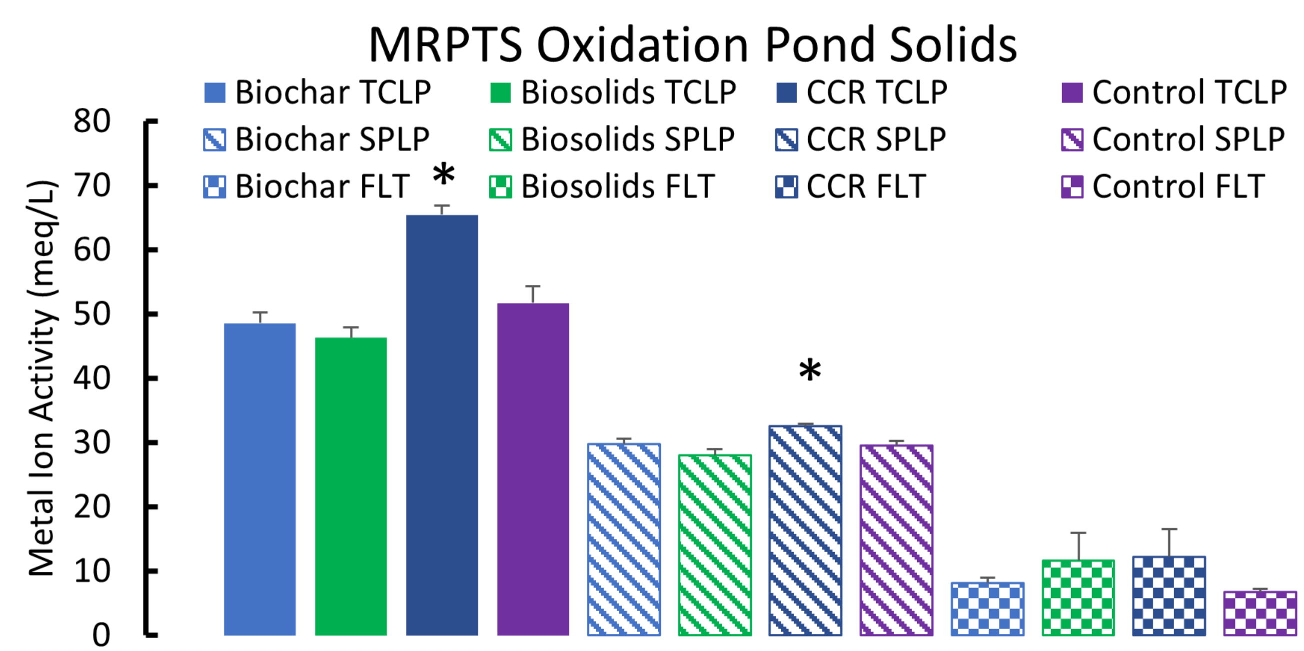
Box and Whisker plots showing lead concentrations.

University of Oklahoma

SORPTIVE AMENDMENTS TO ADDRESS LEACHABILITY OF TRACE METALS FROM HARD ROCK MINE DRAINAGE PASSIVE TREATMENT RESIDUAL SOLIDS

Justine I. McCann and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Passive treatment of mine drainage effectively decreases the concentration of ecotoxic metals in impacted water and sequesters the metals in residual solids, the composition of which vary depending on the biogeochemical process in use. Mine drainage passive treatment systems must undergo rehabilitative maintenance to continue functioning over decadal time scales. This maintenance includes removing residuals from the system, creating large amounts of potentially hazardous waste. In this study, the use of three amendments, biochar, biosolids, and coal combustion residuals, to increase retention of ecotoxic metals in hard rock mine drainage treatment residual solids was examined. Three leaching tests, the Environmental Protection Agency's Toxicity Characteristic Leaching Procedure and Synthetic Precipitation Leaching Procedure, and the United States Geological Survey's Field Leach Test, were used to determine whether the retention of metals was increased by the addition of these amendments. Although the amendments had neutral to basic pH, large surface areas, and cation exchange capacities that were hypothesized to increase sorption of trace metals, the concentrations of most metals were statistically similar or elevated compared to the control. Further research may show that an application rate greater than 5% by mass or a mixture of amendments may decrease the concentration of metals available to the environment.



Metal Ion Activity in the Leachates from Mayer Ranch Passive Treatment System.

University of Oklahoma

EVALUATION OF THE FISH COMMUNITIES IN TAR CREEK TO DETERMINE THE POTENTIAL RECOVERY OF THE FISH POPULATION WITHIN THE TAR CREEK SUPERFUND SITE

Nicholas L. Shepherd and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The abandoned Picher field mining site, located within the Oklahoma and Kansas portion of the Tri-State Lead-Zinc Mining District, ceased mining operations in the 1970s, and left behind multiple sources of contamination. The two primary sources include the tailings piles, locally referred to as "chat", and the contaminated water in the underground mine voids that now discharges at the surface. The chat contaminates the soils, sediments, and streams with elevated concentrations of cadmium, lead, and zinc. Additionally, the chat creates an unstable stream bed that is highly erodible, negatively impacting the biota in the stream. The contaminated water discharging from the underground mine voids, known as mine drainage, contains elevated concentrations of Cd, Fe, Pb, and Zn. Similar to the chat sources, the metals within the water contaminate nearby streams, sediments and biota. However, the elevated Fe concentrations that are associated with the mine drainage leads to iron flocculation that coats the bottom of the stream and stains everything it touches the rusty orange color often associated with Tar Creek. The objective of this study was to determine the potential recovery of the fish population near Douthat, OK, located within the Tar Creek Superfund Site, based on the existing fish population in Tar Creek further downstream in Miami, OK.

The fish communities at each location were evaluated by collecting the fish along a quarter mile of stream using large nets measuring 4'x15' and 6'x30' (Figure 1 C), then identifying and tallying the fish before releasing them. These fish collections were conducted in the summer months in 2018, 2020, and 2021. The most upstream location, Tar Creek at 40 Road (Figure 1), was the most contaminated site and that was reflected in the fish collections. A total of 11 species of fish were captured at Tar Creek: upstream of 40 Rd, averaging 203 individual fish captured during each of the annual collections. Meanwhile, 7.2 miles downstream, at Tar Creek: E Central Ave in Miami, OK (Figure 2), a total of 26 species were captured, averaging 668 individual fish captured during each of the annual collections. Notable species collected at Tar Creek: E Central Ave include White Crappie, Spotted Bass, and Common Carp, along with multiple species of darters. The collections at Tar Creek: E Central Ave suggests the impacts of the contamination from the Picher mining field is far less, and this fish community represents what is available to recolonize Tar Creek at 40 Rd, if the sources of contamination are remediated.

OU CREW members collecting fish

University of Oklahoma

EVALUATION AND DIGITIZATION OF HISTORICAL MAPS OF THE PICHER FIELD UNDERGROUND MINE WORKINGS OF THE ABANDONED TRI-STATE LEAD-ZINC MINING DISTRICT IN THE UNITED STATES

Nicholas L. Shepherd, Ed Keheley, Russell C. Dutnell, Carlton A. Folz, Brandon Holzbauer-Schweitzer, and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Mining began in the Picher field, in the Oklahoma and Kansas portion of the Tri-State Lead-Zinc Mining District in the United States, during the 1900s and ceased in the 1970s, producing an estimated 1.65 million tons of lead and 8.8 million tons of zinc. These underground workings could reach ceiling heights of nearly 120 feet high, where extension jumbos allowed for additional mining of the ceilings (Figure 1). Many of the mining companies had hand drawn maps of the underground workings, but there has not been an effort to create a single map of the Picher mining field since the 1960s, and there has never been an effort to create a digital version of the Picher mining field that included the underground workings in both Kansas and Oklahoma. The objectives of the work presented in this paper were to 1) utilize historical mining map repositories to create a map of the Picher field underground workings in a digital format that is readily accessible and can be easily updated as new information becomes available; 2) determine the areal extent and void volume of the mine workings in the Picher field using AutoCAD Civil 3D and ArcMap; and 3) address and quantify uncertainties of historical mining maps that were not updated before mining operations were abandoned, thus producing a map that represents the minimum extent of the mine workings.

Over 400 historical maps of the underground mine workings were compiled into a single, easily editable map (Figure 2). This map was used to create 3D renderings for calculation of underground mine workings area and volume estimates. An example of these 3D renderings is shown in Figure 3. The workings have an estimated volume of 80,000 ac-ft (260,680,800,000 gallons) covering an area of 3,560 acres (5.56 square miles). The map and subsequent calculations should be considered the minimum extent of the mining field due to the likelihood that many historical maps were likely lost or destroyed. The format of the map allows for continuous updates as new information becomes available.

Miners working underground in the Picher mining field in Oklahoma.

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ECOSYSTEM METABOLISM AS A TOOL TO EVALUATE CONSERVATION EASEMENT SUCCESS IN THE HORSE CREEK WATERSHED OF THE GRAND LAKE O' THE CHEROKEES, OKLAHOMA

David M. Wilcox and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Billions of dollars are spent annually on stream and river restoration projects in the United States, often with the goal of establishing a riparian buffer between upland areas and the water to improve water quality. In the Horse Creek watershed of the Grand Lake o' the Cherokees, stream conservation easements seek to improve water quality by removing land from agricultural production. These riparian ecosystems are transitional between aquatic and terrestrial environments, providing a wide range of ecological functions such as nutrient cycling, primary productivity, and organic matter decomposition. The focus of this study will be to evaluate the impact of the conservation easements in Horse Creek on these functional ecosystem indicators.

A small Unoccupied Aerial System (sUAS) will be used to gather data on vegetation health and distribution within the conservation easements. The sUAS is equipped with a multispectral sensor, capable of gathering information in the blue (475 nm), green (560 nm), red (668 nm), red edge (717 nm), and near-infrared (840 nm) portions of the electromagnetic spectrum, and data gathered will be used to generate vegetation indices correlated with ecosystem functional indicators.

Gross primary productivity and respiration will be evaluated using the open diel oxygen method at various locations in Horse Creek. Decomposition within the stream will be evaluated using a method known as cotton tensile strength loss. This method uses cotton strips made from canvas to simulate the cellulose fibers found in leaf litter, an important source of energy for aquatic environments. Bacteria and invertebrates break down the cotton strips during a two-week incubation period. The tensile strength of the cotton strips is evaluated before and after incubation to determine the rate of loss of tensile strength, which can be compared across easement and non-easement areas of Horse Creek.

Habitat assessments will be conducted to evaluate the health of the riparian zones and their ability to support habitat for aquatic communities.

David Wilcox flying an sUAS over Horse Creek

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EVALUATING EFFECT OF MINE DRAINAGE CHEMISTRY ON SORPTION CAPACITY OF FORMED IRON OXIDE SOIDS AND THEIR POTENTIAL SUSTAINABLE REUSE

Dayton M'Kenzie Dorman and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

The primary unit in mine drainage treatment systems are oxidation ponds which accumulate iron oxide solids over time. The disposal of these iron oxide solids can be financially burdensome and environmentally unsustainable. However, it is well-established that iron oxides have substantial surface area per unit mass and therefore considerable sorption capacity. By properly understanding iron oxide mineralogy, how it changes over time and its effect on sorption capacity, sustainable reuse of mine drainage treatment solids may present an opportunity to offset solids disposal costs and improve the sustainability of mine water treatment activities. The overall goal of this project is to develop a thorough understanding of the relationships between mineralogy and sorption capacity in mine-drainage derived iron oxides, in order to further advance sustainable environmental and economic reuse of mine drainage treatment solids. Beneficial reuse of mine water iron oxide solids not only decreases the environmental footprint of mine drainage treatment, but also alleviates the financial burdens of storing, treating, and disposing of such solids. Iron oxide samples were collected from collected from two passive treatment systems located in the Tar Creek Superfund Site treating naturally net-alkaline hard-rock mine drainage and four abandoned coal mining locations: two passive treatment systems where net acidic mine waters have been rendered alkaline and two untreated net acidic mine drainage discharges.

CREW members sampling iron oxyhyroxides at the Mayer Ranch Passive Treatment System in Ottawa County, OK.

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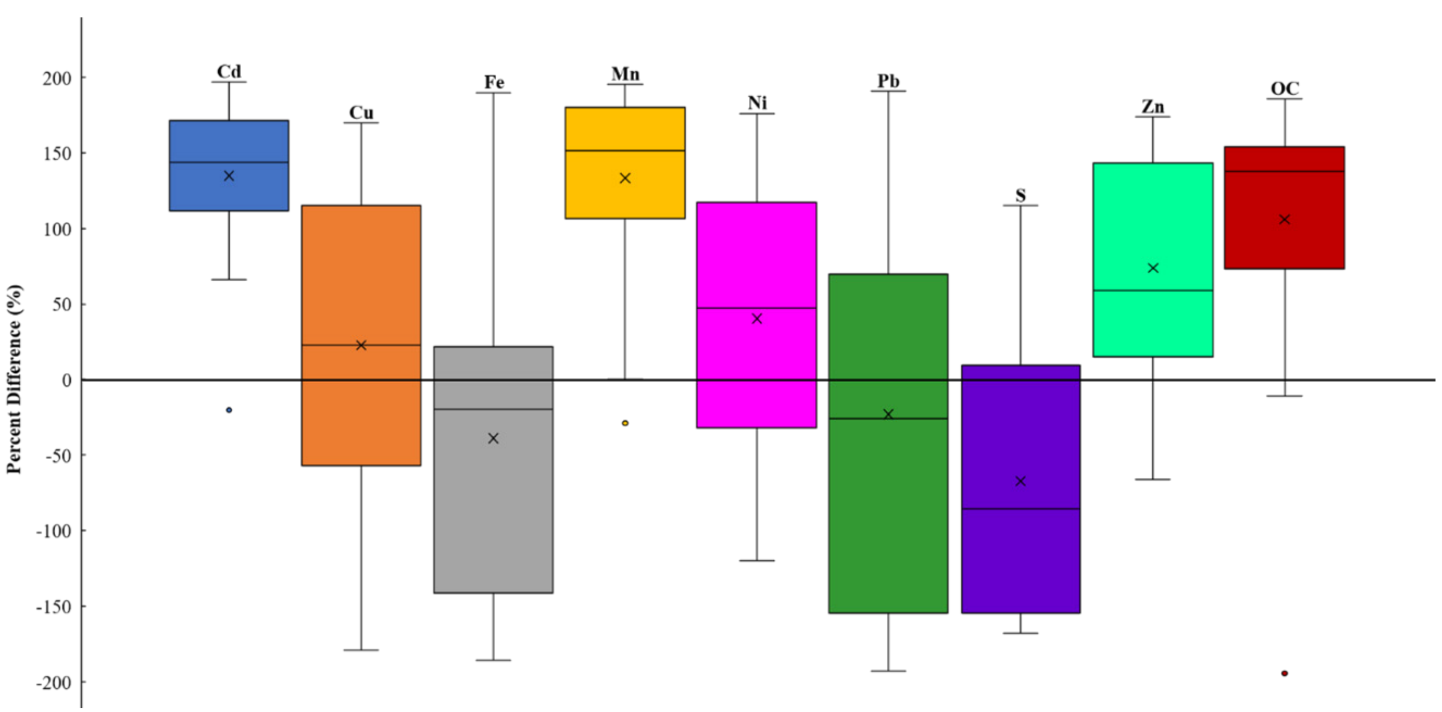
TEMPORAL AND SPATIAL VARIATIONS IN SEDIMENT TRACE METAL CONCENTRATIONS IN STREAMS, RIVERS, AND A RESERVOIR NEAR A DERELICT LEAD-ZINC MINING DISTRICT

Carlton A. Folz and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Historic lead and zinc mining in the Tri-State Mining District has ceased, but the legacy of trace metal contamination (Cd, Cu, Ni, Pb, and Zn) throughout the region still exists. This thesis focuses on stream sediments in and downstream from contaminated areas. This study evaluated temporal changes of trace metal concentrations over 35-years in Tar Creek sediments. The spatial distribution of trace metal concentrations was subject to analyses between Tar Creek, the Neosho River, the Spring River, and Grand Lake O' the Cherokees. The last study focused on the bioavailability of trace metals in sediments and what factors may influence it. The watershed of Grand Lake O' the Cherokees drains multiple National Priority List Superfund sites from mining-related activities. Sources of trace metals entering the surface water systems include artesian flowing mine drainage, mining waste pile leachate, and mine waste in the active channels. When evaluating temporal changes in Tar Creek sediments, Cd, Mn, Ni, and Zn concentrations and organic carbon content increased. At the same time, Fe, Pb, and S decreased from 1985 to 2020. Spatially, Cd, Pb, and Zn concentrations decreased with increasing distance from mining impaired areas. Lastly, evaluating the impact of sediment pH, sediment organic carbon, and total Fe concentrations resulted in a wide range of responses and variability. The bioavailable concentrations of trace metals were not influenced equally by these factors. Use of statistical evaluations at the 95th confidence interval for the appropriate tests allowed for the determination of significance. Sediment-bound trace metals in freshwater sediments have complex behaviors and are becoming distributed downstream of the mining district. As remediation of sediments in the Superfund sites begins, it is imperative to understand the sources, mobility, and bioavailability of the trace metals to increase the effectiveness and efficiency of remediation while minimizing potential human and environmental risks.



Box and Whisker plots showing the percent difference of the nine constituents in the study.

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CHANNEL STABILITY ASSESSMENT AND ECOLOGICAL RESTORATION DESIGN ON THE BARON FORK RIVER, ADAIR COUNTY, OKLAHOMA (U.S.A)"

Carles Crespo-Azorín Martínez, Russell C. Dutnell and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Mining operations in the past had negatively impacted the morphology of the channel of the Baron Fork River, Adair County, Oklahoma. The Oklahoma Department of Wildlife and Conservation (ODWC) is planning to restore it. This Master's thesis aims to orient their final decision, providing an ecological restoration design on the 320-acre land area that they have acquired. This proposal is based on a channel stability assessment that has been carried out as part of this thesis and also, based on the analysis of historical fluvial-geomorphological data that dates back 23 years. Streambank erosion can damage structures and private property. This study shows that the main area of concern is in the northwest portion of the property where the Baron Fork is impinging on the road. Ecological restoration, natural-design techniques and in-stream structures could be used to manage river migration over time and maintain bank stability during major storms. The conceptual design presented addresses these recommendations.

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.

Cross sections for the study site on Barren fork River in Adair County, OK.

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Zepei Tang and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

SEDIMENT DISTURBANCE EFFECTS ON NUTRIENTS AND METALS IN A RESERVOIR RECEIVING BOTH AGRICULTURAL RUNOFF AND HARD ROCK MINE DRAINAGE

A greenhouse microcosm study was completed to simulate nutrient/metal interactions at the sediment layer-water column interface in a large Oklahoma reservoir that receives untreated lead-zinc mine waters and agricultural runoff. To evaluate sediment disturbance influences, three different mixing treatments were established in nine 25-L vessels containing lake sediments and water: control (no mixing), low mixing (200 rpm) and high mixing (500 rpm), using overhead blade-stirrers. A two-hour mixing period produced significant ($p<0.05$) increases in total suspended solids, total phosphorus (P), iron (Fe), nickel (Ni) and zinc (Zn) in the water column, indicating nutrient and trace metal release due to mixing disturbance. During the subsequent 7-day settling period, water column total P, Fe, Ni and Zn concentrations decreased 54.8%, 98.9%, 57.7% and 89.4%, respectively, for the low mixing treatment and 96.7%, 98.7%, 92.1% and 99.0%, respectively for the high mixing treatment, indicating sediment redeposition, metal precipitation, and/or nutrient sorption. After 7 days, sediments showed decreased P and increased metal (Fe, Zn, Cd and Pb) concentrations compared to initial conditions. The growth of algal biomass may have affected P-metal binding, turning bioavailable P into non-bioavailable P and promoting metal sequestration to the sediments with biomass. All aqueous metal concentrations, when compared to US EPA National Recommended Water Quality Criteria, were below both Criteria Maximum Concentration and Criteria Continuous Concentration guidelines. Sediment metal concentrations were below the site-specific sediment quality guidelines (SQGs) both before and after mixing. Overall, resuspension caused by mixing and subsequent settling helps to release sediment P into the water column and precipitate aqueous trace metals to the sediment layer.

THE ROLE OF MINE DRAINAGE RESIDUAL ADDITION ON NUTRIENT AND TRACE METAL RELEASE IN MICROCOSMS WITH BIOMASS GROWTH AND DECAY

A greenhouse microcosm study investigated the impacts of recovered iron oxyhydroxide mine drainage residuals (MDRs) on phosphorous (P) and trace metal distribution at the sediment layer and water column interface. Each mesocosm included 5 kg of lake sediment and 20 L on-site groundwater. Three treatments were examined with triplicate: Control (C) with no addition; Low MDR (LM) with 0.3 kg MDR; High MDR (HM) with 0.9 kg MDR. During the first 10 days, soluble reactive phosphorous (SRP) and total phosphorous (TP) showed decreasing trends due to uptake by biomass with no significant differences among three treatments. After 75 days, biomass died in all three treatments, P concentrations went down in LM and HM treatments due to MDR sorption, while C treatments showed a P release from dead biomass death and decay. Therefore, MDR additions appeared to serve as a long-term internal P loading control method to prevent labile P release back into water column after algal bloom decay which could enhance potential future blooms. Comparing trace metal concentrations in the water column to the USEPA National Recommended Water Quality Criteria and National Secondary Drinking Water Standards, all samples were below both the hardness-adjusted acute and chronic criteria, except for Pb with regard to the chronic criterion, which showed limited concerns for trace metal release from MDR additions. Compared to site-specific Sediment Quality Guidelines (SQGs), all sediment samples were below Tri-State Mining District (TSMD) specific SQGs, indicating that there was no significant toxicity introduced to the sediment layer after MDR addition. Metal concentrations in MDRs, however, exceeded TSMD site-specific SQGs. Future studies may be conducted to look at designs for practical MDR addition practices.

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HORSE CREEK WATERSHED CHARACTERIZATION USING A PAIRED HABITAT ASSESSMENT AND REMOTE SENSING APPROACH

David M. Wilcox and Robert W. Nairn
Center for Restoration of Ecosystems and Watersheds
School of Civil Engineering and Environmental Science, University of Oklahoma

Riparian habitat protection agreements along Horse Creek in the Grand Lake o' the Cherokees watershed have incorporated continuous monitoring efforts to document changes in water quality, water quantity, and habitat and vegetation changes. In agriculturally dominated watersheds such as the Horse Creek watershed, loss of riparian habitat has been identified as a major contributor to water quality degradation. A paired habitat assessment and remote sensing study is proposed, in accordance with current efforts, to supplement ongoing monitoring efforts within riparian easements.

Previous studies have monitored physicochemical water quality data on a monthly basis. However, no studies of in-stream or riparian biota have been conducted to determine if conservation efforts have had an impact on aquatic life. Evaluating the presence and quality of habitat is necessary to assess the ecological stability of stream systems. In-stream and riparian zone assessments are traditionally conducted by performing habitat assessments (HAs) and rapid bioassessment protocols (RBPs), which incorporate periphyton, benthic macroinvertebrate, and fish assemblage data. HAs and RBPs will be completed following the Oklahoma Conservation Commission standard operating procedures, which are based on the US EPA's "Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish" (Barbour et al. 1999).

Completion of these assessments alongside the collection of biotic community assemblage data will occur in late spring and early fall 2021 to quantify the impact of riparian protection and compare results across time and to other reference streams. Riparian vegetation function classification is necessary because these ecosystems provide ecotones between terrestrial and aquatic ecosystems. Functional classification traditionally describes biota at the reach scale by conducting in-situ field surveys according to the "National Riparian Core Protocol: A Riparian Vegetation Monitoring Protocol for Wadeable Streams of the Coterminous United States" (United States Forest Service 2017) standard operating procedures. Remote sensing using a small Unoccupied Aerial System (sUAS) will be conducted by surveying stream reaches with high-definition multispectral imagery. Combining aerial imagery and in-situ field surveys will generate data useful for calculating vegetation recovery and extent.

The shoreline of Horse Creek in Northeast Oklahoma

Employee Directory

Name:	Title:	Email:
Darrell Townsend	Vice President - Ecosystems	darrell.townsend@grda.com
Ed Fite	Water Quality Manager	edward.fite@grda.com
Jacklyn Jaggars	Project Coordinator - Hydro Projects	jacklyn.jaggars@grda.com
Bob Harshaw	Program Manager - Historical Properties	robert.harshaw@grda.com
Jeri Fleming	Environmental Compliance - Grants	jeri.fleming@grda.com
Joel Barrow	GIS Specialist	joel.barrow@grda.com
Stephen Nikolai	Manager - Water Research Labs	steve.nikolai@grda.com
William (Bill) Mausbach	Watershed Ecologist	william.mausbach@grda.com
Dustin Browning	Biologist II	dustin.browning@grda.com
Katherine Wollman	Biologist II	katherine.wollman@grda.com
Courtney Stookey	Biologist I	courtney.stookey@grda.com
Scott Horton	Supervisor - Shoreline Enforcement	phillip.horton@grda.com
Kenny Baker	Administrative Assistant III	kenny.baker@grda.com
Janet Dellisanti	Permitting Admistrator	janet.dellisanti@grda.com
Derrick Bidleman	Police Officer - Shoreline	derrick.bidleman@grda.com
Jacob Graham	Police Officer - Shoreline	jacob.graham@grda.com
Scott Dallas	Police Officer - Shoreline	kenneth.dallas@grda.com
Shane Johnston	Shoreline Technician II	shane.johnston@grda.com
Ira Gaylord	Shoreline Technician I	ira.gaylord@grda.com
Cory Bogle	Shoreline Technician I	cory.bogle@grda.com
Aaron Roper	Manager - Neosho Bottoms	aaron.roper@grda.com
Wyatt Speer	Technician I - ECO Ops	wyatt.speer@grda.com
Jared Griffith	Technician I - ECO Ops	jared.griffith@grda.com

(L-R) Dustin Browning, Ryan Shannon, Jesse Rader, Bill Mausbach, and Steve Nikolai (2021 ECO Water Quality Team)

Closing Thoughts

We hope you find this 2021 annual review 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 water resources that provide so many benefits to the citizens of northeast Oklahoma. Our commitment to these natural resources will never wane 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.

If you have any questions about the ongoing cooperative research programs, the GRDA website at www.grda.com or contact our offices at (918) 256-0723.

To see work that has been featured in previous years, use the QR codes below to access our 10 Year Review, as well as our 2020 Annual Review.

Sincerely,

Stephen Nikolai


Stephen Nikolai
Manager - Water Research Labs

ECOSYSTEMS EXPLORATIONS 10 YEAR REVIEW 2008-2019

ECOSYSTEMS EXPLORATIONS 2020 Annual Review

Ecosystems Explorations: 2021 Annual Review

EDITORS:
Justin Alberty
Dustin Browning

GRAPHIC DESIGN:
Page Layouts: Dustin Browning
Logos: GRDA Corporate Comms.

COVER CONCEPT:
Dustin Browning
Joel Barrow

REVIEWERS:
Melanie Earl
Katherine Wollman
Courtney Stookey

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.

This publication printed by The Boomerang Printing in Tulsa, OK, is issued by the Grand River Dam Authority at no cost to taxpayers as authorized by 82 O.S. Sec. 861 et seq. 300 copies have been printed at a cost of $1592.50. Copies have been deposited with the Publications Clearinghouse of the Oklahoma Department of Libraries.

Ecosystems and Watershed Management
420 Highway 28
PO Box 70
Langley, Oklahoma
74350

Scenic Rivers Watershed Research Lab
611 N Grand Ave. NSU.
Science & Health Professionals
Tahlequah, Oklahoma
74464

Lab: Room SC115
Office: Room LL050