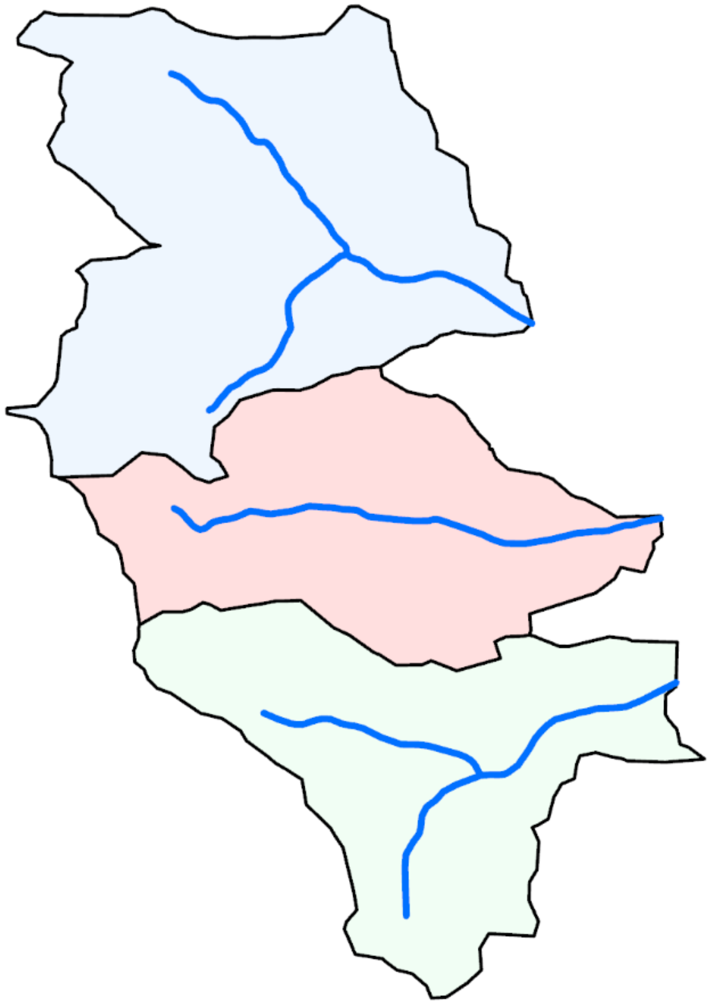
Assessment of Sediment-Associated Contaminants in UGA Campus Watersheds

A UGA Campus Sustainability Project
Project Start Date: January 2020; Project End Date: June 2020



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Abstract

The University of Georgia campus contains many aquatic resources and a number of previous projects have incorporated water quality monitoring. UGA has also recently restored Oconee Forest Pond and reopened the previously closed Lake Herrick recreational area. However, little data exists on the quality of the sediment moving through UGA campus streams and being sequestered in the campus lakes. This study uses an EPA standard method to evaluate sediment samples from sites within UGA campus watersheds for potentially toxic pollutants. Our results indicate that sediment collected from the Tanyard Branch site caused toxicity in test organisms. Based on these results, we recommend that further actions be taken to both identify the toxic pollutants and trace their source.

Introduction

The University of Georgia's campus has many aquatic resources and monitors water quality for a variety of reasons, including environmental safety. In the past, Lake Herrick, Oconee Forest Pond, and some campus streams have been perceived by some in the UGA community as polluted. In 2018, a project was completed to both restore the Lake Herrick Watershed and transform Oconee Forest Park into a space that could be used for classes, outreach events and recreation by UGA students, faculty, and staff. To ensure the sustainability of Oconee Forest Park and UGA's streams, their environmental state must be fully understood. This includes the condition of the fisheries, the water and sediment quality, and overall habitiat suitability.

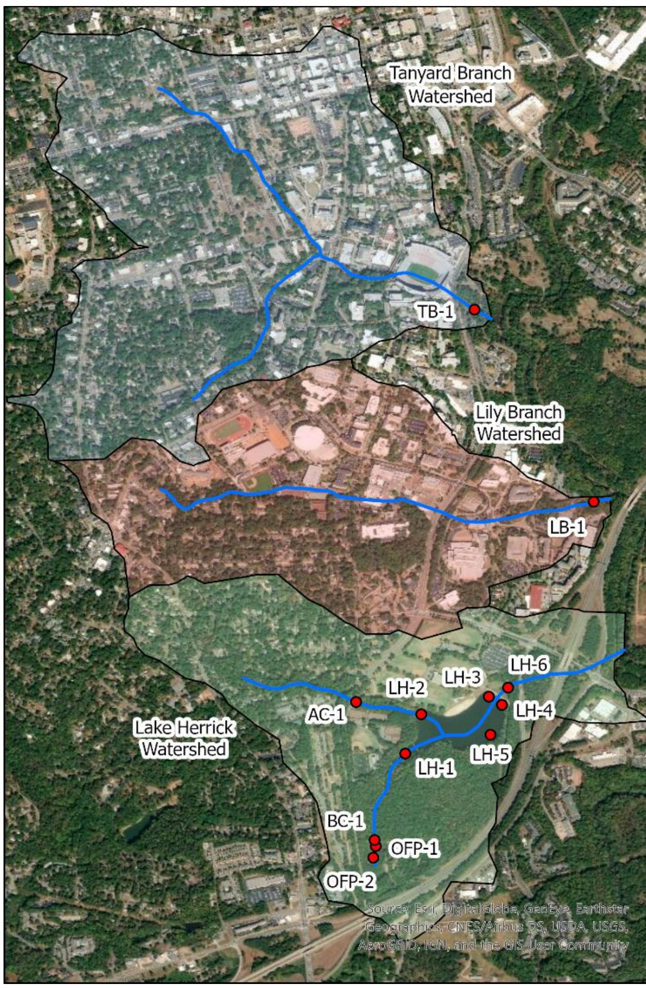
Sediment quality is one of the lesser understood indicators of environmental quality of aquatic systems at UGA. To our knowledge, no assessment of sediment-associated contaminants has been conducted on UGA's watersheds. Therefore, the objectives of this study were as follows:

1. Identify areas of the campus streams and lakes that contain depositional sediment at the time of assessment.
2. Provide baseline data on sediment-associated contamination, or lack thereof, within UGA's watersheds.
3. Dependent the outcomes of goal 2, suggest areas that may need further sampling and investigation.
4. Communicate results to land managers and suggest relevant management actions if necessary.

Methods

Site Descriptions

Sediment samples were collected from 12 total locations (**Figure 1**). Deviations from initially proposed sample locations were due to access concerns or lack of depositional sediment at the time of sampling. Tanyard and Lily Branch sampling locations were chosen in the lower portion of their respective watersheds to assess the total effects of all land uses within each watershed. Armadillo and Birdsong Creek sampling locations were chosen to assess the quality of inflow streams into Lake Herrick and the outflow of Oconee Forest Pond (Birdsong Creek). Lake Herrick and Oconee Forest Pond sampling locations were chosen to assess inflows into the impoundments, the outflows of the impoundments, and the deeper areas where depositional sediments are ultimately sequestered.



Site Information

SiteID	Waterbody	Location
AC-1	Armadillo Creek	Downstream of East Campus Rd. crossing
BC-1	Birdsong Creek	Outflow of Oconee Forest Pond below dam
LB-1	Lily Branch	Upstream of confluence with Oconee River
LH-1	Lake Herrick	Inflow from Birdsong Creek
LH-2	Lake Herrick	Inflow from Armadillo Creek
LH-3	Lake Herrick	West Corner Dam Forebay
LH-4	Lake Herrick	East Corner Dam Forebay
LH-5	Lake Herrick	Eastern Shore
LH-6	Lake Herrick Outflow	Outflow of Lake Herrick below dam
OFP-1	Oconee Forest Pond	Inflow into Oconee Forest Pond
OFP-2	Oconee Forest Pond	Dam Forebay
TB-1	Tanyard Branch	Upstream of confluence with Oconee River

UGA Watershed Boundaries
- Lake Herrick
- Lily Branch
- Tanyard Branch

Other Layers
- Sediment Collection Sites
- UGA Campus Streams

N W E S — 0 500 1,000 Meters

Figure 1. Map showing the boundaries of each watershed in the assessment and the locations of each of the 12 sampling locations.

Sample Collection and Preparation
All sediment sampling was completed on March 16, 2020. Lake sediment samples were composites of 6 to 8-inch cores taken from multiple spots around a central sampling site. Stream sediment samples were composites of surficial sediment from multiple spots around a central sampling site. All samples were labeled, placed in glass jars, and transported to a refrigeration unit at the Whitehall Experimental Forest sediment laboratory.

Prior to use in experimental testing, each of the sediment samples were thoroughly homogenized in a stainless-steel bowl. Aliquots of each sample were separated for experimental testing and for analysis of particle size distribution. The latter aliquot was placed back under refrigeration.

Experimental Procedures
Sediment toxicity was determined using 42-day exposures using *Hyalella azteca*, an amphipod that is commonly used in ecotoxicology and is considered an ideal organism for sediment testing because of its benthic life history (USEPA, 2000).

Seven days before testing began, we assembled culture units, which consisted of a plastic bin, a no. 20 stainless steel sieve, and an air stone. Each unit was filled to just below the rim of the sieve with water from the mass culture tanks and breeding adult *H. azteca* were placed in the sieves. The temperature of the laboratory was adjusted to 25°C to facilitate reproduction. Over the course of 48-hours, the breeding adults reproduced, resulting in known-age neonates that were 24-48 hours old. At the end of this reproduction period, the sieves were moved up and down in the water to force the neonates through the sieve while the adults remained in the sieve. These neonates were counted and placed in 1-L beakers with air stones and reconstituted moderately hard water to begin acclimation to testing conditions (**Figure 2**). Over a seven-day period, ending with day one of the experiment, temperature and dissolved oxygen within each of the beakers was monitored to ensure suitable conditions for the neonates. This procedure resulted in the 7-8-day old organisms required for beginning the experiment.

On the day before testing began, aliquots of homogenized sediment samples were added to the 100-mL mark in 300-mL high-form beakers with a screen-covered notch at the top. Each beaker was a separate experimental unit, and five replicates of each treatment (12 sites, 2 controls) were prepared (70 total beakers) (**Figure 3**). Controls included beakers filled to the 100-mL mark with aquarium sand that had been previously soaked in deionized water and beakers with artificial substrate (plastic screen) from mass culture tanks used to maintain breeding adults. Each beaker was filled to just below the notch with reconstituted moderately hard water (USEPA, 2000) and randomly placed on a static renewal system (**Figure 3**), which began automatically renewing 125-mL of reconstituted water twice daily.

Figure 2. Photo showing neonate acclimation chambers where neonates were grown into 7-8-day old test organisms.

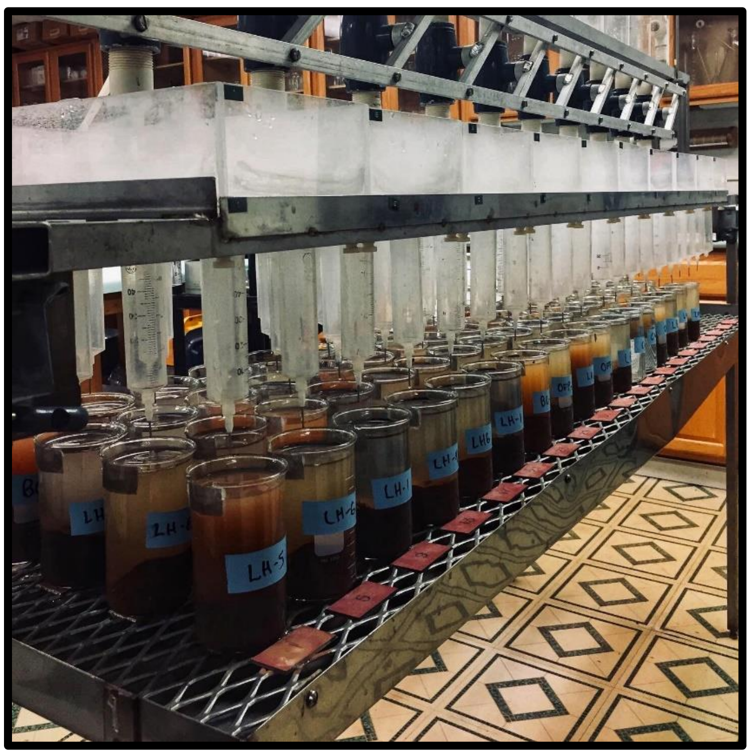


Figure 3. Photo showing setup of static renewal system for renewal of overlying water.

On the first day of the experiment, 10 7 to 8-day old organisms were placed in each of the 70 experimental units. Dry weight of 80 starting organisms (separate from those used in the experiment) was measured to determine the average starting weight of an individual test organism. Each experimental unit was fed 1-mL of YCT food (USEPA, 2000) per day after the morning water renewal. The water temperature was held at a constant mean of 23°C ± 1°C.

Experimental endpoints included survival, growth, and reproduction. The survival endpoint was measured on day 28 by removing all organisms from their experimental units and counting the survivors. After the survival endpoint was measured, surviving organisms were placed in new notched 300-mL high-form beakers that contained a teaspoon of aquarium sand previously soaked in deionized water. These beakers were placed in the same position on the static renewal system and water renewal continued to occur as it did in the previous 28 dsaays. The reproduction endpoint was measured on day 35 and day 42 by removing the organisms from their experimental units and counting any neonates that were present. On day 42, the organisms were examined under a stereoscope for sex-determination so that the number of young per female could be calculated. Male *H. azteca* were identified by the presence of an enlarged second gnathopod. All organisms without an enlarged second gnathopod were considered female. The growth endpoint was measured on day 42 by measuring the dry weight of the surviving organisms, calculating their average individual weight, and subtracting the average starting weight from the average ending weight for each experimental unit.

Overlying Water Quality and Chemistry

The source of water used for these exposures was dechlorinated tap water (conductivity of 150 microsiemens per centimeter adjusted to 25° C). The conductivity of this lab water was adjusted to between 330-360 microsiemens at 25° C by adding reagent-grade salts in the ratio determined by previous research (Smith et al., 1997). to create reconstituted moderately hard water. Sodium bromide (1 mg/L) was added to the water to ensure the minimal level of bromide required by the amphipods (Ivey and Ingersoll, 2016).

The water quality/chemistry monitoring schedule was as follows:

- Water temperature measured daily
- Dissolved oxygen, conductivity, and pH measured 3 days per week
- Ammonia, Alkalinity, and Hardness measured on day 1, day 28, and day 42

All water quality/chemistry measurements were done on a composite of 30-mL aliquots of water from each experimental unit within a treatment. Water samples were collected using a syringe pipette before the morning renewal of overlying water. Temperature, DO, pH, and conductivity measurements were done with a Hach multiparameter water quality instrument; ammonia measurements were done using a Lamotte colorimeter; and alkalinity and hardness measurements were done using Lamotte titration test kits. All parameters stayed within acceptable ranges throughout the experiment and had no significant daily variations (**Figure 4**).

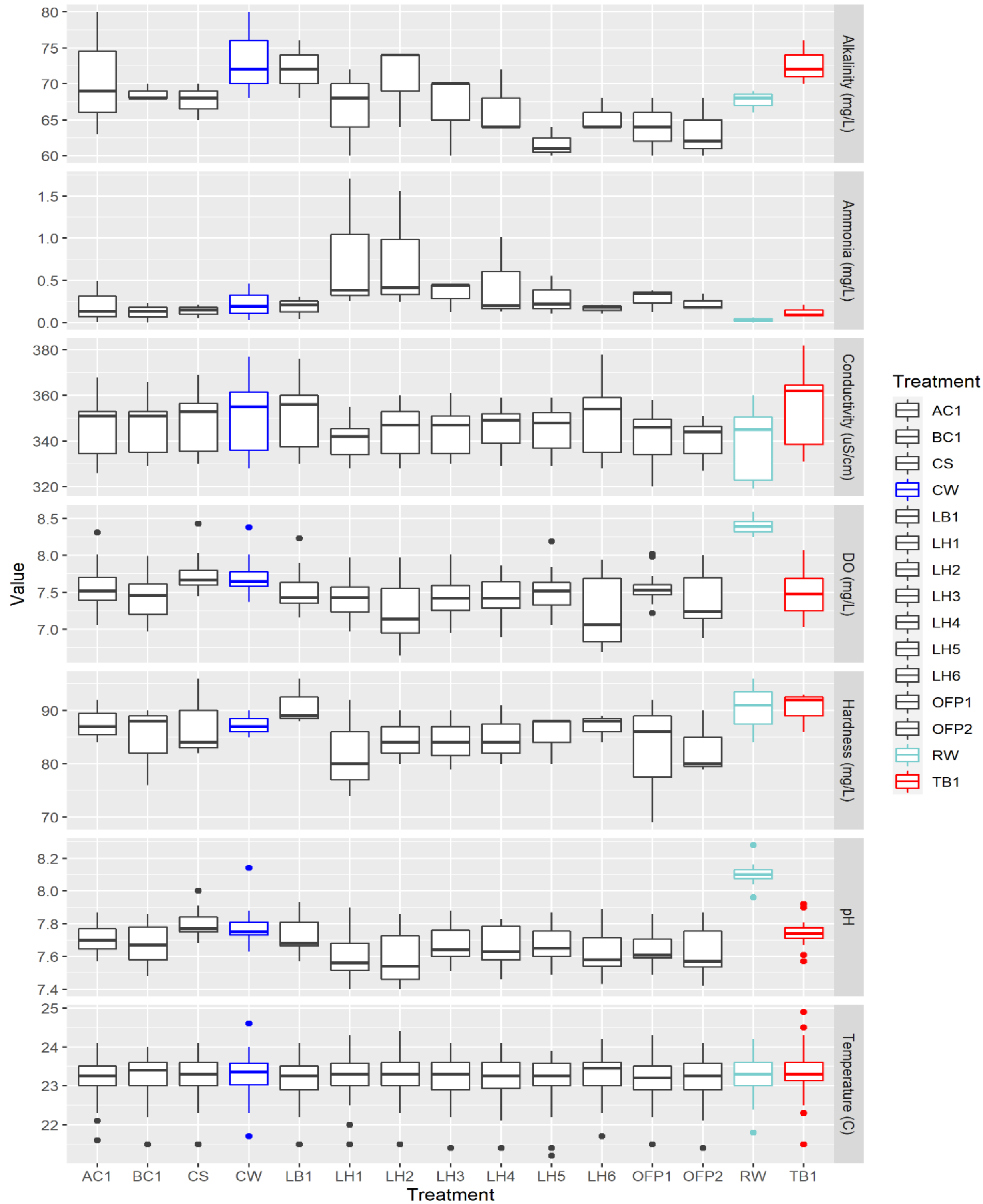


Figure 4. Boxplots showing the means and ranges of water quality parameters monitored throughout the experiment. The control treatment is shown in blue, the measurements from the vat of renewal water are shown in teal, and the TB-1 treatment is shown in red to show that there were no significant water quality/chemistry variations that would explain the overall study results.

Physical Characterization of Sediments
Physical characterization of sediments was done by determining moisture content, total organic matter (Davies, 1974), and particle-size distribution (Miller and Miller, 1987).

Lake Bottom Characterization
Lake bottom characterizations for Lake Herrick and Oconee Forest Pond were done by boat using a Lowrance HDS-9 sonar unit and a 3-in-1 transducer. Sonar data were collected along isobaths that were approximately 10 meters apart. These files were uploaded to Biobase, an online platform for lake bottom characterization using Lowrance sonar files. The Biobase program provides a relative measure of bottom hardness and can help determine what types of sediment are present.

Statistical Analysis
All statistical analysis was done using R statistical programming software (R Core Team, 2019) and all mapping was done using ArcGIS Pro (ESRI). Treatments were compared with an analysis of variance (ANOVA) with a completely randomized design using each of the three experimental endpoints (survival, growth, and reproduction). Residual normality was checked using the Shapiro-Wilkes test, and homogeneity of variances was checked using the Levene test. All three endpoints passed the Levene test for homogeneity of variances. The growth and reproduction endpoints failed the Shapiro-Wilkes test for normality of residuals. Reproduction data were transformed using a square-root transformation and growth data were transformed using a log transformation, so that both endpoints met the residual normality assumption of ANOVA. Tukey's Honestly Significant Difference test (Tukey's HSD) was used for multiple comparisons to determine which treatments differed from the control treatments. An alpha level of 0.05 was used to determine significance.

Results

Survival Endpoint
Due to unknown causes, the sand control treatment had very low survival and was excluded from all analyses. The sand control was not removed from the static renewal system so that experimental conditions remained as constant as possible. The artificial substrate control had sufficient survival and was used as the control treatment for analysis.

According to the ANOVA and Tukey's HSD, the 28-day survival rate of organisms within the sediment from the Tanyard Branch sample site (TB-1) was significantly lower than the survival rate of organisms within the artificial substrate control and all other treatments ($p<0.001$; Figure 5).

Growth Endpoint
According to the ANOVA and Tukey's HSD, the mean growth per individual of organisms from the OFP-1 treatment (Oconee Forest Pond dam) grew significantly less than organisms in the artificial substrate control treatment ($p=0.04$), the LH-2 treatment (Lake Herrick inflow from

Armadillo Creek; p=0.03), and the LH-5 treatment (Eastern shoreline of Lake Herrick; p=0.04) (Figure 6).

Reproduction Endpoint
According to the ANOVA and Tukey's HSD, the mean young per female from the LH-3 treatment (western corner of Lake Herrick dam) was significantly higher than the artificial substrate control treatment (p=0.02; Figure 7). No females survived in the TB-1 treatment, so it was excluded from this analysis.

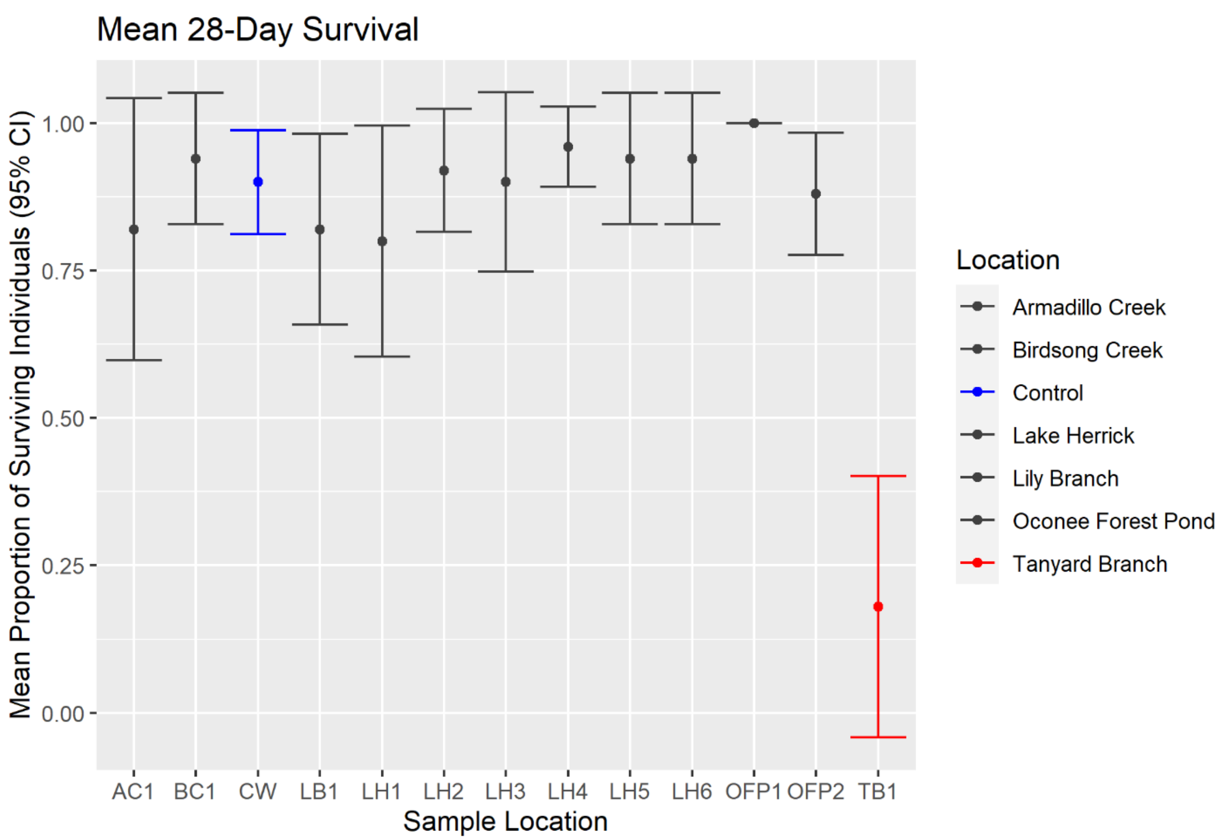


Figure 5. Graph showing the mean (± 95% confidence intervals) proportion of surviving individuals for each of the 13 treatments. The TB-1 treatment had significantly lower survival than all the other treatments (p<0.001).

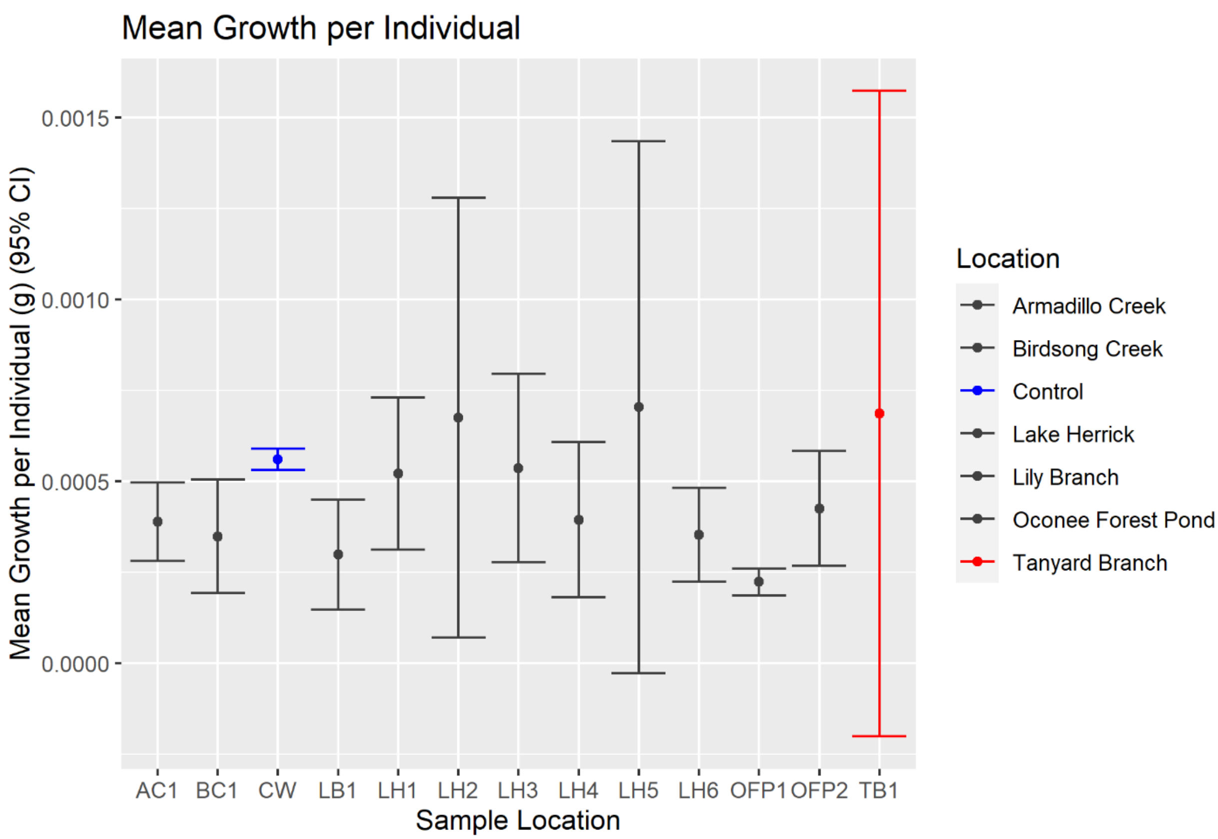


Figure 6. Graph showing the mean (± 95% confidence intervals) growth per individual for each of the 13 treatments. Organisms from the OFP-1 treatment (Oconee Forest Pond dam) grew significantly less than organisms in the artificial substrate control treatment (p=0.04), the LH-2 treatment (Lake Herrick inflow from Armadillo Creek; p=0.03), and the LH-5 treatment (Eastern shoreline of Lake Herrick; p=0.04)

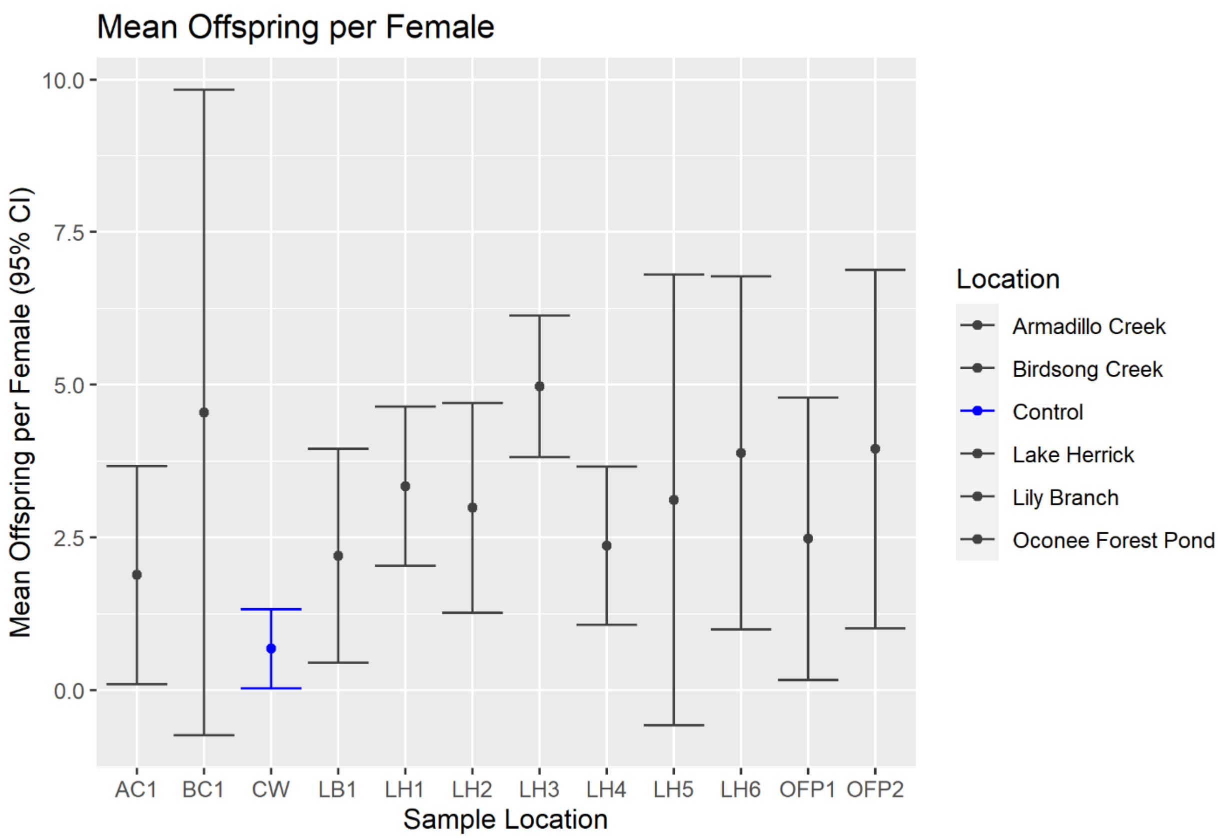


Figure 7. Graph showing the mean (± 95% confidence intervals) offspring per female for each of the treatments that had surviving females. The TB-1 treatment had no surviving females, so it was excluded.

Surveys of Lake Bottom Composition

Sonar bottom characterization of Lake Herrick showed that most of the fine, softer material is contained within the main pool of the lake (**Figure 8**). The inflow areas of the lake were generally harder, indicating that most of the coarser sandy material drops out and is sequestered in these areas. The area of harder material on the northern shore is consistent with the location of the old beach and swimming area and is likely mostly comprised of coarse sandy material.

Sonar bottom characterization of Oconee Forest pond indicates a condition consistent with the recent dredging activity (**Figure 8**). Most of the fine, softer material was removed during dredging, leaving a harder, clay-rich bottom.

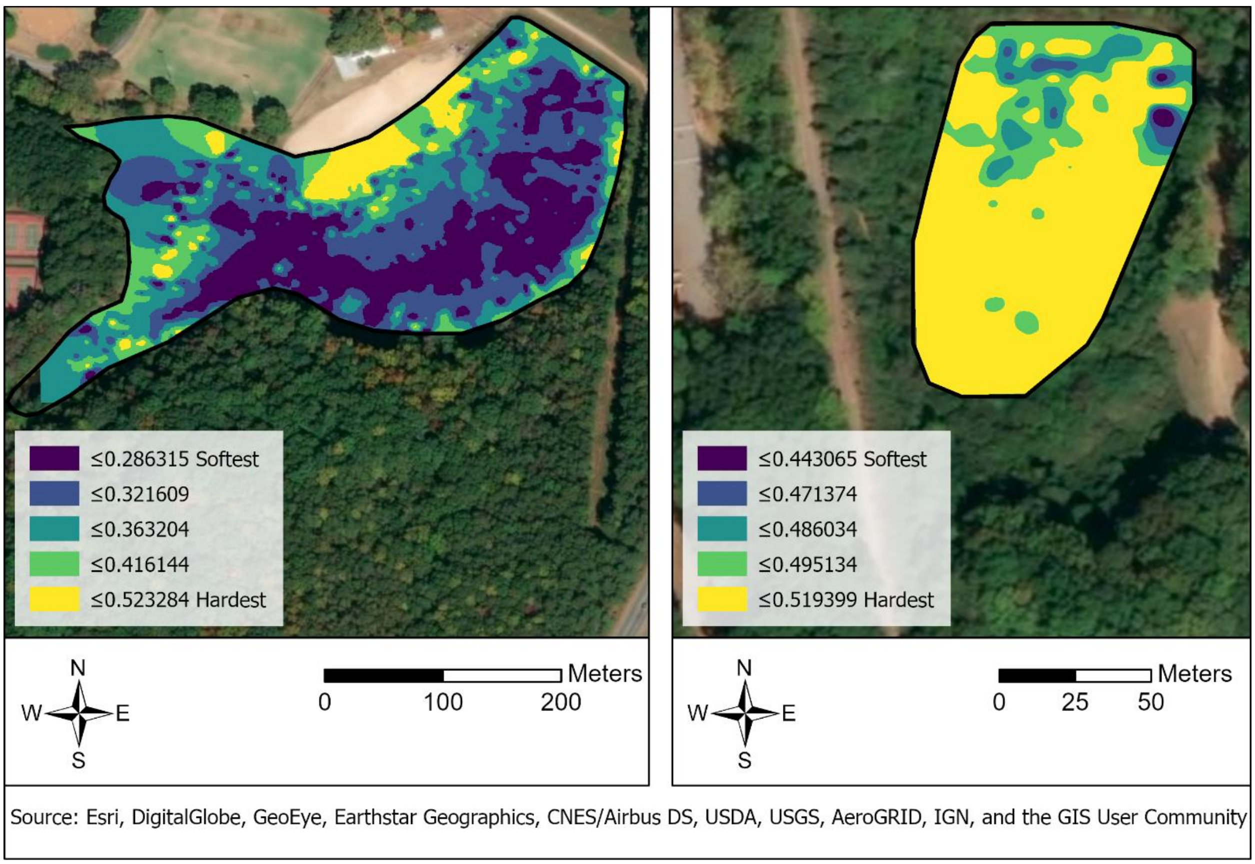


Figure 8. Maps showing bottom characterization of Lake Herrick (left) and Oconee Forest Pond (right) derived from sonar data collected in January 2020.

Particle Size Distribution

Results of sediment particle size analysis are shown in **Table 1.** In general, stream samples contained less organic matter than lake samples. The Tanyard Branch sediment—which showed toxicity in laboratory trials—was mostly sandy with very little organic content.

Table 1. Percent clay, sand, silt, and organic content of sediments used in sediment-associated contaminant trials for Lake Herrick and UGA campus streams.

Sample ID	Clay %	Sand %	Organic %	Silt %
AC1	3.45%	43.37%	0.58%	52.60%
BC1	3.43%	31.49%	0.61%	64.47%
LB1	3.05%	54.52%	0.26%	42.16%
LH1	3.01%	76.07%	5.39%	15.53%
LH2	3.19%	27.18%	4.82%	64.81%
LH3	3.04%	82.19%	5.40%	9.37%
LH4	3.33%	49.44%	2.22%	45.01%
LH5	3.05%	72.60%	3.14%	21.21%
LH6	3.47%	31.88%	0.72%	63.93%
OFP1	4.35%	41.89%	1.65%	52.10%
OFP2	3.09%	79.43%	4.76%	12.72%
TB1	3.14%	79.50%	0.73%	16.63%

Discussion

According to the results of this study, the sediment collected from Tanyard Branch (TB-1) caused toxicity in test organisms. The TB-1 site was located just downstream of a large culvert system that channels Tanyard Branch underneath Sanford Stadium. As a result, this area likely experiences flashy flows that frequently scour and replenish sediment from upstream. This sediment was also sandy and contained very little organic material, which is atypical of sediments that sequester contaminants. However, survival of organisms in this treatment and the sand control treatment is likely unrelated to particle size distribution. Previous research has found that particle size distribution has no significant correlation to survival, growth, and reproduction of *H. azteca* (Ingersoll et al., 1998). Tanyard Branch is an urban stream in a highly urbanized watershed, and as a result it likely has many potential sources for contaminants. The extent to which toxicity continues upstream and the cause of toxicity is unknown and should be of concern.

Based on the results of this study, there were no signs of chronic or acute toxicity in any of the other treatments. Although the OFP-1 treatment showed less growth than some of the other treatments, it also had the highest survival rate (100%), which likely resulted in greater competition for resources than the other treatments. Overall, the sediments from the Lake Herrick and Lily Branch watersheds showed no obvious signs of toxicity or impairment.

Recommended Actions

Based on the results showing that the sediment from the TB-1 treatment caused toxicity, we recommend a more in-depth investigation into the extent of the toxicity and its potential causes. This investigation would involve a multi-phased approach with the following objectives:

- Investigate whether the toxicity is a localized issue specific to the TB-1 site or a widespread issue throughout the watershed
- Determine what contaminant(s) are causing the toxicity
- Track the source(s) of these contaminants

We recommend the following phased approach to completing these objectives:

- **Phase 1:** Conduct more sediment toxicity experiments (like the one used in this study) using sediments from multiple sites throughout the Tanyard Branch watershed
- **Phase 2:** Based on the results of phase 1, complete chemical and heavy metals analyses on the sediments used in phase 1 to attempt to identify the contaminants causing toxicity
- **Phase 3:** Based on the results of the first two phases, use a combination of further sediment toxicity experiments and chemical/heavy metals analysis to trace the source of contaminants

- **Phase 4:** Conduct effluent testing using EPA methods to determine whether toxicity is also present in the water or if it is confined to the sediment.

The results of these studies could be useful in informing the future management and potential remediation of these issues. These described actions are beyond the scope of this project and would require further funding.

Breakdown of Budget Use for This Project

Due to safety concerns related to the COVID-19 pandemic, the student PI of this project (Wesley Gerrin) completed this work without the assistance of the hourly worker that was budgeted in the original proposal. Since this funding was not needed for personnel, the funds were spent on replacements for outdated instruments that were in use in the laboratory. These new instruments will be useful in furthering the work done by this laboratory and making sure it operates sustainably in the future. This funding has been instrumental in the revitalization of an outdated and underutilized facility. The project also incurred minor state vehicle expense costs for trips to Lake Herrick and campus stream sites. The following is a breakdown of the how the funds were spent:

Item Purchased	Total Cost
YSI multilab benchtop water quality instrument	$1,771.20
YSI IDS pH probe	$304.20
YSI IDS conductivity probe	$336.60
YSI IDS temp/DO probe	$765.90
Shipping for YSI	$10.00
Veritas semi-micro balance	$1,149.00
State Vehicle Expense	$43.20
Air Compressor Pressure Switch	$28.56

Outreach and Stakeholder Involvement

The PI and faculty sponsor of this project recognized that there may be some sensitivity associated with the results of this project and refrained from any sort of media involvement up to this point. The PI participated in the Instagram grant spotlight in the earlier stages of the project, which highlighted the premises of the project (no results had been acquired at that point) and was posted to the UGA sustainability Instagram profile. Releases of any of these results (if any occur) will be carefully coordinated with John McCollum, Kevin Kirsche, and Mike Hunter (depending on who the relevant stakeholders are).

Results of the Lake Herrick watershed portion of the study will be communicated with Mike Hunter and Brad Smith (Warnell managers of the property). Results of the entire study and their associated recommendations will be communicated with John McCollum, Kevin Kirsche, and any other relevant stakeholders.

Acknowledgements
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