Environmental Monitoring
USS *North Carolina* Battleship
Living with Water Project

Monitoring Report for NC CAMA
Permit # 97-23

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(1) other research projects, including student research,
(2) publication in a peer-reviewed journal article after 6 months from end of contract period (or other time period to be negotiated), and
(3) post periodic pictures on personal research website.

The Battleship will be provided with copies of all additional data analysis and publications (beyond annual and final reports) resulting from the work or any part of the work.

Table of Contents

List of Figures

Figure Page

List of Tables

Glossary of Terms

There are a few terms and abbreviations that will appear throughout the report and in future reports/updates that describe the environment, specific aspects of the habitat or biological community, and methods. Here we provide working definitions for these terms that provide context for understanding the activities of the project.

Benthic: The bottom of any water body (lake, river, stream, creek, estuary, coastal or ocean) regardless of the depth. Can refer to the bottom environment including the physical aspects of the substrate and biological community.

BirdNET: a software system used to analyze sound recorder to pull out certain bird species

Epi-benthic: Specifically refers to the biological organisms that live in association with the substrate surface.

Infauna: Organisms that live within the substrate matrix.

In-situ: equipment that is installed at a fixed point and collects continuous data over time.

Nekton: Mobile fauna including finfish and crustaceans.

Percent cover: metric of how much of an area is covered by healthy vegetation.

Phragmites australis (P. australis): invasive marsh grass that dominates the greater Battleship wetland area

Quadrats: typically 1 meter by 1 meter horizontal areas chosen to tally plants, which can be used to model the greater area**.**

Reference marsh: marsh to the north of the Battleship which will largely remain unaltered during Living with Water; serves as a model of what the ecology of the area "should" be and will be used a comparison site to the Living with Water construction area.

Settlement: The movement of the planktonic larvae of sessile organisms such as oysters and barnacles from the planktonic phase to the sedentary phase.

Silt Boom: Floating barrier that contains suspended solids during construction. Also referred to as: Sediment Boom, Silt Curtain, Turbidity Curtain.

Spat: The early post-settlement stage of oysters.

StoryMap: a website that integrates geospatial maps, links, photos, and other interactive content. One exists for both the Living With Water project (link) and UNCW's monitoring efforts for the project (link).

sUAS: small unmanned aerial system (drone).

TSS: total suspended solids is a measure of water column turbidity.

Introduction

Summary of Project

The living with water project will install nature-based infrastructure that seeks to address tidal flooding, remediate degraded habitats, and improve water quality with the Cape Fear River Basin (Fig. 1). This project will restore more than 800 feet of hardened shoreline with an intertidal estuarine living shoreline and create wetland habitat by removing two acres of flood-prone parking lot. Over the course of the project, our team at the University of North Carolina Wilmington (UNCW) will evaluate metrics of water and land quality before, during, and after the planned restoration project. We will also assess the ecological impacts of these changes in environmental quality by monitoring vegetative planting success of planned restoration efforts, the use of planted wetland area as macrofauna and insect habitat, and the consequences of these restored terrestrial habitats for the adjacent benthic communities (including nekton, e.g., juvenile finfish and crustaceans, epibenthic community, and macroinvertebrates). We will conduct monitoring at the restoration site itself, as well as at a 'reference' marsh adjacent to the site (as 'before' data cannot be collected at the site itself due to its current 'hardened' or 'built' attributes). We will use the outcomes of this research to report to project funders, publish open access papers and provide educational signage about these changes and the transferability of resiliency concepts to communities across eastern North Carolina.

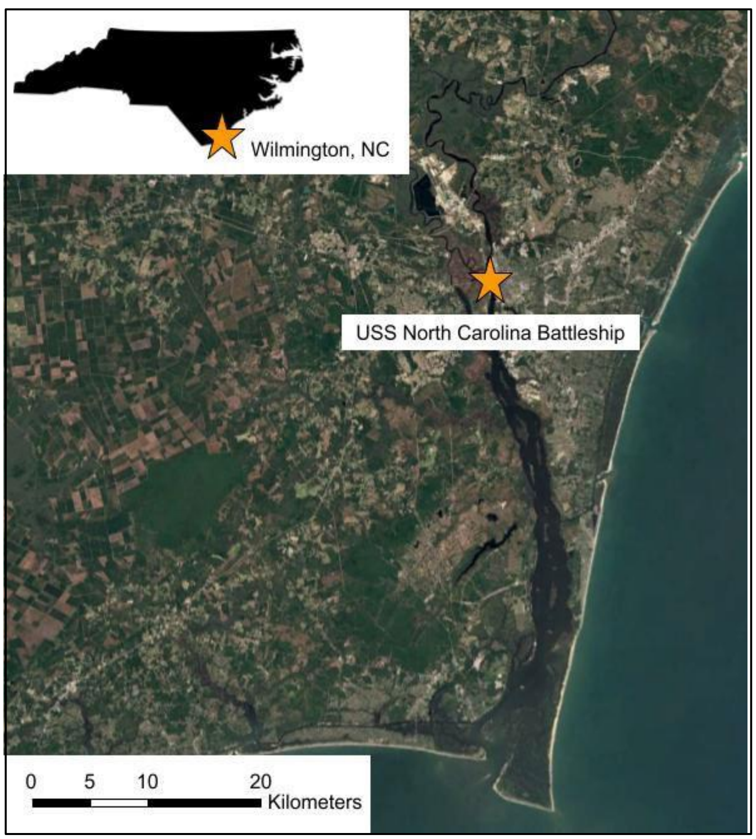

Figure 1. The study area is located in southeast North Carolina where two branches of the Cape Fear River meet near downtown Wilmington.

Scope of Work

1. Map the project area and adjacent habitats using drone imagery and multispectral sensors. The mapping will be conducted pre-construction, post-construction, and twice yearly after that (peak biomass, winter). Additional surveys are budgeted based on the occurrence of storm events such as hurricanes. It is estimated that at least two additional surveys will be required after major storm events. A total of 8 UAS surveys are estimated. UAS survey data will be utilized for multiple objectives and provided to NOAA. True color imagery will be used to map the overall project and reference sites. Near IR and multispectral will be used to map vegetation extent and zonation, vegetation health, and nearshore habitat over the contract period (for constructed wetland and reference marsh sites). Copies of all data will be shared with NOAA contractors and submitted with annual reporting.

2. RTK-GPS will be used to survey UAS control points, all data collection points, transects, and installed monitoring equipment. RTK-GPS will also be tied into NOAA elevation points for consistency and QA/QC and provided to NOAA contractors. Copies of all data will be shared with NOAA contractors and submitted with annual reporting.

3. Surface sediment samples will be collected with benthic community sampling. Sediment will be analyzed for grainsize distribution between sand fractions and percent fines (silt and clay), as well as organic content. Grainsize will be determined using a particle size analyzer and organic content using the LOI (loss on ignition) method. Sediment samples will be collected at the same time (and locations) as benthic community sampling.Wildlife utilization of the project area and an adjacent reference marsh will be assessed with game cameras and stationary recorders. Cameras and recorders will be deployed before construction begins and will be regularly maintained throughout and immediately following construction. Data will be reported as summary of species identified and will focus on species of conservation concern, such as local bioindicator species (e.g. vocal frogs and toads), nuisance species (e.g. white-tailed deer and coyotes), and threatened/endangered species (e.g. piping plovers, roseate terns). Due the memory constraints, select images and recordings will be provided as digital files with annual reporting. All files will be available upon request. *Note: much of the project area is currently a parking lot, which limits our ability to collect pre-construction data.

4. Local plant communities will also be assessed before and after construction. Permanent quadrats will be established in the project area (where possible) as well as at the same reference marsh mentioned above. Quadrats will span across the invasion front of *Phragmites australis* subsp. *australis* (hereafter '*Phragmites*'). This will allow us to document *Phragmites* stem density—a strong indicator for how well *Phragmites* can outcompete native plant species—as well as a snapshot of local plant diversity at several points in time. We will visit quadrats twice yearly in conjunction with mapping. Plant cover and species identity will be documented during peak biomass and *Phragmites* stem density will be documented in winter each year.

5. Benthic fauna communities integrate conditions over a period of months to years. Macroinfauna will be sampled along the shallow subtidal portion of the target area as well as the adjacent reference area during the Aug-September period to reflect the infaunal

community in the study site(s) that may be available to support juvenile finish. Infaunal communities will be assessed for species richness, relative abundance and diversity. In addition to macroinfauna, settlement tiles will be deployed to assess settlement of epibenthic fauna. Settlement tiles will be deployed for 6 weeks at a time to allow new recruits to develop to a size that can be identified with the naked eye.

6. Nekton sampling (including the sampling of juvenile finfish and crustaceans) will be sampled along the shallow subtidal portion of the marsh front in the target area and along the marsh front in the adjacent reference site. Given the steep slope of the shoreline(s) and the unconsolidated substrate surfaces, nekton will be sampled using passive gear. Sampling will occur following critical recruitment periods. To the extent possible, sampling will take place throughout the construction process and post construction. Nekton communities will be assessed for species richness, mean abundance and community diversity. These mobile faunae respond quickly to perturbations and so we anticipate a convergence in similarity between the target area and the refence site.

7. Water quality instruments will be installed at previously identified locations utilized by NOAA contractor. Additional stations will be installed post-construction in the constructed wetland (central to the new channel and at outflow into the vessel basin), as well as at stations located along the educational boardwalk. Parameters of conductivity/salinity, temperature, turbidity, total suspended solids (TSS), and dissolved oxygen (DO) will be monitored for the duration of the project.

Project Objectives

Objective 1: Conduct biological monitoring to address requirements of current funding sources and support the physical monitoring carried out by NOAA's National Centers for Coastal Ocean Science (NOAANCCOS).

a. Assess vegetative communities present (including *Phragmites*).
    ii. evaluate utilization of planted wetland area as macrofauna and insect habitat
b. Assess habitat function for nekton (juvenile finfish and crustaceans), epibenthic community, and macroinvertebrates.
    i. evaluate nekton community composition including the relative abundance of juvenile finfish and crustaceans.
    ii. evaluate the composition of macrofauna that represents a critical food resource for higher trophic levels and support healthy ecosystems.
c. Evaluate water quality improvements.
    i. evaluate improvements to water clarity by monitoring turbidity and TSS.
    ii. evaluate other key water quality parameters such as temperature, conductivity/salinity, and dissolved oxygen.

Objective 2: Develop a "Living Laboratory" collaboration between UNCW and the USS *North Carolina* Battleship location for long-term ecological research.

a. UNCW has a long history of successful collaboration with the Wilmington community. As part of the proposed work, the UNCW co-PIs will work with the USS *North Carolina* Battleship to foster research and educational experiences for undergraduate and graduate students.

Objective 3: Develop a site plan with the USS *North Carolina* Battleship and NOAA NCCOS that integrates Objectives 1 & 2 and provides a framework for future research and monitoring activities.

a. UNCW will work with the USS *North Carolina* Battleship and NOAA NCCOS to collaboratively develop a draft framework and site plan to manage current and future research and monitoring.

Project Timeline

June 1, 2023: contract signed

June 1, 2023 – June 30, 2024: main action items for contract completed

June 30, 2024 – Final Report for pre-construction due

July 1, 2024 – Start of Year 2 contract

December 31, 2024 – Report to permitting agency due

Table 1A. Actions and deliverables June 2023-May 2024. June 2024-December 2024.

A.	**JUN 23**	**JUL 23**	**AUG 23**	**SEP 23**	**OCT 23**	**NOV 23**	**DEC 23**	**JAN 24**	**FEB 24**	**MAR 24**	**APR 24**	**MAY 24**
Supply purchases			**X**			**X**				**X**		**X**
UAS drone surveys			**X**									
RTK-GPS surveys			**X**		**X**							
Surface sediment samples (grain size & organic content)				**X**							**X**	
Nekton Sampling				**X**	**X**						**X**	
Benthic community sampling				**X**	**X**						**X**	
Deploy game cameras								**X**			**X**	
Deploy audio recorders										**X**		
Camera & recorder maintenance	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Establish vegetation monitoring quadrats					**X**							
Marsh veg. (above ground biomass, plant community structure)					**X**							
Monitor *Phragmites* stem density					**X**							
Oyster population				**X**							**X**	
Water quality stations established					**X**	**X**	**X**			**X**	**X**	
TSS sampling								**X**	**X**	**X**	**X**	**X**
Sample processing (audio files, camera photos, benthic samples, etc)				**X**	**X**	**X**	**X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**
Final report & Deliverables												**X** **X** **X**

Table 1B. Actions and deliverables June 2024-December 2024.

B.	**JUN 24**	**JUN 24**	**AUG 24**	**SEP 24**	**OCT 24**	**NOV 24**	**DEC 24**
Supply purchases							
UAS drone surveys			**X**	**X**	**X**		
RTK-GPS surveys				**X** **X**			
Surface sediment samples (grain size & organic content)				**X**			
Benthic community sampling				**X**			
Camera & recorder maintenance	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Marsh veg. (above ground biomass, plant community structure)				**X** **X**		**X** **X**	
Monitor *Phragmites* stem density				**X** **X**		**X** **X**	
TSS sampling	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Sample processing (audio files, camera photos, benthic samples, etc)	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**	**X** **X** **X**
Final report & Deliverables						**X** **X** **X**	**X** **X** **X**

Highlighted boxes indicate work that has been completed for period one.* ***Green* *indicates work done by the Benthic Ecology Lab,* ***Blue*** *indicates work done by the Endriss Lab, and* ***Plum*** *represents work done by the Costal and Estuarine Studies Lab*

Study Site

The USS *North Carolina* is managed by USS *North Carolina* Battleship Commission under the Natural and Cultural Resource department. The ship served as a World War II battleship and now sits on the West bank of the Cape Fear River as a war memorial, historic landmark, and a popular tourist spot.

The site where the Battleship is located (34.236527°N, 77.954357°W) is encompassed by a boardwalk for visitors to view the ship and surrounding wetland and river views (Fig. 2). The wetland experiences semi-diurnal flooding from the river which in turn floods and erodes the low-lying grounds, surface roads, and parking lot around the ship. To combat these issues, 800 feet of hardened shoreline was built along the eroding bank where the ship sits. This wetland provides a vital habitat for nursery fish, native and migratory birds, and larger animals such as alligators, beavers, otters and raccoons.

As a course assignment, graduate student Mikaila Reynolds created an ESRI ArcGIS StoryMap (https://arcg.is/Ke55q) detailing the various monitoring efforts by UNCW. A StoryMap is an interactive website that can be used to display digital maps, website links, articles, and other multimedia. StoryMaps are user-friendly in that they can be shared with various audiences via cell phones, desktop computers, and other devices. The StoryMap, titled "USS NC Battleship - Living with Water Monitoring Efforts":

1. Introduces the USS North Carolina, Eagles Island, and the Living with Water project
2. Describes UNCW's role in:
    i. Water quality monitoring via grab samples and in-situ water quality stations
    ii. Vegetation monitoring via quadrats and drone footage
    iii. Wildlife monitoring via trail cam and bioacoustics recordings
3. Updates the public on all past monitoring efforts through photos, maps, and text boxes
4. Details the partnerships between the USS NC staff, Living with Water stakeholders, the general public, and UNCW student researchers

The USS NC Battleship - Living with Water Monitoring StoryMap will allow the general public that may frequent the Battleship to scan a QR code to access the website to learn more about what the CES lab, Endriss lab, and Benthic lab have and will monitor at this site, with multiple updates throughout the year.

> ***Note**: The StoryMap's URL link will change, as it will be housed online under a faculty account instead of a student account. This change will happen within the next few weeks, along with any changes requested by Living with Water stakeholders. Please email reynoldsm@uncw.edu with potential changes. Other future updates will include the inclusion of bioacoustics wetland audio files, construction camera pictures, water quality metrics, and other recently collected data.*

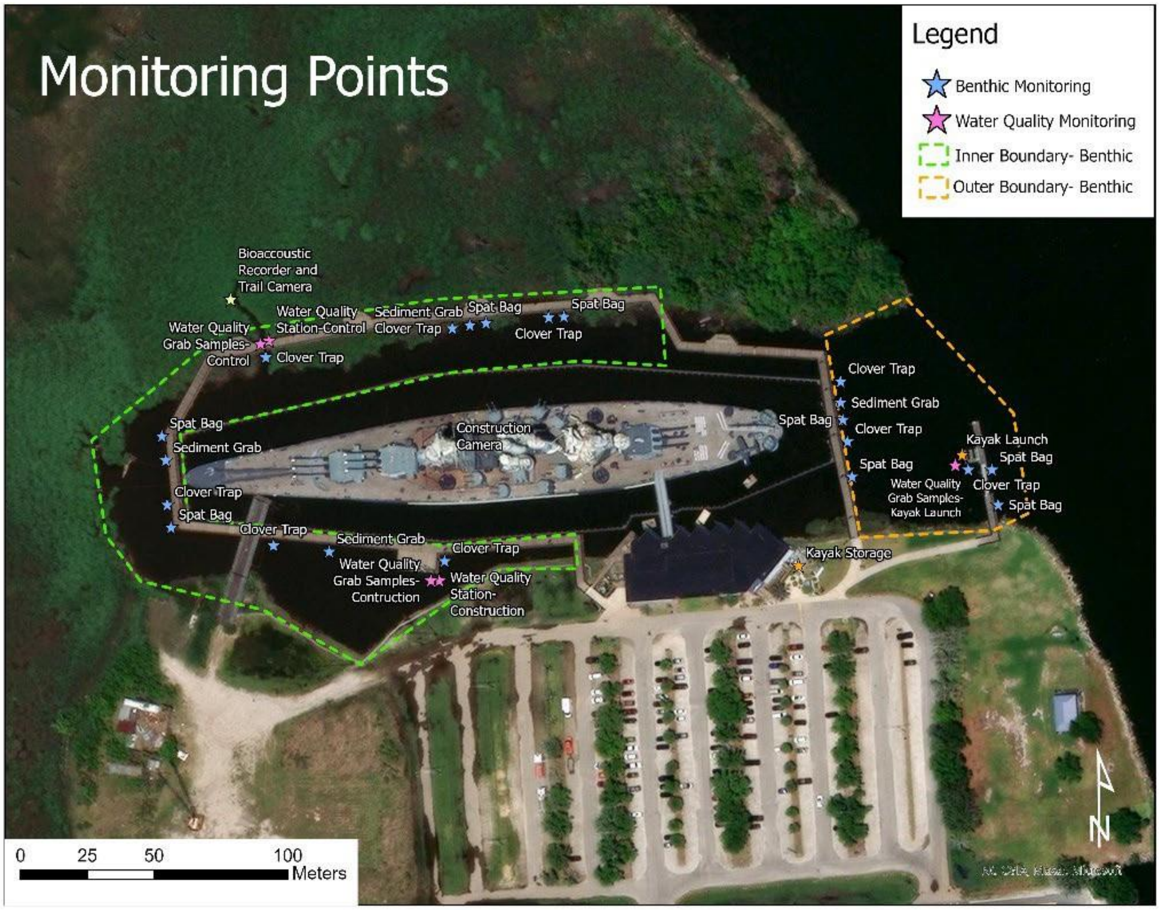

Figure 2. The study site sampling locations and sampling type.

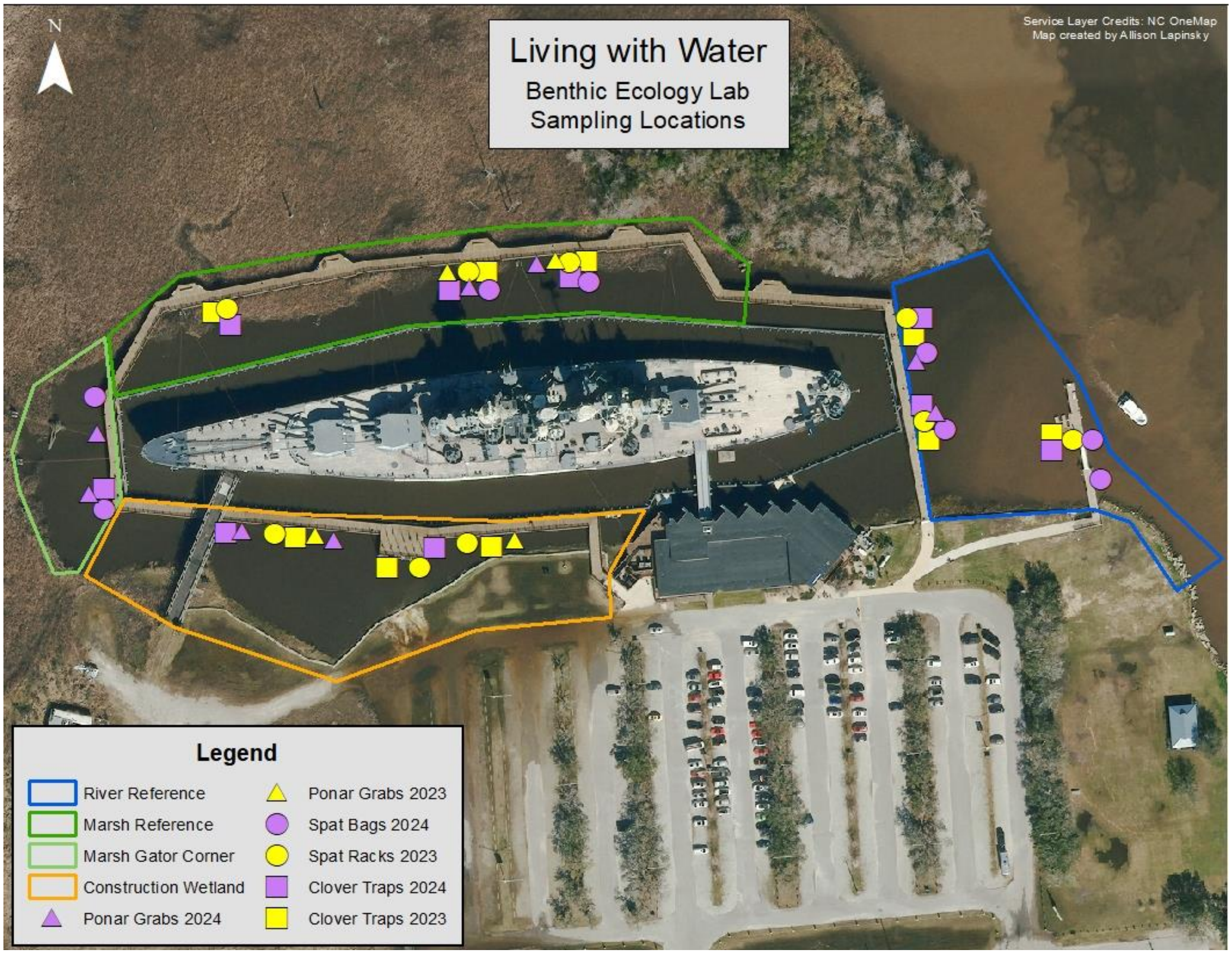

Figure 3. Sampling locations (River Reference, Marsh Reference, and Constructed Wetland) by method for nekton, recruitment studies, and benthos sampling from September 2023 – November 2024. The Marsh Reference section was expanded to include Gator Corner during the 2024 sampling and the River Reference section was split into a walkway area and floating dock area to increase sampling size.

Methodology

The methodology outlined here applies to the collection of baseline (i.e., pre-construction) and during construction data, establishing long-term monitoring locations, and developing the collaborative framework to support the long-term project goals. Figure 2 illustrates the combined UNCW monitoring plan and Figure 3 illustrates sampling statins of the Benthic Ecology Lab.

Vegetation Monitoring (Obj 1a)

Vegetation Monitoring at 'Reference Marsh' - On October 2nd and 4th, 2023, the Endriss and Eulie labs established 12 permanent $1m^2$-vegetation monitoring quadrats using PVC marking posts within our 'reference' marsh on the north (starboard) side of the USSNC (Fig. 4 and 5). We selected our reference marsh due to its small tidal creek, which we believed best mirrored the tidal creek that will be installed as part of Living with Water's nature-based solution on the far side of the USSNC. We spaced quadrats at least five meters apart along three roughly east-west transects that bisected the tidal creek. We simultaneously assessed vegetation within each quadrat (all contained monocultures of introduced *Phragmites australis*) and recorded the number of live and dead *P. australis* stems within each quadrat (Table 3, Fig. 4 and 5). On December 8th, 2023, we revisited our quadrats to use a Trimble R10 RTK unit to get fine-scale GPS and elevation for each PVC marking post that we established to mark the northeastern-most corner of each 1m2- quadrat. Across approximately 75 x 75m across which the quadrats area distributed (~5625 m^2 area), the elevation varied only by 0.34 m. We revisited each of our permanent $1m^2$-quadrats on September 9^{th}–10^{th}, 2024 during peak vegetation biomass to reassess vegetation (again, all quadrats contained complete monocultures of introduced *P. australis*) (Fig. 4). For each quadrat, we therefore recorded the number of live and dead *P. australis* stems. To minimize influences of destructive sampling on long-term monitoring of *P. australis* stem density, we also used plots just adjacent to our long-term monitoring plots to harvest all old and new *P. australis* stems within $1m^2$. Specifically, in addition to counting old and new stems, we cut all stems at their base (within 2 cm of ground level), bundled stems from the same quadrat with duct tape, and returned bundles to the lab for later processing. In the lab, we then cut open each stem bundle and separated stems into two separate piles: one for this season's growing seasons (i.e. 'live' stems at the time of sampling) and one for harvested stems that represented growth prior to the current growing season (i.e. 'dead' stems at the time of sampling). 'Dead' stems were immediately cut and placed in large, paper bags for drying in the oven before measuring dried biomass. For 'live' stems, we measured the diameter (in mm, at the very base of the stem) and height (in cm, from the base to the apical meristem) of each stem, as well as noting whether or not the stem was flowering. We then cut and placed all live stem fragments into a separate paper bag for oven drying.

Figure 4. Map of the twelve permanent $1m^2$-quadrats within our *Phragmites australis*-dominated reference marsh (left), and Danielle Jenkins, a recent graduate of the Master of Marine Science Program at UNCW and continuing member of the Eulie lab, posing within the reference marsh with the survey poles used to collect GPS and elevation of our quadrats.

Figure 5. Shanna Koehler, a Master's student in the Department of Environmental Sciences at UNCW, posing in a stand of introduced *P. australis* within our reference marsh (left). As part of her Advanced Field Methods in Environmental Science class at UNCW (EVS-441), Shanna helped to both assess density of live and dead *P. australis* stems within each of our permanent $1m^2$-quadrats (middle) and to harvest $1m^2$ of live and dead *P. australis* stems just adjacent to each permanent quadrat (right).

Biotic Monitoring (Obj 1b)

In November 2023, the Endriss lab began experimenting with locations and settings for a paired audio and visual recording system. After several months of fine-tuning, we established a successful monitoring station in early 2024 about halfway down the length of the small tidal creek that bisects our reference marsh (approximately 34.237067°N, 77.955531°W). The first successful files were captured on January 23rd, 2024 and March 13th, 2024 for the audio recorder and trail camera, respectively (Fig. 7). From the time of their first successful deployments, to date we have been able to collect more than 2,000 hours of audio. After processing our trail camera photographs to exclude photos without visible wildlife, we also have a collection of 6,000 photographs that have captured several species of invertebrates and other macrofauna within our reference marsh (Fig. 7).

In addition to using passive acoustic monitoring methods, the Endriss Lab has also been sampling stems from within the stands of introduced *P. australis* at the site of the USS *North Carolina* to learn more about the insect communities that feed internally on this plant species.

Nekton and Infaunal Community Assessment (Obj 1b)

Nekton sampling (Obj 1b-i): Nekton were sampled with baited quatrefoil traps (clover leaf traps) with 0.6cm mesh measuring 0.6m x 0.6m x 0.3m (L x W x H). Traps were deployed from the Battleship walkway during a flood tide, retrieved after two hours, and all organisms were measured and recorded. Replicate traps were deployed at each of three sites (Constructed Wetland, Marsh Reference, River Reference; Fig. 3) during two pre-construction periods (September 2023, October 2023; Fig. 3) and one beginning construction period (April 2024; Fig. 3).

Spat Tile and Spat Bag Recruitment Studies (Obj 1b-ii): Examination of settlement to hard substrates (spat tiles and spat bags) provides important information on foundational species such as oysters as well as other taxa, such as barnacles and mussels. Ceramic spat settlement tiles (20cm x 20cm) were deployed in September 2023 and remained on site for six weeks (Fig. 3). Tiles were deployed in sets of six on PVC racks designed to maintain the tiles at the substrate surface. Recruitment studies were repeated in April 2024 utilizing spat bags. Spat bags consisted of fine mesh material containing 25 individual pieces of oyster shell or cultch. Bags were suspended such that they remained at the substrate surface, similar to the sediment tiles. Both settlement tiles and spat bags were deployed at a mid-intertidal position which is most likely to support oysters and associated fauna.

Benthic Infauna (Obj 1b-ii): Benthic infauna are often used as an indicator of ecosystem function because of their relatively sedentary nature and lifespans of months to over a year. This community of organisms represents a critical linkage in benthic-pelagic coupling, transferring energy from both detrital and primary producer pathways to nekton. This group is an important food source for many ecologically and commercially important fishery species. Benthic infauna were sampled at impacted and reference areas using a petite ponar (15cm x 15cm x 15cm) grab sampler deployed from the Battleship walkway. One location within the constructed Wetland site and one location within the Marsh Reference site was sampled in triplicate in September and then again in October 2023. Sampling in 2024 expanded these sites to include the River Reference site and the Marsh Gator Corner site (Figure 3). This method of sampling is a standard approach for sampling benthos in both estuarine and offshore areas. It is the same approach we have used seasonally since 1996 for sampling benthos in various areas of the Cape Fear River estuary, allowing comparisons to long-term data sets.

Benthic Grain Size (Obj 1b-ii): Benthic sediment was sampled at impacted and reference areas using a petite ponar (15cm x 15cm x 15cm) grab sampler deployed from the Battleship walkway. A portion (45 ml) of the grabbed sediment was stored in a vial, taken back to the lab, and frozen until further analysis could take place. Organics were removed from all samples following the Benthic Ecology Lab’s Digestion Protocol. The samples were then run through a Beckman Coulter LS 13 320 Particle Size Analyzer. One round of sampling was taken preconstruction (September 2023) and included one sample from the constructed Wetland site and one sample from the Marsh Reference site (Figure 3). Two rounds of sampling took place during construction (April and September 2024) and included one sample from the constructed Wetland, Marsh Reference, River Reference, and Marsh Gator Corner sites (Figure 3). The data presented in this report does not include the September 2024 collection due to sampling processing time.

Water Quality Monitoring (Obj 1c)

Total Suspend Solids

The USSNC Battleship located on Wilmington, North Carolina's Cape Fear River (CFR) has been affected by King Tides (exceptionally high tides) in recent years. Specifically, the parking lot and surrounding roads have had an increase in tidal flooding. The Living with Water project will re-naturalize an existing part of the parking lot, creating a constructed wetland. This will restore the area into a wetland habitat, divided by a tidal creek. The wetland will help capture and absorb high tides, while the tidal creek will direct water to the CFR. The remaining part of the parking lot will be elevated above the high-tide flood zone. This new parking lot will install a stormwater bio-swale to drain and capture tide and rainwater to the newly constructed wetland habitat. Living shorelines will also be planted in these areas to maintain a natural transition. TSS levels are monitored during this construction process to determine any construction impacts.

This study focuses on the total suspended solids of the surrounding water before, during, and after construction. A water body's total suspended solids (TSS) are the fine sediment particles in the water column. Examples include biological soils, decaying organic matter, and pollutants. An increase in TSS from sedimentation can impact aquatic life by causing diseases in fish and affecting vegetation by limiting light penetration (Fankhauser, 2006). Other effects on wetlands and water bodies include damaging invertebrate populations by covering the bottom of the water, blocking spawning beds, and, if organic, decreasing dissolved oxygen (Fankhauser, 2006). More harmful substances, from anthropogenic impacts such as fertilizers, have additional effects on the ecosystem (Ugbaja, 2019).

Construction can affect the sedimentation of nearby water because of the active movement of sediments and biological soils (USEPA, 2005). Construction deposits more sediments into the air and the ground leading into the nearby water. In a case study from Ohio, total suspended sediments in the downstream samples were slightly higher than in the upstream location where TSS was the most increased water quality characteristic during this study (Houser, 2009). Another study in South Korea observed TSS throughout a construction site over three years of sampling. The data suggests that TSS exhibited a higher concentration during active construction phases, which involves extensive groundwork compared to post-construction (Sajjad, 2019). These studies show that TSS is affected by construction sites, which can be detrimental to an ecosystem. The results of this study can be used for future construction/management efforts, to assess construction impacts on wetlands and water sources.

Three sites are being tested for TSS around the Battleship. The first site is the ‘Construction site’ located closest to the active construction zone on the Southern side of the vessel along the boardwalk (Figure 2). The second site is the ‘Reference site’ which is located on the Northern side of the vessel, along the opposite side of the boardwalk (Figure 2). The third site for the TSS monitoring is the ‘River site’ located along the dock East of the vessel closest to the Cape Fear River (Figure 2).

The TSS monitoring was observed through triplicate grab samples. Triplicate sampling was done to reduce outgoing variables, rule outliers out, and increase precision. Grab sampling is a physical collection process done through a water column sampler. These triplicate grab samples have been collected twice a month, during a ‘dry’ and ‘wet’ period of precipitation (Table 2). A ‘dry’ sample is considered more than 5 days without precipitation, and a ‘wet’ sample is considered precipitation (greater than 0.5 inches of rain) within the last 5 days. Each sampling period was collected at a high, mid, and low tide. A month of sampling has triplicate samples at high, mid, and low tide for each site during a ‘wet’ sample and a ‘dry’ sample. Each month has a total of 54 grab samples.

It is important to note that only one sampling event occurred before construction started during a ‘dry’ period due to the site’s accessibility. During March, there was no ‘wet’ period of sampling due to tide times and scheduling constraints.

Table 2. Sampling Timeline of TSS Collection along Battleship Sites. Each tide and site collection was taken on each date.

Date	Construction Phase	Precipitation Status
February 2nd, 2024	Before	Dry
February 19th, 2024	During	Dry
February 24th, 2024	During	Wet
March 16th, 2024	During	Dry
March 17th, 2024	During	Dry
April 11th, 2024	During	Wet
April 27th, 2024	During	Dry
May 16th, 2024	During	Wet
May 31st, 2024	During	Dry
June 20th, 2024	During	Dry
June 27th, 2024	During	Wet
July 22nd, 2024	During	Wet
August 12th, 2024	During	Wet
August 31st, 2024	During	Dry
September 10th, 2024	During	Dry
September 24th, 2024	During	Wet
October 15th, 2024	During	Dry
October 31st, 2024	During	Wet

After the samples were taken from the site, the collected water filtered through a glass fiber filter paper using a MultiVac filtration system. The amount of water poured in each filtration cycle measures the TSS levels. After the water is filtered through, the total suspended sediments are left on the glass fiber filter paper.

Once the samples are filtered, they are dried in a drying oven at 60°C for 24-48 hours until a net weight is established. Dried samples are then weighed using a gram scale to measure the amount of dry sediments remaining. The weight of the dry sediments remaining and the measured value of liters of water during the filtration phase is the reported TSS value (Eq 1). TSS values are calculated for each sample and each triplicate is averaged.

Eq 1: TSS = grams of dry sediments/liters of water during the filtration phase

After each sample has been filtered and weighed for the TSS value, the samples are placed into a furnace at 500°C for 4 hours, where they are weighed again to measure the amount of inorganic and organic material in the remaining sediment. The weight of the remaining material is the inorganic content (Eq 2). The weight of the dried sediments subtracted by the combustion weight is the organic weight (Eq 3).

Eq 2: Combustion weight = inorganic content

Eq 3: Dry weight-combustion weight = organic weight

Paired In-situ Instrument Stations

In order to monitor water quality before, during, and after construction, a graduate student-led team installed two water quality monitoring stations to collect in-situ data, specifically to monitor turbidity, conductivity, and water level on December 8th, 2023. All three metrics are recorded via Onset loggers, which are made by Hobo, an industry-standard brand for water quality metrics (Hobo, 2024). Turbidity is a measure of water clarity, which is most commonly influenced by TSS levels. This metric is relevant as part of the construction process is grading, which loosens the dirt and soils of an area, potentially leading to increased sediment runoff into an adjacent water body(s). Utilizing instrument measures of turbidity and water sample analysis for TSS provides a more complete assessment of water clarity impacts.

Conductivity, or the ability of the water to conduct electricity, can indicate the amount of pollution and runoff a water body may receive at one point or over a period of time, specifically in respect to salinity. With the semidiurnal tidal cycles, the Cape Fear River is subject to salinity and subsequently conductivity increases with the influx of seawater from the Atlantic twice a day. However, runoff can also impact conductivity over varying temporal scales in a body of water.

The water level logger consists of a pressure sensor. This instrument derives water level from measures of water column pressure in the instrument well. The combination of water level and turbidity, paired with weather and hydrologic data from nearby river monitoring stations provide context for other environmental data sets. Combined with TSS measures (and the addition of future dissolved oxygen in-situ sensors), these represent key metrics for measuring water quality enhancements provided by the project post-construction. The data from these loggers are currently being collected and processed and will be provided as part of the permit-mandated reporting.

The installed water quality stations are comprised of approximately 15-ft PVC pipes with caps on the top, along with the water quality loggers, which are suspended via ropes that place them approximately 6 inches from the substrate (bottom). This way, both high tide and low tide metrics can be taken at the same approximate depth and will be comparable. Currently, the water monitoring station on the southern/construction, or experimental, side is taking continuous metrics, while the station on the northern/tidal creek, or control, side is currently being installed and set up (Fig. 2). The paired sites will allow the CES lab to monitor variations in short- and long-term water quality.

Geospatial and Remote Sensing (Obj 1)

Geospatial data layers were sourced from publicly available sources such as NOAA's Digital Coast, the USGS Earth Explorer, and the state of North Carolina's NC OneMap. These were utilized to create the story map linked to this report and provide baseline context for sUAS (small Unmanned Aerial Systems) data.

sUAS flights took place on August 8, 2023, and covered the entirety of the project area (Fig. 2). Flights were completed using a DJI Matrice 300 sUAS platform using on-board RTK and corrected with a Trimble R12 GPS base station on site. The sensors flown included a YellowScanLiDAR (Light Detection and Ranging) and a MicaSense 7-band multispectral. LiDAR was collected at an altitude of 200 ft (60 m) above ground level and with a 50% overlap per flight line. The multispectral data was collected at an altitude of 280 ft (86 m) above ground level and with a 75% overlap.

Initial processing of raw data was completed at that time; however, detailed analysis has been delayed due to the loss of multiple staff and faculty immediately after these flights. Only recently have some of these staffing challenges been resolved. Detailed data analysis is on track to be completed and will be available for the 2025 annual contract report. Preliminary image mosaics included in Appendix D.

NOAA NCCOS Scope of Work (Obj 3)

NCCOS scientists have been contracted to collect physical and hydrological data on a quarterly basis for 3 years post-construction to support analysis of change over time in the designed conditions. Specific parameters and approximate frequencies of collection are detailed below (Table 3).

Installation and data processing/analysis of Water Level sensor (s) – NCCOS will re-install water level and salinity sensors to track inundation patterns across the site. Data analysis will involve comparison of water level/salinity trends to available precipitation and tide data. Sensors will be visited quarterly by NCCOS staff (UNCW team has agreed to download sensors between NCCOS quarterly visits).

Sediment Accretion – Quarterly installation and sampling of feldspar marker horizon plots to quantify rates of sediment accretion across range of vegetative communities at site

Bathymetric Mapping – Use of remotely operated survey vessel to map and monitor changes in bathymetry within the created tidal creek system and adjacent to living shoreline.

Sediment Core Collection – Sediment cores will be collected annually and analyzed for changes in grain size, bulk density, and particulate nitrogen and carbon content.

Table 3. Actions and deliverables by NOAA NCCOS by quarter.

Parameter	Q1	Q2	Q3	Q4
Accretion	X	X	X	x
Sediment Cores		X		
Sensor Maintenance	X	X	X	X
Bathymetric Mapping		X		X

Progress on Objectives

Objective 1a:

Vegetation

Pre-construction vegetation monitoring will provide important baseline data, especially as introduced *Phragmites australis* is highly invasive across much of North America. Yet short-term suppression of *Phragmites* using herbicide is resource intensive, and permanent eradication is extremely difficult and only achievable for populations smaller than a few hundred square meters (Lombard et al. 2012; Quirion et al. 2018). Further, despite little evidence of success, annual expenditures for herbicide treatments of *P. australis* in the US reached US $4–5 million before 2010 (Martin and Blossey, 2013b). These enormous expenditures, combined with only limited success in controlling introduced *P. australis*, are in part why this species remains a top management priority within the state. The vegetation data we have collected in Year 1 (Fig. 6, Table 4) therefore serves as an important reference for assessing not only how the native vegetation to be planted as part of Living With Water will provide ecological benefits different from the current dominant species at the site (introduced *P. australis*), but also how the introduced *P. australis* in the surrounding area will be impacted by Living With Water's nature-based solution.

Figure 6. Endriss and two graduate students, Danielle Jenkins and Claire Brovold, from Eulie's Lab kayak into the reference plot to establish vegetation quadrats (left and bottom right), while the Endriss lab (top right) acted as support team by passing supplies down from the boardwalk and acting as spotters.

Table 4. GPS, elevation, and counts of introduced *P. australis* stems within each of our permanent 1m^2-quadrats in October 2023 and late September 2024. Live stems refer to stems produced during the current year's growing season that were actively green at the time of the assessment. The total number of standing stems within each quadrat refers to the sum of the number of live stems and the number of old stems—standing stems from the prior years' growing seasons that were brown and senesced at the time of the assessment.

quadrat #	elevation (m)	# of live stems (2023)	total # of standing stems (2023)	# of live stems (2024)	total # of standing stems (2024)
1	0.66	26	94	118	145
2	0.88	37	119	117	187
3	0.89	19	100	67	164
4	0.51	16	61	53	72
5	0.76	40	116	138	167
6	0.71	20	94	58	163
7	0.55	27	83	99	162
8	0.74	38	101	51	135
9	0.6	32	86	51	122
10	0.67	38	119	99	210
11	0.88	41	148	50	110
12	0.85	39	114	61	141

Future plans include an analysis of the drone aerial imagery (multispectral) and LiDAR points taken in Fall 2023 to determine percent cover of introduced *P. australis* within each of our quadrats. Our aerial imagery will therefore allow for broader extrapolation of how *P. australis* dominates the larger landscape, helping us to document changes to the breadth and extent of the invasion over time. We will continue to monitor our vegetation quadrats and estimate percent cover using aerial imagery on an annual basis.

Biotic

From the time of their first successful deployments to the time of this report, we have been able to collect more than 2,000 hours of audio. We are currently running our audio files through BirdNET, a machine-learning program that is trained to identify 984 of the most common bird species (and select amphibian species) of North America and Europe. Specifically, we have developed and continue to fine-tune code in R to automate the processing audio files through BirdNET. Moving forward, we will validate a subset of the calls identified by BirdNET, especially those that are identified as species of conservation concern. Commonly observed species include fiddler crabs (*Uca* sp.), great egrets (*Ardea alba*), red-winged blackbirds (*Agelaius phoeniceus*), and common grackle (*Quiscalus quiscula*).

After processing our trail camera photographs to exclude photos without visible wildlife, we also have a collection of 6,000 photographs that have captured several species of invertebrates and other macrofauna within our reference marsh (Fig. 7).

Figure 7. An undergraduate student, Collin Turner, within the Endriss lab, poses with our audio recorder (top left) which he helped mount on our paired trail camera and audio recording monitoring station (top right). Example photos taken from our trail camera of numerous fiddler crabs (bottom left) and a great egret (bottom right).

Objective 1b:

Nekton Sampling (Obj 1b-i)

A total of fourteen species were recovered in the traps (Table 5). Catches were typical of the mid-estuarine (mesohaline) portion of the Cape Fear River estuary, including benthic/epibenthic crustacean species (e.g. fiddler crabs, *Uca* sp.; grass shrimp, *Palaemonetes pugio;* and blue crabs, *Callinectes sapidus*) as well as various nekton (e.g. pinfish, *Lagodon rhomboides*; spot, *Leiostomus xanthurus*; brown shrimp, *Farfantopenaeus aztecus*; and mummichogs, *Fundulus heteroclitus*). The high abundance of mummichogs at the marsh reference site is consistent with their life history and seasonal movement patterns. Appendix C includes example images of shrimp, eel, and a shark tooth that was also recovered from a core.

Table 5: Sum of species caught in clover leaf traps during sampling per site and date. Sampling took place one day of each month.

	September 2023	October 2023	April 2024
Constructed Wetland			
Anguilla rostrata			1
Callinectes sapidus			2
Evorthodus lyricus	1		
Farfantepenaeus aztecus		18	
Fundulus heteroclitus		4	11
Leiostomus xanthurus			6
Mysid spp		1	
Palaemon pugio	1		30
Palaemonetes spp		1	
Marsh Reference			
Callinectes sapidus	3		3
Evorthodus lyricus	1		
Farfantepenaeus aztecus		18	
Fundulus heteroclitus	54	15	205
Gobiidae spp			1
Lagodon rhomboides		9	
Leiostomus xanthurus			7
Litopenaeus setiferus		3	
Macrobrachium spp		1	2
Palaemon pugio			8
Palaemonetes spp		1	
Uca spp	26		
River Reference			
Anguilla rostrata		1	
Farfantepenaeus aztecus		3	
Gobiidae spp			2
Lagodon rhomboides	1		
Leiostomus xanthurus			6
Litopenaeus setiferus		1	1
Palaemon pugio			8

Recruitment Studies: Spat Tile and Spat Bag (Obj 1b-ii)

Settlement on tiles was low (Table 6) and the tiles do not provide information on associated fauna, such as the fauna associated with oyster shell. Recruitment studies were repeated in April 2024 utilizing spat bags (Figure 3). Though this time period is not generally characterized by high settlement, the spat bags did collect data on associated and attached fauna (Table 7). The low recruitment of attached organisms, such as oysters and barnacles, in April is consistent with seasonal patterns of these organisms, with peak settlement occurring later in the year.

Table 6: Sum of species recruitment for spat settlement tiles. Tiles were deployed over the walkway in September 2023 and remained on site for six weeks.

	Constructed Wetland	Marsh Reference	River Reference
Barnacle scar	3	0	102
Dead barnacle	2	0	67
Live barnacle	27	0	1884
Live spat	0	0	0
Spat scar	0	0	0
Mussel	0	0	4

Table 7: Sum of species recruitment for spat bags by site. Spat bags were deployed over the walkway in April 2024 and remained on site for six weeks. The constructed Wetland Site was not sampled for this technique due to active construction. The Marsh Reference site was broken into two sites (Marsh Gator Corner and Marsh Reference) as was the River Reference site (River Floating Dock and River Walkway).

	Marsh Gator Corner	Marsh Reference	River Floating Dock	River Walkway
Amphipod	0	0	3	0
Clam	0	1	0	0
Fiddler Crab	2	3	0	0
Grass Shrimp	0	0	1	0
Isopod	15	17	4	1
Live Oyster	0	0	0	0
Live Spat	0	0	0	0
Marsh Crab	0	1	1	0
Midge Larvae	0	11	0	0
Oligochaete	0	114	0	0
Snail	0	1	0	0

Benthic Infauna (Obj 1b-ii)

Benthic infauna are often used as an indicator of ecosystem function because of their relatively sedentary nature and lifespans of months to over a year. Results are shown in Table 8 for all 2023 samples, with results indicating similar species richness among sites (six vs seven taxa) but varying patterns of abundance. The polychaete worm *Mediomastus ambiseta* and *Streblospio benedicti* exhibited highest abundances in the constructed Wetland site when they occurred, while oligochaetes were more abundant in the Marsh Reference site in October, with low abundances in September. Interestingly, even though *Mediomastus* and *Streblospio* exhibited higher abundances at the same site (though peaks at different time periods), they have very different functional characteristics with one being a mobile burrowing worm and one being a sedentary tube builder. Sample sorting and identification are ongoing for the other sampling periods. Sediment grain size was also analyzed as part of the benthic infaunal survey. One round of sampling was taken preconstruction (September 2023) and included one sample from the constructed Wetland site and one sample from the Marsh Reference site (Figure 3). Two rounds of sampling took place during construction (April and September 2024) and included one sample from the constructed Wetland, Marsh Reference, River Reference, and Marsh Gator Corner sites (Figure 3). Results for samples taken in September 2023 and April 2024 are shown in Figure 8. Grain size analysis is ongoing for all other samples and will allow us to get a better picture of the sediment composition of the site overall.

Table 8: Sum of benthic species present in sediment samples taken in September and October 2023. Samples were collected via a petite ponar grab deployed from the Battleship walkway.

	September		October	
	Constructed Wetland	**Marsh Reference**	**Constructed Wetland**	**Marsh Reference**
Ampithoe spp		1		
Chiridotea almyra	1			
Chironomidae spp	1	5		
Hemipodia spp		1		
Hermundura spp	6	1		
Mediomastus ambiseta	59	5	31	5
Oligochaeta spp	4	2	1	126
Streblospio benedicti			14	5

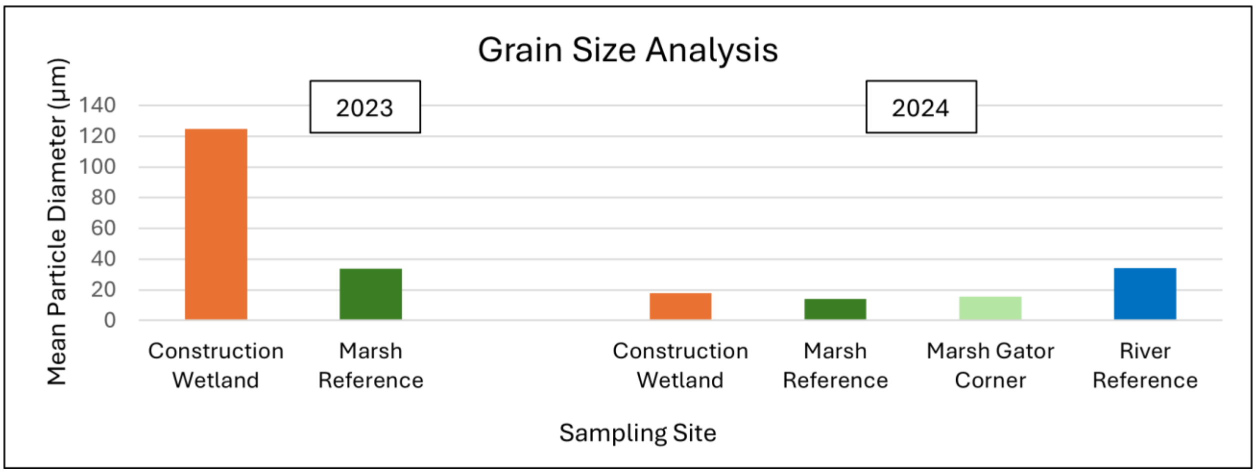

Figure 8: Mean particle diameter of sediment samples taken in September 2023 and April 2024.

Objective 1c:

Total Suspended Solids

After construction began, high tide TSS values started to drop at each site but increased from late April until August (Fig. 9). TSS concentrations ranged from 0.026 g/L on June 20th to 0.001 g/L on October 15th at the Construction Site. At the Reference Site, TSS concentrations ranged from 0/029 on June 20th to 0.001 g/L on October 15th. Finally, high tide TSS concentrations at the River Site ranged from 0.029 g/L on June 29th to 0.001 g/L on October 15th (Fig. 9). All three locations have similar trends and concentrations.

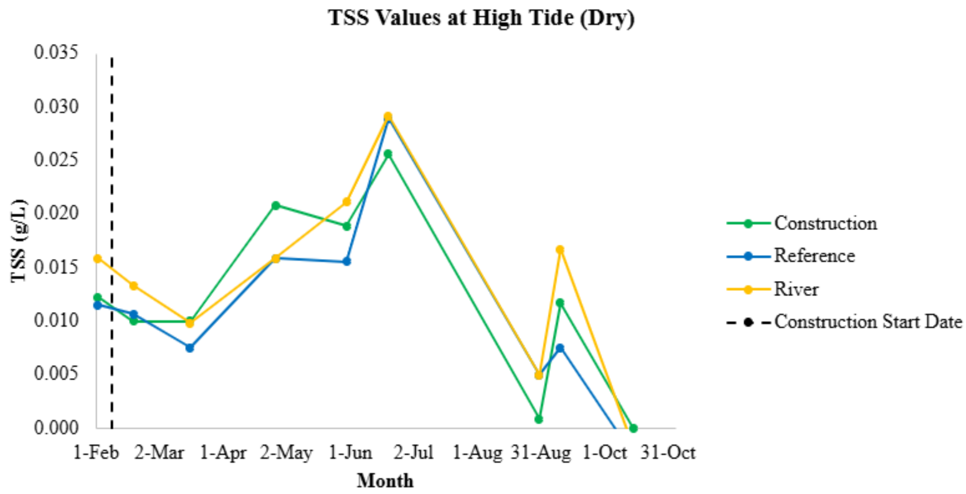

Figure 9. Scatter plot chart depicting TSS values during high tide at each sample site during dry periods.

Similarly to the high tide samples, mid-tide TSS values decrease right after construction and gradually increase through August (Fig. 9). TSS concentrations ranged from 0.062 g/L on September 10th to 0.005 g/L on October 15th at the Construction Site during mid-tide. At the Reference Site, TSS concentrations ranged from 0.049 g/L on June 20th to 0.003 g/L on October 15th. Finally, mid-tide TSS concentrations at the River Site ranged from 0.283 g/L on October 15th to 0.002 g/L on September 10th (Fig. 10). The high increase at the River Site is likely due to runoff from Hurricane Helene.

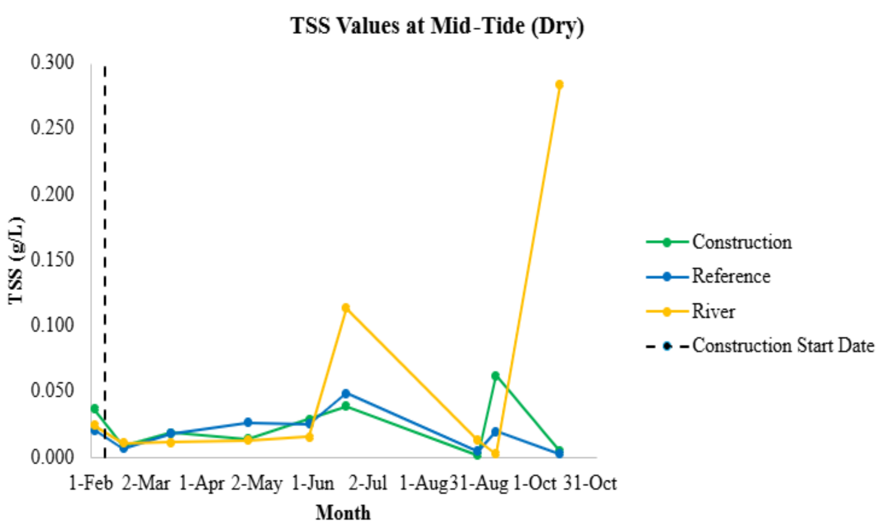

Figure 10. Scatter plot chart depicting TSS values during mid-tide at each sample site during dry periods.

Low tide TSS values vary drastically from the high and mid-tide samples with an increase in TSS concentrations immediately after the construction start date at the Reference Site. However, Construction and River Site TSS concentrations remained relatively similar at low tide (Figure 11). TSS concentrations ranged from 0.755 g/L on May 31st to 0.023 g/L on February 19th at the Construction site during low tide. At the Reference Site, TSS concentrations ranged from 2.540 g/L on June 20th to 0.018 g/L on February 3rd. Finally, low tide TSS concentrations at the River Site ranged from 0.365 g/L on February 19th to 0.015 g/L on September 10th (Figure 11).

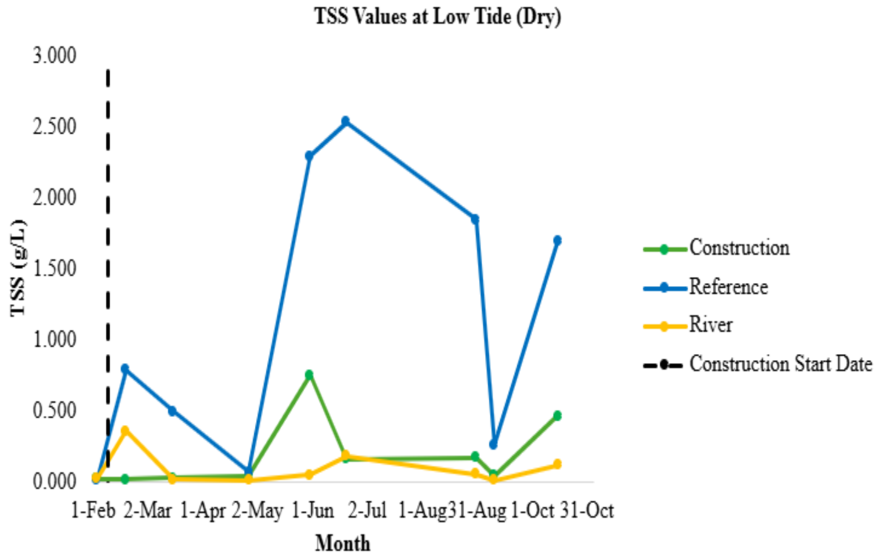

Figure 11. Scatter plot chart depicting TSS values during low tide at each sample site during dry period

It is important to note that TSS concentrations vary drastically with the tides and time of year which could be due to multiple factors such as seasonal productivity changes, rainfall amount, or the increase in construction materials. Comparing sites to each other, the trends on each graph are relatively similar. The high increase at the River Site during September is likely due to Hurricane Helene's runoff from the Appalachian Mountain Range.

Inorganic vs. Organic Content

Organic content at mid-tide ranged from 100% at the control site on August 31st at the River Site to 0% on August 31st at the Reference and Construction Sites and October 15th at the Reference and River Sites. Inorganic content at mid-tide ranged from 100% at the Reference and Construction site on August 31st to 0% at the River Site on August 31st and the Reference and River Sites on October 15th. (Fig. 12). It is important to note that there was a calculation error in August, September, and October causing all the sediment to be classified as Inorganic or Organic, but percentages change with the correct procedures. The current procedures should fix this error. Removing the limitations, the organic content ranged from 99.6% on March 17th at the River Site to 92.6% on June 20th at the River Site. Inorganic content ranged from 7.3% on June 20th at the River Site to 0.37% on March 17th at the River Site (Fig. 12).

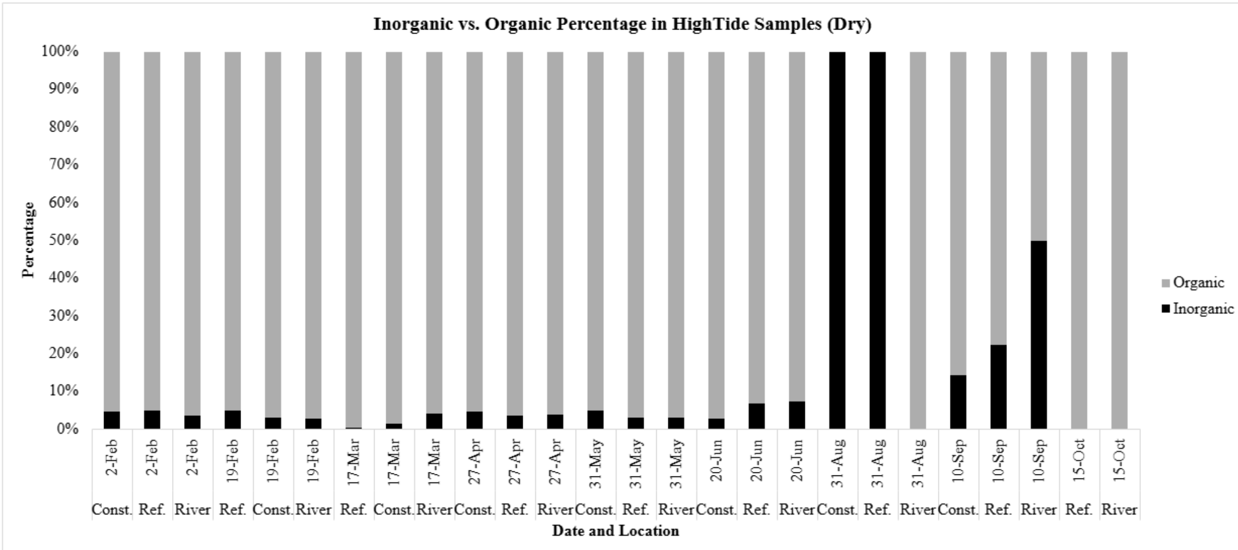

Figure 12. Percent bar graph illustrating the inorganic versus organic content during high tide at each site and sample day. Const= Construction, Ref.= Reference, and River.

Organic content at mid-tide ranged from 100% on September 10th at the River Site to 0% on October 15th at the Construction and Reference Sites. Inorganic content at mid-tide ranged from 100% on October 15th at the Construction and Reference Sites to 0% on September 10th at the River Site (Fig. 13). Removing limitations, the organic content ranged from 97.8% on February 19th at the Reference Site to 86.7% on June 20th at the River Site. Inorganic content ranged from 13.2% on June 20th at the River Site to 2.1% on February 19th at the Reference Site (Fig. 13).

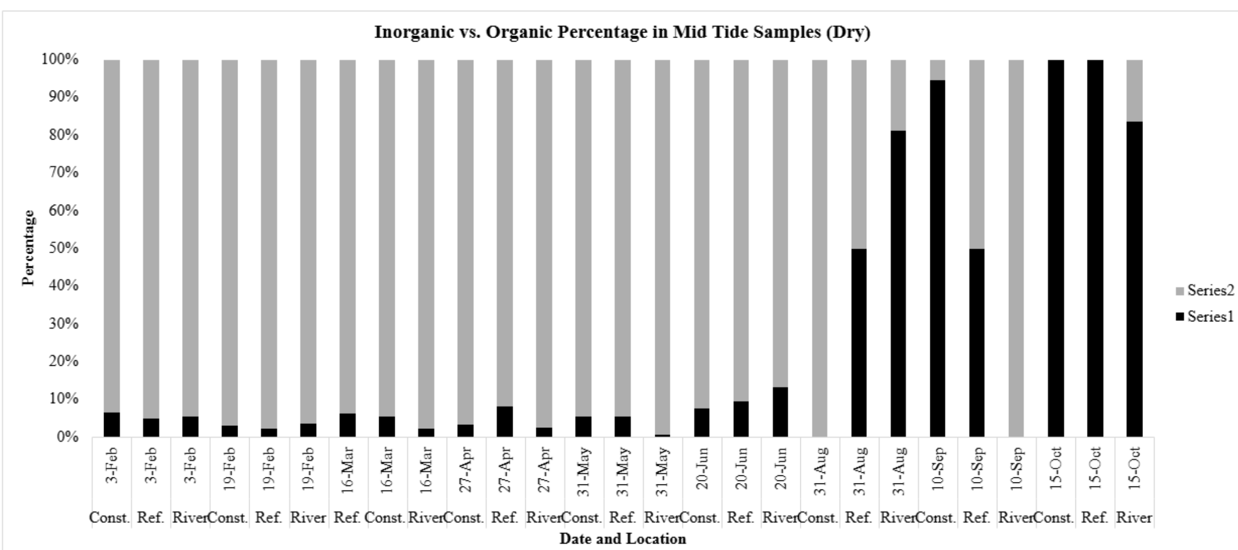

Figure 13. Percent bar graph illustrating the inorganic versus organic content during mid-tide at each site and sample day. Const= Construction, Ref.= Reference, and River.

Organic content at low tide ranged from 96.1% at the River Site on March 16th to 23.9% at the Reference Site on October 15th. Inorganic content ranged from 76.0% on October 15th at the Reference Site to 3.9% on March 16th at the River Site (Fig. 14). Accounting for calculational errors, the organic content ranged from 96.1% at the River Site on March 16th to 30.7% on June 20th at the Reference Site. Inorganic content at low tide ranged from 69% on June 20th at the Reference Site to 3.9% on March 16th at the River Site (Fig. 14).

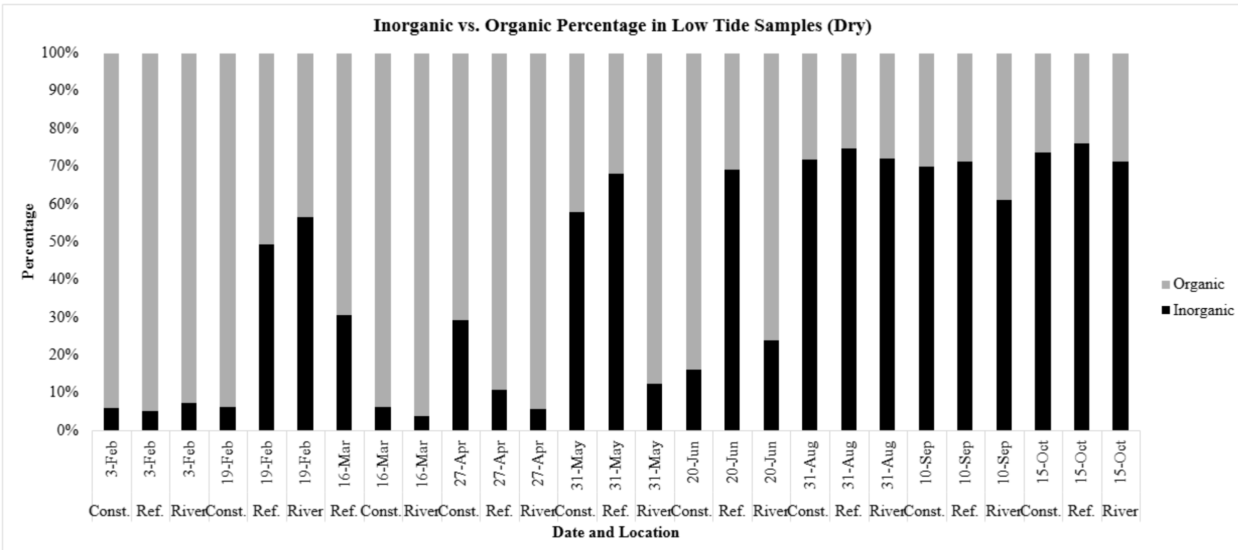

Figure 14. Percent bar graph illustrating the inorganic versus organic content during mid-tide at each site and sample day. Const= Construction, Ref.= Reference, and River.

We observed higher TSS and higher inorganic material at low tide compared to high and mid-tides which could be because of sampling procedures, increased construction material, seasonal productivity, and rainfall. Sampling procedures during low tides could cause an increase in TSS and inorganic material because of low water levels and increased benthic sediment collection. Low tide has the least amount of water present, leading to grab samples being more concentrated with sediment. During low tide sampling, benthic sediment became stuck in the water column sampler, due to this increased sediment in the grab sample, these likely skewed results.

Additionally, the increase in TSS during high and mid-tides from April to August could be due to seasonal changes in productivity, rainfall, or construction. Seasonal variations in rainfall, for example, tend to elevate TSS levels due to increased erosion and runoff into the river (Meybeck, 2003). Also, during hurricane season in North Carolina, runoff from stormwater can increase TSS levels, which likely happened more at the River Site as it is closest to the Cape Fear River.

However, since wet samples were sporadically collected under challenging conditions, it remains unclear whether rainfall directly influenced this study. Moreover, the contribution of construction materials remains to be determined because the analysis did not assess specific compounds in inorganic sediments. The limitation of calculational errors was due to scale and weighing errors. This skewed the inorganic and organic percentages. In the future, these errors will be accounted for and resolved. Silt booms at the construction site aim to mitigate environmental impacts by restricting sediment dispersion (Appendix A-1). However, their effectiveness varies depending on site conditions and deployment methods (Vu, 2013; Oliveira, 2020).

Along with TSS and inorganic/organic content, water quality sensors (HoboWare) have been placed at the construction site and Reference site to observe temperature, pH, dissolved oxygen (DO), and conductivity. These parameters will produce more trends in water conditions from seasons, productivity, construction activity, etc. Future research will involve enhanced monitoring efforts to gain deeper insights into this study's trends and variables.

Geospatial and Remote Sensing

Objectives 2 & 3:

Education and Outreach

Over the past 12 months, the Endriss lab has been piloting educational materials that we can use as a foundation for our “Living Laboratory collaboration between UNCW and the USS *North Carolina* Battleship”. In Fall 2023, Mikaila Reynolds, a UNCW Masters student, helped Endriss develop a 45-minute class field trip as a part her Teaching Assistantship for Endriss’ Wetlands Conservation and Management class (EVS-485), a hybrid advanced undergraduate and graduate course offered at UNCW (Fig. 15). This field trip used a boardwalk ‘walk through’ to offer a first-hand look at our different long-term ecological monitoring approaches, an explanation of UNCW’s partnership with the Battleship, and an opportunity to try their own hand at vegetation monitoring using quadrats that they themselves had constructed earlier in the semester. Endriss, Mikaila Reynolds and another UNCW Master’s student, Taylor Mattioli, then further built out a three-hour hands-on field trip for Eulie’s Field Methods in Environmental Sciences (EVS-515), a required Masters-level course within the Department of Environmental Sciences at UNCW. For this field trip, we not only did a boardwalk walkthrough, but made this more engaging by creating a “Bingo” card (with a small prize) of things that students may observe during their time at the Battleship (Fig. 16). We also used laminated binders of the Eagles Island Central Park Task Force to engage students in a structured dialogue and brainstorming exercise regarding the site’s unique history and environmental challenges. In addition, we gave students the opportunity to practice how to lay vegetation quadrats, set up audio recorders to monitor vocal bird and amphibian diversity, and monitor basic information about water conditions. We also used this as an opportunity to test an interactive ‘soundscape’ exercise to showcase the utility of audio recorders in long-term monitoring, asking students to pretend they are small ‘consulting teams’ tasked with using soundscapes (depicted both visually and auditorily) to solve realistic conservation scenarios. We already know that these types of materials work well for outreach events geared towards people of all ages and backgrounds, as the Endriss lab has implemented similar activities at the Center for Marine Science’s annual open house, MarineQuest’s “Full STEAM Ahead” day at UNCW, and through garnering long-term interest in our long-term monitoring at the USS North Carolina through using soundscapes during an hour- long radio interview with Rachael Hilburn’s Coastline (Fig.17). Now that these materials have been piloted, we look forward to beginning to work with the Battleship staff to incorporate them to continue to establish the site of the USS *North Carolina* Battleship as a Living Laboratory.

Figure 15. Endriss' Wetlands Conservation and Management class enjoying a field trip to the site of the USSNC (top left) as Mikaila Reynolds (top right) assists with explaining our long-term monitoring efforts at this site (top right). Before this trip, students constructed their own vegetation quadrats in the classroom (bottom left), which they then were given an opportunity to use at the site of the USSNC as well as other locations (bottom right).

Figure 16. The Battleship Bingo card the Endriss Lab used to engage UNCW's graduate Field Methods in Environmental Sciences class during our field trip to the site in Fall 2023 (left). Example squares on the bingo card included evidence of flooding or high tides (top right) and alligator holes (bottom right).

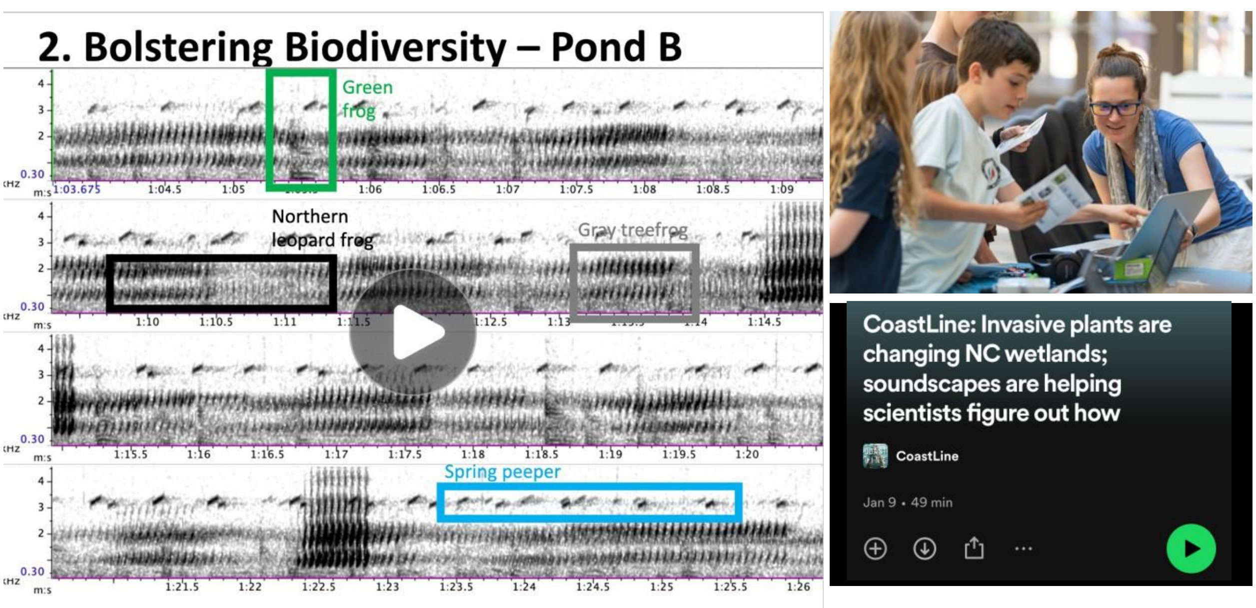

Figure 17. Key for an example soundscape used to engage learners of all ages and background (left), such as used by Endriss during MarineQuest's 2023 "Full STEAM Ahead" event and to highlight the importance of long-term monitoring on national public radio, including our monitoring efforts at the USSNC (bottom right).

In Winter 2024, the Endriss and Eulie labs also installed a construction camera on the port side of the Battleship (Fig. 18) to capture a timelapse of the construction of the wetland. The camera purchased (Hojocojo 4k Time Lapse Camera Outdoor). The camera was initially installed April 30th, 2024, and is programmed to take a high-resolution photo once every hour. With the help of Mr. Terry Kuhn and the Battleship & Site Operations team we have been successfully maintaining this camera for the past month and a half. We have begun processing this data—the camera view is occasionally obscured by morning dew, precipitation, and fog, but this has not negatively impacted the overall timelapse thus far. We hope to continue to maintain this timelapse set-up throughout the remainder of our contracted monitoring period, as long as the Battleship staff continues to have the capacity to assist us with regular access to the camera. These timelapses will help document the impressive scope of the Living with Water project and will be an important visual aid for outreach and reporting back to the funders who have made this project possible.

Figure 18. Construction camera on the south (port) side of the USSNC (top row) to capture progress on the constructed wetland, such as changes in the local hydrology due to the newly constructed tidal creek (bottom row). See Appendix B-1 through B-5 for more imagery.

NCCOS 2024 Accomplishments (obj 3)

During this calendar year the majority of our efforts have been administrative and focused on modifying an existing MOA with the Battleship so that we are ready to begin collecting data as soon as the project is completed. Towards that end, we extended our existing agreement to extend into 2028 to support 3 years of post-construction monitoring. Additionally, we visited the site in October of 2024 to test our approach for collecting bathymetry data and following some modifications to our method, we returned in early December to collect data again. We anticipate providing the interpreted results of the December data collection effort to Battleship staff by January 15, 2025.

Installation of water level sensors and quarterly sampling according to the schedule defined above will begin as soon as construction is completed.

Summary

All pre-construction action items have successfully been completed. Seasonally aligned and construction concurrent activities are on-going, which have been updated and reported for the December 30, 2024, permit-mandated report. Post-construction action items are in preparation in advance of project completion. It is anticipated that our next contract report (Year 2) will have sufficient post-construction data to provide preliminary insight into project success metrics.

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Appendix A

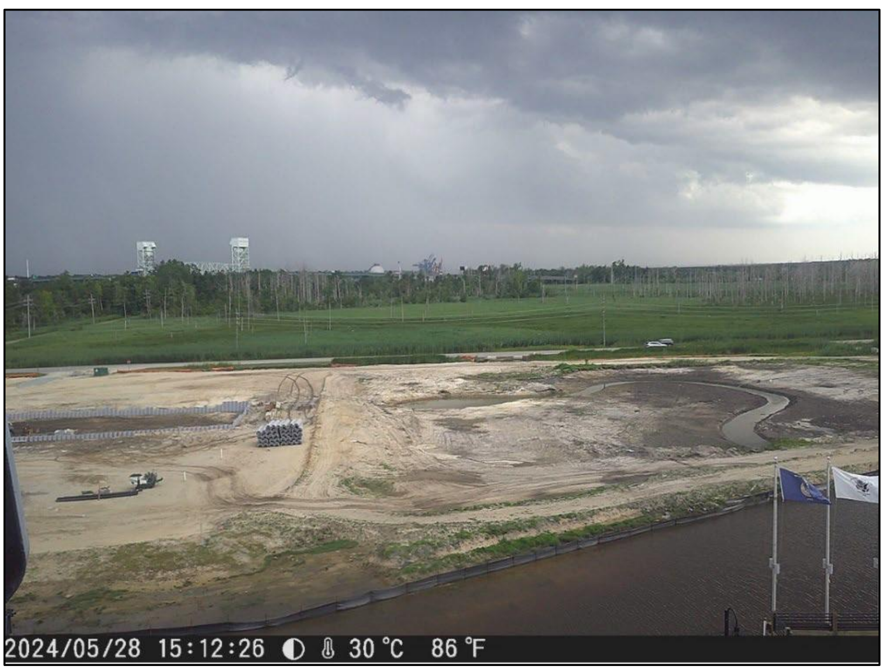
Appendix A-1. Silt boom near kayak launch.

Appendix B

Appendix B-1. Construction camera on the south (port) side of the USSNC on May 7th, 2024.

Appendix B-2. Construction camera on the south (port) side of the USSNC on May 16th, 2024.

Appendix B-3. Construction camera on the south (port) side of the USSNC on May 26th, 2024.



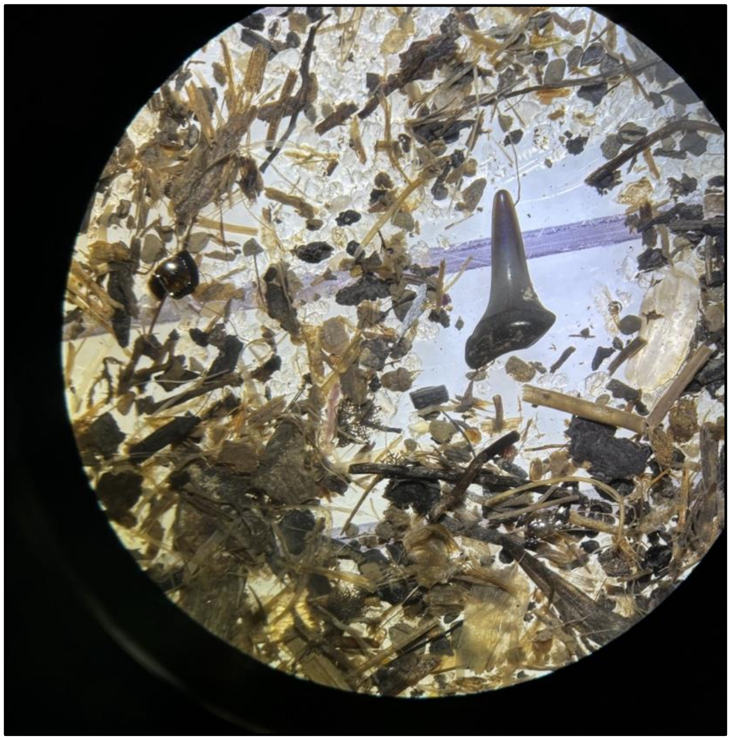
Appendix B-4. Construction camera on the south (port) side of the USSNC on May 28th, 2024.

Appendix B-5. Construction camera on the south (port) side of the USSNC on May 31st, 2024.

Appendix C

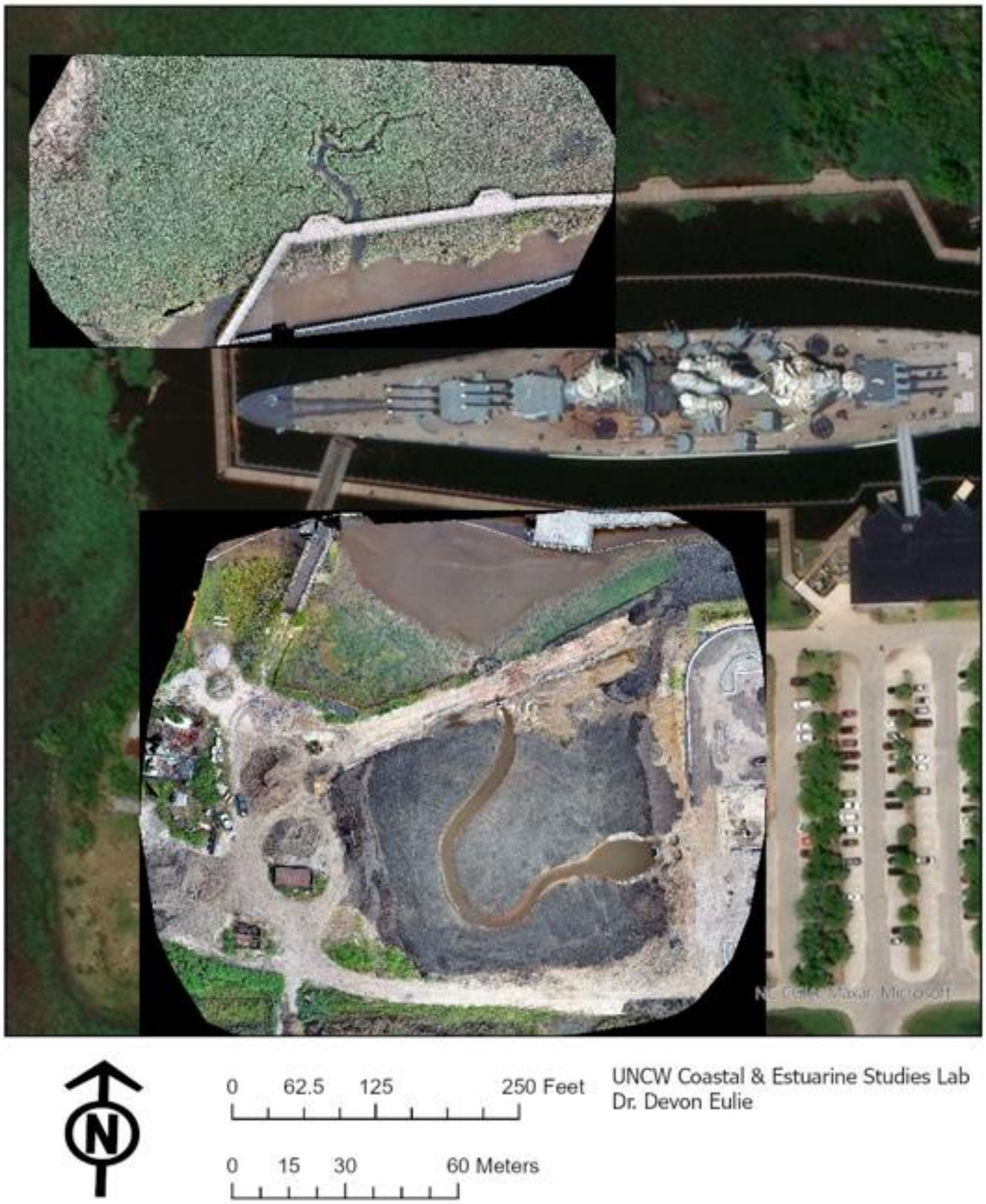
Appendix C-1. *Macrobrachium* shrimp caught in a clover leaf trap.

Appendix C-2. An American Eel (*Anguilla rostrata*) caught in a clover leaf trap.



Appendix C-3. A shark tooth found in a benthic sediment grab. It is most likely a Sand Tiger tooth!

Appendix D



Appendix D-1. UAS imagery derived mosaic of the reference marsh and project area. RGB imagery collected in September 2024, at low tide with an AUTEL Robotics EVO 2 drone platform.

Appendix D-2. UAS imagery derived mosaic of the project construction area. RGB imagery collected Sept. 12, 2024, at low tide with an AUTEL Robotics EVO 2 drone platform.

Appendix D-3. Zoom-in of the UAS imagery derived mosaic of the project construction area post-planting. RGB imagery collected Sept. 12, 2024, at low tide with an AUTEL Robotics EVO 2 drone platform.