Datasets: Field-based and Uncrewed aircraft system (UAS)-based oyster monitoring at five National Estuarine Research Reserves (NERRs) in the southeastern U.S.

This document provides detailed information about two datasets that were generated through a Collaborative Research project titled *Collaborative Development of Novel Remote Sensing Workflows for Assessing Oyster Reef Structural and Demographic Characteristics to Inform Management and Restoration*. This webpage provides information about the project. The project was supported by the National Estuarine Research Reserve System (NERRS) Science Collaborative, which is funded by the National Oceanic and Atmospheric Administration. All Science Collaborative supported projects that collect new data adhere to federal data sharing and archiving requirements.

About the Associated Project

Project page: https://nerrssciencecollaborative.org/project/Kingsley-Smith22
Grant Type: Collaborative Research
Focus Area(s): Habitat Restoration
Keyword(s): remote sensing, oyster reef, monitoring, drones, uncrewed aerial systems (UAS), *Crassostrea virginica*, reef structure, reef demographics, image analysis

Reserve(s): ACE Basin, SC; Guana Tolomato Matanzas, FL; North Carolina; North Inlet-Winyah Bay, SC; Sapelo Island, GA

Project Duration: October 2022 - March 2025
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Project Partners
NOAA National Centers for Coastal Ocean Science

Project Description

Oyster reefs in the southeastern United States offer an abundance of ecosystem services and support both recreational and commercial fisheries. To protect and enhance oyster reefs, resource managers in the southeastern United States need accurate and timely information to guide decisions on fishery closures and restoration efforts. Oyster resource managers and NERR staff in FL, GA, SC, and NC often rely on conventional monitoring approaches to inform management and restoration decisions, but these approaches have limitations. For example, methods like boat-based surveys and *in situ* quadrat sampling are time consuming and limited by spatial scale.

To overcome these limitations, this project evaluated the use of uncrewed aerial systems (UAS), or drones, as a novel tool for measuring reef structural and demographic characteristics relevant to reef function. Building on a previous collaborative initiative (NERRS Science Collaborative 2020 Catalyst), this project brought together oyster resource managers and restoration practitioners across four states. Together, the team developed and refined workflows for using drones to monitor key oyster reef metrics of interest across the region. The workflows provide standard procedures for data collection, analyzing drone imagery and generating estimates of:

1. reef height and elevation;
2. rugosity;
3. reef footprint and area;
4. shell substrate and oyster percent cover;
5. shell volumetric change; and,
6. oyster density and size structure.

These workflows have built technical capacity for the use of drones at the Reserves and state resource agencies. Application of the workflows has demonstrated that drones offer the capability to collect accurate, high resolution remote sensing data across entire reefs at a fraction of the cost of traditional sampling approaches. Integrating drones with existing oyster reef assessment efforts is allowing managers to map and model oyster reef ecosystem function and services on a scale that was previously unachievable.

Overview of Datasets

Two related datasets are described in this document:

- **Dataset 1: Field-based oyster monitoring**
  Field oyster monitoring data includes: 1) reef elevations and coordinates; 2) rugosity measurements and x,y,z coordinates of the beginning, mid points, and end of chains; 3) coordinates and elevations of reef perimeters (footprint); 4) volume of oyster material excavated from sampling plots and x,y,z coordinates from the plots; 5) visual estimates of percent cover shell and additional cover types (*e.g.,* bare sediment) in percent cover plots and coordinates of the plots; and 6) density and oyster lengths from each excavated sample plot. These data were collected to compare with estimates of the same parameters from UAS-based oyster monitoring to assess the fidelity of UAS-based estimates.

- **Dataset 2: UAS-based oyster monitoring**
  UAS oyster survey data includes: 1) project workflows; 2) raw imagery from RGB sensors; 3) digital surface models (made from RGB imagery) and corrected digital surface models; 4) orthomosaics (made from RGB imagery); 5) processing reports; and 6) GIS packages (.ppkx files) from the analyses. These image processing outputs were compared to reef elevations, reef area/footprint, rugosity, shell volume, and oyster demographics collected in the field.

Archival and access:
Imagery and data files are searchable in the project's data package and users will be able to download all the data from the project or individual files as desired. The root folder of the data package includes a 'file structure and naming convention' readme file to assist users with locating data of interest. All data are available from the NERRS Centralized Data Management Office (CDMO) via the following link:
https://nerrssciencecollaborative.org/resource/field-based-and-uncrewed-aircraft-system-uas-based-oyster-monitoring-five-national

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About the Project Datasets

Detailed dataset descriptions are provided below.

Dataset 1: Field-based oyster monitoring

General description of data:

Field oyster monitoring data includes: 1) reef elevations and coordinates; 2) rugosity measurements and x,y,z coordinates of the beginning, mid points, and end of chains; 3) coordinates and elevations of reef perimeters (footprint); 4) volume of oyster material excavated from sampling plots and x,y,z coordinates from the plots; 5) visual estimates of percent cover shell and additional cover types (*e.g.,* bare sediment) in percent cover plots and coordinates of the plots; and 6) density and oyster lengths from each excavated sample plot. These data were collected to compare with estimates of the same parameters from UAS-based oyster monitoring to assess the fidelity of UAS-based estimates.

Search keywords: oysters, oyster reefs, oyster percent cover, oyster density, reef elevation, reef footprint, shell volume, reef rugosity, reef structure, reef condition, oyster demographics

More about the data:

1) **Oyster density and size structure –** Oyster density and size structure were obtained through quadrat sampling and laboratory processing. The distribution of these quadrats encompassed variability in the vertical profile of the reef (*e.g.,* reef crest down to near edge, and high and low clustering). Within each reef, 3-6 0.0625 m^2 quadrat samples were hand-excavated per reef to a depth of 10-15 cm. Latitude, longitude, and elevation were collected at the corners of each quadrat using Real-time Kinematic Global Navigation Satellite System (RTK-GNSS). Mussels that were present within quadrats were collected as well to account for volume contributed. Samples were collected in a mesh bag, rinsed, and stored frozen until ready to be processed.

   Sampling Plots – Coordinates were collected at the corners of each plot using RTK-GNSS. Coordinate system used: Universal Transverse Mercator; Zone: 17 or 18 North; Vertical Datum: NAVD 1988; Horizontal Datum: NAD 1983 (Conus) (Mol); Geoid18; units: meters.

   Laboratory processing of the excavated samples included separating them into 4 categories: live, boxes (dead but both valves attached), cultch (brown), cultch (black from anoxic sediment). Then the live and box categories were all measured for shell height. Then the weight of each category was measured. In instances where the sample was particularly dense, a subsample was quantified and measured.

2) **Reef Area or Footprint –** For sites where the perimeter was walkable, RTK-GNSS points were recorded at ~1 m intervals around the reef where Reef Edge is defined as a continuous line where the percent coverage of substrate, either living or non-living material remaining above the sediment, is equal to or greater than 25%. For sites that were not walkable, “reef extent” endpoints were collected via RTK-GNSS, and digital footprints were created from imagery for comparison.

3) **Reef Elevation –** RTK-GNSS points were obtained across the short and long axes of the reef at 0.5-1 m spacing ending at the reef edge. A designation was made for any points

taken in the water when reaching the reef's edge. Additionally, ~20-50 vertical checkpoints were collected haphazardly across the reef for more robust RMSE/accuracy analysis.

4) **Rugosity** – Rugosity measurements were collected *in situ* using the chain and tape method. Using a ball bead chain (with beads ~3 mm) and length of 1-2 m, the chain was carefully laid along a straight path over an area of the reef and allowed to settle into any crevices. The start and end locations of the chain were surveyed with the RTK-GNSS along with one to two elevations along the chain length. A measuring tape was then used to collect the following measurements: 1) the length of the chain from start to end as it rests on the reef, but with measuring tape mirroring the slope of the reef; 2) the length of the chain from start to end, but with the measuring tape level using a simple line attached; and 3) the linear distance from start to end of the chain as the chain is stretched out.

5) **Shell Volume** – After excavation for the quadrats mentioned above, 3-4 depths were recorded (from the top of the surrounding oysters to the sediment) using a ruler/meter stick.
During laboratory processing of excavated shell material, the categories of shell (live, boxes, cultch [brown], cultch [black]) were measured for volume by water displacement in graduated buckets and cylinders.

6) **Percent Cover Substrate** – The amount of live shell, box (dead vertical shell), dead shell (cultch), and sediment were determined by a series of quadrats using one or more of the following methods: 1) Photos were taken of each percent cover quadrat using a handheld point-and-shoot camera or phone. These images were analyzed later using ImageJ and a digital grid for surficial coverage of shell material. The four corners of the quadrat were surveyed with RTK-GNSS; 2) 1-m^2 quadrats, independent of the excavation quadrats, were placed haphazardly on the reef and percent cover data were then estimated by two individuals and averaged. The four corners of the quadrat were surveyed with RTK-GNSS; 3) The point intercept method was used to estimate coverage of shell material, which entailed using a 1 m^2 quadrat with 50-100 intersections, each intersection was classified as live, dead, box (dead but valves still attached), sediment, or other. The four corners of the quadrat were surveyed with the RTK-GNSS.

Manipulative Experiment – A manipulative experiment was conducted to mimic harvest (shell loss) and growth or restoration (shell gain) to reefs and capture this through UAS-image analysis. Treatment plots (approximately 24 m^2) were established at 3 of the previously surveyed reefs (Figure 1) with corresponding control plots on each of the reefs. The corners of each plot were surveyed by RTK-GNSS. Percent cover quadrats and rugosity lines were established and marked and data were collected both before and after 'harvest' was applied to the treatment plot. Harvest mimicked the culling and collection of market size oysters from the reef until two 5-gallon buckets were full. These buckets were subsampled and taken back for laboratory processing as described above (section 3.b.1). After harvest was complete, a known volume of shell material was added back on to the treatment plot to detect shell gain. Elevation checkpoints were collected haphazardly across the treatment plots before and after 'harvest' as well as after the shell addition.

For more information on data from each participating NERR, please see the metadata files.

Data collection period:

May, 2023 to March, 2024

Geographic extent:

North Carolina NERR (study area boundary corners)

SW: 34.703891° , -76.765738°

NW: 34.773831°, -76.733283°

NE: 34.729648°, -76.580758°

SE: 34.666566°, -76.583020°

NC NERR study area is centered around Beaufort, NC.

North Inlet-Winyah Bay NERR (study area boundary corners)

SW: 33.325777°, -79.195032°

NW: 33.357416°, -79.186752°

NE: 32.627511°, -80.268630°

SE: 33.319455°, -79.167090°

NIWB NERR study area is located near Georgetown, SC.

Ashepoo Combahee Edisto (ACE) Basin NERR (study area boundary corners)

SW: 32.613678°, -80.315039°

NW: 32.635563°, -80.312176°

NE: 33.356115°, -79.155915°

SE: 32.606499°, -80.280452°

ACE Basin NERR study area is located near Edisto Island, SC.

Sapelo Island NERR (study area boundary corners)

SW: 31.422327°, -81.392216°

NW: 31.551583°, -81.296381°

NE: 31.524164°, -81.186036°

SE: 31.378264°, -81.281972°

Sapelo Island NERR study area is located near Darien, GA.

Guana Tolomato Matanzas NERR (study area boundary corners)

SW: 29.646781°, -81.238772°

NW: 29.889734°, -81.341925°

NE: 29.890395°, -81.265523°

SE: 29.643476°, -81.192579°

GTM NERR study area is located near St Augustine, FL.

File format:

Field oyster monitoring data are provided as Microsoft Excel files. Approximate file size is <1 MB per file (and < 5MB collectively).

Data file structure and naming convention

a) Reference documents

- Document detailing protocol used for collecting field data and RTK survey data (data_collection_and_processing_procedures.docx)
  - Folder: /data_collection_procedures
- Reserve-specific field metadata documentation
  - Folder: /metadata

b) **Field data**

- Folder: /in-situ_data_spreadsheets/0#_xxx (where # is 1-5 and xxx is three letter reserve abbreviation). Files include the following field data:
  - Density, volume, and weight
  - Reef elevations
  - RTK survey coordinates
  - Footprint
  - Length frequency
  - Percent cover

Data access and archival:

All data will be made publicly available within one year of the project completion. Data will be archived in the interim with the NERRS Centralized Data Management Office (CDMO).

Imagery and data files will be searchable in the project's data package and users will be able to download all the data from the project or individual files as desired. The root folder of the data package will include a 'file structure and naming convention' readme file to assist users with locating data of interest.

Maps and schematics for data collection

Figure 1. Map of oyster reef survey sites for the North Carolina NERR that were sampled in 2023 (yellow triangles) and those that were also used in the manipulative experiment in 2024 (blue circles).

Figure 2. This figure (oriented north-up) shows the study area within the North Inlet estuary (left side image) and specific study reef areas surveyed (right side images). The two reef areas surveyed in 2023 are bounded within red boxes and the reef area surveyed in 2024 is bounded within the blue box. The centers of specific reefs surveyed are denoted by the yellow stars in the right images. NB = North Boundary reefs; 60B = Sixty Bass reefs; CB = Clambank reefs.

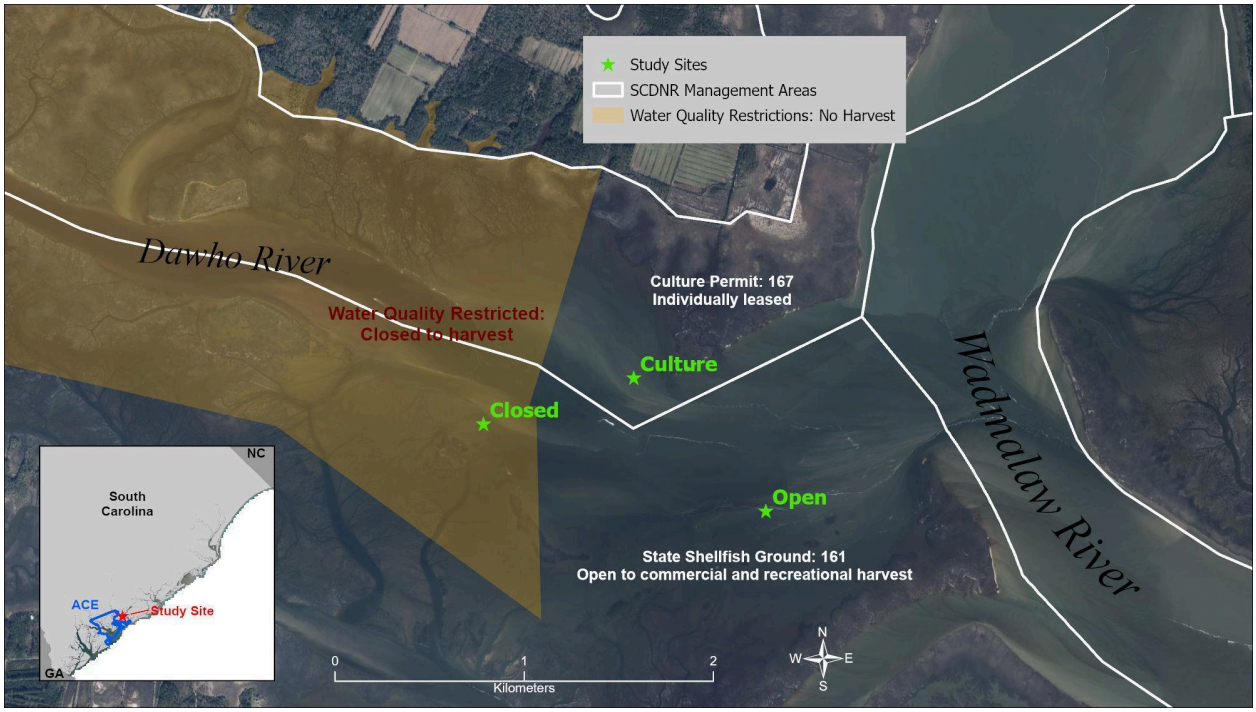

Figure 3. Overview of 3 sites near the ACE Basin that were repeatedly mapped by UAV for this project.

Figure 4. Sapelo Island study area. This figure (oriented north-up) shows the study area within and around the Sapelo Island NERR. Oyster reefs are denoted by when they were surveyed, either in 2023 (light circles) or both 2023 and 2024 as part of the manipulative experiment (red circle).

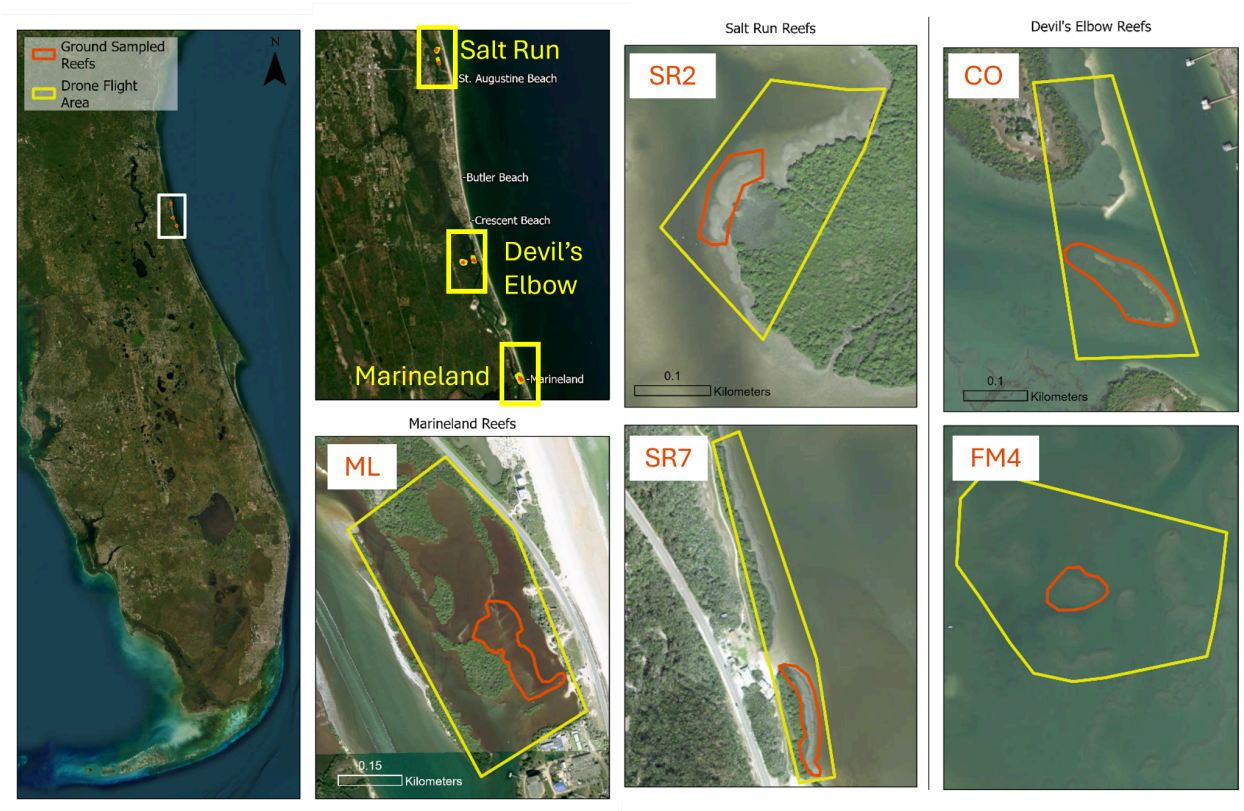

Figure 5. This figure (oriented north-up) shows the Northeast Florida location (left panel), the three site locations (yellow rectangles), the UAS flight areas (yellow polygons), and the reefs sampled for ground metrics (red polygons) within the GTM NERR.

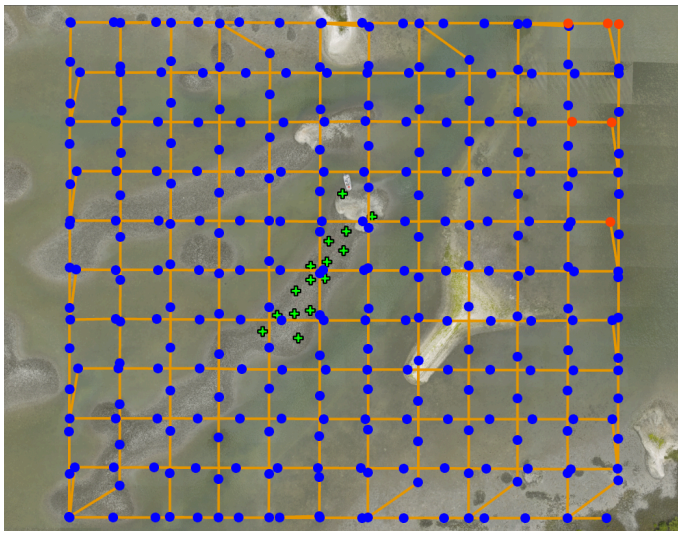

Figure 6. Devils Elbow manipulation experiment site, drone flight path (orange lines), and ground control points (green plus signs).

Dataset 2: UAS-based oyster monitoring

General description of data:

UAS oyster survey data includes: 1) project workflows; 2) raw imagery from RGB sensors; 3) digital surface models (made from RGB imagery) and corrected digital surface models; 4) orthomosaics (made from RGB imagery); 5) processing reports; and 6) GIS packages (.ppkx files) from the analyses. These image processing outputs were compared to reef elevations, reef area/footprint, rugosity, shell volume, and oyster demographics collected in the field (see dataset #1).

Search keywords: oysters, oyster reefs, oyster percent cover, oyster density, reef elevation, reef footprint, shell volume, reef rugosity, reef structure, reef condition, oyster demographics, drones, UAS, remote sensing

More about the data:

See metadata files for details on drone and sensor specifications, flight planning and flight details.

Data collection period:

See information for Dataset 1.

Geographic extent:

See information for Dataset 1.

File format:

UAS oyster survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), digital surface models (~1GB), .pdf for processing reports, and .ppkx files for GIS analysis project packages (~10GB).

Data file structure and naming convention

1) **Reference documents**
    - Document detailing protocol used for collecting imagery and RTK survey data (data_collection_and_processing_procedures.docx)
        - Folder: /data_collection_procedures
    - Document detailing workflows used for imagery analysis (image_analysis_workflow.docx)
        - Folder: /image_analysis_workflows
    - Reserve-specific field metadata documentation
        - Folder: /metadata
2) **Imagery and imagery products**
    - Raw RGB imagery are available as .jpg files
        - Folder: /imagery_&_imagery_products/0#_xxx/raw_imagery (where # = 1-5 and xxx = reserve three letter code)

- Digital surface models
  - Folder: /imagery_&_imagery_products/0#_xxx/DSMs (where # = 1-5 and xxx = reserve three letter code)
- Corrected digital surface models
  - Folder: /imagery_&_imagery_products/0#_xxx/DSMs_corrected (where # = 1-5 and xxx = reserve three letter code)
- Orthomosaics
  - Folder: /imagery_&_imagery_products/0#_xxx/orthomosaics (where # = 1-5 and xxx = reserve three letter code)
- Processing reports
  - Folder: /imagery_&_imagery_products/0#_xxx/processing_reports (where # = 1-5 and xxx = reserve three letter code)

a) Imagery analysis GIS packages and data

- Packages (.ppkx) files associated with each of the focal metrics
  - Folder: /imagery_analysis_arcgis_parkages/0#_xxx/***** (where # = 1-5, xxx = reserve three letter code, and ***** = metric)
- Data output from imagery analysis
  - Folder: /imagery_analysis_arcgis_parkages/0#_xxx (where # = 1-5 and xxx = reserve three letter code)

Data access and archival:
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Maps and schematics for data collection

See maps and schematics for Dataset 1.