Dataset: Assessing Utility of Drone-based Imagery to Enhance Emergent Vegetation Biomonitoring

This document provides detailed information about 12 datasets that were generated through a October 2020 to March 2022 catalyst project titled *Bridging the gap between quadrats and satellites: assessing utility of drone-based imagery to enhance emergent vegetation biomonitoring*. This document also 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.

12 related datasets are described in this document:

1. Field wetland vegetation survey at North Carolina (NOC) NERR
2. UAS wetland vegetation survey at North Carolina (NOC) NERR
3. Field wetland vegetation survey at North Inlet-Winyah Bay (NIW) NERR
4. UAS wetland vegetation survey at North Inlet-Winyah Bay (NIW) NERR
5. Field wetland vegetation survey at Ashepoo, Combahee, Edisto Basin (ACE) NERR
6. UAS wetland vegetation survey at Ashepoo, Combahee, Edisto Basin (ACE) NERR
7. Field wetland vegetation survey at Sapelo Island (SAP) NERR
8. UAS wetland vegetation survey at Sapelo Island (SAP) NERR
9. Field wetland vegetation survey at Guana Tolomato Matanzas (GTM) NERR
10. UAS wetland vegetation survey at Guana Tolomato Matanzas (GTM) NERR
11. Field wetland vegetation survey at Jobos Bay (JOB) NERR
12. UAS wetland vegetation survey at Jobos Bay (JOB) NERR

Data Access and Archival:
The data access process is as follows:

a. A description of data available for download will be provided on the project's webpage hosted by the NERRS Science Collaborative

b. For users interested in reviewing or downloading the data, there will be a 'Request data' link on the project webpage, which will bring up the NERRS Central Data Management Office (CDMO) data request form, which collects requesters name, contact information, occupation, organization and general purpose for requesting the data.

c. Once the data have been requested, the requestor will be sent a link to the project's Google Drive folder to view and download the project data.

The process is 'open' and accessible to anyone with internet access. Data access will not require any kind of subscription for access.

Imagery and data files will be searchable in the project's Google Drive folder and users will be able to download all of the data from the project or individual files as desired. In the project's

Google Drive root folder, we will provide a 'naming convention and file structure' .readme file to assist users with locating data of interest.

The project's Google Drive folder will be archived by the NERRS CDMO.

About the Associated Project

Project title: Bridging the gap between quadrats and satellites: assessing utility of drone-based imagery to enhance emergent vegetation biomonitoring

Name of reserve(s) involved in the project: ACE Basin, SC, Guana Tolomato Matanzas, FL, Jobos Bay, PR, North Carolina, NC, North Inlet-Winyah Bay, SC, Sapelo Island, GA

Project Period: October 2020 - March 2022

Science Collaborative project page URL:
https://nerrssciencecollaborative.org/project/Puckett20

Project lead and contact information:
Brandon Puckett, North Carolina NERR, brandon.puckett@noaa.gov

Purpose: Brief statement of the purpose and scope of the overall project, taken from final report and abstract provided by PI

Abstract:
Monitoring plays a central role in detecting change in coastal ecosystems. The National Estuarine Research Reserve System (NERRS) invests heavily in assessing changes in tidal wetlands through the System-wide Monitoring Program (SWMP). This monitoring is conducted in 1m2 permanent plots every 1-3 years via in situ sampling and at reserve-wide scales via airplane imagery every 5-10 years. While both approaches have strengths, important processes at intermediate spatial (i.e., marsh platform) and finer temporal (i.e., storm events) scales may be missed. Uncrewed Aerial Systems (UAS, i.e., drones) can provide high spatial resolution and coverage, with customizable sensors, at user-defined times. Based on a needs assessment and discussions with NERRS end users, we conducted a regionally coordinated effort, working in salt marshes and mangroves within six reserves in the Southeast and Caribbean to develop, assess and collaboratively refine a UAS-based tidal wetlands monitoring protocol aimed at entry-level UAS users. Using ground-based surveys for validation, we 1) assessed the efficacy of UAS-based imagery for estimating vegetation percent cover, delineating ecotones (e.g., low to high marsh), and generating digital elevation models, and 2) assessed the utility of multispectral sensors for improving products from #1 and developing vegetation indices to estimate aboveground biomass (e.g., normalized difference vegetation index, NDVI). UAS-derived elevation models and canopy height estimates were generally of insufficient accuracy to be useful when compared to field measures. Across sites, root mean squared error ranged from 0.25 to 0.59m for bare earth models, 0.15 to 1.58m for vegetation surface models, and 0.33 to 2.1m

for canopy height. The accuracy of ecotones delineated from UAS imagery varied among ecotones. The average distance between image- and field-based delineations of the wetland-water ecotone was 0.18 ± 0.01m, whereas differences of the low-high marsh ecotone were 1.25 ± 0.11m. Overall accuracy of vegetated and unvegetated classifications among sites was 85 ± 4%. Comparison of field- and image-based estimates of total percent vegetated cover indicated modest agreement between the two approaches, although percent cover was generally overestimated from imagery. Average differences in percent cover between approaches was ~5% at one reserve, but >25% at four reserves. Overall accuracy of species-specific classifications among reserves was 74 ± 6% when using both orthomosaics and surface vegetation models. Comparison of field- and image-based estimates of species-specific cover indicated minimal agreement between the two approaches; the interquartile ranges of the differences were wide for all species (>40%). Aboveground biomass in monospecific Spartina alterniflora plots was highly correlated to NDVI (R2 > 0.69), although the relationship was reserve- and sensor-specific. The strength of the relationship between NDVI and biomass was weaker in mixed-species plots (R2 = 0.52). This project serves as a critical first step for improving tidal wetland monitoring conducted as part of SWMP. Furthermore, the project increased the technical capacity of end users to conduct UAS-based wetland monitoring. This research collaboration was the first of its kind in the region and has catalyzed continued collaboration to identify regional management needs and expand UAS-based monitoring to additional coastal habitats (e.g., oyster reefs).

About the Project Dataset(s)

1. **Field wetland vegetation survey at North Carolina (NOC) NERR**

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 1m^2 plots along transects, 2) canopy height, measured as average and maximum canopy height in each permanent plot, 3) center coordinates of each permanent plot, 4) aboveground biomass in monoculture *Spartina alterniflora* 0.5m^2 plots, as well as mixed species plots, 5) and delineation of three ecotones including the wetland-water, low marsh-high marsh, and wetland-upland ecotones. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #2 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Within each sampling plot, percent cover was visually estimated for all vegetation species and additional cover types (e.g., bare sediment). Visual cover estimates for each species and cover type present in the plot were binned in 10% cover intervals, except at cover estimates < 10%, where 5% intervals were used. For species or cover types that were present, but <5%, their presence was designated as a percent cover of 1%. We included cover estimates of vegetation species present, as well as dead cover, which included plants/wrack with no live plant

tissue. Percent cover of unvegetated cover types such as bare sediment, oyster, and loose shell were also estimated.

Canopy height – Canopy height was estimated as maximum canopy height and average canopy height within each plot. Maximum canopy height was estimated as the height above the sediment surface of the three tallest plants within each plot. Maximum canopy height was measured with and without straightening stems and stretching leaves. Average Canopy height was estimated as the height above sediment of ten randomly selected plants of the dominant species in each plot. Average canopy height was measured with and without straightening stems and stretching leaves.

Plot coordinates – Latitude and longitude were collected at the center of each plot using Real-time Kinematic Virtual Reference Station (RTK-VRS). Coordinate system used: United States State Plan 1983; Z coordinate system = NAVD 1988; Zone: North Carolina 3200; Horizontal Datum: NAD 1983 (Conus) (Mol); Geoid: G12AUS.

Biomass – Aboveground biomass was estimated for two vegetation types: monoculture stands of *Spartina alterniflora* and mixed species vegetation stands (e.g., short-form *S. alterniflora* mixed with *Distichlis spicata*, *Salicornia spp*., and *Spartina patens*). Biomass was harvested destructively in areas proximal to the plots sampled for cover and canopy height, but distant enough not to interfere with those permanent plots. Aboveground biomass was collected by clipping all standing vegetation to the soil surface within a 0.25m2 quadrat. Live (i.e., any rooted plant with green or yellow tissue) and dead biomass within plots (i.e., no live biomass on plant) were stored, processed, and weighed separately. 12 quadrats were sampled for aboveground biomass for each vegetation type. Quadrats were chosen to span the marsh elevation gradient and to span a gradient of stem density and plant height. Latitude and longitude were collected at the center of each plot after harvesting all vegetation from each plot using RTK-VRS. Samples were stored in a freezer until processed. To process samples, vegetation was thawed, washed using a 2mm mesh sieve to remove sediment, and allowed to air dry in separate trays. Samples were dryed at 60C for 72 hours. Plant material was weighed to the nearest 0.1g and biomass was calculated as grams dry weight per m^2.

Ecotones – Three ecotones were delineated: wetland-water, low marsh-high marsh, and wetland-upland. The wetland-water ecotone was defined as the most landward point where vegetation was absent. The low-high marsh ecotone was defined where the dominant vegetation species shifted from low marsh species (e.g., *S. alterniflora*) to high marsh species (e.g., *S. patens*). The wetland-upland ecotone was defined as the landward most extent of wetland vegetation. Ecotones were delineated with RTK-VRS. The RTK antenna was mounted on a backpack, and coordinates were recorded every 1m. Note, elevation measurements are unlikely to be accurate when obtained with a backpack-mounted RTK antenna. The wetland-water ecotone was delineated for 158m, the low-high marsh for 287m, and the wetland-upland for 253m. Coordinate system used: United States State Plan 1983; Z coordinate system = NAVD 1988; Zone: North Carolina 3200; Horizontal Datum: NAD 1983 (Conus) (Mol); Geoid: G12AUS.

Data collection period:

May 2021

Geographic extent:
34.1664056N, -77.8293566W. Nearest town is Wilmington, NC.

File format:
Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- Drone_the_SWMP/
    - NERRS_drone_marsh_monitoring_SOP.docx
    - /NOC_Field_and_UAS_Survey_Archive
        - /Field_Vegetation_Survey [contains field survey metadata, collected data, RTK survey data and select documents]
            - FieldMetadata_NOC_210506.m.docx
            - /field_measurements
                - 20210507NOC_permanent_plot_veg_survey.xlsx
                - 20210507NOC_above_ground_biomass.xlsx
                - /ecotones
                - 20210507NOC _wetland-water_rtk.csv
                - 20210507NOC _low-high_rtk.csv
                - 20210507NOC _wetland-upland_rtk.csv
            - /field_rtk_data
                - 20210506NOC _bio_plots_rtk.csv
                - 20210507NOC _veg_plots_rtk.csv
                - 20210506NOC _checkpt_rtk.csv
                - 20210506NOC _gcp_rtk.csv
            - /field_documents
                - 20210506NOC _readme.txt
                - 20210506NOC _flight_log.docx

Maps and schematics for data collection

Figure 1: Masonboro Island monitoring location (green oval). The large blue dot is the Loosin Creek SWMP station. The enlarged view depicts vegetation transects (yellow lines), SETs (green dots), and groundwater wells (blue dots) inside the green oval.

2. UAS wetland vegetation survey at North Carolina (NOC) NERR

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery), 4) a normalized difference vegetation index (NDVI) orthomosaic (made from multispectral imagery). These image processing outputs were used to estimate canopy height, percent cover, ecotones and biomass. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #1) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_NOC_210506.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
May 2021

Geographic extent:
See dataset #1

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- Drone_the_SWMP/ (main folder)
  - NERRS_drone_marsh_monitoring_SOP.docx
  - /NOC_Field_and_UAS_Survey_Archive (root folder - one per site)
    - UAS_Survey (subfolder)
      - ImageMetadata_NOC_210506.m.docx
      - /uas_imagery
        - /20210506NOCvo
          - (raw rgb images)
        - /20210506NOCvm
          - /210506NOCNDRE
            - (raw multispectral images)
          - /210506NOCNDVI
            - (raw ndvi images)
      - /uas_products
        - /orthomosaic
          - 20210506NOCvo_ortho.zip
        - /elevation_models
          - 20210506NOCvo_dtm.zip

        - 20210506NOCvo_dsm.zip
    - /ndvi
        - 20210506NOCvm_ndvi.zip
- /uas_documents
    - /quality_reports
        - 20210506NOC_quality_report.zip
    - /field_documents
        - 20210506NOC _readme.txt
        - 20210506NOC _flight_log.docx

Maps and schematics for data collection

See dataset #1

3. Field wetland vegetation survey at North Inlet-Winyah Bay NERR

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 1m^2 plots along transects, 2) canopy height, measured as average and maximum canopy height in each permanent plot, 3) center coordinates of each permanent plot, 4) aboveground biomass in monoculture *Spartina alterniflora* 0.5m^2 plots. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #4 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Within each sampling plot, percent cover was visually estimated for all vegetation species and additional cover types (e.g., bare sediment). Visual cover estimates for each species and cover type present in the plot were binned in 5% cover intervals, except at cover estimates < 5%, where 1% intervals were used. We included cover estimates of vegetation species present, as well as dead cover, which included plants/wrack with no live plant tissue. Percent cover of unvegetated cover (bare sediment) was also estimated.

Canopy height – see dataset #1

Plot coordinates – Latitude and longitude were collected at the center of each plot with Real-time kinematic positioning (RTK-GPS) using Trimble R8s receivers for both base station and rover units. Coordinate system used: United States State Plan 1983; Horizontal Datum: NAD 1983(2011); UTM Zone17N; Z coordinate system = NAVD 1988 (computed using Geoid 18).

Biomass – Aboveground biomass was estimated for monoculture stands of *Spartina alterniflora*. Biomass was harvested destructively in areas proximal to the plots sampled for cover and canopy height, but distant enough not to interfere with those permanent plots. Aboveground biomass was collected by clipping all standing vegetation to the soil surface within a 0.25m2 quadrat. Live (i.e., any rooted plant with green or yellow tissue) and dead biomass within plots (i.e., no live biomass on plant) were stored, processed, and weighed separately. 15 quadrats were sampled for aboveground biomass, including 1 quadrat of entirely bare sediment to get a zero-vegetation sample. Quadrats were chosen to span the marsh elevation gradient occupied by *S. alterniflora* in this marsh and to span a gradient of stem density and plant height. Latitude and longitude were collected at the center of each plot after harvesting all vegetation from each plot using RTK-GPS. To process samples, vegetation was washed over a 2mm mesh sieve to remove sediment and then dried at 60 °C to a constant mass (approximately for 96 h). Plant material was weighed to the nearest 0.1g and biomass was calculated as grams dry weight per m^2.

Ecotones – Ecotone delineation was not conducted at NIW.

Data collection period:
May-June 2021

Geographic extent:

667902.474m Easting, 3691132.761m Northing. Nearest town is Georgetown, SC.

File format:
Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- **Drone_the_SWMP/**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/NIW_Field_and_UAS_Survey_Archive**
    - **/Field_Vegetation_Survey** [contains field survey metadata, collected data, RTK survey data and select documents]
    - FieldMetadata_NIW_210531.docx
    - **/field_measurements**
      - 210601NIW _permanent_plot_veg_survey.xlsx
      - 210601NIW _above_ground_biomass.xlsx
    - **/field_rtk_data**
      - 210608NIW _bio_plots_rtk.csv
      - 210608NIW _veg_plots_rtk.csv
      - 210608NIW _checkpt_rtk.csv
      - 210608NIW _gcp_rtk.csv
    - **/field_documents**
      - 210531NIW _readme.txt
      - 210531NIW _flight_log.docx

Maps and schematics for data collection

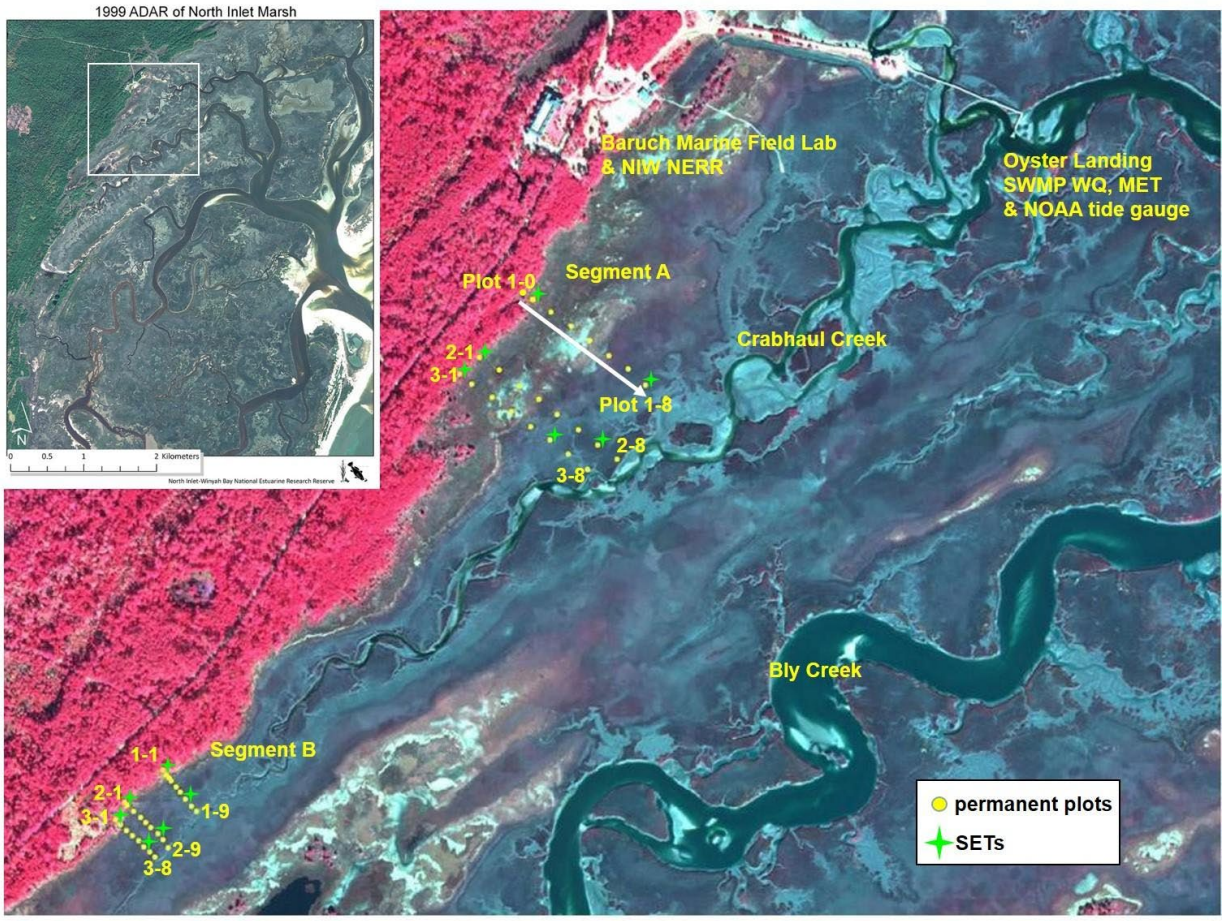

Figure 2. Location and Layout of the NIW vegetation biomonitoring sites indicating direction and numbering of plots along transects as well as the location of SETs. The inset indicates the research area in the greater context of the North Inlet estuary with a scale in kilometers.

4. **UAS wetland vegetation survey at North Inlet-Winyah Bay (NIW) NERR**

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery), 4) a normalized difference vegetation index (NDVI) orthomosaic (made from multispectral imagery). These image processing outputs were used to estimate canopy height, percent cover, and biomass. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #3) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_NIW_210531.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
May-June 2021

Geographic extent:
See dataset #3

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- **Drone_the_SWMP/**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/NIW_Field_and_UAS_Survey_Archive**
    - **/UAS_Survey**
      - ImageMetadata_NIW_210531.docx
      - **/uas_imagery**
        - /img
          - /210531NIWTM_1
            - Flight 1 multispectral images
          - /210531NIWTM_2
            - Flight 2 multispectral images
        - /calibration
          - /calibration_images
            - /210531NIWT_flight1
              - Pre-flight
              - Post-flight *use me*
            - /210531NIWT_flight2
              - Pre-flight

        - Post-flight
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- /**uas_products**
    - /orthomosaic
        - 210531NIW_RGB_ortho.tif
        - 210531NIW_Red_Index_Map.tif
        - 210531NIW_Green_Index_Map.tif
        - 210531NIW_Blue_Index_Map.tif
        - 210531NIW_NIR_Index_Map.tif
        - 210531NIW_RedEdge_Index_Map.tif
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        - 210531NIW_DTM.tif
        - 210531NIW_DSM.tif
    - /NDVI
        - 210531NIW_ndvi.tif
- /**uas_documents**
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        - 210531NIW_Pix4D_quality_report.pdf
    - /field_documents
        - 210531NIW_readme.docx
        - 210531NIW_flight_log.docx

Maps and schematics for data collection
See dataset #3

5. Field wetland vegetation survey at Ashepoo, Combahee, Edisto Basin (ACE) NERR

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 1m^2 plots along transects, 2) canopy height, measured as average and maximum canopy height in each permanent plot, 3) center coordinates of each permanent plot, 4) aboveground biomass in monoculture *Spartina alterniflora* 0.5m^2 plots. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #6 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Within each sampling plot, percent cover was visually estimated for all vegetation species. Visual cover estimates for each species and cover type present in the plot were binned in 10% cover intervals, except at cover estimates < 10%, where 5% intervals were used. For species or cover types that were present, but <5%, their presence was designated as a percent cover of 1%. We included cover estimates of vegetation species present. In addition, the percent cover of all species in a plot was measured using 50 grid points. Very small diameter dowels with 11.1-cm interval markers were placed in holes drilled into the four opposite parallel sides of the sampling frame. Species percent cover is calculated by counting stems touching the resulting 50 grid points created by intersection of the dowels within the frame according to the Braun-Blanquet scale (Kent and Coker 1992); if no stem touches the grid, the substrate cover is recorded.

Canopy height – see dataset #1

Plot coordinates – Latitude and longitude were collected at the center of each plot using Real-time Kinematic Virtual Reference Station (RTK-VRS). Coordinate system used: Universal Transverse Mercator (UTM) Zone 17N; Z coordinate system = NAVD 1988; Zone: 17N; Horizontal Datum: NAD 1983; Geoid: GEOID18.

Biomass – Aboveground biomass was estimated for monoculture stands of *S. alterniflora* (short and tall). Biomass was harvested destructively in areas proximal to the plots sampled for cover and canopy height, but distant enough not to interfere with those permanent plots. Aboveground biomass was collected by clipping all standing vegetation to the soil surface within a 0.25m^2 quadrat. Live (i.e., any rooted plant with green or yellow tissue) and dead biomass within plots (i.e., no live biomass on plant) were stored, processed, and weighed separately. 12 quadrats were sampled for aboveground biomass. Quadrats were chosen to span the marsh elevation gradient and to span a gradient of stem density and plant height. Latitude and longitude were collected at the center of each plot after harvesting all vegetation from each plot using RTK. Samples were stored in a freezer until processed. To process samples, vegetation was thawed, washed using a 2mm mesh sieve to remove sediment, and allowed to air dry in separate trays. Samples were dried at 60C for 72 hours. Plant material was weighed to the nearest 0.1g and biomass was calculated as grams dry weight per m^2.

Ecotones – No ecotones were delineated in the ACE NERR.

Data collection period:
September 2021

Geographic extent:
32.503046N, -80.323493W. Nearest town is Edisto Beach, SC.

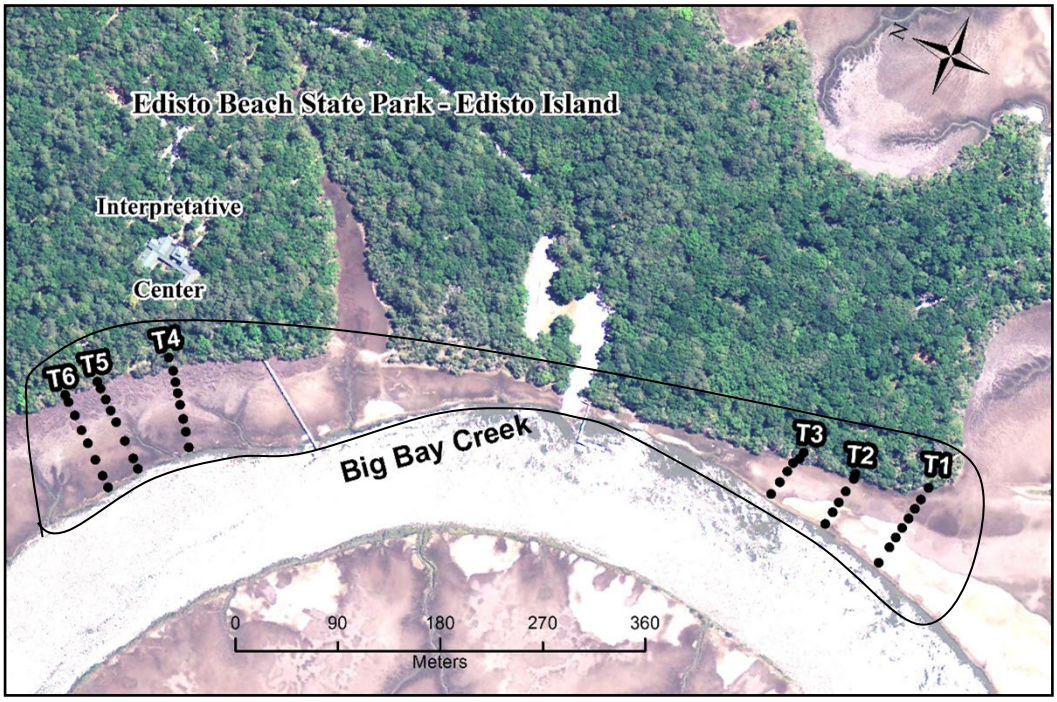
File format:
Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- Drone_the_SWMP/
  - NERRS_drone_marsh_monitoring_SOP.docx
  - /ACE_Field_and_UAS_Survey_Archive
    - /Field_Vegetation_Survey [contains field survey metadata, collected data, RTK survey data and select documents]
      - FieldMetadata_ACE_210914.m.docx
      - /field_measurements
        - 210914ACE _permanent_plot_veg_survey.xlsx
        - 210914ACE _above_ground_biomass.xlsx
      - /field_rtk_data
        - 210914ACE _bio_plots_rtk.csv
        - 210914ACE _veg_plots_rtk.csv
        - 210914ACE _checkpt_rtk.csv
        - 210914ACE _gcp_rtk.csv
      - /field_documents
        - 210914ACE _readme.txt
        - 210914ACE _flight_log.docx

Maps and schematics for data collection

Figure 3. Location and layout of the ACE vegetation biomonitoring sites indicating direction and numbering of plots along transects.



6. UAS wetland vegetation survey at Ashepoo, Combahee, Edisto Basin (ACE) NERR

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery), 4) a normalized difference vegetation index (NDVI) orthomosaic (made from multispectral imagery). These image processing outputs were used to estimate canopy height, percent cover, and biomass. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #5) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_ACE_210914.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
September 2021

Geographic extent:
See dataset #5

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- **Drone_the_SWMP/ (main folder)**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/ACE_Field_and_UAS_Survey_Archive** (root folder - one per site)
    - **UAS_Survey** (subfolder)
      - ImageMetadata_ACE_210914.m.docx
      - /uas_imagery
        - /210914ACEvo
          - (raw rgb images (.tif files))
        - /210914ACEvm
          - (raw multispectral images (.tif files))
      - /uas_products
        - /orthomosaic
          - 210914ACEvo_ortho_north.tif
          - 210914ACEvo_ortho_south.tif
        - /elevation_models
          - 210914ACEvo_dsm_north.tif

        - 210914ACEvo_dsm_south.tif
        - 210914ACEvo_dtm_north.tif
        - 210914ACEvo_dtm_south.tif
    - /ndvi
        - 210914ACEvm_ndvi_north.tif
        - 210914ACEvm_ndvi_south.tif
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        - 210914ACEvo_quality_report_south.pdf
        - 210914ACEvm_quality_report_north.pdf
        - 210914ACEvm_quality_report_south.pdf
        - readme_north-vs-south_images.txt
    - /field_documents
        - 210914ACE_readme.txt
        - 210914ACE_flight_log.docx

Maps and schematics for data collection

See dataset #5

7. Field wetland vegetation survey at Sapelo Island (SAP) NERR

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 1m^2 plots along transects, 2) canopy height, measured as average and maximum canopy height in each permanent plot, 3) center coordinates of each permanent plot, 4) and delineation of the low marsh-high marsh ecotone. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #8 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Within each sampling plot, percent cover was visually estimated for all vegetation species and additional cover types (e.g., bare sediment). Visual cover estimates for each species and cover type present in the plot were binned in 10% cover intervals, except at cover estimates < 10%, where 5% intervals were used. For species or cover types that were present, but <5%, their presence was designated as a percent cover of 1%. We included cover estimates of live vegetation present. Percent cover of anything that was not live vegetation was categorized as unvegetated.

Canopy height – see dataset #1.

Plot coordinates – Latitude and longitude were collected at the center of each plot using Real-time Kinematic Virtual Reference Station (RTK-VRS). Coordinate system used: United States State Plan 1983; Z coordinate system = NAVD 1988; Zone: Georgia East 1001; Horizontal Datum: NAD 1983 (Conus) (Mol); Geoid: GEOID18.

Biomass – Biomass was not sampled at SAP NERR.

Ecotones – One ecotone was delineated: low marsh-high marsh. The low-high marsh ecotone was defined where the dominant vegetation species shifted from low marsh species (e.g., *S. alterniflora*) to high marsh species (e.g., *S. patens*). Ecotones were delineated with RTK-VRS. The RTK antenna was held in hand, mounted on a pole, and coordinates were recorded every 1m. Note, elevation measurements are unlikely to be accurate. The low-high marsh ecotone was delineated for 245m. Coordinate system used: United States State Plan 1983; Z coordinate system = NAVD 1988; Zone: Georgia East 1001; Horizontal Datum: NAD 1983 (Conus) (Mol); Geoid: GEOID18.

Data collection period:
July 2021

Geographic extent:
31.3927537N, -81.2708176W. Nearest town is Sapelo Island, GA.

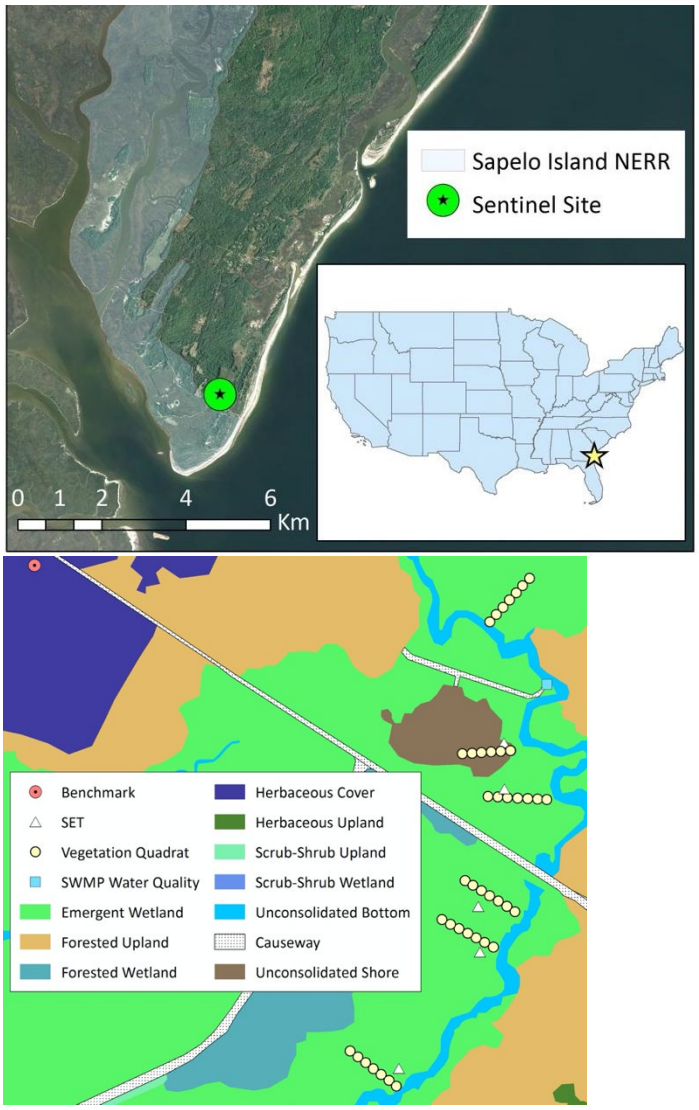
File format:

Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- Drone_the_SWMP/
    - NERRS_drone_marsh_monitoring_SOP.docx
    - /SAP_Field_and_UAS_Survey_Archive
        - /Field_Vegetation_Survey [contains field survey metadata, collected data, RTK survey data and select documents]
            - FieldMetadata_SAP_210712.m.docx
            - /field_measurements
                - 210712SAP_permanent_plot_veg_survey.xlsx
                - /ecotones
                    - 210712SAP _low-high_rtk.csv
            - /field_rtk_data
                - 210712SAP _veg_plots_rtk.csv
                - 210712SAP _gcp_rtk.csv
            - /field_documents
                - 210712SAP _readme.txt
                - 210712SAP_flight_log.docx

Maps and schematics for data collection



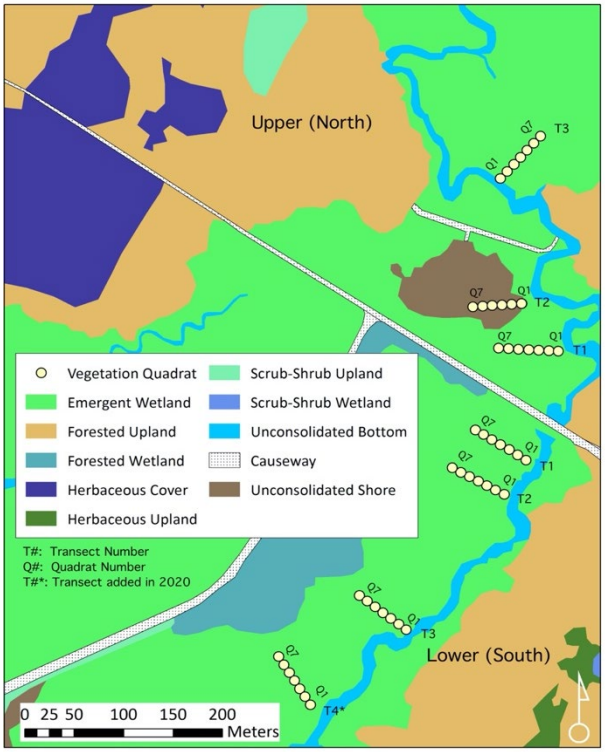


Figure 2. Dean Creek Sentinel Site Vegetation Transects and (T) and Quadrats (Q)

Figure 4. Sapelo Island National Estuarine Research Reserve, McIntosh County, GA with location of Dean Creek Sentinel Site (left), and current infrastructure (surface elevation tables; SETs) at the Dean Creek Sentinel Site overlaid on Sapelo Island NERR habitat map created from 2013 imagery (right).

8. UAS wetland vegetation survey at Sapelo Island (SAP) NERR

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery), 4) a normalized difference vegetation index (NDVI) orthomosaic (made from multispectral imagery). These image processing outputs were used to estimate canopy height, percent cover, and ecotones. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #7) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_SAP_210715.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
July 2021

Geographic extent:
See dataset #7

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- **Drone_the_SWMP/ (main folder)**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/SAP_Field_and_UAS_Survey_Archive** (root folder - one per site)
    - **/UAS_Survey** (subfolder)
      - ImageMetadata_SAP_210715.m.docx
      - /uas_imagery
        - /210715SAPtm
          - /img
            - (raw multispectral images)
          - /calibration (if applicable)
            - /pre-flight
              - (Pre-flight calibration images)
      - /uas_products
        - /orthomosaic
          - 210715SAPtm_ortho_blue.tif, 210715SAPtm_ortho_green.tif, 210715SAPtm_ortho_lwir.tif, 210715SAPtm_ortho_nir.tif,

210715SAPtm_ortho_red.tif,
210715SAPtm_ortho_red_edge.tif
210914ACEvo_ortho_south.tif
- Includes .prj, .tfw, etc files associated with each .tif file.

- /elevation_models
  - 210715SAPtm_ortho_dtm.tif
  - 210715SAPtm_dsm.tif
    - Includes .prj, .tfw, etc files associated with each .tif file.
- /ndvi
  - 210715SAPtm_ndvi.tif
    - Includes .prj, .tfw, etc files associated with each .tif file.

- /uas_documents
  - /quality_reports
    - 210715SAPtm_quality_report.pdf
  - /field_documents
    - 210715SAP_readme.txt
    - 210715SAP_flight_log.docx

Maps and schematics for data collection
See dataset #7

9. Field wetland vegetation survey at Guana Tolomato Matanzas (GTM) NERR

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 1m^2 plots along transects, 2) canopy height, measured as average and maximum canopy height in each permanent plot, 3) center coordinates of each permanent plot. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #10 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Cover was determined by visual estimates in 5% increments in the field. For species where only few individual stems were present, a cover of 1% was assigned in the field. Cover was reported for all species that were present in the plot in some form (e.g., branches from plants in the visual plane of a plot but rooted outside of the plot were included in cover estimates). For terrestrial plots, cover was only recorded for species that were considered understory. Overstory (aerial cover) was not measured; species were listed to record presence. All dead vegetation was considered unvegetated. Total unvegetated cover was determined by summing the percent cover for all vegetation species present and subtracting that total from 100%:

Unvegetated % Cover = 100% - (Species A % Cover + Species B % Cover +…+ Species *n* % Cover).

Due to multiple canopies, the sum of cover from all species present in a plot could result in total cover greater than 100%. If the sum of all species' cover totaled 100% or greater, unvegetated cover was recorded as zero.

Any wrack present in the plot was removed, where possible, prior to estimating cover. Due to high tidal range and flushing, and natural movement of wrack, it was determined that removal would not adversely affect the vegetation and natural dynamics of the marsh.

Canopy height – Canopy height was measured for all species that were rooted in the plot. For terrestrial plots, height was only recorded for species that were considered understory. Canopy height (m) was determined by measuring stem length with a flexible meter stick and averaging the tallest five individuals of each species. For grasses and sedges, stems were straightened to full height for measurement and recorded in centimeters in the field; woody plants and succulent stems were measured as they lay. Flowering plants were included when determining tallest individuals.

Plot coordinates – Latitude and longitude were collected at all four corners and the center of each plot using Real-time Kinematic (RTK). Coordinate system used: United States State Plan 1983; Z coordinate system = NAVD 1988; Zone: Florida East; Horizontal Datum: NAD 1983 (Conus); Geoid: GEOID18 (Conus); Units: Meters.

Biomass – Biomass was not sampled at GTM NERR.

Ecotones – Ecotones were not delineated at GTM NERR.

Data collection period:
June 2021

Geographic extent:
Lower transect: 29.66253N, -81.24871W. Middle transect: 29.65857N, -81.27132W. Nearest town is Palm Coast, FL.

File format:
Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- Drone_the_SWMP/
    - NERRS_drone_marsh_monitoring_SOP.docx
    - /GTM_Field_and_UAS_Survey_Archive
        - /Field_Vegetation_Survey [contains field survey metadata, collected data, RTK survey data and select documents]
        - FieldMetadata_GTM_210610.m.docx
            - /field_measurements
                - 20210614GTM_permanent_plot_veg_survey.xlsx
            - /field_rtk_data
                - 20210610GTM _veg_plots_rtk_LowerTransect.csv
                - 20210610GTM _gcp_rtk_LowerTransect.csv
                - 20210609GTM _veg_plots_rtk_MiddleTransect.csv
                - 20210609GTM _gcp_rtk_MiddleTransect.csv
            - /field_documents
                - 20210610GTM _readme.txt
                - 20210610GTM _flight_log.docx

Maps and schematics for data collection

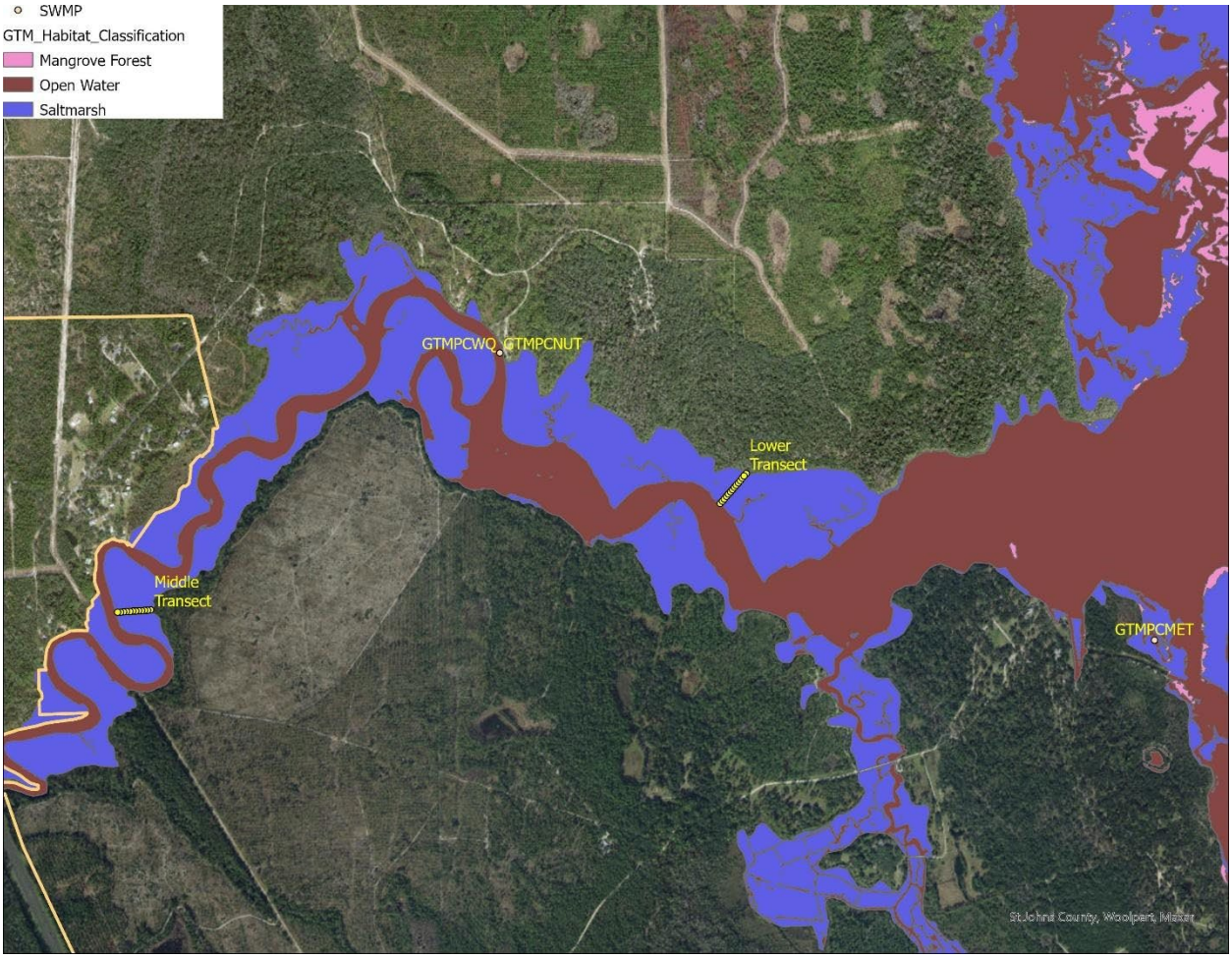


Figure 5. Pellicer Creek SWMP and Vegetation monitoring sites with GTM Habitat Classification

10. UAS wetland vegetation survey at Guana Tolomato Matanzas (GTM) NERR

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery), 4) a normalized difference vegetation index (NDVI) orthomosaic (made from multispectral imagery). These image processing outputs were used to estimate canopy height, and percent cover. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #9) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_GTM_210610.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
June 2021

Geographic extent:
See dataset #9

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- **Drone_the_SWMP/ (main folder)**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/GTM_Field_and_UAS_Survey_Archive** (root folder - one per site)
    - **UAS_Survey** (subfolder)
      - ImageMetadata_GTM_210610.m.docx
      - /uas_imagery
        - /210609GTMIM_MiddleTransect
          - (raw multispectral images)
        - /210609GTMIRGB_MiddleTransect
          - (raw rgb images)
        - /210609GTMI_calibration_MiddleTransect (if applicable)
          - Calibration_coefficients.txt
          - (calibration images)
        - /210610GTMIM_LowerTransect
          - (raw multispectral images)
        - /210610GTMIRGB_LowerTransect
          - (raw rgb images)
        - /210610GTMI_calibration_LowerTransect
          - Calibration_coefficients.txt
          - (calibration images)

- /uas_products
  - /orthomosaics
    - 210609GTMvo_ortho_MiddleTransect.tif
    - 210610GTMvo_ortho_LowerTransect.tif
  - /elevation_models
    - 210609GTMvo_dsm_MiddleTransect.tif
    - 210610GTMvo_dsm_LowerTransect.tif
    - 210609GTMvo_dtm_MiddleTransect.tif
    - 210610GTMvo_dtm_LowerTransect.tif
  - /ndvi
    - 210609GTMvm_ndvi_MiddleTransect.tif
    - 210609GTMvm_ndvi_LowerTransect.tif
- /uas_documents
  - /quality_reports
    - 210609GTMvo_quality_report_MiddleTransect.pdf
    - 210609GTMvm_quality_report_MiddleTransect.pdf
    - 210610GTMvo_quality_report_LowerTransect.pdf
    - 210610GTMvm_quality_report_LowerTransect.pdf
  - /field_documents
    - 210610GTM_readme.txt
    - 210610GTM_flight_log.docx

Maps and schematics for data collection

See dataset #9

11. Field wetland vegetation survey at Jobos Bay (JOB) NERR

General description of data: Field vegetation survey data includes: 1) visual estimates of percent cover of all vegetation species and additional cover types (e.g., bare sediment) in permanent 10m^2 plots, with 5 1m^2 subplots in each plot, 2) canopy height, measured as average and maximum canopy height in each subplot, 3) center coordinates of each subplot. These data were collected to compare with estimates of the same parameters from UAS wetland vegetation surveys (see dataset #12 below) to assess the accuracy of UAS-based estimates.

More about the data:
Cover – Within each sampling plot, percent cover was visually estimated for all vegetation species and additional cover types (e.g., bare sediment). Visual cover estimates for each species and cover type present in the plot were binned in 10% cover intervals, except at cover estimates < 10%, where 5% intervals were used. For species or cover types that were present, but <5%, their presence was designated as a percent cover of 1%. We included cover estimates of vegetation species present, as well as dead cover, which included plants/wrack with no live plant tissue. Percent cover of unvegetated cover types such as bare sediment, oyster, and loose shell were also estimated.

Canopy height – Canopy height was estimated as maximum canopy height and average canopy height within each plot. Maximum canopy height was estimated as the height above the sediment surface of the three tallest plants within each plot. Maximum canopy height was measured without straightening stems. Mangrove plants do not need to straighten stems; mangrove seedlings and small plants grow upright. Average Canopy height was estimated as the height above sediment of ten randomly selected plants of the dominant species in each plot. Average canopy height was measured without straightening stems.

Plot coordinates – Latitude and longitude were collected at the center of each plot using Real-time Kinematic Virtual Reference Station (RTK-VRS). Coordinate system used: United States State Plane 1983; Z coordinate system = NAVD 1988; Zone: 5200 PRVI;
Horizontal Datum: NAD 1983; Geoid: G18.

Biomass – Biomass was not measured at JOB NERR.

Ecotones – Ecotones were not delineated at JOB NERR.

Data collection period:
July 2021

Geographic extent:
17.950887N, -66.245459W. Nearest town is Las Mareas, PR.

File format:

Field vegetation survey data are provided as Microsoft Excel files. Approximate file size is 1MB.

File Structure:

- Drone_the_SWMP/
    - NERRS_drone_marsh_monitoring_SOP.docx
    - /JOB_Field_and_UAS_Survey_Archive
        - /Field_Vegetation_Survey [contains field survey metadata, collected data, RTK survey data and select documents]
            - FieldMetadata_JOB_210728.m.docx
            - /field_measurements
                - 210730JOB_permanent_plot_veg_survey.xlsx
            - /field_rtk_data
                - 210728JOB _bio_plots_rtk.csv
                - 210728JOB _veg_plots_rtk.csv
                - 210728JOB _checkpt_rtk.csv
                - 210728JOB _gcp_rtk.csv
            - /field_documents
                - 210728JOB _readme.docx
                - 210715JOB_flight_log.docx

Maps and schematics for data collection

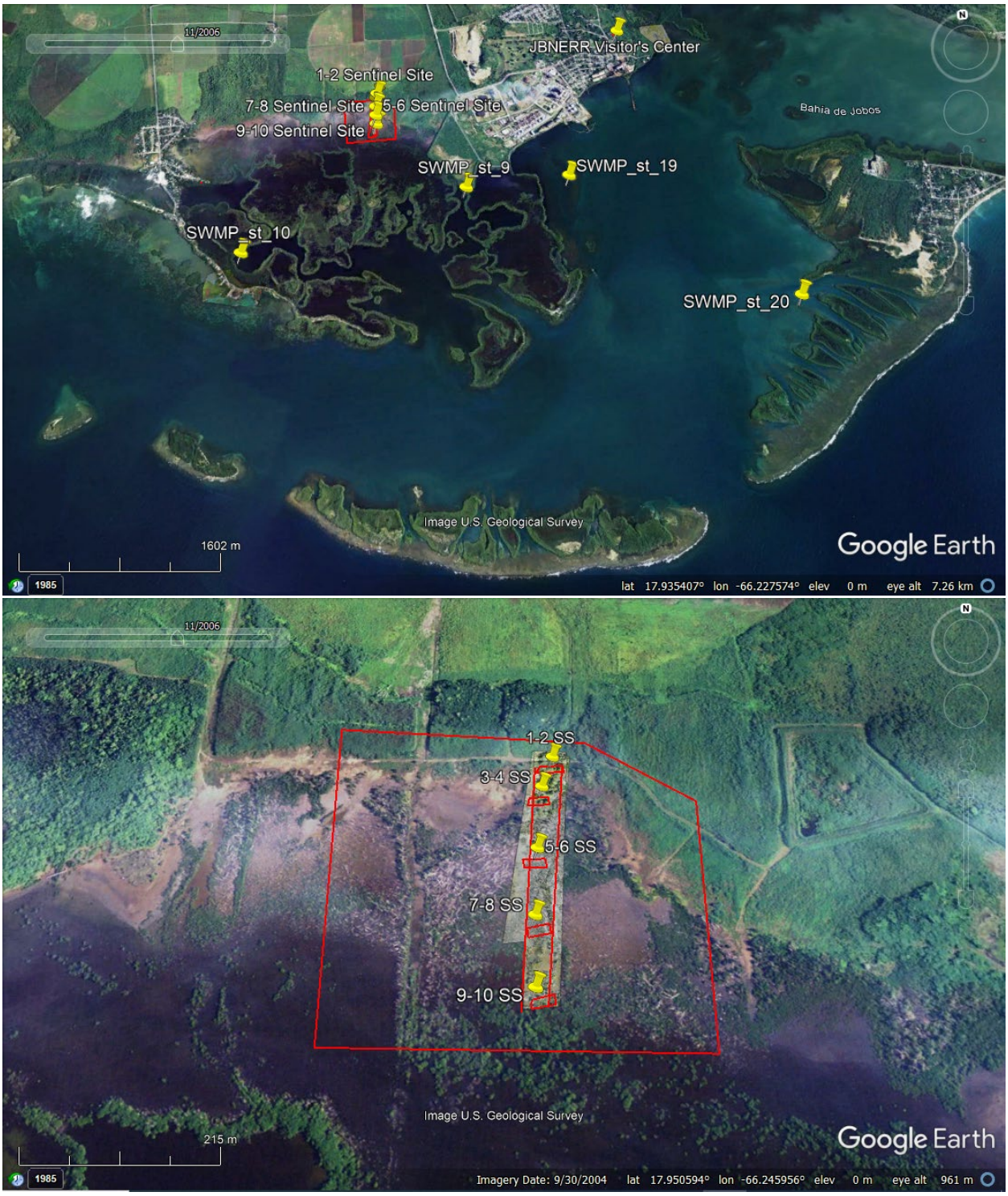


Figure 6. Location and layout of the JOB vegetation biomonitoring sites indicating direction and numbering of plots along transects.

12. UAS wetland vegetation survey at Jobos Bay (JOB) NERR

General description of data: UAS vegetation survey data includes: 1) raw imagery from RGB and multispectral sensors, 2) an orthomosaic (made from RGB imagery), 3) digital elevation models (made from RGB imagery). These image processing outputs were used to estimate canopy height and percent cover. Estimates of these parameters derived from UAS surveys were compared with estimates of the same parameters from field wetland vegetation surveys (see dataset #11) to assess the accuracy of UAS-based estimates.

More about the data:
See metadata (ImageMetadata_JOB_210715.m.docx) for details on drone and sensor specifications, flight planning and flight details.

Data collection period:
July 2021

Geographic extent:
See dataset #11

File format:
UAS vegetation survey data are provided as .jpg files for individual images (~10MB each) and .tif files for image products including RGB orthomosaic (~1GB), elevation models (~1GB), and normalized difference vegetation index (NDVI) orthomosaic (~1GB).

File Structure:

- **Drone_the_SWMP/ (main folder)**
  - NERRS_drone_marsh_monitoring_SOP.docx
  - **/JOB_Field_and_UAS_Survey_Archive**
    - **UAS_Survey**
      - ImageMetadata_JOB_210715.m.docx
      - /uas_imagery
        - /210715JOBvo
          - /img
            - (raw rgb images)
      - /uas_products
        - /orthomosaic
          - 210715JOBvo_ortho.tif
        - /elevation_models
          - 210715JOBvo_dsm.tif
          - 210715JOBvo_dtm.tif
      - /uas_documents
        - /quality_reports
          - 210715JOBvo_quality_report.pdf
        - /field_documents

- 210915JOB_readme.docx
- 210915JOB_flight_log.docx

Maps and schematics for data collection
See dataset #11

Maps and Schematics for Data Collection [if needed]

Dataset Description Examples

- McCarthy
- Sanger
- Angelini
- Findlay
- Sparks