



NJ Department of Environmental Protection

Division of Science and Research

Mapping and Assessing Tidal Marsh Condition Via Multispectral Imaging

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What was the purpose of the study?

Within New Jersey, there are approximately 66,000 hectares of tidal saltwater wetlands. These wetlands are integral to the health and well-being of the residents that live within these coastal areas, as they provide a number of invaluable ecosystem services, including: carbon sequestration (Were et al., 2019), coastal storm energy reduction (Rezaie et al., 2020), flood water storage (Rezaie et al., 2020), water quality enhancement (Fisher and Acreman, 2004), and traditional and cultural significance (Pedersen et al., 2019). However, New Jersey has lost a significant portion of its coastal habitat as a result of climate change and other anthropogenic factors, such as reduced hydrological function from agricultural ditching (Smith et al., 2022). A first step to intervene in these losses is to determine vulnerable habitat as quickly, accurately, and efficiently as possible, in order to prioritize areas of marsh for protection or enhancement.

Currently, multispectral imagery has a wide variety of environmental applications, including assessments related to crop health. Although ecological applications of drone technology continue to expand, there yet remains to be a standard protocol for wetland condition assessment. Appropriate wetland protection and restoration efforts require understanding their spatial and temporal vulnerability, but field-based evaluation methods can be costly and time-consuming. Drones represent an opportunity to assess large areas efficiently to narrow the acreage of wetlands that require in-depth evaluations. The goals of this effort were:

1. Evaluate the use of multispectral drones for the delineation of high and low marsh vegetation communities;
2. Investigate the use of drone-based multispectral imagery to identify conditions that can lead to high marsh pond expansion and vegetation loss by evaluating relationships between soil and porewater chemistry, vegetation, and multispectral indices; and
3. Identify and describe relationships between diatom communities and soil sulfide concentrations.

What was the general approach to the study?

For this project, DJI Phantom 4 Pro & Multispectral drones were used to collect high resolution photos & video for wetland habitat delineation, and multispectral images for wetland condition assessment, respectively. Data collection began within nine zones of Great Bay Boulevard Wildlife Management Area and E. B. Forsythe National Wildlife Refuge in July and August 2022 (Figure 1). Post flight data processing took place over Fall and Winter 2022, including the formation of orthomosaic imagery, spectral band extraction, calculation and summarization of multispectral vegetation indices, object-based image analysis with machine learning, and thematic accuracy assessments. Drone imagery was then compared to ground-sourced data in low and high marsh habitat to determine correlations among spectral signatures, vegetation, and soil parameters. Additionally, diatom samples were collected to better understand the health condition of the selected salt marshes, as diatoms have proven to be accurate indicators of nutrients, pollution, and salinity in tidal wetlands (Desianti et al. 2019). In 2023, an experimental design to evaluate the ability of drone

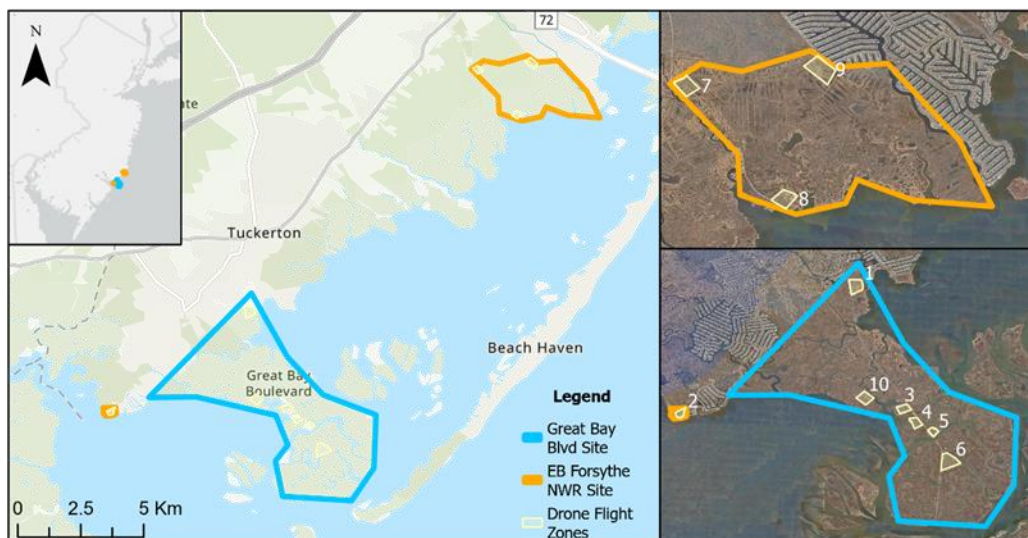


Figure 1. Map of the sampling sites in Great Bay Boulevard Wildlife Management Area (blue polygon) and E. B. Forsythe National Wildlife Refuge (orange polygon). Drone flights covered ten zones of the marsh, with additional on-the-ground vegetation, chemistry, and diatom analysis in plots within each zone.

imagery to identify areas of likely salt marsh pond expansion and vegetation die-off was applied to four of the 2022 surveyed zones (1, 8, 9, and a newly created 10), which were re-surveyed following similar methods at a higher resolution to minimize vegetation shadowing.

Overall, what did the studies show?

The multispectral imagery was successful for high and low marsh habitat delineation to a 7.6-cm (3-inch) resolution (Figure 2). Post-processing results were able to identify a variety of salt marsh species, but the process was not able to be fully automated and required varying levels of site-specific effort, especially concerning differentiation between various mixed-species combinations. Predictive relationships between the multispectral imagery and salt marsh condition (i.e., porewater and soil metrics) were not found. Although data showed that some relationships may exist, the sampling size was too small for the measured variability within many of the metrics for conclusive modeling results. Additionally, we found the timing of drone flights relative to the position of the sun and tide was greatly important for interpreting reflectance while minimizing shadowing. The sampling design accounted for these potential effects, but photo collection took longer than expected

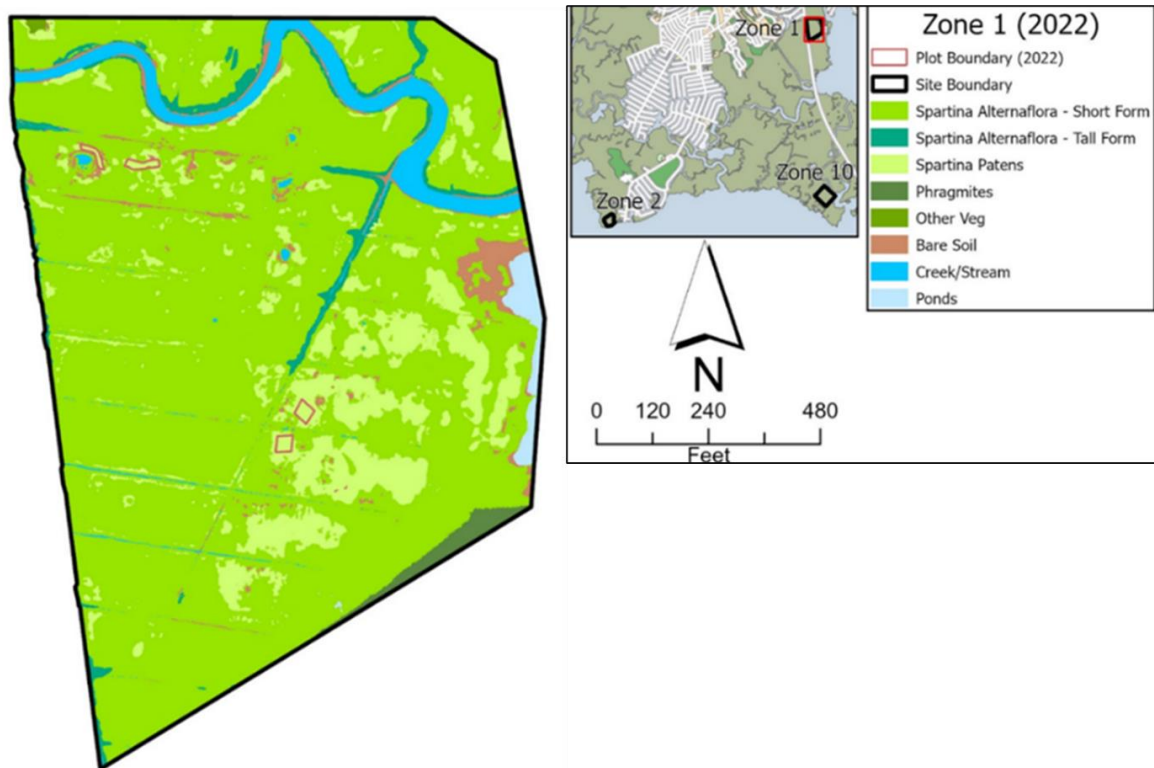


Figure 2. Example of a 7.6 cm resolution classified map showing habitat cover within Zone 1. Note how even small patches of *S. patens* were able to be detected amidst the *S. alterniflora* cover.

resulting in greater variability in water presence than anticipated. Additionally, the variability in vegetation, soil, and porewater metrics were higher within and lower among sites than expected, likely due to influence of the tidal magnitude and geomorphology of the sites driving these levels at a scale greater than our sampling strata (i.e., site location, expanding vs stable ponds, and distance of plot from pond). While these relationships were largely statistically insignificant, we did find useful relationships among the vegetation, chemistry, and diatom communities that can be used to inform our future efforts. Percent cover had a strong negative relationship associated with both pH and oxidation/reduction potential (ORP). Additionally, the multispectral indices showed some strong correlations with a variety of metrics, such as soil penetration depth, depth of water table, pH, sulfides, and sulfate depletion (Figure 3). Unfortunately, low R^2 values indicated that the models were

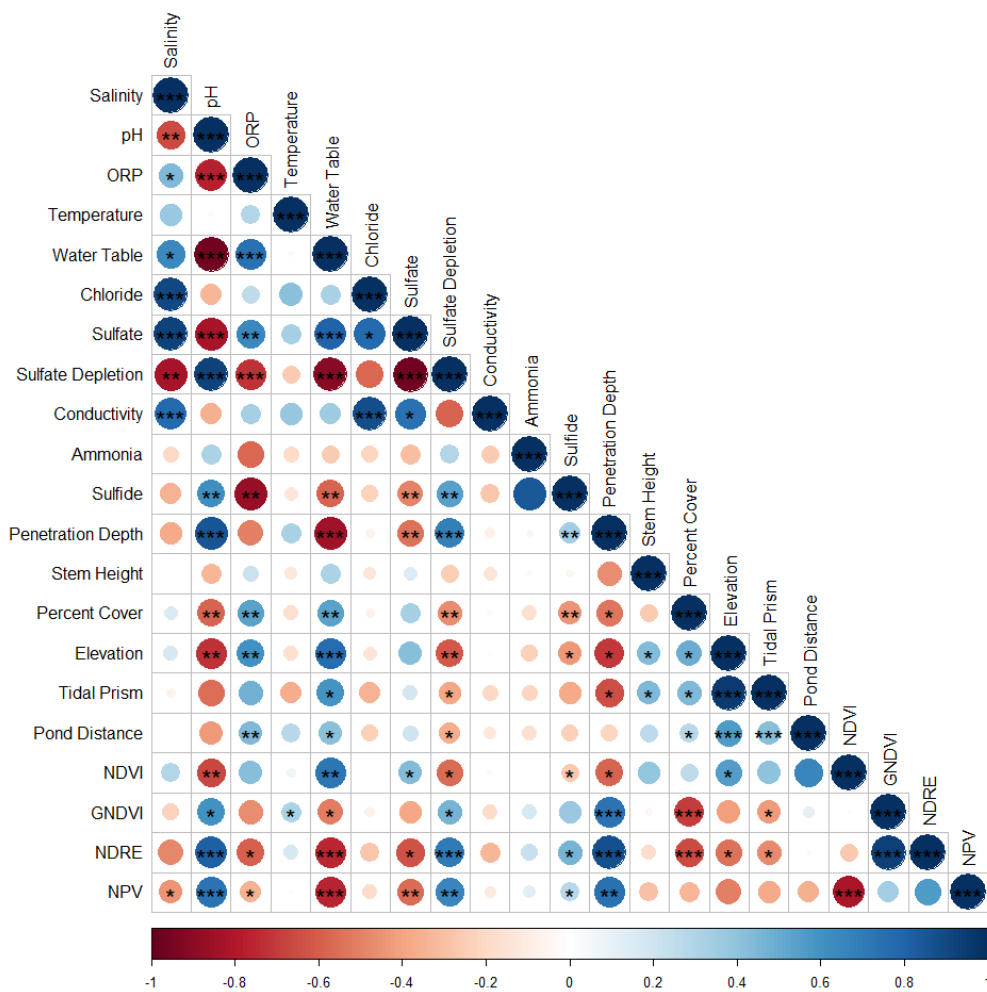


Figure 3. Correlation matrix for multispectral indices and ecologic variables from the *S. patens* 2022 field surveys. All parameters are noted along both axes. Multispectral indices included are Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Normalized Red Edge Index (NDRE), and Non-Photosynthetic Vegetation Index (NPV). Indices are located at the bottom of the y-axis. Dot size indices the strength of the correlation, and color denotes the direction (blue = positive, red = negative). The number of asterisks describes the strength of the correlation at the following alpha levels: “*”: $p = 0.05$; “**”: $p = 0.01$, “***”: $p = 0.001$.

either lacking the appropriate sample size or that there may be other undetermined confounding variables. One significant relationship between the non-photosynthetic index (NPV) and ammonia warrants further evaluation with an enhanced study design to capture varying levels of vegetation cover and direction of growth (i.e., establishing or degrading) along a nutrient gradient. Some issues associated with the collection of the multispectral data, such as the presence of vegetation shadows and the lack of a standardized atmospheric correction methodology, may have affected the results of this effort. But as they have been identified in this study, future efforts could aim to address them more directly.

How will DEP use the data?

Results from this effort can be used for sub-habitat level delineation within coastal salt marshes among distinct and mixed vegetation communities. Additionally, these results can be used to inform future drone-based monitoring efforts regarding wetland condition, with particular focus on loss of high marsh habitat. The DJI Phantom 4 Multispectral drone provides a detailed bird's eye view of the marsh and can measure a wide expanse of useful information. Detailed, 7.6-cm resolution classifications of the salt marsh were successfully created, which can inform future monitoring, estimated of temporal habitat change, and baseline/change maps for habitat enhancement/restoration projects. These high-resolution maps are particularly useful for NJDEP-FW as it could assist in their goals to better conserve saltmarsh sparrow (*Ammodramus caudacutus*), as this species is restricted to nesting only in *S. patens* due to the reduced flooding. Regular monitoring of critical salt marsh habitat by NJDEP-FW could produce necessary trend maps to determine areas of vulnerability within *S. patens*. Future efforts should be made to additionally explore these applications in freshwater wetlands.

Additional insight into the connections between diatom assemblages and soil and porewater chemistry was gained as certain relationships among the vegetation, soil chemistry, and diatom communities were found to be highly correlated. For example, some diatom species were found to be highly correlated with pH and salinity, with potential indirect links to sulfide (Figure 4). We are unaware of these relationships being described within scientific literature, and we intend to continue their exploration in future studies to understand the extent to which diatoms are influenced by these chemical parameters.

Results of this investigation show that capturing data that covers a wider range of wetland health would be important for generating a more accurate/detailed relationship between diatoms/chemistry/plants. Future efforts to evaluate coastal wetland health should include preliminary biogeochemical samples to allow for a more comprehensive condition assessment. Soil ORP would be a particularly useful metric for this type of preliminary assessment because it can be measured quickly and easily in the field and has well-documented relationships with plant species distribution and plant growth. Depending on sedimentation rates, diatom samples would be useful for indicating impacts from adverse pore water chemistry on vegetated marshes covering a wider time scale (e.g., multiple

References:

- Desianti N., Enache M.D., Griffiths M., Biskup K., Degen A., DaSilva M., Millemann D., Lippincott L., Watson E., Gray A., Nikitina D., Potapova M. (2019). The potential and limitations of diatoms as environmental indicators in mid-Atlantic coastal wetlands. *Estuaries and Coasts*. <https://doi.org/10.1007/s12237-019-00603-4>
- Fisher, J., & Acreman, M. C. (2004). Wetland nutrient removal: a review of the evidence. *Hydrology and Earth System Sciences*, 8(4), 673–685.
- Pedersen, E., Weisner, S. E. B., & Johansson, M. (2019). Wetland areas' direct contributions to residents' well-being entitle them to high cultural ecosystem values. *Science of The Total Environment*, 646, 1315–1326. <https://doi.org/10.1016/j.scitotenv.2018.07.236>
- Rezaie, A. M., Loerzel, J., & Ferreira, C. M. (2020). Valuing natural habitats for enhancing coastal resilience: Wetlands reduce property damage from storm surge and sea level rise. *PLOS ONE*, 15(1), e0226275. <https://doi.org/10.1371/journal.pone.0226275>
- Smith, J. A. M., Adamowicz, S. C., Wilson, G. M., & Rochlin, I. (2022). “Waffle” pools in ditched salt marshes: assessment, potential causes, and management. *Wetlands Ecology and Management*, 30(5), 1081–1097. <https://doi.org/10.1007/s11273-021-09835-3>
- Were, D., Kansime, F., Fetahi, T., Cooper, A., & Jjuuko, C. (2019). Carbon sequestration by wetlands: a critical review of enhancement measures for climate change mitigation. *Earth Systems and Environment*, 3(2), 327–340. <https://doi.org/10.1007/s41748-019-00094-0>

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