



Evaluating Effectiveness of UAS Sensors and Platforms for Multi-purpose Mapping of Marshes and Beaches in the NERRS Sentinel Site Network

A proposal submitted to NOAA UAS Program Office Request for Proposals “Evaluation of Unmanned Aircraft Systems (UAS) Observing Strategies Suitable for Transition into Routine NOAA Applications”

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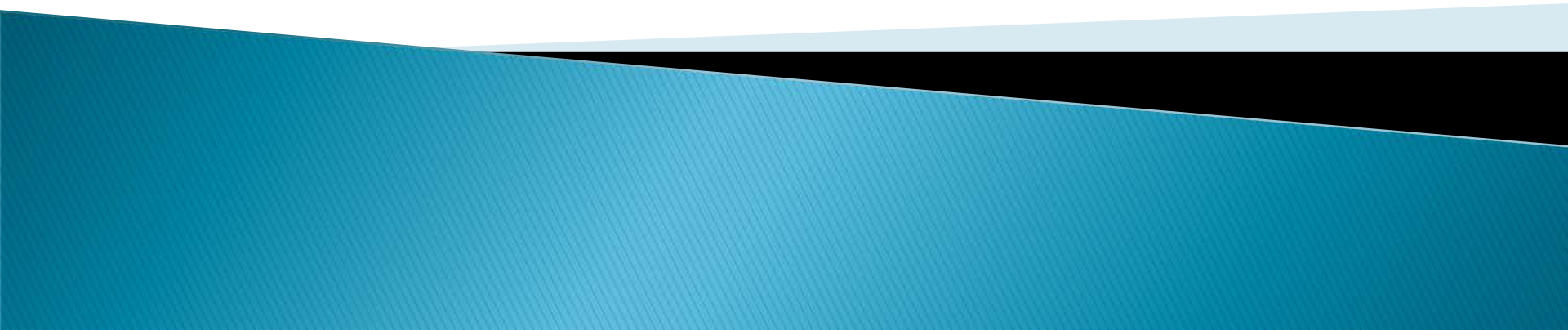
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Outline

- ▶ Project Formation
- ▶ Project Scope
- ▶ Expected Significance
- ▶ Technical Project Plan
 - Vegetation mapping evaluation
 - Elevation evaluation
- ▶ Project Milestones
- ▶ Questions?

Project Formation

RFP released January 13, 2016

OCM solicits input from NERRS and Applied Science staff

Identify popular research interests (NERRS, OCM)

Two separate ideas (imagery for veg, elevation for SLR)

NERRs w/ UAS, Sentinel Site, elevation surveys.

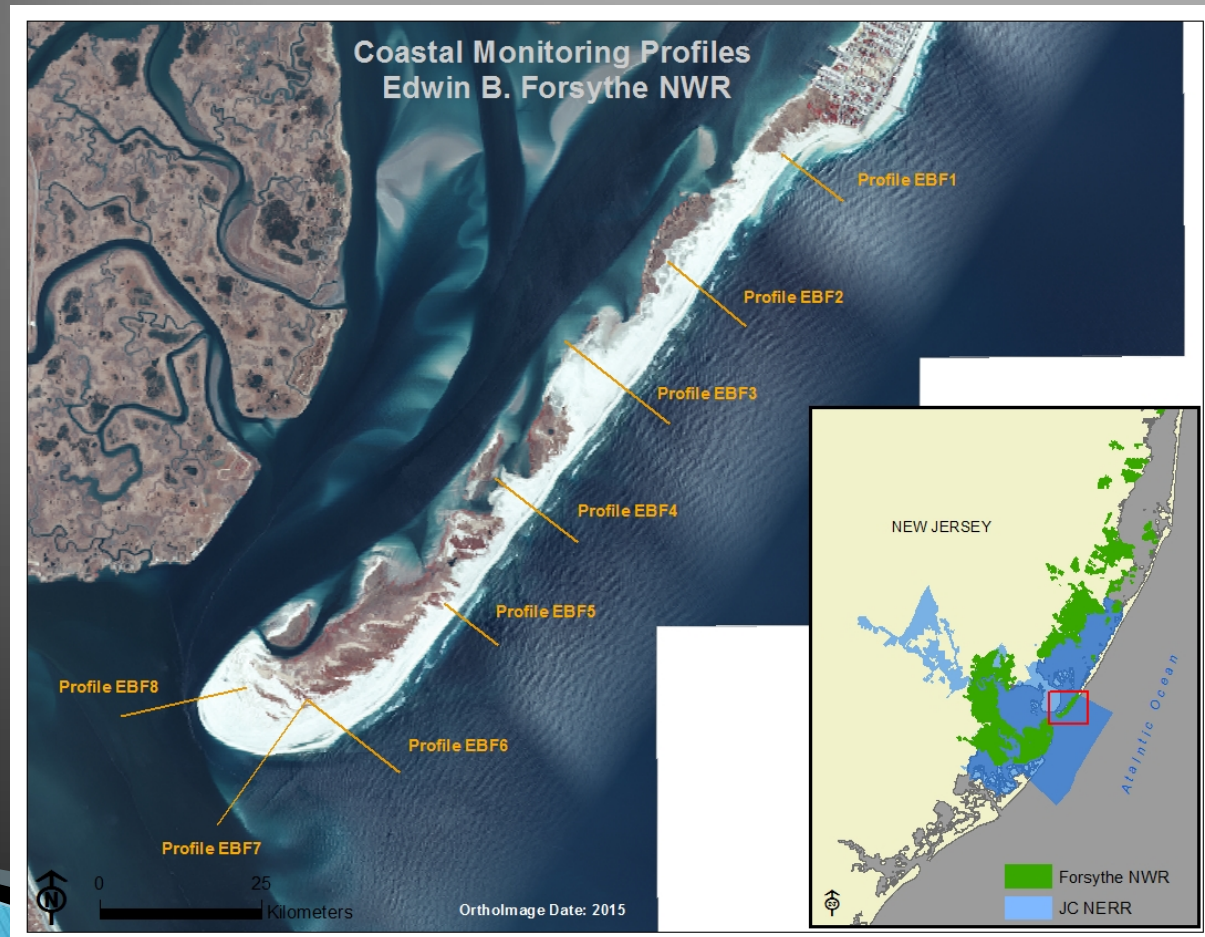
Proposal due February 24, 2016

General Questions to Address

- ▶ Vegetation mapping
 - Need to monitor habitat/veg changes
 - Can UAS imagery provide a better product than manned?
 - If so, at what price?
- ▶ Elevation
 - Need bare-earth elevation for SLR impact studies
 - Lidar is an effective mapping tool, but has had trouble in marsh areas.
 - Can the smaller footprint UAS lidar penetrate the marsh grass?

Project Areas

▶ Jacques Cousteau NERR



Project Areas

San Francisco Bay NERR

Mapping the Marsh with an Unmanned Aerial System (UAS)

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¹San Francisco Bay National Estuarine Research Reserve, ²Solano Land Trust



Introduction

Remote sensing (RS) is an indispensable tool for monitoring vegetation change in estuarine systems (Tuyen et al. 2011). We are currently testing a number of UAS based remote sensing applications at the Rush Ranch Reserve (Solano Land Trust/SF Bay NERR) in Solano County, focused primarily on monitoring vegetation change and invasive species in a remnant tidal marsh. Using high spatial resolution imagery captured with a UAS we compared two pixel-based classification approaches verified by field data. Accuracy assessments were produced for twenty classification trials across five vegetation types to evaluate site and ecologically appropriate classification strategies; standardized remote data collection methods; and assess the repeatability of our sampling and classification approach. Our study demonstrates the utility of UAS for monitoring vegetation in tidal marshes with high diversity. Vegetation maps were consistently accurate (Kappa = > .75), and provided high resolution spatial data.

Opportunities and Challenges

Change detection is notoriously difficult to assess in estuarine systems. Complex vegetation assemblages, unique geomorphology, and hydrologic processes present both logistic and scientific challenges. Sensitive biological resources necessarily limit accessibility to sites while regulatory constraints further restrict already narrow monitoring timeframes. Recent innovations in RS, UAS and GIS technology provide tremendous opportunities to overcome the limitations of field-based monitoring approaches. More importantly, these technologies increase the effectiveness and efficiency of landscape-scale ecological monitoring.



Figure 1. Study site: Rush Ranch in Solano County, California

Goals

1. Quantify the relationship between sample size and classification accuracy and its implication for pixel-based and polygon-based classification strategies at high spatial resolutions
2. Assess classification accuracy for 5 marsh plants: *Grivola stricta*, *Schroepfiella americana*, *Apium graveolens*, *Lepidium latifolium*, *Salicornia pacifica*
3. Evaluate the use of UAS for vegetation mapping in a tidal marsh system
4. Document the effect of plant phenology with regard to spectral differentiation
5. Develop a set of accurate site specific vegetation maps to inform management

Methods and Materials

Image Acquisition and Processing

1. We deployed a fixed-wing UAS equipped with a digital camera to collect high resolution RGB and RGB imagery of our 1 acre tidal marsh study site (Figure 1).
2. All flights were automated via a commercial software solution provided by Drone Deploy.
3. Total flight time was 30 minutes at an altitude of 200m.
4. Imagery orthorectification and georeferencing was processed commercially for all classification trials.

Image Classification

1. Training data were collected for each of the 5 target vegetation classes using two training strategies (Chen & Siew 2002):
 - a. Polygon Strategy - The polygon tool was used to delineate visually distinguishable patches of target vegetation from the RGB imagery to generate a set of training samples. Training samples were merged to form hierarchical classes.
 - b. Shapefile Strategy - The pixel training strategy follows the same methodology as the polygon strategy with the exception of the sample units. Pixel training is limited to the extent of individual pixels. Sample sets (the raw number of sampled pixels and polygons) was iteratively increased for each trial, with each subsequent sample set consisting of a new set of 25 samples in addition to the previously generated subset of training samples.
2. Spectral signature files were generated for each trial.
3. A maximum likelihood Classification algorithm (Spreen) was used to generate the image classification based on the training samples collected for each iteration of the trial.
4. Classifiers, image processing, and analysis was done in ArcGIS 10.3, iCapture, and Idrisi Imagine.

Accuracy Assessment

Accuracy assessment plots were selected in the field. Suitable plots had a homogeneous cover (at least 80% cover) of the target vegetation class. Twenty-five ground truth sites (GRTs) were established for each class. Error matrices, Producers and Users Accuracy, and kappa statistics were calculated for each classification trial.

Analysis



Results

Our initial classification results suggest that accuracy depends largely on detailed, site-specific knowledge of the target vegetation communities, plant morphology, plant phenology, and on the analyst's ability to identify unique spectral and optical characteristics of individual species in a supervised classification routine. Classification based on the polygon strategy was on average 5-10% more accurate (Adjusted K) than the pixel strategy. We were able to consistently identify individual species and vegetation assemblages through direct observation of high-res imagery alone, which has great potential to minimize the impacts of field based monitoring on the marsh system while improving the overall effectiveness of landscape-scale monitoring programs. Classification accuracy was generally related to two factors:

1. Greater inter-band stratification occurred in polygon-training signatures: increased spectral separation.
2. High differentiation in vegetation spectral characteristics: the species selected for the classification trials were visually distinct and therefore more easily classified based on spectral characteristics alone.

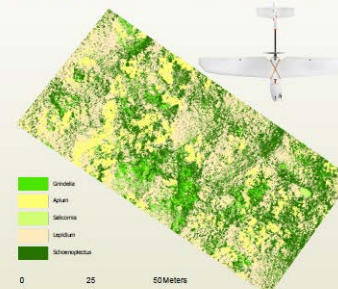


Figure 2. Final 3 cm pixel resolution vegetation map with fixed-wing UAV insect.

Conclusions

1. Polygon training produced consistently higher classification accuracy results.
2. Classification accuracy was highest for Apium and Lepidium classes.
3. Salicornia classification accuracy was low in all trials.
4. Final vegetation maps capture fine scale spatial patterns of species composition and distribution.
5. Integrating multi-resolution segmentation and object-based classification routines may improve the overall accuracy of vegetation classification.

References

1. Chen, D., & Siew, D. (2002). The effect of training strategies on supervised classification of different spatial resolutions. *Photogrammetric Engineering and Remote Sensing*, 68(11), 1335-1342.
2. Tuyen, K., Schell, L., Hershberg, D., Reed, S., Harris, T., Vohay, M., ... & Nelly, M. (2011). Mapping changes in tidal wetland vegetation composition and pattern across a salinity gradient using high spatial resolution imagery. *Wetlands Ecology and Management*, 27(2), 141-157.
3. Tuyen, K., Nelly, M., Schell, L., Reed, S., & Siew, D. (2008). Vegetation observation in a remnant tidal marsh: a remote sensing approach. *Wetlands Ecology and Management*, 24(2), 213-222.
4. Nelly, M., Schell, L., Reed, S., & Siew, D. (2008). Class based detailed vegetation classification with airborne high spatial resolution remote sensing imagery. *Photogrammetric Engineering and Remote Sensing*, 72(5), 799-811.

Special thanks to Heather Smith, ASST @ SFLU, Drone Deploy

For more information visit www.sfbaynerr.org

Project Areas

▶ Grand Bay NERR

Unmanned Aerial Systems at Grand Bay NERR

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Figure 1. Map of Certificate of Authorization area, Grand Bay boundary, and location of each mission.

INTRODUCTION

Aerial imagery is vitally important for coastal resource managers, but acquiring images can be expensive and complicated. Unmanned Aerial Vehicles (UAVs) are an increasingly popular technology that the NERRs can take advantage of for aerial imagery and remote sensing purposes. In cooperation with the NOAA Unmanned Aircraft Systems Program Office, the Northern Gulf Institute, and the Geosystems Research Institute at Mississippi State University, the Grand Bay NERR has coordinated four UAS missions flown at the GBNERR for the purposes of: payload testing, vegetation mapping, disaster response, and wildfire management. Flights were performed using various platforms and payloads to achieve the specific mission goals.

Mission	UAV / Payload	Altitude (ft)	RDD (in)
Tradeoffs	Altair Nova + CIR-modified Canon T300 Rebel SL3	330	1.3
Sentinel Site	PrecisionHawk Lancerator + CIR-modified Nikon J3	280	0.5
Disaster Response	DJI Phantom 3 Vision Plus	Varied	Varied
Wildfire Assessment	PrecisionHawk Lancerator + CIR-modified Nikon J3	330	2.0

Table 1. List of the missions with the size and payload that will be used along with the ground sampling distance of the collected images.

Unmanned Aerial Vehicles

Altair Nova
Large fixed-wing UAV
Good for collecting lower resolution imagery across large areas

PrecisionHawk
Small fixed-wing UAV
Good for collecting higher resolution imagery across smaller areas

DJI Phantom 3 Vision Plus
Quad-copter
Good for real-time imagery, collecting at different resolutions, search and response activities

Figure 2. Comparison between different UAVs potentially available for NERR missions.

TRADEOFFS STUDY



Figure 3. Satellite and Middle Bay NERR imagery.

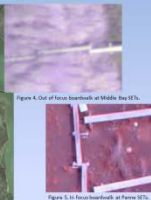


Figure 4. Out of focus bandwidth at Middle Bay NERR.



Figure 5. Sentinel Site and Parris NERR imagery. CIR camera.

OBJECTIVE
 Determine if Altair Nova UAVs will collect imagery useful for GBNERR. Collect a dataset to focus further discussions.

OUTCOME
 Dataset collected was not fine enough resolution for single species mapping. Launch and recover distances are too large for data collection in Sentinel Site areas that lack open adjacent areas.

OBJECTIVE
 Collect imagery sufficient for single species mapping of Sentinel Site areas of interest.

OUTCOME
 Very high resolution CIR imagery (0.5 inch GSD) used to create single species maps for Sentinel Site areas of interest. Need to fly again next Summer for change analysis.

DISASTER RESPONSE



Figure 6. Aerial image of disaster boat and fluorescent dye drop at Bang Lake.

OBJECTIVE
 Monitor movement of fluorescein dye during simulated chemical spill. Provide real-time video to support water sampling efforts.

OUTCOME
 Successful monitoring efforts and a great example of how UAS can be used in disaster response scenarios.

WILDFIRE ASSESSMENT



Figure 7. Marsh wildfire imagery. CIR camera.

OBJECTIVE
 Determine extent of marsh wildfire and conditions of the marsh shortly after the fire.

OUTCOME
 Collected imagery for entire affected area, but the PrecisionHawk was small for the task. A larger UAS, like the NOVA would've been more efficient.

SINGLE SPECIES HABITAT MAPPING

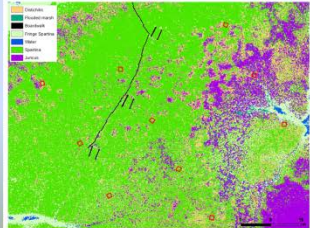


Figure 8. UAS single species classification.

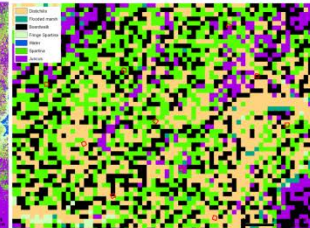


Figure 9. WorldView 3 single species classification.

Using the UAV imagery acquired during the Sentinel Site mission, a single species habitat map was produced. A training dataset of single species polygons was collected and used to classify the image. The same classification scheme and training dataset was applied to a WorldView 3 satellite image collected 11 days before the UAV mission. The WV3 map has a pixel size of 1.2 m, and the UAV map has a pixel size of 1.2 cm. The UAV map has 97 times the resolution when compared to the WV3 map. The red boxes on the maps are the permanent vegetation plots that are measured annually. Within the plots in the WV3 image very little or even no variation is detected, while in the UAV map a large amount of detail can be measured. Compared with the best satellite imagery available, the UAV imagery has much more utility for fine scale vegetation mapping and this kind of imagery and vegetation mapping would add lots of value to Sentinel Site work being performed at any reserve.

CONCLUSIONS

UAVs can be a beneficial tool for the NERRs for many purposes: filling temporal or spatial data gaps, habitat mapping and change, Sentinel Sites, coastal vulnerability assessments, stewardship management, disaster response, pre/post-disaster surveys, stakeholder engagement, wildlife surveys, and nesting bird counts. NERRs that wish to employ UASs should bring in a team with experience operating and maintaining the UAVs and payloads. Working with a team will make different UAVs and payloads available to the NERR to accomplish the varied missions. The NERRs can take advantage of this new technology to add value to many programs and research projects without having to invest large funds in acquiring UASs or training staff to operate them. We would like to thank the NOAA UAS Program Office especially John Coffey and Robbie Hood for making this effort possible.



Project Scope

- ▶ Acquire multi-spectral imagery and lidar in 3 different ecosystems
- ▶ 2 surveys per site to provide multi-season imagery and elevation repeatability
- ▶ Specific objectives:
 - Evaluate the horizontal and vertical accuracy of UAS georeferenced imagery and lidar
 - Evaluate UAS lidar to measure ground elevations through marsh vegetation and compare to manned systems lidar
 - Assess the trade-offs between UAS lidar and interpolated RTK transects
 - Compare UAS imagery to manned systems imagery at the supervised classification step of vegetation mapping
 - Evaluate the gains from additional data sources compared to imagery alone for vegetation mapping
 - Evaluate the ability of the private sector to provide UAS-based data using a Brooks Act contract.

Expected Significance

- ▶ Improve quality of data used for habitat mapping and assessment to support improved understanding and management
 - NOAA Next-Generation Strategic Plan goal – Healthy oceans/estuaries
- ▶ Provide highly detailed rapid assessment with low mobilization costs and minimal environmental impact to understand changes, threats, and dynamics
 - NOS Priorities Roadmap priority – Place-based conservation
- ▶ Evaluate ability of UAS derived coastal intelligence to meet NOAA needs
 - NOS Priorities Roadmap priority – Coastal intelligence
- ▶ Evaluate commercial UAS capabilities to make more informed operational decisions regarding employment of appropriate technology
 - NERRS operations improvement

Technical Project Plan

- ▶ Imagery and lidar surveys contracted through the Coastal Geospatial Services Contract
- ▶ Precision Hawk Lancaster platform, 5-band multi-spectral imager, a Velodyne PUCK lidar
- ▶ Flights at altitudes of 250 to 300'
- ▶ Exact specifications will be determined by the contractor to meet the data requirements

- ▶ Products:
 - Multi-spectral (at least 4-band) image 3-cm resolution or better
 - Lidar flown on the same platform to produce elevation data
 - Lidar data will be classified for ground, water, and unclassified and have a non-vegetated vertical accuracy of 7-cm or better
 - A digital elevation model (DEM) from structure from motion (SfM)



Technical Project Plan

▶ Vegetation Mapping Evaluation

- Automated supervised classification process
- Single species identification
- Evaluate spatial accuracy
- Evaluate combined imagery and elevation for mapping

▶ Elevation Evaluation

- Lidar/SFM error assessment
- Compare lidar vs SFM
- JCNERR – evaluate lidar beach volume
- Business case analysis

Project Milestones

Site implementation/project plans finalized	June 2016
Certificates of Acquisition (COAs) in place; Data acquisition contract in place	July 2016
Flights conducted	November 2016 (first set) May 2017 (second set)
Elevation ground control and vegetation accuracy points acquired	November 2016
Presentation on progress at NERRS Annual Meeting	October 2016
Imagery and lidar positional accuracy evaluated; elevation quantitative and qualitative assessment completed	December 2016
Presentation on progress at NOAA Coastal Geotools	February 2017
Supervised classification of UAS data evaluated against existing maps and similarly processed manned imagery	August 2017
Draft final report presented at NERRS Annual Meeting	October 2017 (est.)
Final report, including component evaluations and overall evaluation of system	December 2017

Contracting Status

- ▶ Initial Statement of Work submitted
- ▶ Technical proposal and pricing received June 4, 2016
 - Significantly higher costs than initially anticipated
 - Prime/sub relationship. Sub collection and processing is near what was anticipated
 - Prime's costs are mostly in lidar specialist time
- ▶ Expect to discuss options June 6, 2016.
 - May do a smaller area of lidar

Questions?

