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September 2026

FINAL Report

Long Island Sound Eelgrass Mapping and Intercomparison Study



Grant Number: F24AC01019

THE
UNIVERSITY
OF RHODE ISLAND



This project has been funded wholly or in part by the U.S. Environmental Protection Agency (EPA)'s Long Island Sound Partnership under an Interagency Agreement DW-014-925667 to the USFWS. The contents of this document do not necessarily reflect the views and policies of the U.S. EPA nor does the U.S. EPA endorse trade names or recommend the use of any products, services or enterprises mentioned in this document.

EXECUTIVE SUMMARY

During 2024 and 2025, the USFWS Coastal Program and the Long Island Sound Partnership collaborated with the University of Rhode Island to study the advantages and limitations of map products from three different remote sensing platforms (satellite, aerial, and small unmanned aerial systems (sUAS), aka drones)). Map data provide essential baseline information for federal and state government agencies, conservation groups, restoration ecologists, and the general scientific community. Drone imagery was collected twice a year (June and September) at three sites for 2024 and 2025. Aerial imagery was collected using a photogrammetric contractor in 2024, which was used as a basemap for photo interpretation and delineation of eelgrass beds. Satellite imagery from Planet.com was used to create an image classification of eelgrass extent and location. Details are provided on the logistics, data output, and analysis of each imagery acquisition platform (i.e. satellite, aerial, and sUAS). Drone results and conclusions are site specific depending on the overhead airspace as defined by the Federal Aviation Administration and include recommendations on time of the year to acquire imagery, field logistics, and the number of sites to sample. The methods for using Planet satellite imagery are described for producing image classification maps of eelgrass extent and location. Aerial and satellite map products for 2024 were compared for accuracy based on a user's versus producer's accuracy matrix. The eelgrass delineations based on aerial photography had an overall accuracy of 84% while the satellite-based mapping had an overall accuracy of 67%. The results of this intercomparison study conclude that all three platforms provide useful monitoring data that when taken collectively, can provide consistent, comprehensive, and comparable results that can be used to confidently determine trends in eelgrass distribution over decadal time scales. Therefore, a monitoring plan was developed that includes all three remote sensing platforms supported and enhanced by field surveys using divers and underwater video.

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A. INTRODUCTION

Eelgrass (*Zostera marina* L.) is the main species of submerged aquatic vegetation (SAV) found in eastern Long Island Sound (LIS). It and other species of SAV play a crucial role in ecosystem function because it provides critical habitat for juvenile marine life, helps stabilize and develop subaqueous soil, and aids in filtering particles from the water column. There are numerous threats to SAV ecosystems including: warming ocean and estuarine water temperatures, water quality and subaqueous soil pollution, and coastal development such as marinas and mooring fields. Because of these stressors, SAV habitats have been in decline world-wide including eastern LIS and in Rhode Island. As a result, these habitats are protected as “special aquatic sites” under the Clean Water Act (Section 404 (b)(1)). In addition, SAV is considered Essential Fish Habitat as defined by NOAA (<https://www.fisheries.noaa.gov/national/habitat-conservation/essential-fish-habitat>). In Long Island Sound, eelgrass meadows are identified as a priority habitat by the Long Island Sound Partnership (LIS Partnership), a collaboration of State and Federal agencies, non-governmental organizations, and academia whose mission is to “lead a collective effort to restore and care for the Sound and its watershed”. The LIS Partnership’s Comprehensive Conservation and Management Plan (CCMP), includes the Thriving Habitats and Abundant Wildlife goal which identifies the objective, *Coastal Habitat*, thus memorializing the goal to protect, enhance, and assess the extent and health of coastal habitats and their associated wildlife through restorative measures and monitoring to combat deterioration and loss. Mapping the distribution and extent of SAV is a critical first step in restoring, managing, and protecting shallow-subtidal estuarine habitats. Map data provide essential baseline information for government agencies, town planners, and the scientific community.

The standard for monitoring and tracking eelgrass trends over time is the hierarchical approach put forth by Neckles et al. (2012). Indeed, the tier 1 mapping method (based on aerial photography photo-interpretation and heads-up digitizing) has been successfully implemented in LIS since 2002. In the Chesapeake, tier 1 aerial surveys of SAV are done every year. While the tier 1 level of the Neckles et al. (2012) monitoring plan has been successful, other tiers, especially tier 2, has been less so at tracking change over yearly time scales. The tier 2 method is a rapid assessment of percent cover and canopy height using a random point located within a hexagonal grid that covers the entire study area. In Rhode Island, the tier 2

approach had limited success due to the variability of locating each sampling location. In addition, water depths often required the use of scuba divers (not available) and using a drop camera with a 0.25m² quadrat proved not to be a reliable method to determine percent cover. Lastly, we do not know any state or federal agency or conservation group that has successfully implemented all three tiers into an integrated monitoring program.

The LIS Partnership has multiple ongoing studies related to differing technologies of collecting imagery (aerial, satellite, and drones). All technologies have their own set of advantages, limitations, and criteria. For example, although the aerial surveys provide higher resolution compared to satellite imagery, some limitations include inconsistent funding for more frequent surveys, weather dependency, and current ineffective methodology to determine percent cover of eelgrass accurately and consistently within an area. While the drone surveys provide some of this information that the aerial cannot, the drone surveys do not have the same coverage as aerial and satellite imagery. Furthermore, while satellite imagery is more reliable and has greater coverage, the resolution is not as high.

B. GOALS and OBJECTIVES

The goals and objectives of this project are to conduct an intercomparison study to assess the comparability and usability between mapping technologies (drones, aerial, and satellite) during the 2024 and 2025 growing seasons. We will quantify seasonal variability in eelgrass bed density using drone imagery and underwater camera transect data at three sites during two survey windows (early and late season). We will compare costs, limitations, accuracy, and mapping products across all three technologies.

C. SMALL UNMANNED AERIAL SYSTEMS DATA COLLECTION

Five potential drone mapping sites were proposed for the intercomparison study (Figure 1.) Of the five, three were chosen for field sampling: Beebe Cove (Groton, CT), Stonington (Stonington, CT) and Barleyfield Cove (Fishers Island, NY). Mumford Cove (Site 3), was dropped due to airspace restrictions. Final sampling sites were chosen during meetings with the Long Island Sound Eelgrass Collaborative (<https://estuarineresearchreserve.center.uconn.edu/lis-eelgrass-collaborative>).

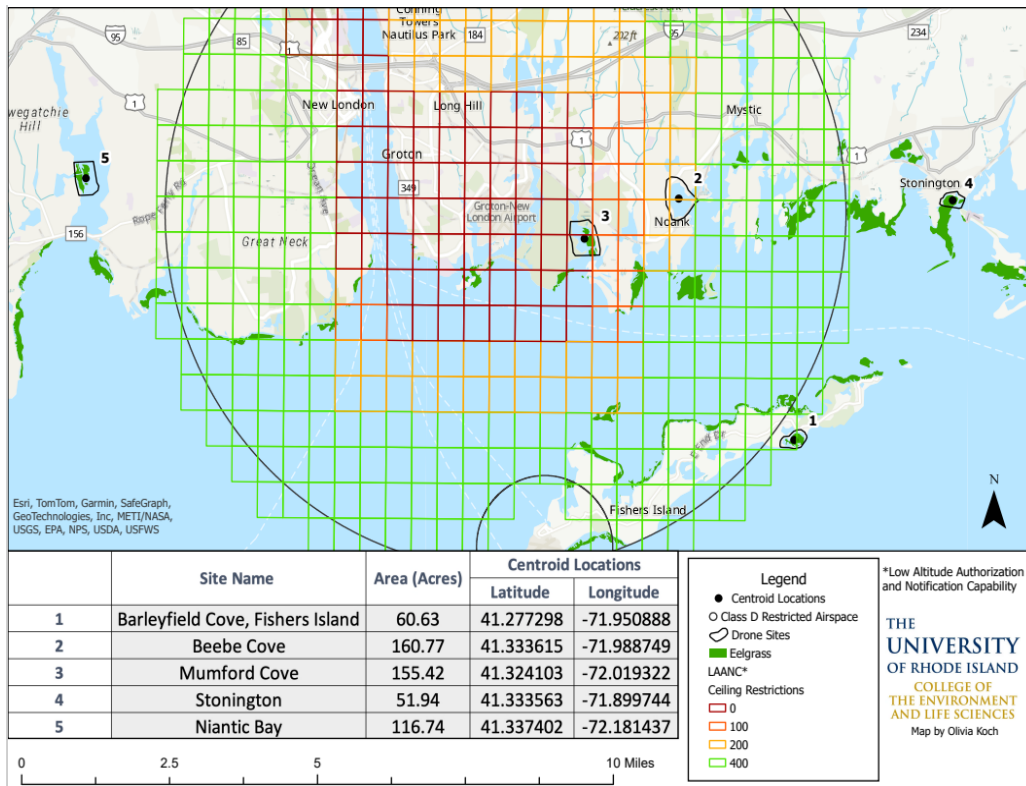


Figure 1. Five potential drone sites were proposed to the Long Island Sound Eelgrass Collaborative. Three were chosen for field surveys: Barleyfield Cove, Beebe Cove, and Stonington.

Drone imagery was collected in partnership with the state of Connecticut Department of Energy and Environmental Protection (CT DEEP) who provided certified FAA remote pilots ([CFR Part 107](#)) to collect the imagery. There are numerous rules and regulations involved with operating a sUAS. Many State and Federal agencies require this certification. Imagery was collected using a DJI Matrice 300 aircraft with a true color (RGB) Zenmuse P1 digital camera as a payload. The airspace at Beebe Cove is restricted via air traffic control at Groton-New London airport (GON) from the ground surface to 2,500ft (AGL). However, a real time waiver from the surface to 200ft AGL is available through the FAA’s Low Altitude Authorization and Notification Capability (Figure 1). In addition, Beebe Cove imagery was collected in collaboration with the Noank Rowing Club (<https://www.noankrowing.org/>) who provided boat support. All imagery was acquired at aircraft altitudes in accordance with flight height restrictions from the FAA (180 – 400 feet above ground level (AGL)). The DJI Matrice 300 is equipped with real-time-kinematic GPS positioning; however, to achieve centimeter accuracy

for imagery mosaics relative to the State Plane horizontal coordinate system (NAD 83, 2011), drone imagery was processed using ground control from a survey-grade GNSS receiver using NTRIP real-time kinematic corrections from the University of Connecticut (<http://acorn.uconn.edu/>). Drone imagery was processed using Pix4D as well as ArcGIS Drone2Map.

Results

Our goal with the drone imagery was to collect imagery two times per year: early in the growing season and late (June and September, roughly). This sampling was designed to capture seasonal changes of percent cover in eelgrass at our sites. We were only somewhat successful with this goal as we were unable to collect June 2025 imagery at Beebe Cove due to weather and our September 2025 flight turned out to be somewhat cloudier when we arrived on site. Thus, we don't have any imagery for Beebe in June 2025, and our September 2025 data processing resulted in most of the over-water areas (images) being dropped due to lack of discernable features in the imagery (turbid water). In addition, the 200 ft AGL flight restriction created much longer flight times (over 1 hour), which means more battery power is required for the aircraft, larger data sets (more photos), and more photos of just open water which could not be used during the final mosaic. For these reasons, Beebe Cove was dropped as a drone site in the final monitoring plan. Similarly, our October 2024 flight at Stonington was windier than we expected and resulted in large data gaps. However, when the imagery was able to be collected and mosaiced, discernable differences in percent cover in eelgrass between June and September were visible at Beebe and Barleyfield Coves (Table 1). In addition, when comparing available imagery collected in June versus September for a particular site, the June photography had much more complete mosaics, suggesting that the better water clarity during late spring is a better time to collect the imagery than September (Figure 2). All drone imagery is available at the University of Rhode Island's ArcGIS Online web portal:

[BARLEYFIELD](#)

[BEEBECOVE](#)

[STONINGTON](#)

Table 1. Comparison of the visibility of seasonal differences in eelgrass percent cover at Barleyfield Cove, Beebe Cove, and Stonington using the drone imagery.

Site	Percent cover differences visible in the drone imagery
Barleyfield Cove	Yes, in both years
Beebe Cove	Yes, when imagery was available
Stonington	No

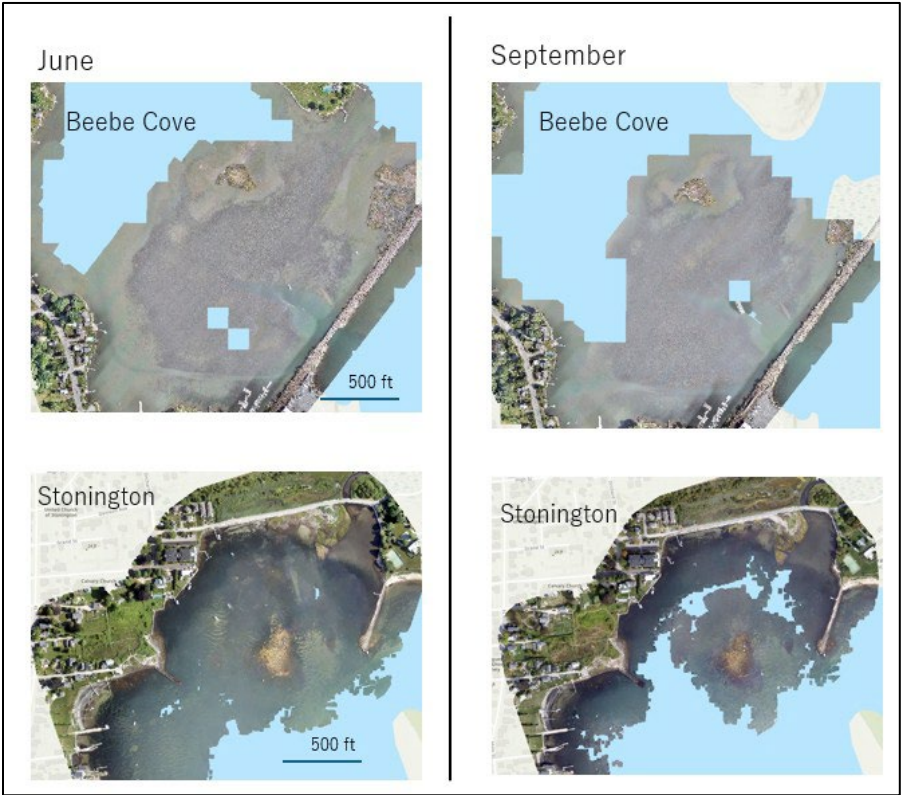


Figure 2. Drone imagery acquired in June and September was compared at two sites (Beebe Cove and Stonington). For both sites, the mosaic was more complete for the June acquisition. Photographs with no discernable features (e.g. turbid open water) are dropped during the mosaic process.

D. SATELLITE IMAGERY ANALYSIS

Imagery from Planet.com was viewed and inspected for turbidity and solar glint for low tide

days from 1 June to 30 September 2024 and 2025. Beginning in 2019, Planet.com launched SuperDove satellites in limited coverage that collect 3m 8-band imagery. Luckily, the SuperDove constellation was available for summer 2024 and 2025. SuperDove satellites acquire imagery over eastern LIS from 10:30 am – 1 pm every day. When viewing the Planet.com imagery library, available imagery was filtered based on area of interest, low tides during imagery acquisition, dates, SuperDove sensor, imagery with ground control, and imagery that has undergone internal Planet.com QAQC. Besides selecting imagery with little solar glint and turbidity, scenes with boat traffic were also identified since these would be typically low wind and sunny days. Selected scenes were then ordered from the online viewer by choosing the orthometric rectified and surface reflectance 8-band product. In addition, the Sentinel 2 harmonized option was chosen. Early growing season imagery provided by Planet.com did not look useful in terms of the spectral reflectance of eelgrass. We therefore used imagery acquired in August, September and October for mapping.

Underwater video from an underwater drop camera was recorded by boat throughout eastern LIS during summers of 2024 and 2025. Underwater video recordings were collected at the slowest boat speeds possible (~1 knot) or by drifting through the eelgrass bed. Each video file was then run through a Python script that created snapshots of the video at a predetermined time interval (~5s). In addition, the script uses an optical character recognition library to glean the lat long off each snapshot and output to a comma delimited text file (CSV). Each snapshot was then manually interpreted for habitat type: Eelgrass, Low Cover Eelgrass, Sand Shells, Macro Algae Rock, or Mix Algae / Eelgrass. Finally, all snapshots and habitat classification were combined with the lat long points in the CSV file to produce the final point GIS database.

Eelgrass Depth Analysis

A clip polygon was created as a mask for deep water in eastern LIS that does not support eelgrass. To create the mask for deep water areas, a depth analysis was conducted with a topobathy data set downloaded from NOAA's Digital Coast data portal (<https://coast.noaa.gov/digitalcoast/>). These data were collected in 2023 using a combination near-infrared and green laser wavelengths with a maximum depth penetration through the water column of 52 ft NAVD88, which is well beyond the depth that is expected for eelgrass

(https://noaa-nos-coastal-lidar-pds.s3.amazonaws.com/laz/geoid18/10273/supplemental/NOAA_NY_Long_Island_Topobathymetric_Lidar_Imagery_Report_Final.pdf). Under water video points collected during the summer of 2024 were selected for “eelgrass” only (see above) and intersected on the topobathy DEM. The depth value was extracted using the ‘Extract Multi Values to Points’ geoprocessing tool in ArcGIS to derive the depth for each eelgrass point in the database (Figure 3). Ninety-five percent of these data were less than 17 ft (NAVD88) deep, therefore all depths from 0 to -17 ft were selected from the topobathy DEM to create a depth band where eelgrass was most likely to occur. A composite image of the 0-17ft topobathy and the Planet.com imagery was made to create the final 9 band, 3 m resolution image, used for classification.

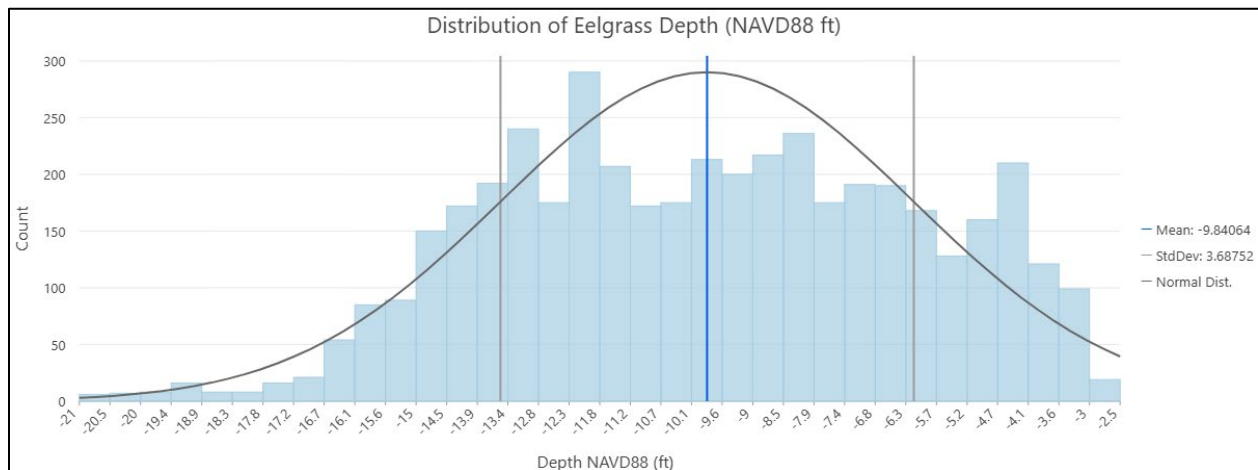


Figure 3. The histogram of eelgrass depth in eastern Long Island Sound has a normal distribution. The depths of -17 ft NAVD88 and less fall within the 95th percentile of the dataset.

The Support Vector Machine (SVM) image classification model within ArcGIS was used along with training data developed using the underwater video points to classify eelgrass on pixel by pixel basis on the composite 9-band image. The SVM model is a machine learning model that has been used successfully for mapping benthic habitats (Cui et al., 2021). The overall accuracy of the mapping was 67% (Users v Producers matrix). This lower accuracy, when compared to aerial mapping delineation, is due to areas where eelgrass and rocks and

macroalgae co-exist and are not easily discernable by the SVM model (Figure 4). In addition, areas of low cover eelgrass (~5% cover) are beyond the detection limits of the imagery.

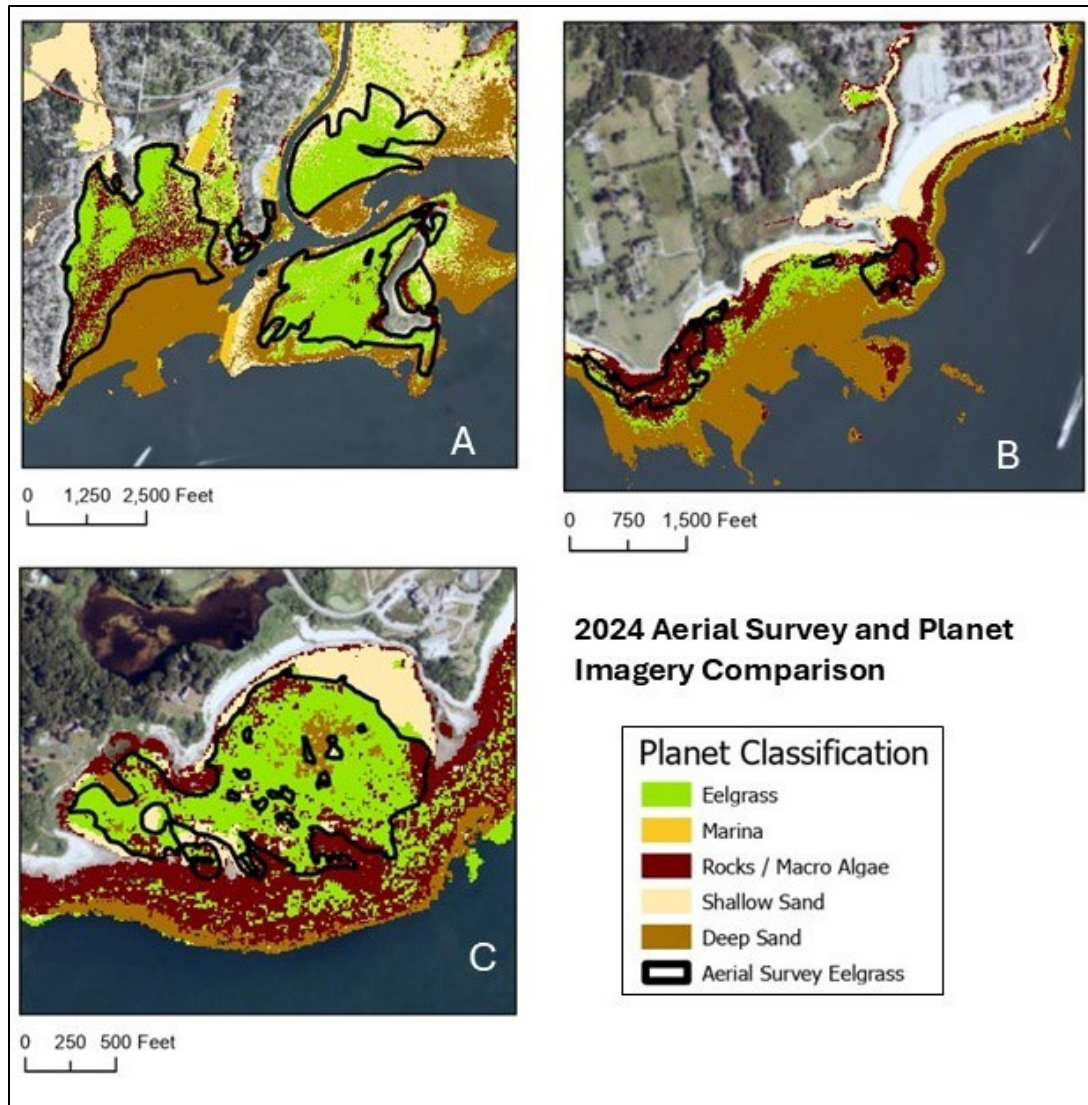


Figure 4. We compared the eelgrass extent for three sites in Long Island Sound: Groton Long Point, CT (A), Ocean Beach New London, CT (B), and Barleyfield Cove, Fishers Island, NY (C) using traditional aerial survey photography and satellite imagery acquired from Planet.com. We used the same underwater video data as validation points for both the satellite imagery image classification and the aerial imagery delineations to calculate a User's v Producers Accuracy matrix. The overall accuracy for the aerial survey was 84% while for the Planet.com survey, it was 67%. Note the difficulty the SVM model has with rocky areas (B).

E. AERIAL IMAGERY ANALYSIS

Aerial imagery mapping methods and procedures have been well documented in other reports and projects (<https://lispartnership.org/ecosystem-target-indicators/coastal-habitat/coastal-habitat-extent/>). However, for this project we analyzed and compared the timing of the aerial surveys (which happen in early June to July) to test whether it makes a difference to acquire the aerial imagery during peak biomass in August and September (Figure 5).

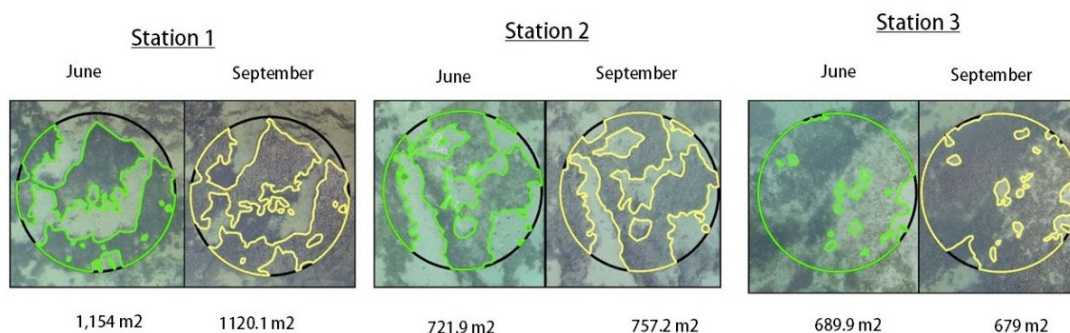


Figure 5. Drone imagery was taken at the Barleyfield Cove site in June and September of 2024. Black circles are 40m in diameter and represent vegetation plots where percent cover of eelgrass was determined by diver. As expected, percent cover of eelgrass was significantly different ($P < 0.001$) at all three stations between June and September. However, when eelgrass was manually interpreted and digitized within the 40m circle to determine eelgrass area, only station 2 had a slight increase in percent cover. These results indicate that acquiring aerial imagery early in growing season does not underestimate eelgrass area.

F. INTERCOMARISON STUDY RESULTS

Table 2. Relative cost, operational, and logistical comparison of the drone, aerial, and satellite mapping platforms.

Platform	Upfront (\$)	Operational ¹	Field Logistics ²
Drone	Medium (20-70K for a photogrammetric drone – one time purchase)	High	High
Aerial	High (~50 – 75K per mapping year for image acquisition and processing)	Medium	Medium
Satellite	Low (imagery is free)	Medium	None

1. Operational: relative cost of field work; data processing and management; analysis

2. Field logistics include permits and steps required to collect the imagery

Table 3. The benefits and limitations of the drone, aerial, and satellite mapping platforms.

Platform	Benefits	Limitations	Accuracy	Mapping Method; Metric
Drone	• Very high-resolution imagery (cm pixels) • Crews can acquire imagery on relatively short notice thus there is flexibility when acquiring the data • Relatively new technology thus there is untapped potential • Low cover areas of eelgrass (~5%) are visible	• Limited to acquisition area of about 1 mi² • Open water areas where the seafloor is not visible are very difficult to mosaic and results in data gaps • Voluminous data to process	+/- 1 cm (with ground control) +/- 1 m (without ground control)	Automated image classification; Area and percent cover
Aerial	• Imagery can be acquired for several square miles • Open water is easily acquired and is accurately mosaiced • Very good basemap for heads-up photointerpretation and digitizing of habitat • Can acquire imagery when conditions are good therefore maximizing ortho-mosaic quality • Pixels are 30 cm. • Low cover areas of eelgrass (~5%) are visible	• Solar glint is sometimes a factor • Acquisition requires a few hours of good weather • Requires a photogrammetric contractor • Mapping output is only polygons of eelgrass presence	+/- 1m	Manual digitizing of polygons using photointerpretation; Area
Satellite	• Imagery is available on demand year-round • Mapping output can include other benthic habitats such as sand and macroalgae	• Pixel resolution is the lowest of the three platforms • Resolution is not good for manual digitizing • Mapping methods can require scripting • Voluminous data to process • Low cover (~5%) are beyond the detection limits	+/- 3m	Automated image classification; Area and possibly percent cover

G. LONG ISLAND SOUND MONITORING PLAN

A good monitoring plan for eelgrass will cover the appropriate time scales and spatial resolution to account for several of the known habitat disturbances. For example, an analysis of the frequency of marine heat waves in southern New England indicates about a 3-year interval, which is the proposed interval for the aerial surveys (<https://psl.noaa.gov/marine-heatwaves/>). By including data collection strategies that span from in-water resolution (divers and underwater video), to remote sensing from space, the plan put forth is one of the more comprehensive of any known geographic region (Table 4). It is not based on tiers, but instead on the collection of several different data sets at different time scales and resolution, that are comparable to each other year after year, and when analyzed collectively, will provide a comprehensive picture of the status and trends off eelgrass in eastern Long Island Sound.

Table 4. The Long Island Sound eelgrass monitoring plan.

Monitoring Method	Frequency	Extent	Metric	Example of disturbance covered by monitoring method
Drone	yearly	3-5 sites	% cover; accuracy assessment	Coastal development
Satellite	yearly	Region wide	Area and extent	Hurricanes
Dive surveys	2x / year	2-3 sites	Seasonal % cover	Disease
Underwater video surveys	yearly	Region wide	Accuracy assessment	Disease
Aerial	Once every 3 years	Region wide	Area and extent	Marine heat waves

H. ACKNOWLEDGEMENTS

This project was funded through the Interagency Agreement DW-014-925667 from the Long Island Sound Partnership to the USFWS Southern New England and New York Coastal Program. The authors would like to thank: Remote Pilots in Command Charles Morrison, Dan Denyer, and Matt Green from CT DEEP who provided drone operations; MacKenzie Payne with USFWS, who provided field technical support; University of Rhode Island undergraduates Alyssa Ronan and Slate Northington, who provided GIS support and image habitat classification; the LIS Eelgrass Collaborative provided outreach and science communication for the project; and lastly but certainly not least, the EPA Dive Team who collected eelgrass percent cover estimates. Special appreciation for Thomas Halavik, boat captain extraordinaire!