2021 Tier 1 Mapping of Submerged Aquatic Vegetation (SAV) in Rhode Island and Change Analysis

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Photo: Aerial oblique view of the SAV mapping team (Photo credit: NBNERR).

Photo: Typical underwater scene from Narragansett Bay with a mix of *Codium* and *Zostera*.

INTRODUCTION

In Rhode Island (RI), submerged aquatic vegetation (SAV) has been deemed a critical marine resource and is currently protected by both Federal (Clean Water Act; 33 U.S.C. 26 § 1251 *et seq.*) and state regulations (RI Coastal Resource Management Council (CRMC); 650-RICR-20-00-1.3.1(R). Eelgrass (*Zostera marina* L.) and other species of rooted submerged aquatic vegetation (*Ruppia maritima* primarily) play a crucial role in ecosystem functions by providing critical habitat for juvenile marine life, filtering particles from the water column, and help stabilize and develop subaqueous soil (Dennison et al. 1993; Fonseca 1996; Bradley and Stolt, 2006). Furthermore, many species of commercially important finfish and shellfish are directly dependent on SAV beds for refuge, spawning, attachment, and food (Laney, 1997). As such, the Atlantic States Marine Fisheries Commission (www.asmfc.org) has a stated policy on the assessment, protection, and study of SAV as a recommendation for all member States (ASMFC Habitat Committee, 1997).

Mapping the distribution and extent of eelgrass is a critical first step in understanding, managing, and protecting shallow-subtidal estuarine habitats. GIS data provide essential baseline information for government agencies, municipalities, and the scientific community. Neckles et al. (2012) proposed a 3-tiered hierarchal strategy for mapping and monitoring SAV in estuaries of the northeastern U.S. The smallest scale of these tiers (Tier 1), utilizes true-color aerial photography whereby photo signatures of SAV are interpreted and delineated using orthophotography (aerial photographs with the distortion removed). In RI, a collaborative committee (The RI Eelgrass Mapping Taskforce) was established to implement and modify (as needed) the Neckles et al. (2012) monitoring protocols to include Tier 1 mapping at 3-5 year intervals (Raposa and Bradley, 2009). The Taskforce has included a variety of partners from Federal, State, and non-governmental organizations including USEPA, USFWS, Save The Bay, The Watch Hill Conservancy, RIDEM, and the Narragansett Bay Estuary Program in addition to the authors' affiliations.

The goals of the 2021 survey were similar to previous surveys: 1) conduct a comprehensive regional survey of SAV utilizing the methods put forth by the Eelgrass Mapping Taskforce. These methods include orthophotography acquired in early summer 2021 to be used as a base-map and extensive fields surveys, and 2) examine trends of SAV using the data collected from the previous Tier 1 surveys (2006, 2009, 2012, and 2016).

METHODS

Aerial Photography Acquisition

Digital four-band (true color and infra-red) aerial photographs of Narragansett Bay, Block Island, and the coastal ponds (total area of interest = 418 mi^2), were taken by a photogrammetry vendor (NV5 Geospatial.) utilizing two flights on June 6th and June 18th, 2021 (Figure 1). The photographs were taken following NOAA's Office of Coastal Management guidelines (Finkbeiner et al., 2001). Based on these guidelines, photographs were taken at a low sun angle, two hours within low tide, when wind and atmospheric haze where minimal, and when water clarity was high. Altitude of the aircraft during photo acquisition was about 16,000 ft (NV5 Geospatial, 2021). The vendor was chosen by utilizing the USGS Geospatial Product and Service Contracts (https://www.usgs.gov/programs/national-geospatial-program/geospatial-products-and-services-contracts).

Accuracy assessments of the orthophotography product were done by NV5 Geospatial using 20 GPS control points (NV5 Geospatial, 2021). Locations of features (e.g. manholes, parking lot lines) on the ground and also visible in the photography were compared and statistically analyzed. The listed accuracy of the orthophotography was 1.725 ft (NSSDA; 95% CI), which corresponds to a scale of about 1:2400 following National Map Accuracy Standards (www.fgdc.gov). The pixel resolution of the orthophotography (ground sample distance) was 1 foot.

In December 2021, 1,012 individual orthophotography tiles (241 gigabytes) were delivered on external hard drives to the URI Environmental Data Center. The photography was copied to a lab server for internet distribution utilizing ArcGIS 10.9.1 Server Image Service technology. The orthophotography could then be viewed in ArcGIS (and on the internet) utilizing a singular data connection.

Photo-interpretation

Initial SAV delineations and areas to be ground-truthed were identified by eye and digitized on-screen by hand using draft orthophotography as a base map delivered to URI in August 2021. Historical data sets (including GPS ground truth points) were also used as supplemental sources to aid in photo interpretation. Areas that have historically supported SAV were targeted first for the photo interpretation of new beds. However, to avoid any bias, digitizing of the 2021 polygons was always done with historical data sets turned off. All digitizing was conducted at approximately a scale of 1:1500.

Field Surveys

Surveying in the field was conducted by boat or kayak between August and October 2021 (eleven field days total) in collaboration with CRMC and NBNERR. SAV photo-signatures from true-color aerial photographs can be highly variable and flight specific, thus every effort was made to conduct the field surveys during the same year the photographs were taken. The presence of SAV was determined using underwater video recordings with GPS overlay (SeaViewer, Inc.). Not all polygons were field visited this year.

The goals of the field surveys were to verify digital photo signatures of SAV, to assess the imagery quality for identification of the deep water edge of SAV beds, and verify areas of change from the 2016 mapping effort. Initial SAV delineations and imagery tiles were taken into the field and viewed simultaneously with GPS position using a Trimble GPS device with 1-m real-time horizontal accuracy. The deep water edge of the 2021 imagery was not clearly visible at many sites so GPS and video data were used to estimate the extent of SAV beds in deeper water and to delineate the deepwater edge.

GPS data points were collected and coded for presence of SAV within and at the edge of SAV beds. The edge of an eelgrass bed was defined as when cover dropped to approximately 5%. Final SAV delineations were adjusted using the ground truth data (GPS points). In the GIS database, polygons were coded with a habitat type (eelgrass or widgeon grass), most recent ground–truth year (e.g. 2016, 2012, 2006), ground-truth method, and site name (e.g. Jamestown).

Accuracy Assessment

SAV mapping delineations were analyzed for accuracy using a user's versus producer's accuracy matrix (Story and Congalton, 1986). Underwater video recordings with GPS overlay were converted to GIS (point file) by analyzing the underwater video track recordings at approximately 30 second intervals. At each 30 second interval in the video recording, the GPS location and the presence or absence of SAV was recorded and converted to a GIS point-file. In total, 1238 video points were interpreted. Before the final SAV interpretation and delineation process began, 10% of these points were randomly withheld and set aside. The interpreted video points (minus 10%) were then used to create the final polygon database. After the final delineations were completed, the withheld points were intersected with the final polygons and tabulated for mapping errors. For example, an error of omission would be noted if a withheld point indicated the presence of SAV but it did not intersect with the final mapped delineations.

RESULTS

During the summer and fall of 2021, we collected over 15 miles of underwater video in Narragansett Bay for the purposes of identifying and delineating SAV beds in Rhode Island. we collected 1344 field points of SAV presence or absence using GPS and boat observations. Using the field survey data along with the aerial photography as a basemap to identify photo-signatures of SAV, we mapped 187 polygons of SAV totaling 999 acres in coastal Rhode Island (Figures 2 and 3). In addition, the SAV mapping for 2021 had a user's and producer's accuracy of 83%.

Most of the SAV acreage (96%) is eelgrass while the remaining is widgeon grass or a mixture of eelgrass and widgeon grass. It should be noted that some of the largest delineations of widgeon grass, primarily within Greenwich Bay, were not field visited due to time constraints. The largest SAV bed observed in Rhode Island is 88 acres in Little Narragansett Bay (Westerly, RI). This particular SAV bed has been the largest since Tier 1 mapping has been conducted in RI by the USFWS in 2002.

In order to view all the Tier 1 mapping efforts, we compiled all of RI Eelgrass Mapping Taskforce data (imagery and polygons) through 2021 in a single web application which can be found at the URL below:
https://edc.maps.arcgis.com/apps/webappviewer/index.html?id=ed8de382fa414c60b82ceaf881232994

Table 1. The users versus producers accuracy matrix for the 2021 eelgrass mapping effort. A total of 121 video locations were withheld (reference data) to identify errors during the photointerpretation and delineation process (classified data). The overall user's accuracy is **83%**.

Reference data \ Classified Data	eelgrass	not eelgrass
eelgrass	45	10
not eelgrass	10	56

DISCUSSION

During the summer and fall of 2021, we mapped 999 acres of SAV utilizing consistent methods and protocols from previous Tier 1 mapping efforts in 2006, 2009, 2012, and 2016. These methods utilize extensive field surveys with a geo-referenced underwater video system in tandem with draft delineations from contemporaneous aerial imagery to identify photo signatures of SAV. The field surveys are critical to accurately classify areas where SAV is difficult to delineate due to deep water, rocks, macro algae, or inconsistencies in the aerial imagery base map. In addition, underwater video systems provided accurate estimations of seagrass percent cover when compared against diver surveys of seagrass percent cover (August et al., 2021). An accuracy assessment conducted for the 2016 mapping effort found that 27% of the final SAV acreage was identified as a result of the field survey efforts, resulting in a user's accuracy of 89% for the 2016 Tier 1 survey (Bradley et al., 2019). Similarly, this year's SAV delineations and classification had a user's accuracy of 83%.

The 999 acres mapped in 2021 corresponds to a general decrease of SAV in all of the study area of about 28% since the RI Eelgrass Mapping Taskforce began mapping all coastal RI waters in 2012 (Figure 3). Most of the declines in SAV during this time period have occurred in the coastal ponds (or lagoons) along the south shore of RI and in the Narrow River (Figures 3 and 4)

However, over that time span in Narragansett Bay, SAV acreages have been relatively consistent (with the exception of a slight decrease in 2016) over the four mapping efforts in 2006, 2012, 2016, and 2021 (Figure 3). And in fact, generally the Bay has sustained the observed increase in SAV since the first comprehensive survey of SAV in 1996 (Bradley et al., 2017). The west passage of Narragansett Bay, in particular, has seen increases in eelgrass since 2012 (Figure 5).

In summary, the 2021 SAV tier 1 survey for Rhode Island mapped 999 total acres (83% user's accuracy), which generally is a decrease in the acreage mapped in previous years, especially in the coastal ponds of the south shore. Future surveys will be aided by the archive of all the underwater video recordings for 2021, the first year which we had this ability. In addition, we developed Python scripts to automate the management, analysis, and geo-referencing of underwater video recordings, saving staff time and increasing the efficiency of the Tier 1 mapping process. However, in order to increase the confidence in the trends we are observing, yearly Tier 2 (percent cover assessments) should be implemented at select sites in RI and Tier 1 surveys should be conducted every 3 years.

With this effort in 2021, the RI Eelgrass Mapping Task Force continues to be well-suited with the methods and technology to assess the likely future challenges to this critical and endangered habitat in the face increasing estuarine water temperatures and inhospitable subaqueous soils due to climate change. For more information on the Task Force, please contact the corresponding author.

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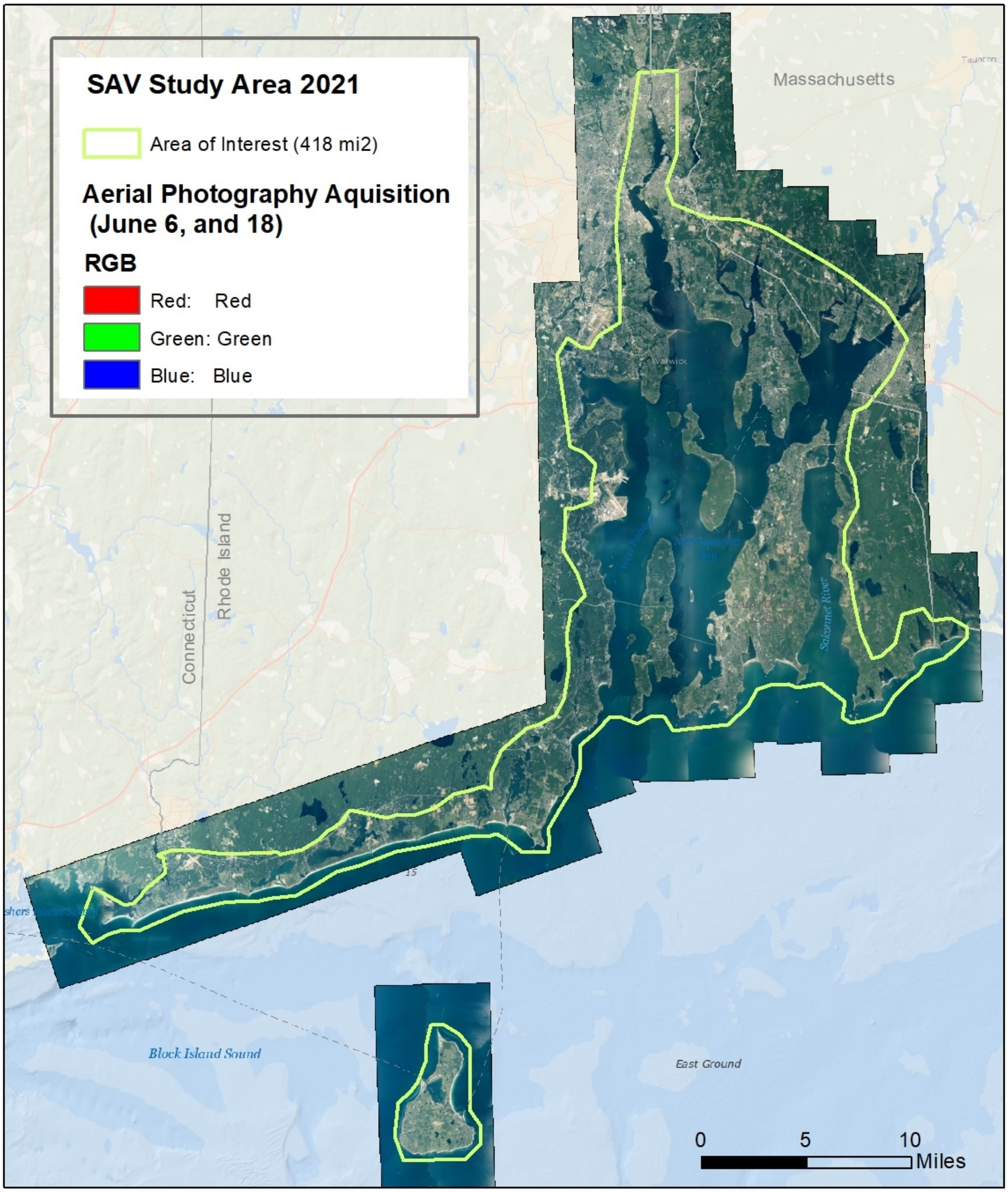


Figure 1. Aerial photography for the SAV base map was collected on June 6 and 18, 2021.

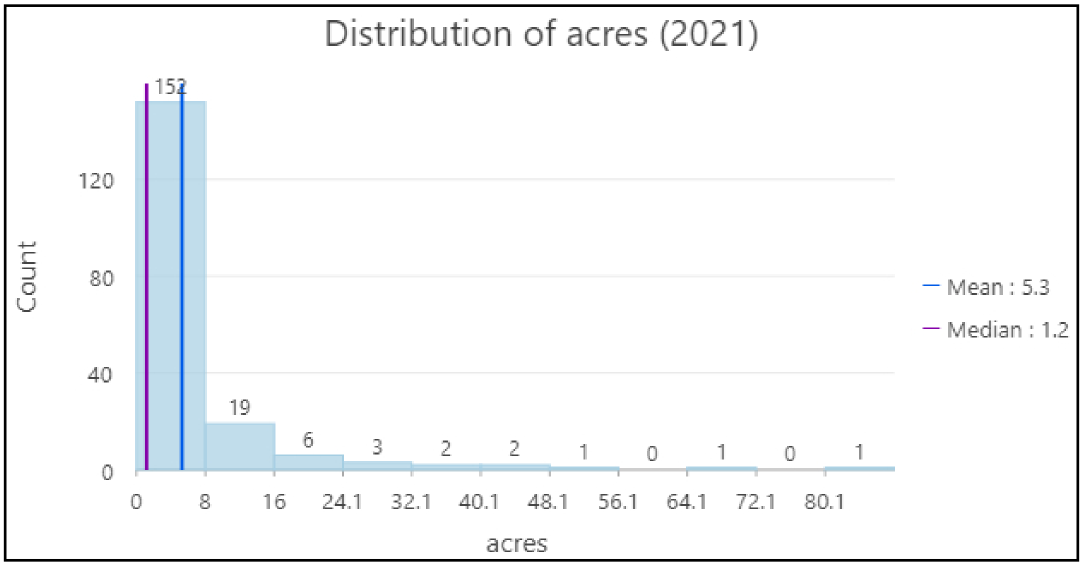
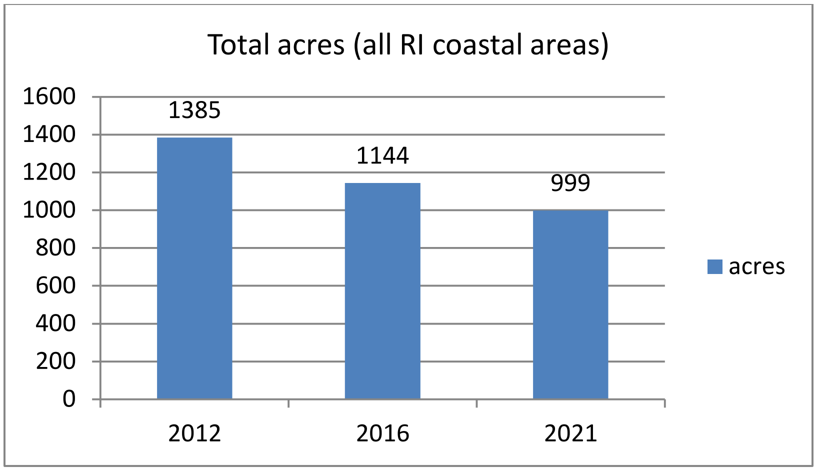
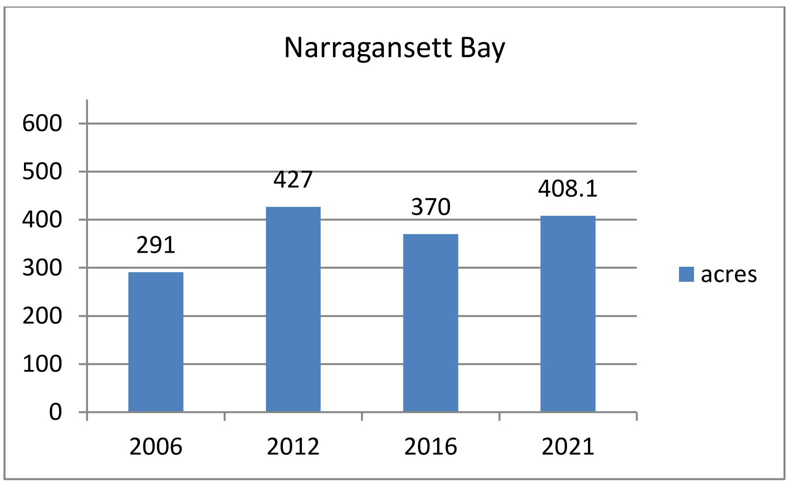


Figure 2. A large majority of the polygons were ≤ 8 acres according to a histogram of the distribution of the size (in acres) of the polygons mapped in 2021. The minimum mapping unit was 0.02 acres (1000 ft^2), but 79% of the polygons were ≥0.25 acres.





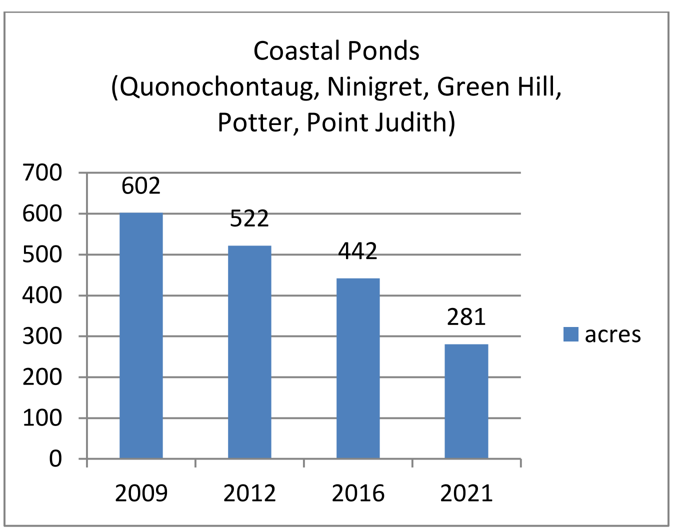


Figure 3. The SAV trends for all of Rhode Island, Narragansett Bay, and the coastal ponds.

Figure 4. The acreage of eelgrass in the Narrow River has declined considerably since 2012 as noted with the lack of any photo-signature of eelgrass in the 2021 aerial imagery. Field surveys in 2021 confirmed the lack of eelgrass in this area.

Figure 6. The acreage of eelgrass in the west passage of Narragansett Bay increased in 2021 as noted by the dark photo signature in 2021 and verified with field surveys. Note the lack of a photo-signature of eelgrass in the mooring field in 2012 and 2016.