2016 Tier 1 Mapping of Submerged Aquatic Vegetation (SAV) in Rhode Island and 20-year Change Analysis

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INTRODUCTION

Eelgrass (*Zostera marina* L.) and other species of submerged aquatic vegetation (SAV) play a crucial role in ecosystem function by providing critical habitat for juvenile marine life, helping stabilize surface sediments, and filtering particles from the water column (Dennison et al. 1993; Fonseca 1996). 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). In Rhode Island (RI), SAV has been deemed a critical marine resource and is currently protected by both Federal (Clean Water Act; 33 U.S.C. 26 section 1251 et seq) and state legislation (RI Coastal Resource Management Plan, Section 300.18).

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, including tier 1 mapping at 3-5 year intervals (Raposa and Bradley, 2009).

Over the past 20 years, there have been several Tier 1 mapping projects in RI (Table 1), with most covering only a portion of the state. Beginning in 2012, at the recommendation of the Eelgrass Mapping Taskforce, all coastal waters in Rhode Island were mapped in one year for the first time (Bradley et al., 2013).

The goals of the 2016 survey were similar to previous surveys: 1) conduct a comprehensive survey of SAV (primarily eelgrass and to a lesser extent widgeon grass (*Ruppia maritima*)) in RI coastal waters, and 2) examine trends of SAV using the data collected from the previous Tier 1 surveys. To accomplish our second goal, we selected datasets from Table 1 that, in our estimation, are the most comparable considering survey methods, technology, and study area extent.

METHODS

Aerial Photography Acquisition

Digital four-band (true color and infra-red) aerial photographs of Narragansett Bay, Block Island, and the coastal ponds were taken by a photogrammetry vendor (Quantum Spatial Inc.) on June 15th and 26th, 2016 (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 (Quantum Spatial, 2016). Water clarity was measured by volunteers using secchi disks as target dates for acquisition of aerial photography approached. The vendor was chosen by utilizing the USGS Geospatial Product and Service Contracts (https://geodatacontracts.er.usgs.gov/gpsc_information_sheet.html).

Shortly after the photography was acquired, samples were sent to project leaders for review and comment. After approval, photography was ortho-rectified (distortions removed), color balanced, mosaicked, and projected to the Rhode Island State Plane Feet (NAD83) coordinate system.

Accuracy assessments of the orthophotography product were done by the Quantum Spatial Inc. using GPS control points. 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 1.068 m (NSSDA; 95% CI), which corresponds to a scale of about 1:1200 following National Map Accuracy Standards (Quantum Spatial, 2016). The pixel resolution of the orthophotography was 0.5 m.

In September 2016, 96 individual orthophotography tiles (117 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 10.4 Server Image Service technology. As a result, the orthophotography could be viewed in ArcMap (and on the internet) utilizing one data connection.

Photo-interpretation

Initial SAV delineations and areas to be ground-truthed were identified by eye and digitized on-screen by hand using the orthophotography as a base map. 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 2016 polygons was always done with historical data sets turned off. All digitizing was conducted at around a scale of 1:1500. The minimum mapping unit was 0.03 acres, but 87% of the polygons were ≥0.25 acres.

Field work and ground-truthing

Ground-truthing in the field was conducted by boat or kayak between September and October 2016 (nine field days total). Observations of eelgrass wrack lines were also made as an indicator of the presence of an eelgrass bed in the area. SAV photo-signatures from true-color aerial photographs can be highly variable and flight specific, thus ground-truthing was conducted during the same year the photographs were taken. The presence of SAV was determined using an underwater video camera (SeaViewer, Inc.). Not all polygons were ground-truthed this year.

The goals of ground-truthing 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 2012 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 2016 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 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 5-10%. 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).

Change Analysis

At least three time series of Tier 1 data (and corresponding orthophotography) were used for the change analysis of eelgrass (Table 1). In all cases, datasets used in the change analysis were carefully analyzed for consistency in the study area extent as well as comparability in terms of project methods and techniques. For example, in Little Narragansett Bay, USFWS coded polygons as ‘low’ eelgrass cover (≤5 % cover); these were removed from the dataset since our mapping protocols only include areas with ≥ 5% cover. Additionally, the acreages for Narragansett Bay do not include the *Ruppia* mapped in Greenwich Bay in 2012 and 2016. The 1996 dataset was not included as a whole due to inconsistencies in the ground-truth and stated problems with identifying the deep water edge of eelgrass beds (Huber, 1999). However, we did include the 1996 acreage for Prudence Island because it was ground-truthed by boat and with divers (Save The Bay, personal communication). The 1999 mapping of SAV for the coastal ponds was comprehensive and the corresponding report includes maps of the field sites visited (Huber, 2003). We therefore report those acreages here but it should be noted that we do not have any digital orthophotography for either 1996 or 1999 so re-examination of the mapping (i.e. polygon overlay on top of the photography) to confirm changes on a site-by-site basis was not possible. In order to define our sites for the change analysis, we identified 12 sites based on comparability of the datasets (Figure 2).

RESULTS

Over 844 GPS locations were collected during the late summer and fall of 2016. Using these field surveys and the 2016 orthophotography, 187 polygons of SAV were delineated totaling 1,144 acres. This represents about an 18% decrease of SAV acreage in Rhode Island coastal waters from 2012. A web map was created of the 2016 and 2012 delineations which can be found at **https://tinyurl.com/lqjam4p**.

Most of the SAV in the study area (91%) was eelgrass and eelgrass surveying was the focus of the ground-truthing field work. As such, no widgeon grass was noted on any field forms. However in our final mapping, we did delineate widgeon grass beds in Greenwich Bay (25.4 acres) and a mixture of eelgrass and widgeon grass (83 acres) in Ninigret and Green Hill ponds based on the 2012 field observations of widgeon grass in these areas. Due to time constraints, we were unable to ground-truth the polygons in Ninigret and Green Hill ponds in 2016.

Between 2012 and 2016, SAV acreage declined at most sites that we analyzed (Table 2). The sites with the largest decline in eelgrass acreage between the two years are: Quonochontaug (52%), Point Judith (48%) and Little Narragansett Bay (25%). Even though Jamestown had a decrease of eelgrass acreage (19%), this site and Ninigret Pond continue to have the most eelgrass of any sites in RI. Additionally, Ninigret was the only coastal pond to not have a decrease in acreage. The Narrow River was the only site in the study area that had a large increase in eelgrass acreage from 2012 to 2016 (45%) (Table 2).

Long-term Change Analysis

With the completion of the 2016 mapping effort, we have consistent and comparable data for three years (2006, 2012, and 2016) over a 10 year period for Narragansett Bay. Because of the difficulties of the 1996 Tier 1 mapping effort (Huber, 1999; Bradley et al. 2013) a Narragansett Bay-wide trend analysis was not conducted using these data. The 2016 acreage of eelgrass in Narragansett Bay is less than in 2012 but more than was reported in 2006 (Figure 3).

For the coastal ponds, we have four data sets dating back to 1999 (Figure 4). Generally it appears that since 2009, SAV in the coastal ponds has been decreasing at a rate of almost 23 acres/year (Figure 4). Quonochontaug Pond has seen a dramatic decrease of 61% of its eelgrass beds since 2009 (8 acres/year). Potter Pond had a decrease of 39% from 1999 to 2009 but has maintained about 70 acres of SAV ever since. A notable exception is Ninigret Pond, which has had about 200 acres of SAV every year since 2009, an increase of 42 acres since 1999.

SUMMARY and DISCUSSION

The methods outlined by the RI Eelgrass Mapping Taskforce (Raposa and Bradley, 2009) have now been successfully implemented for two state-wide Tier 1 mapping efforts (2012 and 2016). However, since we observed a decrease in 2016 from 2012, we still have not observed a consistent positive or negative trend in SAV in Narragansett Bay since 2006. Any actual trends, should they exist, will only be identified by conducting additional Tier 1 efforts in future years.

Given the differences in methods and difficulties of the 1996 survey, we did not use the total acreages reported for Narragansett Bay in that study (Huber, 1999; Bradley et.al, 2013). However, if we assume that a majority of the error associated with the 1996 survey is an error of omission, then any increase in acreage from 1996 to the present is still probably larger than any mapping error associated with the 1996 study. This view was substantiated by scientists involved in the 1996 study (Chris Deacutis, pers comm). The increase is reflected in the acreages for Prudence Island for which we have particular confidence given the ground-truthing work conducted there in 1996 (Figure 3). In addition, we have now mapped Prudence Island with consistent methods three times over a ten-year time span (2006, 2012, 2016). During this time, eelgrass has averaged 33 acres / yr (STD= 5.8), an average well above the 9 acres mapped there in 1996. We have also looked more closely at two other small sites within Narragansett Bay mapped in 1996 (Bradley et al. 2007) and found that at these sites, eelgrass acreage also increased between 1996 and 2006. If we use the trend of eelgrass at Prudence Island as a proxy for the rest of Narragansett Bay, we are confident that SAV, and eelgrass in particular, has expanded considerably in Narragansett Bay over the past 20 years. However, the magnitude of the increase in Narragansett Bay over this time is still difficult to ascertain given the deficiencies of the 1996 mapping effort.

In 1999, the Natural Resources Assessment Group mapped coastal wetlands and SAV for all the coastal ponds of southern RI giving us four observations over a 17-year period. The report by Huber (2003) contains an appendix of all the field sites visited during that summer so the methods are somewhat comparable to the more recent mapping efforts. The appendix does not include any field maps for southwestern Point Judith Pond however, a location where eelgrass has occurred during every subsequent mapping effort. This may explain the somewhat low acreages reported for Point Judith Pond in 1999. Notwithstanding, the 1999 data are a valuable data point and give some insight into the historical extent of SAV in the coastal ponds.

While we have seen recent declines of eelgrass in Narragansett Bay and the coastal ponds, one site in particular has seen a substantial increase. From 2012 to 2016, eelgrass acreage has increased by 48% in the Narrow River (Figure 2; Table 2). Unfortunately, the Narrow River was not part of the study area during the 2006 mapping effort. But upon re-examination of the 2006 photography however, we observed photo-signatures that were most likely eelgrass. We examined some historical leaf-on imagery of the Narrow River taken during the growing season in 2003 and observed no eelgrass (Figure 5). Interestingly, we also observed in the 2003 imagery the removal of the small culverts which constricted tidal flow into the river (Figure 5). Based on the presence of eelgrass in 2006, we believe that the restoration of tidal hydrology in 2003 had a dramatic positive effect on eelgrass in the Narrow River.

RECCOMENDATIONS

We are making progress toward understanding the extent and dynamics of SAV in RI coastal waters but more data are needed to begin to quantitatively assess trends on the decadal-time scale. During the summer of 2017, we will conduct an error assessment of the Tier 1 surveys, which will give us an idea of some of variability and uncertainty associated with these surveys. In addition to more large-scale mapping (e.g., 1:500) with un-manned aerial systems (or drones), we recommend conducting statewide mapping at least every three years to increase the confidence in acreage totals for the sites and sub-sites. The current specification for the orthophotography is a 0.5 m pixel resolution. At this resolution, the vendor collected the images at 16,000 feet above ground level (Quantum Spatial, 2016). At this altitude, the deep water edges of many sites were difficult to discern which is important considering not all eelgrass beds can be ground-truthed every year. Therefore, more large-scale orthophotography is likely needed (e.g. 0.25 m or 0.3 m). Lastly, we need to continue and expand the implementation of the complementary Tier 2 and 3 of the monitoring protocol described by Raposa and Bradley (2009) in order to increase the granularity of mapping and monitoring efforts.

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TABLES

Table 1. A list of all the Tier 1 mapping efforts conducted that include sites in RI coastal waters.

Year	Geographic Area Covered	Authors
1996	Narragansett Bay	NBEP; NRAG
1999	Coastal Ponds	NBEP; NRAG
2002	Little Narragansett Bay	USFWS
2006	Little Narragansett Bay	USFWS
2006	Narragansett Bay	RI Eelgrass Mapping Taskforce
2009	Little Narragansett Bay	USFWS
2009	Coastal Ponds	RI Eelgrass Mapping Taskforce
2012	Little Narragansett Bay	USFWS
2012	Rhode Island	RI Eelgrass Mapping Taskforce
2016 (this study)	Rhode Island	RI Eelgrass Mapping Taskforce

NBEP = Narragansett Bay Estuary Program
NRAG= Natural Resources Assessment Group (University of Massachusetts, Amherst, MA)
USFWS = US Fish and Wildlife Service

Table 2. Calculations of eelgrass change for sites within the study area from 2012 to 2016.

Location	**2012 (acres)**	**2016 (acres)**	**%change**
Narragansett Bay	422	389	-8
Coastal Ponds	522	442	-19
Rhode Island Sound	104	108	+4
Little Narragansett Bay	127	96	-25
Sub-sites			
Prudence Island	37	35	-5
Jamestown (Conaniticut)	222	187	-16
Point Judith Pond	101	52	-48
Potters Pond	67	67	0
Quonochontaug Pond	71	34	-52
Green Hill Pond	91	88	-3
Ninigret Pond	193	201	+4
Narrow River	24	44	+45

FIGURES

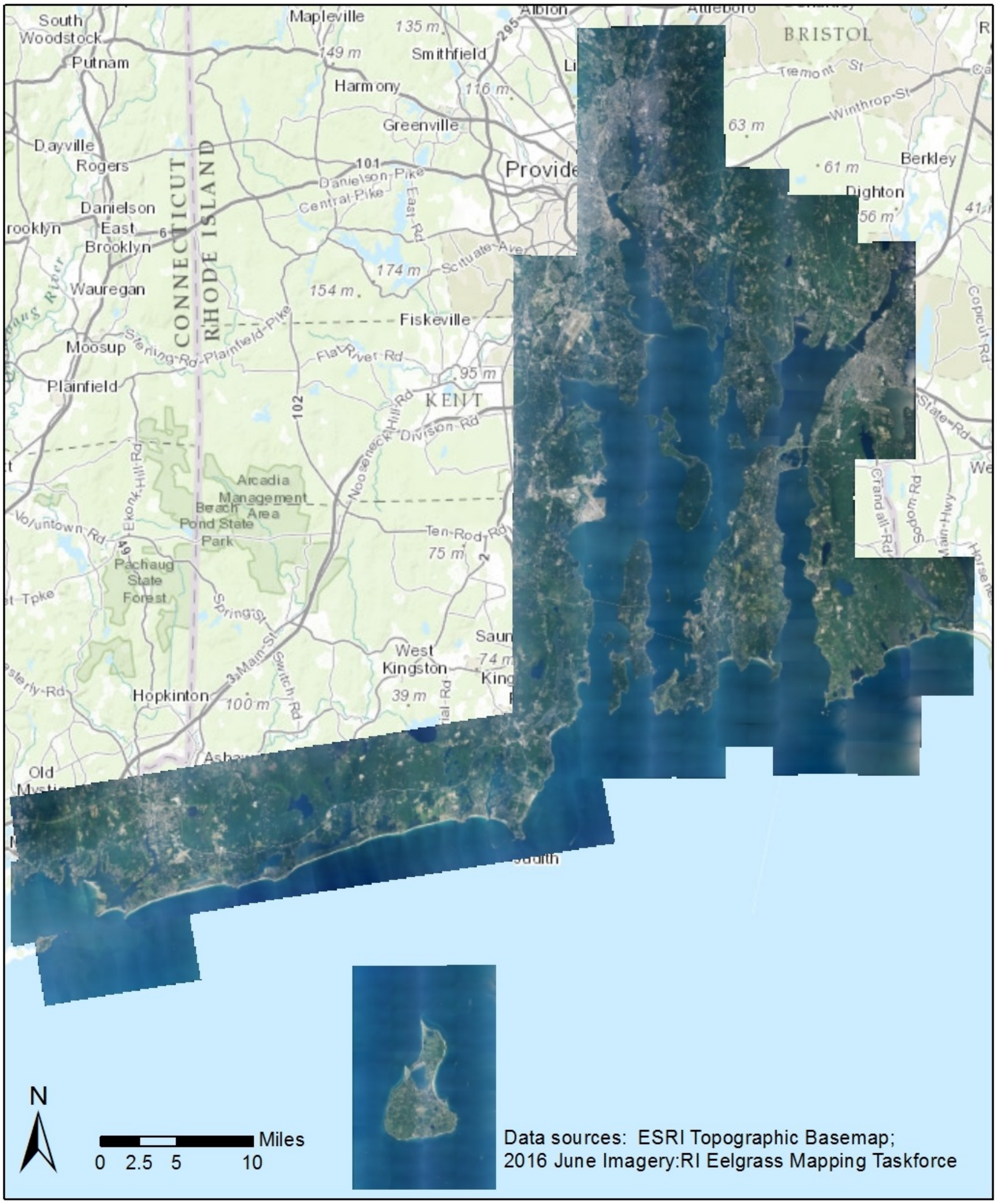

Figure 1. The extent of the 2016 imagery.

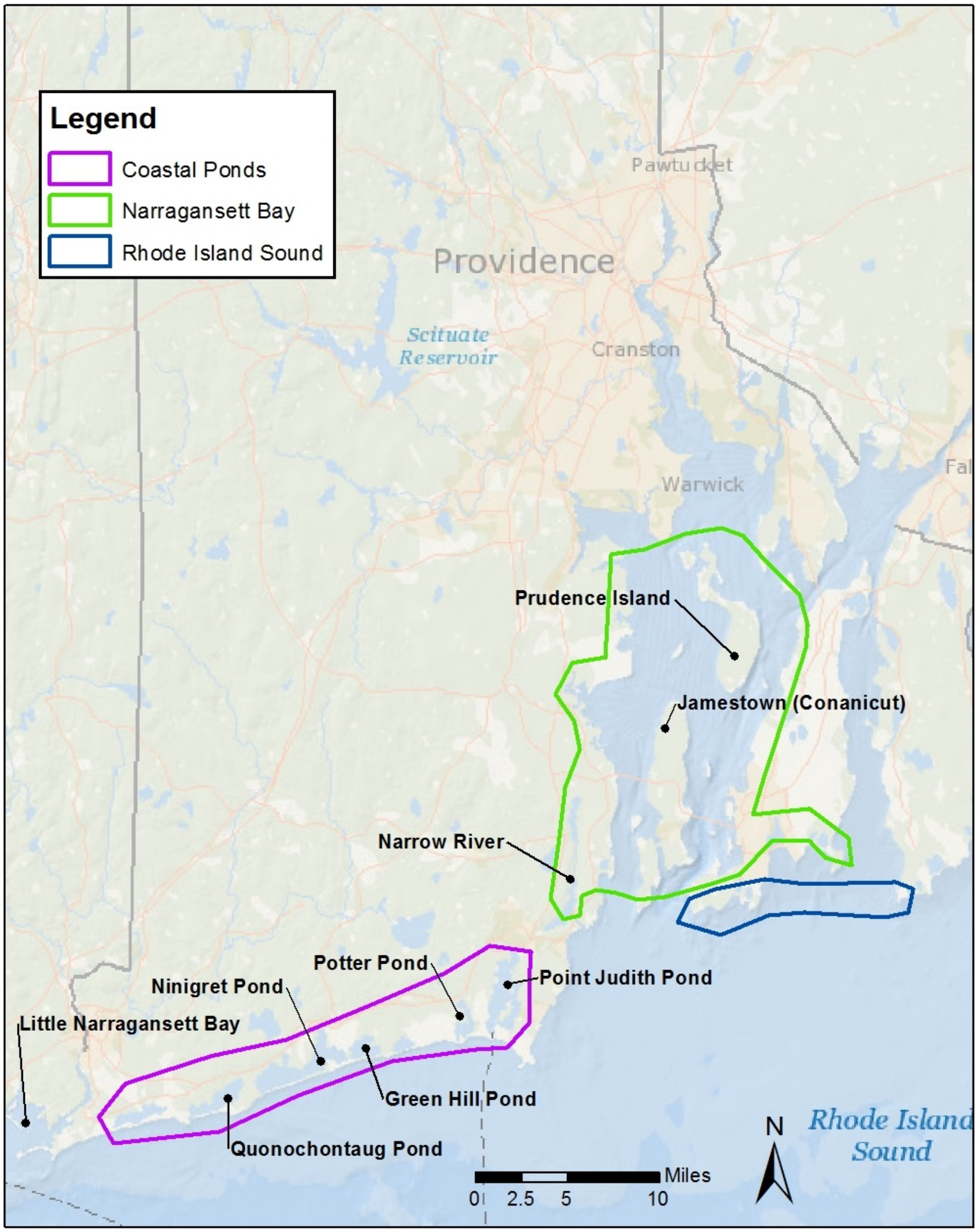

Figure 2. The twelve sites chosen for the eelgrass trends analysis.

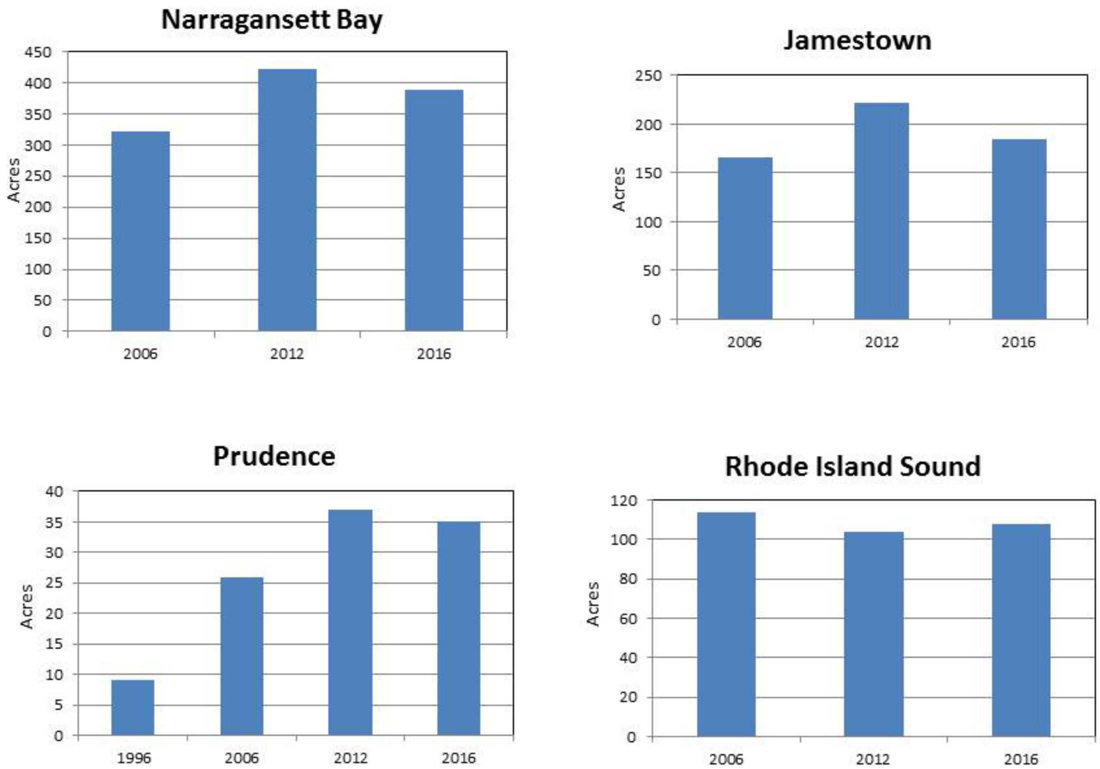

Figure 3. The eelgrass trends for Narragansett Bay, Jamestown, Prudence, and Rhode Island Sound.

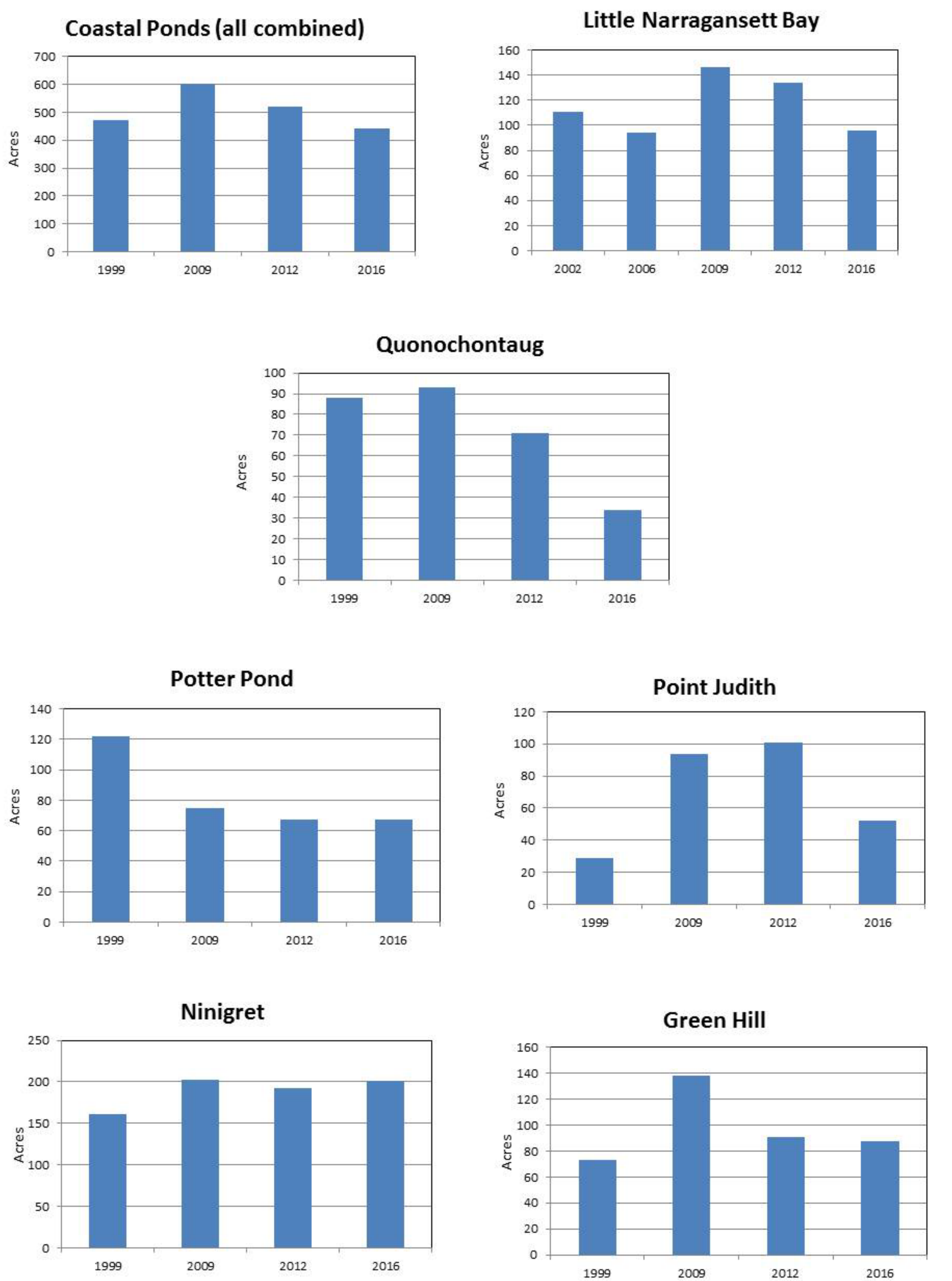

Figure 4. The eelgrass trends for the all the coastal ponds combined, Little Narragansett Bay, and the individual coastal ponds that we included in our trends analysis.

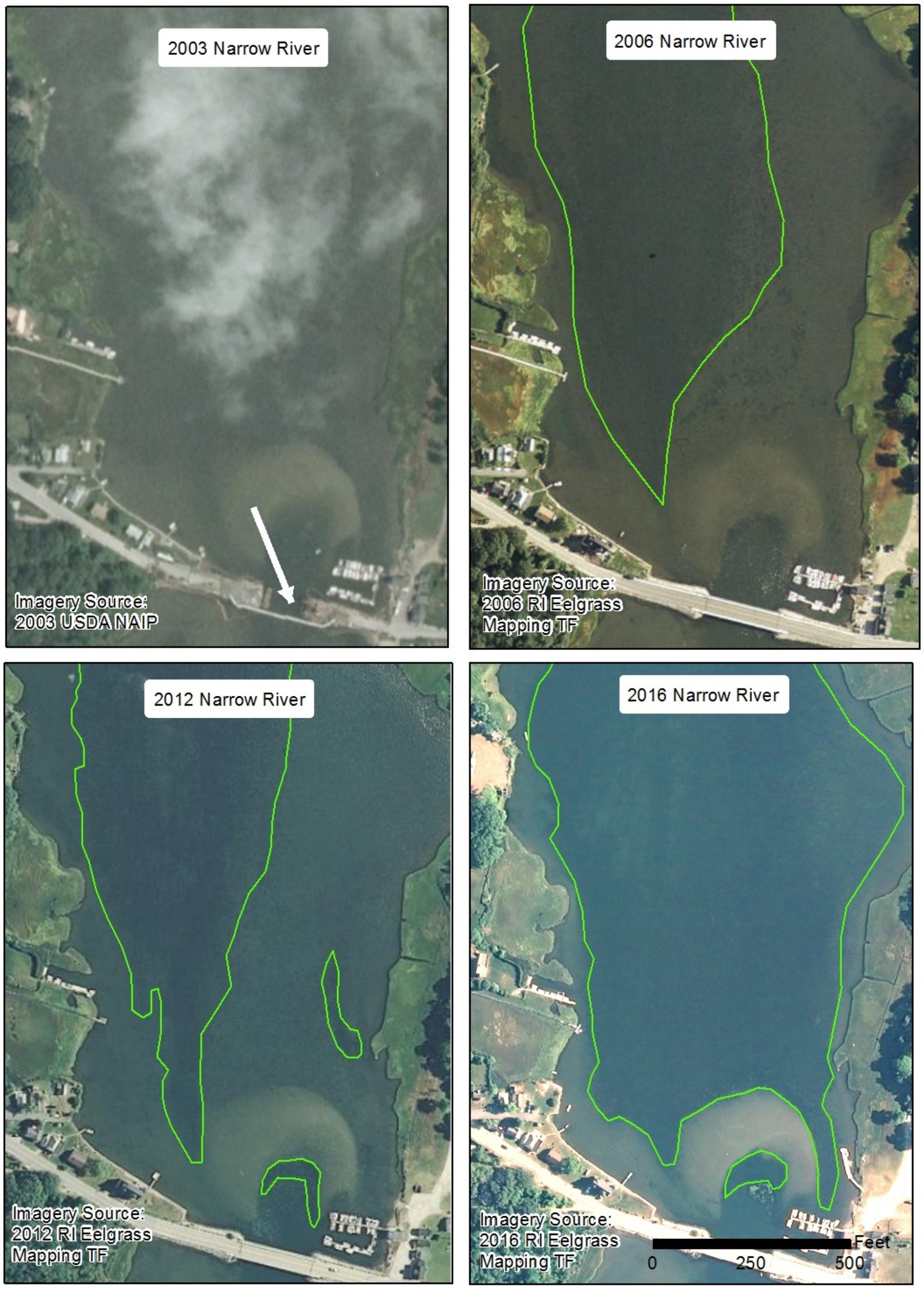

Figure 5. The distribution of eelgrass (green polygons) over time has increased within the Narrow River since 2003 when the tidal hydrology of the river was restored with the construction of the new bridge which replaced a small culvert (white arrow 2003). In the portions of the 2003 image without clouds, no eelgrass signatures are visible.