Tier 1 2017 Mapping of *Zostera marina* in Long Island Sound and 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, stabilizing and developing subaqueous soil, and filtering particles from the water column (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). 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 (Connecticut Coastal Management Act Chapter 444, Sections 22a-90 to 22a-112, New York Seagrass Protection Act). In addition, monitoring the extent of SAV is a critical component of the Long Island Sound Study's (LISS) 2015 Comprehensive Conservation and Management Plan (longislandsoundstudy.net).

Mapping the distribution and extent of SAV is a critical first step in understanding, managing, and protecting shallow, subtidal estuarine habitats. Geospatial 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 broadest 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). Tier 2 surveys involve a stratified random sampling design whereby percent cover of SAV species is quantified. For the Tier 3 surveys, many metrics such as biomass and plant height are assessed along a transect. For the Long Island Sound study area, there have been four previous Tier 1 survey efforts (2002, 2006, 2009, and 2012) conducted in partnership with the US Fish and Wildlife Service and the LISS (Tiner et al., 2013). The goals of the 2017 Long Island Sound survey were similar to previous surveys: 1) conduct a comprehensive survey of SAV (primarily eelgrass) using similar methods as the previous surveys, and 2) examine broad trends of eelgrass in the Long Island Sound Study area.

METHODS

Aerial Photography Acquisition

Digital four-band (true color and infra-red) aerial photographs were taken by a photogrammetry vendor on June 28th, 2017 (Figure 1). The extent of the area photographed was based on recent (this century) presence of eelgrass in Long Island Sound (Tiner et al., 2013 , Connecticut Dept. of Env. Protection, 2007). 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 were minimal, and when water clarity was high (Figure 2). Altitude of the aircraft during photo acquisition was about 17,000 ft (Quantum Spatial, 2017). 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, pilot areas and draft imagery were sent to project leaders for review and comment. After approval, photography was color balanced, mosaicked, and projected to the Connecticut State Plane meters (NAD83_2011) coordinate system.

Accuracy assessments of the orthophotography product were done by 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 $RMSE_x = 0.207$ m and $RMSE_y = 0.282$ m (Quantum Spatial, 2017). The pixel resolution of the orthophotography was 0.31 m.

On September 30, 2017, 212 individual orthophotography tiles (408 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 10.5 Server Image Service technology. As a result, the orthophotography could be viewed in ArcMap (and on the internet) utilizing one data connection.

<u>Photo-interpretation</u>

Initial eelgrass 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 eelgrass were targeted first for the photo interpretation of new beds. However, to avoid any bias, digitizing of the 2017 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 88% of the polygons were ≥0.25 acres.

<u>Field Work and Ground-truthing</u>

Ground-truthing in the field was conducted by boat between September 8 and October 19, 2017 (ten field days total) (Figure 3). Eelgrass 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 eelgrass was determined using a high-definition, digital underwater video camera linked to a GPS and capable of recording video for archive purposes (SeaViewer, Inc.). Not all polygons were ground-truthed in 2017.

The goals of ground-truthing were to verify digital photo signatures of eelgrass, to assess the imagery quality for identification of the deep water edge of eelgrass beds, and to verify areas of change from the 2012 mapping effort. Initial eelgrass 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 2017 imagery was visible at many sites, however GPS and video data were still used to estimate the extent of eelgrass beds in deeper water and to delineate bed edges.

Eight hundred eighty-four GPS data points were collected in the field and coded for presence of eelgrass within and at the edge of eelgrass beds. The edge of an eelgrass bed was defined as when cover dropped to approximately 5%. Final eelgrass delineations were adjusted using the ground truth data (GPS points). In the GIS database, polygons were coded with a habitat type (eelgrass), whether the polygon was field-surveyed with video and GPS.

RESULTS

Over the summer and fall of 2017 we mapped 1,465 acres of eelgrass in the study area which resulted in a GIS database of 156 polygons. Of these polygons, 51% were field visited and most of them were the larger beds in the study area. Thus, more field-time was spent trying to identify bed edges for the larger beds we mapped. The largest contiguous bed we mapped was in Lords Point, Stonington, CT (165 acres). Additionally, the most eelgrass in our study areas was found east of the Thames River along the Connecticut coast (Figure 4; Table 1).

A web-map was created of the final eelgrass delineations which can be found here: http://edc.maps.arcgis.com/apps/View/index.html?appid=5e9065b777d14249a5dbd05bf84ab955

The data listing for the orthophotography was created by the University of Connecticut and can be found here: http://cteco.uconn.edu/data/flight2017_Ecoast/index.htm

Change Analysis (2012- 2017)

The survey effort in 2012 was interrupted by Hurricane Sandy, thus very little field ground truthing was conducted (Tiner et al., 2013). As a result, we thoroughly reviewed these data by comparing the delineations in 2012 and the historical (2002, 2006, and 2009) GPS and video points in order to verify, assess, and standardize these delineations to the 2017 delineations and database. Luckily, many (but not all) of the delineations from 2012 intersected with GPS and video surveys from previous years. Further, we removed map units from the 2012 dataset which were not comparable to our map unit classifications. These map units consisted of delineations of generic “SAV” which were not field-verified. Additionally, we adjusted our study area to correspond to the official Long Island Sound Study area of interest (Figure 1). Thus, eelgrass beds in Little Narragansett Bay R.I. and south of Orient Point, N.Y. were not included in our analysis. However, we have included the change analysis for Little Narragansett Bay in as an appendix (Appendix A). As a result of the study area modification, we calculated a total of 1736 acres of eelgrass in 2012 which is a lower number than previously recorded by Tiner et al. (2013) (Table 1).

In order to quantitatively assess changes of eelgrass extent between 2012 and 2017, we intersected the two polygon data layers to create one polygon layer using the 'union' command in ArcGIS. Database queries were then conducted to code all polygons within the resultant data layer with the following: eelgrass present in both years; eelgrass present in 2012 but not in 2017; and eelgrass not present in 2012 but present in 2017 (Table 2). Most polygons were coded as eelgrass present in 2012 but not present in 2017 (Table 2). We then sorted the dataset based on the largest polygons that were not eelgrass in either year. Using the orthophotography and the GPS video observations (points) from 2012, we systematically assessed and analyzed each polygon (>= 3 acres) to verify whether a change of eelgrass presence and extent had occurred between the two years. For example, if an eelgrass signature and a GPS point verifying eelgrass presence was identified in 2012, and that same area had no eelgrass signature and a GPS video observation indicating no eelgrass presence in 2017, then those areas were coded as "Probably Loss". The reverse is true for areas coded as "Probably Gain" (Figure 5). Due to time constraints, we were unable to assess the 2009 aerial photography, thus all of our comparisons are from the 2012 survey.

Further, if we account for areas that were "Probably Gain" (103 acres in 2017) then we calculate an overall net loss of 102 acres (8.8%) in the Long Island Sound study area (Table 3). However, almost half of the area of change between 2012 and 2017 (47%) was coded as "Uncertain" (Table 3). An example of "Uncertain" polygons include areas where the bottom is not viewable in one or both years due to depth, solar glint, waves, shadows, poor water quality, or other imperfections in the aerial photography. However, there is usually some justification for the existence of the polygon in the dataset such as eelgrass nearby or eelgrass presence in a previous years' survey. In addition, some of these polygons include areas that had a photo signature identified as possible eelgrass but there was no GPS point in 2012. In 2017 we collected GPS video observations in the area identifying the photo signature as probably rocks or macro algae. These polygons were coded as "Uncertain" because there is a chance that eelgrass occurred in some other part of the polygon. And since we did not analyze other aerial photography from previous years there may be some unknown evidence that eelgrass existed in the area during an earlier survey (2002, 2006, or 2009 e.g.).

SUMMARY and DISCUSSION

During the summer and fall of 2017 we mapped 1465 acres of eelgrass in the Long Island Sound Study area utilizing aerial photography and field surveys with an underwater video camera, evidence that this is a cost-effective and efficient method to map and inventory eelgrass within the LISS. This amount reflects an 8.8% loss in eelgrass when compared to the 2012 Tier 1 survey. In addition, this loss is comparable to the losses reported in Narragansett Bay, R.I. during this time frame (Bradley et al., 2017).

Between 2012 and 2017 we identified two sites in the study area that experienced an overall gain in eelgrass extent (Figure 6A and 6B). These sites near the towns of Mystic and Noank, CT made up almost 68% of the overall gain (103 acres total) in eelgrass. Interestingly, the sites display two very different potential mechanisms for increase of eelgrass at a site: expansion of an existing bed (Noank) and formulation of two separate and larger beds than the one that was there historically (Mystic). Alternatively, we discovered two sites that experienced a majority (54%) of the overall decrease in eelgrass (Figure 7A and7B). The site south of Mystic harbor (Figure 7B) experienced a loss of eelgrass along the bed edges as well as internally in shallower and possibly warmer waters. We observed the largest decrease of eelgrass in our study area in the Niantic River (Figure 7A). This site has been well studied over the years by scientists at Dominion Energy who have mapped and monitored eelgrass there every year since around 1985 (Keser et al., 2003 and DNC, 2013). In order to independently verify our observations of eelgrass declines at this site, we compared our mapping to what DE observed in 2006 and 2017 and found a very good correlation between the two studies at this site (Figure 8A and 8B).

Discerning trends of eelgrass gain or loss utilizing Tier 1 methodology is best conducted using standardized and comparable datasets and survey methods. In practice however, slight differences and inconsistencies between survey efforts are common if somewhat unavoidable. In order to account for this, we utilized GIS analysis tools to quantitatively assess any trends of eelgrass within the LISS. However, much of the uncertainty and variability we found can be addressed if the Tier 1 surveys were done more consistently on 3-year intervals. Tier 1 surveys are the only way to sample regional study areas such as the LISS and we have shown that using this method we can discern broad trends. However, much of the uncertainty with eelgrass dynamics could be resolved when the Tier 1 surveys are synchronized with other monitoring tiers. In order to fully understand decadal eelgrass dynamics within the LISS or any region, more data (i.e. Tier 2 and 3 surveys; see Neckles et al. 2012) are needed that are collected consistently and that utilize standard survey methods. Indeed, more confident ecological conclusions and management decisions can be made by implementing this mapping and monitoring strategy.

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single rock (!) which is a testament to his superior navigation skills in the shallow rocky waters of eastern Long Island Sound.

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Table 1. Acreage results and dates* from the Tier 1 surveys done in Long Island Sound

Site Name	06_28_17	08_07_12	07_14_09	06_16_06	06_18_02
New London East	766	792	788	812	662
Fishers Island	347	403	346	201	194
New London West	338	522	483	575	443
Orient Pt / Plum Is, NY	14	19	18	35	16
Total	**1465**	**1736**	**1635**	**1623**	**1315**

*Date of aerial photography acquisition (mm_dd_yr).

Table 2. Acreage results of the intersection of the 2012 and 2017 datasets.

2012		**2017**	
		Yes	**No**
	Yes	1101	**797**
	No	**363**	xx
Total area of change between the 2 years		**1160**	

Table 3. The results from the change analysis of individual polygons between the two years.

Type of Change	Acres
Probably Gain	103
Probably Loss	205
Uncertain	531
Not Assessed	320
Total	**1159**

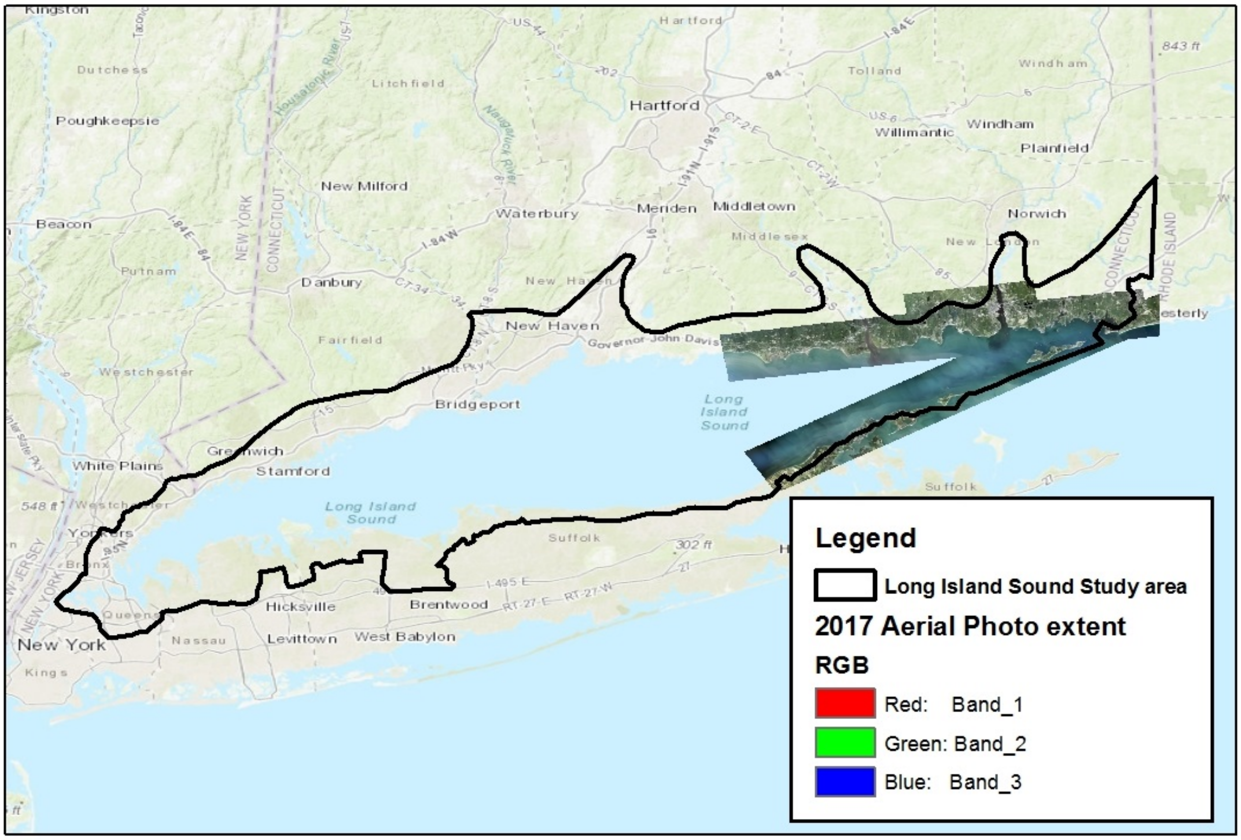

Figure 1. The extent of the aerial photography acquired on June 28th, 2017 along with boundary of the Long Island Sound Study (longislandsoundstudy.net).

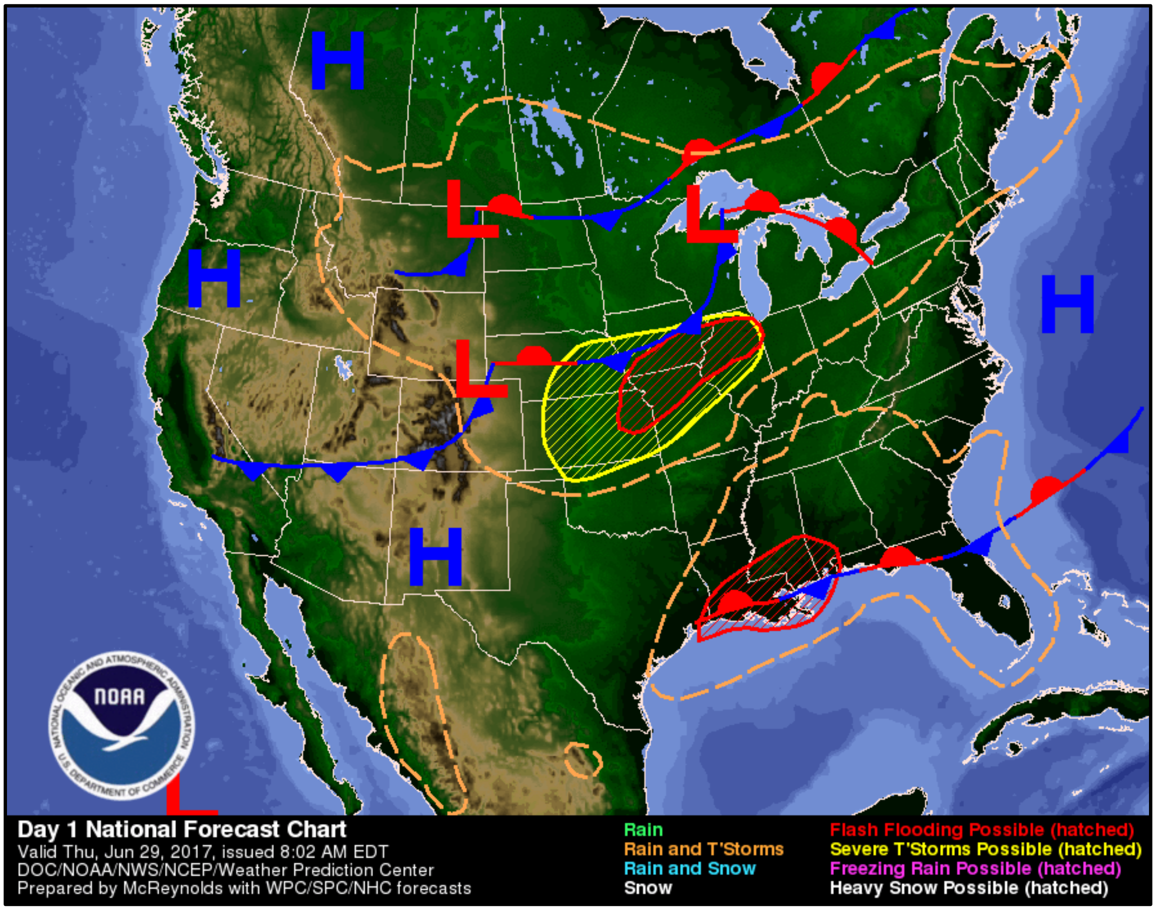

Figure 2. The weather conditions (high pressure and stable fronts along the mid-Atlantic coast) on the date of aerial photography acquisition from the NOAA Weather Prediction Center.

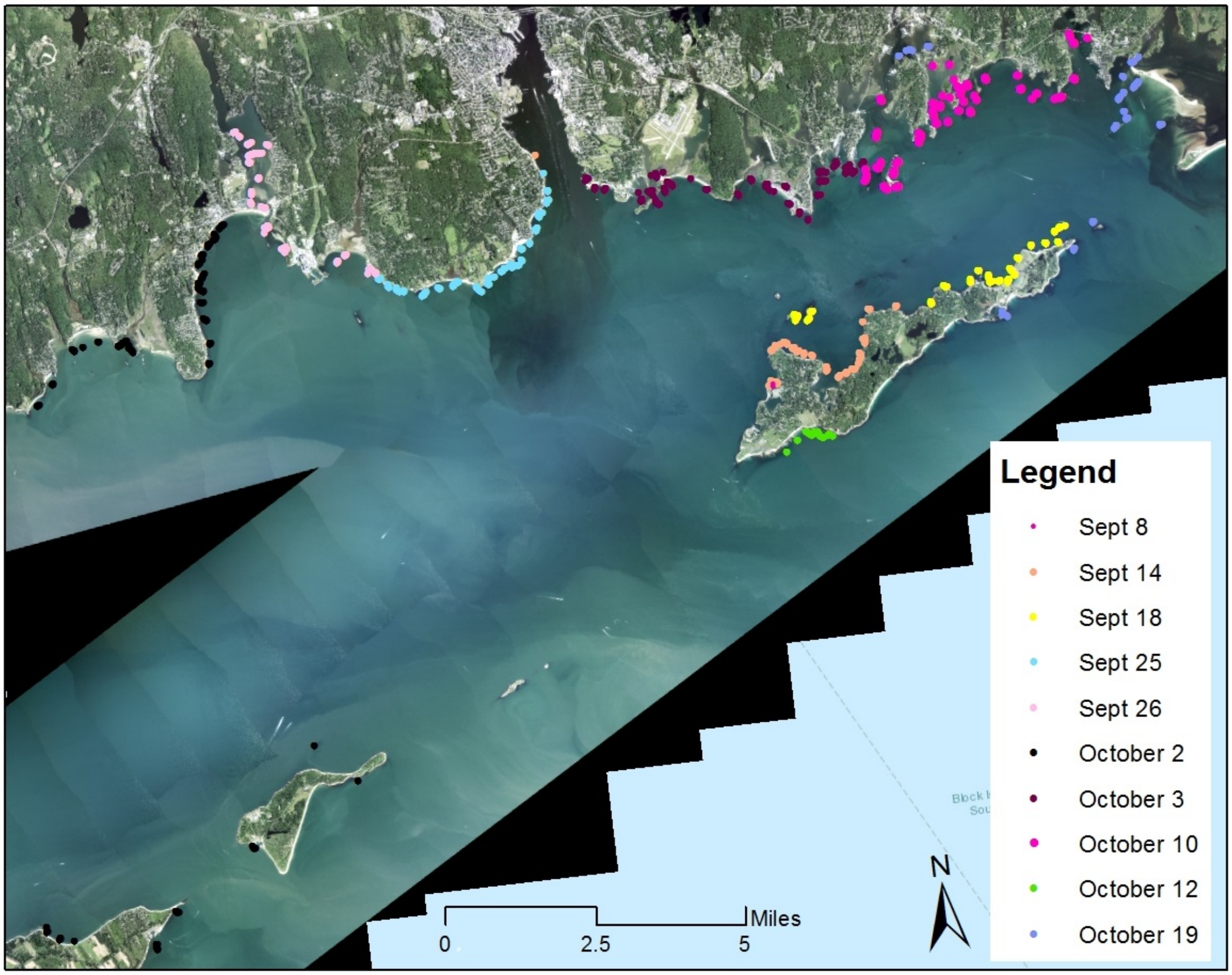

Figure 3. The extent and dates of the GPS and video surveys collected for this project.

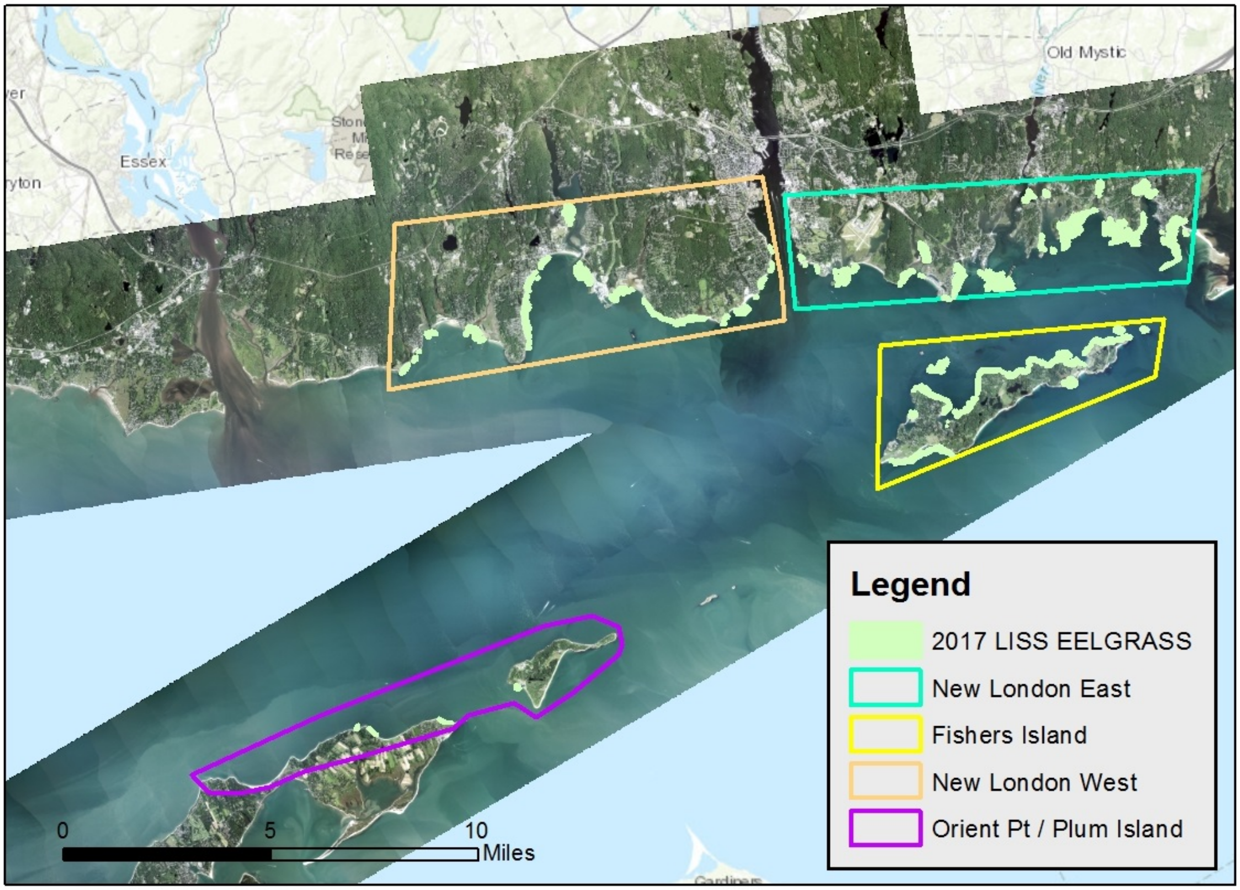

Figure 4. The New London East study area had the most eelgrass (766 acres) of the four we analyzed.

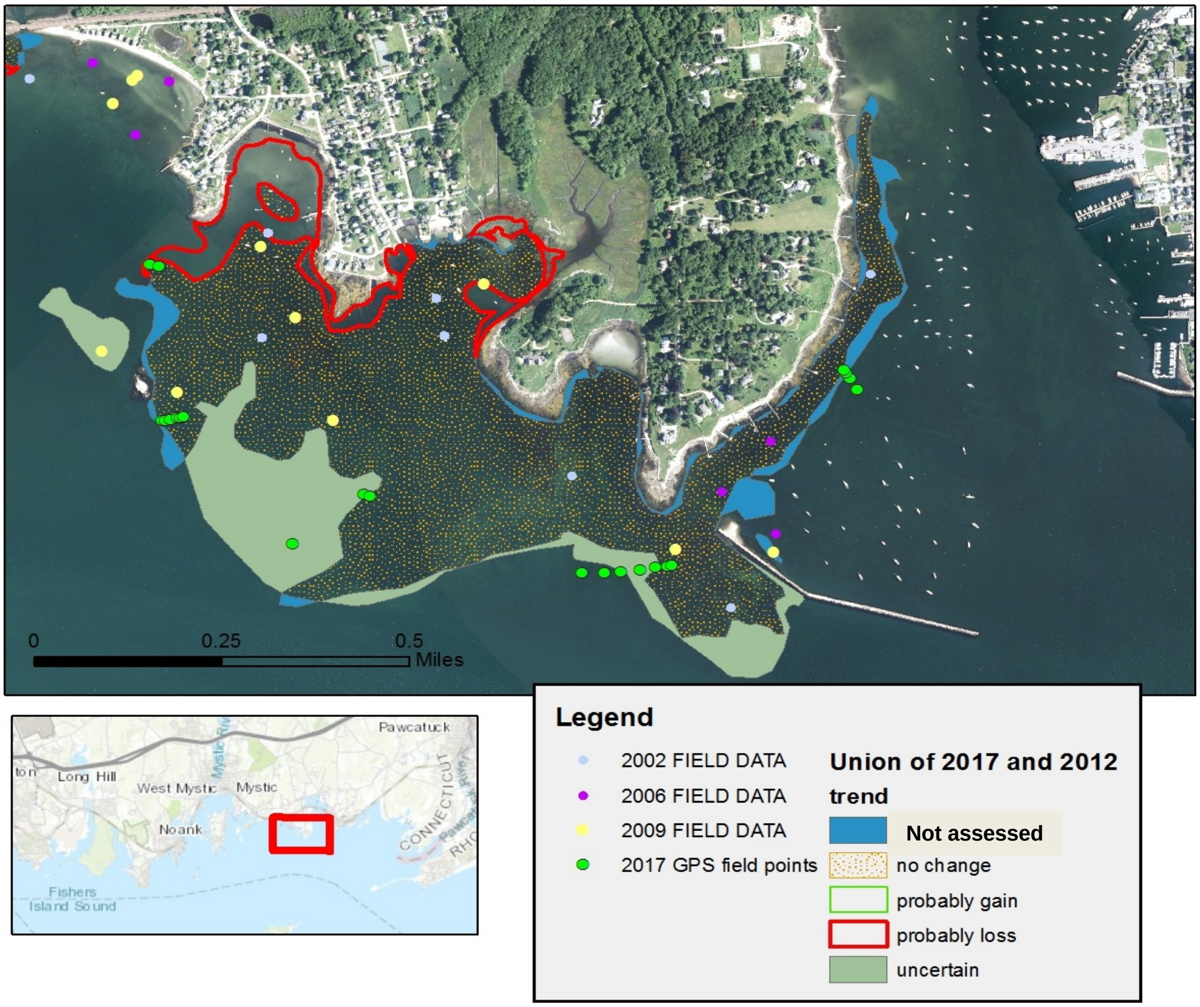

Figure 5. The result of the union of the 2012 and 2017 polygons was five classes of trend categories.

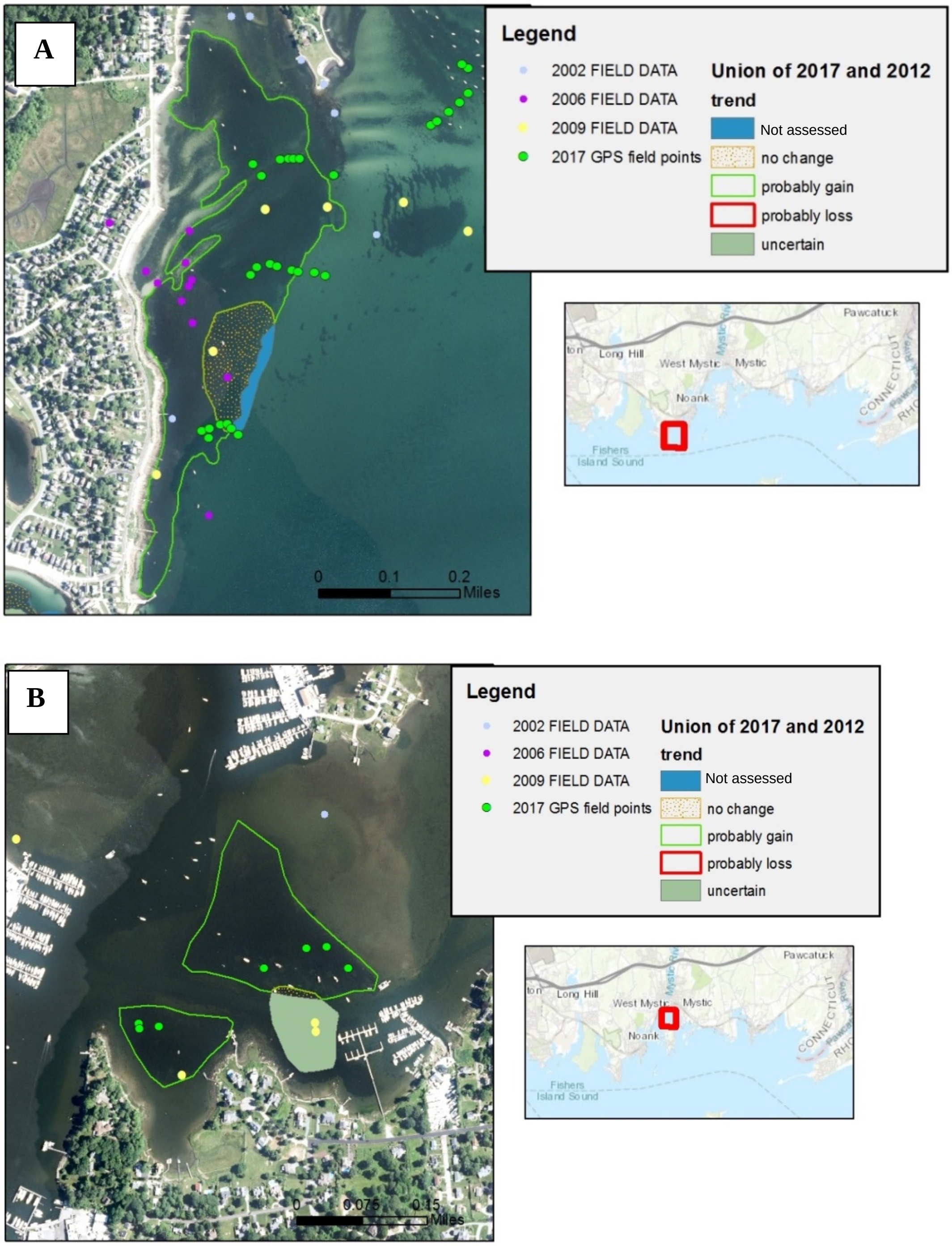

Figure 6A and 6B. These two areas had the most gain of eelgrass from 2012.

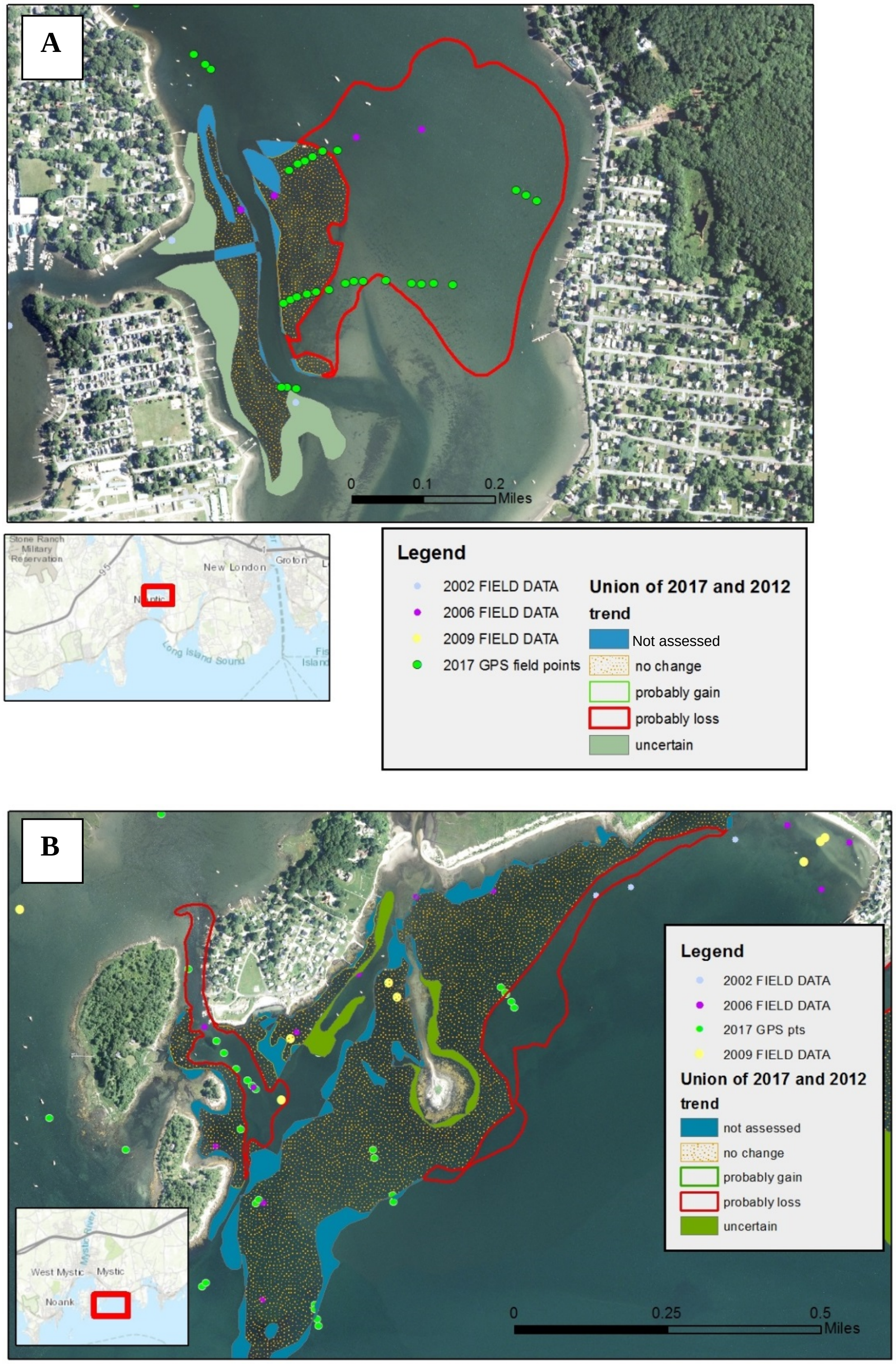

Figure 7. These two sites had the majority of eelgrass loss from 2012.

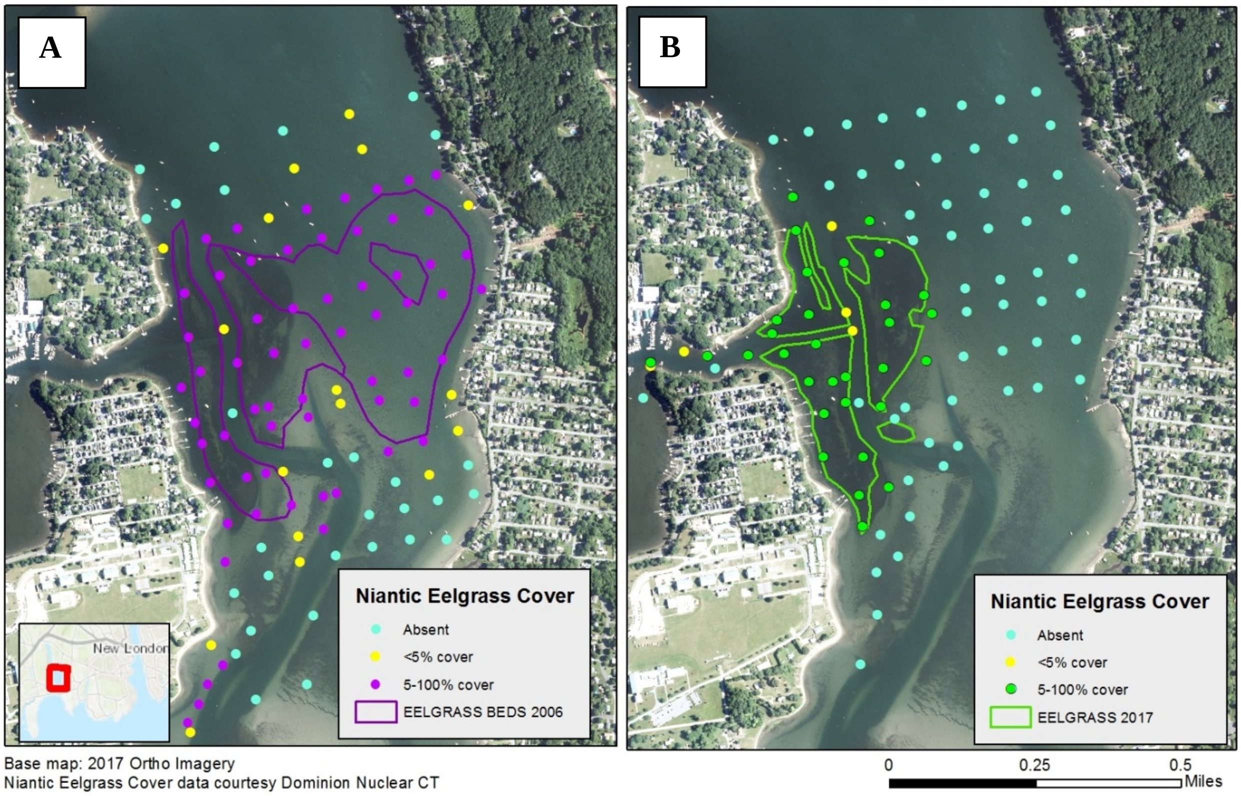

Figure 8. We compared our mapping from 2006 (A) and 2017 (B) to the intensive data collected by Dominion Nuclear and found a favorable comparison.

APPENDIX – Little Narragansett Bay – Rhode Island

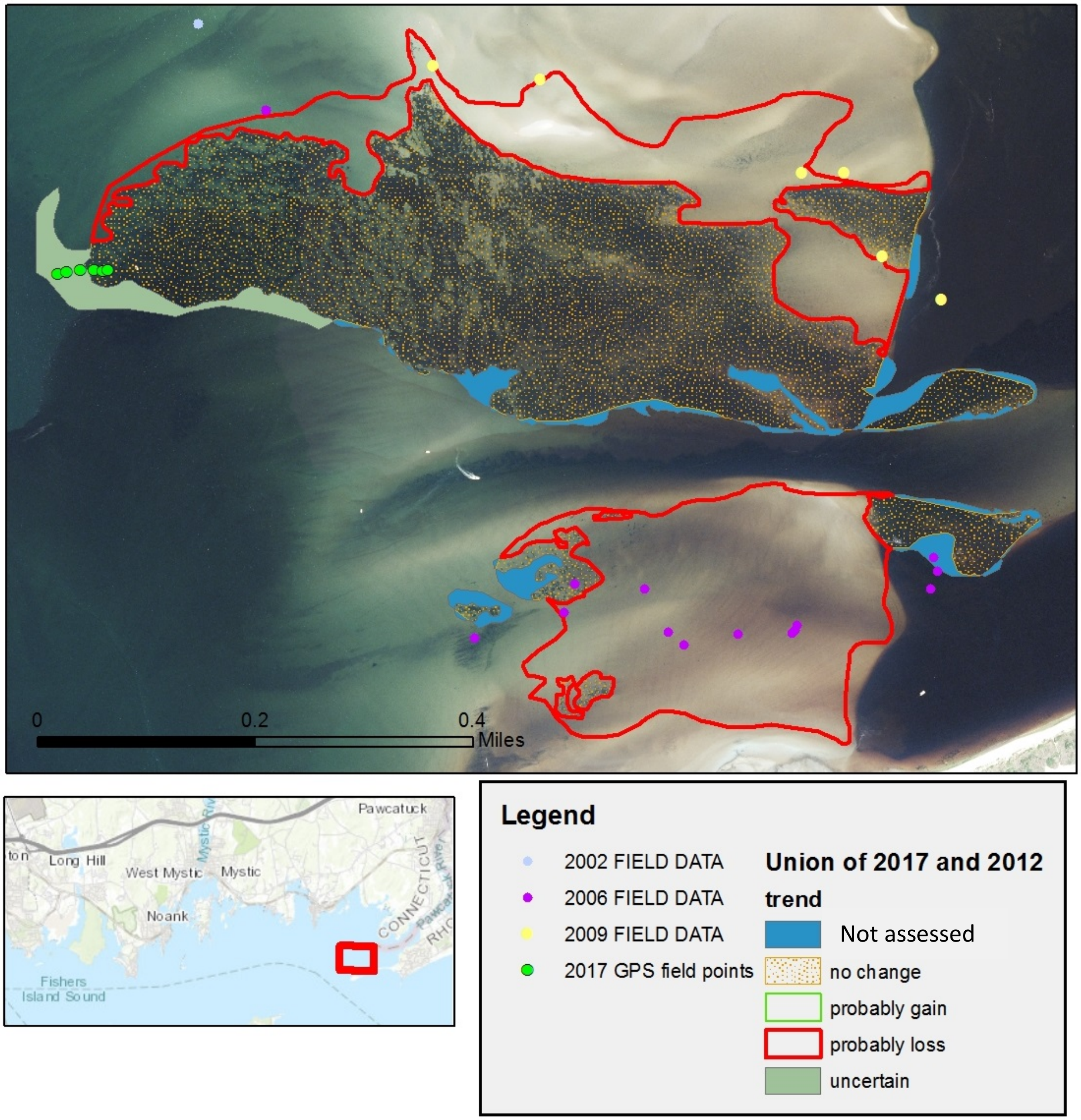

Figure 9. In 2012, 163 acres of eelgrass were mapped by Tiner et al (2013) in Little Narragansett Bay (RI). In 2017, we mapped 93 acres for a 43% loss at this site between the two studies.